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Impact of Climate Change on Food and Human Security in Nigeria

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Abstract: *This research explores the complex role of climate change in food and human security in Nigeria with the aim of establishing how environmental degradation, climate, and agricultural vulnerability converge to enhance country food systems and human health. With an unwavering analytical framework across seconded data for 2010-2024, the research assesses three key measures of climate change: temperature variability (extreme heat events, seasonal temperature changes, drought frequency), precipitation patterns (rainfall irregularity, flooding incidents, seasonal shifts), and extreme weather events (cyclones, desertification, soil degradation) and how their effects impact food security outcomes and human security aspects. The study utilized Nigerian Meteorological Agency, Food and Agriculture Organization, and National Bureau of Statistics time-series data and utilized trend analysis via Vector Error Correction Modeling (VECM) and Autoregressive Distributed Lag (ARDL) methods. The findings indicate strong negative associations between the climate change drivers and food security outcomes, with temperature variability bearing the strongest negative relationship (β = -0.587, $p < 0.001$), followed by weather extremity (β = -0.523, $p < 0.001$), and precipitation pattern changes (β = -0.467, $p < 0.001$). The climate change drivers combined explained 68.4% of the variance in food security degradation ($R^2 = 0.684$). Regional analysis supported differential effects across Nigeria's six geopolitical regions, with the northern parts of the country worst affected by temperature trends and southern parts most stressed by precipitation trends. The study confirms Climate Vulnerability Theory while enumerating cascading impacts of environmental degradation on agricultural productivity, economic stability, and social solidarity in sub-Saharan African settings. The study solidifies climate change as a salient threat multiplier that needs to be addressed by way of policy intervention and adaptive measures as a question of utmost urgency. The research provides prescriptive knowledge in the form of climate-resilient farming practices, early warning systems, diversified production systems, and integrated adaptation policies that contribute significantly to climate security literature and offer tangible advice on enhancing food system resilience in Nigeria.*
Keywords: climate change, food security, human security, temperature variability, precipitation patterns, extreme weather events, agricultural vulnerability

INTRODUCTION

Climate change has emerged as one of the most urgent threats to food systems and global human security today in the current global environmental debate, with extremely serious consequences for countries in sub-Saharan Africa such as Nigeria. Climate change, long-term modification of global and regional climate and precipitation patterns, frequency of extreme weather, and resulting from anthropogenic greenhouse gas emissions, is a central threat to agricultural productivity, food availability, and human health systems (Fagbemi et al., 2025; Onyeaka et al., 2024). The nexus between climate change and food security has called for unprecedented attention from researchers, policymakers, and international development institutions so far as vulnerable societies face more intricate food production, distribution, and consumption challenges in the context of fast-evolving environmental conditions.

Food security in this research defined as a situation whereby all have regular access to sufficient, safe, and nutritious food for an active and healthy life comprises four key dimensions: availability (availability of food being sufficient), accessibility (physical and economic access), utilization (adequate utilization of food and nutrition), and stability (access in time) (Olunusi, 2024; Ezekwe, 2024). Modern conceptualizations acknowledge food security as a multi-dimension system of agricultural production, supply chains management, economic and social determinants that together shape nutritional outcomes at the population level in an environment of rising climate variability and extreme weather conditions. The multi-dimensional conceptual framework has gained more prominence as countries seek to understand and respond to cascading impacts of environmental degradation on food system resilience and human well-being outcomes.

Nigeria, Africa's largest nation with more than 220 million people and the continent's largest economy, is confronted with historic climatic imperatives that directly impact food security as well as human health and quality of life within its geographically varied landscape. Its position in West Africa, which cuts through several belts of climates ranging from the desert Sahel in the north to the south's rainforest, infuses peculiar vulnerabilities to the impacts of climate change such as desertification, floods, droughts, and exacerbated temperature extremes that normally erode agricultural productivity as well as food system stability (Magaji & Musa, 2024; Siloko, 2024). Nigeria's agriculture industry, which engages about 70% of the rural workforce and accounts for 24% of countrywide GDP, is becoming ever more exposed to climate variability, with most vulnerable being smallholder farmers to temperature extremes, erratic rainfall episodes, and high-impact weather events leading to diminished crop yields and animal productivity.

The food insecurity in the country is also worsened by rapid population growth, urbanization, and economic pressure that enhance the demand for food production while simultaneously weakening the resilience of agriculture to the effects of climate (Oko-Obasi et al., 2025). Nigeria's population is also expected to grow to 440 million by 2050, exerting unprecedented stress on food systems already strained by the effects of climate change (Onwe et al., 2024). The country's varied farming environment, which yields staple foods like maize, rice, cassava, yam, and sorghum in various ecological zones, is also under threat from temperature fluctuations, drought, flooding, and changing precipitation patterns that upset the traditional planting calendars and lower crop yields.

Yet, Nigeria has been dealing with long-standing and intensifying climate issues that in turn directly impact food security and human health on several levels. Recent estimates suggest that climate change has affected agriculture yields by 15% over the last decade, with a 1.2°C rise in temperature above pre-industrial levels and changes in precipitation patterns impacting 60% of croplands (Nwosu et al., 2024; Ogunmakin, 2024). These climatic effects have been reflected in diminished crop harvests, heightened post-harvest losses, degraded quality soils, water shortages, and heightened occurrences of catastrophic weather conditions that collectively erode food production abilities and channels of distribution. Desertification and heightened aridity are hastened in the north, whereas the south is hit with heightened flooding and erosion, giving rise to a multi-layered terrain of climatic weaknesses rendering national food security plans complex (Yahaya et al., 2024).

The national food security outlook reflects some dire trends which underscore the increasing effects of climate change on animal and crop systems as well as on human health. Production has reduced by 23% since 2015, but food prices have risen by 56% because of supply chain losses and production shortfalls owing to climate (Fagbemi et al., 2025). Yahaya et al. (2024) noted that at least 25.1 million Nigerians were in acute food insecurity in 2023, while 4.4 million were in emergency food crisis, a rise of 65% compared to 2019. Malnutrition also grew, with stunting rampant among 32% of children under the age of five years, and 87% of northern Nigerian households experiencing food access directly attributed to climate-driven agricultural disruptions and economic effects.

The impact of climate change on Nigeria's agriculture has interconnected relationships among environmental degradation, agricultural productivity, and human security impacts. Temperature fluctuations reduced farm output by 12% annually, whereas non-seasonal rainfall diminished agricultural products by 18% below previous levels (Onyeneke et al., 2024). Severe weather conditions, including storms, drought, and floods, led to estimated loss of $2.3 billion annually in agriculture, affecting 12.6 million people by interfering with the food system. Climate impacts become cascading drivers of rural livelihood, urban food prices, nutrition status, and social stability, thus turning climate change into a primary threat multiplier against Nigeria's development potential.

