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Assessment of the impacts of Climate change, migration, food security and Vulnerability in the rural Gambia

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Dedication

This PhD Thesis Is Dedicated To The Following:

First: To Allah Subhaanah Wa Taala

Secondly: To My Parents, My Late Father and My alive Mum. Big Thank You to Them Both

Thirdly: My Wife And My Children Namely Aboubacarr Ceesay, Omar Ceesay, Ya Bintou Ceesay And Rokeyatou Ceesay. Thank You And Thank You To All My Children Too.

Fourthly: My Late Sister and My Best Sister Jarra Ceesay, I Pray Continuously For Allah to Grant Her Jannatul Firdausi.

Lastly: My Late Supervisor Professor Fatou Gueye May Allah Grant Her Jannatul Firdausi.

Declaration

I, Ebrima K. Ceesay state that this PhD thesis, which I submit for the degree of PhD program in Economic Sciences, specialty Climate Change Economics at the University of Cheikh Anta Diop University (UCAD), Dakar, Senegal is totally my individual work and has not been surrendered to any place different from UCAD for the award of the degree.

Objective 1 part of the thesis had been published in ''Elsevier'', Research in Globalization-DOI https://doi.org/10.1016/j.resglo.2022.100089.

Some mistakes in thoughtfulness and blunders are completely my personal responsibility.

Signed.....

Name: Ebrima K. Ceesay

March, 2023.

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Abstract

This thesis concentrated on three essential objectives. The first addressed the time series econometrics part on climate change, food availability, and other variables in The Gambia. The second objective analyses the impacts of food security on migration response by looking at the climate change interaction. Objective three examines farmers' vulnerability to change in climate at households and regions. Four main approaches are adopted to address these central themes. The first tactic is time series analysis using VAR, FEVD, Impulse response function, granger causality tests, ARDL, and ECM methodologies. It is based on estimating the unit root test using the ADF, PP, and KPSS tests. After unit root tests, we can select which time series method is more appropriate and why.The forest errors variance decomposition (FEVD) and impulse response function (IRF) follow after the VAR models. So after, we also determine the F- bounds statistics values to see whether co-integration exists among the variables and whether we should select ARDL in the short run or ARDL in the long run. Therefore, appropriate model is ADRL long run, which contains the error correction parts. In the second approach, we used the multilevel version of the conventional logistic regression to predict the probability of odds of moving to an international destination from the rural areas of The Gambia, where households i is located. In estimating this model, we started with the based models, climate change only model, food security only model, and climate change and food security interaction model to find the probability of the international move from the rural Gambia. The third approach is divided into two approaches. In the first approach of the third, we used one of the econometrics approaches to measure vulnerability to poverty called vulnerability to expected poverty approaches. This tactic is based on valuing the probability of log consumption below or equal to the poverty line, given that climate shocks or other household characteristic shocks affect household consumption levels (See details on the methodology of objective 3).The method is used to assess the household level's vulnerability using the single cross-sectional data we collected. We used dependent variables as a change in total consumption expenditure. In the second approach of the third, we used the integrated approaches to understand vulnerability, and the Principal Components Analysis was the best approach for this kind of study. We employed the PCA to create vulnerability indices for each vulnerability component and conduct the analysis across the rural regions in The Gambia. We attached the positive values to adaptive capacity and negative values for exposure and sensitivity indicators of vulnerability as adopted by IPCC, 2001, 2007 and after we validated the vulnerability index by using the different complete variables. The analysis results for objective one stated that: Climate change affects agriculture negatively and, in turn, harms food availability. There is a positive correlation between food security and agriculture value added. The results also found that growth increases with the growth rate of agriculture and food availability. Finally, in theme one, as population growth increases annually, food availability decreases in The Gambia. For migration responses, we found that the food security status of the households slightly increases migration to an international move. Food insecurity households do not migrate. The results further reveal that floods and temperature changes do not cause migration, but heavier rainfall, changes in rainfall, and drought lead to migration. We also found that remittance received households are more likely to migrate than non-remittance received households. Income, employment as farmers, stop at secondary education, and illiterate, the probability of migration in these categories is much higher according to our findings. Finally, with food security consumption level, the likelihoods of migration become weaker. Lastly, the final chapter results are summarized: secondary education increases vulnerability to poverty and employment as farmers increase vulnerability to poverty. The empirical results finding stated that floods, changes in rainfall, and drought increase the probability of future vulnerability, looking at the changes in total

consumption expenditure as a proxy variable for vulnerability. In addition, indicators-based approaches revealed that rural regions have different vulnerability levels to climate change. All the rural regions were more vulnerable to climate change due to high exposure and sensitivity and low adaptive capacity. Moreover, the thesis finally reveals that according to PCA's vulnerability components and vulnerability indices, farmers in these regions are highly vulnerable from socioeconomic and biophysical attributes to climate change. Furthermore, the outcomes of validation indicated that NGO support reduces farmer's vulnerability to change in climate in the rural Gambia by 82 percent, whereas government support increases farmer's vulnerability to climate change by 79 percent.

Résumé

Cette thèse s'est concentrée sur trois objectifs essentiels. Le premier a abordé la partie économétrie des séries chronologiques sur le changement climatique, la disponibilité alimentaire et d'autres variables en Gambie. Le deuxième objectif analyse les impacts de la sécurité alimentaire sur la réponse migratoire en examinant l'interaction du changement climatique. L'objectif trois examine la vulnérabilité des agriculteurs au changement climatique au niveau des ménages et des régions. Quatre approches principales travaillent pour aborder ces thèmes centraux. La première tactique est l'analyse de séries chronologiques à l'aide de VAR, FEVD, fonction de réponse impulsionnelle, tests de causalité de Granger, ARDL et méthodologies ECM. Il est basé sur l'estimation du test de racine unitaire à l'aide des tests ADF, PP et KPSS. Après les tests de racine unitaire, nous pouvons sélectionner la méthode de série chronologique la plus appropriée et pourquoi. Nos modèles choisis sont au-dessus après que les tests de racine unitaire nous le disent. La décomposition de la variance des erreurs forestières (FEVD) et la fonction de réponse impulsionnelle (IRF) suivent les modèles VAR. Le granger a été utilisé pour nous dire de prédire la direction de la variable exogène provoque la variable endogène en regardant les valeurs passées des variables exogènes sur les valeurs à venir de la variable endogène. Ainsi, après les tests de racine unitaire, nous avons également constaté que certaines variables sont dans des ordres mixtes de signification statistique. C'est-à-dire certains significatifs au niveau de la forme et d'autres aux premières différences, et donc les modèles appropriés, dans ce cas, sont les modèles ADRL. Donc, après, nous déterminons également les valeurs statistiques des bornes F pour voir si la co-intégration existe entre les variables et si nous devons sélectionner ARDL à court terme ou ARDL à long terme. Par conséquent, le modèle approprié est ADRL à long terme, qui contient les parties de correction d'erreur. Dans la deuxième approche, nous avons utilisé la version multiniveaux de la régression logistique conventionnelle pour prédire la probabilité de se déplacer vers une destination internationale à partir des zones rurales de la Gambie, où se trouvent les ménages i. Pour estimer ce modèle, nous avons commencé avec les modèles basés sur le changement climatique uniquement, le modèle de sécurité alimentaire uniquement et le modèle d'interaction entre le changement climatique et la sécurité alimentaire pour trouver la probabilité du mouvement international depuis la Gambie rurale. La troisième approche se divise en deux approches. Dans la première approche de la troisième, nous avons utilisé une des approches économétriques pour mesurer la vulnérabilité à la pauvreté appelée approches de vulnérabilité à la pauvreté anticipée. Cette tactique repose sur la valorisation de la probabilité d'une consommation logarithmique inférieure ou égale au seuil de pauvreté, étant donné que les chocs climatiques ou autres chocs caractéristiques des ménages affectent les niveaux de consommation des ménages (Voir détails sur la méthodologie de l'objectif 3). La méthode permet d'évaluer la vulnérabilité au niveau des ménages à l'aide des données transversales uniques que nous avons collectées. Nous avons utilisé des variables dépendantes comme variation des dépenses de consommation totales. Dans la deuxième approche de la troisième, nous avons utilisé les approches intégrées pour comprendre la vulnérabilité, et l'analyse des principaux composants était la meilleure approche pour ce type d'étude. Nous avons utilisé l'ACP pour créer des indices de vulnérabilité pour chaque composante de vulnérabilité et effectuer l'analyse dans les régions rurales de la Gambie. Nous avons attaché les valeurs positives à la capacité d'adaptation et les valeurs négatives pour les indicateurs d'exposition et de sensibilité à la vulnérabilité tels qu'adoptés par le GIEC, 2001, 2007. Les résultats de l'analyse pour l'objectif un indiquaient que ; Le changement climatique affecte négativement l'agriculture et, à son tour, nuit à la disponibilité alimentaire. Il existe une corrélation positive entre la sécurité alimentaire et la valeur ajoutée agricole. Les résultats ont également révélé que la croissance augmente avec le

taux de croissance de l'agriculture et de la disponibilité alimentaire. Enfin, dans le thème un, à mesure que la croissance démographique augmente chaque année, la disponibilité alimentaire diminue en Gambie. Pour les réponses sur la migration, nous avons constaté que l'état de sécurité alimentaire des ménages augmente légèrement la migration vers un déménagement international. Les ménages en insécurité alimentaire ne migrent pas. Les résultats ont en outre révélé que les inondations et les changements de température ne provoquent pas de migration, mais que des précipitations plus abondantes, des changements dans les précipitations et la sécheresse entraînent des migrations. Nous avons également constaté que les ménages recevant des envois de fonds sont plus susceptibles de migrer que les ménages n'en recevant pas. Revenus, emploi comme agriculteur, arrêt au secondaire, et analphabètes, la probabilité de migration dans ces catégories est beaucoup plus élevée selon nos constatations. Enfin, avec le niveau de consommation de la sécurité alimentaire, les probabilités de migration deviennent plus faibles. Enfin, les résultats du chapitre final sont résumés : l'enseignement secondaire augmente la vulnérabilité à la pauvreté et à l'emploi alors que les agriculteurs augmentent la vulnérabilité à la pauvreté.Les résultats empiriques ont indiqué que les inondations, les changements dans les précipitations et la sécheresse augmentent la probabilité de vulnérabilité future, en considérant les changements dans les dépenses de consommation totales comme une variable proxy de la vulnérabilité. De plus, les approches basées sur des indicateurs ont révélé que les régions rurales ont différents niveaux de vulnérabilité au changement climatique. Toutes les régions rurales étaient plus vulnérables aux changements climatiques en raison de leur forte exposition, de leur sensibilité et de leur capacité d'adaptation. De plus, la thèse a finalement révélé que selon les composantes de vulnérabilité et les indices de résilience de l'APC, les agriculteurs de ces régions sont très vulnérables des attributs socioéconomiques et biophysiques au changement climatique.

TABLE OF CONTENTS

Contents

Declaration iii

ACKNOWLEDGEMENTS iv

Abstract vi

Résumé viii

LIST OF TABLES xvii

ACRONYMS AND ABBREVIATIONS xxii

GENERAL INTRODUCTION 1

Overview of Climate Change, migration dynamic, and food security in Africa and The Gambia 1

Problem Statement 2

Research questions 3

What is the impacts of Climate change, migration, food security and Vulnerability in the rural Gambia? 3

The sub research- questions are: 3

General Objective 3

Specific objectives of the Study 3

Hypothesis testing 3

Justification of the Study 3

Relevance to policymakers 4

The motivation of the Study 4

Organization of the thesis 5

CHAPTER ONE 5

STYLIZED FACTS ABOUT CLIMATE CHANGE, MIGRATION DYNAMICS, FOOD SECURITY AND VULNERABILTY 5

INTRODUCTION 5

Drivers of climate change on food security 6

Emigration versus immigration 8

Emigration 8

Immigration....8
Net Migration and Remittance....11
Drivers of change in climate and migration....11
Drivers of migration and food security....13
Definition Climate change, Food security, Migration and Vulnerability....15
Climate Change:....15
Migration:....16
Food Security:....16
Vulnerability....17
Conclusion....17
CHAPTER TWO....17
LITERATURE REVIEW....17
2.1. Introduction....17
Macroeconomic theory of Migration, 2) Microeconomic theory of Migration....19
2.5. Theoretical framework for the interplay between Climate change, Migration dynamic, and Food Security....22
2.7. Conceptual framework of vulnerability assessment to climate....24
2.8. Theoretical frameworks of food security....26
2.8.4. Income as a theory of food security....30
2.8.5. Basic needs as a theory of food security....31
2.9. Empirical Literature of climate change, migration dynamics, and food security....31
2.10. Gaps in the Literature....32
Conclusion....33
CHAPTER THREE....33
METHODOLOGY....33
3.1.2. Areas of study....33
3.1.3. Sampling Design....35
3.1.4. Sample frame....35

3.1.5. Sample section methods and sample size 35

3.2. Objective one: The influences of change climate on food availability using time series approaches; Evidence from the Gambia. 36

3.2.1. Theoretical framework 36

3.3. Data and methods 37

3.3. Data and Data Analysis 37

3.3.1. Data Collection, Data measurement, and Data Presentation 37

3.3.2. Empirical Models 38

3.3.2.1 Empirical Vector Autoregressive (VAR) Model 38

3.3.2.2. Impulse Response Function 39

3.3.2.3.ARDL bounds testing procedure for Co-integration 39

3.3.2.3.1. ARDL Model 39

3.3.2.4. ECM 39

3.3.3.4.1. VECM: vector error correlation model 39

3.4. Objective two: Assessing the impacts of food security on migration responses: A case study in the rural Gambia 40

3.4.1. Theoretical model 40

3.5. Methodology 42

3.5.1. Analysis of data 42

3.5.2. The analytical framework of multilevel logistic regression 43

3.5.3. Outcome variable 44

3.5.3.1. Migration 44

3.5.3.2. Household-level control variables 44

3.5.4. Primary Predictor 45

3.5.4.1. Climate variability 45

3.5.4.2. Food Security and Food Consumption 45

3.6. Objective three: Vulnerability assessment at households and regional levels: Evidence from rural areas in the Gambia Towards climate change 45

3.6.1. Theoretical framework 45

3.6.1.1. Measuring Vulnerability: Econometric approaches 46
3.6.1.2. Vulnerability as expected utility 46
3.6.1.3. Vulnerability uninsured exposure to risk 46
3.6.1.4. Vulnerability as expected poverty 46
3.7. Material and Methods 47
3.7.1. The Econometric method and Data analysis 47
3.7.1.a. Vulnerability as expected poverty Framework to assess vulnerability at household level 47
3.7.1.b. Model Specification 49
3.7.2. Integrated Vulnerability assessment at regional levels 50
3.7.2.1. Conceptual framework 50
3.7.2.2. Methodological framework 52
3.7.3. Variables description applied in the Principal Components (PCA) 55
Conclusion 56
CHAPTER FOUR 57
RESULTS AND DISCUSSION 57
4.1. Objective one: The impacts of climate change on food availability using time series approaches 57
4.1.2 Unit root tests 58
4.1.3. Pre-estimation tests 59
Stability test for VAR models 59
Normality test 59
Correlation of errors test by applying Breusch-Godfrey LM 59
Test Heteroskedasticity: White 59
First 1: No-cross terms 59
Second 2: Yes-Cross terms 59
4.1.4 Co-integration test 59
4.1.5 VAR outcomes and discussion 60

4.1.6. Granger Causality 62

4.1.7. ARDL estimation 63

4.1.7.1. F-Bound test Approach for Co-integration for Food Security in the Gambia 63

4.1.7.2. Specification of ARDL Short-run, ARDL Long-run and ARDL Error correction Equations 64

Specifications of Short-run ARDL models 64

Dependent Variable: Food Security 64

Specifications of Long-run ARDL model: 64

4.1.7.3. ARDL Error correction model Specifications: 65

4.1.7.4. Interpretation of estimation parameters 65

Conclusion and Policy Recommendation 68

Objective two : Assessing the impacts of food security on migration in the rural Gambia 68

4.2.1. Descriptive statistics 68

4.2.2. Pairwise Correlation 70

4.2.2.1. Pairwise Correlation analysis- Pearson product-moment correlation coefficients 71

4.2.3. Multilevel version of conventional logistic regression results 72

4.2.3.1. Food Security and Change in climate 74

4.2.3.2. Climate effects 75

4.2.3.3. Food Security Effects 76

4.2.3.4. Interaction Effects 77

4.2.3.4.1. Food security- Climate change interactions 77

4.2.3.4.2. Remittance received- Climate change interactions 78

4.2.3.5. Discussion of the results 79

4.2.3.6. Conclusion and Policy recommendation 79

4.1. Objective three: Vulnerability assessment at households and regional levels: Evidence from a rural area in the Gambia regarding climate 80

4.3.1. Quantifying farmers vulnerability to change in climate at household levels in the rural Gambia 80

4.3.1.1. Descriptive statistic from the household survey data: Designated socioeconomic and change in climate in the rural region in the Gambia 80

4.3.1.2. Combination of Scattered plot, Histograms and Bar Plot 83

4.3.1.3. Pair wise correlation analysis 86

4.3.1.4. Multicollinearity test 87

4.3.1.5. Results for VEP 88

4.3.1.6. Model Results and Discussion 88

4.3.1.6.1. Total consumption expenditure per capita per months 89

4.3.1.7. Conclusion and Policy recommendation 92

4.3.2. Quantifying farmer's vulnerability to climate change across the three regions in the Rural Gambia 92

4.3.2. 1. The vulnerability of agriculture to climate change in the Gambia 93

4.3.2.2. Description Statistic of Socio-economic and climatic conditions 93

4.3.2.4. Results and discussion 98

4.3.2.4.1. Scoring coefficients 100

4.3.2.4.2. Vulnerability Components 102

4.3.2.4.3. Vulnerability Index 104

4.3.2.4.4. Time Trend for vulnerability index 106

4.3.2.4.5. Validation of PCA results 107

4.3.2.5. Conclusion and policy recommendation 109

Conclusion 110

CHAPTER FIVE 111

4. GENERAL CONCLUSIONS, GENERAL POLICY IMPLICATIONS, GENERAL LIMITATIONS OF THE STUDY, AND GENERAL SUMMARY 111

General Summary 112

4.3. General Policy Implications 113

4.4. General Limitations of the Study and Areas for Additional Research 113

REFERENCES 114

APPENDICES 127

Appendix i: Questionnaires 127

Appendix ii: 130

Appendix iii: Indices formula, boxplots and time series stationary graphs. 131

Appendix iv: Boxplot and time series graphs 132

Appendix v: Descriptive Statistic Graphs 135

LIST OF TABLES

Table 1:The Rural Gambia Households' Migration Status 10

Table 2: Migration responses by Changes in rainfall in the rural Gambia 12

Table 3: Perception of Environmental Drivers of migration and food insecurity in the rural Gambia 13

Table 4: shows the name of the variables, source and comment of those variables what they means. 37

Table 5 :Explanatory variables that are used in the study while the dependent variable is migration response (yes/no coded 1/0) 43

Table 6: Summary of approaches or theories to measure of vulnerability 47

Table 7:Explanatory variables; the dependent variable is log consumption per capita per month. LogC = Prob(monthly per capita consumption < poverty line) to measure hh. Vulnerability. 49

Table 8: Models variables 54

Table 9: Descriptive Statistics of variables used in the study 57

Table 10: Results for correlations 58

Table 11:: Unit root test 58

Table 12: Co-integration 60

Table 13: Forecast Error Variance Decomposition 61

Table 14: Granger Causality test outcomes 62

Table 15: Granger causality outcomes 62

Table 16: Granger causality test results 63

Table 17: Results of F- Bounds test for Cointegration 64

Table 18: Short-run Coefficients and (ECM) error correction coefficient. Dependent Variable is LNFSFP 66

Table 19: Descriptive statistics of continuous variables 68

Table 20: Descriptive statistics of dummy explanatory variable 69

Table 21: Bivariate correlations between household Migration responses and the other explanatory variables. 70

Table 22: Multicollinearity tests results....71

Table 23: Base models on international migration from Rural Gambia. 73

Table 24: Special effects of food security and climate on outmigration from Rural's Gambia 74

Table 25: Impacts of climate change on outmigration from Rural Gambia 76

Table 26: Special effects of food security effects on outmigration from Rural's Gambia 76

Table 27: Interactions amid climate change, food security and remittance on outmigration from the Rural's Gambia 78

Table 28: Distribution of sampled villages and regions 81

Table 29: Basic household characteristics of the surveyed farmers 81

Table 30: Basic Assets of the respondents or Welfare Measures 81

Table 31: Climate condition in the study area 82

Table 32: Main tremors experienced by surveyed farmers....82

Table 33: Pairwise correlation analysis 87

Table 34: Variance inflation factor (VIF) test for multicollinearity analysis 87

Table 35: dependent variable is log consumption per capital per month. LogC = Prob (monthly per capita consumption < poverty line, $57) to measure hh. Vulnerability i.e., log57=4.0431 89

Table 36: dependent variable is log consumption per capital per month. LogC = Prob (monthly per capita consumption < poverty line) to measure hh. Vulnerability -Ex-ante variance, log57=4.0431....91

Table 37: Indicators for Exposure (All %) 94

Table 38: Indicators for Sensitivity....95

Table 39: Indicators for Adaptive Capacity (%)....96

Table 40: Indicators 98

Table 41: Principal components, eigenvalues, differences between the eigenvalues, standard deviation, and proportion of variance explained....98

Table 42 : Eigenvector/Factor scores/loading/scoring coefficients for the third Principal Components (PCA)....101

Table 43: Vulnerability Components....103

Table 44: Vulnerability index (VI) in the rural Gambia 105

Table 45: Validation of vulnerability index 108

LIST OF FIGURES

Figure 1: None Stationary time series graphs 6

Figure 2: GGPLOT for growth in food availability and growth of food accessibility 7

Figure 3: Stationary time series graphs 8

Figure 4: Migrates and Remittance received by region 9

Figure 5: Changes in CO2 from 1971 to 2020 from WDI. 13

Figure 6: Growth of remittances as key drivers of food security in the Gambia from WDI. .. 14

Figure 7: Outmigration from 1971 to 2020. Sources: Own evaluation using Stata 16 for window from 14

Figure 8: Changes in mean temperature in the Gambia from 1971 to 2020 15

Figure 9; Theoretical Model to interlinks between Climate Change, Migration dynamic and Food Security 23

Figure 10: Background Information for conceptual Framework in assessing the impact of Climate change, Migration dynamics and Food Security 26

Figure 11: Map of the study area 34

Figure 12: Adopted from IPCC and fourth and fifth assessment reports on Vulnerability. Low adaptive capacity, high exposure and sensitivity lead to high Vulnerability, whereas high adaptive capacity, low exposure and sensitivity lead to low Vulnerability 51

Figure 13: Graphs impulse response function Using Eviews 12 SV(x64).Year=Period 61

Figure 14F: Cumulative Sum (CUSUM) test when short run food security is the dependent variable 64

Figure 15: Cumulative Sum (CUSUM) test when long run food security is dependent variable 65

Figure 16: Cumulative Sum (CUSUM) after ECM when the dependent variable is food security 65

Figure 17: Dummy Variables indicators for migration and food security status(left), food security status and remittance received(right) 70

Figure 18: Vulnerability indicators food consumption and total household consumption 83

Figure 19: Combined Scatterplot vs. Histogram 83

Figure 20: Combined Bar Plot. 84

Figure 21: Combine histogram with normal curve. 84
Figure 22: Combine histogram with normal curve. 84
Figure 23: Combine histogram. 85
Figure 24: Combine boxplot with normal curve. 85
Figure 25: Combine boxplot with normal curve 85
Figure 26: Combine boxplot with normal curve 86
Figure 27: Combine boxplot with normal curve 86
Figure 28: Average annual Natural occurrence in the Gambia 93
Figure 29: The Selected regions in the rural Gambia. 94
Figure 30: Slow Onset to climate change 95
Figure 31: Climate change extreme 95
Figure 32: Household characteristic in the rural Gambia used survey data 2021 96
Figure 33: Household characteristic in the rural Gambia used survey data 2021. 97
Figure 34: Scree plot of eigenvalues after pca 100
Figure 35: Plot of component scores and component loadings 100
Figure 36: Vulnerability components of the three rural regions selected in the Gambia. 104
Figure 37: Vulnerability index (VI) of the three local regions in the Gambia 106
Figure 38: Time trend for vulnerability index (VI) of the three local regions in the Gambia 107
Figure 39: Relationship between Vulnerability index (VI) and indicators in the rural Gambia 109

ACRONYMS AND ABBREVIATIONS

IPCC: INTERCONTINENTAL PANEL OF CLIMATE CHANGE
FAO: FOOD AND AGRICULTURE ORGANIZATION
INCCA: INTEGRATED CLIMATE AND CARBON
ICMPD: INTERNATIONAL CENTRE FOR MIGRATION POLICY DEVELOPMENT
IOM: INTERNATIONAL ORGANIZATION FOR MIGRATION
GGPLOT:OPEN-SOURCE DATAVISUALIZATION PACKAGE FOR
THE STATISTICAL PROGRAMMING LANGUAGE R
R: SOFTWARE FOR DATA ANALYSIS (STATISTIC AND COMPUTING)
WDI: WORLD DEVELOPMENT INDICATORS
UN DESA: UNITED NATION DEPARTMENT OF ECONOMICS AND SOCIAL AFFAIRS
STATA: GENERAL-PURPOSE STATISTICAL SOFTWARE PACKAGE
UNDP: UNITED NATIONS DEVELOPMENT PROGRAMME
IDMC: INTERNAL DISPLACEMENT MONITORING CENTRE
GDP: GROSS DOMESTIC PRODUCT
IFAD: INTERNATIONAL FUND FOR AGRICULTURAL DEVELOPMENT
WFP: WORLD FOOD PROGRAM
IQ: INTELLIGENCE QUOTIENT
WFS: WORLD FOOD SUMMIT
UN: UNITED NATIONS
SDGS: SUSTAINABLE DEVELOPMENT GOALS
UNICEF: UNITED NATIONS INTERNATIONAL CHILDREN'S EMERGENCY FUND
WHO: WORLD HEALTH ORGANIZATION
NGO: NON GOVERNMENTAL ORGANIZATION
R: DISCOUNTED RATE
VAR: VECTOR AUTO-REGRESSIVE
ARDL: AUTOREGRESSIVE DISTRIBUTED LAG
FGLS: FEASIBLE GENERALIZED LEAST SQUARES
VEP: VULNERABILITY AS EXPECTED POVERTY
VEU: VULNERABILITY AS EXPECTED UTILITY
VER: VULNERABILITY AS UNINSURED EXPOSURE TO RISK
UNFCCC: UNITED NATIONS FRAME WORK CONVENTION ON CLIMATE CHANGE
EKC: ENVIRONMENTAL KUZNET CURVE
PCA: PRINCIPAL COMPONENT ANALYSIS
GHGE GREENHOUSE GAS EMISSIONS
GDPPC: GDP PER CAPITAL
CO2: CARBON DIOXIDE
VI: VULNERABILITY INDEX
AC: ADAPTIVE CAPACITY
EX: EXPOSURE
S: SENSITIVITY
AAT: AVERAGE ANNUAL TEMPERATURE
IFPRI: INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
GBOS: GAMBIA BUREAU OF STATISTIC

GENERAL INTRODUCTION

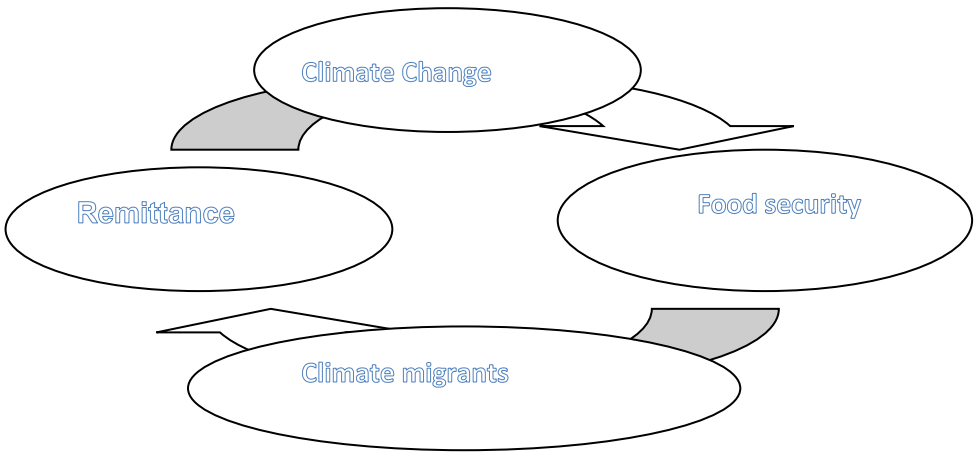
Overview of Climate Change, migration dynamic, and food security in Africa and The Gambia

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. As of 2022, The Gambia has a population of 2.5 million and a human development index of 174 out of 189 countries. Agriculture is the leading economic activity in the Gambia. Still, it has witnessed a downturn since the 1990s because of numerous issues, including poor rainfall distribution, inadequate marketing infrastructure, shortage of access to credit and an inadequate resource base (FAO,2016), and a high level of migration. Two kinds of migration that occurred in the Gambia recently are rural-urban migration and international migration due to both push and pull factors of migration in which environmental change and climate change are part of push factors. So if low rainfall happens, in the following year, some family members migrate elsewhere to search for jobs (skilled or unskilled) or income to send to a family that is left behind, especially women, including their wives. mothers or siblings, children, elders and the disabled. This migration decision is based on intention and plan, and households, individuals, or communities solely make the final decision in those regions to solve food security problems. Flooding, drought, sea level rises, and bushfires after damages are done to their livelihoods for survival. all can cause rural-urban or international migration, temporary, seasonal, or permanent migration elsewhere to look for a place that is food secure and stable. Furthermore, the Gambia faces several development challenges, including high food insecurity due to changing rainfall patterns and temperature that lead to low availability of food commodities in the market, increasing food prices. Food export is lower due to the lower contribution of agricultural production, which is also dependent on the government's low budget and associated climate change effects assigned to agriculture. The Gambia is vulnerable because it depends on food import that reduces the economy development as found by Ceesay et al. (2021) by time series data and WFP (2018). Even if youths did not migrate to The Gambia, this would reduce the economic growth in The Gambia. Since the youths that move are more unskilled, and even if they stay, they will act as a burden to the economy and their family, the study noted. The climate change affecting crops, livestock, fishing, hunting, forestry, and so on will still harm the growing of the economy and overall standard of living. The trend of temperature change and annual precipitation change in the Gambia and the import of rice rises motivate specific adaptation strategies for rice cultivation to solve the problems of national food insecurity and improve security of food and living of the population, especially the rural poor. The association between change in climate, migration dynamics, and insecurity of food require tremendous knowledge of the characteristic of the continents, countries, regions, town and villages, clusters, and geospatial phenomena. Such as knowledge of geographical locations, demographical characteristics, poverty status, hunger status,

climate change status (rainfall, temperature, drought, flooding, sea level rises, salinization, erosion, bushfire, and so on), supply and demand status of out-migration and in-migration, temporary or permanent migration, traditional and custom status, and food insecurity status.

Problem Statement

A lack of interdisciplinary teaching and cooperation has significantly hindered the advancement in environment and population investigation (Hunter and O'Neill, 2014). The IPCC's fifth assessment report delivered a cumulative evidence on change in climate. According to Barbieri et al (2010) change in climate negatively impact agricultural output, underscoring resident's mobility since working devices are insufficient toward alleviating the economic effects in Northeast Brazil.Moreover, 84 percent of migration in West Africa is still intra-regional ICMPD, 2015 and IOM, 2015. Regarding migration, the influence of climate change on indigenous, local children, and populations with disabilities and reaffirms to protect of their rights has been recognized by Paris Agreement, 2016. Furthermore, developing countries will suffer a lot due to shortage of adaptive capacity to solve problems associated with climate change (Gutmann and Field, 2010). In contrast, opposing climate tremours may constrain internal migration and out-migration among impoverished and marginalized populations. They may "trap" people, animals, plants, and those in the sea and on the Earth's surface (Black et al. 2011). Consequently, in case of adaptation plans being unsuccessful, households might make effort to recuperate by international migration (Henry et al, 2004).Sometimes, not allowing them to migrate will harm the economy more because they are highly unemployed and highly unskilled on the one hand. On the other hand, this will happen when households are not migrating due to change in climate like flooding, droughts, salinization, sea-level rises, bushfire etc. In those cases, the solution for intention, planning, and final decision of household members to migrate should be reduced by adaptation as a coping strategy. The link among food safety, climate change, and relocation dynamics is documented (McMichael, 2014). This study will add more light on that too, to empirical change qualitative data into quantitative data to run the perceptions on change in climate, relocation dynamics, and food security. In addition, the problem the research explores how climate change upsets food security in The Gambia. On the other hand, the thesis investigates the influence of migration dynamics on safety of food by looking at the contributions and remittances from rural-urban migration and global migration that remain predominant in The Gambia. The final chapter is a vulnerability assessment at regions and households' levels.



Circular flow in the relationship between climate change, Migration dynamic, and food security is quite complex and can be seen as a vicious cycle
Sources: Author's compilation. It is complex pathways'.

Research questions

What is the impacts of Climate change, migration, food security and Vulnerability in the rural Gambia?

The sub research- questions are:

- How might climate change upset food security in The Gambia?
- What are the influences of food security on migration response in The Gambia?
- What is the vulnerability assessment at household levels and regional levels towards climate change in the rural Gambia?

General Objective

The Study's general objective is to assess the impacts of climate change, migration dynamics, and food security in The Gambia.

Specific objectives of the Study

- To determine the influence of climate change on food availability in the Gambia
- To analyse the influence of food security on migration responses in The Gambia
- To identify the most vulnerable households and regions in The Gambia to climate change

Hypothesis testing

The Study wants to achieve these specific objectives by performing the following hypothesis tests.

1. The food availability in The Gambia does not correlate with climate change.
2. Migration responses do not cause food security in The Gambia.
3. The degree of vulnerability of farmers to change in climate does not meaningfully vary in diverse households' and regions in The Gambia.

Justification of the Study

In this study, we want to justify that as climate changes is worsen, food insecurity will rise (Ericksen, P., Thornton, P., & Notenbaert, A. (2011)) and that, in turn, causes massive migration internally (Alam et al., 2020) and externally (Sadiddin et al., 2019) especially vulnerability group of households. According to the theoretical model, we use the agriculture model to understand the utility driven by agriculture production and consumption (Wall, 2021). Agriculture is affected by floods and droughts (Ceesay, E. K. (2020)). This, in turn, disturbs crop production and food availability. In The Gambia, according to (Ceesay et al., 2021), youth participation in livestock production is an optimistic sign and fish production, though foreigners dominated the fish industry. Climate change is real (Haunschild et al., 2016) .it affects agriculture through fluctuation in rainfall (Belford et al., 2020) and high temperature (Belford et al., 2020 b) in The Gambia. Most women reduce subsistence farming due to the fluctuations of rainfall and high temperature, the problem of pests and diseases, and locusts that affect crops, especially during harvesting. This is confirmed in most of the regions in the Gambia. It, in turn, leads to massive migration. In this present study, we want to justify whether migration is caused by climate change(Entwisle et al., 2016) and other socio,

demographic, political, economic, conflict, and geographic factors and other push-pull factors that lead to climate-induced migration Bettini, G. (2014) from the rural's Gambia. The capital of The Gambia is highly affected by sea level rises, which in turn causes damage to the city through floods affecting the graveyards and other places. It eventually causes urban population movement. This thesis justifies the conceptual, theoretical, and empirical literature to understand the key drivers of food safety and migration due to change in climate and additional social, economic and biophysical issues of vulnerability at household and regional levels towards poverty and climate change.

Relevance to policymakers

The Study on change in climate migration dynamics and security of food in the rural Gambia is essential and it is the right time to have a wakeup call for policymakers to look at the thesis profile and apply it to the broader population and to control long-run problems associated with climate stressors, migration dynamics wildly irregular force and climate migrants. It is timely as The Gambia is facing a food shortage through poor agriculture, which is driven by low rainfall and high temperature, which in turn affect the standard of living, the health, education, economic development and employment of the youth and entire population in The Gambia. Climate change affects most of the land, and agriculture, through salt intrusion, sea level rises, flood, drought, bush fire, over-grazing, desertification, poor soil, poor/shortage of water for arable land and inadequate water for animals. It, of course, brings migration and food insecurity. Migration internally and internationally can be illegal or legal migration. The most common that policymakers should look at is illegal migration as most of the youths trap on the way and even arrive with no job because they are unskilled migrants, and those left behind in the Gambia suffer from food insecurity, education for students, health effects and, in turn, causes malnutrition. This study has an important optimistic impact on the country to understand that climate change, migration, and food security can bring long-term positive impacts to a country if proper adaptation and coping strategies occur in agriculture and migration, respectively. This adaptation will solve the vulnerability that most households face, that the expected poverty level will rise due to poor agriculture and livelihoods. At the same time, most youths are always thinking of irregular migration due to the socio-economic disorder they have in their society and their respective communities. If migration is used as an adaptation strategies, it will help to cope with climate stressors, to help households from traditional to modern ways of farming by providing education and innovation to small holders' farmer. On the other hand, they can engage the youths in agriculture by providing a value chain for mangoes, different rice varieties, irrigation methods, poultry farming, and animal husbandry. Climate change, migration dynamics, and food security are significant concerns in The Gambia as the country depends mainly on agriculture and migration as a basis of food security and remittances. In case of the climate crisis, rain-fed agriculture will eventually collapse, and this, in turn, causes severe damage to the population through food insecurity, hunger, and poverty. It will lead to massive migration to urban areas for income, either internally or externally or a combination of both. According to Ceesay, E. (2020), climate change will affect agriculture, employment in agriculture will eventually reduce economic growth in The Gambia, and change in climate will upset all four pillars of food security (FAO, 2018). If the four pillars of food security are affected, this will lead to migration to have food to eat and food to export and to reduce food importation.

The motivation of the Study

My main interest is to make available this investigation because of the multifaceted issues to bring to the attention of policymakers that change climate and its impact are real. Climate change causes migration, food security issues especially vulnerable households. All these motivated me to comprehend the links among climate change, food security, migration and susceptibility at households and rural regions in The Gambia and to understand the change in climate, security of food and other macroeconomic variables connection in The Gambia.

Approaches and methods used in the Study

The technique used in this thesis is mixed methods. Both qualitative methods and quantitative data were used in the thesis. For objective 1, we used secondary data by applying time series methodologies such as VAR, GRANGER CASUALTY, ARDL, and ECM to analyze the data. We did a simple random and stratified random sampling for objectives two and three of the thesis using the multilevel version of the conventional logistic regression model and vulnerability assessment at the household's level and across regions in the rural Gambia. Further, for objective three, we used two kinds of approaches to compute vulnerability. At the level of household, we used the vulnerability as expected poverty method as econometrics measures. At the selected regions, we applied principal components analysis (PCA) to calculate vulnerability index and we validated the results of Vulnerability index.

Organization of the thesis

Chapter one provides stylized facts about climate change, migration dynamics, and food security in The Gambia. Chapter two presents a literature review. Chapter three presents methods and data analyses. Results are provided in chapter four, while Chapter five presents a general conclusion, policy recommendations, study limitation, and general summaries.

CHAPTER ONE

STYLIZED FACTS ABOUT CLIMATE CHANGE, MIGRATION DYNAMICS, FOOD SECURITY AND VULNERABILTY

INTRODUCTION

1.1. Facts about variation in climate, migration dynamics, and food security

The impact of population growth in the Gambia will lead to migration and food security problems from the influence of climate change on mobility. Moreover, in the future, climate variation, especially variability in rainfall and temperature, will cause severe threats to both food security and population movement (Clima, 2018). Adverse climate scenarios will cause food insecurity through poor agriculture production from heat waves, pest and diseases, and diminishing water supplies. The price escalation is due to food unavailability from damages done by pets and diseases. However, the intersection between climate, food security, and population movement has little consideration. It is due to its complex nature. The graphs in Fig 2 indicate that food production, net migration, and climate change variables have a different dimensions in most cases. McMichael et al. (2012) argues that we know slightly about the interplay amid the ecological system, climate stressors, then environment, which causes socioeconomic vulnerability of the households and the potential outcome in terms of population-induced migration. Moreover, increases in population causes climate conflict through increases GHG emission and increases in consumption-animals-based foods, political violence, climate threats to food security, climate violence, climate threats to agriculture, infrastructure, and manufacturing sector, and causes natural disasters or hazards.

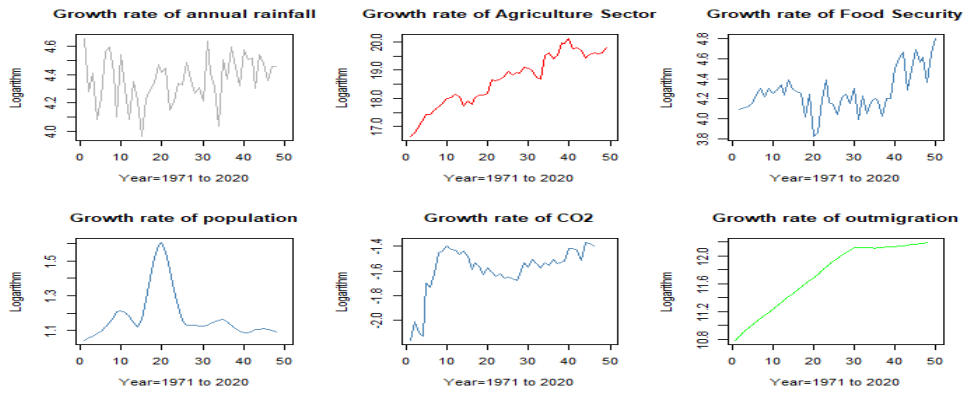


Figure 1: None Stationary time series graphs

Sources: Author's compilation using R data from WDI

There is complex nature to interlink climate change, migration dynamics, and food security due to different drivers. According to IPCC, vulnerability of African countries toward change in climate effect was determined via variety of features comprising frail technology, irrigational facilities associated with weak adaptive capacity, poor agricultural production and production systems, high dependence on ecosystem goods for livelihoods, lack of climate change financing tools, poor human capital, poor regulation quality, rampant corruption, lack of supporting groups for the society to aware climate change impact and to overcome its long-term effects, lack of environmental protection and regulation and surveillance tools or mechanisms to protect the surrounding affected by climate and environmental disasters. Climate change will affect agricultural production and will likely affect the sustainable development goals in Africa (Guterres, 2020). Climate variability and change affect many sectors, but we cannot feel the climate impacts due to less research on them. Temperature and weather changes in Africa affect Africa and its people in different ways. These conditions affect energy production and consumption, economic growth, food security, massive migration, and poor agricultural systems (IPCC, 2014). In Africa, agricultural systems rely heavily on rainfall (Klein & Persson, 2008). Furthermore, agriculture in Africa is associated with small holder farmers (Mendelsohn, 2008). For instance, in Africa, climate change impact on the agricultural sector has undesirable influence on food price (Watts et al., 2015).

Drivers of climate change on food security

Drought, floods, salt intrusion, ocean acidification, higher temperature, bushfire, storm, and lightning, variability of rainfall and temperature pattern affects cereal crops and other food crops around the world. Since climate change can be felt locally or at the community level, droughts, desertification, land degradation, flooding, and salt intrusion can lead to food shortages, price escalation, and loss of fertile soil, which causes food insecurity. Globally, two billion people are subjected to moderate or severe food insecurities. Climate extreme events such as drought threaten food prices, food supply, and overall food production (Fallis, 2013). Climate change affects agriculture (National & Pillars, n.d.), and this trend causes food security problems. Accordingly to Nicholson, S. & Tucker M.(1998), drought causes low precipitation as a dominant climate driver of maize yield during this event, given the severity of the precipitation anomaly and the predominant rain-fed agriculture in this region of Western Africa. In addition, the rising food prices were due to locust invasion, low employment in agriculture (Ceesay et al., (2021), and drought affecting both cereal crops, especially maize (FAO. 2001), groundnut and rice. It, in turn, causes the many Gambians to have severe hardships in terms of household food security from rising food prices, particularly in the markets and shops. Climate variability and change in climate caused by drought directly impact food price hikes, which occur due to a decline in agricultural products from poor yields of staple food and other related food items. In the Gambia, climate change is projected to affect crop production (Jaiteh Malanding, 2010a). Further, IPCC (2001) states that climate change causes food insecurity and breakdown of food systems. Climate change is a driver of food security through its effects on trade flows, food markets and food price

steadiness, and that could have risks to human health (Croppenstedt, A. & Muller, C. 2000). In most cases, climate change affects the population that is more vulnerable and increases their vulnerability to food security, hunger, malnutrition, and poverty.

