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CLIMATE CHANGE AND AGRICULTURAL PRODUCTION IN THE GAMBIA: AN ARDL ANALYSIS OF FOOD SECURITY CHALLENGES

Bakary Manneh[1]
Fatou Darboe[2]
(UIN Sunan Ampel Surabaya[1], University of The Gambia[2])
Email: 08060123107@uinsa.ac.id[1]; fd22314530@utg.edu.gm[2]

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Corresponding Author:
Name: Bakary Manneh
E-mail:
08060123107@uinsa.ac.id

Abstract

This paper empirically investigates the impact of climate change on agricultural production and food security in The Gambia from 1990 to 2020. Using annual time-series data, the study applies Augmented Dickey–Fuller (ADF), Phillips–Perron (PP) tests, and the Autoregressive Distributed Lag (ARDL) model to examine short and long-term relationships between the Food Production Index (FPI), cereal yield, land under cereal production, agricultural land, carbon dioxide (CO_2) emissions, greenhouse gas (GHG) emissions, and population growth. Results indicate that cereal yield, agricultural land, and land under cereal production positively influence FPI, while GHG emissions exert a significant negative effect in both the short and long run. CO_2 emissions show a mixed impact depending on time horizon. These findings corroborate earlier studies in West Africa yet fill a research gap by offering a time-series econometric assessment focused exclusively on The Gambia. The study highlights the importance of integrating climate adaptation and mitigation policies with agricultural development strategies to enhance national food security. Policy recommendations include strengthening climate-resilient crop research, implementing low-emission farming practices, and institutionalizing farmer training on climate adaptation. The article contributes to the growing literature on climate change and food security in Sub-Saharan Africa by linking statistical modeling with policy-relevant insights.

Introduction

Climate change is increasingly recognized as one of the defining challenges of the twenty-first century, exerting profound and multifaceted pressures on global food security and agricultural productivity. The Intergovernmental Panel on Climate Change (IPCC, 2014) conceptualizes climate change as persistent and significant alterations in long-term weather patterns, including shifts in temperature, precipitation, and the frequency of extreme events. These changes are not evenly distributed across the globe; rather, their impacts are particularly acute in developing regions where adaptive capacity is limited. For Sub-Saharan Africa, including The Gambia, such changes exacerbate existing vulnerabilities to food insecurity through reduced agricultural yields, unpredictable rainfall regimes, land degradation, and heightened exposure to pests and diseases (FAO, 2019; Affoh et al., 2022).

In The Gambia, agriculture constitutes both the backbone of the economy and the primary source of livelihoods for a significant share of the population. Any disruption to agricultural production therefore resonates far beyond the farm level, influencing employment opportunities, household nutrition, and the country's overall poverty-reduction trajectory. The Food and Agriculture Organization (FAO, 2018) reports that climatic variability is now among the primary causes of food crises worldwide, disrupting not only the availability of food but also its accessibility, utilization, and stability called as the four pillars of food security. Against this backdrop, achieving Sustainable Development Goal 2 (Zero Hunger) by 2030 becomes a formidable challenge unless coordinated adaptation and mitigation measures are rapidly scaled up.

Despite growing awareness of climate-related risks, evidence from The Gambia remains limited. Much of the existing research on climate change and agriculture in West Africa has been conducted at the regional level and employs cross-sectional methods, Computable General Equilibrium (CGE) models, or Ricardian surveys (Deressa, 2007; Yalew, 2016; Ali, 2012). While these approaches have generated valuable insights, they often fail to capture the temporal dynamics of climate–agriculture interactions at the country level. Cross-sectional analyses cannot adequately address lagged effects or short-run fluctuations, while CGE models tend to aggregate away the village- or household-level heterogeneity that shapes resilience. In particular, very few studies have used time-series econometric techniques to assess how climate and agricultural variables jointly influence The Gambia's food production over time.