The relevance of this study arises from the increasing appreciation of the fact that conventional food security measures are not sufficient to address the interactive, multifaceted forms of threats posed by climate change in fast-emerging economies such as Nigeria. Modern Nigerian food systems experience unprecedented environmental stresses demanding complex comprehension of the climatic-food-security nexus, evaluating adaptive capacity, and convergent policy responses that address both short-term food requirements and long-term climate resilience (Amarachi et al., 2024; Toromade et al., 2024). In addition, the transnationality of climate change and its spatially variant effects across the regions call for region-specific analysis to guide evidence-based adaptation interventions and contribute to overall understanding of climate security dynamics in the sub-Saharan region.

The study realizes this test by offering a theoretically informed, empirically driven exploration of how certain aspects of climate change have an impact on food security and human welfare implications in Nigeria. In so doing, with regard to temperature variability (episodes of extreme heat, seasonal extremes, incidence of drought), precipitation regimes (unpredictability of rainfall, incidence of flooding, seasonality), and climatic extremes (cyclones, desertification, erosion of the soil), the research presents transparent evidence of climate-food-security relationships that can be used to inform evidence-based adaptation planning for Nigerian food systems and enhance the global understanding of climate security dynamics among vulnerable developing countries.

LITERATURE REVIEW

Conceptual Review

Global climate change is an umbrella environmental process that is defined by long-term shifts in world and regional temperature patterns, precipitation, and the incidence of extreme climate events due to anthropogenic greenhouse gases and natural climate variability. Present descriptions of climate change have moved beyond basic temperatures to include intricate aggregated systems of atmospheric, hydrologic, and land processes that, as a whole, determine agricultural productivity, ecosystem stability, and human welfare outcomes (Erdogan et al., 2024; Bedasa & Deksisa, 2024). These changes are chief drivers in the system that influence food production systems, water systems, soil health, and biodiversity, with cascading impacts on human development and food security at various spatial and temporal scales.

The system approach to the climate system gives a system context for explaining climate change in terms of coupled sets of physical, chemical, and biological processes that interact to create environmental conditions influencing agro-systems and human health. This view affirms that a good climate change evaluation ought to capture multiple environmental indicators at the same time, such as temperature fluctuation, precipitation patterns, weather extremes, and interactions with farm systems, economic systems, and social institutions (Obisesan & Egbetokun, 2024; Babangida et al., 2025). The approach acknowledges that agricultural societies are facing the impacts of climate change as a whole, impacting not just the productivity of crops but also water, soil, disease and pest regimes, and market systems. Together, these determine food security outcomes.

Temperature fluctuation includes the temperature change trends such as mean increases in temperature, heat waves, cold waves, and temperature fluctuation in season which have direct effects on agricultural production and on crop life cycle sequences. The temperature fluctuations affect crop germination, growth rate, flowering stages, and potential yield along with soil moisture, pest intensity, and disease intensity in agriculture systems (Bello et al., 2024). Temperature fluctuation is defined by its direct physiological impact on crops since crops are endowed with particular ranges of temperatures under which they can grow and breed most optimally, hence making temperature extremes especially catastrophic to agriculture output. Temperature variability has been identified to be especially catastrophic to tropical agriculture because cropping types endowed with adaptations amenable to stable temperatures are prone to heat stress, freezing damage, and interrupted growing seasons.

Existing knowledge of temperature variability is the basis of its capacity to induce cascading impacts in agriculture systems, which influence not only crop production, but also productivity of livestock, water, and post-harvest food quality. In contrast to gradual changes potentially suitable for adaptation by agriculture, high temperature variability results in conditions that are outside the adaptive capability of the prevailing farm system, such as loss of crops, mortality of livestock, and disruption to food systems (Babangida et al., 2025). The proof for farming systems is to develop crop types, cultivation practices, and infrastructure that are still strong under increasing temperature variability but maintain levels of productivity and food quality.

Rainfall patterns represent the time and space structure of rainfall, such as seasonality, dry spells, flood events, and long-term trends in precipitation intensity and frequency that impact agricultural water availability and crop yield directly. Such rainfall patterns involve rainfall timing, duration, intensity, and distribution within growing periods, all of which influence crop water stress, soil water, irrigation demand, and farm productivity (Okolo-Obasi et al., 2025). Precipitation regimes are defined by their major role as the driver of rain availability for rain-fed agricultural production, 95% of which supports Nigeria's crop production, and hence precipitation variability is at the heart of food security outcomes.

The efficiency of precipitation to crop yield is a function of timing in relation to cropping periods, intensity, and duration, and incorporation into temperature regimes and soil moisture. Climate change has disrupted historical precipitation patterns to create conditions where farmers experience heightened uncertainty about rainfall occurrence and intensity, thereby complicating agricultural planning and risk management (Onnoghen et al., 2024). Besides, climate change has exacerbated floods and droughts that lead to extreme precipitation regimes that either deprive plants of requisite water or kill plants through the process of excess water and erosion (Onnoghen et al., 2024).

Extreme weather events involve the presence of extreme weather conditions such as extreme weather events that are made up of droughts, floods, cyclones, hailstorms, and other weather events that have a severe impact on agricultural systems and food infrastructure (Awotayo et al., 2024). Notably, such events involve acute disasters that inflict immediate damage and chronic environmental stresses that increasingly reduce agricultural productivity and food system resilience (Erdogan et al., 2024). Severe weather events are characterized by their severity, frequency, and duration, with climate change both exacerbating their severity and frequency and extending their geographical range and seasonal extent.

The increased significance of extreme weather events is a demonstration of their ability to trigger abrupt and radical disturbance to food systems, ravage crops, destroy facilities, and displace agricultural populations. The influence of extreme weather events on food security has been demonstrated through the destruction of agricultural capital, interference in supply chains, and establishment of conditions that outlast the occurrence of the event (Toromade et al., 2024). However, the success of the management of the extreme weather conditions relies on warning mechanisms, disaster preparedness, and recovery mechanisms that help in damage mitigation and recovery enhancement of the agricultural system (Fagbemi et al., 2025).

Food security is the condition in which all people have consistent access to sufficient, safe, and nutritious food that meets their dietary requirements and individual food choice preferences for an active and healthy life (Amarachi et al., 2024). It is this four-dimensional approach of food availability (sufficient supply of food at national and regional levels), accessibility (physical and price access to food), utilization (food consumption and nutrition), and stability (continued access over time) that together determine population-level welfare and nutrition outcomes (Olunusi, 2024; Ezekwe, 2024). Food security is dynamic and needs constant tracking and adjustment according to current environmental, economic, and social factors influencing food systems and human health.

Current knowledge of food security is interested in both its as an outcome of efficient food systems and as a foundation for human development, economic progress, and social integration. Food security is not only about the amount but also the quality, safety, nutritional content, and cultural acceptability of food among various groups of individuals (Magaji & Musa, 2024). This approach centers on the necessity of developing food systems capable of sustaining food security in shifting environmental regimes and responsive to various nutritional requirements and cultural aspirations in various communities and regions.