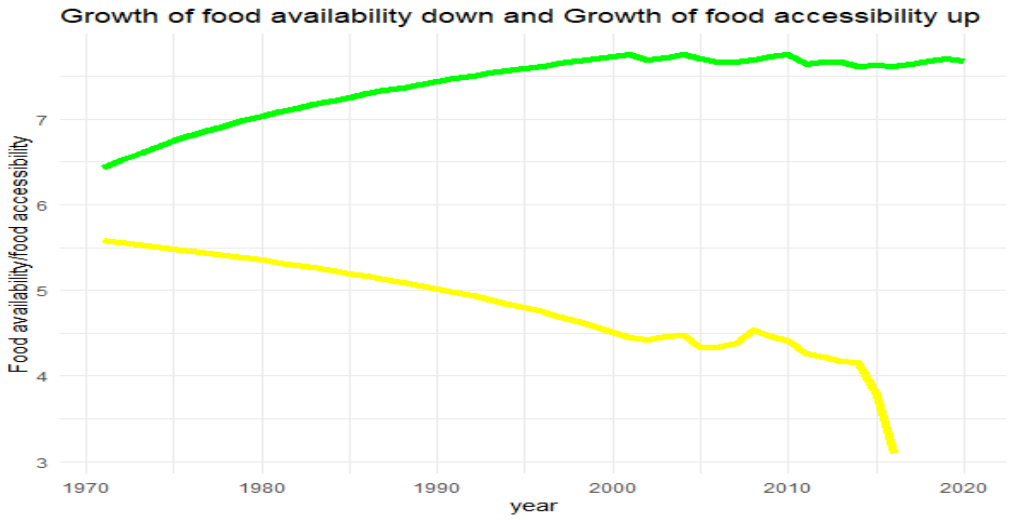


Figure 2: GGPLOT for growth in food availability and growth of food accessibility

Sources: Author's compilation using R data from WDI

The green color is the growth of food accessibility and the yellow is the growth of food availability in the Gambia. However, food accessibility is easier in the Gambia than food availability.

1.3. **Drivers of climate change and food insecurity**

Food insecurity and extreme climate events leads to lower yields of crops and causes animals to die because growth grasses is staunched and they wither early. Animals must find food and water for survival. Climate change threatens agriculture in the dry season through water scarcity, and in the wet season, it causes threats from low rainfall and high temperature. Rainfall affects crops due to low yields, higher prices, due to lower supply from producers, and high demand for consumers, so this will lead to disequilibrium amid the food supply and the food demand system, caused by dangerous climate events such as fluctuating rainfall pattern, temperature fluctuation, flooding, drought, bushfire, salt intrusion, sea level rises and lightening and erosion. The crop are affected, animals are affected, forestry and fishing are affected, and hunting declines due to the dearth of animals in the forest. In some cases animals die due to hunger driven by climate change shocks which in turn causes severe food insecurity. Climate change affects food availability, causes lower production, food inaccessibility caused by drought or flooding, food supply instability caused by rising food prices, food imports are higher and exports low, and food utilization caused by utility drive from food to have lower nutrients from obviously lower maturity of crops, while animals die from climate change impact.

1.4**. Climate and agriculture**

According to FAO (2016,2018), climate change affects agriculture and food security and around 800 millions peoples suffered undernourishment are small holder farmers, pastoralists and fishers. In the various regions, evidence confirms that Climate change leads to decreased productivity of trees, vegetables and animals as a result of droughts and floods and changes in temperatures. As a results, water scarcity, acidification, and poor nutrition all result in climate change effects and that lead to food insecurity that causes low birth weight, malnutrition and eventually high mortality rates especially in children

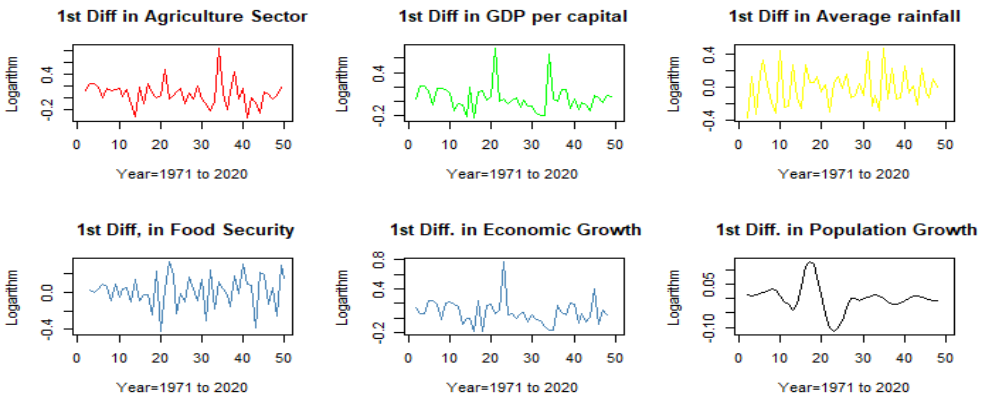


Figure 3: Stationary time series graphs

Sources: Author's compilation using R data from WDI

The Gambia's population is currently 2.5 million (IOM, 2017), and it is one of the smallest countries in the world. Despite its small size, migration plays an invaluable role in the households and society in the country. Personal remittances are also crucial for migrants and their parents or migrants' households. As of 2017, according to IOM (2017) The Gambia's net migration rate was -1.217 migrants/1000 population, but personal remittance received from outside was 215.7 million dollars. Remittance is an essential determinant of migration in The Gambia (Ceesay E., 2020). According to IOM (2017), women as a percentage of international migrant stock stand at 47.3 percent, with the smallest country and small population, The Gambia. Thus, in most households in The Gambia, men migrate far more than women especially illegal means to Europe. These cause many women to have marital problems, either waiting for years, seeking a divorce, or getting divorced. Those left behind are also affected by food security, household consumption, and production expenditure.

1.5. **International Migration**

Emigration versus immigration

In The Gambia, the flows/movement of people are done by either internal migration, emigration, immigration, refugees, climate induced migration, short distance migration. Climate induced migration are those people's lives their homes due to climate stressors; heavy flooding, droughts, sea level rises, changes in rainfall etc.

Emigration

The Gambia is a country of international migration due to the number of emigrations recorded. The number of those emigrating from the Gambia and outside the country is alarming. According to IOM (2017) there are 140 000 Gambians that are living abroad, constituting 7 percent of the population of 2.3488million (WDI), 2019. According to IOM (2017), data recently found that 48 percent arrived by sea in Italy, and 6 percent were from The Gambia. So, Gambia is a country of emigration. About 50 percent of Gambia are emigrated (UNDESA, 2015). This emigration, either by sea, road, or air, is due to economic instability in The Gambia, poor agriculture, high commodity price and food insecurity, poverty and hunger.

Immigration

Immigration is the people moving into a specific country. According to www.knomad.org/data/ the summary of immigration status of the Gambia is as follows: the Stock of immigrants in the Gambia stands at 162,900 people, approximately 8.9% of the population. Additionally, more than half of the immigrants are

female (about 51%). The top countries of immigrants that are in The Gambia are Senegal, Guinea, Guinea-Bissau, Mali, Mauritania, and Sierra Leone.

1.6. **Internal Migration**

Internal migration in the Gambia is not very common due to the stable nature of the country. There is limited data on the internal migration in the Gambia. However, there is rural-urban migration which mainly occurs in the dry season, where many youth go to the city for business or other jobs. It helps households affected by drought or low rainfall and have poor agricultural yield or harvest, which in turn affects their food security, education for children, school fees, health, and other expenditures. Most of these challenges are resolved by the internal migrants, either rural to urban or urban to rural or rural to rural or urban to urban. Urban to urban is mainly caused by climate disaster(Adamo, 2010) or environmental problems such as sea-level rise, air, water, and land pollution. Thus, most youths migrate for high skills such as to educational institutions (Browne, 2017) that are not in the rural areas to further their education in the urban areas. Most of them also migrate since the prices of agricultural goods drop, and they substitute it with businesses, construction jobs, retail jobs, and so on. It is why some youths migrate to be following old white ladies and gentlemen. After the independence from Great Britain, the economic growth rate in The Gambia fluctuated over time It affected other areas of the development sectors in The Gambia, such as health, energy, and education. As depicted in figure 5 below, a region with high migration responses receives a larger share of remittance.

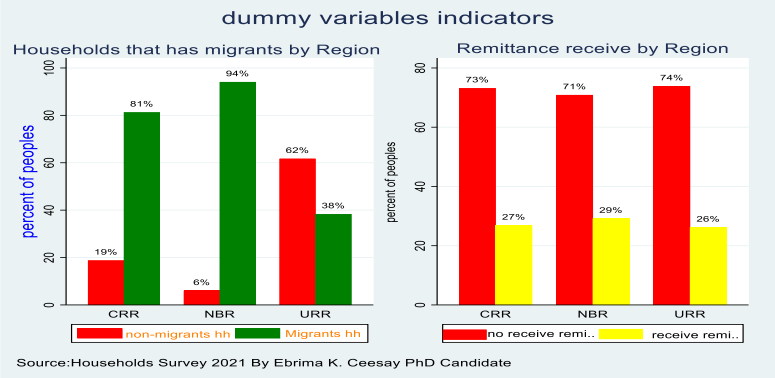


Figure 4: Migrates and Remittance received by region

Sources: Author's compilation using Stata 16 data from household's survey data, 2021

With water scarcity, crop failure, land degradation, pest and insect damages, and climate changes, most of the youth in The Gambia or indeed, population in the rural areas was left unemployed, and in that case, many more to urban areas for survival and to provide basic amenities for those they left behind. Still, unemployment rates remain high in The Gambia (UNDP, 2016). A significant percentage of the population in the Gambia live abroad, almost 5 to 7 percent of the population to 7 percent (Jaiteh Malanding, S. (2010). Thus, internal migration in The Gambia is due to displacement, driven by natural disasters such as floods, droughts, sea level rise, bushfires, and landslides (IA, 2017, Ceesay, 2019). The other form of disaster is less discussed in most of the literature. It sometimes happens to people in a disaster caused by wells, trees, rivers, cars, motorbikes, pollution, and lightning. These disasters kill many people in The Gambia, and less research is carried out on them. It, of course, causes internal displacement and internal migration either short distance or to the city. Even sea level rises are climate change events that cause migration in The Gambia, as well as the salt intrusion, which is most common in the rural area of The Gambia and leads to internal migration. Due to political unrest in The Gambia in 2016, the number of international displacement persons was 4,600 (IDMC, 2017). Most of them went to the neighbouring country, Senegal. For instance, political upheavals cause violence, which often times lead to international migration. (Caux, 2017, IRIN, 2017, IDMC, 2017). As they cross the border, it will be categorized as international migration, which amounted to 40 000 people in the 2016 political turmoil (IDMC, 2017).

Table 1:The Rural Gambia Households' Migration Status

Migration type		
	Frequency	%
Seasonal	70	17.99
Temporal	125	32.13
In-migration	161	41.39
Out-migration	33	8.48
Total	389	100%
Migration Status of the households		
	Frequency	%
Never migrated	156	40.10
current internal	107	27.51
current international	36	9.25
returned internal	79	20.31
returned international	10	2.57
Total	389	100%

Own Evaluation Using survey data (2021)

In the rural Gambia, most households have internal migrants (about 41.39%). The second most common migration type is temporal migration (seasonal migrates are those comes to stay for a season especially raining season for employment in agriculture), and the least is the out-migration or international migration (about 8.48%) respectively. Furthermore, according to respondents, the migration status of the households in the rural Gambia that have never migrated were 40.10%. Most are current internal (27.51%), returned internal are 20.31 percent, current international is 9.25 percent, and returned international either deported, came back by themselves or illness or mental issues and other related social and personal issues; 2.57%.

Note: internal migrates might contain temporary migrates sometime if a person lives within national borders. Therefore temporary internal migrates and temporary international migrates are different.

1.7. **Net migration**

The net migration rate in The Gambia was negative from 2015 to 2020, standing at -1.217 (IOM, 2017, Ceesay, 2020, WDI, 2015). Net migration is the different between emigrates and immigrates and contain both residents and non-resident within a country in a given period of time. As of now, the net migration is falling in The Gambia. Thus, international migration is relevant in The Gambia because the country is a debtor country because of its economic growth associated with deficit. Poor growth makes many Gambian youths unemployed, worsened by poor climate associated leading to poor agricultural productivity, and food insecurity, and poor human capital. It prompts many Gambians to migrate to Western countries. and the

primary destination is the USA (DESA, 2015, Kebbeh, 2013). Some Gambians migrate using flights, and others use illegal migration route to Europe. According to WDI (2017), 78 percent of the migrants are male, while 22 percent are female. The Gambia is one of the top five countries that use "backway" or illegal migration en route from Libya to Europe (Hunt, 2017). Many youths die on the way, some returned, and some developed mental disorders or psychological problems. Furthermore, those who travel by air are more educated than those who travel by sea. Regardless, some well-known people and educated ones traveled by sea due to easy access and affordability and the relatively easy documentation process compared to travel by air. Skilled and unskilled migration has lots of benefits to The Gambian populace. It brings remittances, which is a source of revenue for most of the households in The Gambia. Remittances have an optimistic and substantial coefficient influence on the GDP in The Gambia (Ceesay, 2019, 2020, Kebbeh, 2013, WDI, 2016). Remittances impact the quality of education, food security, health facilities or treatment of ill household members, and to help villages or towns in their development agent and occupation in agriculture. It however, lacks adequate statistics to back up the findings. There is still inadequate research to properly buttress and document this net migration relationship with remittance and other variables above.

Net Migration and Remittance

Changes in net migration in The Gambia started to manifest in 1960. There was a break in migration from 1965 to 1970 and part of 1980s. It may be attributed to the independence from Great Britain and, simultaneously, to get the Republic. Freedom and the new administration were the fundamental causes. At the same time, The Gambia also faced a coup detat, which damaged properties, killed innocent citizens in The Gambia, and affected the flow of people. If migration happened then, it would be short distant migration. In some part of the 1980s, net migration started to rise and significant fall up to the year 2000. In the year 2000, it increased a bit and started to fall; as of now, net migration is constant. Factors may be due to demographic characteristics of the country and its households (micro), political condition, economic (macro), social, location/environment. Change in personal remittances received from the diaspora in US dollars changes with time. As depicted in the figure above, it is the key driver of the economy and well-being in The Gambia. Without applying the change, personal remittances received from the diaspora increased with time. The shape is quite different from the one we applied logarithm. In conclusion, things change with time, and the changes are increasing factors that affect the trend of migration and remittances.

Drivers of change in climate 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).

Table 2: 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). 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.

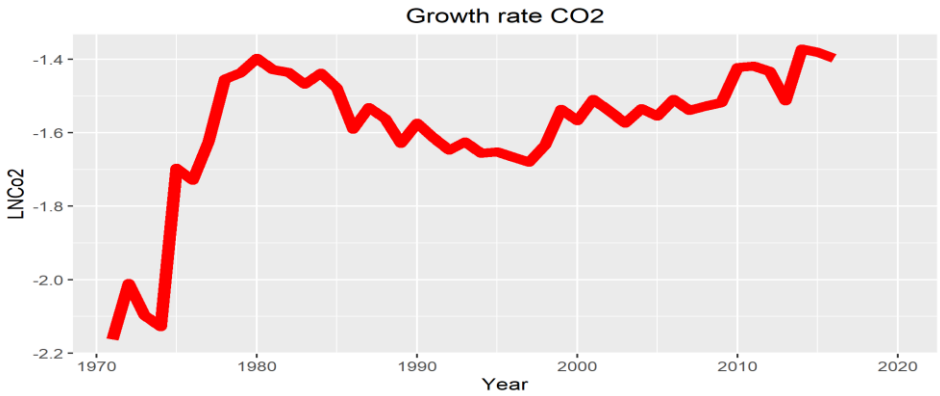


Figure 5: Changes in CO2 from 1971 to 2020 from WDI.

On evaluation using rstudio data from WDI.

Figure 6: From 1971 to 2020, the trends of the growth rate of CO2 emission proxy for environmental quality fluctuating but increases with time. Therefore, an increases in CO2 emission from GHG emission was due to non-renewable energy generation such as fossil fuel from the industries and from environment combustion. So to reduce CO2 emission we must transform to green environment or using more renewable energy generation.

Drivers of migration and food security

Migration can drive food security through remittances received from abroad, though, the linkage between migration and food security from agriculture is complex. Therefore, migration as one of the drivers of food security through remittance is a choice. To provide thorough evidence on this matter, we consider why people migrate from rural and urban areas or to developing and developed countries. This migration can be seasonal, internal, or international migration. Food security is a driver of migration from poor agricultural harvests. The migrants can move either internally or overseas to find employment and send remittances back home to help family members that are left behind regarding food security. Therefore, migration brings remittances, and remittances can help families, households, or individuals to improve agriculture and to be food secured. Migration drivers are economic features that lead to food insecurity. Conflict can lead to migration, which causes food insecurity, hunger, and rural poverty. Therefore, food insecurity makes rural populations or people to migrate (Intention, plan, and final decision). At the same time, migration can act as a tactic to handle the risks associated with starvation and undernourishment. Thus, all drivers of migration lead to food insecurity, such as economic factors, employment opportunities, poor agriculture, climate change, conflict, land disputes, shocks and psychological reasons, poverty, environmental degradation, and pollution in either water, sea, land or air pollution and as well as energy dis-utilization. The food insecurity is the determinant of international move in most households, communities and countries (Ruel, 2013).The youth migrate due to rural poverty, which is driven by poor agriculture and leads to food insecurity. There is, therefore, the positive contribution of migrants sending remittances, which boost economic growth, rural poverty reduction, and food security. As migration can drive food security from migrants sending remittances back home, this can have a positive dynamic to increase productivity, increase income and act as poverty reduction. The economic reasons for migrating from the place of origin is poor living conditions, which lead to food uncertainty. The change in climate leads to poor agriculture, and which leads to migration. Natural hazards can also lead to food insecurity and migration. Better knowledge of drivers of migration will help to link with food security. Most rural poor also migrate because of a lack of additional options to sustain their living in their place of origin, either rural areas or urban areas.

Table 3: Perception of Environmental Drivers of migration and food insecurity in the rural Gambia

Climate change indicators	Perception of the respondent affected (%)

Changes rainfall	97.50
Changes temperature	95.25
Salinization	40.05
Rising sea-levels	36.59
Drought	73.28
Flood	70.74

Source: Own evaluation using Stata 16 from survey data, 2021

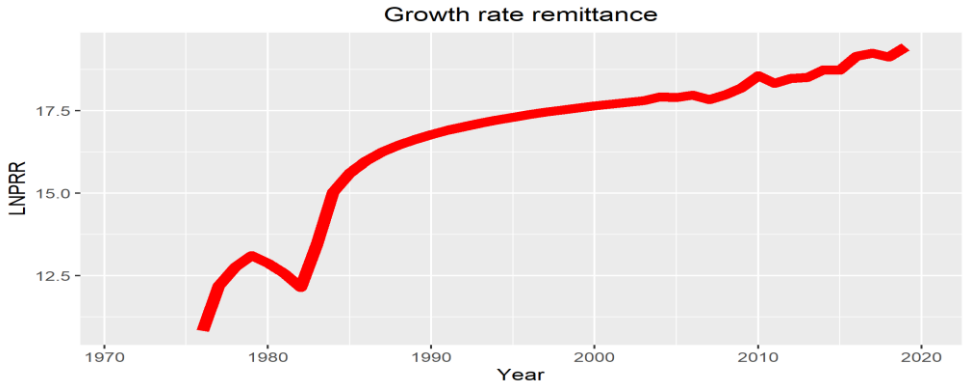


Figure 6: Growth of remittances as key drivers of food security in the Gambia from WDI.

1.11. **Factors that drive migration**

Migration can be driven by many factors such as macro, micro, push, and pull factors. Most if not all lead to food insecurity in the place of origin. Macro factors are migrant decisions on the origin and destination area, what migrants notice in these two areas such as the employment opportunities, economic growth, poverty and inequality, persecution, conflict, and macroeconomic conditions. Micro factors include education, age, income, employment status and preference of the individual/power relations within the individual household, preference of resources differences, and land disputes. Push factors are absence of employment chances, food insecurity, conflict, high crime rates, civil war, natural hazards, and political instability. The pull factors that drive migration in the destination countries are decent jobs, security, standards of living, safety, equality in gender, educational investment and resources, and better education, knowledge, and facilities. So, the push factor, the macro factors, the micro factors, and the push factors are determinants of migration in one way or the other. Food insecurity is one of the reasons for migrating either internationally or internally.

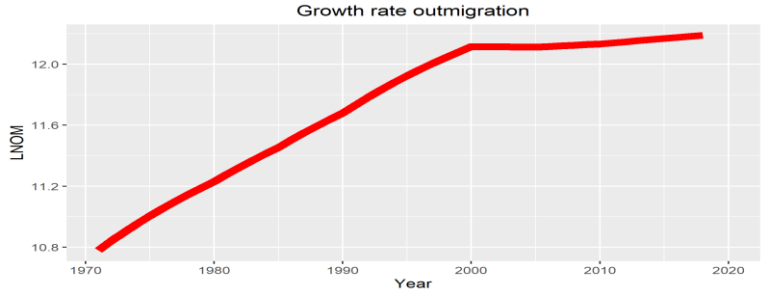


Figure 7: Outmigration from 1971 to 2020. Sources: Own evaluation using Stata 16 for window from

World and regional statistics, national data, maps, rankings (knoema.com)

1.12. **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. Furthermore, in The Gambia, climate change variables like CO2 emission are not the only ones, but precipitation and temperature change also have a destructive effect on our lives and property. See figure 9 for example:

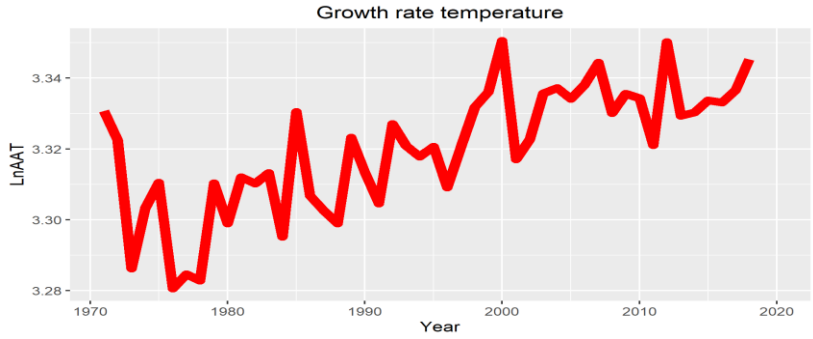


Figure 8: Changes in mean temperature in the Gambia from 1971 to 2020

Source: Own evaluation using stata 16 from WDI

Definition Climate change, Food security, Migration and Vulnerability

There are several and widely used definition of climate change, migration and food security.

Climate Change:

Definition 1: Climate change refers to change in long terms means/averages for all the essential climate variables (FAO...).

Definition 2: Climate change can refer to as only human-induced changes in the climate system (UNFCCC, 1995).

Definition 3: Climate change refers to long-term changes in average weather conditions (WMO, 1992, 2005).

Definition 4: Climate change (IPCC, 1995) definition stated climate change as referred to in the observational record of climate occurs because of internal changes within the climate system or in the collaboration amongst its mechanisms, or because of vicissitudes in outside compelling, either for natural details or because of human doings/activities.

Definition 6: Climate is the average pattern of weather for a particular place over several decades (at least three decades) Olayide et al., 2016.

Migration:

Definition 1: Migration designates a process of moving, either across an international border, or within a State. It is a population movement, encompassing any kind of movement of people, whatever its length, composition and causes; it includes migration of refugees, displaced persons, uprooted people, and economic migrants (IOM, 2004, 2018)

Definition 2: The movement of persons away from their place of usual residence, either across an international border or within a State (IOM, 2019).

Definition 3: International migration the movement of people across international boundaries (World Bank, 2019)

Definition 4: the movement of people to a new country or area in order to find work or better living conditions (Oxford Dictionary definition of migration)

Definition 5: Migration involves the movement of people from one place to another with intentions of settling, permanently or temporarily, at a new location (World Migration Report 2020, International Organization for Migration, 2019).

Food Security:

Definition 1: Food security is availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices (United Nations. 1975. Report of the World Food Conference, Rome 5-16 November 1974. New York)

Definition 2: Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food favorites for an energetic and healthy lifetime (World Food Summit 1996) (FAO 2008).

Definition 3: the ultimate objective of world food security should be to ensure that all people at all times have both physical and economic access to the basic food they need. Food security should have three specific aims, namely ensuring production of adequate food supplies; maximizing stability in the flow of supplies; and securing access to available supplies on the part of those who need them." (FAO. 1983. World Food Security: a Reappraisal of the Concepts and Approaches. Director General's Report. Rome.)

Definition 4: Food security as follows: Access (physical and economic) to sufficient and nutritious food for all people at all times for present and future generations 2017 M. J. Ibarrola-Rivas and L. Galicia.

Vulnerability

Vulnerability denotes to exposure, sensitivity and adaptive capacity and trouble for households to cope with the problems of vulnerability mentioned (Chambers 1989).It can also mean the uncertainty of persons or communities or households in the expression of altering conservation, ecological, economic and political environments in the procedure of tremors, long-standing tendencies or cyclical/seasonal cycles (Moser 1996, Farrington et al. 2002).

Food security and Climate change

Food security contains four main pillars and that is food availability, food accessibility, food utilization and food stability .Thus, climate change and global warming affect all these four pillars of food security. The factor affect food security are; scarcity of land, technological barriers, access to credit and agriculture extension workers, information for adaptation. Subsequently, adaptation increases food productivity.

Conclusion

In the stylized fact of the thesis that contain the relationship between the selected variables was highlight. We conclude that climate change affect food security and that is from feeble agriculture and that in turn causes hunger, malnutrition and health issues. We demonstrated that in the Gambia, availability of food is down due to lack of quality and quantity of enough food for the population. This is due to lack of adaptive capacity because small holders farmers lack resources, agriculture extension workers are not training farmer's new method of farming and there is lack of new agriculture technology tools and inputs. Lastly, income is another problems for rural farmers in the Gambia. Moreover, climate change affect migration especially flood and drought, changes in rainfall and temperature are majors climate change indicators that causes migration in the rural Gambia. In the rural Gambia, flood affect agriculture sector and farmers migrate to urban area to get income in order increase their consumption for the households and drought as an indicators affects rural farmers because of long spell of drought causes plant and animals to die and that translated to migration in the rural Gambia. Finally, food insecurity increase migration especially international migration, which is predominant in the Gambia.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

A change in climate has straight and indirect effects on food security and migration dynamic/population movement (McMichael, 2014, McMichael, 2015, Ceesay et al., 2020, USDA, 2015, Brown et al., 2013, and FAO, 2015). Climate change is still around because most of it is caused by ‘’human-induced abusing the

environment. For some years, there has been an increase in the interests of academic communities and beyond to comprehend and build policy solutions for the influences of climate change on food security and migration. Thus, climate change is a complex phenomenon with multifaceted problem and interlinking to migration dynamics and food security will bring more complex pathways (Deegan et al., 2014, McMichael, 2014; McMichael, 2015; Jacobson et al., 2017)

Change in climate dynamics → Food (In) security → Migration

It is very complex to interlink these three variables due to the multiple dimensions it brings. Estimates have suggested that one billion people lack food security as of change in climate effects. In the subsequent 40 years, most of these food insecurity problems and mass migration will happen in developing countries like Africa and Asia (Crush, 2013, Nickanor et al., 2016, Duda et al., 2018, Sadiddin et al., 2019 Hotez, 2020). FAO IFAD IOM WFP. 2018, Findlay, 2011, Dondi et al., 2020). This literature chapter mainly focuses on the theoretical, conceptual, and empirical framework on how individuals or households are food insecure due to climate change effects or how individuals or households decide to migrate because of climate change impacts. The chapter will also highlight how to measure vulnerability through vulnerability as expected poverty framework. The research will conclude by applying the adaptation strategies that will help to reduce Migration and increase food security, especially for children, women, and the disabled that are left behind and are food insecure. Climate change, food security, and migration dynamics are multifaceted, and complexity is due to multifaceted phenomena:

1. Climate change causes food security problems due to disrupting access to food, disrupting food availability, high rainfall destroying food crops such as rice (rice is predominant in Africa and stable food in most countries, e.g., The Gambia), drought destroying food production, and productivity through lower yields and food quality possible to be destroyed due to climate change effects such as windstorms, salt intrusion, bushfire, pest, insects, and diseases.
2. Climate change like change in temperature patterns then change/fluctuation in rainfall patterns, affects agriculture production and productivity/yields.
3. Climate change also causes Migration and forces people to displace.

The migrates laborer works in food security industries and in turn works in agriculture farms. So, migrates labor increases, food security increases and production of agriculture increases. Subsequently employment in agriculture increase, food security increase and migration from origin decline. The links between agriculture, food security and migration can be indirect through income to cope with certain conditions .Migrates send remittances and purchase enough food and also purchase inputs use in the farms Ceesay, E. K., & Masoero, G. (2021).

2.2. Theoretical frameworks of Migration Study

There are numerous theories of Migration in many areas of academic disciplined. For the present study, some of the theories do not fit in; therefore, they will be listed here without going through them in more detail. As the name for the topic apply-climate change economics, the theories should be based on social-economic theories of Migration. According to Stefanie Kley 2010, explaining migration phases in the life-course theories state that Migration is a complex issue, and its decision-making and behavior process is still at its early stages and is not entirely understood(Arango, 2000 Stefanie Kley, 2010). Additionally, migration dynamics based on decision-making and behavioral characteristic is not fully understood due to the complex nature of migration phenomena such as social embedding, life-course event, demographic characteristic, psychological characteristics, and structural factors interact with individual migration characteristics decision-making from intention, planning and final decision to migrate.

2.3. Neoclassical economic theories of Migration

Neoclassical economic concepts of Migration assume economics plus labor markets move to equilibrium in trade and Migration in the long way (Harris and Todaro, 1970).Migrants travel from societies where labor is plentiful but very hard, and salaries are meager to societies where labor is very rare but small and incomes are very high (Sjaastad, 1962; Todaro, 1970; Borjas, 1980 Bayoh et al., 2006; Kainth, 2010; Abdul-Azeez & Opoola, 2011). The decision to migrate differs amid emerging and industrialized countries. In the case of emerging countries, the decision to migrate can be based on an individual level or household's level, such as the household head, or it can be the combination of both individuals and households but primarily not based on community decisions. Each Individual or head or guidance of the household decides who to migrate. If there is the financial ability and the family is poor, they can meet and decide who to migrate to help the family in terms of food consumption, fish money, health care, educational needs of the children, and so on. Overall, the remittance sent back home can be a source of revenue for the households and communities in those regions where the migrates came from (ceesay, 2019, 2020). The neoclassical theory assumes Migration is triggered mostly by economic relationships of comparative welfares and expenditures analysis, including monetary and psychosomatic reasons (De Haas, 2010). It can also be due to economic reasons, the environment in which one lives, climate change conditions, behavioral reasons, and family characteristics. The elementary model of neoclassical theory points tall that migration outcomes from interregional salary discrepancies, the remoteness amid source countries and destination countries and Income as factors determining Migration (Stark and Bloom, 1984, Harris and Todaro, 1970). Therefore, other things might be the equal neoclassical theory of Migration does not talk about only wages but if there is a lack of or sufficient of the following n the place of origin such as employment opportunities, good institution, good governance, good administration, roles of laws, political stability, food security, hunger, famine, malnutrition, conflict, violence, encourages the likelihoods of migration decision(Sjaastad, 1962; Gans, 1968m Todaro, 1970; Borjas, 1980, and Lagakos et al., 2017). From figure 3, we demonstrate from a neoclassical perspective Individuals or households can move from developing countries, especially Africa, due to higher/brutal labor force with fewer wages to areas or western nations with small labor force with high wages. It is attributed to the fact that developing countries lack the technology or total factor productivity. In contrast, developed nations have adequate technology or total factor productivity, which attracts most people or youth in the developing world to migrate to the Western world. Nonetheless, according to figure 3, most of them are trapped on their way to Western countries. Suppose they are illegal to go either in the Saharan desert or otherwise. In that case, they catch disease on the way, are health hazardous, stay in Libya and can't return to their country of origin or even return or deported or die on their way. All these are shortcomings for migrates from the developing world. Even if they arrive, they may have difficulty in relocation places such as jobs, Income, and so on.

2.4. Neoclassical economic theories of migrations are divided into two main categories;

Macroeconomic theory of Migration, 2) Microeconomic theory of Migration.

2.4.1. **Neoclassical Macroeconomic theory of Migration**

It is the standard and best-known theory by means of migration discover is apprehensive. For instance, labor migration brings economic growing and expansion in both the countries of source and terminus countries.

According (Bailey et al., 2001 and Massey et al., 2011), their theories and their extension led to migration study, internal Migration, and worldwide Migration is produced by a topographical difference aimed at labor demand and labor supply from states of origin to destination countries. The more the origin countries suffer from labor shortages, the also face lower wages. The countries of destination have more work and are associated with higher wages. It encourages migration decisions from developing countries to rich nations. The movements of together productions features in conflicting instructions, and the connected merging of salary levels are a technique of reappearance to the equilibrium in economic, where the income discrepancy reveals individual the expenditures of responsibility migration (Zlotnik, 1998). The resulting movement can be explained by the aggregate supply and demand curve (Piore, 1979). In that curve, they stated that for equilibrium to achieve in migration economics, the demand for and supply for labor should be intersected (Massey et al., 1993). The Nations that are blessed with the most significant labor to capital are associated with a downward sloping demand curve, a negative relationship between labor and capital, and countries that have the smallest or not more challenging labor to capital are associated with an upward sloping supply curve, positive relationships between labor and capital. The resultant wage discrepancy reasons workers from the low-wage country to move to high-wage countries. In contrast, the supply of labor increases in the destination countries, the demand for labor rises as wages decrease (Buera & Kaboski, 2012, Magruder, 2013 and Monras, 2019) in the country of destination, leading to equilibrium or the intersection of demand for Migration equalized with the supply of Migration and those enable equilibrium for demand and supply curve for Migration to achieve. The more peoples migrate from countries. Workers reduce, and wages increase, discouraging shortages of workers from migrating. Still, the destination countries will be over-populated, making employers reduce their wages as the demand for jobs is higher. Migration values noticing that in the entire neoclassical methods, relocations are complex and at the disequilibrium marvel, which ends as quickly as the balance is touched (see Harris and Todaro, 1970). Then, stability to achieve the demand for labor and supply of labor in the countries of origin must be intersected with the demand and supply of labor in the countries of destination. A neoclassical macroeconomic theory of Migration also elaborated on the capital investment from capital-rich countries to capital-poor countries (Lewis, 1940).Skilled migrants from rich countries come to developing countries to enjoy high earnings/wages due to the developing countries lack of human capital and unskilled labor. In this macroeconomic theory of Migration, human capital theory explains Migration in the context of human capital as a source of investment in the destination countries and as the source of loss in the country of origin (Sjaastad 1962, Stark and Wang 2001).

2.4.1.1. **Dual Labor Market Theory of Migration**

It is discoverer by Piore 1979, the dual labor market theory of Migration states that migration movements are determined by the demand characteristics of developed industrial nations on the one hand. On the other hand, Piore (1979) put it in this way intercontinental Movement instigated thru enduring request for settler employment characteristic of industrialized nations' economic structure. The decision of Migration is ration and are made by individual Stark and Bloom, 1985; Stark, 1991) or households heads, which goes beyond the social, geographic or economic, or unified context of migration decision-making. It can be psychological reasons or otherwise. The dual labor market theory of Migration explains that economic dualism is between the labor and capital, characterized in advanced industrial economies. The theory explains the separation of labor marketplaces. The dual labor market theory similarly provides motives aimed at the supremacy of females and young persons amid travelers as they remain additional ready to receive some jobs in critical circumstances than additional clutches.

2.4.1.3. **The world systems theory of Migration**

To oversimplify the macroeconomic perception, the (Wallerstein 1974) undertakes global Relocation stands related to developments of the commercial scheme and worldwide marketplaces system not alone in the planet's economy but then again outlying areas. To hand stay various powerful forces behindhand technique. Happening unique impact, nearby a cumulative request aimed at little skilful labor in essential provinces. Manufacturing sector's occupations become fewer needed for indigenous population. Moreover, commercializing agronomic manufacture within boundaries of the wealth movements enlarged output and

reduced call for native labor. Further, the world systems theory also recognizes several additional links, such as material, historical, cultural, linguistic, and so on, amid the source and terminus republics' nexus, impacting relocation flows. Jennissen (2004) renowned that though this philosophy stretches estates viewpoint of change in globalization drive.

2.4.2. **Neoclassical Microeconomic theory of Migration**

Neoclassical microeconomic theory of Moving is reliable to large scale economic model plus a microeconomic model of specific assortment (Sjaastad 1962). The structure, specific rational players choose to migrate due to a charge and advantage control that clues them to imagine optimistic net reappearance or human capital investment, usually a value of money from Migration. In that, they can also have a better salary for the long term for themselves and their families based on their ability, I.Q., and skills. Beforehand, they can have the highest wages with more excellent labor productivity and capture the higher wages associated with more significant labor. The following are types of microeconomic theory of Migration, and they are;

2.4.2.1. **The new economic theory of Migration**

Rendering to this model of Exodus, choice to travel is not complete via distant specific actors. Still, it is the outcome of a shared decision to make the most of income and employment opportunities and to minimalize hazards the individual and households may face on Migration**.** The new economic theory of Migration, which is part of the microeconomic theory of Migration of individual choice (Stark and Bloom 1985, Stark 1991), proposes that migration-induced allied judgments are complete through household's heads or specific households rather than by individuals or single person in making migration decision. Mincer, 1978; Castro and Rogers, 1983 revealed travelling procedures remain characterized in detectable domestic designs and demographers characteristics, respectively. From their point of view on migration procedures, expanded migration plans of specific domestic memberships are an tool of managing hazard at the Individual's close somewhat maximization of the predictable revenue at a superficial level. According to their approaches, salary gaps amongst origins in destination countries are not prerequisites in lieu of Exodus.

2.4.2.2. **Human Capital Theory of Migration**

According to human capital theory, people change places due to the discounted values of expected yields/returns to individual human capital, which are reduced by migration costs. Besides, potential migrants select the destinations that maximize the take-home current worth of their predictable upcoming revenue. A complete outline of migration theory can be formal (Massey et al., 1993; Borjas, 1990, 2006). This theoretical possibility has been additionally verified by Stark and Wang (2001) within the logical microeconomic context. Their investigation offers that possible optimistic and positive net returns from Migration are a basis of externalities in the form of a general upsurge in the human capital formation in the region of origin and destination. A Skilled migrant benefits the two regions, and unskilled migrants have mostly cost the two regions, i.e., original and destination countries.

2.4.2.3. **Migration System theory and Network theory of Migration**

Migration systems theory is the various schemes and other system theories. All propose that migration movements obtain a degree of steadiness and erection over interplanetary time, allowing the ID of steady international migration schemes. The migration systems theory (Kritz et al., 1992, following the pioneering work by Mabogunje, 1970, after Zlotnik, 1998) differentiates migration systems of multiple sending and receiving countries branded by similar migratory designs.

2.4.2.4. **Push-Pull Factors theory of Migration**

Rendering to "Piore," push factors do not produce immigration in sending countries, such as climate change effects, low wages, psychological stressors, economic reasons, or high unemployment, but pull factors in receiving countries, such as a chronic and inevitable necessity for foreign workers, high pay wages, and high demand for workers and so on. Most households' youth want to migrate, but financial stressors are the main reasons that hinder their decision. Most of them also want to migrate due to the exciting opportunities in Western countries, and sometimes they do not see how and manners they think. Others it due to reasons of ambitions or ambitions of reasons. The idea of chances provided background creating push-pull factors method of Lee (1966). Lee's theory of Migration clarifies that Migration is strong-minded by attending to tempting pull issues at terminus/destination countries and deterring push factors at source/origin countries. The supremacy of specific factors controls to some degree the features of the migrating population like the promising pull factors at destination countries tend to attract migrants who are positively designated in footings of human capital formation as a source of investment or motivation as a source of human capital. That motivation rises with economic growth and development.

2.4.3. **set back the theories of migrations**

The chief test here is to intricate a suitable theoretical framework of Migration that is not deterministic and sophisticated enough to contract with the heterogeneity issues of Migration and complexities of migration-development interactions such as climate change and food security. Papadimitriou and Martin (1991) previously claimed that there is no involuntary device by which international Migration and its correspondent remittances result in development. Limited migration researchers could currently race this overall declaration (see Russell 1992), but it stretches a painful sensation to permit it just at that. Djajic (1986) piercing available and former neoclassical approaches to migration decisions ruled out the option of an improvement for non-migrants, as they did not reflect remittances in their models. Another problem is the synthesizing approach may deliver an incomplete answer to the problem noticed by Massey et al. (1993), that the neoclassical theory of Migration, both macroeconomic and microeconomic theories of Migration, and new economic theories of exodus are central to different assumptions and conclusion around the roots caused of Migration and nature of international Migration. An alternative effort to make of a creating theoretical background of universal Migration has remained lately commenced by Massey (2002). However, at the present development phase, these notions are far from establishing a comprehensive Migration theory and appear scarcely likely to be operationalized in applied claims.

2.5. Theoretical framework for the interplay between Climate change, Migration dynamic, and Food Security

This part of the literature brings them together and inspects the association between climate change, migration dynamics, and food security. First, we must intersect and conceptualize the link amid climate change, migration dynamics, and food security. In that, we must first understand each and how each interacts and bring about the interplays between them by conceptualizing. Several widely used definitions of climate change, Migration, and food security exist.

2.5.1. **The Connections between climate change, migration dynamics, and food security**

In figure 10, the theoretical model finds the nexus between change in climate on security of food, Migration nexus, Migration and food safety nexus and adaptation as a strategy to reduce Migration and increase food security. Through measuring preceding involvements of climate change, food security, and migration dynamics, educations are then incidental for replying to the upcoming trials of human-induced climate change. Climate Change and weather extreme events such as coastal erosion, desertification, variability in precipitation and temperature pattern, salinization, flooding, drought, sea-level rises, natural resource degradation, e.g., land degradation, deforestation, bushfire, windstorm, water scarcity, overgrazing, natural disaster, salt intrusion, and ocean acidification and if one or all these scenarios happened it lead to food

insecurity or lack of food security such as local food insecure. Damage to assets and losses of production, hunger, a decline in agriculture, a decline in fishery and livestock, insecure livelihoods, degradation of natural resources, vulnerability to change in climate , and prompt Migration. The nexus between climate variation and food safety and security of food and Migration happened due to migration Dynamics. Migration has two main issues on food security 1) Food insecurity worsened from insecure agriculture and livelihoods.2) Migration brings about Remittances and investment in agriculture, transfer of knowledge and technology, and rural development. However, drought is a crucial driver of food insecurity. Long-standing and recurring drought circumstances and vicissitudes/variations to food making and food security may stretch to migration to a place where people pursue to migrate to parts where food bases and agricultural livelihoods are extra consistent (Mendelsohn et al. 2007). As a result, the movement of people can also be delivered as a managing approach that varies and reinforces people's living, properties, and profits and in go assistance to decreasing food insecurity (Black 200, Bardsley and Hugo 2010). In the current age, numerous rumors and education recorded the effect of long-standing environmental procedures and processes, predominantly drought, population movement/mobility, and relocation (IFRC 2009; NRC 2011).