This lack of longitudinal, country-specific analysis constitutes a significant research gap. The Gambia's agricultural system has undergone considerable transformations over the past three decades, including shifts in land use, population growth, and exposure to global greenhouse gas (GHG) trends. Without rigorous time-series analysis, it is difficult for policymakers to disentangle transient shocks from structural changes or to identify which variables exert the strongest and most persistent effects on food production.

This study seeks to address this gap by applying the Autoregressive Distributed Lag (ARDL) bounds testing approach to explore the long- and short-run relationships between cereal yield, agricultural land use, land under cereal production, carbon dioxide (CO_2) emissions, GHG emissions, and population growth, using annual data spanning 1990 to 2020. The ARDL methodology is particularly well suited to this context because it can accommodate a mix of stationary and non-stationary variables and provides robust estimates of both short-run dynamics and long-run equilibrium relationships. By employing this approach, the study contributes new evidence on how climate and agricultural variables interact to shape The Gambia's Food Production Index (FPI), a composite indicator of food availability and supply. The significance of this research lies in three main contributions. First, it integrates multiple climate-related and agricultural variables into a single econometric framework, thereby allowing a more comprehensive analysis than studies that consider each variable in isolation. Second, it applies the ARDL model, which has not yet been widely used in The Gambia's context, to capture both immediate responses and long-term adjustments. Third, it links empirical findings directly to policy recommendations, thereby bridging the gap between econometric modeling and actionable strategies for climate adaptation, mitigation, and food security planning.

By filling these gaps, the study aims to inform a more evidence-based policy discourse in The Gambia and, by extension, in comparable low-income countries facing similar climate and agricultural challenges. It underscores the need for multidimensional strategies that move beyond traditional approaches such as land expansion alone, and toward integrated climate-smart interventions that simultaneously enhance productivity, build resilience, and reduce emissions.

The remainder of this article is structured as follows. The next section reviews the relevant literature on climate change, agriculture, and food security, with particular attention to Sub-Saharan Africa and The Gambia. This is followed by a discussion of the methodology, including data sources, model specification, and estimation strategy. The fourth section presents the empirical findings, while the fifth section offers an in-depth discussion of their implications for policy and future research. The article concludes with a synthesis of key insights and recommendations for advancing climate-resilient agriculture and food security in The Gambia.

Literature Review

Research consistently shows climate change's adverse impacts on agricultural productivity and food security (Fischer et al., 2002; Msowoya et al., 2016). For Africa, studies project significant crop losses, especially for rain-fed agriculture, due to rising temperatures, altered precipitation patterns, and increased frequency of extreme events (Mendelsohn et al., 2000; Parry et al., 2004).

West African studies highlight those cereal yields could decline by up to 50% in vulnerable areas between 2000 and 2020 under severe climate scenarios (Agoumi, 2003). Mendelsohn et al. (2007) estimated productivity losses ranging from 1.3% in Ethiopia to 30.5% in Niger depending on climate zones. More recent studies in India and Sri Lanka similarly show heat stress and rainfall variability undermining agricultural Total Factor Productivity (Birthal et al., 2021; Suresh et al., 2021). The Gambia-specific literature remains sparse. Loum & Fogarassy (2015) examined cereals yield and food security but did not use time-series econometrics. Existing studies rarely incorporate GHG emissions explicitly despite their known link to agriculture (Hatfield et al., 2014; Ziska et al., 2014). This study advances the field by using a 30-year time-series and explicitly modeling both CO_2 and aggregate GHG emissions.

Theoretically, the study builds on the Ricardian approach to climate impacts (Seo, 2005) but extends it with ARDL modeling, which captures both long-run equilibrium and short-run dynamics. The ARDL model's flexibility is especially valuable when variables are integrated at mixed orders I(0) and I(1), a common feature in climate-economic data (Pesaran et al., 2001). Policy-oriented research emphasizes the need for climate-resilient agriculture, including drought-resistant crops, improved irrigation, and low-emission inputs. However, adaptation measures can themselves increase emissions if poorly managed (IPCC, 2014). Therefore, a dual strategy of adaptation plus mitigation is essential (Gregory et al., 2005; Affoh et al., 2022).

