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Climate-Induced Flooding and Food Security Outcomes: Evidence from Vegetable Farmers in Kaduna South LGA, Kaduna State

By
GODWIN Akobi Ekawu Amama
Directorate of Linkages and Collaboration, Faculty of Arts and Social Science, Nigeria Defence Academy, Kaduna

Abstract

This study investigated the impact of climate-induced flooding on food security outcomes among smallholder vegetable farmers in Kaduna South Local Government Area (LGA), Kaduna State. Utilizing a descriptive survey research design, the study employed a multi-stage sampling technique to select 350 vegetable farmers across five flood-prone wards: Barnawa, Makera, Kakuri, Tudun Wada, and Sabon Gari. Data collection was executed using structured questionnaires based on the Food Insecurity Experience Scale (FIES) alongside Focus Group Discussions (FGDs) covering the 2022–2025 flood cycles. Empirical analysis revealed that recurrent flooding severely destabilized all five pillars of food security. Local food availability collapsed due to the physical destruction of 75% of high-value horticultural farmlands. Market accessibility was severed by the submergence of critical rural-to-urban transit routes, isolating harvests at the farm gate. Affordability was heavily compromised as supply shocks triggered localized post-flood vegetable price spikes of over 40%. Systemic rainfall unpredictability destroyed agricultural stability, dismantling traditional planting schedules. Furthermore, nutritional utilization was degraded by widespread flood-induced biological contamination of open wells, sparking surges in waterborne pathogens. The study concludes that hydro-climatic flooding drives chronic, structural food insecurity rather than short-term transitory deficits. It recommends that the Kaduna State Government enforce urban zoning reforms, integrate spatial-hydrological planning, and introduce weather-indexed micro-insurance schemes alongside early-maturing, flood-tolerant cultivars to build long-term agrarian resilience.

Keywords: Climate Change, Flooding, Food Security, Vegetable Farmers, Kaduna South.

1. Introduction

Sub-Saharan Africa has emerged as a major focal point for the severe impacts of global climate change, where erratic meteorological transformations directly undermine rain-fed agricultural frameworks. Within Nigeria, this climate crisis manifests as a complex hydro-climatic paradox: while northernmost territories endure accelerating desertification, peri-urban agrarian zones within the Guinea Savanna most notably Kaduna South are repeatedly inundated by high-velocity flash floods and riverine overflows. This environmental instability represents a direct localized manifestation of the Anthropocene epoch, where human-driven atmospheric changes have altered the historic baseline safety margins relied upon by smallholder production systems.

In the macro-economic landscape of Nigeria, agriculture remains a primary driver of rural livelihoods, employing more than 70% of the rural populace and contributing substantially to the national Gross Domestic Product (GDP). Despite its critical role, the sector exhibits extreme vulnerability to sudden hydro-climatic shocks. In Kaduna State, a vital agricultural hub for the federation, high-value horticultural production is concentrated within the "Fadama" riparian floodplains along the corridors of the Kaduna River. These alluvial floodplains supply nutrient-dense topsoil ideal for cultivating highly perishable micronutrient crops like tomatoes, peppers, onions, and leafy greens. However, the same proximity to the river that facilitates dry-season irrigation transforms these fertile belts into high-risk disaster zones during volatile wet seasons.

This structural vulnerability is further intensified by rapid, unplanned urbanization. As metropolitan boundaries expand, natural permeable surfaces are replaced by asphalt and concrete infrastructure, which elevates the run-off coefficient and turns seasonal rainfall into catastrophic flash floods. Unlike resilient cereal varieties, fragile vegetable crops are highly sensitive to poor soil aeration and rapid pathogen spikes. A 48-hour period of submergence often results in absolute yield failure. When these peri-urban production belts collapse under annual floodwaters, the farm-to-fork pipeline is severed, causing immediate supply deficits and severe spikes in food price inflation across urban distribution networks.

1.2 Statement of the Problem

While national agricultural policies often address food insecurity through a macroeconomic lens, there is a profound lack of granular data detailing how hydro-climatic shocks disrupt specific local supply chains. Although frameworks like the Climate Change Act of 2021 and the National Flood Emergency Preparedness and Response Plan exist at the federal level, their practical implementation at the Local Government Area (LGA) tier remains limited. Smallholder vegetable farmers in Kaduna South are frequently caught in a systemic poverty trap. Lacking access to formal financial credit or climate-indexed insurance options due to the "high-risk" classification of floodplain agriculture, these producers face regular asset depletion with every major flood cycle.