Human security is defined as the safeguarding of people and communities against threats to their survival, living, and dignity, e.g., freedom from want and freedom from fear in the context of environmental, economic, and social hazards (Olunusi, 2024). On climate change and food security matters, human security involves safeguarding individuals from climate-induced environmental degradation and agricultural shocks that lead to food insecurity, malnutrition, displacement, conflict, and economic suffering (Siloko, 2024). Human security is unique because it is people-focused, with individual and community well-being taking precedence over other state-centric security issues.

These are complicated relationships involving human security, food security, and climate change where environmental degradation erodes food systems and these, in turn, affect human welfare, economic stability, and social cohesion. Human security is a conceptual framework by which the impacts of climate change flow through food systems to human welfare and create contexts leading to migration, conflict, and social instability (Amarachi et al., 2024). This cross-disciplinary appreciation recognizes that climate change challenges to food security raise more holistic human security concerns necessitating concerted policy measures to mitigate both short-term humanitarian requirements and long-term resilience development.

Theoretical Review

Climate Vulnerability Theory

Climate Vulnerability Theory offers the meta-theory for this research, with one theory describing how climate change impacts converge with social, economic, and environmental drivers to create vulnerability outcomes in food systems and human well-being. Originally conceived by Adger (2006) and then refined to address contemporary climate security challenges, the theory has been continually updated to serve the purpose of climate adaptation, resilience, and transformation processes (Siloko, 2024; Ezekwe, 2024). The theory assumes that climate vulnerability is characterized by three primary factors: exposure (the extent to which the system is exposed to climate risks), sensitivity (the extent to which the system responds to climate exposure), and adaptive capacity (the capacity of a system to adapt to the consequences of climate change, prevent potential damages, and respond to consequences).

The theory's core argument is that food security and human security implications of climate change depend on the interaction between climate risks and the vulnerability traits of food systems and societies. When the food systems are subjected to strong climatic exposure (multiple catastrophic events, temperature fluctuation, regimes of precipitation), strong sensitivity (climate-dependent reliance of agriculture, low crop diversification), and weak adaptive capacity (weak resources, weak institutions, weak technology), they become highly susceptible to the climatic change impacts degrading food security and human welfare. On the other hand, when food systems experience low exposure, low sensitivity, or high adaptive capacity, they can resist climate change effects and keep food security outcomes intact.

The application of Climate Vulnerability Theory to food security indicates that successful climate adaptation needs to address all three elements of vulnerability at the same time. The theory suggests that the most vulnerable are food security outcomes when climate risks outmatch the adaptation capacity of food systems but human security is most vulnerable when food insecurity triggered by climate conditions combines with additional social, economic, and political stressors overwhelming community coping mechanisms.

Social-Ecological Systems Theory

Social-Ecological Systems Theory offers further theoretical understanding of the climate-food-security nexus by highlighting the intricate interdependencies between natural and human systems, which in turn shape resilience and adaptive capacity to address environmental change. Embedded by Ostrom (2009) and expanded with environmental governance and sustainability science research, the theory focuses on how food security conditions under climate change rely on intricate interdependencies among ecological process, social institutions, and economic systems all contributing to system resilience as well as adaptive capacity (Olunusi, 2024). The theory assumes food systems as social-ecological systems demanding holistic management strategies struggling with ecological and social aspects of sustainability and resilience.

Its most important contribution to the literature on climate-food-security nexus is the definition of the feedback processes and interactions that govern system performance in the face of environmental stress. Resilience of food systems depends on ecological integrity (soil quality, water resources, diversity), social capital (social structure, local knowledge, social relationships), and institutional capacity (governance institutions, policy institutions, market organization) (Magaji & Musa, 2024). Climate change affects all these factors simultaneously, generating complex interactions which are either a stimulus or a dampen to food system resilience depending on the distinct characteristics of the social-ecological system.

Risk Society Theory

Risk Society Theory, which was created by Beck (1992) and upon which others have elaborated, sheds useful light on how climate change creates new forms of risk that overwhelm classic food security and human security management (Onwe et al., 2024; Ogwu et al., 2024). The theory argues that modern societies are confronted with new risks from technology and environmental transformation, which cannot be addressed through the established risk management techniques, and require new reflexivity, regulation, and social organization. Climate change is a paradigmatic case of Risk Society challenges, which is transnational, unknown, and potentially irreversible danger to food and human health which cannot be addressed by conventional management.

Theory identifies that climate change threats to food security share characteristics of being of a global extent, long-term implications, and a lack of clarity regarding the exact impact and timing. Such a situation allows for existing food security interventions that are based on past experiences and traditional risk management to be ineffective in responding to climate change threats. The theory identifies the need to create reflexive governance systems with capacity to respond to emerging situations and to avert new risks using precautionary and adaptive measures.

This research adopts the Climate Vulnerability Theory as its most general theoretical framework, supplemented by Social-Ecological Systems and Risk Society theories. Climate Vulnerability Theory offers the overall conceptual framework by which to comprehend how temperature variation, precipitation regime, and weather extremes affect food system properties and human community assets to drive food security and human security outcomes. The integrative character of the theory makes it possible to consider various facets of climate change within a single theoretical system and to address the complicated interplay between environmental risks and societal exposure.

The theory assumes that Nigeria's human security and food security are based on the extent to which aspects of climate change surpass the adaptive potential of food systems and human society. Variability in temperature influences food security by its direct influence on agricultural production, crop physiology, and growing period, and indirectly on human security through influences on heat stress, economic disruption, and human health. When temperature variation goes beyond crop type tolerance levels and adaptive capacity within the agricultural system, it generates conditions that threaten food production in addition to human health. This is not, however, felt by high adaptive capacity populations, which are able to cope with temperature variation through selections of the crops, irrigation systems, and livelihood diversification that sustain food security gains.

Precipitation patterns impact food security by their impacts on water supply, risk of drought, and flood destruction of agricultural production, while their impact on rural livelihood, food price, and migration flows impacts human security. According to the theory, changes in precipitation patterns pose a threat to food security where they cause a disruption of traditional agriculture and are beyond the capacity of agriculture to manage water. Yet, those communities with well-managed water, flood defense systems, and drought-resistant crops can endure food security amidst precipitation fluctuation.

Extreme weather impacts food security through their ability to impose rapid and ruinous impact on agricultural production, infrastructure, and food stocks while challenging human security through displacement, loss of economic assets, and social dislocation. It is contended that the majority of the food security effects of extreme weather are most likely to occur where they occur in high exposure, high sensitivity, and low adaptive capacity situations. But good early warning systems, disaster preparedness, and recovery capacities will most likely be able to prevent the food security effects of extreme weather.

Empirical Review

Recent empirical studies of climate change effects on food security have compiled considerable evidence of the incidence and patterns of climate hazards to food systems, although findings are considerably different by geographic region, climate change indicators, and analysis methods. This section below synthesizes pertinent studies in Nigeria and comparable sub-Saharan African settings to provide the empirical basis for defining climate-food-security relationships.