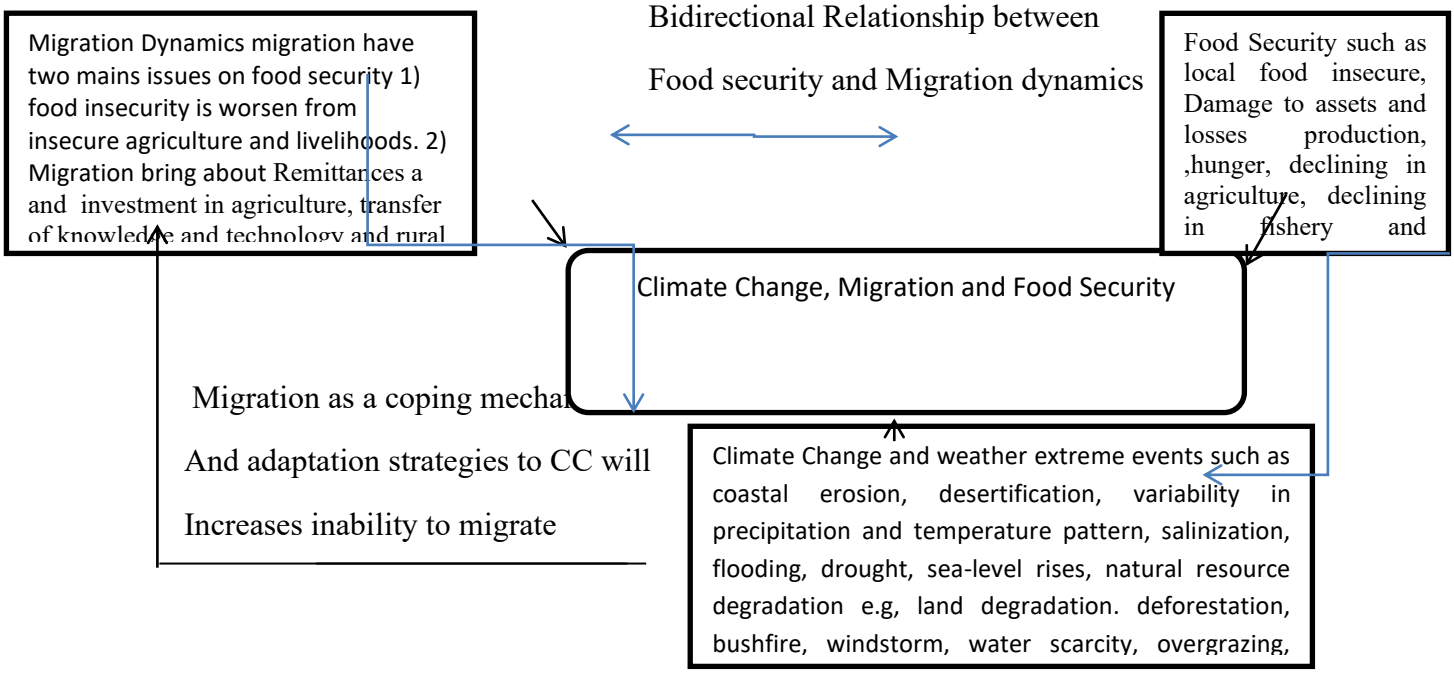


Figure 9; Theoretical Model to interlinks between Climate Change, Migration dynamic and Food Security

Own Evaluation, Adopted from Massey et al., 1993. McMichael et al. 2012, Ajay Kumar and Pritee Sharma (2013), IPCC, 2014, IOM, 2016 and FAO, 2018 on: The influence of climate variation on food safety, the climate variation and migration dynamic nexus; the food security and migration nexus; Migration as coping and adaptation strategies to climate change; finally, climate change, migration dynamics, and food security intersect.

2.6. **Summary and significances of the theories to the present study**

The theoretical reviews on migration and food security above are widely used as a theoretical framework to build conceptual literature and empirical literature examining the links amid climate change, migration dynamics, and food security. The assumptions and ideas behind migration and food security theories are categorized into four main futures.These theories are relevant to the present study since the research objectives try to determine the impact, climate change-induced migration and migration-induced food

security and the likely adaptive capacity and coping tactics for climate migration by way of some of the theories explain the vital roles of food security as they mention two critically important things about food security such as availability and accessibility to get food for the overall population to have security and benefit from the livelihoods. The relevance of the theories is that a food supply is a crucial determinant for households or individuals to be food secure in the short, medium, and long terms. Another essential relevance of migration theories to this present study is that the demand characteristics of developed countries determine migration flows, and according to the dual labor market theory of migration pull factor at the countries of destination is the key determining migration. In contrast, the push-pull theory of migration is determined by both push factors such as environmental damages and natural disasters and pull factors such as good jobs and education, which are determined by migration decisions by individuals (Stark and Bloom, 1985; Stark, 1991) or household's heads. Different views and also relevant to this study is the Keynesian view of migration which states that migration is determined by unemployment and not wages differences. The new economic theory, which is also very relevant to the present study, states that the household rather than an individual decides to migrate as the study points out, from this theory that the choice to migrate is normal and is made exclusively by individuals or households head. The present study explains that human capital is the crucial determinant of migration decisions. Therefore according to human capital theory, migration results from rational cost-benefit analysis and a source of investment. Therefore the theories relevant to this study are food availability theory, food accessibility theory, sustainable livelihoods theory, neoclassical macroeconomic and microeconomic theories of migration, and some assumptions, if necessary, were also taken into consideration to have more detailed theories of food security and migration in the Gambia and way forward to solve food security and migration through adaptation.

2.7. Conceptual framework of vulnerability assessment to climate

Füssel 2005,2007, Füssel & Klein, 2006; Füssel, 2012, Füssel, 2016, Otto et al., 2017; and Adger et al., 2019 revealed that due to different definitions because vulnerability is a broadly used concept by academicians and international communities with diverse fields of specialty. This part of the chapter in the literature will deal with chapter three of this thesis, which states that; the central part of the research is; what is the vulnerability assessment between climate change and agriculture productivity and what causes migration in the rural Gambia? And the specific research question is; to identify the most vulnerable regions in the Gambia to climate change. The concept of vulnerability started from risk. Risk is the probability is of an events and it consequences (Aven & Renn, 2009). The second aspect of vulnerability is the hazard that comes with risk and that is the dangerous phenomena's that can lead to loss of lives, properties, livelihoods, from earthquake, volcano, heavy downpours, heat wave, tornadoes etc. and causes substantial loss of agriculture and communities and ecosystem services. Vulnerability can lead to migration and food insecure is due to vulnerable population does not have modern agriculture for sustainable agriculture a for survival.

2.7.1. **Vulnerability to change in climate**

In the rural Gambia, the government of the Gambia due to centralization nature, the planning, decision are made at the top management level and that was why the government support together with the infrastructure support costs the rural regions to have bad unfavorable markets, poor road, lower energy supplied, declining in agriculture, flash flooding, unemployment in agriculture increases, distant to market is longer, children have risk to go to school due to poverty nature of the households whereas the NGO support is decentralized and the workers in those international organization or domestic organization reach at the households level and find the types of risks and shocks households are facing in the rural Gambia and they talk with households head and the elders and they always do focus group discussion and advice the women, children, elderly and even the returnee how to make impacts in their communities by providing them with access to credit, training them new method of farming, poultry farming, support them with farm inputs, etc. In addition to that, NGO support is beneficially in the rural Gambia and in that rural households are less risk because of their support while government support due to mismanagement of funds, bribery, corruption, rural Gambia households are highly risk to government support. Subsequently, it is good for us to know whether rural Gambia will develop based of the vulnerability status of the households and what is the

contribution of certain indicators to comprehend vulnerability nature across the rural Gambia. Therefore, vulnerability symbolizes weakness/injury/harm and is plagiaristic after the Latin "vulnerable," which means "wound. "The idea of vulnerability is numerous and practical in diverse arenas and corrections. Vulnerability investigation is commonly worried with classifying and comprehending issues that put people, society, and places at peril, decreasing the aptitude to answer to intimidations (Cutter 2003). Now, the case of climate change research, vulnerability research is essential categorize human systems are pretentious by variations in change in climate (McDowell et al., 2016, Räsänen et al., 2016, and Wanget al., 2014) and building upon seminal studies in the natural hazards such as (flooding, drought, and weather-related extreme events) field in the 1970s and 1980s (Hewitt 1983). According to IPCC, 2007 climate change vulnerability is defined into sensitivity, exposure and adaptive capacity and in that attached negative coefficients to climate exposure and climate sensitivity and positive coefficient to climate adaptive capacity.

2.7.2. **Conceptual Framework between Climate Change, Migration dynamic, and Food Security.**

In the conceptual framework we want to links climate change, and food security issues that will lead to migration in the rural Gambia and how climate change vulnerability was caused by food security issues and that lead ones to migrate for better lives with better food security. Agriculture is the main sector affected by climate change vulnerability especially when adaptations are lacking. Contrast and critical examination of the study of food security, Burch and De Moro (2016). The emerging nations will hurt greatest from the opposing special influences of climate change since of inadequate technology, capacity, knowledge, and training to help us to solve problems related to change in climate and overall impacts (Guttmann and Field 2010).Consequently, change in climate extreme like drought, flood, bushfires, natural disasters, heat-waves, windstorms, and erosion will strongly impact rural households that depend on natural resources and agriculture for survival (Wodon et al. 2014). Confirming this dynamic, according to Nawrotzki et al. 2016, a decline in Several African countries have observed global exodus in reply to hostile climatic circumstances (Gray and Wise 2016).linking amid food security, climate change, and migration dynamics has remained documented (McMichael, 2014).Thus, instigate satisfying this hole, we examine the interaction between climate problems is associated with migration and food security problems in these regions, in the rural Gambia: NBR, CRR, and URR. These three regions in the Gambia are known for migration-induced climate change, the Gambia food basket region, widespread hunger, and poverty, lack of food security, and flooding and drought, most common in URR. All the regions, in one way or the other, are pretentious by climate change harms like flooding, drought, etc., from rainfall patterns and temperature variations. Accordingly, FAO, 2016 summarizes the 'root causes of (rural) migration as follows: Environmental reasons Economic reasons such as Rural poverty and food and nutrition insecurity in the absence of alternative opportunities to improve livelihood prospects and farming practices (e.g., lack of access to credit or other services that would improve agricultural productivity; lack of access to training or financial services); Lack of employment and other income generating opportunities in the rural area of origin in the context of unstable incomes and poor safety nets for agricultural workers and smallholder farmers. Political reasons include inequality between rural and urban areas, limited access to health, education, essential services in the rural areas.

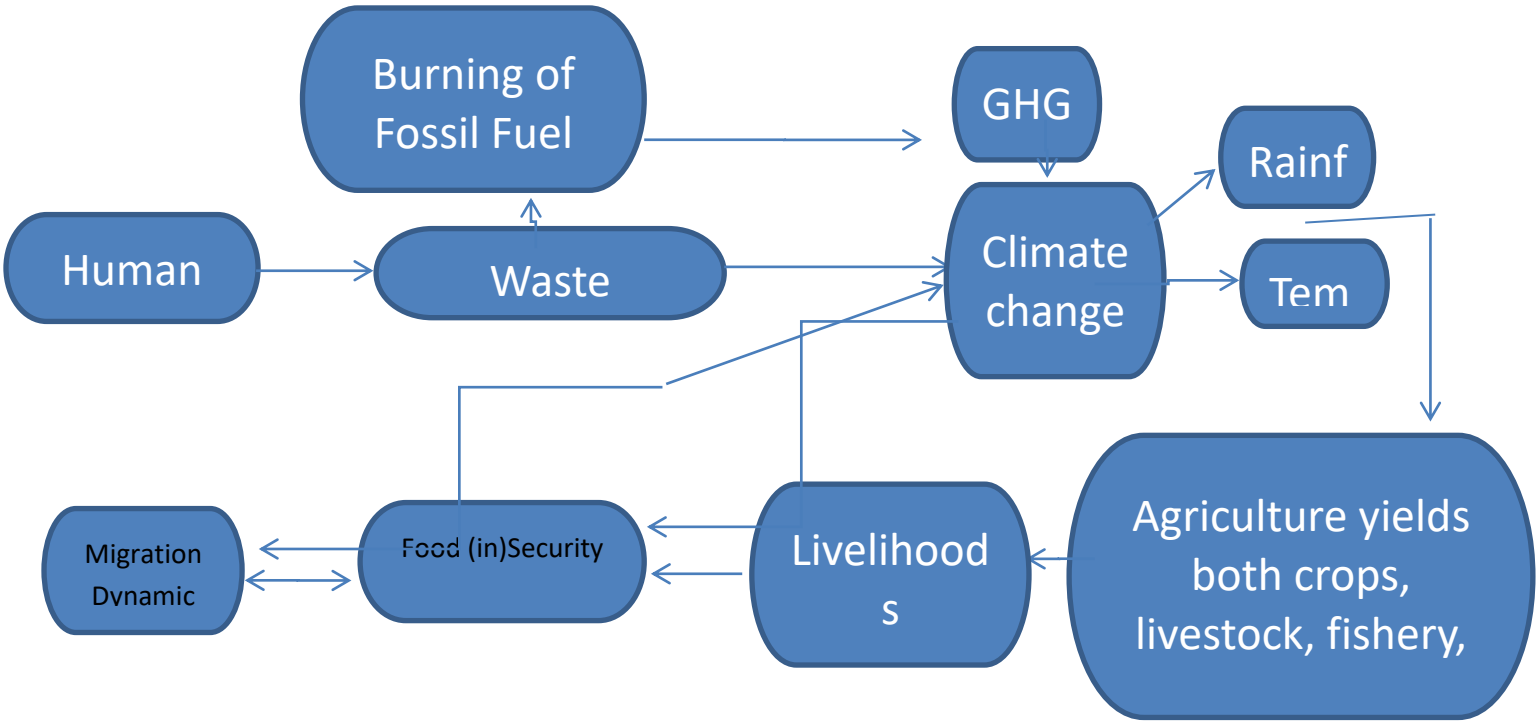


Figure 10: Background Information for conceptual Framework in assessing the impact of Climate change, Migration dynamics and Food Security

Sources: Own evaluation

From figure 11, above, the following conceptual concept was drawn with their explanations; The Human and Climate change nexus: Human interaction brought about waste and burning of fossil fuel as indicated in the following figure. Humans are the leading cause of climate change and the earth's temperature by wildfire, bushfire, erosion, deforestation, biofuel, and biomass and so on. As in the above figure, the intersection between change in climate and agriculture nexus. Change in climate distresses agriculture in many behaviors, such as low precipitation and extreme temperature, causes drought and flood. Drought leads to a plant being damaged and animals dying or developing diseases. Drought also caused plants to not mature, and all of these led to massive migration to areas where land is good and agriculture production and productivity increase. For instance, flooding leads to damage to crops and livestock. It causes profound loss of crops and animals, it destroys natural vegetation and reduces yields for animals; it directly kills most of it and causes pests and diseases, and for humans, it causes food insecurity, and it also leads to migration, and migration have both the positive and negative effects. The positive effect is sending back remittances, and the negative effect is that you may trap in the ways and either continue or come back or stay or develop diseases and lack of employment opportunities, another negative effect of migration and lack of income. Migrants, if migrates due to climate change-environmental related issues can have substantial effects due to relocation may have a shortage of employment, health, and related issues. Climate change affects agriculture directly through lower rainfall and high temperature. Further, lowering or variability's rainfall pattern causes agriculture productivity to reduce, including plants, livestock, crops, forestry, fishery, etc. Climate change also affects livelihoods, lowering living standards and promoting a minimum balanced diet. Continually, climate change affects agriculture that in turn affects our environment, destroying the energy sector, agriculture sector, industrial or manufacturing sector, and subsequently also affects the function of the energy sector, especially non-renewable energy such as coal, oil, etc.

2.8. Theoretical frameworks of food security

Food and Agriculture Organization of United Nation defined food security to means that all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their

food preferences and dietary needs for an active and healthy life, Walter Fraanje, Samuel Lee-Gammage, 2018, FAO-WFS, 1996.

- Chronic food insecurity is a long-term or persistent inability to meet minimum food consumption requirements.
- Transitory food insecurity is a short-term or temporary food deficit.

Theorizing on food insecurity has proceeded in a somewhat linear approach from Malthusian analytical scenarios involving shortages in food availability to philosophies of poverty that have stressed the privileges disappointments and finally to livelihood backgrounds that uphold rights as the essential instructive strength (Malthus,1798, Yaro, J.A. 2004). Theories of food security can be categorized into food availability decline, entitlement failure, and livelihood failure. The food security has four pillars such as food availability, accessibility, utilization and stability of food.

- Availability of food. Availability addresses the supply side. The expression mentions to the physical influx and attendance of harmless and nourishing food at a assumed period and in a assumed dwelling.
- Access to food. Access is anxieties itself with whether or not an individual or household or communities or countries or continents is capable to increase right to use to obtainable/available food. It also speeches about the capability of buying or conversation goods for foods stuffs.
- Utilization of food. Utilization speeches the body's aptitude to brand the greatest out of the nutrients in food that is spent. Utilization of food can be pretentious by issues such as poor storing, decay, cooking practices, food security, that strength disturb enough consumption and absorption of food stuffs.
- Stability scratches crossways and upsets all the other mechanisms. Food may be obtainable and nearby to people who are able to use it efficiently and effectively, but this national of businesses wants to be lasting and so steady over-time, somewhat than existence a temporary national that is theme to variations.

By reading the book of Dreze and Sen 1989 and to the UNDP HDR on human security 1994 are mostly needed to combine and comprehend or understand the five main theory of food security. The five theory of food security are describes below;

2.8.1. Food availability as a theory of food security

The first approach to food security that we present is the "food availability" approach, because it is certainly the oldest one and still the most influential. Although the core ideas of this approach could be traced back to

the Venetian thinker Giovanni Botero (1588), it was Thomas Malthus (1789) that popularized it and in datum it also known as the Malthusian theory of population and food. The method is focused on the (dis)equilibrium between population and food and in command to uphold this equilibrium the rate of growth of food availability should be not lower than the rate of growth of population and they should be at-least intersect to have food that satisfied the population growth. In a closed economy setting, this depends mainly on food production and stocks, while in an open economy also food trade can play a relevant role. Until the early 1970s, this was the reference approach for the international community, both at political and academic level. This is well reflected in the definition of food security given at the World Food Conference of 1974: "Availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices" (UN 1974). Devereux & Maxwell 2020 put it in this way that, at the 1974 World Food Conference food security was defined availability at all eras and times of satisfactory world provisions of rudimentary food-stuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices' The primary focus of this approach is on food supplies as a major cause of food insecurity. This led to huge investments in green revolution technologies designed to increase food supplies for both national self-sufficiency and for export. The Food availability theory of food security entitlements that, whatsoever the reason, a severe weakening in the source of food is an essential disorder for scarcity to arise (Fine 1997). Hence in normal circumstances a growing supply of food relative to population is sufficient to assurance nonappearance of famine. The 1974 World Food Conference caused in the scheming of initial cautionary schemes to screen the food supply state in emerging nations (Frankenberger 1992). According to Dreze & Sen (1989), the picture of the typical African rural poor as a self-sufficient peasant exclusively engaged in food production is, for most African countries, little more than a misleading chestnut. Also evidence of the diversification of activities by peasants and recently by urban dwellers goes against the canons of the FAD(food availability decline) theory. The food availability theory of food security method distillates its examination at the equal of collective supply somewhat than at the disaggregated stages (Fine 1997). In the meantime, famine and hunger eventually kills an individual who nose-dives improvement entree to the nationwide food basket. it is significant to move emphasis to individual food access and its influence to the macro level ''supply of food'' in adding to other foundations/sources of supply. On the "supply side", the need to boost (per capita) food production–namely agricultural production. This is some of the set back to this theory and the theory that follow is called entitlement failure theory.

2.8.2. Entitlement failure theory of food security

Many developing countries have more than enough supplies of food, and yet millions go hungry every day. The failure of the food availability theory of food security is to clarify this inconsistency provided birth to the entitlement theory of food security, which essentially responsibilities poverty for the incapability of people to improvement entrée or access to food and food related issues. The comprehension that food

availability theory of food security unaccompanied does not safeguard access by all to have sufficient food supply that inequality in access to capitals will central to unsatisfactory delivery of food and chances and, that purchasing power(income) is of dominant position which led to the appearance of the entitlement theory of food security (Nyborg & Haug 1995). The entitlement theory of food security originated from the pioneering work of Amartya Sen (1981), which delivers a systematic context for the definition and valuation of vulnerability, hunger, famine and food security. The entitlement theory of food security to hunger and scarcities distillates on the aptitude of people to information food over the legal incomes obtainable in the society, counting the usage of production possibilities curve, trade opportunities/opportunities costs, scale of preference entitlements the state, and the other means of obtaining food. A person starves either because he does not have the ability to command enough food, or because he does not use this ability to avoid starvation. (Sen 1981).Henceforth, how much food households actually have right to use to comes from their personal production, exchange goods, exchange cash for food or food for cash, income, get-together of punitive foods, community sustenance, support from aids, properties, migration, and remittance (Frankenberger 1992). The food security problem is seen as a problem both of supply and of lack of effective demand amongst the poor. A variety of socioeconomic issues is required that regulate entree to food. Certain of the aspects on the demand equation side of the food (in)security comprise, household expenditure on food-daily, household income sources either farming, employment, trading(petty),economic possessions, prices, demographic issues such as education, gender, age of the households or head, marital status of households, ethnic city of the households, location and socio-cultural-traditional issues such as health, either the society is polluted or not, cleanliness, education level of the households, cultural norms, food consumption habits of the household or individual, vulnerability of households in case food, house and cloths (Okyere et al. 1997). Food security theory based on entitlements approaches are the normal of supernumerary commodity sets, that a person can ability in a society by the entirety of rights and chances (Sen 1984). A person's talent establishes the assets, which are distorted as finished manufacture and occupation/trade into food or commodities to conversation for food. Furthermore, in the book title "Hunger and Public Action" (1989), Dreze and Sen include the study from food entitlements theory of food security as the set other sets of commodities such as potable water or services such as sanitation and health care over which the person can have command. The entitlement theory of food security deals with all kinds of sets of commodities that benefits one way or the others households and also deals with the alternatives goods and services such as sanitation, health care, environmental cleaning and related issues that benefits.

2.8.3. Sustainable livelihood theory of food security

The forecasted 2030 Plan for Sustainable Development Goals(SDGS') lays foundation accelerative a transformational idea knowing that our world is moving, which carrying with it original tests that must be overwhelmed, in case we are to live in a world without hunger, food insecurity and malnutrition in any of its forms(FAO, IFAD, UNICEF, WFP and WHO. 2019).The sustainable livelihood framework refers to the

Sustainable Livelihood Approach adopted to understand the context in which a household pursues its livelihood and food needs. This outline studies the effect/impact of stabilization policy of macroeconomic and organizations on household livelihood choices (USAID 2012). The important theory of the sustainable livelihood frame is the ‘’sustainable livelihood’’. Livelihoods are defined as the competences, material, activities and social assets that are essential for a means of alive (Chambers and Conway 1992). A live is livelihood and livelihood is supportable the time it can adjust to intimidations and it can uphold or develop its talents and possessions and it does not cooperation extra livelihoods at nearby and more extensively for at the present and in the future (Chambers and Conway 1992).The sustainable livelihood theory of food security commenced at an extension of the Household Economy theory of food security. This theory of food security has been considered as a livelihood based approaches according to ‘’Amartya Sen’s theory of exchange entitlements’’ which this tactics is an instrument used to forecast temporary variations in the population’s entry to food (Seaman et al. 2000 and Holzmann et al. 2008).Therefore, sustainable Livelihoods framework of food security is not fair a method/tactic to food security, nonetheless is an extra overall tactic to expansion, growth, hunger, food security and poverty. Nevertheless the idea was surely used earlier; the “stress on livelihood as main determinants of sustainable livelihood theory of food security” which was commenced in the 1980s thru Chambers (1983) in his seminal book in which he presented the rudimentary essentials of this method that was emphasis on rural development- poverty nexus.

2.8.4. Income as a theory of food security

The long and lasting understanding of food security as a tricky of food availability has been partially reentered within a new macroeconomic theory of food security. The attention on food sector originally only focus on agricultural production and productivity, and similarly food trade afterward all has been critiqued by economists for being too concerted on one single economic sector of food security, which is part of agricultural sector. Identifying that the economy is self-possessed of many interdependent sectors, food security cannot be viewed as an elite delinquent of the agricultural sector or in other word food sector.That is why the first effort to widen the discipline was actually an attempt to change the analysis towards national economies as a whole i.e. the GDP of the country. This meant bringing in the analysis variables such as GDP per capital, Gross Domestic Product (GDP) both constant and current, economic growth, which are sometimes dependently on food production yields and others variables such as employment, inflation, investment, consumption, saving, net export and some non-economic measures such as quality of life, education, poverty, hunger, environment, climate change effects, mental health problems, psychological set up, and other services and industrial or manufacturing sectors and all affect the GDP and it related variables. In a economic that is categorized as market economy, a sturdier economic system may permit the import of goods such as food production and food yields. This macroeconomic theory of food security was also most reliable with old and very powerful economic theories such as Ricardo’s theory of comparative advantages, according in which a/are country (ies) has to specialize or built it focuses in the sector in which it has an

advantage given profusion of resources (natural resources per se). The whole of macroeconomic theory of food security is to increase the aggregate economic output based on food availability theory of food security. Conversely, according to the study done by level Reutlinger and Selowsky 1976; Haq 1976; Griffin and Khan 1977 confirmed that the most important change was from food availability theory of food security at macro-level to income at microeconomic level, which is determine by households or individuals.The method is very like to the one by tradition used to evaluate poverty dynamic-chronic and transient poverty. Poverty is part of food insecurity and it is called chronic food insecurity and transient food insecurity which means that lack of enough income necessary to buy the amount of food required at given period of time (Sibrian et al. 2007; Sibrian 2008).To be specific, the different foods are transformed/changed into calories, which is the main features to understand those that are food insecure or not and in other word the characteristics to factor out the households or individual that are food below certain thresholds are classified as food insecurity or food secure. The calories of each households members are or combination of households members are measure and if the calorie availability is lower than the minimum requirement set by international standard, that households is categorized as food insecure or vice-versa.Many applied economists have estimated the calorie contents of each food item and then aggregate them in order to have the total amount of calories available for household members. The income as a theory of food security have some shortcoming due to the fact that e.g. children calaries contains may dependent on their respective parents but what of the cases children are smaller and their parents died and what of the cases children are smaller and only depend on guidance or so on.It (Children) will be difficult to know their thresholds level and to determine their overall calorie intake and in turn to classify them into food secure or insecure.

2.8.5. Basic needs as a theory of food security

In the second half of 1970s century, one of international organization i.e. the International Labour Organization has suggested a novel model of development, the basic needs theory of food security, with the purpose/intent of integrating also non-economic dimensions of food security or dimension of development (ILO,1976).Non-economic measure also dealt with quality of life, environment, standard of living, education and so on because they will have long run effects on economic growth and development. The problems of poverty, unemployment, and expansion of growth rate of economic and the period of recession, the fluctuation of economy, all will have depend on basic needs as a theory of food security.

2.9. Empirical Literature of climate change, migration dynamics, and food security

Meanwhile then, numerous literatures on change in climate and movement take terrified bright going on the subject (Raleigh et al., 2008 ,Gray and Bilsborrow 2013), then that focus motionless needs sustained and general thoughtfulness as climate change functions at the worldwide whereas hostile are touched nearby level. Solving so start in local communities to fight the severity of climate-induced migration-food insecurity nexus. To find the nexus of climate change-induced migration through agriculture, livelihoods, and remittances, Bryan et al., 2013, applied binomial logistic regression to determine people's response perception of food insecure and confirmed that, Lower agriculture yields such as crops and livestock would related to high change in climate effects example rise temperature causes drought and increases in rainfall

cause flooding, sea-level rises, salinization, bushfire and the like. These indicators will negatively affect agriculture productivity. Further, Bryan et al., 2013 revealed that Climate crises would statistically significantly worsen the risk that rural households fall into poverty because of worsening food security. Additionally, Amelie Bernzen 2019, using multi-logistic regression analysis of the households survey in the climate-environmental stress in the rural communities of coastal Bangladesh, revealed that 1/3 of the communities are displaced by coastal flooding affects their land for agriculture/arable land. They also confirmed in their results that environmental migration is more common. This destruction of arable land will make farming difficult, leading to losses of agriculture productivity. It will cause food insecurity that, in turn, causes mass migration within or outsides of the country of origin. Raphael J. Nawrotzkia, Allison M. Schlakb, and Tracy A. Kugler, 2016, confirmed that climate change, migration dynamic, and food security is a cause of concern for humanity now and in the future. Climate change resolve unfavorably disturb food security in numerous regions. It may give to climate migration where agricultural livelihoods and food bases are safer, particularly rural-urban migration. It happened at the time of causes and frequency of flooding, drought, salinization, bushfire, erosion; sea-level rises, etc., especially in rural areas, and people migrated to urban areas to search for income and employment to have sent money to households for consumption, especially for those left behind for the case of climate rural-urban migrate and this is to contract with if climate change causes permanent migration or make all of them to migrates either temporarily or permanently. Climate change is predictable to reason upsurges in human population undertaking in the approaching decades due to many factors such as weather patterns, flooding frequency, and drought. Sea-level rises, etc. Other issues comprise population pressures, malnutrition, psychological reason, food insecurity, hunger, violence, poor education services, landlessness, low wages, lack of income, unemployment, rise in urbanization, pandemic diseases like covid-19 and the like, and government inadequacies, together with cultural conflict and conservative fights, violence, and conflict. Solving so start in local communities to fight the severity of climate-induced migration-food insecurity nexus. To solve the problem, the agriculture model was used in the theoretical models following closely the work of "Chayanov's concept of theory of Peasant economy of Russia," 1925, to apply an agricultural model of households. The Russian economist Chayanov stated that one of the objectives we selected in this chapter is; How to get the peasant to modernize agriculture, especially farming techniques? Chayanov's 1925 revealed that his "economic theory of the peasant farm" is viewed as an enterprise, and the main aim is to profit by operating with the hired workers. The global movement is frequently expensive to pledge. When severe climate circumstances demoralize income generation, livelihoods, and occupation choices, households may absence the financial capitals to send associate away because climate crises due to severe flooding, drought, sea level rises, bushfire, salinization, and the related climate risks have destroyed all the properties of farmers including crops, livestock, and income for survival. Confirming this migration dynamic, a weakening out-migration in response to the hostile effect of climatic circumstances has been detected in numerous countries in Africa (Henry et al. 2004, Gray and Wise 2016).

2.10. Gaps in the Literature

To satisfy this gap, we look at change in climate and food security (proxy food availability) nexus in Gambia and other variables affecting food availability for objective 1. Thus, the study will observe both the direct and indirect effects of climate change, agriculture value added, population growth rate annually and economic growth on food availability in The Gambia for the periods under investigation. This study will add more light on the problem statement to empirical uses quantitative data to run climate change, economic growth and food security (proxy food availability) nexus by using econometric techniques. In additional, the problems the research want to explore is that how climate change affect food security(proxy food availability) and economic growth in the Gambia taking account growth rate of agriculture sector and population growth rate. For objective two, the links amid change in climate, food security and migration nexus. This objective attempt to interact migration and climate change and in which I used drought, floods, salt intrusion, changes in rainfall, and changes in temperature and I called it environmental migration.

Moreover, I used food security, food consumption, and empirically tested with migration response. Finally, I empirically examine whether changes in remittance, and remittance received by households in the rural Gambia causes them to migrate back. In conclusive, objective three we look at the household level vulnerability in Gambia on one hand then vulnerability across rural region in the Gambia towards climate change impacts on the other hand. In addition, the novelty we calculated vulnerability component using Principal component analysis following IPCC definition of vulnerability which included adaptive capacity, exposure and sensitivity, vulnerability index, validated the vulnerability index and finally checked the time trend of vulnerability in the study areas.

Conclusion

In the literature part of the thesis, we examined climate change, theory of migration, concepts of migration, empirical, theory of food security, concept of food security, empirical, theory of vulnerability, concept of vulnerability and empirical to climate change. We concluded that theories of migration are draw from economics, social, and geography background while food security theories are draw from food availability, entitlement, income and sustainability theories of food security. Finally, vulnerability theory are draw from maginalization of vulnerable groups of peoples.

CHAPTER THREE

METHODOLOGY

3.1. Research Design and Methodology

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

3.1.1. 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.

3.1.2. 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:

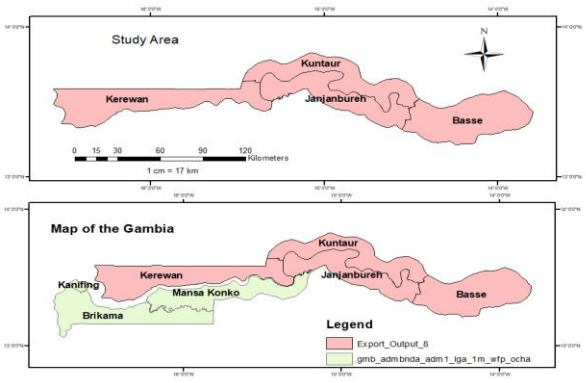


Figure 11: Map of the study area

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.

3.1.2.1. 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.

3.1.2.2. 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.

3.1.2.3. 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.

3.1.3. 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.

3.1.4. 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.

3.1.5. 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;

$$n = N / 1+Ne^{\wedge}2$$

$$n=350,000/1+ (350,000)(0.05)^{\wedge}2$$
$$n=350,000/1+875$$

$$\therefore n= 399.5433789954337 \sim 400$$

- 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;

	CRR	NBR	URR
• Regions codes:			
• 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 etc……

3.2. Objective one: The influences of change climate on food availability using time series approaches; Evidence from the Gambia**.**

3.2.1. Theoretical framework

The thesis accepts the theoretical notion of production function by containing climate changes variable (Nicholas Apergis, James E. Payne, 2011),(lee and lee 2012), and (Ceesay, E. K. (2020)). Meanwhile growth accounting equation propose direction for the linkages between variation in climate, agricultural value added, economic growth, and their influence on food security (proxy food availability) as derived below:

$$FSFP_{it} = F(AAR_{it}, AFFVAC_{it}, GDPPC_{it}, L_{it}, K_{it}) \ldots\ldots\ldots eq(1)$$

Where:

$Y_{it} = FSFP_{it}$: Food security, at time t and observation i

AAR_{it}: is average annual rainfall

$AFFVAC_{it}$: Agriculture valued added

L_{it}:Total labour force

K_{it}: Gross capital formation

$GDPPC_{it}$: GDP Per capita as a proxy for economic growth.

Food security (proxy food availability) depends on total capital, labour, average annual rainfall, economic growth, Agriculturl value added and annual population growth rate. From equation 1, Dell et al., 2008, Ceesay, E. K. (2020) and Bond et al., 2010.

$$Y_{it} = FSFP = Ab^{\alpha T_{it}} K_{it}^{\rho} L_{it}^{1-\rho-\sigma-\vartheta-\pi} AAR_{it}^{\sigma} AFFVAC_{it}^{\vartheta} GDPPC_{it}^{\pi} e^{\varepsilon} \ldots\ldots eq(2)$$

Such that: $\rho + \alpha + \sigma + \vartheta + \pi = 1$

$$\frac{\Delta A_{it}}{A_{it}} = g_i + \beta T_{it} \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where Y is Food security (proxy food availability), L, Labour, A, technology, K, capita stock, and T, impact of average annual rainfall (good proxy variable for change in climate), g the rate of growth of capital stock, t, time and e, random error. Equation 2, the direct correlation between change in climate and other variables and food security nexus

Log both side of equation 2 above, we got equation 4: $g_{it} = g_i + (\alpha + \beta)T_{it} - \alpha T_{it-1} \ldots\ldots\ldots(4)$

Where git is the rate growth of output, direct impact, α, indirect effect, β.

3.3. Data and methods

3.3. Data and Data Analysis

The data for this objective were obtained from World Development Indicators (WDI). Table 4 displays the descriptive statistics.

3.3.1. Data Collection, Data measurement, and Data Presentation

World Development Indicators is the main World Bank source for indicators for development, collected and formally documented from each country, continent, and globally.

Table 4: shows the name of the variables, source and comment of those variables what they means.

Name of Variable	Source	Comment
GDP per capita	WDI	GDP per capita
Agriculture	WDI	Agriculture value added
Food security	WDI	Food production
Rainfall	WDI	Average annual rainfall
Population Growth Annually (%)	WDI	Population growth rate
GDP current	WDI	GDP current $

Own Compilation extracted from WDI data.

The essence of this table is to list the variables and their sources for the objective one of the thesis. Moreover, the definition of each variable indicated below:

GDP per capita is gross domestic product divided by midyear population (WDI, 2021)

Agriculture includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production (WDI, 2021)

Food security is availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices (United Nations. 1975. Report of the World Food Conference, Rome 5-16 November 1974. New York)

Average precipitation is the long-term average in depth (over space and time) of annual precipitation in the country and precipitation is defined as any kind of water that falls from clouds as a liquid or a solid(WDI, 2021)

Population growth annually is derived from total population and is the rate of change in the size of resident population in a given country, region, for a given period.

GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products (WDI, 2021)

3.3.2. Empirical Models

3.3.2.1 Empirical Vector Autoregressive (VAR) Model

VAR-Vector auto-regression is a stochastic procedure in time series to find the linear interdependencies among variables. The error is presumed to be white noise procedures that may be contemporaneously connected and are uncorrelated with past or future disturbances. According to sim 1980 VAR model variables in macro-econometric as a way of multivariate simultaneous equations. In a VAR model, the endogenous variable is a function of its own lagged and other variables' lagged. Thus, VAR must be stated in the levels form. In the other equations, the growth of food security or climate change variables as endogenous, and they depend on their lags as exogenous and other control variables as exogenous too. Finally, the study will use other control variables as endogenous to depend on its lags as exogenous and the lags of additional exogenous variables such as food safety and change in climate variables.

The equation for empirical VAR can be represented below:

LNFSFP Food Production from WDI as a proxy of food availability

$$\text{LNFSFP} = \alpha + \sum_{i=1}^{p} \gamma_i \, \text{LNFSFP}_{t-i} + \sum_{j=1}^{P} \beta_i \, lnAFFVAC_{t-j} + \sum_{k=1}^{p} \theta_i \, lnGDPPc_{t-k} + \sum_{l=1}^{p} \delta_i \, \text{lnAAR}_{\ t-l} + \epsilon_{1t} \ldots (1)$$

Agriculture value added (current US$) as a proxy of agriculture sector

$$lnAFFVAC_t = \varphi + \sum_{i=1}^{p} \gamma_i \, lnGDPPc_{t-i} + \sum_{j=1}^{P} \beta_i \, AFFVAC_{t-j} + \sum_{k=1}^{p} \theta_i \, lnFSFP_{t-k} + \sum_{l=1}^{p} \delta_i \, \text{lnAAR}_{\ t-l} + \epsilon_{2t} \ldots (2)$$

Average Annual rainfall (AAR) as a proxy of climate change

$$lnAAR_t = \pi + \sum_{i=1}^{p} \gamma_i \, lnFSFP_{t-i} + \sum_{j=1}^{P} \beta_i \, lnGDPPc_{t-j} + \sum_{l=1}^{p} \delta_i \, \text{lnAAR}_{\ t-l} + \sum_{m=1}^{p} \delta_i \, \text{lnAFFVAC}_{\ t-m} + \epsilon_{3t} \ldots (3)$$

GDP Per capital

$$lnGDPPc_t = \sigma + \sum_{i=1}^{p} \gamma_i \, lnFSFP_{t-i} + \sum_{j=1}^{p} \beta_i \, lnAFFVAC_{t-j} + \sum_{k=1}^{p} \theta_i \, lnAAT_{t-k} + \sum_{l=1}^{p} \delta_i \, \text{lnAAR}_{t-l} + \sum_{m=1}^{p} \rho_i \, \text{lnGDPPc}_{t-m} + \epsilon_{4t} \ldots (4)$$

3.3.2.2. Impulse Response Function

The function returns the dynamic reply) to a one-standard-deviation tremor to a variable in a VAR(p) model. To evaluate the IRF of a dynamic linear model categorized by structural, auto-regression, IRFs suggest the impacts of a novelty tremor to one variable on the reply of all variables in the method.

The IRF equation is formulated below;

$$y_{t+h} = \gamma_h + \vartheta_h shock_{CO2zyt} + \delta_h(L) Z_{t-1} + \text{quadratic trend} + \varepsilon_{t+h} \quad (5)$$

Where y is the variable of concentration such as food availability and other control variables in the model, shock is the identified shock if either food security is shock or other control variables if and only if we consider the interest variables as economic growth or food availability vice versa. Z is a vector of control variables and a polynomial in the lag operator. All regressions for IRFs contain two lags of the shock-to wash up any serial correlation that can happen, transformed food availability, transformed GDP per capital, and the other control variables. The as a coefficient delivers the reply y at the time to the shock on time t if we nominated food availability as the interest variable and otherwise will modification.

3.3.2.3.ARDL bounds testing procedure for Co-integration

Practice ARDL bounds testing for co-integration to evaluate climate change and food security nexus. The ARDL bound testing methods established via Pesaran et al.(2001) (Nicholas Apergis a, James E. Payne b,∗,2011),(lee and lee 2012),(Ceesay, E. K. (2020)), Belford, C.; and al (2020), (Dell et al., 2008), Pesaran 2007), Menejaki (2019), Alkire, S. (2002)) and Thursby and Schmidt (1977), which is improbable the other approaches, we can factor the impact of lag on the variables for additional lengthy period. The ARDL-bound testing technique co-integration is a healthier approach, and it gives unbiased outcomes (Haug, 2002; Alimi, 2014). The ARDL equations' can be stated as follows:

3.3.2.3.1. ARDL Model

$$lnFSFP = \alpha_0 + \sum_{i=1}^{p} \alpha_i \, lnFSFP_{t-1} + \sum_{i=0}^{q} \beta_{1i} \, lnGDPPc_{t-1} + \sum_{i=0}^{p} \beta_{2i} \, lnAFFVAC_{t-1} + \sum_{i=0}^{p} \beta_{3i} \, lnAAR_{t-1} + \sum_{i=0}^{p} \beta_{4i} \, lnGDPC_{t-1} + \sum_{i=0}^{p} \beta_{5i} \, \text{LnPG}_{t-1}$$
$$+ \lambda_1 lnFSFP_{t-1} + \lambda_2 lnGDPPc_{t-1} + \lambda_3 lnAFFVAC_{t-1} + \lambda_4 lnGDPC_{t-1} + \lambda_5 lnPG_{t-1} + \lambda_6 lnAAR_{t-1} + \varepsilon \ldots eq(6)$$

$\beta_1, \beta_2, \beta_3 \, \beta_4 \, , \beta_5$ are short run coefficients and $\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \lambda_6$ are long run coefficients. Pesaran and Shin (1999) and Pesaran, et al 2001 was used to check co-integration.