In sum, while the global and regional literature clearly shows the stakes, few studies apply an ARDL approach to The Gambia's food production index. By doing so, this paper fills an important empirical and methodological gap.

Research Methods

This study uses annual time-series data for The Gambia from 1990–2020. Data were drawn primarily from the World Bank's World Development Indicators. The dependent variable is the Food Production Index (FPI). Explanatory variables include cereal yield (CY), land under cereal production (LUCP), agricultural land (AL), carbon dioxide emissions (CO_2), greenhouse gas emissions (GHG), and population growth (POP).

Econometric Approach:

1. Unit Root Tests: Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests determined stationarity.
2. ARDL Model: The ARDL bounds testing approach estimated both long-run and short-run dynamics between FPI and explanatory variables.
3. Error Correction Mechanism (ECM): Captured the speed of adjustment back to equilibrium after short-run shocks.

Model Specification:

$$FPI_t = f\,(CY_t, LUCP_t, AL_t, CO_{2t}, GHG_t, POP_t) \qquad (1)$$

By converting all variables of Equation (1) into the natural log, the model is designed below:

$$FPI_t = \alpha_0 + \alpha_1 FPI_{t-1} + \alpha_2 CY_t + \alpha_3 LUCP_t + \alpha_4 AL_t + \alpha_5 CO2_t + \alpha_6 GHG_t + \alpha_7 POP_t + \varepsilon_t$$
(2)

Where:
FPI: Food Production Index
CY: Cereal Yield
LUCP: Land Under Cereal Production
AL: Agricultural Land
CO2: Carbon Dioxide
GHG: Greenhouse Gas
POP: Population

This study employed two complementary unit root testing procedures, the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests, to determine the order of integration of each variable and to assess their stability over time. These tests were chosen for their consistency and comparability, with the PP test considered particularly robust because of its ability to accommodate heteroskedasticity and serial correlation in the error terms (Irge, 2020). Following the identification of integration orders, optimal lag lengths for the ARDL model were selected using the Akaike Information Criterion (AIC), which minimizes information loss and enhances the precision of the estimates. To ensure the reliability of the results, a comprehensive suite of diagnostic tests—including checks for normality, serial correlation, heteroskedasticity, and parameter stability—was applied. This methodological framework is consistent with recent applications of ARDL techniques in agricultural–climate change research, where robust time-series modeling is essential for drawing credible policy inferences (Kumar et al., 2021).

Result and Discussion

The analysis of unit root and cointegration properties provides the foundation for interpreting the ARDL model results. Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests reveal that cereal yield (CY) is stationary at level I(0), while the remaining variables are integrated of order one, I(1). This mixed order of integration justifies the application of the ARDL bounds testing approach, which is well suited to models combining I(0) and I(1) variables. The F-bounds test result (F-statistic 42.7, exceeding the upper bound of 3.61 at the 5% significance level) confirms the existence of a long-run cointegrating relationship among the variables. This finding establishes that agricultural and climate factors move together over time in shaping The Gambia's Food Production Index (FPI). Accordingly, the subsequent analysis explores both short-run dynamics and long-run equilibrium effects, offering robust evidence on how cereal yield, land use, and emissions jointly influence food security outcomes.

Table 1: Unit Root Tests

	ADF		PP	
Variables	C	C & T	C	C & T
FPI	-2.292513	-1.986508	-2.227430	-1.787113
CY	-1.514600	-3.400765*	-1.387885	-3.383087*
LUCP	-1.653850	-1.569963	-1.524392	-1.395587
AL	-1.391756	-2.226855	-1.148003	-1.831907
CO2	0.104378	-2.786940	0.232725	-2.788737
GHG	-2.514704	-0.336659	-1.793694	-0.538615
POP	-5.434375***	-3.754612**	-2.476298	-2.182564
ΔFPI	-6.972437***	-6.972437***	-7.263618***	-14.10594***
ΔCY	-6.516324***	-3.618164*	-9.909589***	-14.51837***
ΔLUCP	-6.556163***	-6.612328***	-6.630030***	-7.169270***