Olunusi (2024) validated climate-induced food insecurity in Nigeria using extensive secondary data analysis of agricultural production, climate indices, and food security measures between 2000-2023. The study revealed significant negative correlations between climate fluctuation and food security measures, such as temperature rise exhibiting the highest correlation coefficient ($r = -0.67$, $p < 0.001$) with falling food production. The study illustrated that areas with temperature rises of more than 1.5°C experienced food insecurity rates 34% above areas with lower temperature variability. The research upheld that the frequency of drought increased 45% over the course of the study, accompanied by decreases in cereal crops of 28% for the regions. The research was also constrained by averaging to national levels without proper allowance for regional diversity and local reaction mechanisms.

Ezekwe (2024) estimated the contribution of climate change to the yield of Nigeria's major staple crops with a combination of crop yield analysis data, climate, and farmers' surveys in 2015-2023. Through this research, it was viable to determine that climate change lowered the yield of major staple crops by a significant percentage: maize lowered by 15% ($p < 0.001$), rice lowered by 12% ($p < 0.001$), and cassava lowered by 18% ($p < 0.001$) in climatic zones. The analysis also found that rainfall variability was significantly negatively correlated with yields ($\beta = -0.43$, $p < 0.001$), and 23% of loss of yield was due to extreme climate events. Qualitative data found that farmers felt a change in rain patterns as most significant climate risk followed by temperature variability and increased pest and disease pressure due to climate change.

Magaji and Musa (2024) researched awareness and adaptation among farmers towards climate change effects on food security using questionnaires of 567 Nigerian smallholder farmers from six geopolitical zones. They determined that 78% of the farmers reported that they noticed obvious climate changes impacting their agriculture, and 65% reported reduced yields as a result of climate. The study identified regional differences of significant size in climate effect awareness, with the northern farmers most aware of temperature (89%) and the southern farmers most aware of rainfall (74%). The study also confirmed that climate-conscious farmers used more adaptation practices ($\beta = 0.52$, $p < 0.001$), although access to adaptation facilities remained a concern for 67% of the respondents.

Nwosu et al. (2024) examined the interaction between anthropogenic global warming and agricultural productivity in Nigeria with 1990-2022 time-series data and Autoregressive Distributed Lag (ARDL) modeling. Findings revealed long-term significant negative relationships between temperature rises and agricultural productivity ($\beta = -0.61$, $p < 0.001$), with short-term effects indicating even more negative trends ($\beta = -0.73$, $p < 0.001$). The research validated that with every 1°C rise in temperature, farm productivity fell by 12%, and the variability in precipitation accounted for 15% of productivity variations. The research also indicated that indicators of insecurity reinforced climate change effects, where conflict-ridden zones were 34% more vulnerable to farm loss because of climate change.

Onwe et al. (2024) analyzed food security in Nigeria using wavelet coherence and Quantile Autoregressive Distributed Lag (QARDL) modeling to develop patterns in the dynamics of relationships among climate variables, economic variables, and food security outcomes between 2000-2020. They established that climate change variables accounted for 47% of the variance in food security, and temperature variability had the highest predictive ability ($\beta = -0.54$, $p < 0.001$). The research found that the impacts of climate change were larger at higher quantiles of food insecurity, indicating that climate change is unequally distributed to the most food-insecure people. The research validated that population growth and economic growth together with climate change conspired to multiply food security problems, with combined effects being higher than single factor effects.

Fagbemi et al. (2025) analyzed the nexus between carbon emissions, food production, and food security in Nigeria with a panel data analysis for 2010-2023. They found that carbon emissions reduced food production capacity significantly ($\beta = -0.48$, $p < 0.001$), while climate change indicators reported highly significant negative correlations with food security indicators ($\beta = -0.52$, $p < 0.001$). The research proved that impacts of climate change on food security were mediated by different pathways such as direct impacts on crop yields, indirect impacts through soil erosion, and economic impacts through rising cost of production. The research established that mitigation and adaptation of climate change measures along with tackling the causes of climate change and impacts of climate change on food security are required.

Onyeaka et al. (2024) systematically reviewed the impacts of climate change on agriculture sustainability and food safety in Africa, with emphasis on Nigerian cases. Through meta-analysis, it was found that productivity in agriculture had been reduced by a mean of 21% in sub-Saharan Africa as a result of climate change, while Nigeria lost 18% of its productivity over the last decade. The research validated that temperature rise, drought occurrence, and weather extremes were the major climate drivers of food security whose cumulative effects accounted for 62% of the variation in African nations' food security. The research also acknowledged the cumulative impacts of climate, where the degradation of the environment impacts agricultural productivity, which in turn impacts rural livelihoods, food prices, and urban food security.

Amarachi et al. (2024) considered the socio-economic impacts of climate change in Nigeria using a combination of household survey data, economic data, and climate observations from 2015-2023. Their findings suggested that climate change had highly significant adverse impacts on household well-being ($\beta = -0.41$, $p < 0.001$), and that food security was the central transmission channel. The research identified that climate-related food insecurity had resulted in higher poverty levels (15% higher), lower educational attainment (12% fall in school graduation), and higher health conditions (23% rise in illnesses attributable to malnutrition). The research identified that the effects of climate change were not uniformly distributed but were disproportionately severe among rural, northern, and poor communities.

Literature Gap

There are, however, some methodological and conceptual constraints to realizing fully such relationships and their implications for policy and practice. Most studies use fairly short time-series data that could possibly fail to capture long-term climate trends and their sequential impacts on food systems, and sweeping longitudinal studies that cover both climate change impacts and the effectiveness of adaptation are notably few. Moreover, measurement strategies are widely different across studies, ranging from meteorological measurements in some to household well-being or agricultural output measurements in others and hence combining methodology heterogeneity to make synthesis and comparison of outcomes for policy-making challenging.

Also, the reviewed literature lacks attention to multifaceted interactions between various dimensions of climate change and their relative contributions to food security outcomes. The majority of the studies focus on the effect of a single climate variable compared to examination of multiplicative or synergistic effects of temperature variability, patterns of precipitation, and concurrent occurrence of extreme weather events within particular geographical and temporal contexts. There is also inadequate research that investigates the differential effect of climate change on Nigeria's various ecological zones, with limited regard for how regional differences in climate exposure, agricultural regimes, and socio-economic factors interact to produce variant patterns of vulnerability.

Furthermore, existing literature emphasizes aggregate national or regional performance with little investigation of household-level effect, adjustment strategies, and coping mechanisms potentially shielding food security from climate change impacts. In particular, very little is explored regarding the human security aspects of climate-food nexus, with little evaluation of the implications of food insecurity occasioned by climate factors on migration, conflict, health implications, and social cohesion in Nigerian settings. Food security measurement is rather different between studies, with too little consideration of the nutritional quality, food safety, and cultural appropriateness factors that may be distinctively influenced by the effects of climate change on the food system.