3.3.2.4. ECM

3.3.3.4.1. VECM: vector error correlation model

Illustration on effort by Granger, 1969 and Sims (1972), a causal connection can be tested inside to frame the (ECM)Error Correction Model. We apply the Granger causality in ECM as in (Gulikey and Salemi, 1982; Gewekeetal, 1983). The test for Granger causality founded on VECM is thus strong-minded by the subsequent ARDL:

$$lnFSFP = \alpha_0 + \sum_{i=1}^{p} \alpha_i \, lnFSFP_{t-1} + \sum_{i=0}^{q} \beta_{1i} \, lnGDPPc_{t-1} + \sum_{i=0}^{p} \beta_{2i} \, lnAFFVAC_{t-1} + \sum_{i=0}^{p} \beta_{3i} \, lnAAR_{t-1} + \sum_{i=0}^{p} \beta_{4i} \, lnGDPC_{t-1}$$
$$+ \sum_{i=0}^{p} \beta_{5i} \, \text{LnPG}_{\,t-1} + \lambda_1 lnFSFP_{t-1} + \lambda_2 lnGDPPc_{t-1} + \lambda_3 lnAFFVAC_{t-1} + \lambda_4 lnGDPC_{t-1} + \lambda_5 lnPG_{t-1}$$
$$+ \lambda_6 lnAAR_{t-1} + \text{ECM}_{\,t-1} + \varepsilon .. eq(7)$$

ECMt-1 signifies lagged value after running the long run model and generate the residual

3.4. Objective two: Assessing the impacts of food security on migration responses: A case study in the rural Gambia

3.4.1. Theoretical model

3.4.4.1. Migration and Agriculture model

We used the model of occupational choice by Sjaastad,1962b, and Barkley, 1990b because we assume that households' decision to migrate from agriculture production areas is due to climate and related environmental disasters. We further assume that decision of households or community or society, or individual's to migrate from their agricultural occupations to areas that have better agriculture are due to the following environmental disaster/stressor and climate change shocks(Ma, 2001) such as the like of earthquake, flooding, drought, water scarcity, bushfire/wildfire, tsunami, salt intrusion, sea-level rises, land degradation, deforestation, overgrazing, salinization, pollution and so on. All these stressors may bring about the decision to migrate either internally or externally. The internal migration decision can be a short distance, such as a village next to the migrants, villages or towns far from the migrants', or in the city. This obviously will help the migrants to solve the stressors of climate change that happened in their area(s) to move to the area(s) that will increase their livelihoods. The migration can also internationally(Massey et al., 1993, (International Organization for Migration, 2013 Golash-Boza, 2015) if climate change occurs, such as what is called environmental refugees, Climate change refugees(Myers, 1997 and Bates, 2002) and other refugees, all are boiling down to lack of occupational choice on agriculture farm or land in which this theoretical model is based unto. Russian economists built the agriculture model- Chayanov, 1925, and Sjaastad, 1962,pioneering migration viewed a source of human capital formation investment and the study of labor migration by Todaro's two sector approaches. We applied the two sectors' approaches to migration decision-making because the model disaggregates the economy into agriculture production sectors such as crop production, livestock production, food production, forestry, land, fishing, and nonfarm sector that comprises all other sectors of occupational choice (Mundlak, 1988, Harris and Todaro, 1970). Harris and Todaro 1970 considered the migration of workers in a two sector economy, namely, the rural and urban sectors. The difference between these sectors is the type of goods produced, the production skill/technology, and the wage determination process. We now consider the following closely the work of Chayanov, 1925; Harris and Todaro, 1970; Barkley, 1990, and Massey et al., 1993, that individuals facing wages return due to migration in two mutually exclusive occupations. The occupations that give wages returns are farm labor and nonfarm labor. Agricultural production of commodities $(i = 1)$ and nonfarm employment in which $(i = 2)$.The two sectors model of production is given by $i = 1 \; and \; 2$. The choice of occupations either farm workers or non-farm workers depend on the discounted utility derived from each occupation over the given career of individual or households that are migrated due to climate change or demographic reasons, psychological reasons, economic reasons, water scarcity and environmental stressors.A person or individual participate in the labor force at age 0 i.e G_0 and after retires at age T i.e. T_0.The maximum optimization to these problems confronted by such a person/individual can be written in equation1 as below, where r is denoted by discounted rate from agriculture occupational choice and nonfarm as occupation.

$$eq1 \ldots\ldots\ldots PP_{ik} = \int_{G_1}^{T} e^{-rt}\, U(X_{it}, L_{it})\partial t - \int_{G_1}^{T} e^{-rt}\, \left[U(X_{jt}, L_{jt}) - C_{ijt}\right]\partial t$$

We used PP_{ik} as net utility drive from migration of the households member. The net utility was drive from whether the migration occurred due to environmental reasons, social reason, occupational reason, psychological reason, geographical reason, social reason and economic reason, health reason, and educational reason, demographical reason of migration.Where: $X_{it} = q_{it}, w_{it}, L_{it}$ *and*: $X_{jt} = q_{jt}, w_{jt}, L_{jt}$ utility of the person satisfaction of work in time t is a function of both consumption in period t(X_{it}) then work-hours spent at jobs in period t (L_{it}).The drive of an economic agent from one occupation/job to another occurs when the predictable lifetime utility resulting from a possible profession rises overhead the lifetime utility predictable in the present job. Net of the disutility associated with the transfer between occupations. Agriculture jobs career i and j is other occupation. This occupation was due to climate change migration, which is one of push factor of migration decision.As they migrated due to environmental reasons they tend to find very difficult to have nonfarm occupation but continue with farm occupation of their choice. C_{ijt} Which is denoted the cost of changing occupation. This cost off-course included both pecuniary cost and psychic cost. Therefore, migration occurs when the villages or rural areas are severe damages by climate change(R J Nawrotzkiet al.,2015), natural disaster(Drabo & Mbaye, 2015, Mbaye & Zimmermann, 2016 and Mbaye, 2017) and the households may all migrates or elder as the big son or sibling to migrate in order to help the family at the time of climate change events and to help them with food for consumption, children school fees, health for the family, and in that the net utility above is negative if and only if $PP_{ik} < 0$. The push-pull factor of migration (Thet, 2014, Ramos, 2017; Eurostat, 2017) such as environmental change-rainfall and temperature variability, drought, floods, sea-level rises, bushfire, over-grazing, land degradation, deforestation, salinization, and so on are the significant reasons of migration in these cases. If migrated, the occupation choice of climate–migrants' is another issue of concern. This environmental migration occurs due to poor agriculture, livelihoods, and remittances. We extended the model to include the push-pull factor model of migration. To incorporate migration caused by climate change and that in turn affect food security-high food prices, less food availability, less food accessibility, stability, and utilization and that in turn also derive migration to an area that has food security, free of hunger and poverty as SDGs; 2 and 1(United Nations Statistics Division, 2016 and Sachs et al., 2019) put it and SDGs; 13(Bruce M et al., 2018) and water availability for their livestock and crops, good educational skills and talent with high wages overall. The flow of labor migrants from low to higher wages countries does not happen continually since, which represents a unit of how to obtain jobs in countries in their higher wage sectors; in other words, the sector that pays higher wages (Todaro model). It can also be instead of obtaining a job in agriculture. The migrants might obtain employment in another sector such as industry or manufacturing. As they migrated due to climate change and related reasons, they tend to have fewer skills for other jobs but concentrate more on agricultural labor. Therefore, the probability of obtaining jobs will be higher with higher wages. Climate changes migrants need lots of training to obtain higher pay jobs due to inability, unskilled, uneducated because natural disasters prompt them to migrate. This is because migrants are not prepared to immigrate but because of forced migration from extreme climate events or hostile influence of change in climate. Thus, the extension of Barley model, 1990 illustrated regarded the flow of labor out of agriculture due to a lack of food security, which is produced by change climate and extreme climate actions –flooding, drought changing patterns of rainfall and temperature, and other determinants of change in climate impact. The impact of migration is since factors, poor agriculture, and other non-farming activities are the key determinants of migration. Individuals' decision to change careers also influences their migration (Duncan & Perrucci, 1976, Krieg, 1997; Quinn & Rubb, 2005). Potential migrants that migrate due to poor agriculture as a driver must estimate the probability of obtaining in other nonagricultural sectors in the destination country q_j in eqn-1 in other to calculate the net utility of two sector model above.The migration of individual K occurs if $PP_{ik} < 0$. $f_{ik} is\ employed$ to separate households that migrate due to climate change effects- lack of food security, which is derive from poor agriculture from non-migrants' households.

$eq2 \ldots PP_{ik} f_{ik} \leq 0$, where f_{ik} is dummy variables

$$= \begin{cases} 1\ if PP_{ik} < 0 (migration\ occurs\ in\ the\ HH \\ \\ 0\ if\ PP_{ik} \geq 0 (non - migrants' households) \end{cases}$$

This index function will allow us to aggregate individual migrants by summation of f_{ik} .

The gross rate of migration from agriculture in the country of origin to other sector j , the country of destination is denoted by

$$\text{Eq3}\ldots\ldots M_{ij} = \sum_{K=1}^{z} f_{ik}$$

Where z is the person employed other occupation such as manufacturing.

If agriculture problem is solved some can flow from non-farm jobs to farm jobs in a given time period. M_{ji}, is from nonfarm agriculture to agriculture farm.

$$\text{Eq4}\ldots M = M_{ij} - M_{ji}$$

i is agriculture farm and j is non-agriculture farm.

3.5. Methodology

3.5.1. Analysis of data

The study wants to model how migration affects food security through agriculture and remittance. One study confirmed that remittance is essential to growth (Ceesay and al., (2019b), and growth determined by the standard of living and food security is part of it. Hence, migration is a multi-faceted phenomenon and needs a multi-faceted method to analyzing it. We will use multilevel logistic regression in this chapter as in chapter 1. The logistic regression will predict the old of international and domestic migration as food security worsens in regions of the Gambia. The study will use household and climate change status as outcome variables because the intention, plan, and final decision to migrate are based on individual and collective household levels in most regions in the Gambia. This is revealed by a study done by Massey et al., 1993, that choice to travel is reached at family level in most developing countries like the Gambia. Climate change will also determine the extent to which people at the household level migrate due to climate variation effects such as variability in rainfall and temperature fluctuations. This is confirmed in the study done by Lobell et al. 2013, Roberts 2009, who conducted "Agronomical research" discovered temperature and precipitation/rainfall actions that are beyond some thresholds are extra problematical for agricultural than disparities in normal circumstances and may consequently be more powerfully related with livelihood products. We also selected the food security index as binary variables to designate one for the probability of households that migrated due to food security problems and zero otherwise. Finally, we also have control variables in the household model, such as social and demographic issues such as household head, religious status, age, educational level, social capita status, health status, and the like. Most of the household control variables are confirmed in some studies, such as the like of; Brown and Bean 2006; Booysen, 2006; Taylor and Martin, 2001, Nawrotzki et al., 2013, Abu et al., 2014)., Mberu 2006; Nawrotzki et al., 2013). After, we finally employed multilevel logistic to evaluate the ratios of odds of transfer to global destination from households at individual I situated inside a region j in the Gambia. Furthermore, the chapter will clear testing from more empirical findings to see the model of climate change-induced migration using food security as a potential driver. This chapter's primary motivation is because the intention, plan, and final decision to migrate are based on households, individuals, or communities and are caused by either climate shocks or otherwise, such as some push and pull factors of migration.

3.5.2. The analytical framework of multilevel logistic regression

This section applied a multilevel logistic form of the predictable logistic (see details explanation by Raphael J. Nawrotzki and Maryia Bakhtsiyarava, 2016 and Raphael J. Nawrotzkia, Allison M. Schlakb, and Tracy A. Kugler, 2016) to evaluate the probability of odds of a transfer to an worldwide 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 link function is used to estimate the binomial migration response of households i located 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 of food security, change in climate and remittance on migration response $\text{logit}(Z_{ij})$, as the dependent variable. Food security is from agriculture impact on migration and change in climate variables can be the effect of climate extreme or adverse climate shocks on migration response. As mentioned earlier due to association among variables in our model, only one model containing on one climate change variable eg. Precipitation and one food security variable e.g., household food consumption and remittance received by the households will be encompassed in the model.Furthermost significant is the interactions terms in our study such as $(FS_j * CLM_j)$, in which θ_3 reflects the effects of given food safety and change in climate measure, θ_4 reflects the given influence 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. $\theta_n = \theta_6\ \theta_{7,}\ \theta_8\ ,\theta_9, \ldots\ldots, \theta_{k,}$ 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} ,…., x_{kt}). $x_{t,}\ \ t = 6, \ldots\ldots, .., k,$ which is operating at households or community as designated in above general subscript, t. Finally, 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.

Table 5 :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(+/-)
Migration response as the dept. variable	yes=1, no=0	
Age	Year	-
size of the households	Number	+/-
Total Household income	US Dollars	+
Landowner	dummy	+
Marital status	Married or not	+
Gender	Male or female	+/-
Remittance	Dummy	+/-
Education status	1 = yes, 0 = no	+
Employment status	1 = employed, 0 = unemployed	+/-
Changes rainfall	Dummy variables, yes=1, no=0	+/-

Is your household's food secure or not?	Dummy variables, yes=1, no=0	+/-
Climate variability	yes=1, no=0	+/-
Food security consumption levels	Continue	+/-

Source author's own evaluation from household survey, 2021.

Table 5: Explanation of the dependent variable and independent variables.

3.5.3. Outcome variable

3.5.3.1. Migration

As part of this census questionnaire, households in the three regions in rural Gambia were asked different questions about their migration status, and they are as follows; 1. Do you have to migrate(s) in your household during the time of food (in)security?; 2) Do you have to migrate(s) in your household in general? ; 3) Who is involved in making the final migration decision in your household? ;4) Migration type ?; 5) Migration Status of the households? And so on. Questions 1 and 2 of these variables were coded as one if a household had at least one migrate in general or had a migrate at the time of food insecurity due to climate or other environmental pressures and zero otherwise. In all the multilevel model's regression, the most crucial variable used is the number 2, i.e., Do you have migrate(s) in your household in general? Even though sometimes we interchanged to see the impact of food security or insecurity on migration response in the rural Gambia, we want to clearly show whether households have any migrants outside the homeland or not. Due to unskilled migrants in the Gambia, we found in our study that if net migration upsurges by 0 units, economic growth will be reduced by 1.83(Ceesay, E. K. (2020)) and Ebrima K. Ceesay (2020). Another separate study by Adepoju, 2004 confirmed that Migration should be tacit as a livelihoods strategy in rural households in West Africa, and the domestic move is for family formation (Henry et al., 2004). Migration is round (Hampshire & Randall, 1999).

3.5.3.2. Household-level control variables

Religious affiliation, marital status, food security, food security consumption level, educational status, Employment status, Change remittance pattern, Remittance, Household income, Household size, Age, and Gender are important household-level control variables. Henceforth, to understand the social relationship of the households, we construct dummies for these variables. According to (Ceesay, E. K. (2020)) established that received in remittance have important detrimental influences on net migration in Gambia. For instance, a study by Lokshin et al. (2010), poverty reduction in Naples was due to remittance and labor migration. Komla Amega shows that remittance has important optimistic impacts on schooling. In their part, Amakom and Iheoma (2014) found that primary and secondary school enrollment rises as remittance increases in Sub-Saharan African countries. The study about marital status and Migration found that marital status increases Migration. (Abu et al., 2014). For gender, according to IOM Glossary, 2005), male Migration is higher than female Migration (about 48% of the migrants are women). According to (Bradley, D. E., and C. F. Longino 2009, King, K. M., and K. B. Newbold,2009 and Zimmermann K. F., and A. Zaiceva,2016), mainly aging reduces relocation as older people have a tendency to stay more than the younger generation. Further, a direct relationship exists between education and Migration, Barrientos (2007).In adding, the amount of household memberships employed and the human capital are essential factors for Migration (Abu et al., 2014). For Landownership, these are some of the questionnaires we asked the rural household in the Gambia. Do you own land? The land you owned, what is the size? If yes, how do you use your land?

VanWey, L.K., 2003 wrote about landownership as the factor of Migration in rural Thailand, and the results confirmed that households with small landholding households are diversifying by Migration to complement the rural income of the households, while households with more extensive landholdings are diversifying to overcome the absence of accessible credit in the village.

3.5.4. Primary Predictor

3.5.4.1. Climate variability

We used some climate change indicators as a proxy of climate variability in rural Gambia. First, we used the temperature change to measure the heatwave (maximum temperature). It coded as one of the household's observed changes in temperature in the last 10-20 years, compared to the situation today and 0 other. Second, we used changes in rainfall to measure shifting patterns or drought, which is coded as one if households experience changes in rainfall and 0 otherwise in the last 10 t-20 years, related to the situation today. According to Schlenker and Roberts 2009, Lobell et al. 2013, originate that temperature then precipitation at certain thresholds are more likely to cause problems to agriculture and prompt Migration. Heatwave will lead to food insecurity and causes Migration, whereas drought will lead to food insecurity and causes Migration. Heatwave wave or high-temperature causes problem for both human, animal, and plant, and this, of course, lead to Migration. Changes in rainfall can lead to drought, which causes a decline in agricultural yields, causes food insecurity, and prompts Migration to an area with food availability and good agriculture or livelihoods. Third, we also used excessive precipitation to measure floods and coded it as one household's experienced flood over the last 10-20 years and 0 otherwise. According to IPCC 2001, average yearly temperature and precipitation are expected to rise. The salt intrusion was coded as one if households in those regions in rural Gambia experienced salt intrusion and 0 otherwise. Jaiteh, M. and A.Saho 2006, found that a rise in sea level would allow saltwater to enter farther inland.

3.5.4.2. Food Security and Food Consumption

We used two food indicators to determine their linkages with migration response in rural. The first is food security, coded as a one if the household is food secure and 0 otherwise. Second, we used household food consumption level as a continuous variable, and the question is framed as this, Total household food consumption per capita per month. It is in local currencies, and we converted it to international $US dollar currency. Minh Cong Nguyen and Paul Winters, 2010 wrote nexus between Migration and food consumption levels in Vietnam and by using Vietnam and found that temporary Migration has a optimistic result on food diversity. In the author's opinion, the links between food security and Migration are complex. Income problems, unemployment, lack of education, climate shocks, high food price, problems with available food, food accessibility problems, poor land nutrient, conflict, and poverty are some pressing issues that could trigger Migration to an area to escape from hunger and societal problems.

3.6. Objective three: Vulnerability assessment at households and regional levels: Evidence from rural areas in the Gambia Towards climate change

3.6.1. Theoretical framework

There are numerous models on how to theorize the Vulnerability of climate change((Change, 2001, Pandey et al., 2014, Pacifici et al., 2015) and migration an adaptation strategy (Aitken et al., 2008, Black et al., 2011 and Vinke et al., 2020) and coping mechanism for climate change / environmental respectively. Refugees or climate migrants' are discussed in the following authors' (Reidsma, 2007, Hoddinott and Quisumbing, 2003).

3.6.1.1. Measuring Vulnerability: Econometric approaches

Presently many models in what way to theorize then measure change in climate Vulnerability ((Change, 2001, Hoddinott and Quisumbing, 2003; Pandey et al., 2014, Intergovernmental Panel on Climate Change, 2014 Pacifici et al., 2015; Gunther & Harttgen, 2006; W. Naude' et al., 2009; Malone & Engle, 2011; Nelson et al., 2010; Deressa et al., 2008; Chang & Huang, 2015; Hoddinott & Quisumbing,2003; Pandey et al., 2014; Ligon & Schechter,2003 and Zha). Thus, the Econometric method uses household survey data like social, economic surveys, and integrated household surveys to analyze and interpret the diverse stages of households' vulnerability conditions.

3.6.1.2. Vulnerability as expected utility

According to Kanbur 1987; Adger, 2006; and Krishnan (2000); Günther & Maier, 2014; VEU is defined as the difference amid predictable utility driven by consumption and the total utility from some consumption. As they studied the panel data model of Vulnerability, they applied the method in the data set used in Vietnam and Bulgaria, respectively. They confirmed that risk and poverty play crucial roles in the household's welfare losses attributed to shock(Ligon and Schechter, 2003, Magrini et al., 2018). According to Kanbur, 1987, the shortcoming of this method of vulnerability study is that it does not account for specific household risk choices, and therefore those individuals are not well informed about their preferences, particularly procedures that are uncertain.

3.6.1.3. Vulnerability uninsured exposure to risk

Ravallion (1999) defined this vulnerability measure as an ex-post for the valuation of the degree to which undesirable shocks lead to a welfare loss. For their part, Skoufias 2003, Geffersa et al., 2019, and Pham et al., 2021, employed panel data methodology in order to comprehend the influence of tremors at time of Vulnerability in Russia and establish that shocks impose a welfare loss. It reduces consumption in the time of absence of risk management tools. However, Households poverty does control the Vulnerability the households. The more poor households are, the more vulnerable they become. Consequently, there is a level to calculate the vulnerability status of the households at specific thresholds-minimum side by side, medium level, and maximum thresholds.

3.6.1.4. Vulnerability as expected poverty

The VEP is dynamic of poverty by Chaudhuri et al. (2002) and Kamanou and Morduch (2002). For instance, this method contains two things; either chronic poverty or transient poverty. Therefore, this vulnerability measure views consumption or income as a good proxy for welfare losses.We will approximate the probability based on households' consumption or food consumption shocks at definite thresholds (Deressa et al., 2008). However, compared to the others, this method's unique drawback is that the assessment uses a single cross-sectional, and numerous cross-sectional assumptions or simple cross-sectional hypotheses are missing (Hoddinott and Quisumbing, 2003 Deressa et al., 2008).

Table 6: Summary of approaches or theories to measure of vulnerability

Method	Authors'	Advantages	Disadvantage	Model	Why or why not I select this method
Vulnerability as exposure to risk(VER)	Ravallion (1999),Vakis (2006) Povel (2010, 2015)	-It is a good measure of tremors at the time of crises -It is an ex-post.	smooth consumption inability	Cross section data	The results will be biased, inconsistent and inconclusive
Vulnerability to poverty(VEP)	Christiaensen and Boisvert (2000), Chaudhuri et al. (2002)	-Probability.	Single cross section is present	Cross sectional data/panel data	It is the best method aimed at small sample size

Author's own evaluation from articles

3.7. Material and Methods

3.7.1. The Econometric method and Data analysis

3.7.1.a. Vulnerability as expected poverty Framework to assess vulnerability at household level

This is one of the methods to measure households' vulnerability status. Hence, the study is a household survey; the paper adopted the expected vulnerability poverty approach. The VEP measure dealt with probability because risks and shocks are uncertain. Risk and shocks are unpredictable and can occur at any time, especially in poor households. In this method, we want to understand the probability of households that are poor or non-poor during climate shocks or socioeconomic features shocks or other control variables that faces households underneath a approved level of households consumption, poverty line, or the tremors, especially the climate shocks force the consumption to stop below the minimum flat if it is by now below this flat and this is the baseline ((Chaudhuri et al. 2002).VEP is an ex-ante vulnerability measure. It is better for panel data due to the large sample size. Now that panel data on shocks and risks are very limited in developing countries, and the best solution is to use cross-sectional data to replace the panel to analyze the VEP. Consider first a sample of VEP. The probability that households consumption in the future will be below the poverty line is as follows

$$\text{eq1} \quad \ldots \text{VEP}_{i\,t} = \text{Prob}(c_{i,t+1} \leq A)$$

Where vulnerability of households (or individual i) and at period t, is the likelihood that an individual i-th households consumption at a period $t+1$, $c_{i,t+1}$ be underneath, above, or equal to the poverty line, A (Gaiha and Imai 2004). Here, we assume that the future consumption in the study areas is the same. The depending variable consumption is log-linearized. According to Pritchett et al.,2000, another alternative approach to measure vulnerability is that a household is weak if the hazard, risk, or shock in n-periods is more significant than a probability threshold.

$$eq2 \dots V_i(p,n,A) = I\{R_{it}(n,A) > p\}$$

The limitation can be overcome by rewriting equation 1 as below;

$$eq1(a) \dots V_{it} = \sum_s {}^sP_s \ *\text{Prob}(c_{i,t+1}, A) = \sum_s {}^sP_s \ * I\left[\, c_{i,t+1} \le A\right] * \left[\frac{(A - c_{i,t+1})}{z}\right]^{\beta}$$

Where $\sum_s {}^sP_s$ the amount of the probability of all potential is state of nature, s in era $t+1$ and β is the wellbeing weightiness. β May perhaps take values 0, 1, 2….,,,,. In order to transform N panel households using cross sectional data (Kamanou and Morduch, 2002) as given;

$$eq3 \dots (1/N) \sum_i^N \sum_s {}^sP_s \ * I\left[\, c_{i,t+1} \le A\right] * \left[\frac{(A - c_{h,t+1})}{z}\right]^{\beta}$$

A vulnerability measure such as (3) is relevant in aggregating a large sample. If terrible weather happens and all the crops and livestock decline, then future consumption will likely be affected, and vulnerability will rise. We begin the analysis from a method (Chaudhuri et al. 2002), in which they assumed that consumption/Income of a household h is a stochastic procedure with mean and standard deviation of the household, which are normally distributed and is given by;

$$\log C_h = \gamma X_h + \varepsilon_h \dots (4)$$

Where; log is the natural logarithm, C_h is per capital consumption expenditure of the household (total)/per capital food consumption of the household, X_h comprises a bundle of households features, γ is a vector of parameters and, ε_h is a mean zero residual and OLS used to estimate the error term.

We take the variance of both sizes in equation (4) gives:

$$\sigma_{\varepsilon,h}{}^2 = X_h \vartheta \dots (5)$$

We will estimate the parameters γ and ϑ using a three-step FGLS procedure proposed by Amemiya (1977). We now takes the expected value and variance in equation 4 and 5 to estimate equation 6 and 7 below;

$$\hat{E}[\log C_h / X_h] = X_h \hat{\gamma} \dots (6)$$

$$\hat{V}[\log C_h / X_h] = \hat{\sigma}_{\varepsilon,h}{}^2 = X_h \hat{\vartheta} \dots (7)$$

We assume that log consumption is normally distribute and that enable us to estimate the above equation by using. Letting $\aleph(.)$ show the cumulative density function of the standard normal distribution and the probability evaluation is specified by:

$$\widehat{VEP}_h = \hat{P}(\log C_h < \log A / X_h) = \aleph\left(\frac{\log A - X_h\hat{\gamma}}{\sqrt{X_h\hat{\vartheta}}}\right)\ldots(8)$$

Where $\log A$ is the change of the smallest consumption beyond which a households might be vulnerabled. Note hence it is cross section data we used normal probability distribution assumption due to small sample size.

3.7.1.b. Model Specification

Hence it is household survey data, and we used cross-section to measure VEP in the study area due to the small sample size. We replaced log income with monthly log consumption expenditure per capita and monthly log food consumption expenditure per capita in the below specification. Similarly, mark our outcomes similar to previous studies on vulnerability to poverty as expected (Gaiha et al.,1993; Gaiha et al.,2004). This is because cross-sectional data can replace panel data. Hence, users of single cross-sectional data can use cross-sectional changeability as proxy aimed at inter-temporal changeability (data for more than one point in time or one year) with similar characteristics. From Gaiha et al., 1993; and Gaiha and Imai, 2004, our model specifications of VEP can be written as follows;

$$eq9 \ldots \ln C_i = x'_i\delta_1 + L'_i\delta_2 + H'_i\delta_3 + \epsilon_i$$

$$eq10 \ldots \sigma^2{}_{\epsilon,i} = x'_i\ \beta_1 + L'_i\ \beta_2 + H'_i\ \beta_3$$

Where:
I: indexe
s
Ci: households consumption per capita expenditures

Xi: households characteristic.

Li: is own land its square, the share of irrigated land, and non-land production asset, its square, climate change indicators such as flood, drought, variability in temperature and rainfall, and saltwater intrusion.

Hi: is human capital such as the education status of the household head and its squared, employment status and its squared

ϵ: Is the variance of the error term.

Finally, we can measure by FGLS applied three steps approaches (see for details Chaudhuri, Jalan and Suryahadi (2002) and Hoddinott and Quisumbing (2003).

Table 7:Explanatory variables; the dependent variable is log consumption per capita per month. LogC = Prob(monthly per capita consumption < poverty line) to measure hh. Vulnerability.

Variables Name	Description of the Variable	Expected Sign(+/-)
Household consumption is the dept. var.	log of hh consumption is Continuous	
Age of household head category-xi	Age of the households-continuous	-/+

Age of household head squared-xi	Age squared of the household head	-
Household size-xi	Size of the household-continuous	-/+
Household size squared-xi	Size square of the household	-
Owned area of land-li	Area of land owned by the households	+
Owned area squared-li	Squared of the land area	-
Caste system(noble or slave)-xi	Caste system affect vulnerability	+/-
Share of irrigated land-li	Irrigated land-dummy	+/-
Non-land production assets-li	dummy	+/-
Non-land production assets squared-li	The square of it	+/-
Education status of the responded -hi	Measure human capita and it is dummy	_
Education status of the responded squared -hi	Square of it	+
Educational attainment	Continuous	
Educational attainment squared	Square of it	
Households' food security consumption level	Level of food security of the household	+/-
Gender	dummies	
Climate change indicators-Flood, drought, changes in rainfall, changes in temperature and salt intrusion	dummies	
Employment of the hh heads	dummies	
Employment of the hh heads squared	Square of the hh heads	

Source author's own evaluation from household survey 2021 in the rural Gambia.

3.7.2. Integrated Vulnerability assessment at regional levels

3.7.2.1. Conceptual framework

This thesis investigated the vulnerability of Gambian farmers towards change in climate by constructed on the integrated vulnerability assessment. These indicators also contain different socio-economics and

biophysical characteristics of three rural areas in the Gambia. Each rural area's socio-economic and biophysical indicators are categorized into three leading indicators in line with IPCC 2001, and Hahn et al., 2009 meaning of susceptibility. The IPCC explains vulnerability to change in climate: "The degree to which a system is susceptible, or unable to cope with adverse effects of climate change, including climate variability and extremes and vulnerability is a function of the magnitude and character, and rate of climate change variation to which a system is exposed, sensitivity, and adaptive capacity." The definition contains three leading indicators, rendering to IPCC's fifth assessment report on vulnerability IPCC, 2014. We adopted the IPCC fifth assessment reports as integrated vulnerability approaches and, at the same time, used Principal component analysis as a statistical tool to analyze vulnerability. Figure 13 below about the conceptual framework adopted in this study from IPCC reports on vulnerability. In the below figure, exposure and sensitivity are the possible impacts on vulnerability to climate change. Exposure contains slow onsets to changes in climate (changes rainfall and changes temperature) then sensitivity contain climate extremes (floods and droughts). Sensitivity and exposure affect each other. Exposure increases, sensitivity rises, vulnerability increases vice versa. In this sense, adaptive capacity (socio-economic vulnerability) can reduce exposure to climate risks like agriculture failure, lower income, and vulnerability will decline. Adaptive capacity can also reduce sensitivity (biophysical vulnerability) and vulnerability to climate change reduces (Diouf and Gaye 2015). Finally, in the below figure, if we combine exposure (slow onset) with sensitivity as likely influences, adaptive capability diminishes the vulnerability. Still, it does not change it (Deressa et al. 2010, Diouf and Gaye 2015). At the regional level, we used integrated assessment approaches-indicators-based approaches. We used Principal component analysis as a statistical tool to measure and weightiness variables for all comparative vulnerability score (Pandey and Jha, 2012, Tun Oo, A. 2018 and Yu et al.,2021. In addition, Allison et al. 2009 applied it globally, whereas O'Brien et al. 2004 applied it on a subnational or nationwide scale. However, numerous econometrics and indicators-based approaches to measuring vulnerability at the household, regional, and national levels, comparing regional, sub-regional, and worldwide.

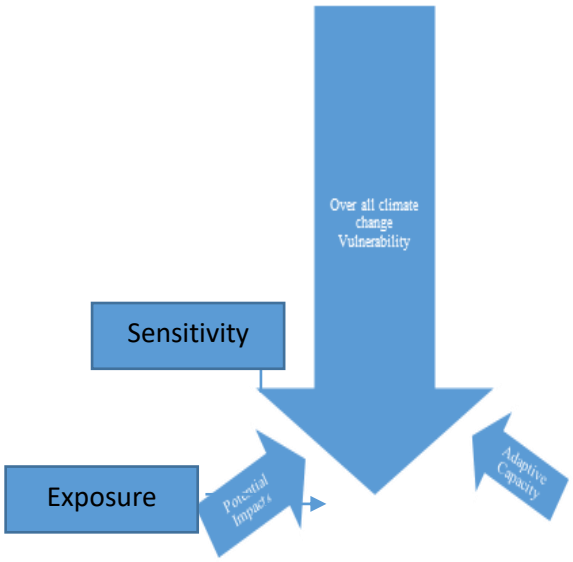


Figure 12: Adopted from IPCC and fourth and fifth assessment reports on Vulnerability. Low adaptive capacity, high exposure and sensitivity lead to high Vulnerability, whereas high adaptive capacity, low exposure and sensitivity lead to low Vulnerability

Eq (11)…Vulnerability = F (exposure, adaptive capacity, sensitivity)

This equation (11) means that exposure risks increase, and Vulnerability rises. Adaptive capability increases socioeconomic and Vulnerability to change climate reduce. Sensitivity (biophysical or behaviors attribute)

increases, vulnerability decline. Alberta Sustainable Resource Development, 2010 indicated that the application of low exposure to variation in climate, low sensitivity to climate actions, and high adaptive capacity lead to low Vulnerability. Similarly, low adaptive capacity, high sensitivity, and high exposure indicators lead to high Vulnerability. If both exposure and sensitivity rise together thru low adaptive capability, there will be extreme Vulnerability to change in climate in that area(s), food security, poverty, health issues, environmental problems, social problems, cultural problems, political problems, lower income, lousy infrastructure, skills, etc. Thus, the author elaborated that high risk and high Vulnerability are positively correlated and should be the priority areas of intervention. The selection of indices was carry out and assessment of the following literature Filmer and Pritchett (2001), Deressa et al. (2009), Abdi & Williams (2010) , were read and applied in the context of rural Gambia as follows; the index formula for a region j for indicator i is given by:

$$\text{eq(12)} \ldots I_j = \sum_{i=1}^{k} w_i (b_{ij} - \bar{b}_i)/\sigma_{b_i}$$

The index for Adaptive capacity (AC) of region j for the indicator i

$$\text{eq(13)} \ldots Ac_j = \sum_{i=1}^{k} w_i^{Ac} (b_{ij}^{Ac} - \bar{b}_i^{\,Ac})/\sigma_{b_i}$$

The index for exposure (Ex) of region j for the indicator i

$$\text{eq(14)} \ldots Ex_j = \sum_{i=1}^{k} w_i^{Ex} (b_{ij}^{Ex} - \bar{b}_i^{\,Ex})/\sigma_{b_i}$$

The index for sensitivity(S) of region j for the indicator i

$$\text{eq(15)} \ldots S_j = \sum_{i=1}^{k} w_i^{S} (b_{ij}^{S} - \bar{b}_i^{\,S})/\sigma_{b_i}$$

Where:

I: index

w:weight

VI: Vulnerability index

Ex=exposure

Ac=Adaptive capacity

S=Sensitivity

σ = standard deviation

3.7.2.2. Methodological framework

As explained above, the final step is the attachment of weights/loading/factor scores/eigenvector to the vulnerability indices using principal components analysis (PCA). For this step, the normalization of the indicators was carried out (Quackenbush, 2002), and the technique of PCA were employed to find the unequal weight of all indicators of the selected variables classified into sensitivity ,exposure, and adaptive capability (see explanation: Deressa et al. 2009, Tun Oo, A. 2018 and Yu et al., 2021. Numerous technical and scientific research fields use the principal component analysis. We used the statistical method (PCA) to freely generate the weight for this study. Scientifically, the PCA relied on eigenvalue and eigenvector of data decomposition correlation and matrix covariance (Abdi & Williams, 2010). In other words, PCA is a technique for removing those few orthogonal linear amalgamations of variables from a set of variables most positively capture shared facts. For instance, the PCA1 capture most variables and with significant information that are shared to all the variables under examination. Supposing that we have Y-variables (b*1i to b*yi) that signifies the Y-variables features of each region i. Firstly, the normalization of variables using it means and the standard deviation by using the pca. Thus, b1i = (b*1i – b*1)/ σ*1, where b*1 is the mean of b*1i across regions I in the rural Gambia and σ*1 is its standard deviation of across region I in the rural Gambia. The selected variables is a linear combinations of a set of essential components called Principal for each region i:

$$b1i = X11\ Z1i + x12Z2i + \ldots + x1zZyi$$

……

$$i = 1 \ldots I$$

$$bz1j = Xz1iZ1i + Xz2Z2i + \ldots + xzzZyi, \ldots\ldots\ldots\ldots..eq(17)$$

Z's: are the components

X's: are the coefficients on every component

Since individual the left-hand side of every link is detected, the answer to the tricky is unspecified. PCA overpowers this indeterminacy by discovery the linear amalgamation of the variables with supreme variance, then discovery a second direct amalgamation of the variables orthogonal to the main and maximal enduring variance, and so on. Strictly the technique resolves the equations of eigenvalues and corresponding eigenvector. The scored factors is by overturning equation (12). This provides a set of estimates for each of the Y, principal components:

$$Z1i = a11\, b1i + a12\, b2i + \cdots + a1z\, bzi$$

…….

$$i = 1 \ldots I$$

$$Zzi = az1\, b1i + az2\, b2i + \cdots + azz\, bzi, \ldots\ (18)$$

These are scores factors/loading. Subsequent the work strictly by Filmer and Pritchett (2001), Deressa et al. (2009), and Abdi & Williams, 2010), the pca1, articulated in relations of actual (unnormalized) variables in region in the rural Gambia is an index based on the following expression:

$$Z1i = a11\ (b*1i – b*1)/(\sigma*1) + \ldots + a1z\ (b*Zi – b*Z)/(\ \sigma\ *Z)\ldots\ldots..eq(19)$$

The last point this thesis measured in making vulnerability is calculating the indices by components and index. Vulnerability examination ranges from the local or household or regional, or worldwide scale (Deressa et al. (2009), Tun Oo, A. 2018; Yu et al., 2021). The select of scale depends on availability of data. In this thesis, household level and three rural regions' data were collected and coded. So the scale is within

the villages and villages within the region covered in the survey in rural Gambia. After that validation of vulnerability index was carried out and numerous paper that studied vulnerability does not test the results by validation. In conclusive, we are not aware of any studied added time trend to comprehend the severity of vulnerability across the regions. For example, vulnerability index is severe in one region, decline in other and then on average it becomes massively increases across rural regions in the Gambia

Table 8: Models variables

No.	Indicators	Description	Unit
1	Changes in temperature	Exposure	%
2	Changes in rainfall	Exposure	%
3	Salt intrusion	Exposure	%
4	Access to water during drought	Sensitivity	%
5	Flood	Sensitivity	%
6	Drought	Sensitivity	%
7	Age	Sensitivity	year
8	Household size	Adaptive capacity	Number of people
9	Income	Adaptive capacity	$
10	Fertilizer	Adaptive capacity	%
11	Remittance received	Adaptive Capacity	%
12	Farm size	Adaptive Capacity	Hectares
13	Secondary education	Adaptive Capacity	%
14	Illiterate	Adaptive Capacity	Continuous
15	August stranded months	Adaptive Capacity	%
16	Livestock	Adaptive Capacity	%
17	Own land	Adaptive Capacity	%
18	Caste system	Adaptive Capacity	%
19	Access to credit	Adaptive Capacity	%
20	Access to agriculture extension	Adaptive Capacity	%
21	Food markets	Adaptive Capacity	%
22	Irrigation potential/Share of irrigated	Adaptive Capacity	%

23	Agriculture technology	Adaptive Capacity	%

Own Compilation from based on the household surveyed, 2021

3.7.3. Variables description applied in the Principal Components (PCA)

Thus, variables used in this part of the thesis were categorized and analyzed according to the study's conceptual framework and their respective indicators (see details in figure 12 and tables 15-18). IPCC 2001, and 2007 define potential impacts as exposure and sensitivity indices. By definition, exposure replicates the degree, and way, the feature is exposed to change in climate (IPCC, 2001). In our study, indicators for exposure selected are; changes in rainfall, changes in temperature, and salt intrusion. It is commonly established that rising sea levels can cause massive migration. It can damage farmland, which in turn causes the land to be eroded and infertile, leading to poor agriculture yields and food insecurity, poverty, hunger, and malnutrition. Similarly, it also agreed that variations in rainfall and temperature affect agriculture in Gambia in particular and Africa in general. Smallholder's subsistence farmers depend on rain-fed agriculture for production and consumption, and negative impacts on precipitation will affect farmers' yields negatively. As indicated in figure 30, all rural Gambia regions are affected by rainfall and temperature changes and are therefore exposed to climate change risk. CRR and URR are also affected by bushfires, especially after their harvest. Rice and groundnut fields affect the major crops produced in those regions. According to IPCC, 2001, and Francesca Giordano, 2020, sensitivity as biophysical indicator is the degree in which change in climate affects the scheme either unfavorably or positively. It can be direct. For example, as changes in rainfall happen, there will be immediate changes in crop yields or changes in temperature directly changes agriculture, both crops and animals. It can also be indirect. For example, salt intrusion affects land cover and causes agricultural productivity loss. Therefore, the indicators for sensitivity are; floods, drought, and access to water during drought are climate changes extreme variables, and food consumption expenditure, total consumption expenditure, and total expenditure on crops are proxy's variables for poverty. The respondents said drought and floods affected their farmland in all the study areas, leading to reduced yields. We used total expenditure on crops, food consumption expenditure, and total consumption expenditure as a proxy for poverty to understand and generally agreed that regions in that household expenditure rise correspond to poverty increases. It demonstrated that regions where food consumption per capita per month increases correspond to lower standard of living and high poverty compared to a region with a lower expenditure per month. Age is also sensitive in that climate changes can directly affect it because older and younger are more susceptible to hunger and malnutrition.Rendering IPCC, 2001, adaptive capability, by definition, is capacity of schemes, humans, organizations, and organisms to regulate to possible harm, take benefit of chances, or respond to penalties. In this study, see the detail in table 18 about the indicators for adaptive capacity. It comprises the IPCC 2001 main characteristics indicators control the adaptive capacity of the regions, countries, communities, households, continents, etc. The total household income differs in the three regions, which is an excellent example of which regions have applied adaptive capacity. Households that receive income can translate that income to have insurance, coping capacities, and other safety networks, and that in turn reduces the risk and vulnerability to climate change and other hazardous circumstances or shocks(Cutter et al. 2000).In the rural Gambia, more than 90 percent of the farmers apply fertilizer to their crops, increasing crop yields. Household size is expected to increase vulnerability to climate changes due to extended household size in the rural Gambia. This is, of course, many mouths to feed, and with the fluctuation of rainfall and poor agriculture, this will be translated to the biggest vulnerability of the household at the period of change in climate. Practicing livestock as an indicator of adaptive capacity is used in this study, and food security will rise, and vulnerability will reduce. Godber et al., 2014 revealed that livestock farming is essential for sustainable food security and reducing vulnerability. Farm size is vital for food security in rural Gambia, and this result is predetermined. Mutabazi et al., 2015 found that Increased farm size enhanced the income level, and a additional upsurge in farm size abridged upcoming vulnerability. Migration and remittance are selected in this study as adaptive capacity to vulnerability towards climate

change. David et al., 2019 revealed in their analysis that women (vulnerable to sex and domestic work as a form of modern slavery), men (forced to do labor on the farms and construction works in the manufacturing industry and children (labor, trafficking, as a form of child abuses) faces a different level of vulnerability based on migration. Remittance is an essential part of households' welfare and increases migration, increases remittance, and reduces vulnerability to climate change. Even with rainfall impacts, migrants can send remittances back home, which, in turn, are used for household food and total consumption.Most respondents said they did not receive infrastructural support in the rural Gambia. Out of 100 percent and 400 total samples surveyed, the result revealed that the proportion of received. Infrastructural support is high in URR (about 13%) and lower in NBR (about 2%) and (CRR about 1%). It is ridiculous that people in these regions do not receive infrastructure support, which will negatively affect their aging, life expectancy, trade, energy sector, food security, poverty, health services, road, transportation, market, climate change, etc. The education status of the respondents is an essential human capital formation. Therefore, we selected 0-9 grade of education as a measure of human capital part of adaptive capacity to reduce or adapt to the negative effect of climate change, and we found that the CRR has a high 0-9 grade of education (about 86%), and NBR has the least number with a grade of 0-9 level education. A society with a high level of educated people will be associated with high decision-making, skills, and talent, which will translate into a sustainable society. This is in the same line as Striessnig et al., 2013 used 125 countries to see whether primary and secondary education educational attainment will significantly increase adaptive capacity and coping mechanisms, reducing vulnerability to climate variability. They establish that superseding the importance of primary and secondary education reduces the impacts of climate change vulnerability. We measure illiterate as does that got 0 or no grade of education. Therefore, the surveyed URR had a high illiterate (about 26%), and low illiterate in CRR (about 18%), and NBR had 23 percent illiterate. So it means that households will be exposed to change climate and adversely affected by the influences of change in climate extreme due to an absence of knowledge and skills to carry out adaptive capability and susceptibility to poverty and change in climate will rise. Thus, the present hypothesis was in the same line as Gunter et al., 2008 confirmed that Indigenous People to Climate variability in Bangladesh are illiterate. There is high exposure to climate change risk, shocks such as temperature and precipitation, and sensitivity to climate extremes such as flooding and droughts, and they have low adaptive capacity. In the rural Gambia, the proportion of employment in agriculture is higher in NBR and lower in URR. Agriculture is exposed to slow onset to change in climate like fluctuation of rainfall and temperature changes and soil intrusion, sea-level rises, and is sensitive to climate extremes such as floods and droughts. Therefore employment as a farmer is an important variable in examining farmers' vulnerability status and whether adaptive capacity reduces vulnerability. Climate changes affect agriculture through yield reduction, pest and diseases, insects, locust invasion, and other related hazards, and it causes high vulnerability in the rural Gambian society. This is confirmed in the study by O. Jamshidi et al. 2019 Hamadan province, Iran, which found that subsistence farmer relatively vulnerable to change in climate. According to the respondents, rural Gambia's households said that in August perse, they are stranded or have no money to buy food and other necessities(about NBR-815, URR-96%, and CRR-100%).So vulnerability is higher in rural Gambia in August in general. We also selected some variables that are significant for vulnerability to change in climate, such as access to credit, access to agriculture extension, caste system, and food market, and some adaptation techniques such as early and late varieties, agriculture technology, the share of irrigated land as a proxy for irrigation potential and soil and water conservation.