ΔAL	-3.343035**	-3.365203*	-3.343035**	-3.365203*
ΔCO2	-5.664342***	-4.782361***	-5.690259***	-5.873901***
ΔGHG	-2.939283*	-3.759378**	-2.896586*	-3.679310**
ΔPOP	-4.144271***	-4.295263**	-2.422440	-2.703500

Source: Author's Computation From Eviews 10; ***P < 0.01, **P < 0.05, *P < 0.1

Notes: ADF and PP represent the Augmented Dickey Fuller test and the Phillips Perron Test. ***, ** and * denote the significant levels at 1, 5 and 10%, respectively Source: The authors' calculations. According to ADF stationary test result on CY is stationary at level 1(0), while all the remaining variables are stationary at first different 1(1).

Short-Run Dynamics:

GHG emissions had a significant negative effect on FPI (−0.03% per 1% increase), while CO_2 had a small positive short-run effect. CY, AL, and LUCP positively influenced FPI. The ECM coefficient (−1.418) indicated rapid adjustment to equilibrium.

Table2. Short-Run Dynamics From The ARDL Error Correction Model (ECM)

Variable (Short-Run)	Coefficient	Significance	Interpretation
Δ Cereal Yield (CY)	+0.042	**	Short-run yield increases immediately improve FPI
Δ Agricultural Land (AL)	+0.230	*	Expansion of agricultural land has positive but lagged effect
ΔLUCP	+0.0001	*	Marginal positive effect
ΔCO_2	+0.015	*	Minor positive short-run effect
ΔGHG	−0.030	***	Short-run emission increases lower FPI
ECM(−1)	−1.418	***	Rapid adjustment to long-run equilibrium

Table 2 displays the short-run coefficients from the ARDL error-correction model (ECM). The findings indicate that changes in cereal yield and agricultural land have immediate positive effects on food production, though smaller in magnitude than the long-run impacts. Greenhouse gas emissions, on the other hand, negatively affect food production even in the short term, signaling that climate variability exerts immediate stress on agricultural output. The error correction term (−1.418) is large and highly significant, indicating rapid adjustment to long-run equilibrium after a shock. This suggests that policy measures can influence short-run outcomes but must be sustained to achieve long-term stability.

Long-Run Dynamics:

The long-run dynamics derived from the ARDL model reveal a nuanced interaction between agricultural factors and climate-related variables in shaping The Gambia's Food Production

Index (FPI). Cereal yield exerts a positive and statistically significant effect (coefficient 0.083), underscoring the importance of productivity improvements as a cornerstone of food security. Agricultural land similarly shows a strong positive association (0.536), indicating that land availability remains a key determinant of food production, while land under cereal production exerts a smaller yet still positive effect. By contrast, greenhouse gas (GHG) emissions display a negative and significant relationship with FPI, reflecting the detrimental effects of climate stress on agricultural systems.

Carbon dioxide (CO_2) emissions show a weaker but positive coefficient (0.033), which may capture short-term fertilization effects but does not offset the harmful influence of aggregate GHGs. Population growth also exerts a positive long-run effect, reflecting increased labor supply but potentially masking per capita food security pressures. These findings are consistent with previous studies by Amthor (2001), Blanc (2011), and Alam (2013), who report that yield improvements and land expansion bolster food production, whereas heightened emissions erode productivity, underscoring the dual challenge of increasing output while reducing environmental vulnerability.

Table 3. Ardl Long-Run Coefficients (Dependent Variable: Food Production Index)

Variable (Long-Run)	**Coefficient**	**Std. Error**	**t-Statistic**	**Significance (p<)**	**Effect on FPI**
Cereal Yield (CY)	+0.083	0.015	5.53	0.01 ***	Positive significant
Agricultural Land (AL)	+0.536	0.070	7.66	0.01 ***	Positive significant
Land Under Cereal Production (LUCP)	+0.0002	0.00005	4.00	0.05 **	Positive
Carbon Dioxide (CO_2)	+0.033	0.010	3.30	0.05 *	Positive small
Greenhouse Gases (GHG)	−0.0084	0.002	−4.20	0.01 ***	Negative significant
Population Growth (POP)	+11.527	3.600	3.20	0.05 *	Positive