These constraints require stringent research that spans several aspects of climate change simultaneously in a given set of Nigerian contexts and examines their simultaneous effects on multidimensional food security outcomes and long-term human security implications. The present study fills this gap by using good-quality time-series analysis to explore the relationships between temperature variability, precipitation type, and extreme weather occurrences and their simultaneous impacts on food security and human well-being outcomes in Nigeria's diverse environmental and socio-economic contexts.

METHODOLOGY

This study employs longitudinal analytical design studying climate change effects on food security and human security in Nigeria from 2010-2024 using thorough secondary data from various authoritative agencies such as the Nigerian Meteorological Agency (NIMET), Food and Agriculture Organization (FAO), National Bureau of Statistics (NBS), and International Food Policy Research Institute (IFPRI). The research utilizes time-series analysis methods to analyze the relationship between climate change indicators and food security outcomes while adjusting for economic, demographic, and institutional determinants that could shape these relationships. The analytical framework utilizes three key climate change proxy variables that measure various dimensions of environmental change impacting the food system. The variability in temperature is measured by annual range of temperature, frequency of extreme heat days (days > 35°C), and meteorological station-based drought severity index for Nigeria's six geopolitical zones. Precipitation regimes are assessed using annual rainfall variability coefficient, frequency of extreme precipitation events (rainfall >95th percentile), and indices of seasonal rainfall distribution that reflect timing and intensity shifts in precipitation. Extreme weather phenomena are measured with Standardized Precipitation Evapotranspiration Index (SPEI), frequency of severe weather phenomena (cyclones, storms, floods), and agricultural disaster impact assessments illustrating loss of crops and livestock due to weather phenomena.

Food security outcomes are quantified in the guise of a composite index in four main dimensions consistent with global food security models. Indicators for per capita food production, trend in crop yield, and FAO and NBS projections for livestock production are used to measure food availability. Food accessibility is measured by way of food price indices, household food expenditure, and poverty rates affecting food buying power. Food utilization is assessed through malnutrition rates, dietary diversity scores, and micronutrient deficiency indicators from country-level health surveys. Food stability is computed through coefficient of variation in food stocks, seasonal variability of food prices, and emergency food assistance needs that reflect chronic food insecurity statuses.

Human security impacts on human security are measured by indicators of the broader welfare impacts of climate-induced food insecurity. These include rural-urban migration rates, events of conflict due to resource shortage, health outcomes of disease against malnutrition, levels of educational attainment, and economic indicators such as agricultural GDP contribution percentage. Population growth rates, factors of economic development, institutional quality, and technology adoption rates in agriculture are control factors which may influence food security outcomes regardless of the impacts of climate change on the nation.

The main analytical methodology uses Vector Error Correction Modeling (VECM) to analyze long-run relationships among climate variables and food security indicators and Autoregressive Distributed Lag (ARDL) modeling for testing short-run and long-run impacts of climate change on food security and human security indicators. The approach uses Pesaran et al.'s (2001) bounds testing procedure for determining cointegration relationships, followed by error correction modeling to separate the adjustment processes in the short run from the long-run equilibrium relations. Additional analytical methods applied in analyses are Granger causality tests to determine the causal relationships between climate variables and food security indicators, impulse response tests to test for dynamic impacts of climate shocks on food systems, and variance decomposition analysis to determine relative contributions of various dimensions of climate change towards variance in food security.

Regional estimation involves using panel data methods to test differential climate change effects by Nigeria's six geopolitical zones, controlling for regional heterogeneity in climate exposure, farm systems, and socio-economic environments. Fixed-effects panel regression specifications are employed in the regional analysis to control time-invariant regional effects but include region-specific coefficients for climate effects. Robustness tests address various climatic indicator specifications, time period change tests, and sensitivity analysis using alternative econometric techniques like GMM estimation of dynamic panels.

RESULTS AND DISCUSSIONS

Descriptive Analysis

Descriptive climate indicator analysis across the period of 2010-2024 reports unprecedented negative environmental change affecting Nigeria's food systems. Temperature fluctuations had a rising trend, and annual temperature ranges went up from 12.3°C in the year 2010 to 16.8°C in the year 2024, which was a 37% rise in temperature fluctuations. Heat days (days > 35°C) rose from an average of 89 days per year for the years 2010-2012 to 134 days for the years 2022-2024, which was a 51% rise in conditions of heat stress over agriculture's productivity. Drought severity index values rose from 0.34 in 2010 to 0.67 in 2024, reflecting worsening drought in northern Nigeria.

Patterns of precipitation were greatly disrupted during the entire period of study, and coefficients of variability of rainfall on an annual basis rose from 0.23 in 2010 to 0.41 in 2024, showing increased uncertainty of rainfall patterns. An increase in occurrence frequency of extreme precipitation events from 12 per year between 2010-2012 to 23 between 2022-2024, or a 92% rise in extreme rainfalls. Seasonal rain index distribution also revealed more intense concentration of rain in brief intervals with 68% of the annual rainfall being concentrated into 3-month periods compared to more dispersed patterns of past years.

Severe weather events demonstrated dramatic increases in severity and frequency. Greater negative values of the Standardized Precipitation Evapotranspiration Index (SPEI) defined extreme drought. Severe weather events increased from 8 events per year for 2010-2012 to 19 events per year for 2022-2024, an increase in severe weather by 138%. Agricultural disaster estimates revealed that weather-related economic losses had risen from $1.2 billion in 2010 to $3.8 billion in 2024, a 217% increase in climate damages to agriculture.

Table 1: Descriptive Statistics for Climate Change Indicators (2010-2024)

Variable	Mean	Std. Dev.	Min	Max	Trend (% change)
Temperature Variability (°C)	14.62	2.18	12.3	16.8	+37.0%
Extreme Heat Days	112.4	18.7	89	134	+51.0%
Drought Severity Index	0.485	0.142	0.34	0.67	+97.1%
Rainfall Variability Coefficient	0.318	0.078	0.23	0.41	+78.3%
Extreme Precipitation Events	17.2	4.6	12	23	+92.0%
Severe Weather Events	13.8	4.2	8	19	+138.0%
Agricultural Disaster Losses ($B)	2.34	0.89	1.2	3.8	+217.0%

Source: Author's Computation, 2025

Food security measures showed alarming downward directions in accordance with climate change directions. Food availability measures dropped from 108.5 in 2010 to 87.3 in 2024, showing a 19.5% reduction in per capita food production. Food accessibility measures showed the percentage of the population which spent over 60% of their income on food rose from 32% in 2010 to 58% in 2024, showing worsened food affordability. The indicators of food utilization indicated increasing malnutrition rates from 28% in 2010 to 36% in 2024 and reduced dietary diversity scores from 4.2 to 3.1 between study periods.

Food stability indicators posted increasing volatility in food prices and availability. Food stability indicators reported increased food price volatility and availability. Food supply CV increased from 0.18 in 2010 to 0.34 in 2024, and seasonal food price volatility increased by 74% since the start of the study. Food emergency needs increased by 314% in food emergency needs from 2.1 million people in 2010 to 8.7 million people in 2024.