The methodology appears good. However, there are too many redundant statements that will need to be cleaned off. There are also so many grammatical and spelling inelegancies that must be taken care of.

Conclusion

The research is mixed methods, i.e., containing qualitative and quantitative data to assess the effects of climate change, migration dynamics, food security and climate change vulnerability in the rural Gambia. Primary study and the questionnaire includes the following sections: Interview information/Geographical locations, Personal and demographic information of the households, Economic activities, Agriculture and

Livelihood-related issues, Climate change Variability, Effect of changing rainfall on livelihood and food security, Food Security, Consumption and Livelihood, Coping and Adaptation strategies, Natural disasters and coping, Migration Patterns of all the household members (Male and Female) ,Migration and Remittance and social status. The methods in this study are time series regression analysis, multi-level logistic regressions, and vulnerability assessment carried out using vulnerability as expected poverty (feasible GLS methods) and Principal components analysis (PCA) to study climate change vulnerability, respectively. The Primary research adopts simple and stratified random sampling approaches contingent on the excellence of the information provided from the households' survey, focus group discussion, and expert interviews. Subsequent, we concluded that, the research designed and methodology are consistent with the research question and objectives of the thesis. The sampling techniques used are in line with say objectives and hypothesis and theoretical models developed are in the line of the objective. The data used are mixed method contain both secondary data for objective one and primary data for objective two and three were all in line with analysis of the data.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Objective one: The impacts of climate change on food availability using time series approaches

4.1.1. Results

4.1.1.1. Descriptive statistic

The indicators used for this theme of the thesis were obtained from the World Development Indicators (WDI). Table 9 displays descriptive statistics.

Table 9: Descriptive Statistics of variables used in the study

Variable	Obs.	Mean	Std	Min	Max
LNFSFP	49	4.266967	0.2081572	3.821442	4.799091
LNGDPPc	49	6.098171	0 .5633579	4.758396	6.829266
LnAAR	48	4.365117	0 .1619503	3.963814	4.653288
LNAFFVAc	49	18.64221	0 .9270481	16.64361	20.1128
LNGDPC	48	19.73353	0 .9853207	17.62592	21.0893
LNPG	48	1.186681	0 .1405012	1.043032	1.60516

Own evaluation using stata 16 for window in 2021

The correlation is defined to control association among two variables. The relationship between food security growth and population growth rate is negative. As the growth of the population escalates by 1 unit, the rate of growth of food availability declines by 41%. The growth of agriculture value added is also negatively influenced by the population growth. In addition, the growth rate of average annual rainfall as a proxy for climate change has negative correction with the growth of the population annually. Therefore, Climate change affects agriculture, which, in turn, causes food shortages. The relationship between food security (proxy food availability) and climate change is slightly positive and near zero.

Table 10: Results for correlations

Variable	LNFSFP	LNAFFVAc	LNGDPPc	LNPG	LNGDPC
LNAFFVAc	0.3591	-			
LNGDPPc	0.2489	0.9338	-		
LnAAR	0.0793	0.3089	0.2481	-0.0743	0.2617
LNPG	-0.4100	-0.2086	-0.0776	-	
LNGDPC	0.3738	0.9200	0.8942	-0.1885	-

Own Compilation Date?

4.1.2 Unit root tests

The unit root test results (Table 11) are based on Augmented Dickey-Fuller: ADF, Phillips-Perron: PP and Kwiatkowski-Phillips-Schmidt-Shin: KPSS. To begin with, the natural logarithm of the variable applied was created, and thereafter calculated the first differences of the variables using annual data from 1971 to 2020. In addition, the LNGDPPc, LNAFFVAc, LNGDPC, and LNFSFP were stationary at the first difference. Furthermore, the population growth per annum and average annual rainfall were stationary at the initial level form. Thus, at the bottom of the table, the stars indicated the significance level at different percentage level of alpha. In conclusion, the variables were integrated in the different order in the level and first differences and therefore, the appropriate model is ADRL.

Table 11:: Unit root test

Variable Names	ADF		PP		KPSS	
	Level.ADF	1st Diff	Level.PP	1st Diff	Level.KPSS	1st Diff
LNGDPPc	-2.419	-4.62***	-2.281	-6.70***	1.0514***	0.14529
LNAFFVAc	-1.848	-5.69***	-1.871	-6.92***	1.2448***	0.17019
LNGDPC	-1.718	-4.07***	-1.818	-6.40***	1.1328***	0.16581
LNFSFP	-1.548	-6.12***	-2.387	-9.95***	0.58296**	0.13772
LNPG	-5.060***	-7.10***	-1.631	-2.348	0.22454	0.11485

LnAAR	-4.407***	-7.31***	6.162***	-10.79***	0.37114*	0.10114

Note: *, **, and *** are statistically significant at 10 percent, five percent, and one percent, respectively
Source: Authors' calculation using Stata 16 for a window.

4.1.3. Pre-estimation tests

Stability test for VAR models: The result revealed that the four variables used for VAR model lies inside the unit circle and therefore VAR stability condition satisfy.

Normality test

The Jarque Bera test for normality: We attempt to test normality of the indicators used and we justify that errors have a significant critical probability. The LNGDPPc, LNAFFVAc, LNGDPC, LNPG, LNAAR, and LNFSFP follow the standard and lognormal rules.

Correlation of errors test by applying Breusch-Godfrey LM

We concur that the theory test is H0: the error is uncorrelated, and H1: the error terms are associated. The disturbance terms are connected since the p-value is more significant than BG.

Test Heteroskedasticity: White

The theory elucidates H0: disturbance terms are homoskedasticity and H1: if disturbance terms are heteroskedasticity.

First 1: No-cross terms

The crucial result in this case is 3.2457, and the p-value is 0.7774. The model for the error terms is homoscedasticity at 0.05.

Second 2: Yes-Cross terms

The Invaluable result in the case of cross term is present is 29.222, and the p-value is 0.3502. The errord are unrestricted at 0.05.

4.1.4 Co-integration test

The amount of co-integrating associations for the four variables, based on trace statistics and eigenvalue statistics at a 5% significance level, is in Table:- 12. No co-integration among the variable is rejected at 5 percent.

Table 12: Co-integration

Hypothesized No. of CE(s)	Trace Statistic	Eigenvalue	Max-Eigenvalue Statistic	Critical Values (0.05) Trace Max Eigen	Prob. Trace	Max-Eig
None	40.9210***	0.3992	22.4206***	47.8561 27.5843	0.1912	0.1996
At most 1	18.5004***	0.1951	9.5475***	29.7971 21.1316	0.5293	0.7860
At most 2	8.9529	0.1304	6.1485	15.4947 14.2646	0.3697	0.5942
At most 3	2.8044**	0.0617	2.8044**	3.8415** 3.8415**	0.0940	0.0940

Source: Compiled by author from cointegration results using Eview 12 SV(x64) Max-Eigenvalue test shows no cointegration at the 0.05 level. Trace test specifies no cointegration at the 5% level. Note: **, *** signify significance at 5% and 1% level of significance.Data from WDI.

4.1.5 VAR outcomes and discussion

The Vector autoregressive (VAR) outcomes were revealed. The growth of agriculture takes an insignificant negative influence on food security at lag one and an insignificant positive impact on food security at lag 2. This outcome is a priori expectation because agriculture does not cause food security due to a minor level of adaptive technology attached to agricultural development. Similarly, food security has a significant adverse influence on the of agriculture sector. Therefore, change in climate extreme event problems, the growing mean annual rainfall as a proxy variable for change in climate, has a fundamental negative influence on food safety and agriculture at lag 1. At lag 1, GDP per capita has an insignificant negative impact on the growth of agriculture. Outcomes are consistent with the following study (Kamitewoko, E. (2021), Somlanare Romuald Kinda Muhammad Shafiullah. (2021), and Ceesay et al., (2021)) in which they found a negative association between food security and these variables. Overall, the theoretical insinuations of these variables can be extra assessed from the forecast error variance decomposition (FEVD).In this thesis we are worried about status of the progress of change in climate, development of agriculture, and GDP per capita shocks on the growth of food security. The shocks in food security extended within 100 percent in the first year, lessening to about 98 percent in period 2, deteriorating further to 97 percent in years 3, 4 and 5, 96 percent in year 6 and 95 percent in years 7 and 8, 94 percent and 93 percent in the years 9 and 10, respectively. Subsequently, we can see that the shocks in food security in most of the two years' connectives are similar in most cases due to similar variations of climate and some inputs that disturb smallholder farmers in The Gambia, predominantly in the provinces, where the subsistence farming is the mainstay.

Table 13: Forecast Error Variance Decomposition

Variance Decomposition of LNFSFP					
Time Period	S.E	LNFSFP (%)	LNGDPPC (%)	LNAFFVAC (%)	LNAAR (%)
1	(0.1595)	100.0000	0.000000	0.000000	0.000000
2	(0.1733)	98.05885	0.751698	1.043083	0.146368
3	(0.1812)	97.79479	1.114485	0.954342	0.136386
4	(0.1843)	97.55254	1.286072	1.004826	0.156564
5	(0.1858)	97.14988	1.422628	1.255780	0.171716
6	(0.1868)	96.60350	1.543684	1.679804	0.173008
7	(0.1876)	95.96125	1.649860	2.216058	0.172828
8	(0.1883)	95.28834	1.750618	2.788213	0.172829
9	(0.1889)	94.62237	1.850004	3.354912	0.172713
10	(0.1896)	93.98754	1.947502	3.892347	0.172607

Source: Own Evaluation Using Eviews 12 and data from WDI

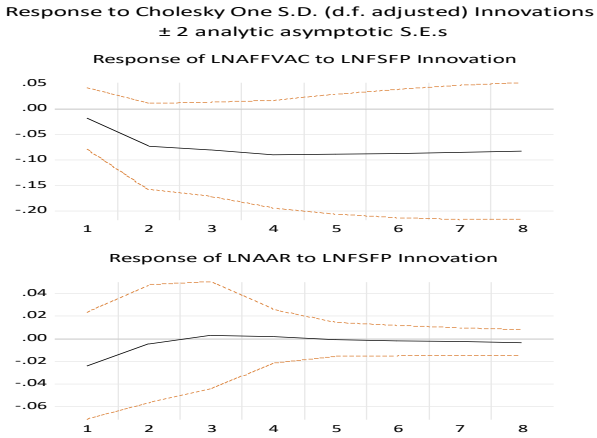


Figure 13: Graphs impulse response function Using Eviews 12 SV(x64).Year=Period

From figure 14 above, the Impulse response functions delivered by VAR models are used to distinguish where the influence of alteration in one variable can be created over all the other variables. Then, a response of the agriculture sector to food security, a standard deviation tremor (innovation) to the development of food security initially has a clear, slightly optimistic impact on the agriculture sector in period one and a negative impact on period two correspondingly. From year two, the response gradually declines to 5.6 years, i.e., five years and six months, when it hit its steady-state value. Beyond the sixth period, the development of the agriculture sector increases above the maximum state value and remains in the undesirable region. Shocks to food security will have a slightly optimistic effect on the agriculture sector in the short span and substantially adverse effects in the long term. Food security shocks will also lead to poor agriculture in the long period. The response of change in climate shock to food security, one standard deviation shock

(innovation) to food security current has a harmful influence on climate change in periods one and two. From year 3 to year 4, the climate change answer to food security was positive and remained negative from year 5 to year 8. Shocks to food security in The Gambia will negatively influence climate change in one year (medium run). In all other periods, the shocks to food availability as a proxy for food security will due to climate change in the long term and even in the short run. As food security is shocked, change in climate crises will be more severe in both periods. Food security shocks happen because climate change affect agriculture yields and loss of harvest and decline in animals' population.

4.1.6. Granger Causality

The main aim of causality assessment of the variables is to confirm causal link amid the diverse variables as depicted in Table 14. Conversely, causality assists us to verify the directional association between and among selected variables under analysis.

Table 14: Granger Causality test outcomes

	Fail to reject: $\gamma_{yx_1} = \gamma_{yx_2} = \cdots \gamma_{yx_t} = 0$	Reject: $\gamma_{yx_1} = \gamma_{yx_2} = \cdots \gamma_{yx_t} = 0$
Fail to reject: $\gamma_{yx_1} = \gamma_{yx_2} = \cdots \gamma_{yx_t} = 0$	y $\not\Leftrightarrow$ x (no granger causality)	$y \Leftrightarrow x$ (bidirectional relationship)
Reject: $\gamma_{yx_1} = \gamma_{yx_2} = \cdots \gamma_{yx_t} = 0$	x $\not\Rightarrow$ y $y \Rightarrow x$ (y cause x and x does not cause x=unidirectional relationship)	y $\not\Rightarrow$ x $x \Rightarrow y$ (x causes y and y does not cause x=unidirectional relationship)

Source: Own Evaluation

The outcomes in Table 10 illustrates an astonishing image as the progress of food security causes expansion of GDP per capita but per capita GDP does not causes the food security growth -unidirectional relationship.

Table 15: Granger causality outcomes

Equation	Excluded	Direction	P-value	Equation	Excluded	Direction	P-value
LNFSFP	LNGDPPc	INDI	0.905	LNGDPPc	LNFSFP	DI	0.028**
LNFSFP	LNAFFVAc	INDI	0.517	LNGDPPc	LNAFFVAc	INDI	0.143
LNFSFP	LnAAR	INDI	0.574	LNGDPPc	LnAAR	INDI	0.559

LNFSFP	Overall	INDI	0.350	LNGDPPc	Overall	INDI	0.103

Source: Authors' computation, 2020. N.B. * p=0.10, ** p=0.05, *** p=0.01 note DI is direct/granger, INDI is indirect/not granger

Table 15 above shows that food production index does impact agriculture positively. The result is indirect. Agricultural growth does not necessarily lead to the development of food security. Planting more trees for more rainfall, in turn, increases agricultural productivity. Therefore, Progress of agriculture (tree planting) promotes incidence of rainfall, and the growth of agriculture significantly causes progress of the rainfall and reciprocal growth of rainfall on the development of the agriculture-unidirectional relationship. The shifting rainfall affects agriculture and security of food=bidirectional relationship. Whilst, variation in annual average rainfall is irrelevant to agriculture development and security of food. It is confirmed by (Ceesay et al. (2021)) and (Sun Z. & Zhang D. (2021)). This is also confirmed in the following study (He, Y., & Lee, E. (2016) and Singh, N. K., & Borrok, D. M. (2019).

Table 16: Granger causality test results

Equation	Excluded	Direction	P-value	Equation	Excluded	Direction	P-value
LNAFFVAc	LNFSFP	DI	0.058**	LnAAR	LNFSFP	INDI	0.858
LNAFFVAc	LNGDPPc	INDI	0.318	LnAAR	LNGDPPc	INDI	0.291
LNAFFVAc	LnAAR	INDI	0.924	LnAAR	LNAFFVAc	DI	0.077*
LNAFFVAc	Overall	INDI	0.276	LnAAR	Overall	DI	0.088*

Source: Authors' computation, 2020. N.B. * p=0.10, ** p=0.05, *** p=0.01.nte DI is direct Granger, INDI is indirect/not Granger.

4.1.7. ARDL estimation

Subsequently, we control the optimum lag for the anticipated model to meet the situation when the dependent variable is change in the security of food and the unit root test types above are strictly at first-difference stationary. The minimum lag length is -12.12* and under (AIC). Therefore, the best lag is three using AIC.

4.1.7.1. F-Bound test Approach for Co-integration for Food Security in the Gambia

The outcomes accessible as stated in Table 17 specify significant cointegration among food security (LNFSFP), Agriculture sector (LNAFFVAc), (LnAAR), climate change (average rainfall proxy), (LNGDPC), economic growth (GDP Current as a proxy) and population growth (LNPG). In model 1, the F-bound statistics value of 5.673 is larger than the critical value of upper bounds, I(1) on 10%, 5%, 2.5%, and 1% levels of significance, which indicated that cointegration among food security as the dependent variable, agriculture sector, economic growth, climate change, and population growth. Henceforth, cointegration exists among the variables in the model. The appropriate model is to evaluate the long-term coefficient of the ARDL, which contains the error correction type. Understanding that the long span stability contains the

short span equation in the ARDL model is logical. In this case, we will approximate the short and long terms.

Table 17: Results of F- Bounds test for Cointegration

Dependent Variable Models	lags	F- Statistics	Co-integration	Further
LNFSFP	ARDL(1,2,3,3,3,1)	F_{LNFSFP} =5.673	Yes	Estimate ECM(long-run model)

Source: Author's own evaluation using Stata 16 for Windows. *:1%, **:5%, and ***: 10% denotes significant level of significance respectively

4.1.7.2. Specification of ARDL Short-run, ARDL Long-run and ARDL Error correction Equations

Specifications of Short-run ARDL models

Dependent Variable: Food Security

$$\Delta lnFSFP_t = \varphi + \sum_{j=1}^{p} \beta_i \, \Delta AFFVAc_{t-j} + \sum_{k=1}^{p} \theta_i \, \Delta lnFSFP_{t-k} + \sum_{l=1}^{p} \delta_i \, \Delta \text{lnAAR}_{t-l} + \sum_{i=1}^{p} \gamma_i \, \Delta lnGDPPc_{t-i} + \sum_{i=1}^{p} \gamma_i \, \Delta lnGDPC_{t-i} + \sum_{i=1}^{p} \gamma_i \, \Delta lnPG_{t-i} + \epsilon_{2t} \ldots (8)$$

d(lnfsfp) c d(lnfsfp(-1)) d(lnaffvac(-1)) d(lnaar(-1))d(lngdppc(-1)) d(lngdpc(-1)) d(lnpg(-1))

Figures 15, 16, and 17 are after running the short-run ARDL model, long-term ARDL model, and after running the error correlation model. The long-term estimates' constancy was controlled using the cumulative sum test method. The CUSUM determines the stability, and the coefficients are stable once the dependent variable is food security. For example, the test controls the stability of the variance of the model. The tests show that the estimate and the variance were steady as the error reduction inside 5% critical limits. The null hypothesis expectations are disallowed in the examinations.

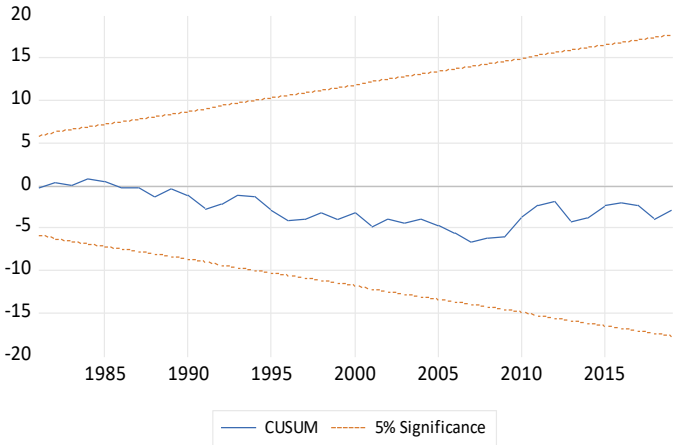


Figure 14F: Cumulative Sum (CUSUM) test when short run food security is the dependent variable

Specifications of Long-run ARDL model:

$$lnFSFP_t = \alpha_0 + \lambda_1 lnFSFP_{t-i} + \lambda_2 \Delta AFFVAc_{t-i} + \lambda_3 lnAAR_{t-i} + \lambda_4 \Delta lnGDPPc_{t-i} + \lambda_5 \Delta lnGDPC_{t-i} + \lambda_6 \Delta lnPG_{t-i}$$

$$(lnFSFP)\ c\ (lnFSFPc(-1)(lnAFFVAc(-1)(\text{lnAAR}\,(-1)(lnGDPPc(-1)(lnGDPC\ (-1)(lnPG(-1))$$

lnfsfp c lnfsfp(-1) lnaffvac(-1) lnaar(-1) lngdppc(-1) lngdpc(-1) lnpg(-1)

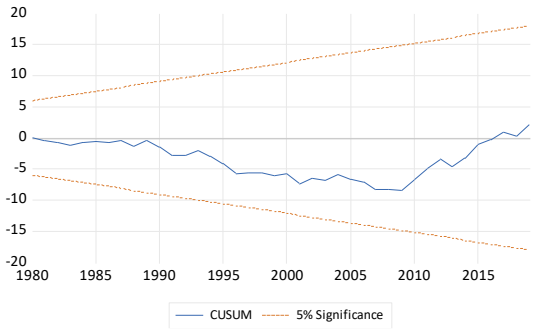


Figure 15: Cumulative Sum (CUSUM) test when long run food security is dependent variable

4.1.7.3. ARDL Error correction model Specifications:

$$\Delta lnFSFP_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i\, \Delta lnFSFP_{t-k} + \sum_{i=0}^{q} \beta_{1i}\, \Delta AFFVAc_{t-1} + \sum_{i=0}^{p} \beta_{3i}\, lnAAR_{t-1} + \sum_{i=0}^{p} \beta_{4i}\, \Delta lnGDPPc_{t-1} + \sum_{i=0}^{p} \beta_{5i}\, \Delta lnPG_{t-1} + \tau \text{ECM}_{t-1} + \varepsilon .. eq(10)$$

d($llnFSFP)\ c$ d$\big(lnFSFPc(-1)\big)d(lnAFFVAc(-1))d\big(\text{lnAAR}(-1)\big)d(lnGDPPc(-1))$
$d(lnGDPC(-1))d(lnPG(-1))$ ecm(-1)

d(lnfsfp) c d(lnfsfp(-1)) d(lnaffvac(-1)) d(lnaar(-1)) d(lngdppc(-1)) d(lngdpc(-1)) d(lnpg(-1)) ecm(-1)

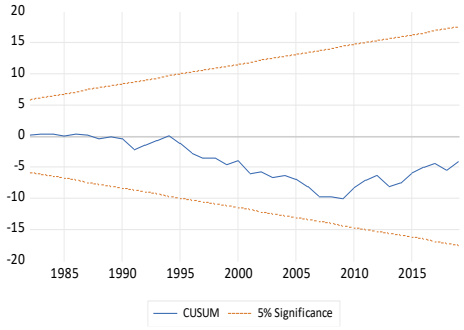


Figure 16: Cumulative Sum (CUSUM) after ECM when the dependent variable is food security

4.1.7.4. Interpretation of estimation parameters

Table 18 depicts the short span, ecm and long run coefficient evaluations of Autoregressive distribution lag model, when the dependent variable is the logarithm of security of food. It displays that an alteration in the growth of food security on its lag is significant and negative in the short term. The degree of development of the agriculture sector is an essential harmful impact on the growth rate of food security. A 100% increase in the growth of agriculture clues to the lessening of growth of food security by 0.1122% in the short span.

Whilst, in the long span, agriculture growth increases food availability by 0.0704%. This means that family farm agriculture does not sufficiently solve the food supply in Gambian households. Therefore, the government should shift farmers from traditional agriculture to modern ways of farming, such as comes with new technology such as irrigation, adaptation, and mitigation, to fight change in climate and ameliorate the glitches associated with food security. To have that, the subsistence farmers should be provided with the following like credit or loans, frequently agriculture extension workers to visit their farmlands, provision of fertilizer, pesticide, insecticide, tractors, and any modern equipment that will make work easier and quicker, and can translate to high yields and colossal income. This will enhance productivity for both the farmers and the government, thereby reducing food imports and increasing food export. This is confirmed by (Patrick (2009). The GDP per capita adversely affects food security using ARDL short-run approaches. This is long-established by Ali, S et al., (2019). The study further revealed that average rainfall as a proxy variable for climate change is an insignificant positive correlation with the growth rate of food security at lag 1 in the short run. The climate change extreme it insignificant may be attributed to shifting patterns of rainfall in the Gambia from August to October, and this cost farmers to lose potential yields from their production. At the time of distribution, the climate change strategy reason transportation and marketing distress, which led to insufficient food security due to lesser food export and high food import and which led economic to reduce. Economic growth as a proxy for GDP is a significantly destructive impact on the growth of food security in the short term.10% increase in economic growth deteriorations the growth of food security by approximately 0.03%. This is attributed to the reduced budget assigned to agriculture, which translates to lower food production and productivity. The general economy is dampened down to a negative. The result also revealed that population growth is an important undesirable influence on food security in the short term. A population increase annually reduces food availability (proxy food security) by 0.0105%. The study noted that the government of The Gambia should be careful about food security problems because it means more population, numerous mouths to feed, and associated less food supply. Therefore, the government of The Gambia should allocate more budget to agriculture, thereby being able to feed the growing population. On the other hand, to deal with population increment, the government should look at the fertility and maternal mortality rates. For instance, in the long run, food security has essential optimistic outcome. Correspondingly, in the short run, population growth is a strong detrimental influence on food security. With a percentage growth in population, there is a drop in food security by 0.033%. This is an enormous reduction in food security. Unless we intervene in the population, the impact on food security will likely escalate. The following are vital: agriculture, fertility, and maternal mortality. The fluctuation of rainfall, the fluctuation of temperature, floods, droughts, land degradation, windstorm, rainstorm, salt intrusion, artificial pollution like the one from cars, nonrenewable energy, etc., disturb most of the people and our environment in The Gambia. Therefore, climate change, which means annual rainfall as a proxy variable, upsets all the four pillars of food security in the long run. This result is insignificant. Similarly, in the short-run, economic growth in which GDP current is the proxy variable in the long term has an unimportant and adverse effect on food availability as GDP per capita makes the available standard of living. Overall, per capita GDP harms food security in the long run. So GDP per capita in the Gambia does not translate to our standard of living due to Insufficient GDP.

Table 18: Short-run Coefficients and (ECM) error correction coefficient. Dependent Variable is LNFSFP

Variables	coeff.	std.error	t-Statistic	prob.
C	0.0335	(0.0261)	1.2468	0.2199
Δln LNFSFP(-1)	-0.3542***	(0.1450)	-2.4427	0.0192

Δln LNAFFVAc(-1)	-0.1122	(0.2056)	-0.5457	0.5884
Δln LnAAR(-1)	0.0834	(0.1140)	0.7318	0.4689
Δln LNGDPPc(-1)	0.2782	(0.2249)	1.2369	0.2235
Δln LNGDPC(-1)	-0.3090**	(0.1490)	-2.0733	0.0448
Δln LNPG(-1)	-1.0526**	(0.5161)	-2.0395	0.0482
ECM(-1)	-0.7201**	(0.2811)	-2.5616	0.0145

Estimated Long run Coefficients.Dependent variable is $lnFSFP_t$

Variables	coeff.	std.error	t-ratios	p-value
C	1.9546	(01.0826)	1.8055	0.0785*
LNFSFP(-1)	0.4491	(0.1428)	3.3556	0.0017***
LNAFFVAc(-1)	0.0704	(0.014)	0.7708	0.4454
LnAAR(-1)	0.0929	(0.1522)	0.6104	0.5451
LNGDPPc(-1)	0.0853	(0.1339)	0.6365	0.5281
LNGDPC(-1)	-0.0799	(0.0644)	-1.2405	0.2220
LNPG(-1)	-0.3276	(0.1840)	-1.7805	0.0826*

*** and ** and * denotes significant at 1% and 5% and 10% level of significances respectively.

Source: Author's own compilation using Stata 16.

ECM(-1) = -0.7201, P-value = 0.0145, Standard error in parenthesis = (0.2811) and t-statistic = -2.5616. From finding out these results from error correction model (ECM) representation and having found out from the unit root tests, the variables in the model are stationary at the first differences, I(1) and co-integrated for ARDL F- bound test approaches.The ECM permits the long-term conduct of the dependent variable to meet long-run equilibrium association, whereas agreeing to a wider variety of short-run dynamics coefficients. In other words, the ECM comprises the long-run variables being assessed and runs with short-run variables. The coefficient of ECM term with lag 1 for the log of food security as a dependent variable carries an appropriate sign (-0.7201). It is statistically important at 1% alpha, has a positive coefficient absolute term, and lies between 0 and -1. The speed of equilibrium change is 72% (see Table 18). It confirms the stability of the model from the diagnostic tools test conducted such as cusum, cusum square, recursive test, serial correlation for LM, and recursive residual test for normality. A large absolute value from the coefficients on the ECM confirmed that equilibrium agents remove a long-run disequilibrium in each period from 1971 to 2020. The important speed of adjustment is rapid. The little speed of adjustment to equilibrium means a slight absolute value of the ECM. In our model, when the dependent variable is food security, the speed of adjustment towards the equilibrium is rapid, i.e., 72%. It is speedy to remove disequilibrium and adjust to

equilibrium. Finally, food security will rapidly reach equilibrium after the innovation that touches it due to climate change variability, poor economic performance, poor agriculture, and so on.

Conclusion and Policy Recommendation

The dissertation investigates climate change, food security, economic growth, population growth rate, agriculture value-added, and GDP per capita. The results shows that agriculture negatively correlates with food security in The Gambia in the short run and positive in the long run. Change in the average annual rainfall significantly and negatively impacts food security. The GDP per capita positively impacts food security in the first-period lags and negative impacts on food security in the second-period lags. However, shocks to food security will require a slightly optimistic influence on the agriculture sector in the short span and a considerably negative influence in the long span. Food security shocks will also lead to poor agriculture in the long term. Food security and GDP per capita as a unidirectional relationship. Similarly, short-term demonstrations indicates that a variation in the growth of food security on its lag is significant and negative. The agricultural sector is has significant adverse impact on food security. A 100% rise in agricultural sector growth results in a fall in food security growth by 0.1122%. With a percentage growth in population yearly, there is a fall in food security by 0.033%. Finally, the error correlation part of the ARDL model found that the coefficient of the ECM term at lag 1 for the log of food security as a dependent variable carries an appropriate sign (-0.7201). It is significant at 1 percent of alpha, has a positive coefficient absolute term, and lies between 0 and -1. The policy recommendation is that agriculture is essential for food security in rural Gambia. The government should work on adaptation, mitigation, and resilience methods such as irrigation and using different varieties and early crops, animal rearing/practising livestock farming to ensure that the society and households are food secure in rural Gambia.

Objective two : Assessing the impacts of food security on migration in the rural Gambia

4.2.1. Descriptive statistics

Table 19: Descriptive statistics of continuous variables

Household characteristics	Mean	Std.	Min	Max	Sample mean		
					NBR(n=130)	CRR(n=140)	URR(n=130)
Age	47	12.14	23	105	48.95122	47.13846	45.63077
Household Size	21	17.26	2	212	18.26829	23.17829	20.79231
Educational ttainment	2.54	1.49	1	7	2.692913	2.387597	2.546154
Household income	159.60	83.70	0	488.76	163.9973	170.2384	145.65
Heavier rainfall	1.94	1.24	1	5	1.868217	2.021429	1.928571

Note: Std, min and max are for all Households (n=400).

Table 20: Descriptive statistics of dummy explanatory variable

	NBR (n=130)		CRR (n=140)		URR (n=130)		All Households (n=400)	
HH characteristics	Frequ.	%	Frequ.	%	Frequ.	%	Frequ.	%
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
Educational 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 stata 16 from household survey data

For migration respondents of the households, about 70 percent of the rural households in the Gambia has at least one migrant. Thus, NBR has more migrants (about 94.06%), and by implications has a higher amount of remittances received (about 29.13%). See both the table above and the figure below. For marital status, 92.39 percent were married. For instance, married people are more likely to migrate (about 72%) than single or widows and divorced (about 48%). For Gender, 66.67% of the respondents are male, and they are most likely to migrate than females. According to the respondents, 76% of the migrants are male while 57% are female, respectively. 73.8 percent are those that food secure and are more likely to migrates Non-migrant households in the Gambia are food insecure than migrates. Remittance-received households are more food secure (about 88.5%) compare to no-remittance-received households (70.4%). For all households combined, more than 90% said changing rainfall and temperature have changed and affected them in the last 10 to 20

years. Some 69.4 percent said changing rainfall causes them to migrate, while 68 percent said changing temperature causes migration. Some 80 percent, whether rainfall changes or not, migrate.

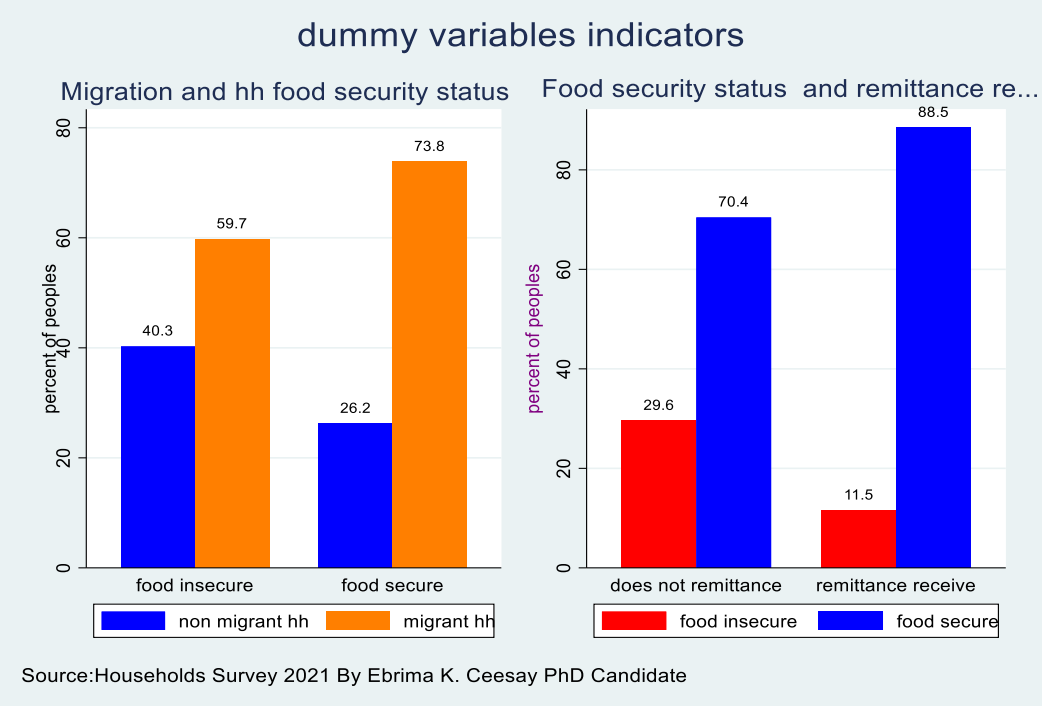


Figure 17: Dummy Variables indicators for migration and food security status(left), food security status and remittance received(right)

4.2.2. Pairwise Correlation

Table 21: 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 stata 16

4.2.2.1. Pairwise Correlation analysis- Pearson product-moment correlation coefficients

Bivariate Analysis of the migration response of the household in general and the other Explanatory Variables is explained in more detail in Table: 21 above. From the literature reviews on the likely factors of household migration status, 19 explanatory variables were inputted in the Pearson product-moment correlation coefficients. Multicollinearity does not bias the estimate; therefore, all the explanatory variables are comprised in the multilevel type of conventional logistic (see detailed explanation in the methodology). For all the households, 13 variables are found to have a positive correlation with household migration response status, and six are found to have a negative correlation with the migration status of the households (See detail in Table...). For example, income and migration are positively correlated (the correlation coefficient is about 20.2 percent). The variables from the bivariate analysis-Pearson product-moment correlation coefficients that have a tolerance value greater than 0.20 and variance inflation factor (VIF) lower than five after conducting a linear regression analysis followed by VIF will be further Analysis in a multilevel version of the logistic regression model. Those who passed the multicollinearity test remained exposed to further statistical Scrutiny; the multilevel version of the logistic regression model was employed to understand better their influence in determining household migration status in the rural Gambia.

Table 22: Multicollinearity tests results

	Collinearity Statistics	
Variables	Variance Inflation Factor(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

Conditions: VIF>5 and 1/VIF<0.20, Multicollinearity is present.

Source: Own Evaluation Using Survey data (2021)

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. It is suitable for the VIF to lie amid 1–10. As shown in Table 22, none of the variables showed any multicollinearity signs, but even in the logistic regression analysis, some variables were removed due to omitted. Finally, the model was estimated after checking multicollinearity issues.

4.2.3. Multilevel version of conventional logistic regression results

Following the works of well-known migration experts such as Raphael J. Nawrotzkia, Allison M. Schlakb, and Tracy A. Kugler, 2016, Brown & Bean, 2006, and McMichael,2013, the paper used a multilevel version of the conventional logistic regression model to model the international move if climate change dynamic, food security and remittance pathways and their interaction terms. Therefore, to capture the ratio of Odds of an international relocation, we built a multivariate part of conventional base model (see detail in Table), tests for multicollinearity, and ran the models for rural Gambia. To test the multicollinearity test using this model specification, VIF and tolerance factor indicated that it is free from multicollinearity (see above Table for multicollinearity). We run both logit and logistic regression models to interpret the coefficients and odds ratio of our predictors, and the parameter estimated reported Odd ratio is as follows; Age of the household heads is an essential indicator for migration response for the household in the rural Gambia. The pairwise correlation between age and migration response is positive. Age here measures actual age in years or experience. Age rises with experience, which positively correlates with migration response. As depicted in Table 23 age is insignificant at all levels of alpha (1%, 5%, and 10%) and positively influences the household migration status. The odds ratio value confirms that the probability of the household having a migrant increase by a factor of 1.014 as age increases by one year, keeping other independent variables constant. Age increases and migrant household rises in rural Gambia. This means that the odds ratio value increases as the explanatory variable rises and vice versa. Large family size is essential for migration response in the Gambia. The study revealed that in rural Gambia, they have a large number of people in the

households. For that being the case, they have a large number of migrants. So, the results confirmed that the probability of the household's migration status increases by a factor of 1.01 as household size increases by one person, keeping other predictor variables constant. We combined all regions called the rural Gambia, and we also have a separate region. As indicated age and household size above, the sociodemographic, which included the Interview information/Geographical location and Personal and demographic information of the households on the probability of international move, shows many similarities in the rural Gambia. Furthermore, the typical international migrant from the rural Gambia comes from large households with married people and male-headed households where few members can read and write, mainly employed as farmers. For instance, household income positively and significantly affects migration responses in the rural Gambia. Those households with higher income have more migrants.1 unit rise in household income, the probability of international move increases by a factor of 1.004, keeping other explanatory variables constant. The study noted that married and male-headed households are more likely to migrate to the individual region than female, single, widows, or divorced households. For each region, age and household size cause migration, respectively.

Table 23: Base models on international migration from Rural 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
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+0	0.991

							7	
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
LR Chi2(19)	41.39		44.47		38.74		70.34	
Prob>chi 2	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

Source: own evaluation using stata 16 from household survey in the rural Gambia

For climate responses in the base models, results revealed that when we combined all the regions, salt intrusion, flood, and temperature change have a detrimental and significant influence on migration responses except for the change in temperature, which has insignificant effects. For the individual region, flood is a vital climate change variable for migration response in URR compared to other regions. The results are significant and positive, and the probability of international move increases by a factor of 0.00031 as floods rise, keeping other explanatory variables constant. Thus, drought, change in rainfall, and heavier rainfall positively impact migration decisions. With one unit increase in drought, the probability of migration rises by approximately 0.703. Drought causes yield and production to decline, food insecurity rises, and households in the rural Gambia respond to it by migrating internationally. Food security increases and migration response reduces in the rural Gambia (see a detailed explanation of the odds ratio value)

4.2.3.1. Food Security and Change in climate

Security in food and change in climates on the odds of the international move are discussed in the table below. The results from logit regression confirmed that food secure's households are more likely to migrate than food insecure households. The odds ratio value confirms that the probability of the household being has 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 harms migration response. The odds ratio confirm that the probability of the households having migrants decreases by a factor of 0.758 as the food security consumption level increase by 1 unit, keeping other explanatory variables constant. This is true because migration happens due to both pull and push factors due to food insecurity. So, as household food security consumption level decreases, peoples tend to migrate to the rural Gambia through the back way or airway, the authors noted.

Table 24: Special effects of food security and climate on migration response from Rural's Gambia

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

	Ratio	value	Ratio		Ratio			
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**	0.02
Intercepts	0.363	0.508	0.096***	0.017	3.413**	0.055	38.771***	0.002
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

Source: own evaluation using stata 16 from household survey in the rural Gambia

In addition, change in rainfall, salinization, or saltwater intrusion have a negative coefficient and significant impact on migration responses at a 1 percent level of significance except for the change in temperature, which has an insignificant effect on migration response. The odds ratio confirms that the probability of the households having 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. Nevertheless, variabilities in rainfall and droughts have positive significant coefficients on an international move. The odds ratio confirms that variation in rainfall and droughts increase by 1 unit, and the probability of the household migration status rises by 1.3907 and 1.407, respectively. The probability of chi-square is highly significant in all cases

4.2.3.2. Climate effects

Climate change impacts, we looked at how climate change can cause international migration in rural Gambia by modeling and running the logistic regression by including only climate change variables. The results reveal that flood, temperature changes, and salt intrusion have a detrimental and significant outcome on migration response except for change in temperature, which has both negative and insignificant impact. For instance, change in rainfall pattern, drought, changes in rainfall, and heavier rainfall have significant influence on migration response. Flood, variability 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.

Table 25: Impacts of climate change on outmigration from Rural 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
LR Chi2(19)	23.68		32.97		27.92			56.34
Prob>chi 2	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

Source: own evaluation using stata 16 from household survey in the rural Gambia

In addition, the odds ratio confirms that the probability of the households having migrants increases by a factor of 3.363, 1.87e+07, and 2.089, respectively, as changes in rainfall pattern, changes in rainfall, and heavier rainfall increase by 1 unit, keeping all other predictor constant. Changes in rainfall pattern and heavier rainfall are all statistically significant at 1 percent and 5 percent levels of significance. The probability of chi-square and the pseudo-R^2 indicated that the models are suitable to support the hypothesis.

4.2.3.3. Food Security Effects

Food security is an essential determinant of an international move. The results reveal that food security and significant food crops have a positive and insignificant impact on migration response. In contrast, food security consumption level has a negative and significant effect on household migration status. Total household food consumption has fundamental optimistic coefficient influence on migration response.

Table 26: Special effects of food security effects on outmigration 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
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	0.01**	0 .910	0.287	-	-	1.062	0.301
intercept	6.8945	0.03**	11.843**	0.054	0 .187	0.045**	1.100	0.851
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	

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

Source: own evaluation using stata 16 from household survey in the rural Gambia

The odds ratio confirms that the probability of the households having migrants increases by a factor of 1.521, 1.0067, and 1.062, respectively, as food security, total food consumption, and significant food crops increase by 1 unit, keeping all other predictors constant. Food security, total food consumption, and major food crops are all statistically significant at 1 percent and 5 percent significance levels. The odds ratio confirms that the probability of the households having migrants decreases by a factor of 0.644262 respectively as the food security consumption level increases by 1 unit, keeping all other predictors constant. The probability of chi-square and the pseudo-R^2 indicated that the models are suitable to support the hypothesis.