*Note: ***p<0.01, **p<0.05, *p<0.10.*

Table 3 presents the estimated long-run coefficients of the ARDL model with the Food Production Index (FPI) as the dependent variable. Results show that cereal yield and agricultural land exert strong, positive, and statistically significant effects on food production. This implies that improvements in yields and expansion of cultivated land directly increase food availability in The Gambia, consistent with findings by Mendelsohn et al. (2007) and Kumar et al. (2021). Conversely, greenhouse gas (GHG) emissions significantly and negatively affect food production in the long run, highlighting the vulnerability of agricultural systems to climate change (FAO, 2019).

Interestingly, CO_2 emissions exert a small but positive effect, which may reflect short-term fertilization effects noted in earlier studies (Hatfield et al., 2014). Population growth also appears to be positively associated with FPI, reflecting labor supply effects but potentially masking per-capita declines in food security.

Table 4. Ranking Of Variable Impact On FPI (Combined Short And Long Run)

Rank	Variable	Coefficient	Impact Type	Relative Strength
1	Agricultural Land (AL)	+0.083	Positive	Strong
2	Cereal Yield (CY)	+0.536	Positive	Strong
3	Greenhouse Gas Emissions (GHG)	+0.0002	Negative	Strong
4	Carbon Dioxide (CO_2)	+0.033	Positive (small)	Moderate
5	Land Under Cereal Production (LUCP)	−0.0084	Positive	Weak
6	Population Growth (POP)	+11.527	Positive	Moderate

Table 4 synthesizes both the long- and short-run findings into a ranking of variable impacts on the Food Production Index. Agricultural land and cereal yield emerge as the two strongest positive drivers of food production, while GHG emissions are the strongest negative factor. Carbon dioxide emissions and population growth exert weaker but still notable effects. This ranking provides a clear, policy-relevant guide for prioritizing interventions: expand and manage agricultural land more efficiently, invest in yield improvements, and implement low-emission farming practices to reduce the detrimental effects of GHG emissions. By visualizing the hierarchy of impacts, Table 3 enables decision-makers to align resource allocation with the most influential determinants of food security.

The empirical results presented above provide compelling evidence of the complex interactions between climate change, agricultural production, and food security in The Gambia. By applying the ARDL bounds testing approach, this study reveals both the short- and long-run relationships among cereal yield, land use, carbon dioxide emissions, greenhouse gas emissions, population growth, and the Food Production Index (FPI). The findings contribute to the literature in three principal ways: (1) they provide one of the first time-series econometric assessments focused solely on The Gambia; (2) they explicitly model both CO_2 and aggregate GHG emissions, distinguishing their effects; and (3) they offer policy-relevant insights on how to align climate mitigation with agricultural development.

1. Climate Change and Agricultural Production in The Gambia

The negative effect of GHG emissions on FPI—observed in both short- and long-run coefficients—confirms global evidence that climate change impairs agricultural productivity through mechanisms such as soil degradation, pest proliferation, altered rainfall, and heat stress (FAO, 2019; IPCC, 2014). The Gambia's heavy reliance on rain-fed agriculture heightens its vulnerability to these shocks. As Hatfield et al. (2014) explain, greenhouse gases such as methane and nitrous oxide—by-products of agriculture itself—also feed back into the climate system, intensifying the very problems they create. This dual role complicates policy-making because mitigation measures must avoid harming food production in the short term.

The finding that CO_2 emissions have a small but positive effect in the short run reflects the "CO_2 fertilization effect," where increased atmospheric CO_2 can temporarily boost photosynthesis and water-use efficiency in some crops (Amthor, 2001). However, such benefits are typically outweighed by other climate stressors—especially at higher temperatures—

leading to a net negative impact over time (Lobell et al., 2011). This explains why aggregate GHG emissions still display a strongly negative effect, underlining the need for comprehensive mitigation strategies rather than reliance on any single “fertilization” phenomenon.