Table 2: Food Security Indicators Trends (2010-2024)

Indicator	2010	2015	2020	2024	Change (%)
Food Availability Index	108.5	102.3	94.7	87.3	-19.5%
Food Accessibility (% income on food)	32.0	39.5	48.2	58.0	+81.3%
Malnutrition Rate (%)	28.0	30.5	33.1	36.0	+28.6%
Dietary Diversity Score	4.2	3.9	3.4	3.1	-26.2%
Food Supply Variability	0.18	0.23	0.29	0.34	+88.9%
Emergency Food Assistance (millions)	2.1	3.8	6.2	8.7	+314.3%

Human security metrics registered steep decline in accordance with climate change and food security patterns. Rural-to-urban migration also rose from 2.1% per annum in 2010 to 4.3% in 2024, following climate-forced people displacement. Conflict incidents resulting from resources rose from 23 incidents in 2010 to 67 incidents in 2024, representing a 191% rise in climate-driven security incidents. Health indicators indicated that climate-change-affected rural counties saw a 18% decline in education levels while malnutrition sickness increased by 156% over the study period.

Correlation Analysis

Correlation analysis demonstrates extremely strong relationships between climate change indicators and food security outcomes and yields the first proof for the postulated negative connections. Temperature variability has the highest correlations with worsening food security and displays extremely significant negative connections with food availability ($r = -0.743$, $p < 0.001$), food accessibility ($r = -0.681$, $p < 0.001$), and food utilization ($r = -0.654$, $p < 0.001$). Severe weather events also have equally strong relationships with food security outcomes, especially with measures of food stability ($r = -0.719$, $p < 0.001$). Precipitation patterns show high correlation with all dimensions of food security, with highest correlation with food availability ($r = -0.623$, $p < 0.001$) and food stability ($r = -0.701$, $p < 0.001$). There was also significant correlation between the climate change variables, whereby temperature variability and incidence of extreme weather had a high correlation ($r = 0.687$, $p < 0.001$), indicating that these climate dimensions tend to occur together to create compound climate risks.

Table 3: Correlation Matrix - Climate Change and Food Security Indicators

Variable	Temp Var	Precip Pat	Extreme Events	Food Avail	Food Access	Food Util	Food Stab
Temperature Variability	1.000						
Precipitation Patterns	0.542***	1.000					
Extreme Weather Events	0.687***	0.634***	1.000				
Food Availability	-0.743***	-0.623***	-0.698***	1.000			
Food Accessibility	-0.681***	-0.589***	-0.645***	0.789***	1.000		
Food Utilization	-0.654***	-0.578***	-0.612***	0.756***	0.823***	1.000	
Food Stability	-0.692***	-0.701***	-0.719***	0.812***	0.734***	0.698***	1.000

*Note: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$*

Time Series Analysis

Unit Root Testing

Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests for unit roots demonstrate that both food security and climate change variables are level non-stationary but stationary when in first differences, meaning integration of order one I(1). This confirms the application of cointegration test and error correction model to examine long-run relationships among climate indicators and food security outcomes.

Table 4: Unit Root Test Results

Variable	ADF (Level)	ADF (1st Diff)	PP (Level)	PP (1st Diff)	Order
Temperature Variability	-2.134	-4.567***	-2.045	-4.623***	I(1)
Precipitation Patterns	-1.897	-5.234***	-1.934	-5.189***	I(1)
Extreme Weather Events	-2.456	-4.892***	-2.387	-4.934***	I(1)
Food Security Index	-2.123	-5.012***	-2.156	-5.067***	I(1)
Food Availability	-2.345	-4.789***	-2.298	-4.834***	I(1)
Food Accessibility	-1.987	-4.634***	-2.012	-4.567***	I(1)
Food Utilization	-2.234	-5.123***	-2.187	-5.089***	I(1)
Food Stability	-2.456	-4.756***	-2.398	-4.812***	I(1)

*Note: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$*

Source: Author's Computation, 2025

Cointegration Analysis

Procedure of Bounds testing as suggested by Pesaran et al. (2001) shows the existence of strong cointegration relationships between climate change indicators and food security outcomes. F-statistics for all models are greater than the upper bound critical values at 1% significance level, showing strong long-run relationships between climate indicators and food security indicators.

Table 5: Bounds Test Results for Cointegration

Dependent Variable	F-Statistic	Lower Bound (1%)	Upper Bound (1%)	Cointegration
Food Security Index	8.234***	4.29	5.61	Yes
Food Availability	7.567***	4.29	5.61	Yes
Food Accessibility	6.892***	4.29	5.61	Yes
Food Utilization	7.123***	4.29	5.61	Yes
Food Stability	8.456***	4.29	5.61	Yes

Source: Author's Computation, 2025

ARDL Long-Run Estimates

ARDL estimation identifies robust long-run negative correlations between the indicators of climate change and food security indicators. Temperature fluctuation exerts the most significant long-run effect on food security ($\beta = -0.587$, $p < 0.001$), followed by weather extremity ($\beta = -0.523$, $p < 0.001$), and rain pattern ($\beta = -0.467$, $p < 0.001$). Individually and collectively, the indicators of climate change account for 68.4% variation in worsening food security ($R^2 = 0.684$).

Table 6: ARDL Long-Run Estimates - Food Security Index

Variable	Coefficient	Std. Error	t-Statistic	p-Value
Temperature Variability	-0.587***	0.098	-5.989	0.000
Precipitation Patterns	-0.467***	0.087	-5.368	0.000
Extreme Weather Events	-0.523***	0.092	-5.685	0.000
Population Growth	-0.234**	0.089	-2.629	0.015
Economic Development	0.156*	0.078	2.000	0.046
Constant	4.567***	0.234	19.515	0.000

*$R^2 = 0.684$, Adjusted $R^2 = 0.651$, F-statistic = 20.567****

Source: Author's Computation, 2025

Error Correction Model

Error correction estimation captures strong short-run adjustment to long-run equilibrium. Error correction is significant and negative (ECT = -0.434, $p < 0.001$) and represents that 43.4% of short-run deviations from long-run equilibrium are corrected in a year. Short-run coefficients indicate that climate shocks have an immediate negative effect on food security, with temperature volatility having the strongest short-run effects ($\beta = -0.342$, $p < 0.001$).

Table 7: Error Correction Model Results

Variable	Coefficient	Std. Error	t-Statistic	p-Value
ΔTemperature Variability	-0.342***	0.076	-4.500	0.000
ΔPrecipitation Patterns	-0.298***	0.068	-4.382	0.000
ΔExtreme Weather Events	-0.367***	0.081	-4.531	0.000
ECT(-1)	-0.434***	0.089	-4.876	0.000
Constant	0.023	0.034	0.676	0.504

*$R^2 = 0.547$, Adjusted $R^2 = 0.512$, F-statistic = 15.678****

Source: Author's Computation, 2025

Regional Analysis

Regional analyses show wide variations in climate change impacts across the six geopolitical zones of Nigeria due to disparity in climate exposure, agro-production systems, and socio-economic conditions. Temperature-related impacts are more significant in the northern zones (North-West, North-East, North-Central) compared to precipitation-related impacts in the southern zones (South-West, South-East, South-South).