4.2.3.4. Interaction Effects

4.2.3.4.1. Food security- Climate change interactions

In table 27, the next step is to interact with 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 examine whether flood-dependent regions are more susceptible to food insecurity. The outcomes confirmed that food security has optimistic and significant influences on migration response for the URR region in particular and rural Gambia in general. The odds ratios confirm that the probability of household migration response rises by 6. 37225 as food security increases by 1 unit, keeping all explanatory variables constant. Due to the importance of higher precipitation to agriculture, a flood has a negative relationship with outmigration. The odds ratio confirms that the probability of household migration response decreases by 0.6986 as flood increases by 1 unit, keeping other predictors constant. Insignificant and negative coefficient interactions predominantly emerged for the rural Gambia for security of food and the change in climate indicators of floods. This suggests that the food security-migration relationship similar to a flood occurring in agriculture rather than other climate change indicators.

Table 27: Interactions amid climate change, food security and remittance on outmigration 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.FoodSecurityStatusFSS	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
Food Security Status FSS#Flood | 1 1	-	-	-	-	.0707	0.02**	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
Remittances Received#Drought | 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

Source: own evaluation using stata 16 from household survey in the rural Gambia

4.2.3.4.2. Remittance received- Climate change interactions

We observe significant and negative interaction emerging in the rural Gambia for remittance received and drought as probability of international move. Table 27 depicted that the effect of droughts varies substantially by region. In the North Bank Region (NBR), the odds ratio confirms that migrations response increases by 9.699 as drought increases by 1 unit. This is different in other regions, where drought has

opposite effects on migration. Finally, in the rural Gambia, the results revealed that significant and negative interaction emerged between remittance received and the climate change indicators of drought. This suggests that remittance and migration dynamics differ in climate indicators like drought. The outcome of drought on probability of migration in rural Gambia is more substantial, and the influence of remittance received becomes more potent too. Suggestion, predominantly drought causes migration and remittance received causes migration from logit regression results which reported the coefficients.

4.2.3.5. Discussion of the results

In our results, we found that the married person's age, household size, gender-male headed household, and marital status positively influenced migration in the rural Gambia. In contrast, owning land hurts migration responses. This is confirmed in the following study in which they found positive links between migration and sociodemographic characteristics of the households Hunter et al., 2014; Fussell & Massey, 2004; Gubhaju & De Jong, 2009. In contrast, Hunter et al., 2014 found positive links between own land and migration while we found a negative relationship. Education status and education attainment of the households has negative and insignificant impacts on migration response, while employment has a optimistic impact on migration. Employment rises, more income, which in turn causes outmigration in the rural Gambia (e.g., youth that works on agriculture farms in the rainy season use their harvest's income to migrate). Raphael J. Nawrotzkia, Allison M. Schlakb, and Tracy A. Kugler, 2016, Amakom and Iheoma (2014) found education is a vital part of migration response, and DaVanzo, Julie,1978 he found education is an essential relationship with migration responses. In contrast, we found negative links between education(0-grade 9 level) and migration. The study noted that most migrants in rural Gambia have less education. Remittance received has a positive relationship with the probability of migration responses. This means that they use those remittances for food consumption and send another child (other children) to migrate. This is confirmed 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 rural Gambia. This is confirmed by Nguyen (2009) and Minh Cong Nguyen and Paul Winters, 2010 found that food consumption decreases migration responses. In additional, Greenwood, M.J. 2005 and Laborde, D., Bizikova, L., Lallemant T., & Smaller, C. 2017 shown that the connection between food insecurity and migration is positive, as people do not see viable options other than migrating for escaping hunger or conflict. Climate effect on the odds of an international move. The results revealed that climate change variables have mixed effects on the odds of an international move. Heat wave will lead to food insecurity and causes migration, whereas drought will lead to food insecurity and causes migration. Heat wave wave or high temperature causes a problem for humans, animals, and plants, leading 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 predominantly emerged for the rural Gambia for security of food and the change in climate indicators of floods. Secondly, drought rise, and migration rises in the rural Gambia. This is confirmed in the study done by Henry et al., 2004 and Kambiranda et al., 2011; Reddy et al., 2003 found that drought increases migration through lower agriculture production and yields, and drought depresses migration through less water for animals and less water for crops.

4.2.3.6. Conclusion and Policy recommendation

In this study, we used rural households' response to migration by looking at the base model, in which migration response is binary variable. After, we look at the influence of change in climate and food security on ODDS of an international move. In addition, we look at the interaction terms between climate change and food security, climate change and remittance received by households, and between Remittance and food security on the odds of an international move. First, in the base model, the size of the family matter to determine the international move from rural Gambia. Age is also a critical determining factor for migration.

The results further indicate that those in married and male-headed households are more likely to migrate than the single, widow, or divorced, and they are female-headed households. Remittance received households are more likely to migrate than non-remittance received households in rural Gambia. It means that those who received remittance can use that move to send another member of the family internationally, the study noted. For all the regions combined, the study found that educated and employed people are more likely to migrate. Income also in the rural Gambia causes migration of the household members. In the case of climate shocks, change in temperature, flood, and salt intrusion do not cause migration; during drought, changes in rainfall and heavier rainfall cause migration. It means that drought causes poor agriculture yields and translates to food insecurity, leading to migration. In contrast, the author meditated that heavier rainfall is translated to a bumper harvest, which leads to food security and reduces migration. Secondly, the author noted that when we used food security and climate change pathway, food security causes migration in the rural Gambia while food security consumption decreases migration responses. Flood, salt intrusion, and temperature change as proxy variables for climate change decrease migration responses. As in the base model, this is attributed to agriculture and livelihood pathways. The study noted that drought causes agriculture production and productivity to be lower, which translates to a bad harvest and a decline in migration in the rural Gambia. Thirdly, when we included only climate change variables, the results found that flood, temperature changes, and salt intrusion has a adverse and substantial influence on migration response except for the change in temperature, which has both negative and insignificant impact, while drought increases migration responses. It was noted that migration declines due to good harvest if floods happen in the Gambia. Fourthly, when we used only food security on the odds of an international move, we found that food security and major crops (cereal, fruit crops-mangoes, cashew, vegetables, etc.) have optimistic irrelevant influence on migration response in the rural Gambia. In contrast, the food security consumption level in rural households has an adverse insignificant influence on household migration responses. In addition, total food consumption per capita per month positively and significantly impacts migration response in the rural Gambia. Furthermore, when we interact with remittance received and climate change inhibitors, we observe significant and negative interaction emergent in the rural Gambia for remittance received and drought in the probability of international move. When interacting with food security and climate change, the results reveal that food security has positive and significant impacts on migration response for the URR regions in particular and rural Gambia in general. In contrast, insignificant and negative coefficient connections mainly emerged for rural Gambia for food security and flood. Finally, the study limitation may be because household surveys should be repeated many times to find changing rainfall patterns and other climate change inhibitors that cause migration in rural Gambia by looking at it over many times, let said ten years or more. In that, we will know the household problems that lead to them migrating to the rural Gambia. Thus, with these limitations in mind, our findings have several important policy implications. Contrary to the assumption, adverse climate conditions will lead to massive population displacement worldwide (Myers, 2002; Stern, 2007). our findings suggest that adverse climatic conditions in rural Gambia, such as flood and change in temperature and salt intrusion, may trap people in place in the rural Gambia and that stop them from migrating, or it may be that flood helps agriculture to have good yields, and that reduces migration response due to food security at household level while drought and change in rainfall lead to migration internationally. This is true because long dry spells and shifts in rainfall lead to food insecurity, and the response to that is migration internationally.

4.1. Objective three: Vulnerability assessment at households and regional levels: Evidence from a rural area in the Gambia regarding climate

4.3.1. Quantifying farmers vulnerability to change in climate at household levels in the rural Gambia

4.3.1.1. Descriptive statistic from the household survey data: Designated socioeconomic and change in climate in the rural region in the Gambia

4.3.1.1a. Household characteristics

In this study, 13, 14, and 13 villages were randomly selected with replacements in the research regions', respectively. Ten households were surveyed in each village. In total, 400 households were surveyed.

Table 28: Distribution of sampled villages and regions

No. of Villages	No. of households	No. of sample	Regions
13	10	130	NBR
14	10	140	CRR
13	10	130	URR

Source: Own Evaluation using surveyed data 2021 in the rural Gambia

The average household size in the three regions in the study area is 21 members per household. Furthermore, in the rural Gambia, 77% can read and write, 69% are farmers, 55% believe in the caste system, 92% are married, and 74% are food secure.

Table 29: Basic household characteristics of the surveyed farmers

Variable	Average($)	Percentage
Household size	21	
Education		77
Gender		67
Age	47	
Employment		69
Caste System		55
Marital status		92
Food secure		74

Source: own evaluation using stata 16 for window using surveyed data

The rural Gambian households are normally poor.. The food consumption expenditure per capita per month stands at $159, and the food security consumption level stands at $1.969.

Table 30: Basic Assets of the respondents or Welfare Measures

Variable	Average($)

Total household consumption per capita per month	169
Total household food consumption per capita per month	159
Food Security Consumption Level	1.969

Source: own evaluation using stata 16 for window used surveyed data

4.3.1.1b. Climatic conditions and shocks

As described earlier in this study, the surveyed regions are in the rural Gambia, which differs in many ways in terms of fluctuations in rainfall and temperature. As expected, the average change in temperature in NBR and URR is higher than in CRR.

Table 31: Climate condition in the study area

Regions	Average change in Temperature	Average change in rainfall
CRR	0.893	0.936
NBR	1	1
URR	0.969	0.992

Own evaluation using stata 16 used households' surveyed data, 2021.

Table 32: Main tremors experienced by surveyed farmers

Tremor	Number	%	Descriptive	
Floods	278	70.74	mean	Std
Drought	288	73.28		
Salinization	149	40.05		
rainfall	315	79.35		
Temperature	381	95.25		
Water Accessibility during drought	232	64.80		
Animals/live stock decline			1.400	0.899

Source: Own evaluation using stata 16 used households' surveyed data, 2021.

According to surveyed farmers, 70.74 percent encounter floods as major shocks; 73% encounter drought; 40 percent encounter salinization; 79 percent experienced changing in rainfall; 95 percent experienced changing in temperature; 64 percent had access to water during drought. Animals that are declining represent 1.4 on the average during climate shocks with a standard deviation of 0.898

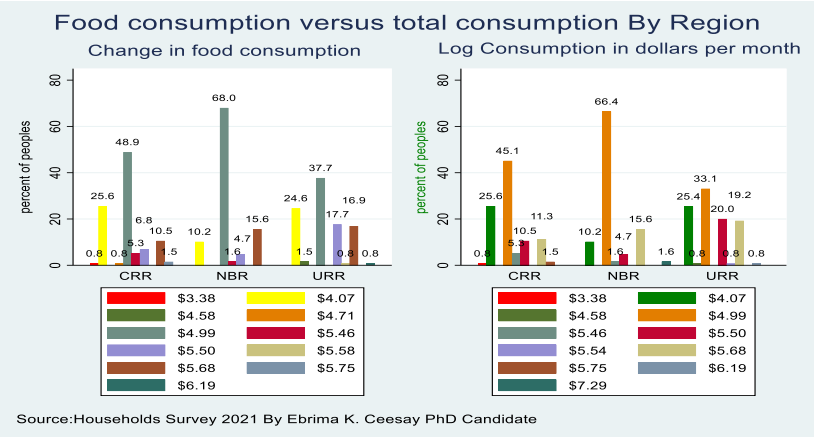


Figure 18: Vulnerability indicators food consumption and total household consumption

In figure 18 above, 68% experienced a change in food consumption at $4.99, and 66.4% experience log consumption at $4.99. In these three regions in rural Gambia, vulnerability to poverty is significantly higher based on specific households' characteristics and climate shocks.

4.3.1.2. Combination of Scattered plot, Histograms and Bar Plot

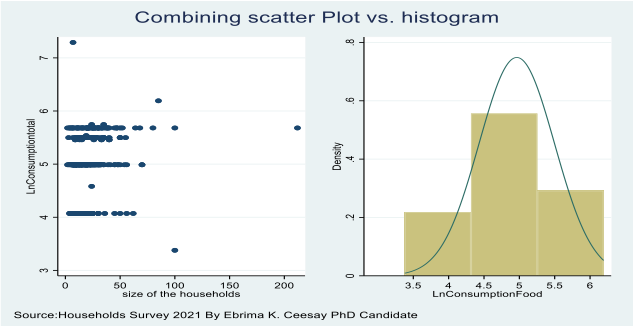


Figure 19: Combined Scatterplot vs. Histogram

Figure 19 describes the scatterplot and histogram for change in consumption versus the household size in the rural Gambia. As illustrated, as the size of the households get larger, the change in consumption stage closer and with additional increases in the household size, the consumption apart and this, of course, say something about household vulnerability status. The vulnerability of the household increases as the household's size becomes more larger. The histogram is somehow averagely distributed for the changes in consumption. Change in food consumption ranges from 3.5 to 6. This tells us that rural Gambia's population and per capita income are far apart.

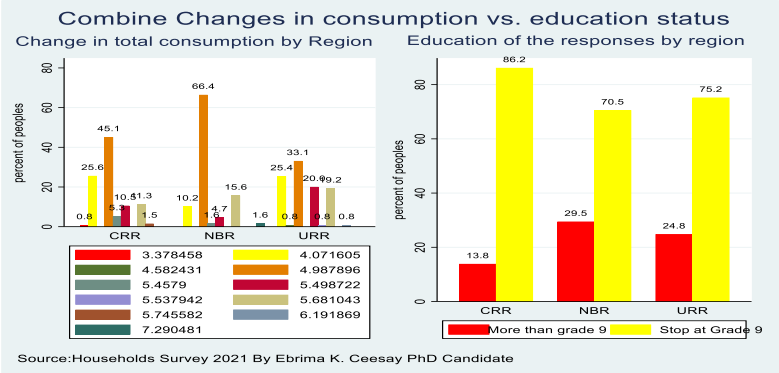


Figure 20: Combined Bar Plot.

In figure 4 above in CRR, 45% consume 4.99 dollars, 13.8 percent have more than grade 9 level of education and 86.2 has grade 0 to 9 level of education. In NBR, 66 percent consume 4.99 dollars, 70.5 percent have 0-9 grade of education and 29.5 percent have more than grade 9. Finally, in the URR, 24.8 has more than grade 9 level of education, with 75 percent stopping at grade 9, and 33.1 percent expend 4.99 dollars a day..

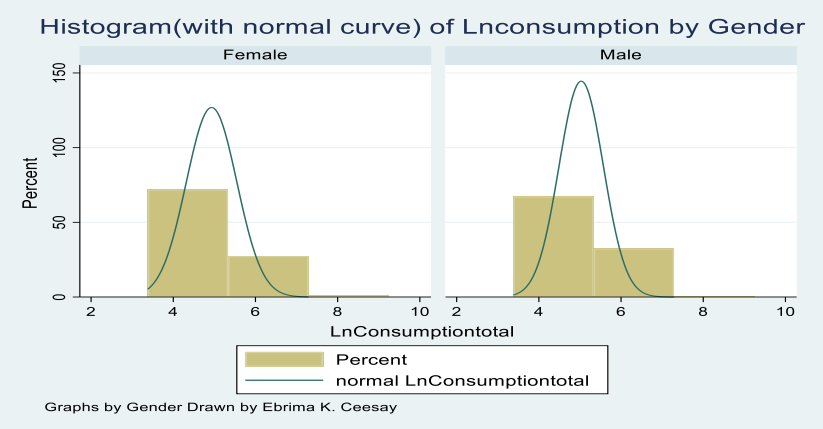


Figure 21: Combine histogram with normal curve.

The graphs also show a difference in the mean consumption expenditure values for the males and females in the rural Gambia. To determine whether a significant difference in population means exists, we did a 2-sample t-test. The results are that gender contains both female and male, and the p-value is insignificant for the 2-sample test. Furthermore, when we test only for males, the p-value is statistically significant, but for females, the p-value is not significant. There is mean differences between female and male in the sample.

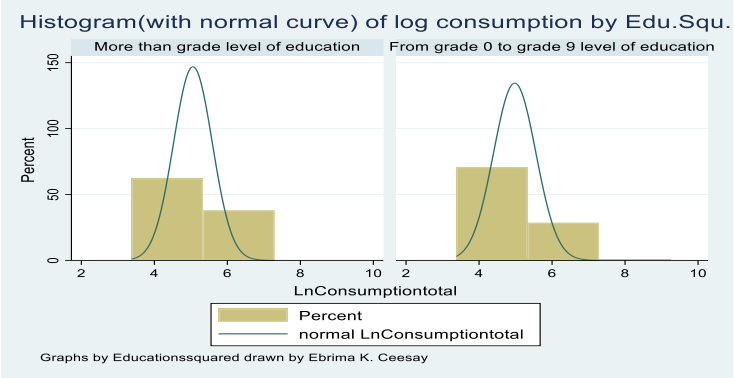


Figure 22: Combine histogram with normal curve.

The graphs also show that there is a difference in the mean consumption expenditure values for the for those household's head that has more than grade 9 level of education and those who stop at grade 9 level of education. To determine whether a significant difference in population means exists, we did 2-sample t-test. The results found that the mean differences have a Pr (T < t) = 0.5000 and it is not statistical significant.

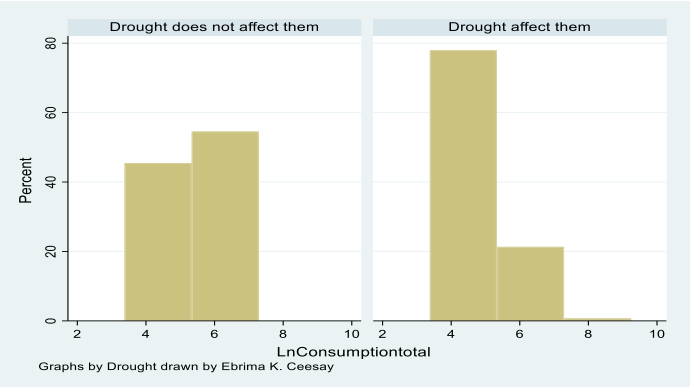


Figure 23: Combine histogram.

In figure 23 also show that there is a difference in the mean consumption expenditure values for the drought affected households versus without drought affected households. The drought affected households are rightward skewed and not normally distributed.

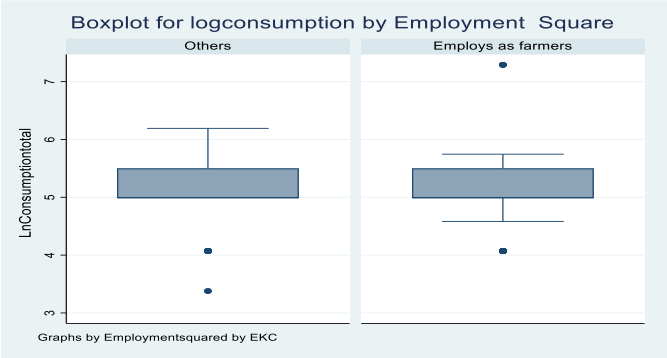


Figure 24: Combine boxplot with normal curve.

Boxplot summarizes the 5 number summaries. Employers as farmers as two outliers, the minimum and above the maximum. Furthermore, working in either businesses or construction or another has outliers lower than the minimum.

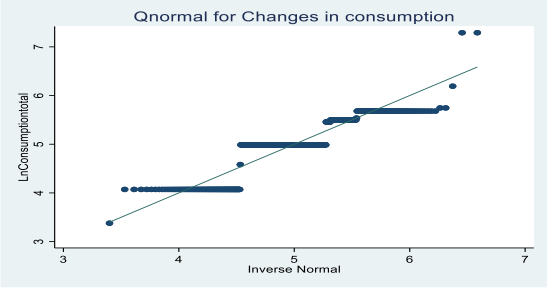


Figure 25: Combine boxplot with normal curve

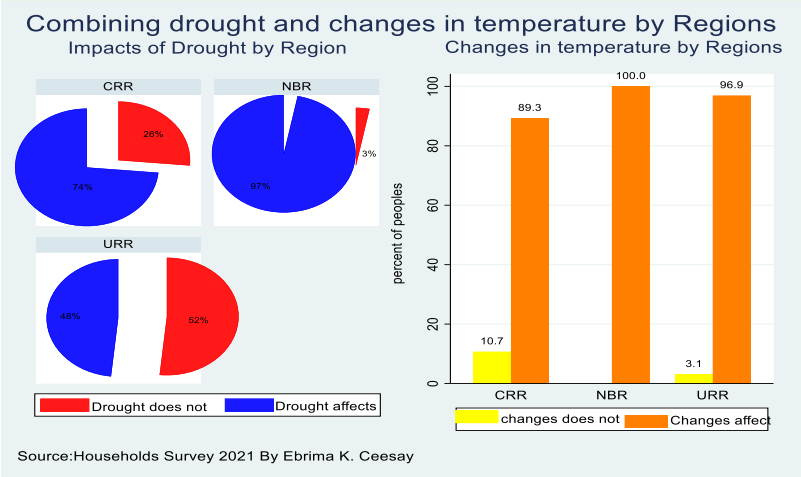


Figure 26: Combine boxplot with normal curve

In figure 26, the pie chart to the left, in CRR, 74% of the respondents said drought affect them while 26% said drought does not affect them. In NBR, almost all the respondents said drought affect them and in the URR 48% and 52% said drought affects and does not affect them respectively. To the right of figure ??? (bar chart), in NRB region 100% of the respondents said changes in temperature affect them and in URR 96.9% said changes in temperature affect them. In CRR 89.3 percent said temperature changes affect them.

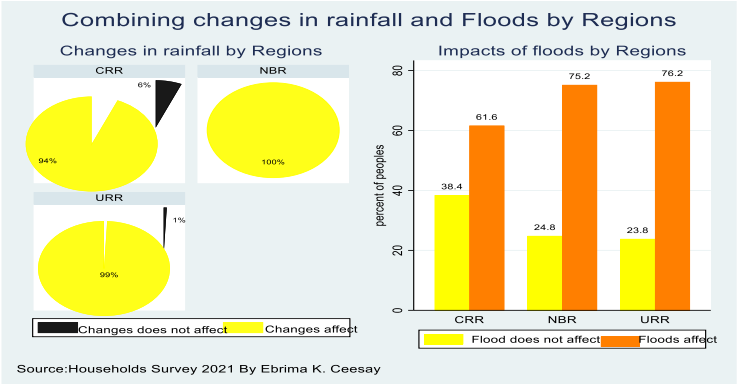


Figure 27: Combine boxplot with normal curve

In NBR, changes in rainfall affects the entire households. In URR only 6 percent of the households are not affected by changes in rainfall. In CRR 99 percent are affected by changes in rainfall. For right graphs on floods. The results found that URR, approximately 76 percent of the households are affected by floods and this is similar to NBR. In CRR, closed to 62 percent are affected by floods.

4.3.1.3. Pair wise correlation analysis

The Pearson relationship matrix is used to define the correlation amid two variables. It ranges from -1.00 to +1.00.The result from the below table found that education status and log income, log consumption and log food consumption is negative and with association coefficient are -0.1049, -0.0583 and -0.0695. Size of household has positive correlation with income and consumptions. Larger households, food consumption, income and total consumptions become higher compare to smaller households. Employment as positive or direct relationship with income in the rural Gambia while employment status and consumption are negative relationship. Increases in employment in the farm, food consumption and total consumption decreases. This is due to traditional ways of farming in the rural Gambia.

Table 33: Pairwise correlation analysis

Variables	LnConsumption total	LnConsumption(Food)
Age of the households' head	0.1054	0.1130
Size of the households	0.1856	0.1984
Education status	-0.0583	-0.0695
Gender	0.0812	0.1270
Employment	-0.0119	-0.0178
Caste system	0.0610	0.0266

Source: Own computation using stata 16 from household survey.

4.3.1.4. Multicollinearity test

In the VEP analysis, it is important to test multi-collinearity among the independent variables to know which variables to be included in the model. Due to multicollinearity issues, education status squared of the households were removed. Conditions: 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 between 1–10. As shown in Table 34, apart from education status squared, none of variables showed any multicollinearity signs. Subsequently, the expectations of non-collinearity were content, and the model was then estimated.

Table 34: Variance inflation factor (VIF) test for multicollinearity analysis

Variable	VIF	1/VIF
Size of the households	4.23	0.236557
Household size squared	4.06	0.246017
Own land	1.22	0.818357
Educational attainment	2.30	0.435072
Education status of the responded	2.17	0.461151
Employment of household head category	1.16	0.864579
Non land production assets	1.45	0.687906
Share of irrigated land	1.13	0.887841
Gender	1.17	0.855463

Caste system	1.40	0.715774
Flood	1.28	0.782142
Changes in rainfall	2.52	0.396688
Drought	1.53	0.652666
Changes in temperature	2.32	0.431281
Salinization and saltwater intrusion	1.41	0.708020

Own Evaluation using Stata 16 data from household survey

4.3.1.5. Results for VEP

The thesis carried out econometric estimate of the VEP measure based on model specification. We used monthly consumption expenditure per capita as a good proxy to quantify vulnerability at the household level in the rural Gambia. To identify households' welfare losses during climate change in rural Gambia. It depends on consumption expenditure; we understand whether households will be susceptible to poverty by looking at current consumption to predict the future consumption and variation of the future consumption, as well as whether these regular consumption and variances are below the poverty line. We made Monthly log Consumption a good proxy for vulnerability. The study employed the three-step Feasible Generalized Least Squares (FGLS) estimation method. In the first step, we calculated the ex-ante mean using OLS and predicted the residual in the second step. We generated the residual squared as the variance. We calculated the variance by OLS. In the final steps, we estimated the structure of heteroskedasticity from OLS to estimate vulnerability to poverty and predict which households are more likely to be poor or non-poor, looking at their current consumption. The three crucial things for vulnerability as expected poverty in this paper are looking at the poverty line, ex-ante mean or expected future consumption, and finally, ex-ante variance to see the variation in future total consumption based on households' characteristics such as households size, age, education, gender, caste system, employment, climate risks- drought, changes in rainfall pattern, changes in temperature, salinization, and floods, own land, non-land production, the share of irrigated land. Climate shocks are important determinants to find out which households likely to the poor or non-poor looking at their current situations. As our knowledge is limited, we are unaware of any paper exploring vulnerability to climate change using total consumption expenditure as the dependent variable. Another novelty, no study looks at climate change indicators such as floods, drought, and changes in rainfall, salinization, and temperature changes to see whether households will be vulnerable to future consumption shocks.

4.3.1.6. Model Results and Discussion

As in our methodology, we applied Equations (9) and (10) using single cross-sectional household surveyed in rural Gambia by looking at household's consumption expenditure as good substitution for the vulnerability of each household from results based on three steps FGLS in the line of Gaiha and Deolalikar (1993), Chaudhuri, Jalan and Suryahadi (2002), Gaiha and Imai (2004) and Gaiha and Imai, (2008). The results are given in Table 35 below. This is the first to study vulnerability at household levels in the rural Gambia. Another important novelty of this paper is vulnerability to climate change papers do not includes changes in rainfall and salt intrusion. Still, I saw a paper that included changes in temperature, flood, and drought. However, to our knowledge, we are not acknowledging a paper written on vulnerability as expected

poverty, i.e., econometrics methods of vulnerability in the Gambia. Finally, we also know that household characteristic is an integral part of household consumption status and that they measure households' vulnerability to poverty status. We identified variables that are very important for the households in the rural Gambia and that, if affected, will cause the household to be deepening into future poverty, such as size of the households, caste system, sex, schooling, employment, non-land production assets, share of irrigated land, own land and educational attainment.

4.3.1.6.1. Total consumption expenditure per capita per months

Table 35: dependent variable is log consumption per capital per month. LogC = Prob (monthly per capita consumption < poverty line, $57) to measure hh. Vulnerability i.e., log57=4.0431

LnConsumptiontotal	Coef.	Std. Err.	t	P>|t|
Sizeofthehouseholds	0.0118	(0.0032)	3.67	0.000***
Householdsizesquared	-0.0001	(0.0000)	-2.87	0.004***
Ageofthehouseholdshead	0.0010	(0.0134)	0.75	0.456
Ageofhhheadsquared	-0.0001	(0.0001)	-0.42	0.673
Ownland	-0.1695	(0.0984)	-1.72	0.086*
Educational attainment	0.1471	(0.0801)	1.84	0.067*
Educationalattainmentsquared	-0.0140	(0.0099)	-1.41	0.161
Educationstatusoftheresponde	0.1046	(0.1007)	1.04	0.300
Employmentofhouseholdsheadca	-0.0908	(0.0660)	-1.38	0.170
Nonlandproductionassets	0.2530	(0.0703)	3.60	0.000***
Shareofirrigatedland	0.0064	(0.0674)	0.10	0.924
1.Gender	0.0481	(0.0687)	0.70	0.484
1.castesystem	0.0183	(0.0681)	0.27	0.788
Flood	-0.1380	(0.0703)	-1.96	0.051**
Changesinrainfall	-0.7078	(0.2968)	-2.38	0.018***
Drought	-0.2331	(0.0794)	-2.93	0.004***
Changesintemperature	0.0992	(0.2087)	0.48	0.635
Salinizationandsaltwaterintr	0.1256	(0.0700)	1.79	0.074*

*** Significant at 1% level: ** = significant at 5% level: and *= significant at 10%.
Source: Own computation using stata 16 from household survey.

For log Monthly total consumption expenditure is dependent variable, the outcomes revealed that household size has an optimistic and significant impact on households' total consumption. Please reader, increases in consumption expenditure is associated with negative impacts. One unit increase in the household size in general, log total consumption rises by 1.18 percent, and the standard errors are in parenthesis. Then, vulnerability to poverty increases. This is a good finding because the truth in rural Gambia is that many extended families and many expenditures on different consumption like education, health, food, fish money, clothes, shelter, rent or land, security, etc. However, the squared of the household size becomes negative, and significant.1 unit increase in household size squared, the log total consumption expenditure decrease by 0.01 percent, and vulnerability to poverty decrease. However, the Age has optimistic significant on consumption expenditure and vulnerability to poverty increases. The Age squared negatively impacts total household consumption at a 10 percent significance level, and vulnerability to poverty decreases. Older Age in African contexts means that your consumption expenditure is lower, which is the proxy for vulnerability measure. Increases in aging go with lots of risks, shocks, isolation, hunger, food insecurity, and of course, vulnerability to poverty increases. Another important comment here may be that it depends on the household head's social, economic, location, environment, and ideology. Educational attainment has a positive and important effect on log total consumption expenditure. In addition, with one year added to your schooling, total consumption expenditure increased by 14.71 percent. Surprisingly, the coefficient for education squared is the negative and insignificant impact on a log of total consumption expenditure. One more year added to your higher education. Then likely, there will be a 1.4 percent decrease in log total consumption expenditure. Vulnerability rises with educational attainment. With higher education square, education expenditure declines, and poverty vulnerability declines. Furthermore, the coefficient for the education status of the household head category is positive. One year increase in education status, log total consumption rises by 10.46 percent, and vulnerability to poverty rises. As education expenditure increases, the risks of dropping out increase, and the vulnerability drop from school increases. Therefore, working as a farmer in the rural Gambia hurts household log total consumption. As total expenditure decreases, vulnerability to poverty decreases.1 unit increases employment as farmers, and log total consumption expenditure decreases by 9.08 percent. Farmers can be employed as farmers in both smallholders and garden vegetable growers. In addition, Non-land production assets positively and significantly impact log total consumption expenditure. The result is highly significant and positive at a 1 percent significance level. The vulnerability to poverty increases as the share of irrigated land is the explanatory variable. Gender is coded as one if the head of the households are male and 0 if the head of the households are female respectively. Therefore, a male-headed household has optimistic and unimportant influence on total consumption expenditure. In case of illnesses for the male head and other related issues, the household's vulnerability will increase. Thus, a female-headed household does not influence the total consumption in the compound, and vulnerability to poverty decrease if the household head is female. The caste system is an important determinant in rural Gambia or Gambia. The caste system has a positive and insignificant impact on household log total consumption expenditure expenditure.1 unit increase in the caste system, when the household is noble, the log total consumption expenditure increases by 1.8 percent. Then, the vulnerability to poverty increases. This is attributed to the fact that those households or individual that are noble has many dependencies that affect their consumption expenditure, and that increases their risk of being vulnerable. Moreover, vulnerability to climate change affects rural Gambian farmers. However, climate shocks cause agriculture to decline and lead to poor livelihoods in rural Gambia. Therefore, the flood has negative and significant impacts on log total consumption expenditure, and vulnerability to poverty decreases.1 unit increase in flood, and log total consumption expenditure declines by 13.8 percent. Most of the time in the Gambia, rainfall changes, and any year floods happen, it makes agriculture yields increase and vulnerability

to be poor decline. Salt intrusion has optimistic and important coefficient on log total consumption expenditure, and weakness to poverty increases. Further, change in rainfall and temperature negatively and positively impact log total consumption and vulnerability to poverty decline and increase, respectively. Furthermore, drought has an adverse and important impact on variability in consumption level and vulnerability to poverty decline.

Table 36: dependent variable is log consumption per capital per month. LogC = Prob (monthly per capita consumption < poverty line) to measure hh. Vulnerability -Ex-ante variance, log57=4.0431

Ex-ante variance	Coef.	Std. Err.	t	P>|t|
sizeofthehouseholds	0.0019	(0.0133)	0.14	0.887
Householdsizesquared	0.0000	(0.0001)	0.76	0.451
Ageofthehouseholdshead	-0.0734	(0.0556)	-1.32	0.187
Ageofhhheadsquared	0.0006	(0.0006)	1.11	0.269
Ownland	0.6462	(0.4085)	1.58	0.115
Educationalattainment	-0.4873	(0.3328)	-1.46	0.144
Educationalattainmentsquared	0.0560	(0.0412)	1.36	0.175
educationstatusoftheresponde	-0.4215	(0.4183)	-1.01	0.314
Employmentofhouseholdshead ca	-0.1915	(0.2741)	-0.70	0.485
Nonlandproductionassets	-0.8794	(0.2921)***	-3.01	0.003
Shareofirrigatedland	0.1705	(0.2801)	0.61	0.543
1.Gender	-0.1277	(0.2853)	-0.45	0.655
1.castesystem	-0.4595	(0.2826)	-1.63	0.105
Flood	-0.1432	(0.2919)	-0.49	0.624
changesinrainfall	3.0146	(1.2324)***	2.45	0.015
Drought	-0.2131	(0.3299)	-0.65	0.519
changesintemperature	-1.0896	(0.8665)	-1.26	0.210
Salinizationandsaltwaterintr	-.4795	(0.2906)	-1.65	0.100

*** Significant at 1% level: ** = significant at 5% level: and *= significant at 10%.

Source: Own computation using stata 16 from household survey.

The household size and the squared have an optimistic and insignificant influence on the variation of log consumption.1 unit increase in the household and its squared, the variance of log consumption increases by 0.19 and 0.068 percent, respectively. The vulnerability to poverty increases. The age of the households has adverse irrelevant influence on the log of total consumption, and age squared becomes positive and insignificant. Own land is optimistic irrelevant effect on the variance of the log of total consumption. Education attainment is harmful, and it squared become positive, which education status becomes negative. It means that the variation of the log of total consumption is not stable over time. Further employment of the household head is adverse, and variation of vulnerability to poverty declines. Non-land production assets have a negative sign, and the share of irrigated land has a positive variation of log consumption and vulnerability to poverty decline and increase, respectively. The male household head harms the variation of vulnerability to poverty. Likewise, the caste system negatively affects the vulnerability to poverty. Climate shocks such as flood, change in temperature, salt intrusion, and drought causes a decreased variation of vulnerability to poverty. This may be their influence on agriculture yields, production, productivity, and livelihood. In addition, change in rainfall has increased variation with vulnerability to poverty. Change in rainfall decrease the variation of vulnerability to poverty. Finally, if we make all variables constant, the variation of log consumption becomes negative.

4.3.1.7. Conclusion and Policy recommendation

Some significant findings are summarized from the results for the case of the rural Gambia household vulnerability assessment to poverty. The results found that size is optimistic and vital, and size squared has an undesirable and essential effect on the household's vulnerability to poverty (see details explanation in the above table). The caste system is a dummy variable indicating if the household head is noble and 0 otherwise. The caste system has an optimistic and essential impact on vulnerability to poverty in rural Gambia. So to be chronic poor, illness or lack of employment can cause it. Using log food consumption as the dependent variable, the results revealed that size squared increases household future vulnerability status to poverty. At the same time, you are more vulnerable to poverty in the caste system, using food consumption as the dependent variable. Own-land, the probability of vulnerability to be poor becomes higher. The chapter's important conclusion and policy implication is that vulnerability and poverty are related. If you are vulnerable due to natural disasters, climate shocks, poor agriculture, high price hike, illness, unemployed, an enslaved person, larger household size, do not have own land, and poor share of irrigated land using income variation as the dependent variables, you may likely to be vulnerable to poverty. Likewise, using total consumption and food consumption, looking at the current food consumption or total consumption for the household in rural Gambia, climate extreme shocks may increase the probability of being vulnerable to poverty shortly. Present savings determine future total consumption and future food consumption. If present saving is lower, the likelihood for the rural household to deepen into poverty is much higher. Diversification of income, good adaptation practice by farmers, diversification of the production assets, employment diversification, increases in education, nuclear family, noble in the society, good rainfall, and age as a proxy for experience, likelihood of the household to be susceptible to poverty is very slim, author meditated. The policy recommendation to the government of the Gambia is that in the rural Gambia, there are major's impacts of climate change affecting the household consumption expenditure, especially during the rainy season. So to solve these problems, climate adaptation can be a crucial option to improve livelihoods in rural Gambia.

4.3.2. Quantifying farmer's vulnerability to climate change across the three regions in the Rural Gambia

4.3.2. 1. The vulnerability of agriculture to climate change in the Gambia

Climate hazards in the Gambia comprise both slow onset and climate change extremes. The most important weather and climate change connected risks are river floods, wind storms, drought, and water scarcity.

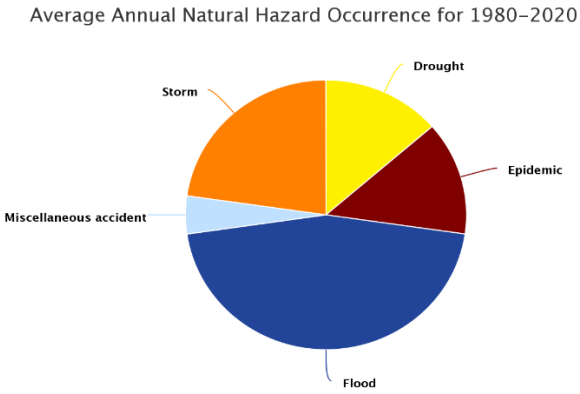


Figure 28: Average annual Natural occurrence in the Gambia

Sources: https://climateknowledgeportal.worldbank.org/)

As depicted in the above pie chart, flood hazard level is high across the western coastal regions and include inland up the Gambia River. A projected (about 20%) of The Gambia is flooded yearly, and the mangrove ecosystems are already affected by salinization (see details https://thinkhazard.org/ and https://climateknowledgeportal.worldbank.org/). According to Ceesay EK (2020), floods affect the Gambia's agriculture sector. Using time series data from World Bank, the authors criticized that natural disasters such as floods have experienced extraordinary costs to animals, humans, and social and economic features, affecting the local and worldwide economies. Though the frequency of floods time it takes for a flood to last, the cause of floods, affected areas, and economic damages are happening during the rainy season in the Gambia. Subsequently, this is also true by using single cross-sectional household data that floods positively affect agriculture growth in the Gambia. Any year flood happens, agriculture yield drastically increases, and positively affecting households in rural Gambia, mainly since more than half depend on agriculture for livelihood and food consumption. So, the weakness of Gambian agriculture to climate change lies in the fact less adaptation capacity, and climate change exposure and sensitivity are very high in the Gambia. The adaptive capacity farmers lack access to credit, agriculture extension services, education, potential irrigation, planting different crop varieties, early and late varieties, and other adaptive capacity methods. The slow onset of climate change that triggers farmer's agriculture growth includes changes in rainfall and temperature, which causes slow growth and late maturity of crops and declining livestock and crop yields in the Gambia. So climate exposure as a vulnerability indicator affects farmers' productivity. Another biophysical attribute that affects agriculture in the Gambia is the drought and floods, and the Gambia agriculture is sensitive to climate extremes.

4.3.2.2. Description Statistic of Socio-economic and climatic conditions

The table below indicates the indicators of adaptive capacity (socio-economic indicators), sensitivity indicators (biophysical attributes), and exposure indicators (slow onset climate changes and climate change extreme) across the three regions in rural Gambia. There is a sample of (n=400) households surveyed in total in the rural Gambia, and 35 %(n=140) of those households resident in the CRR region in the Gambia and equally households are surveyed in NRB (n=130) and URR (n=130), respectively.

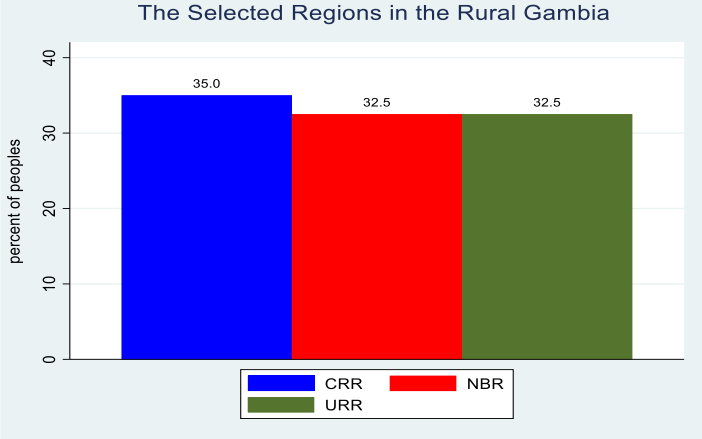


Figure 29: The Selected regions in the rural Gambia.

In the rural Gambia, the regions differ from biophysical, socio-economic, social dimension, economic dimension, cultural dimension, environmental dimension, slow onset change climate and change in climate extreme. Table 37 to 39 illustrate exposure, sensitivity, and adaptive capacity in three regions selected in rural Gambia. The indicators for exposures selected in this study are; sea-level rises, changes in rainfall, changes in temperature, bushfire, and saltwater intrusion/salinization. In NBR, CRR, and URR most of the respondents said temperature changes and rainfall changes affect their livelihoods as depicted in the table 37.The percentage of peoples that sea-level rises affected is higher in CRR, follow by NBR and lower in URR. However, percentages of peoples affected in by salt intrusion are equally in NBR and CRR and lower in URR. Similarly, 40 percent of peoples are affected by bushfire in URR and only 16 percent are affected by bushfire in NBR. This analysis indicated that slow onset climate changes affected rural Gambia communities through crops failures, infertility of the soil, migration through sea level rises, livelihood decreases through impacts on bushfire and changes in rainfall, animals and plant decline through the changes pattern of temperature, the author noted.

Table 37: Indicators for Exposure (All %)

Region	CR	CT	Saltwater intrusion	ATWDD
NBR	100	100	46	77.57
URR	99	97	29	42.02
CRR	94	89	46	75.00

Own evaluation from household survey in the rural Gambia using stata 16 core.

The indicators we selected for sensitivity indicators are; floods and droughts. According the table 38 below, in NBR, 75 percent affected by floods and 97 percent affected by drought. We can see that drought is a major problems that causes food insecure in this region of the rural Gambia. In URR, affected least by drought and CRR is affected highest by flood in the rural Gambia. Due to climate condition differential, expenditure on crops are different across the three regions selected. In CRR, farmers total expenditure on crops are higher (about $234.51) compare to NBR (about $53.09), which is the lowest (see table 40 below). According to the respondent, this is the amount they spent on purchases different crops and seedling they uses in the garden and farms. In Similar vein, food consumption expenditure per month are highest in URR,

and lowest in CRR. Overall total expenditure per capita per month is highest in NBR and lowest in CRR. Due to highest temperature exist, URR during drought only 42 percent has access to water compare to 78 percent in NBR and 75 percent in CRR respectively.