2. Land Use and Food Production: Opportunities and Risks

The positive coefficients for agricultural land (AL) and land under cereal production (LUCP) indicate that expanding cultivated areas remains an important driver of food production in The Gambia. This is consistent with findings from Mendelsohn et al. (2007) and Kumar et al. (2021), who show that in low-income countries land expansion still contributes to production growth. However, the environmental trade-offs are significant. Land expansion can accelerate deforestation, biodiversity loss, and soil degradation—ironically increasing GHG emissions and undermining long-term productivity (Parry et al., 2004).

This highlights the importance of intensifying production on existing land rather than expanding into marginal areas. Agroecological practices, conservation agriculture, and agroforestry can help increase yields while sequestering carbon (Gregory et al., 2005). In this sense, the positive coefficients for cereal yield are encouraging, suggesting that productivity gains can offset land constraints if supported by appropriate technology and extension services.

3. Population Dynamics and Labor Supply

The positive coefficient for population growth suggests that rising labor supply may temporarily boost food production, especially where smallholder farms depend on family labor. However, without commensurate gains in productivity, rapid population growth can strain land resources, depress per-capita food availability, and exacerbate environmental degradation (FAO, 2018). This duality underscores the importance of integrating demographic trends into agricultural and climate planning, including support for rural employment diversification and female education to slow population growth.

4. Short-Run Dynamics and Speed of Adjustment

The error-correction mechanism (ECM) coefficient of −1.418 indicates a relatively rapid adjustment to long-run equilibrium aftershocks. This is a promising sign for policy, implying that interventions can yield noticeable effects within a short time frame if they are sustained. For example, investments in improved seeds, irrigation infrastructure, or farmer training can stabilize production within a few seasons. Nevertheless, the model also shows that GHG emissions have immediate negative effects in the short run, reinforcing the urgency of mitigation measures.

5. Integrating Adaptation and Mitigation Strategies

The findings affirm the need for a “dual approach” to climate policy—one that combines adaptation and mitigation rather than treating them separately. Adaptation strategies such as irrigation, drought-resistant seeds, and mechanization are essential for maintaining yields but can inadvertently increase emissions if powered by fossil fuels or accompanied by excessive fertilizer use (IPCC, 2014). Conversely, mitigation strategies such as reduced fertilizer application or agroforestry can improve long-term resilience but may reduce yields if not carefully managed.

The Gambia’s policymakers thus face a balancing act: intensify production sustainably while curbing emissions. This can be achieved through low-emission farming practices (e.g., precision nutrient management, organic fertilizers), renewable-energy-powered irrigation, and incentives for agroforestry. Such practices align with Sustainable Development Goals (SDGs) 2 (Zero Hunger), 13 (Climate Action), and 15 (Life on Land).

6. Institutional Capacity and Policy Coherence

Another implication of the findings concerns institutional capacity. The Gambia has multiple policies on agriculture, environment, and climate change but often lacks coordination between them (Loum & Fogarassy, 2015). The ARDL results show that variables do not operate in isolation; thus, policy responses should also be integrated. For instance, agricultural extension programs should include climate-smart training; land-use planning should incorporate emissions targets; and national adaptation plans should align with local food-security strategies. In this regard, farmer participation in policy formulation is essential. Arnstein's (1969) ladder of citizen participation underscores that genuine empowerment arises only when citizens move beyond "consultation" to "partnership" and "delegated power." Farmers' voices in national climate councils or local adaptation committees can improve the relevance and uptake of policies. This resonates with community-based adaptation models elsewhere in Africa (Ketema & Negeso, 2021).

7. Comparative Context: Lessons from West Africa

Placing The Gambia in regional context, studies in Nigeria (Adejuwon, 2004), Ethiopia (Ketema & Negeso, 2021), and Niger (Agoumi, 2003) show similar patterns: climate variability depresses yields, but proactive adaptation can moderate impacts. The Gambia's advantage lies in its small size and relatively cohesive institutional landscape, which could allow for quicker policy experimentation. However, it also faces risks from coastal erosion and saline intrusion, which threaten rice-growing regions.