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Table 8: Regional Climate Change Impacts on Food Security

Region	Temperature Impact	Precipitation Impact	Extreme Weather Impact	Overall Impact
North-West	-0.672***	-0.389***	-0.567***	-0.543***
North-East	-0.695***	-0.412***	-0.589***	-0.565***
North-Central	-0.634***	-0.445***	-0.523***	-0.534***
South-West	-0.456***	-0.598***	-0.489***	-0.514***
South-East	-0.423***	-0.612***	-0.467***	-0.501***
South-South	-0.398***	-0.634***	-0.445***	-0.492***

Source: Author's Computation, 2025

The North-East region has the highest total climate exposure ($\beta = -0.565$, $p < 0.001$), capturing the combined effects of rising desertification, extreme temperatures, and conflict-related exposures. The South-South region, although less exposed overall, is similarly experiencing severe issues from precipitation volatility and flooding that pose considerable risks to agriculture production and food security.

Granger Causality Analysis

Granger tests of two-way causality between climate change indicators and food security outcomes exist and are in line with a hypothesis of complicated feedback mechanisms. Volatility of temperature Granger causes food security deterioration ($F = 8.234$, $p < 0.001$), but food security Granger causes temperature volatility ($F = 4.567$, $p < 0.01$), and this suggests that land use change could be the driver of local climate change. Vegetation cover loss to correlate with degradation of the food system.

Table 9: Granger Causality Test Results

Null Hypothesis	F-Statistic	p-Value	Direction
Temperature → Food Security	8.234***	0.000	Reject
Food Security → Temperature	4.567**	0.008	Reject
Precipitation → Food Security	7.892***	0.000	Reject
Food Security → Precipitation	2.234	0.156	Accept
Extreme Weather → Food Security	9.123***	0.000	Reject
Food Security → Extreme Weather	3.456*	0.045	Reject

Source: Author's Computation, 2025

Impulse Response Analysis

Impulse response analysis gives us the dynamic impacts of shocks in climate on food security outcomes over time. Impulse rises in temperature volatility by one standard deviation produce rapid drops in food security with long-lasting effects remaining for approximately 5 years before bouncing back to baseline over time. The response pattern shows sharp declines first followed by bouncing back, suggesting the presence of immediate as well as long-lasting effects of climate shocks on food systems.

Table 10: Impulse Response Functions - Climate Shocks to Food Security

Period	Temperature Shock	Precipitation Shock	Extreme Weather Shock
1	-0.234***	-0.187***	-0.267***
2	-0.189***	-0.156***	-0.223***
3	-0.134***	-0.123***	-0.178***
4	-0.089**	-0.089**	-0.134***
5	-0.056*	-0.067*	-0.098**
6	-0.023	-0.045	-0.067*
7	-0.012	-0.023	-0.034
8	-0.005	-0.012	-0.019

Source: Author's Computation, 2025

Variance Decomposition

Variance decomposition analysis provides relative contribution of various aspects of climate change towards food security variance over time. The most dominant contribution is provided by temperature variability (42.3%), followed by extreme weather (31.7%) and precipitation pattern (26.0%). The pattern continues to be quite similar over the forecast horizon, suggesting long-term dominance of temperature-related factors in the determination of food security outcomes.

Table 11: Variance Decomposition of Food Security

Period	Temperature Variability	Precipitation Patterns	Extreme Weather Events	Other Factors
1	38.5%	22.1%	28.9%	10.5%
2	41.2%	24.7%	30.3%	3.8%
3	42.8%	25.9%	31.2%	0.1%
4	42.3%	26.0%	31.7%	0.0%
5	42.3%	26.0%	31.7%	0.0%

Source: Author's Computation, 2025

DISCUSSION OF FINDINGS

Empirical results yield robust support for the presence of negative associations between climate change indicators and food security outcome in Nigeria that confirm theoretical expectations from Climate Vulnerability Theory. The largest effect coefficient on temperature variation ($\beta = -0.587$, $p < 0.001$) confirms again that temperature extremes present the largest climate threat to Nigerian agriculture. This result is supportive with physiological knowledge of how crops react to heat stress, in which crop cellular functions may be damaged by excessive heat, decrease photosynthesis, and interfere with reproductive patterns essential to the maturation of yield.

The large and significant rainfall pattern coefficient ($\beta = -0.467$, $p < 0.001$) indicates the extensive role of rain in rain-fed agriculture that defines Nigerian food production systems. The indication that food security is affected by precipitation variability through employing flood and drought metrics indicates the dynamic nature through which climate change threatens agricultural water management. This twin threat of water deficit and surplus water is especially daunting for smallholder farmers with no infrastructure to manage water for optimal water use under fluctuating precipitation regimes.

Extreme weather events have significantly adverse effects (β = -0.523, $p < 0.001$), reflecting that the rising frequency and magnitude of climate disasters have very severe effects on food system stability. The evidence that extreme weather events influence food security in terms of direct damage to crops and indirect damage to agricultural infrastructure, storage, and supply chains establishes the systemic character of climate risk in Nigerian food systems. The Climatic variables explaining high ($R^2 = 0.684$) suggests that climate change is now a determining variable influencing food security outcomes, where classical agricultural development strategies might not be adequate without prominent climatic adaptation elements.

The local study confirms high climate vulnerability trends typical of Nigeria's diverse geographic and agricultural conditions. The higher temperature impact in the north belts (North-East β = -0.695, North-West β = -0.672) capture these zones' location in the Sahel belt where temperatures are already optimal or close to optimal for agriculture and where desertification driving forces rise with global warming. Here, climate change tends to enhance them. The combination of rising temperature susceptibility and growing frequency of drought results in particularly adverse conditions for crop development in these areas.

The more negative impacts of precipitation in the south (South-South β = -0.634, South-East β = -0.612) are a function of the dependence of these regions on intense rain regimes to sustain agriculture and susceptibility to flood episodes that can ruin crops and erode soil fertility. The spatial trend indicates that climate change is imposing differential stresses on the agricultural system of Nigeria such that northern regions are facing growing aridness while southern regions are facing more variable and intense precipitation regimes.

These regional variations have significant policy and planning implications for food security and climate adaptation. The findings indicate that country-wide uniform climate adaptation methods may not be useful, hence region-specific interventions addressing the overarching prevailing climate threats in regions are needed. The northern regions of a nation might need drought-tolerant crops, water-saving systems, and diversification of livelihoods, whereas the south regions would need flood-control systems, drainage systems, and waterlogging- and heavy rainfall-tolerant crops.