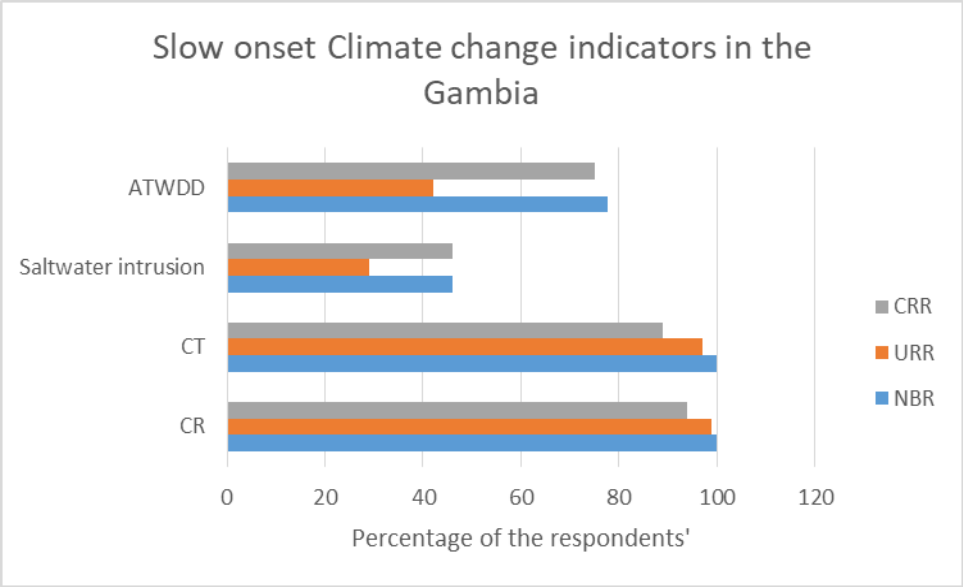


Figure 30: Slow Onset to climate change

Table 38: Indicators for Sensitivity

Region	Flood (%)	Drought (%)
NBR	75	97
URR	76	48
CRR	62	74

Own evaluation from household survey in the rural Gambia using stata 16 core.

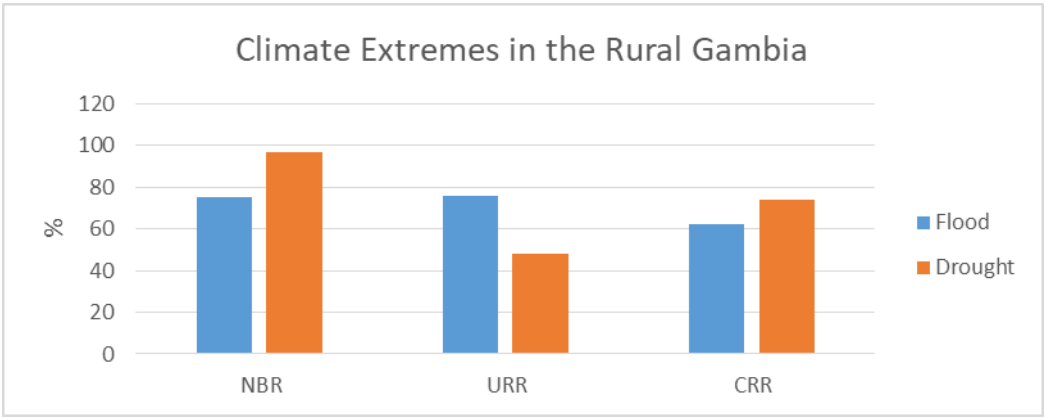


Figure 31: Climate change extreme

According to drivers of adaptive capacity as indicated the below table 39, all the farmers used related similar proportion of fertilizer in their farms. Average household is larger in

CRR and lowest NBR region respectively. Farmers living in URR is wealthier and in the CRR are poorer. We measure wealth based on the average income as depicted in table below. Life expectancy, age measure it and we found that average age of the farmers exist in the NBR. NBR region's farmer's lives longer (average 49 years) and URR farmer's lives average age of 46 years. This may be attributed to change in temperature across the regions in the Gambia. Hotness exist in URR of the Gambia than the other regions.

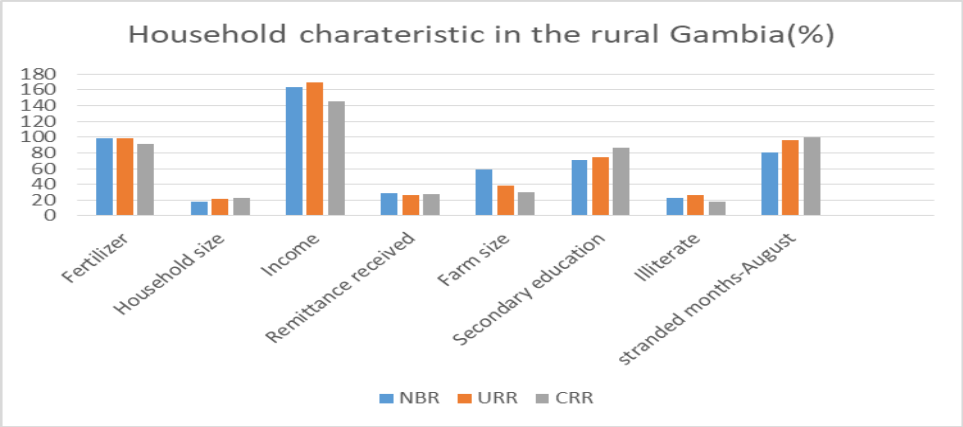


Figure 32: Household characteristic in the rural Gambia used survey data 2021

In migration responses, NBR has the uppermost number of migrants, and URR takes the smallest amount of migrants per household. URR received more infrastructural support than the two other regions combined. More migrants, more remittance, NBR received more remittance. Though, the proportion of migrants does not match the proportion of remittances received. North Bank farms have the most significant farm size measures in hectares, and CRR farmers have the lowest proportion of farm size. On average, 98 percent of the farmers across the three regions get NGO support.0-9 grades of education are equally distributed across the three regions selected. The highest number of respondents are farmers in the NBR and CRR. The proportion of those who cannot read and write is the highest URR and lowest in CRR. Most of the respondents said the month of August is stranded across rural Gambia. All the regions selected practice livestock farming.

Table 39: Indicators for Adaptive Capacity (%)

Indicators	NBR	URR	CRR
Fertilizer	99	98	91
Household size	18	21	23
Income	164	170	146
Remittance received	29	26	27
Farm size	59	39	30
Secondary education	71	75	86
Illiterate	23	26	18
stranded months-August	81	96	100

Practicing livestock farming	87	55	75
Own-land	94	77	90
Caste system	89	30	47
Access to credit	2	17	10
Access to agriculture extension	5	15	8
Food markets	90	85	98
Share of irrigated land	15	27	38
Agriculture technology	67	38	74

Own Compilation used survey data 2021.

The proportion of respondents who own land is highest in NBR and CRR and lowest in URR.65 percent of the respondent said they have non-land production assets in the NBR region, whereas 39 and 31 percent said they have non-land production assets in URR and CRR, respectively. Most respondents said caste systems exist in the NBR region, while the lowest said it exists in URR. The credit access proportion is higher in URR than in CRR and NBR combined. In a similar vein, access to agriculture extension is highest in URR. Ninety-eight percent of the respondent in CRR said they buy food from the market, while 90 and 85 percent in NBR and URR said they buy food from the market, respectively. As a measure of potential irrigation, CRR has the highest proportion of share irrigated land (about 38%), and NBR has the lowest share of irrigated land (about 15%).NBR region farmers do more planting late and early varieties of crops while URR does less. Due to irrigated rice fields in the Gambia, CRR has the highest agriculture technology, and URR has the lowest. URR and CRR did equally on soil and water conservation. URR does more poultry business, and NBR does the most small poultry business as a mode of adaptation.

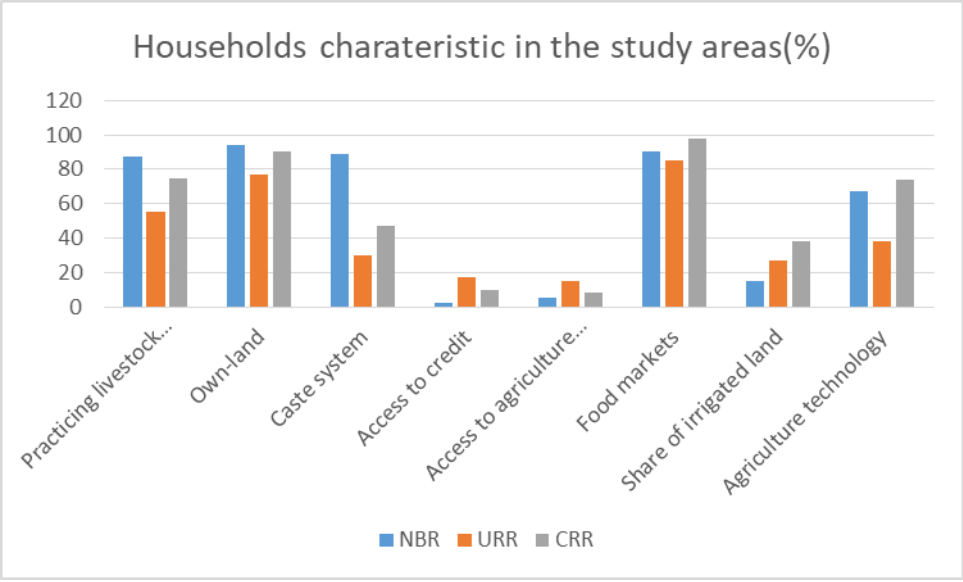


Figure 33: Household characteristic in the rural Gambia used survey data 2021.

Table 40: Indicators

Region	Bushfire %	Sea-level rises %	Total expenditure on crops $	Total expenditure per capita per months $	Poultry Farming %	Food expenditure per capita per month $
NBR	16	41	53	184	2	164
CRR	35	23	235	149	25	145
URR	40	44	137	175	45	170
ALL	29	36	144	169	23	159

Own computation used Stata/MP 16.0 used survey data 2021

Furthermore, bushfire affects URR region most (about 44%) and less in NRB whereas sea-level affect more in URR and least in CRR. Total expenditure monthly is higher in NBR and lowest in CRR as depicted in table 3 above. However, only 2 percent of the respondent said they do poultry farming in NBR and 45 percent in URR. Food expenditure monthly is higher in URR (about $170) and lowest in CRR (about $145).

4.3.2.4. Results and discussion

Table 41: Principal components, eigenvalues, differences between the eigenvalues, standard deviation, and proportion of variance explained

Component	Eigenvalue	Difference between eigenvalues	Standard deviation	Proportion of variance explained	Cumulative proportion of the variance explained
Comp1	3.85	1.43	1.84	0.17	0.17
Comp2	2.42	0.25	1.56	0.11	0.28
Comp3	2.17	0.19	1.47	0.09	0.37
Comp4	1.98	0.54	1.41	0.09	0.45
Comp5	1.44	0.11	1.20	0.06	0.52
Comp6	1.33	0.14	1.15	0.06	0.57
Comp7	1.20	0.16	1.10	0.05	0.63
Comp8	1.04	0.06	1.02	0.05	0.67
Comp9	0.98	0.09	0.99	0.04	0.71

Comp10	0 .89	0.09	0.94	0.04	0.75
Comp11	0.80	0 .07	0.89	0.03	0.79
Comp12	0.73	0.06	0.85	0.03	0.82
Comp13	0 .67	0.07	0.82	0.03	0.85
Comp14	0.60	0.06	0.77	0.03	0.87
Comp15	0.54	0.06	0.73	0.02	0.90
Comp16	0 .48	0.04	0.69	0.02	0.92
Comp17	0.44	0.08	0.66	0.02	0.94
Comp18	0.36	0.05	0.60	0.02	0.95
Comp19	0.31	0.04	0.56	0.01	0.97
Comp20	0.28	0.06	0.53	0.01	0.98
Comp21	0.22	0.08	0.47	0.01	0.99
Comp22	0.14	0 .01	0.37	0.01	0.99
Comp23	0.12	.	0.35	0.01	1.00

Own evaluation using Stata/MP 16.0. Note eigenvalue is the standard deviation squared used household survey 2021

In the table above, the firsthand information of the data after running the PCA on our variables. The amount of components identical to total amount of variables (23) selected. Eigenvalue is the standard deviation square. The first 8 components has eigenvalue greater than one and elucidate 67% of the difference in the data. The initial 5 components clarify 52% of difference. Component 1 explains the least of the variation in the data set (17%) and components 22 explains 99% of the variation. Proportion of the variance explain of component 1 add to proportion of variance explain to component 2 gives the resulted cumulative proportion of the variance explained. The difference between the eigenvalue columns above tell us the differences between component 1 eigenvalue and component 2 eigenvalue and so on. In the observation above, as the components rises, the amount of variance elucidated declined and cumulative amount of variance clarified increased. Finally, All 23 components clarify the complete difference in the data (100%).

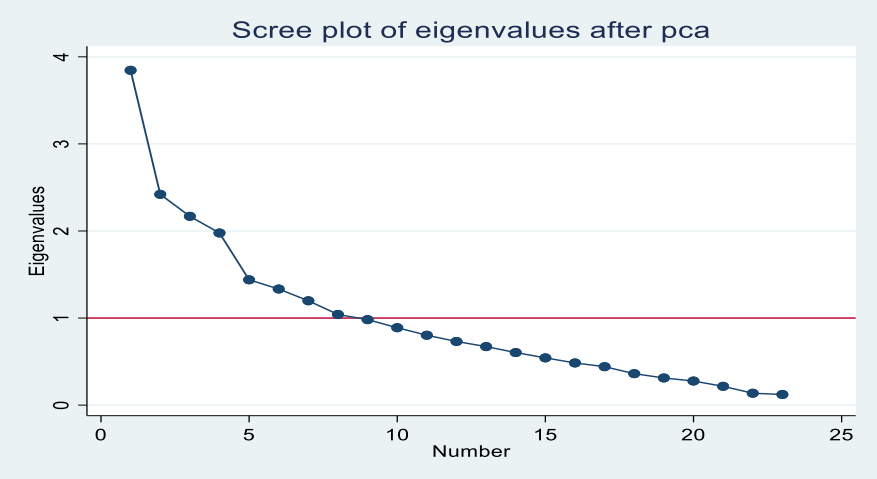


Figure 34: Scree plot of eigenvalues after pca

Own evaluation using stata 16 used survey data 2021

Figure 34: illustrates the scree plot of eigenvalues after PCA for all the variables as indicated in the dot above. For instance, the first 8 components have eigenvalues above 1.Combining they explains almost 67% of the variation of the data from the original variables. Our target is the first 5 components and they explain 52% of the variation of the variables from the original variables. If you observed closely here "elbow" amid 5 and 8 components. Thus, 5 components will be used for this analysis but it also possible to use all the 8 components that has eigenvalues above one.

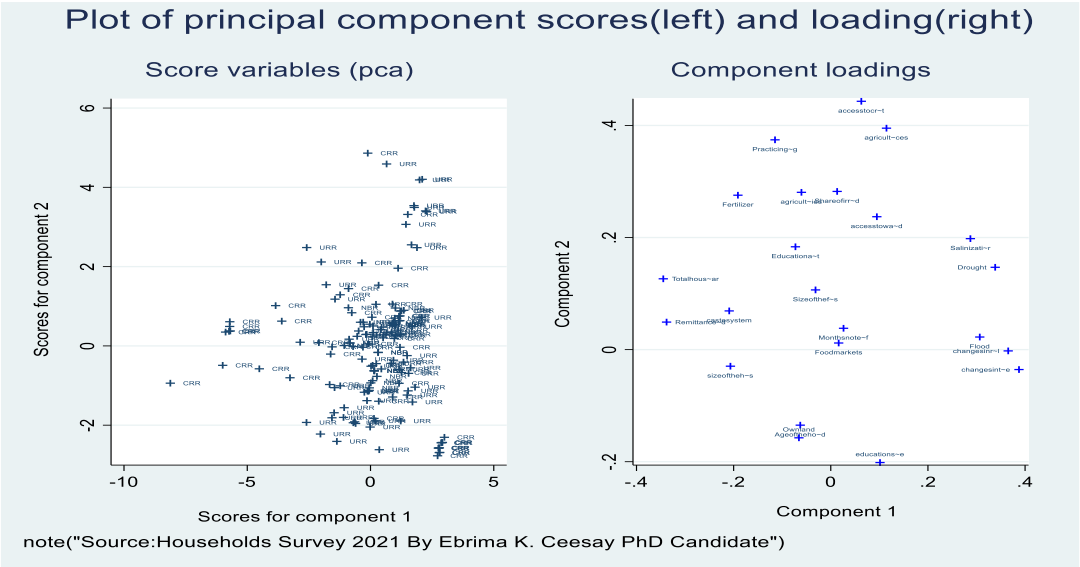


Figure 35: Plot of component scores and component loadings

Own evaluation using Stata 16 used survey data 2021

4.3.2.4.1. Scoring coefficients

Figure 35 illustrate the score variables plot and components loading graphs above indicated the position or location of the variables between the first two components of the data. Thus, this gives an idea about the location of observations in the principal component space. The URR, and CRR has outliers that has negative variables and it associated the following variables has negatively loaded in these regions; age and drought corresponding to CRR and URR-Lower life expectancy and drought affected regions respectively. After the first hand information on the data to summarize and have some graphics to get the full pictures of our

variables variation, and the number of components for the PCA analysis was selected, we run the factor scores for the 5 components in the PCA on the indicators variables above and reported the first Principal component results as listed in Table 42.As explained above, the 8 components has explained 67 % of the disparity in the data set but due to an elbow that appeared between component 5 and 8.It means the PCA will keep only 5 components and in other words we run only 5 components and skip the rest of the components of the analysis. The PCA has shown 8 components with eigenvalues beyond 1. These eight components clarify almost 67% of the entire discrepancy in the data set. The principal component explained the least of the variation 17%, second principal component clarified 27%, the third clarified the 37%, the fourth Principal component elucidated 45% and the fifth enlightened 52% of the difference in the data set respectively and this is why we retained 5 components because they explained almost half of the variation of the data set from the original data. According to the PCA analysis we can uses any of the components with eigenvalues above 1 to construct the vulnerability indices and therefore the third components was chosen. As can be observed when we normalized the variables by using their means and standard deviation(see appendix for normalization using Z-score), we found that most of the variables in our vulnerability components index below and vulnerability index below and the factor scores of the third Principal has a corrects signs. Meaning indices on exposure is negatively associated in the vulnerability components and VI below and sensitivity is also negatively correlated with the indicators and adaptive capacity positive correlated with the indicators (see details on tables 43 and 44). If you looks carefully in the rural Gambia, this is true because exposures and sensitivity affected farmers in this study areas and they did not do any adaptive means to practice adaptation and that is why we can found that most of the household's characteristic has negative associated in the third components. Finally, in order for us to constructs the vulnerability components and vulnerability indices, we selected the variables to be included in the calculation of the vulnerability components and VI for the rural Gambia that has negative associated with exposure and sensitivity and positive with adaptive capacity. In this case out of 23 variables or components, 14 variables are finally selected because they associated with correct signs. Note you can select any components to constructs the vulnerability components index and vulnerability index e.g. pca 1, pca 2, pca 3 and so on.

Table 42 : Eigenvector/Factor scores/loading/scoring coefficients for the third Principal Components (PCA)

Vulnerability indicators	Factor scores	descriptions
changes in rainfall	-0.2003	Exposure
changes in temperature	-0.1261	Exposure
Flood	-0.0471	Sensitivity
Age of the households head	0.1077	Adaptive capacity
size of the households	0.0402	Adaptive capacity
Remittance Received	0.1097	Adaptive capacity
Secondary completion rate(0-9 grade)	0.4141	Adaptive capacity
Stranded month	0.1983	Adaptive capacity

Practicing livestock farming	0.2120	Adaptive Capacity
Own land	0.0621	Adaptive Capacity
caste system	0.1296	Adaptive Capacity
Food markets	0.1521	Adaptive Capacity
Share of irrigated land	0.0686	Adaptive Capacity
agricultural technologies	0.3480	Adaptive Capacity
PVE	**0.06**	
CPVE	**52%**	

Own Evaluation using stata16/MP.PVE: Proportion of variance explained; CPVE: Cumulative proportion of variance explained used survey data 2021

4.3.2.4.2. Vulnerability Components

The vulnerability components(VC) across the three regions is calculate as follows (see details on index formula above/below); all the regions combine using factor scores from the third Principal components and the rest of the individual region follow.

The index formula for a region j for indicator i is given by:

$$eq(12) \dots I_j = \sum_{i=1}^{k} w_i(b_{ij} - \bar{b}_i)/\sigma_{b_i}$$

The index for Adaptive capacity (AC) of region j for the indicator i

$$eq(13) \dots Ac_j = \sum_{i=1}^{k} w_i^{Ac}(b_{ij}^{Ac} - \bar{b}_i^{Ac})/\sigma_{b_i}$$

The index for exposure (Ex) of region j for the indicator i

$$eq(14) \dots Ex_j = \sum_{i=1}^{k} w_i^{Ex}(b_{ij}^{Ex} - \bar{b}_i^{Ex})/\sigma_{b_i}$$

The index for sensitivity(S) of region j for the indicator i

$$eq(15) \dots S_j = \sum_{i=1}^{k} w_i^{S}(b_{ij}^{S} - \bar{b}_i^{S})/\sigma_{b_i}$$

Vulnerability components for all using the above equations was calculated as follows;

$$Ac_{J=ALL} = [(0.1077 * -3.8263) + (0.0402 * -1.1641) + (0.1097 * -0.5034) + (0.4141 * -1.4299) + (0.1983 * -16.7973) + (0.2120 * -1.1259) + (0.0621 * -2.3636) + (0.1296 * -0.8442) + (0.1521 * -2.6879) + (0.0686 * -0.4487) + (0.3480 * -0.5160)] = -5.5512$$

$$Ex_{J=ALL} = [(-0.2003 * -6.4383) + (-0.1261 * -4.5986)] = -1.8695$$

$$S_{J=ALL} = [(-0.0471 * -1.6001)] = -0.0754$$

For example, the vulnerability components for NBR using the factor scores from the third components is calculated as follows: (see details on index formula above);

$$Ac_{J=NBR} = [(0.1077 * -4.4448) + (0.0402 * -1.1973) + (0.1097 * -0.3981) + (0.4141 * -0.6366) + (0.1983 * -20.2015) + (0.2120 * -1.9853) + (0.0621 * -3.6179) + (0.1296 * -2.4290) + (0.1521 * -2.6001) + (0.0686 * -0.2262) + (0.3480 * -0.6939)] = -6.4529 Ex_{J=NBR} = [(-0.2003 * 0) + (-0.1261 * 0)] = 0$$

$$S_{J=NBR}[(-0.0471 * -1.7813)] = -0.0839$$

The vulnerability components for CRR using the factor scores from the third components:

$$Ac_{J=CRR} = [(0.1077 * -4.1134) + (0.0402 * -0.9983) + (0.1097 * -0.3565) + (0.4141 * -1.2905) + (0.1983 * -0) + (0.2120 * -1.2365) + (0.0621 * -2.8185) + (0.1296 * -0.6711) + (0.1521 * -5.6882) + (0.0686 * -0.6371) + (0.3480 * -0.8938)] = -2.8007$$

$$Ex_{J=CRR} = [(-0.2003 * -4.0024) + (-0.1261 * -3.003) + (-0.0471 * -1.3089)] = -1.1804$$

$$S_{J=CRR} = [(-0.2003 * -4.0024) + (-0.1261 * -3.003) + (-0.0471 * -1.3089)] = -0.0616$$

The vulnerability components for URR using the factor scores from the third components:

$$Ac_{J=URR} = [(0.1077 * -3.7410) + (0.0402 * -1.7467) + (0.1097 * -0.3441) + (0.4141 * -0.7791) + (0.1983 * -0.1432) + (0.2120 * -0.6963) + (0.0621 * -1.7105) + (0.1296 * -0.3704) + (0.1521 * -1.9163) + (0.0686 * -0.4505) + (0.3480 * -0.0556)] = -1.5055$$

$$Ex_{J=URR} = [(-0.2003 * -11.5150) + (-0.1261 * -5.7155)] = -3.0272$$

$$S_{J=URR} = [(-0.0471 * -0.809)] = -0.0381$$

Table 43: Vulnerability Components

Vulnerability Components	Adaptive capacity	Exposure	Sensitivity
NBR	-6.4529	0	-0.0839
CRR	-2.8007	-1.1804	-0.0616
URR	-1.5055	-3.0272	-0.0381
All	-5.5512	-1.8695	-0.0754

Own Evaluation using pen, paper and calculator

Vulnerability components is classified into socioeconomic indicators and bio-physical indicators. They measure risks level of the region, country or continents towards climate change. As indicated in the table above and figure below, the vulnerability components in the study areas are interprets as follows; In the NBR region, adaptive capacity very low and associated with negative sign. Meaning the socio-economic indicators of vulnerability to climate changes are negligence and farmers have less education, large household size, feeble lands, lower knowledge of agriculture technology, lower irrigation facility and land is affected by flood and land is infertile, water scarcity, agriculture yields declines and cost of fertilizer may

also be another costs and old age affected farmers because young peoples migrated either international or internally. Though they are highest receiver region of the remittance in the rural Gambia. This those not translate for farmers to solve the problems associated with climate change. The thesis demonstrated that in NBR regions, floods affects farmers seriously and that eroded the soil in the farmlands and leave the soil barren and infertile for crop production and even livestock rearing. In that rain-fed agriculture and less yields from agriculture production follows and that causes the region to be food insufficient. In addition, floods damages farmland, destroy households assets and income and can causes diseases and eventually food insecurity and high mortality rate in this region in the rural Gambia. Thus, practicing livestock is common in this region but due to the influences of change in climate, there is mass decline in animals. This is due to water scarcity and less grass to graze throughout the raining season and in the dry season no water, no food to eat or provide for animals and these eventually reduces their population. Especially we can notice that in the feasts most of the animals bought are from the neighboring countries such as Senegal and Mali. An exposure to slow onset climate change is zero and vulnerability to slow onset to climate change is slightly high in this region such as variability in temperature and variation in rainfall. Likewise, sensitivity as vulnerability indicators in NBR regions is medium high meaning floods as the variable used to measure sensitivity will negatively significant affect the region. In CRR, and URR adaptive capacity is very low as in the NBR and weakness to climate change is very high. Likewise exposure and sensitivity has correct sign, negative and vulnerability to climate changes is very high too. Please see more details on the table above and figure below.

	NBR	CRR	URR	All
Adaptive capacity	-6.4529	-2.8007	-1.5055	-5.5512
Exposure	0	-1.1804	-3.0272	-1.8695
Sensitivity	-0.0839	-0.0616	-0.0381	-0.0754

Figure 36: Vulnerability components of the three rural regions selected in the Gambia.

For example, the vulnerability index for NBR is calculated as follows using the factor scores from the first components and the rest of the regions follow :(see details on index formula above)

4.3.2.4.3. Vulnerability Index

$$\text{Vulnerability index} = \text{VI} = \sum_{i=1}^{k} \left[\frac{w_i^{Ac}\left(b_{ij}^{Ac} - \bar{b}_i^{Ac} \right)}{\sigma_{b_i}} - \left(\frac{w_i^{Ex}\left(b_{ij}^{Ex} - \bar{b}_i^{Ex} \right)}{\sigma_{b_i}} + \frac{w_i^{S}\left(b_{ij}^{S} - \bar{b}_i^{S} \right)}{\sigma_{b_i}} \right) \right]$$

(Weighted each of indices)

Combined the three rural regions' using the third components scores factor

$$VRI_{i=ALL} = [(0.1077 * -3.8263) + (0.0402 * -1.1641) + (0.1097 * -0.5034) + (0.4141 * -1.4299) + (0.1983 * -16.7973) + (0.2120 * -1.1259) + (0.0621 * -2.3636) + (0.1296 * -0.8442) + (0.1521 * -2.6879) + (0.0686 * -0.4487) + (0.3480 * -0.5160)] - [(-0.2003 * -6.4383) + (-0.1261 * -4.5986) + (-0.0471 * -1.6001)] = -3.6063$$

NBR using the third components scores factor

$$VRI_{i=NBR} = [(0.1077 * -4.4448) + (0.0402 * -1.1973) + (0.1097 * -0.3981) + (0.4141 * -0.6366) + (0.1983 * -20.2015) + (0.2120 * -1.9853) + (0.0621 * -3.6179) + (0.1296 * -2.4290) + (0.1521 * -2.6001) + (0.0686 * -0.2262) + (0.3480 * -0.6939)] - [(-0.2003 * 0) + (-0.1261 * 0) + (-0.0471 * -1.7813)] = -6.3690$$

CRR using the third components scores factor

$$VRI_{i=CRR} = [(0.1077 * -4.1134) + (0.0402 * -0.9983) + (0.1097 * -0.3565) + (0.4141 * -1.2905) + (0.1983 * -0) + (0.2120 * -1.2365) + (0.0621 * -2.8185) + (0.1296 * -0.6711) + (0.1521 * -5.6882) + (0.0686 * -0.6371) + (0.3480 * -0.8938)] - [(-0.2003 * -4.0024) + (-0.1261 * -3.003) + (-0.0471 * -1.3089)] = -1.5587$$

URR using the third components scores factor

$$VRI_{i=URR} = [(0.1077 * -3.7410) + (0.0402 * -1.7467) + (0.1097 * -0.3441) + (0.4141 * -0.7791) + (0.1983 * -0.1432) + (0.2120 * -0.6963) + (0.0621 * -1.7105) + (0.1296 * -0.3704) + (0.1521 * -1.9163) + (0.0686 * -0.4505) + (0.3480 * -0.0556)] - [(-0.2003 * -11.5150) + (-0.1261 * -5.7155) + (-0.0471 * -0.809)] = 1.5598$$

Table 44: Vulnerability index (VI) in the rural Gambia

	NBR	CRR	URR	All
Vulnerability index(VI)	-6.3690	-1.5587	1.5598	-3.6063

Own evaluation using pen, paper and calculator

The definition of vulnerability index is to measure the shocks the regions, nations or households or continents faces at the time of risks and whether the indicators measures categorized as adaptive capacity, sensitivity and exposure gives a correct signs. According to IPPC, 2001, 2007 Vulnerability is classified into three indicators i.e. adaptive capacity, exposure and sensitivity. Adaptive capacity must have positive sign for less vulnerable and exposure and sensitivity must have negative signs for less vulnerable. If this signs are in order, it means that region is not vulnerable to that shocks/calamities. As we finally calculated the VI from VC above. The vulnerability index (VI) was constructed to see the extend which region is relatively more and less vulnerable in the rural Gambia. So as illustrated in the figure 37 below, NBR region has vulnerability index of -6.369 - approximately and the region is relatively high vulnerability to climate change. This is due to the fact that in the NBR of the study areas variations in rainfall and fluctuations in temperature are negatively loaded and other socio-economic characteristics are positively loaded. In the URR, the only region that has positive VI, meaning that they are not vulnerable to climate changes and other household's shocks based on VI but when we calculated the components above they are vulnerable to change in climate. Thus, we concur that this attributed to high temperature-extreme heat wave, water scarcity, river flood, and bushfire. In CRR even due to share of irrigated land (proxy for potential irrigation), the VI is negative and vulnerability to change in climates are exposure. The region with high food secure is

CRR but vulnerability to adaptive capacity is negative in this region and that is why overall VI is negative and vulnerability to climate change is high. Finally, overall, in the rural Gambia according to the vulnerability indicators selected from vulnerability components in constructing the vulnerability index, we revealed that the regions' are vulnerable to change in climate and other indicators listed in table 42 and figure 37 below with VI is equal to -3.6063.The vulnerability of the rural Gambia to change in climate is due to many factors include less adaptive capacity, strange dependence on ecosystem for living, less agriculture technology, poor drainage system, changes in rainfall, water scarcity, bush fire, large family size, lower tertiary completion rate, lower life expectancy, poor market and transportation system, insufficient food availability, high changes temperature, and rainfall changes causes damages to agriculture. Finally, this will have certain risk and consequences in the Gambia such as agriculture failures included crop and livestock declines, water scarcity especially most neighborhoods and schools, livelihoods, food insecurity, public health, high migration-internal and international, commodity prices rises, energy problems-most villages still did not have electricity and causes problems to have irrigation facilities, market problems-to sell their goods and bad weather spoil their harvest, the author recommended.

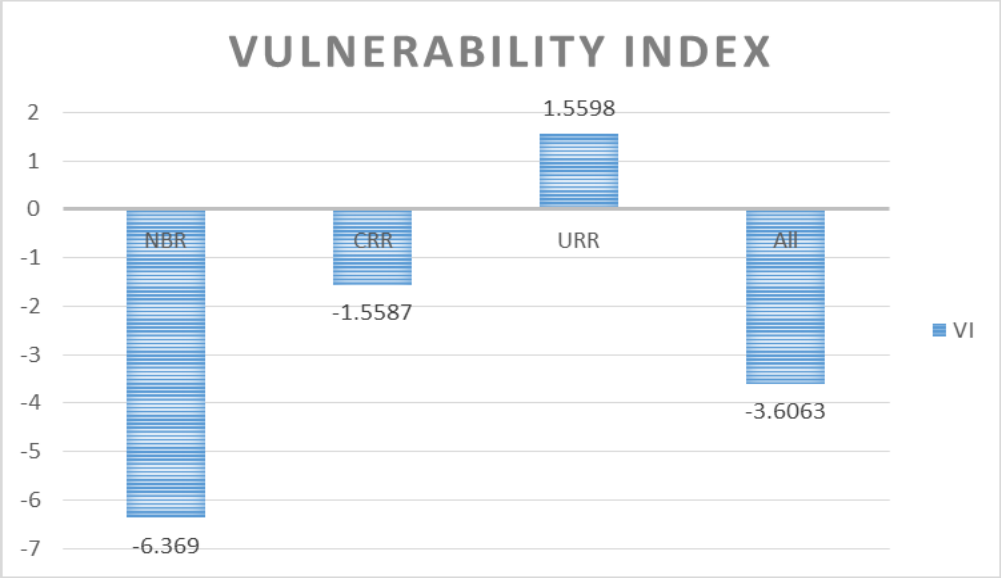


Figure 37: Vulnerability index (VI) of the three local regions in the Gambia

Own evaluation using excel

4.3.2.4.4. Time Trend for vulnerability index

In the figure below we see trends of vulnerability to change in the climate in the rural Gambia. We found that NBR region has highest vulnerability to change in climate in the rural Gambia. Subsequently, the region has zero exposure and it is sensitive to lack of floods. In addition, feeble adaptive capacity is a problem in this region. So, to remedy this issues the policy makers should train farmers new knowledge of farming, to get access to credit, provision of inputs and fertilizer, flood dykes, good market for their produces to increases their income etc. Moreover, CRR region, the vulnerability in slightly negative and it means that in this region vulnerability to change in climate is slight high. Climate change affect crops and livestock in this region and it turn affects farmers and their households in term of food security, livelihoods and standard of living. Further, the URR region, the vulnerability index is positive and it means that they are not vulnerability to change in climate. This is due to the fact in this region, NGO support helps farmers to reduces climate shocks and other household shocks by provision of fertilizer, credit, manure, training financial planning, educate new method of farming, visit women and farmers in their vegetable garden and farms land frequently. In conclusion, overall, in the Gambia, vulnerability index is equal to -3.6063,

meaning the three regions on average were vulnerability to climate change due to negative adaptive capacity and positive exposure and positive sensitivity to climate change. In IPPC, the adaptive capacity must should have positive sign and exposure and sensitivity should have negative sign for vulnerability to decline and opposite sign means vulnerability increases.

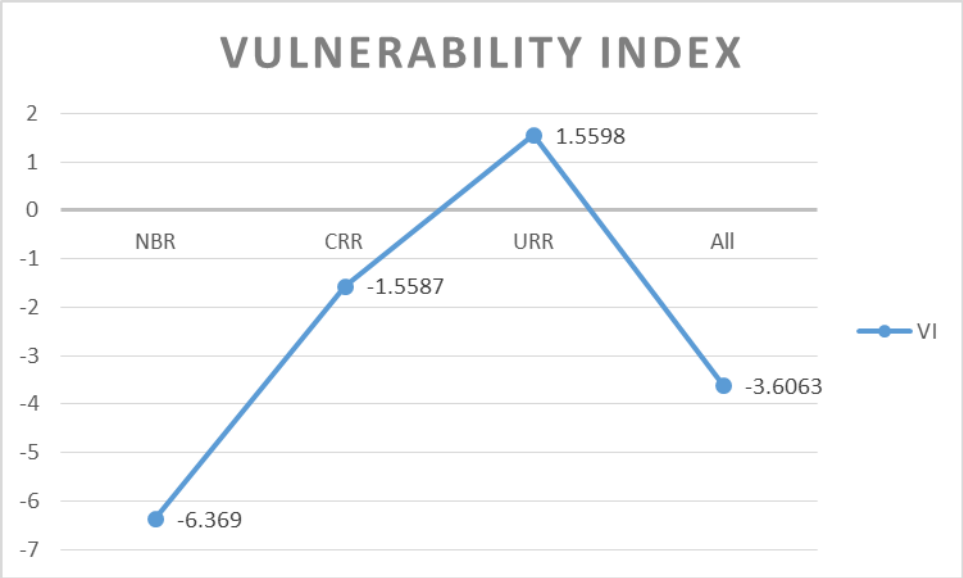


Figure 38: Time trend for vulnerability index (VI) of the three local regions in the Gambia

Own evaluation using excel

In conclusive, we added new innovation to the paper by looking at vulnerability of the time during the time period the surveyed was conducted. The time trends tell us how vulnerability is tended to increase severity and decline massively at a point in the URR region of the Gambia and averaging across the rural region of the Gambia vulnerability increases.

4.3.2.4.5. Validation of PCA results

On table 7 in appendix below: Firstly, I selected the indices and classified them into adaptive capacity, sensitivity and exposure. After, I constructed the indices based on weight and z-score by normalization and calculated each vulnerability component. In addition, after vulnerability components are calculated, we finally calculated vulnerability index. We found that based on the selected indices for vulnerability study, adaptive capacity is low, exposure and sensitivity is very high and vulnerability to climate change risk is very high in the rural Gambia. Subsequently rural Gambia does not have good agriculture and each season they have poor yields and maturity for crops are very poor, the income drives from harvest is low, difficult to sell their produces due to poor market, distance to market, transportation is poor and food in local region in the Gambia are easily spoiled due to no cool store and no processing machine, or related to preserve the food for sometimes so that farmers and the whole population can benefit from it by exporting and by generating revenue. After vulnerability calculation, we now selected different variables to validate that actually vulnerability to climate change is really affecting across the rural Gambia. What we do here is that we calculated the vulnerability index above and we now find the average values of indicator selected below and find the correlation between vulnerability index and average values of the selected variables in rural Gambia. We used completely different indicators in order to understand truly that vulnerability to climate change exist in the rural Gambia. The indicator selected are; NGO support, government support, Food consumption, food security, rising sea level affect your farm land, Use more labour power machines, Receiving infrastructural support, Migration of household members, Plant other crops or varieties, Taken insurance, Total expenditure on crops, and Changing remittances. NGO support reduces vulnerability to changes in climate by 82 percent. The international organization provides different support to rural Gambia population in terms of providing skills and training, bilateral supports, provides health facilities for them,

provides seedling and fertilizer, provides taps to access water, sometimes provides bicycle for children with poor background and the distance to school is far, they provides books and other learn materials for children and they provides some training and inputs for women especially those working in vegetable garden in the rural Gambia, the author noted(see table below. As depicted in table above, we found that as contrarily to NGO support, government support and vulnerability index has positive correlation. Therefore, government support increases farmer's vulnerability to changes in climate in the rural Gambia. This is true because due to mismanagement of fund and other related corruption issues, the government of the Gambia placed low budget to agriculture and in that adaptive capacity is small and vulnerability rises. To solve this problem the government of the Gambia might provide support to the rural farmers by increases employment in agriculture, availability of water to rural farmers and provides them sufficient electricity to supply water to their produces and that will increases their productivity and train them, provides them with fertilizer, tractors and other related inputs. Diverting and mismanagement in government sectors cost the subsistence farmers in the rural Gambia to depend on NGO support that assist. As government support increases, vulnerability to climate increases by 79 percent.

Table 45: Validation of vulnerability index

Variables	Correlation	Component
NGO support	-0.82	Adaptive Capacity
government support	0.79	Adaptive capacity
Lacking food consumption	0.10	Sensitivity
Lacking food security	-0.86	Sensitivity
rising sea level affect your farm land	0.00	Exposure
Use more labour power machines	0.78	Exposure
Receiving infrastructural support	0.74	Adaptive capacity
Migration of household members	0.83	Adaptive capacity
Taken insurance	-0.94	Adaptive capacity
Total expenditure on crops	0.55	Adaptive capacity
Changing remittances	0.97	Adaptive capacity
Plant other crops or varieties	0.91	Adaptive capacity
Access to credit	0.97	Adaptive capacity
Access to extension	0.92	Adaptive capacity

Own Evaluation using StataMP/16.0 used household survey 2021.

In the below figure, NGO support in the graph below is near to vulnerability index and therefore we found that NGO support reduces vulnerability to change in climate in the rural Gambia. In the rural Gambia, there are different NGO that assist farmers about different farming technique and they help households' different technique to grow and therefore this tends to reduce farmers responsibility on different households consumption expenditure especially if they have large household size the purchasing of food, fish money for the family and so on. However, government support increases vulnerability of farmers at the time of climate change because the government of the Gambia due to high level of corruption and mismanagement of funds diverted the money mean to increases agriculture production by farmers and either used it personal gain.

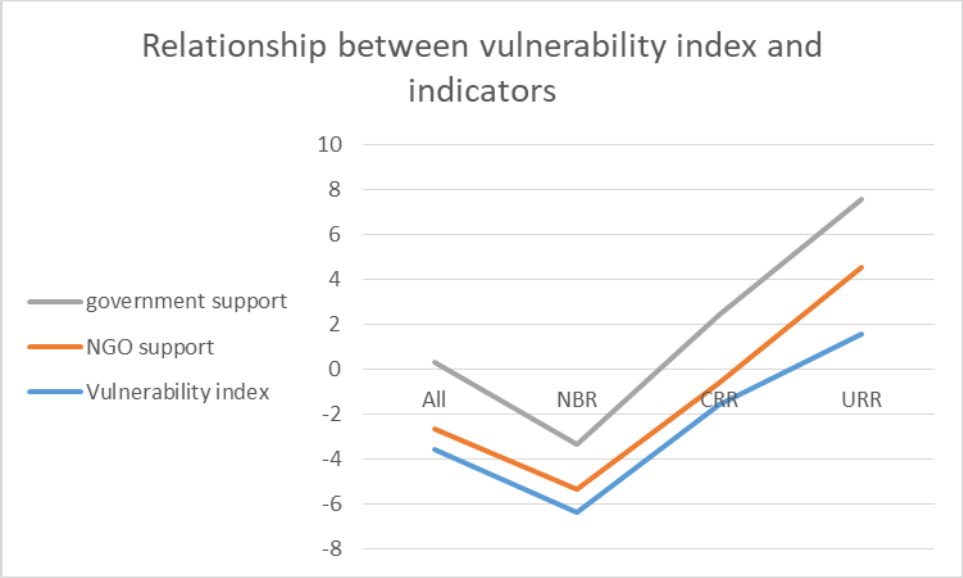


Figure 39: Relationship between Vulnerability index (VI) and indicators in the rural Gambia

Source: Own evaluation using excel

4.3.2.5. Conclusion and policy recommendation

Chapter three of the thesis examined the vulnerability across rural Gambian households and farmers to climate change by generating vulnerability components and vulnerability indices and comparing these indices across the three regions under study in The Gambia. The variables are classified into three vulnerability indicators as indicated in the IPPC: adaptive capacity, exposure, and sensitivity. Adaptive capacity is classified into socioeconomic attributes of vulnerability, and exposure and sensitivity are under the category of biophysical attributes. Further, exposure is a class of slow-onset climate change, and sensitivity is part of climate extremes such as floods and drought (see details in tables above).Thus, exposure and sensitivity are parts of environmental factors of vulnerability. Finally, the integrated vulnerability assessment approaches as indicator-based methods were adopted to join biophysical and socioeconomic vulnerability indicators. The socioeconomic factors classified into the adaptive capacity of vulnerability comprise age, size of the households, income, fertilizer, remittance received, farm size, secondary education completed, illiterate, stranded months, practicing livestock, caste system, access to credit, access to agriculture extension, food market, the share of irrigated land(potential irrigation proxy), and agriculture technology. The biophysical factors are classified into exposure and sensitivity, including changes in rainfall, changes in temperature, salt water intrusion, and access to water during drought, flood, and drought. The variables in each region are normalized using the mean and standard deviation. After the PCA method was employed, the vulnerability component and vulnerability index were finally constructed from the vulnerability indices constructed from the third Principal component and the normalized of each variable from each region and across regions. Vulnerability components and vulnerability index was calculated as the net result of sensitivity and exposure and adaptive capacity. Outcomes from vulnerability components and vulnerability index revealed that for vulnerability components individually, NBR, CRR, and URR are

uppermost vulnerable to change in climate. Since, exposure and sensitivity to change in climate affect these regions due to feeble adaptive capacity. The results for the vulnerability index summarized that NBR and CRR are vulnerable, and URR is less vulnerable to climate changes due to the more or fewer influences of climate extremes. This, of course, causes a decline in the livestock, animals, plant, and even income during floods. Finally, for VI, the selected rural regions are vulnerable to climate change. Poor institutions associated with poor human capita are the crucial cause of susceptibility to climate change in these regions. Hence in households surveyed, there may be some bias based on each region having different customs, cultures, traditions, macroeconomic factors, population growth rate, climate characteristics, infrastructure capability, governance structure, NGO support, government intervention, and community intervention. Therefore, the variation above based on socioeconomic characteristics and biophysical attributes should be considered to target which region is more vulnerable and which areas should be highly targetable to solve climate change impact at the region level, as demonstrated in objective three of the thesis. As the study clears the air of general futures of vulnerability in each region in the particular and combined region is generally in the rural Gambia. Future research in this kind of study should look at the district level of each region, the household levels, and the village level of each region or compare the region with another region by cross villages or cross-region, cross-district or cross-national variation of vulnerability to climate change. They will identify which region is more vulnerable and which is less vulnerable and which intervention should be placed in which region(s).Based on the analysis of the vulnerability situation in rural Gambia, vulnerability to climate change is synonymous with agriculture failures in the Gambia. If agriculture fails due to exposure and sensitivity to climate changes, hunger and food insecurity will rise, resulting in poverty and unachievable sustainable development goals. The intervention of poverty reduction should be a key goal for the government and development communities. Another vitally important thing climate change adaptation methods, as introduced by IPCC, should be implemented to increase adaptive capacity and reduces early exposure and sensitivity to change in climate such as variation in rainfall and variability in temperature with their associated changes in floods and drought.