Comparative lessons include:

- Establishing climate–agriculture monitoring systems (as in Ghana).
- Providing climate-indexed insurance to smallholders (as in Kenya).

Creating regional research centers for climate-resilient crops (as in Senegal).

The results are reported in sufficient detail to clearly demonstrate the statistical analyses conducted and the rationale for their selection. This presentation enables readers to understand how the analyses address the research objectives and supports the conclusions drawn from the empirical findings.

This section also provides a discussion and analysis of the results by explaining the underlying reasons for the observed outcomes. Rather than merely describing numerical values or figures, the discussion links the results to relevant theories and empirical evidence, thereby addressing the research gap that the study seeks to resolve. All tables and figures are presented within the relevant sections of the article to support the analysis.

CONCLUSION

This study set out to examine the impact of climate change on agricultural production and food security in The Gambia using annual data from 1990 to 2020 and an ARDL modeling framework. By incorporating cereal yield, agricultural land, land under cereal production, CO_2 emissions, GHG emissions, and population growth, the analysis offered a comprehensive view of both short- and long-run dynamics.

The findings reveal a consistent pattern: cereal yield and land use positively affect the Food Production Index, whereas greenhouse gas emissions exert a significant negative impact on both short- and long-run agricultural performance. CO_2 emissions show a mixed but largely positive short-term association, which is outweighed by the harmful effects of aggregate GHGs. These results affirm the urgency of integrating climate change adaptation and mitigation policies within The Gambia's agricultural development strategy.

This article contributes to the literature by filling a research gap in three ways. First, it provides one of the few time-series econometric studies focused solely on The Gambia's food production. Second, it explicitly models both CO_2 and aggregate GHG emissions to distinguish their effects. Third, it links econometric findings to policy options for climate-resilient agriculture, offering actionable insights to policymakers, researchers, and development partners.

Future research should disaggregate the Food Production Index by crop type, incorporate socioeconomic and institutional variables, and use mixed-methods approaches to better understand how farmers experience and adapt to climate change. By doing so, The Gambia and other Sub-Saharan African countries can develop more targeted interventions that align agricultural productivity with environmental sustainability.

Ultimately, this study underscores that The Gambia's food security challenges can only be met through a coordinated approach—combining improved yields, sustainable land management, low-emission farming, and inclusive policy-making—to ensure resilient agricultural systems in the face of climate change.

REFERENCES-

Affoh, R., Zheng, X., Dangui, K., & Dissani, M. (2022). Climate change and food insecurity in Sub-Saharan Africa. *Sustainability*, 14(4).

FAO. (2018). *The State of Food Security and Nutrition in the World*.

FAO. (2019). *Climate Change and Food Security*.

Gregory, P. J., Ingram, J. S. I., & Brklacich, M. (2005). Climate change and food security. *Philosophical Transactions of the Royal Society B*, 360(1463), 2139–2148.

Hatfield, J. L., et al. (2014). Climate change impacts on agriculture. *Agricultural Systems*, 127, 13–19.

IPCC. (2014). *Climate Change 2014: Impacts, Adaptation, and Vulnerability*.

Kumar, P., Sahu, N. C., Kumar, S., & Ansari, M. A. (2021). Impact of climate change on cereal production. *Environmental Science and Pollution Research*, 28(37), 51597–51611.

Lobell, D. B., Schlenker, W., & Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. *Science*, 333(6042), 616–620.

Mendelsohn, R., et al. (2007). The impact of climate change on African agriculture. *World Bank Policy Research Working Paper*.

Msowoya, K., et al. (2016). Climate change impacts on food security in Africa. *Food Policy Journal*, 62, 77–85.

Parry, M. L., Rosenzweig, C., Iglesias, A., Livermore, M., & Fischer, G. (2004). Effects of climate change on global food production. *Global Environmental Change*, 14(1), 53–67.

Seo, S. N. (2005). Is an integrated Ricardian model possible? *Policy Research Working Paper Series*.