The results of the error correction model show significant temporal dynamics in climate-food security interactions with large and statistically significant error correction term (ECT = -0.434, $p < 0.001$) showing that food systems recover partially from climate shocks but remain with long-run exposure to climate change effects. The identification of 43.4% of the short-run deviations to be corrected within one year implies that food systems have partial shock-absorbing mechanisms but cannot recover completely from climate shocks without external intervention or adaptation strategies.

The impulse response test yields valuable insights into the persistence of climate change effects on food security. The evidence that temperature shocks influence food security for about 5 years attests to the fact that climate effects persist in the long term beyond the short-term growing season. This pattern of persistence implies that climate change damage to food systems might accumulate in the long run, with repeated climate shocks building cumulative vulnerabilities that erode food system resilience.

The variance decomposition outputs identify the dominant temperature variability contribution to food security variance at 42.3%, validating the conclusion that the most critical climate risk to Nigerian food systems is temperature extremes. The relatively consistent pattern of contributions over time illustrates that climate change has resulted in long-lasting structural risks in Nigerian food systems that call for long-term adaptation interventions instead of short-term crisis response interventions.

Empirical data of human security outcomes indicate that the food security implications of climate change have wider welfare effects reaching to influence social stability, economic development, and human well-being. The 191% increase in resource conflict is congruent with worsening food security and provides theoretical evidence that food insecurity as a function of climate change can initiate social instability and conflict. This finding has important bearing for acknowledging climate change as a security threat warranting the use of combined policy solutions directed at both environmental and security concerns.

The rise in the rural-to-urban migration rates from 2.1% to 4.3% indicates that climate change is also inducing additional demographic change that will create additional pressures on urban food systems and social services. The observation that climate-driven migration is associated with food security concerns implies that climate adaptation efforts need to focus not only on rural agricultural resilience but also on the ability of urban food systems to absorb climate-displaced populations.

The associated health consequences, a 156% rise in malnutrition-related disease, illustrate the effect of climate change on food security in terms of food and in terms of nutrition and health. The decline in rural societies' education attainment rates illustrates the broader development impact of climate change, where food insecurity can be expressed as food options that give primacy to short-term human development increments.

CONCLUSION AND RECOMMENDATIONS

The research offers compelling empirical support for the deep negative effects of climate change on Nigerian food and human security during 2010-2024. The results show that temperature variability, precipitation regimes, and weather extremes together form pervasive threats to food system resilience, farm yield, and human well-being outcomes. The study confirms Climate Vulnerability Theory and sets the multi-dimensional, chronic, and space-heterogeneous nature of climate-food-security relationships in sub-Saharan African contexts. The empirical findings indicate that climate change is now a major driver of food security effects in Nigeria, as climate variables accounted for 68.4% explanation of food security decline. Variability in temperature is the most influential climate risk ($\beta = -0.587$, $p < 0.001$), followed by extreme weather ($\beta = -0.523$, $p < 0.001$) and rainfall ($\beta = -0.467$, $p < 0.001$). These results confirm climate change as an acute threat multiplier calling for quick policy intervention and concerted adaptation strategies. Regional analysis shows broad differential impacts across Nigeria's six geopolitical zones, with more extreme temperature-related impacts in the northern zones and more precipitation-related impacts in the southern zones. The temporal analysis shows that climate impacts last for around 5 years, meaning that climate change leads to long-term exposures that need to be addressed through constant adaptation. The human security analysis shows that climate-linked food insecurity powers broader welfare consequences like enhanced migration, conflict, and health.

On the basis of the empirical evidence, this paper presents the following evidence-informed recommendations for mitigating the effects of climate change on food security and human security in Nigeria:

i. Develop and release heat-resistant varieties of crops to be released forthwith in every agricultural belt. Release weather observation networks with alarm systems to notify farmers of extraordinary events of heat. Set up facilities for heat stress management like cooling units and shades for animals.
ii. Develop integrated water management frameworks that are able to adapt to flood and drought. Develop rainwater harvesting systems and improved drainage systems in areas prone to flood. Adopt soil moisture conservation management for the aim of attaining optimal water use efficiency during rainfall uncertainty.
iii. There is need for disaster preparedness mechanisms with quick response strategies for extreme weather. Put in place climate-resilient agriculture infrastructure that will be capable of withstanding the shock of extreme weather. Establish emergency food stocks and weather-indexed agriculture insurance schemes for farmers.

Study Limitations

This study identifies some of the weaknesses that may affect generalizability and results interpretation. Secondary data sources have the potential to produce measurement and data quality issues, particularly historical climate and agricultural data. National and regional analysis may silence useful local variations in climate vulnerability and adaptive capacity. The quantitative design of the study, while yielding strong statistical evidence, cannot capture qualitative aspects of climate vulnerability, such as social, cultural, and institutional determinants of food security. The limitation in data on adaptation responses can hamper the estimation of adaptive capacity and resilience determinants. These are problems that need to be addressed by follow-up research using complementary qualitative studies, longer time series data, and higher-resolution local-level data.

Future Research Directions

This research also generates some crucial directions for future research on climate change, food security, and human security in Nigeria and other comparable cases in the future. The effectiveness of various adaptations must be tested by future studies utilizing impact evaluation studies that will be able to quantify the performance of climate-resilient agricultural technologies, water management practices, and policy interventions. Longitudinal studies tracking the nexus between climate and food security over longer periods can offer insights into adaptation processes and long-term building of resilience.

Climate change impacts on gender dimensions research would add to increased knowledge of climate change impacts on various population groups and to more comprehensive adaptation strategies. Climate-food-security relationships studies for urban dimensions would add to knowledge on the climate change impacts on urban food systems and on food relations between urban and rural areas. Cross-country comparison may reveal common trends and context-specific determinants of climate-food-security relationships in sub-Saharan Africa.

Interdisciplinary studies involving climate science, agronomic science, social science, and policy analysis would offer more systematic information on climate-food-security systems and guide more effective adaptation policy. Future studies of this kind would also need to take into account the mediating role of technological innovations, institutional arrangements, and social capital in linking climate-food security.

Significance and Contributions

This research contributes in a number of ways to sub-Saharan Africa's climate change, food security, and human security literature. The formal empirical evidence of climate-food-security linkages comes with state-of-the-art econometric modeling and broad data coverage. The regional-level evidence delivers important evidence on climate vulnerability spatial heterogeneity that can be used in designing geographically specific adaptation schemes.

Temporal analysis introduces new insight on the continuity and dynamics of the impacts of climate change on food security, with evidence suggesting that climate impacts are not only short-term farm growing seasons but also establish long-term sensitivities. Synergistic integration of food security and human security analysis offers a more complete evaluation of the impacts of climate change extending beyond agricultural yields to consider more universal welfare impacts.

The policy-relevant findings and policy recommendations of the study offer practical guidelines for climate adaptation planning and food security policy in Nigeria and comparable settings. Theoretical contributions advance knowledge regarding climate vulnerability theory and social-ecological systems theory through empirical validation and sharpening of theoretical assumptions.

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