Conclusion

The results found that agriculture has positive correlation with food security in the Gambia. Change in the average annual rainfall has significant and negative impact on food security. The GDP per capita has positive impact on food security in the first period lags and negative impacts on food security in the second period lags. Shocks to food security will require a slightly optimistic influence on agriculture sector in the short-run and considerably negative impact on the long-run. Food security shocks will also lead to poor agriculture in the long term. Food security and GDP per capita have unidirectional relationship. In addition, we concluded that climate shocks such as drought, excessive precipitation, and shifting in rainfall are major causes of international move. Households that received remittance are other major causes of migration large household size and less education also cause outmigration in the rural Gambia. Moreover, NGO support reduce climate change vulnerability by 82%. Government support increases vulnerability to climate change in the rural Gambia by 79%. Use more labor power machines increases climate vulnerability by 79%. Take insurance reduces vulnerability to climate by 94%. Migration of household members and changing in remittance increases vulnerability to climate change by 83% and 97% respectively. North Bank Region is highly vulnerable to climate change according to Vulnerability index. Overall rural Gambia is highly vulnerable to climate change. Lastly, Households size increases and changing in consumption increases and vulnerability decline. Households size squared increases and log consumption decline and vulnerability to poverty increases. Educational attainment increase changing in consumption and vulnerability reduces whereas educational attainment squared increases vulnerability. Flood, changes in rainfall and drought all increases vulnerability to poverty.

CHAPTER FIVE

4. GENERAL CONCLUSIONS, GENERAL POLICY IMPLICATIONS, GENERAL LIMITATIONS OF THE STUDY, AND GENERAL SUMMARY

4.1. General Conclusions

Climate change is becoming a major problem in the Gambia. It directly links food insecurity and migration, especially in rural areas. The consequence of climate change in the rural communities in the Gambia is that it increases the poverty and vulnerability of the households. This thesis evaluates the impacts of climate on migration and food security in rural Gambia. It looks at the extent to which the rural region(s) is/are highly vulnerable to climate change by exploring the vulnerability as expected poverty approaches and integrated assessment as indicators to measure vulnerability status across the regions. Agriculture and the service sector are the backbones of the economy of the Gambia. The major problems associated with it are the fluctuation of rainfall and changes in temperature patterns that affect the farmers' yields. In most countries in Africa in general and the Gambia in particular, we rest on rain-fed or subsistence farming for food security. Therefore, slow-onset change in climate such as variations in rainfall, variability in temperature, salt water intrusion, sea level rises, and climate extremes, e.g., floods and droughts and other variables, affect the rural Gambia communities and rapid migration. Though, many features contribute to agriculture's poor performance, including poor adaptive capacity, growth deficit, high exposure and sensitivity to climate variables, increasing lack of agriculture technology, access to credit and access to agriculture extension services, and dependence on imports prompt food insecurity. Many factors lead to migration, such as biophysical attributes of climate change, macroeconomics, and microeconomic migration theory. Lastly, many factors lead to vulnerability to poverty, such as expenditure on food, total household consumption, age, size of the households, income, illiteracy rate, caste system, ethnicity, flood, changes in rainfall and temperature, drought, own land, potential irrigation/share of irrigated land, NGO support, infrastructural support, institution, energy, farm size, practicing livestock, remittance received, agriculture technology, feeble adaptive capacity, feeble mitigation, and lack of coping mechanism. In the Gambia, there is a preliminary study on how climate changes affect agriculture, food security, and rapid migration. Furthermore, there is insufficient research on farmers' vulnerability at the household level and across regions. Moreover, the questionnaires asked households how climate change affects them now and in the future and how household characteristics fluctuated in their homes. The vulnerability and climate change variability that affect agriculture yields, rapid migration, and causes food insecurity are predictable to sustain further research. This is the key motivation of this thesis. The objectives are divided into three, which are as follows; Objective one discusses the links between climate changes, food security (proxy food availability). The results from the study found that growth in agriculture translated to growth in food security. The result further revealed that climate change decreases agriculture yield and causes a threat to the agriculture sector. Moreover, the annual growth of the population translated to food insecurity in the Gambia both in the short span and in the long span. Objective two: The impacts of food security on migration in rural Gambia. Climate change migration is becoming the most popular form in the rural Gambia. The study found that predominant drought causes migration, remittance received causes migration and food insecure causes migration. If the unit rises in drought, the probability of migration increases by 70 percent. Furthermore, salt intrusion, floods, changes in rainfall and heavier rainfall, and temperature changes do not cause migration in rural Gambia. When we used the individual region at a time, we found that predominant flood causes migration in the URR of the Gambia. The last objective: Vulnerability to poverty in households in rural Gambia and exposure to climate change across the rural regions. The results from the VEP at the household

level found that secondary education completion increased by 1 unit, and total consumption per capita per month declined. Employment on agriculture farms reduces total consumption expenditure. In the empirical results, household size, age, illiterate, and employment as farmers negatively affect consumption expenditure, and vulnerability to poverty rises. The study further elaborates that flood, drought, variation in rainfall, and temperature variations have an adverse and significant influence on consumption expenditure and vulnerability to poverty increases. However, the caste system harms changes in consumption expenditure and increases vulnerability to poverty. Furthermore, vulnerability across the regions state of the Gambia, the results from the Principal component analysis (PCA) found that NBR and all other regions have the lowest adaptive capacity and highest exposure and sensitivity, and vulnerability is extremely high. According to the result, URR is less vulnerable to climate change. Finally, across the areas', rural Gambia is highly vulnerable to change in climate.

General Summary

This thesis describes climate change, migration, and food security and highlights vulnerability to poverty and vulnerability to climate change at household and regional levels in the rural Gambia communities. Both quantitative tactics and qualitative tactics are applied in this thesis. The time series approaches the quantitative approaches, which covered objective one of the thesis and qualitative approaches by collecting primary data from households to households in each village and each region were collected to get first-hand information about how climate changes and other factors affect each household and across each region in the rural Gambia. The data from WDI was analyzed using time series VAR, GRANGER CASAULITY, ARDL, AND ECM approaches to see the endogenous variables depend on their lags as endogenous and other variables as endogenous. In the VAR model, no exogenous variables. The granger causality framework helps to understand how the dependent variables can predict the other variables by looking at the past values of the dependent variables on the explanatory variables. The ARDL helps to see the dynamic nature of the variable in the short period and in the long span to see the extent in which the independent variable will have a consequence on the dependent variable. Finally, the error correction can help to see the time of adjustment that will take the variables to return to equilibrium by looking at the shocks or consequences that affect that variable(s).In objective two, migration and food security and the results revealed that food security and major food crops have a positive and insignificant impact on migration response. In contrast, food security consumption level has an adverse and significant influence on household migration conditions. Total household food consumption has vital and optimistic coefficient influence on migration response. However, results further revealed flood, temperature change, and salt intrusion have a negative and significant effect on migration response except for the change in temperature, which has both negative and insignificant impacts. For instance, change in rainfall pattern, drought, and changes in rainfall, heavier rainfall has optimistic significant influence on migration response. Finally, regarding vulnerability to poverty and climate change, the result summarizes that employment as a farmer increases vulnerability and climate extreme and slow onset climate change shocks increase vulnerability by using vulnerability as expected poverty, i.e., an econometric measure of vulnerability. Using the Principal component analysis (PCA) and indicators-based or integrated assessment methods to classify vulnerability to change in climate into 3 main categories according to IPCC, i.e., exposure, sensitivity, and adaptive capacity. The vulnerability index (VI) was constructed to see the extent to which region is relatively more and less vulnerable than the rural Gambia to climate change. So as illustrated in figure 37 above, the NBR region has a vulnerability index of -6.369 - approximately, and the region is a relatively high vulnerability to change in climate. Nevertheless, in the NBR of the study areas, variations in rainfall and variations in temperature are negatively loaded, and other socio-economic characteristics are positively loaded. In the URR, the only region with positive VI, meaning that they are not vulnerable to climate changes and other household shocks based on VI, but when we calculated the components above, they are vulnerable to climate change. This is attributed to high temperature-extreme heat waves, water scarcity, river floods, and bushfire. In CRR, even due to the share of irrigated land (a proxy for potential irrigation), the VI is negative, and vulnerability to climate change and weather is high. The region with high food security is CRR. Still, this region's vulnerability to adaptive capacity is negative, which is why overall VI is negative, and vulnerability to climate change is high.

Finally, overall, in rural Gambia, according to the vulnerability indicators selected from vulnerability components in constructing the vulnerability index, we confirmed that the regions are vulnerable to change in climate and other indicators listed in table 42 and figure 37 below VI is equal to -3.6063.The vulnerability of the rural Gambia to climate change is due to many factors, including less adaptive capacity, strange dependence on the ecosystem for living, less agriculture technology, poor drainage system, changes in rainfall, water scarcity, bush fire, large family size, lower tertiary completion rate, lower life expectancy, poor market, and transportation system, insufficient food availability, high changes temperature, and rainfall changes causes damages to agriculture.

4.3. General Policy Implications

The policy intervention for climate change, economic growth, population growth, agriculture, and food availability must focus on building green trees forestry, which in turn can bring sufficient rainfall and that will translate to high agriculture yields and food security will follow through intervention by building fantastic store and food processing factory to reduce food waste and increases food preservation and reduces food import and fulfill the demand for food to be unable to feed the growing population and increases food export. Another essential policy intervention that encourages return migration or stops migration in the rural Gambia is training the youth about new businesses such as poultry farming, financial or bank saving planning, and provision of modern agriculture equipment.The experiment from experts and values will help across the regions that have new knowledge and training of a different kind of adaption method, and that will have to play a crucial role for social protection and causes agriculture experts to help farmers by new method of farming by agriculture extension services and access to credit will also add more adaptive capacity and intervention. Thus, experts' interviews and focus group discussion will better help to know which agriculture adaptation methods will help and better facilitate food self-sufficiency in rural Gambia. The poverty reduction intervention can be introduced to better bits of help which region is more vulnerable in terms of probability of future consumption and how to solve the policy intervention to that effect. However, different regions have different problems with which mode of adaption is lacking, which climate shock exposure, and which climate indicator is sensitive to vulnerability. Finally, IPCC, 2001 indicated that for the region to have sufficient food and reduces vulnerability to poverty and climate change, strong adaptation must be the main job.

4.4. General Limitations of the Study and Areas for Additional Research

This thesis has numerous and different limitations that need to be addressed by future researchers on climate change, migration, food security, and vulnerability study. The first limitation is that time series data results are biased and insufficient due to long data collection and compilation periods. Mainly, most of the indicators in the time series data have heterogeneity issues such as their quantity, the time duration for collecting the data, the transparency in disclosing the information, and the frequency of visiting and coming back to that country or region at exact point in time to see the extent in which climate change, food security, economic growth, population, and other variables are moving from one direction to another. That checking will help to solve the heterogeneity issues in the data set. Future research should also add more variables to understand the time series variation of climate change on food availability by considering the other pillars of food security. Moreover, for migration studies, future research should also consider internal migration and how food security impacts it. As the interaction between international migration, food security, and climate changes is crucial, future researchers in this chapter should add internal migration, internal displacement, and internal refugees to see the food security problems for the vulnerability to poverty using vulnerability as expected approaches a measure it. Due to the absence of panel data, cross-section variation is equal to inter-temporal variation, and in that still, many heteroskedasticity will appear in the future, The regional variation in terms of mean and the variances based on their social, economics, culture, and traditional setup. In that households, villages, and regions will have different shocks before and after, other political turmoil before and after, different climate issues before and after, and so on. The specific fixed effects results will help find the unobserved fixed effect problems, control the bias and inconsistency of the data, and balance the data.

The results will be better than a single cross-section study. It lacks sufficient evidence because the single cross-section study collects data from 1 month to a year, and equalizing it to many years will bring many discrepancies to the data set and household characteristics and regional variation in different indicators selected for the analysis. For example, studying vulnerability using indicators approaches and using single cross-section data will have inadequate information because different regions in the rural Gambia have different exposure, household variables characteristics, climates, and biophysical and social-economic attributes. Also, different regions, households, or communities have different scales of adaptation, different farm sizes, and different ways of practicing livestock farming, different caste system, and so on. The variation of the vulnerability index differs across the regions in the rural Gambia. The population for the three regions differs, the mode of adaptation also differs, the application also differs, and yield from agricultural produces differs after adaptation and food security level differ. Future research on this study must make some assumptions and tests for the data before running the model as we did in the study but may add factor analysis instead of principal component analysis or do both the factor analysis and Principal components analysis.

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APPENDICES

Appendix i: Questionnaires

Questionnaire of the Households Survey, Expert Interview and Focus Group Discussion Survey
Topic: Assessing the impacts of Climate change, migration dynamics and food security in rural Gambia

WASCAL PhD Program in Economics Science, specialist in Climate Change Economics.

Name: Ebrima K. Ceesay

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,,

Consent Seeking

Dear Households and FGD Participants,

You have been randomly designated to be share of this survey. The info you deliver will only be used to study about the connection amid climate change, Migration dynamics, vulnerability and food security. We need to understand how people respond when altering weather patterns affect their livelihood. The survey is part of my Ph.D. I am undertaking a dissertation at the Cheikh Anta Diop University Of Dakar, Senegal. If you agree to contribute, this household survey will take about 3 hours and will be accepted out today. We will ask questions about you, your household, and your members. The info you deliver is intimate and will

not be revealed to anyone. It will only be used for my Ph.D. research determinations. Your name and other private information will be substituted with a code that will be used to identify your responses without using your name. If you have any questions about this survey you may ask me straight.

Date……. Signature……

I. Interview information/Geographical location

Household ID:

Questionnaire number: _ _ _ _ _ Date of interview: _ _ _ / _ _ _ / _ _ _ (DD/MM/YY)

Data entry person: Name of Region; 1. NRB, 2, CRR, 3, URR

Data entry date: Name of interviewer:

Comments/Notes by the interviewer:

Name of Village:

Name of location (GPS-waypoint, if possible): Latitude _____ S and Longitude E ____

Time of interview: _ _: _ _ to _ _: _ _ (HH:MM)

Interviewee name (optional), sex and age:

Household ethnicity (s):

Religion:

Household mother tongue(s):

II. Personal and demographic information of the households

a) Respondent is the household head? 1) Yes 2) No,

b) if No, Relationship with household head----------

c) Number of people in the Households----------

d) Gender: 1) Male 2) Female

e) Age :

20-30	**30-40**	**40-50**	**50-60**	**61≥**

f) Marital Status

1. Single
2. Married
3. Window
4. Divorced

g) How many years of education have you completed?

1. 0-6 years of schooling 2. 0-9 years of schooling
3. 10-12 years of schooling 4. More than 12 years

h) Education attainment

1- Illiterate 2-Primary School
3- Middle School 4-High School
5- Above 12 years of schooling 6-Masters
7-Others (Diploma, etc.)

i) Migration type? 1) Seasonal 2) Temporal 3) in-migration 4)out-migration

j) Migration Status of the households? 1) Never migrated 2) current internal 3) current international 4) returned internal 5) returned international

k) Employment of household head category? 1= farmer (independent) 2= fisherman 3= cattle raiser 4= farm worker 5= road construction worker 6= construction worker 7= trade/retail 8= transport 9= household services 10= community services 11= student 12= unemployed 13= daily laborer 14= textile worker 15= other

l) Total household consumption per capital per month
1) 1000-5000 2) 5000-10000 3) 10000-15000 4) >15000

m) Total household income in Dalasi per capital per month
1) 1000-5000 2) 5000-10000 3) 10000-15000 4) >15000

n) Total household food consumption per capital per month
1) 1000-5000 2) 5000-10000 3) 10000-15000 4) >15000

q) Do you have caste system? 1) Yes 2) No.

r) Do you have Non-land production assets of the households 1) Yes 2) No?

s) Do you have irrigated land 1) Yes 2) No

III. Economic activities

A. Do you own land? 1. Yes 2. No

B. The land you owned, what is the size?

C. If yes, how do you use your own land? (multiple options possible)

1) Crops. production 2) Animal rearing 3) Forestry 4) Not planted

D. Do the households have access to water at the time of drought
1) Yes 2) No

E. Did rising sea level affect you farmland? 1) Yes 2) No

F. Do you own livestock? 1) Yes 2) No.

IV. Agriculture and Livelihood-related issues

1. Do household have access to credit?
   a) Yes b) No

2. Do your households receive infrastructural support
   a) Yes b) No
3. Whether the household has access to agricultural extension services or not
   a) Yes b) No

V. Climate change Variability

1) Did you observe changes in rainfall over the last 10-20 years, compare to the situation today (case by case)? Please explain
   a) Yes, please explain b) No
2) Did you observe changes in temperature over the last 10-20 years, compare to the situation today (case by case)? Please explain
   a) Yes, please explain b) No
3) In this place, have you experienced more drought or dry spells over the last 10-20 years than before?

a) Yes, a lot more b) Yes, more c) About the same as before d) No, less than before e) Did not exist at all

4) In this place, have you experienced more flood over the last 10-20 years than before?

a) Yes, a lot more b) Yes, more c) About the same as before d) No, less than before e) Did not exist at all

5) Have you experienced heavier rainfalls over the last 10-20 years?

a) Yes, a lot more b) Yes, more c) About the same as before d) No, less than before e) Did not exist at all

VI. Effect of changing rainfall on livelihood and food security

6) Is your household food secure or not?
   a) Yes b) No
7) What is your household food security consumption level a) high b) moderate c) low

To count for vulnerability assessment of the household

VII. Food Security, Consumption and Livelihood

8) What is the major food crop that you grow on your own?
List the crops…….
9) Do you produce food for your household consumption only
a) Yes b) No

10)Are there any month of the year where you regularly do not have enough food	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
a) Not enough money to buy food												

VIII. Coping and Adaptation strategies

23) If you ever had to rely on external help did you… (multiple options possible) a) Borrow money or food from other family members in the village b) Borrow money or food from neighbors/ friends in the village c) Get government support. If yes, please specify what kind.
d) Get NGO Support. If yes, please specify what kind….
25) Do you use fertilizer into your agriculture? a) Yes b) No
26) Which adaption modes do you practice?
27) Do you have bilateral aids or foreign aids/donors or aids 1) Yes 2) No

IX. Natural disasters and coping

26) What types of disasters affected your household in the last 12 months? (Check all that apply, if not affected skip)
a. Flood b. Drought c. Storm/wind/ excessive rain d. River erosion e. Cold wave f. bushfire g. None
27) What did you do to cope with this disaster? a. Sold productive assets b. Sold land c. Formal loan (bank, NGO) d. Adjusted food purchases/ meals e .Took a child out of school f. Migrated temporarily f. Other
28) Did bushfire affect your crops and livestock? a. Yes b. No
29) Total expenditure on crops…D……..

X. Migration Patterns of all the household members (Male and Female)

1. Do you have migrate
A) Yes B) No

XI. Migration and Remittance

1. Does your household currently (in the last 12 months) receive money from migrants (remittances)?
a) Yes b) No

Appendix ii:

Normalization before PCA
Vulnerability index for each region, Normalization of each variables using the mean and standard

Region	A	SH	SM	OWL	RR	FM	SE	LS	CR	CS	AT	SIL	CT	F
NBR	-4.4	−1.3	-20	-3.6	-0.3	-2.6	-0.6	-1.9	0	-2.4	-0.7	-0.2	0	-1.8
URR	-3.7	-1.7	-0.1	-1.7	-0.3	1.9	-0.8	-0.7	-11	-0.4	-0.1	-0.5	-5.7	-0.8
CRR	-4.1	-0.9	0	-2.8	-0.4	-5.7	-1.3	-1.2	-4	-0.7	-0.9	-0.6	-3.0	-1.3

deviation:$Z_i = \frac{x-\mu}{\sigma}$. Note $\mu = \bar{x}$

Own Evaluation. A: Age, SH: Size of the hh, OWL:Ownlands, RR: Remittance received. FM: Food Market, SE: Secondary Education, LS: Livestock, CR: Changes in rainfall, CS: Caste System, AT: Agriculture technologhy, SIL: Share of irrigated land, CT: Changes in temperature, F: Flood, SM: Stranded Month.

Appendix iii: Indices formula, boxplots and time series stationary graphs.

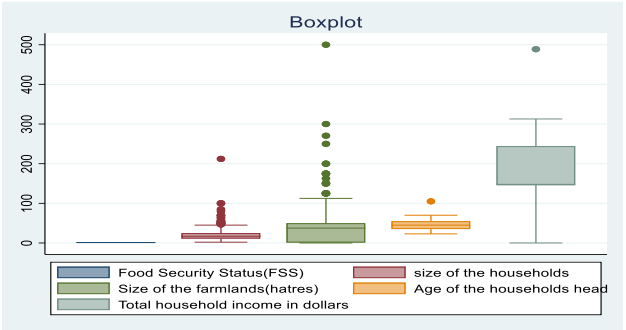
The index formula for a region j for indicator i is given by: $I_j = \sum_{i=1}^{k} w_i(b_{ij} - \bar{b}_i)/\sigma_{b_i}$

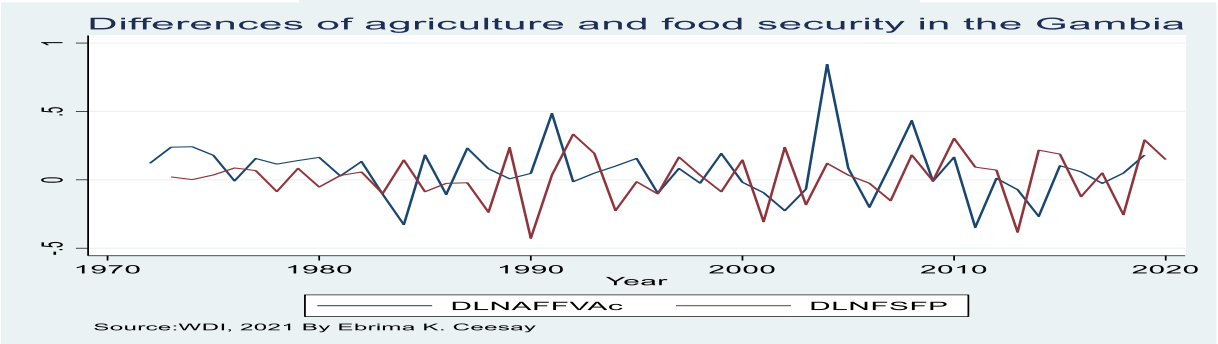
The index for Adaptive capacity of region j for the indicator i:$Ac_j = \sum_{i=1}^{k} w_i^{Ac}(b_{ij}^{Ac} - \bar{b}_i^{Ac})/\sigma_{b_i}$

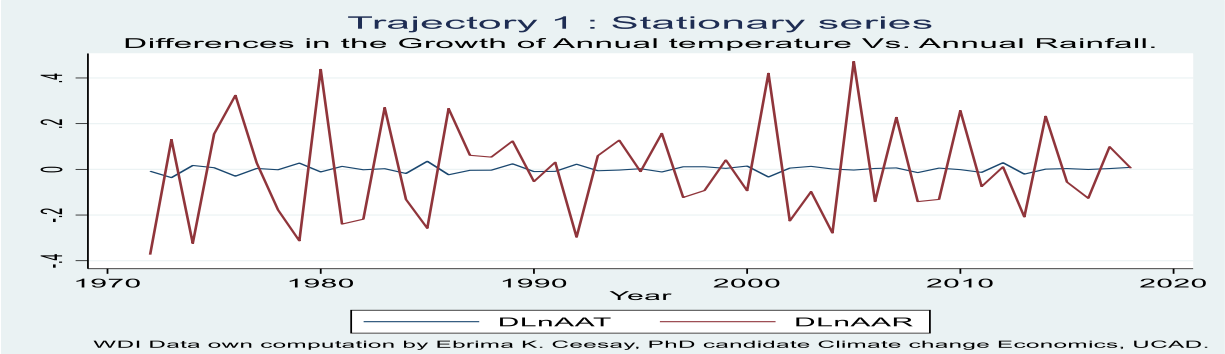
The index for exposure of region j for the indicator i:$Ex_j = \sum_{i=1}^{k} w_i^{Ex}(b_{ij}^{Ex} - \bar{b}_i^{Ex})/\sigma_{b_i}$

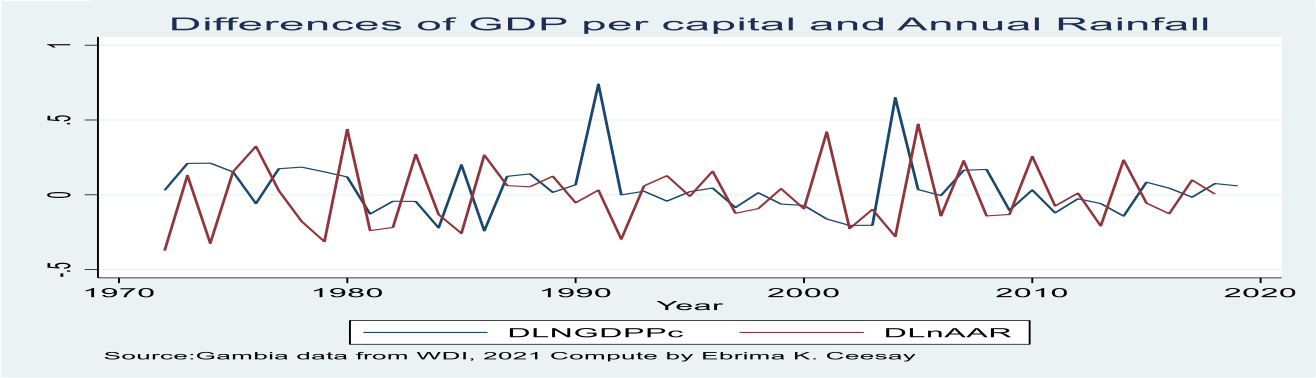
The index for sensitivity of region j for the indicator i:$S_j = \sum_{i=1}^{k} w_i^{S}(b_{ij}^{S} - \bar{b}_i^{S})/\sigma_{b_i}$

$$\text{Vulnerability index} = \text{VI} = \sum_{i=1}^{k}\left[\frac{w_i^{Ac}\left(b_{ij}^{Ac} - \bar{b}_i^{Ac}\right)}{\sigma_{b_i}} - \left(\frac{w_i^{Ex}\left(b_{ij}^{Ex} - \bar{b}_i^{Ex}\right)}{\sigma_{b_i}} + \frac{w_i^{S}\left(b_{ij}^{S} - \bar{b}_i^{S}\right)}{\sigma_{b_i}}\right)\right]$$

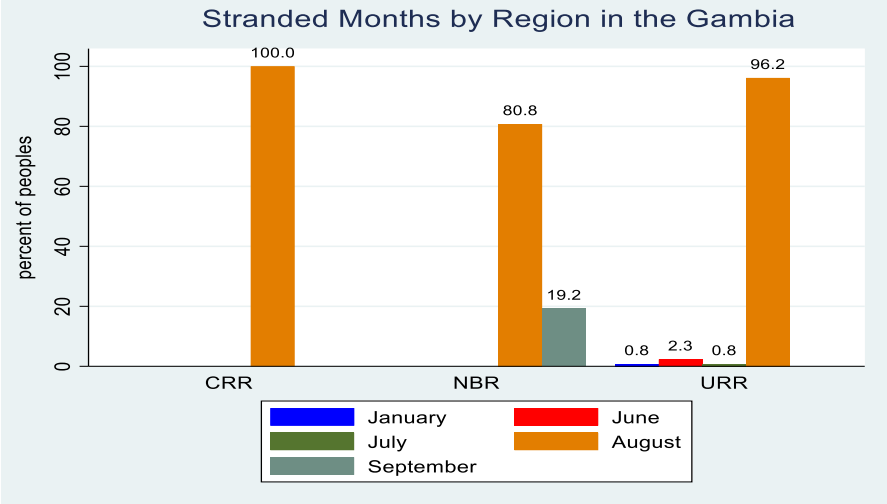


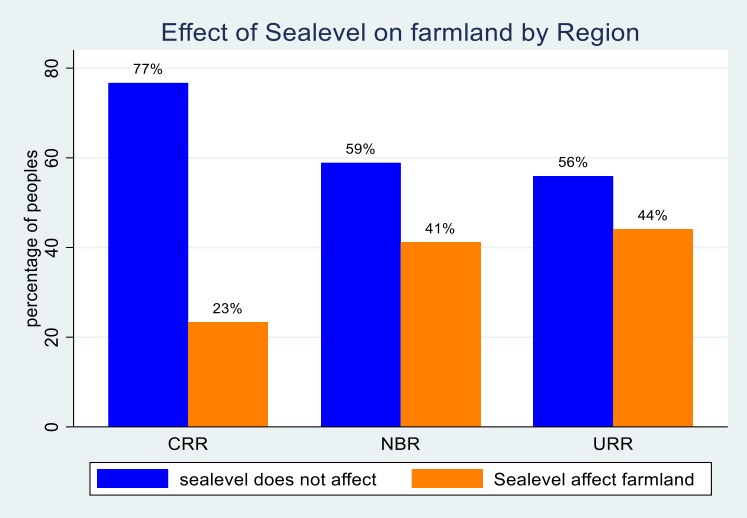


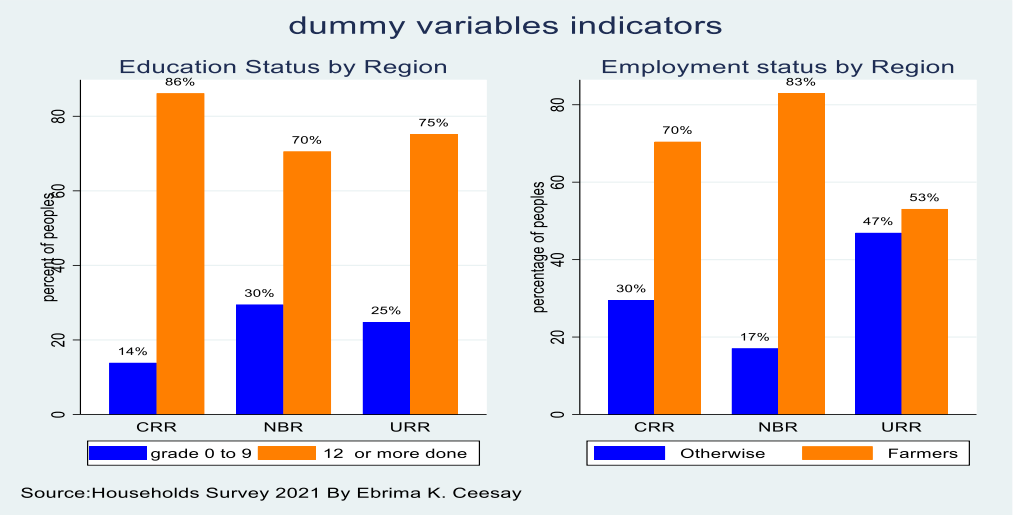




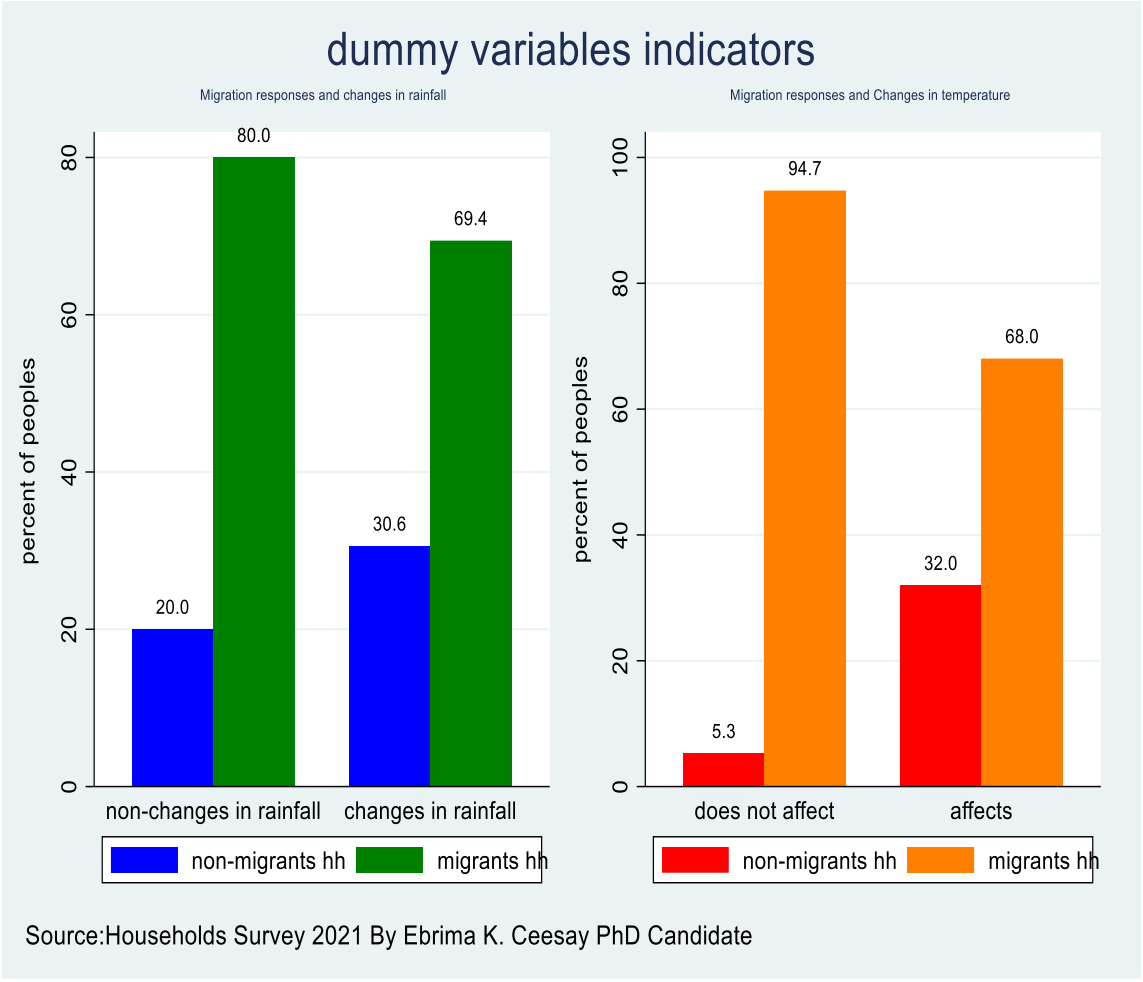
Appendix iv: Boxplot and time series graphs



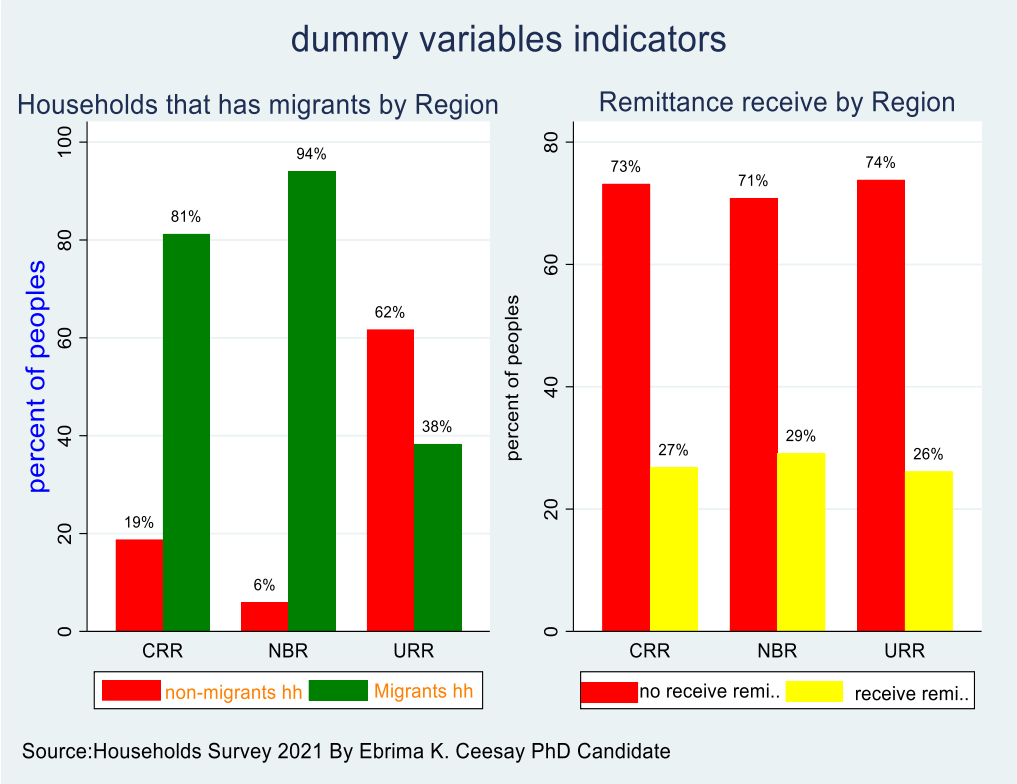




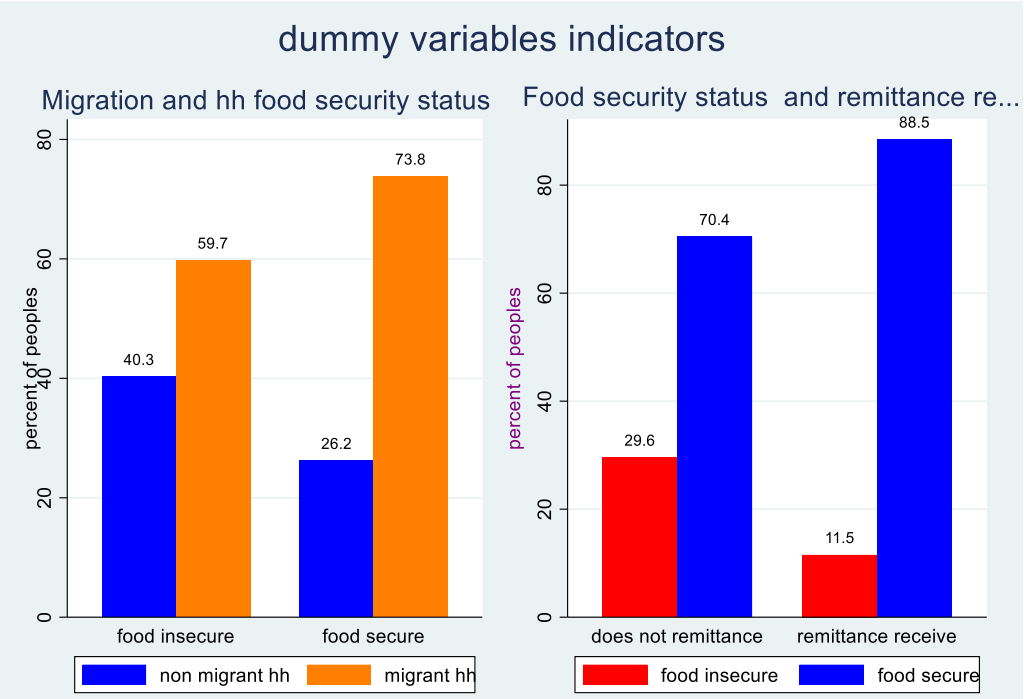
Source:Households Survey 2021 By Ebrima K. Ceesay



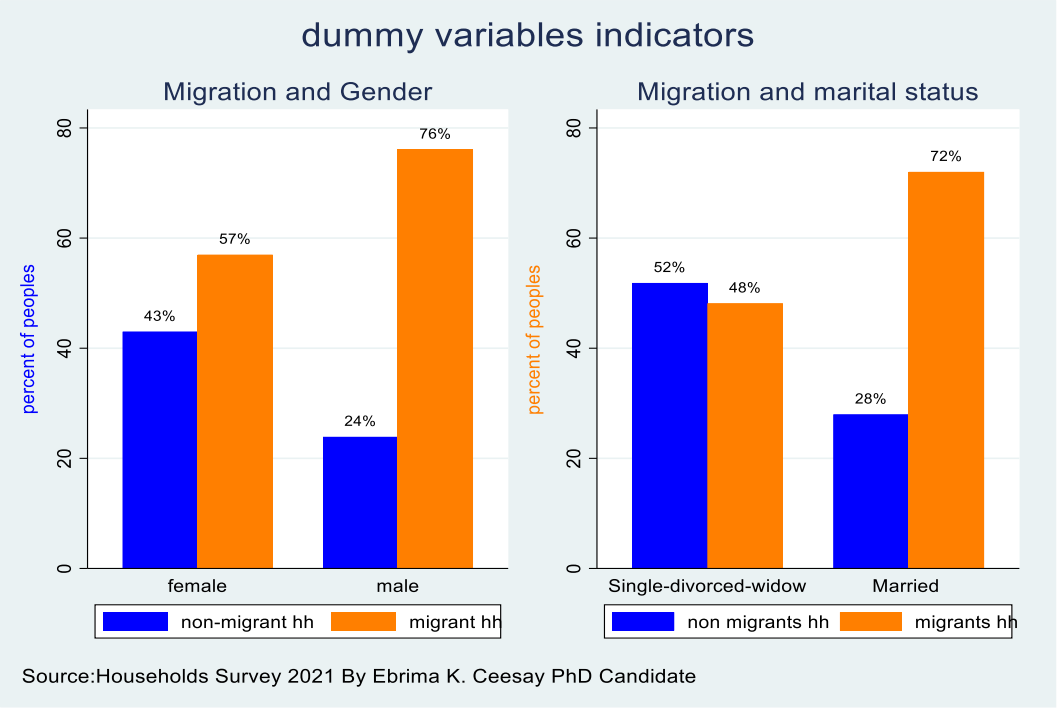
Source:Households Survey 2021 By Ebrima K. Ceesay PhD Candidate



Source:Households Survey 2021 By Ebrima K. Ceesay PhD Candidate



Source:Households Survey 2021 By Ebrima K. Ceesay PhD Candidate



Own evaluation using stata 16.

Appendix v: Descriptive Statistic Graphs