The core of this problem lies in the comprehensive erosion of the five dimensions of food security at the household level: availability, accessibility, affordability, stability, and utilization. Flooding does not merely cause temporary crop damage; it systematically deconstructs the structural architecture of the local food system. Direct crop loss drives down physical availability. Submerged transit paths isolate salvageable harvests, severing accessibility. The resulting supply shortfalls drive rapid market price spikes, placing nutrient-dense fresh produce out of reach for low-income urban consumers. Stability is undermined by extreme seasonal unpredictability, which discourages long-term investment in modern agricultural inputs. Finally, utilization is degraded by the contamination of shallow wells, which drives waterborne diseases that prevent normal physiological nutrient absorption. This study addresses these issues by documenting empirical field realities to help transition reactive disaster relief toward proactive, climate-resilient agricultural governance.

1.3 Objectives of the Study

The primary objective of this study was to analyze the relationship between climate-induced flooding and food security outcomes among smallholder vegetable farmers in Kaduna South LGA. The specific research objectives were:

1. To quantify the extent of crop loss and production deficits (Availability) within the target wards.
2. To analyze the post-flood logistics of food distribution and market connectivity (Accessibility).
3. To evaluate the socio-economic burden of post-flood price shocks on producers and consumers (Affordability).
4. To assess how erratic weather patterns alter long-term planting cycle predictability (Stability).
5. To investigate the health-nutrition nexus driven by flood-induced water contamination (Utilization).
6. To document and critique existing indigenous coping mechanisms and formal state-led interventions.

1.4 Conceptual Clarification

Climate-Induced Flooding

Climate-induced flooding refers to the abnormal overflow of water onto normally dry land, driven by extreme precipitation events or the structural failure of hydrological infrastructure due to climate variability. Within Kaduna South LGA, this is an atmospheric-hydrological process characterized by a departure from historical seasonal river cycles. It occurs through two primary mechanisms: flash flooding and riverine inundation. Flash flooding is caused by intense, short-duration rainfall that instantly overwhelms urban soils that have lost their natural permeability to concrete structures and blocked drainage systems. Riverine inundation occurs when prolonged rainfall across the northern hydrological basin fills the catchment areas of the Kaduna River, causing it to breach its natural banks and submerge the low-lying Fadama floodplains under fast-moving, silt-heavy water. This is compounded by under-designed stormwater channels and a lack of automated, early-warning dam release protocols upstream.

Food Security is defined as a situation where all individuals, at all times, maintain physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs. This multi-dimensional state requires five distinct pillars to remain simultaneously intact:

Availability: The continuous physical presence of sufficient quantities of appropriate quality food, derived via local cultivation, commercial channels, or inbound aid.

Accessibility: The removal of geographic, physical, and financial barriers, ensuring households can secure food via functioning transit corridors and market infrastructure.

Affordability: The economic relationship between market pricing and consumer purchasing power, ensuring that essential micronutrient diets do not over-consume household income.

Stability: The constant, uninterrupted preservation of availability and access over time, safeguarding households against sudden environmental shocks or cyclical seasonal scarcity.

Utilization: The physiological and biological absorption of nutrients by the human body, which requires a diet rich in micronutrients, clean drinking water, adequate sanitation, and freedom from disease.

1.5 Theoretical Framework

Entitlement Theory

This study is theoretically grounded in Amartya Sen's (1981) Entitlement Theory. Sen posited that food insecurity is rarely a consequence of a structural decline in total food availability, but rather a failure of individual access capabilities or "entitlements". An individual's entitlement set represents the alternative commodity bundles they can legally command using their social, economic, and legal rights.

In Kaduna South, flooding systematically dismantles these critical entitlement options:

Production-based entitlements: The direct subsistence harvest smallholders obtain from their capital-intensive investments is washed away overnight by river overflows.

Trade-based entitlements: Because horticultural production is highly market-driven, the loss of perishable vegetable harvests destroys the liquid purchasing power farmers need to buy other dietary staples like maize, rice, and yams.

Own-labor entitlements: For landless agricultural laborers, long-term field submergence drops the demand for manual labor to zero, cutting off their daily wage earnings and market access.

Social-Ecological Systems (SES) Theory

To address the environmental dynamics of these shocks, the study integrates the Social-

Ecological Systems (SES) Theory pioneered by Ostrom (2009). SES theory views human societies and biophysical systems as deeply intertwined, co-evolving components rather than separate entities. In Kaduna South, a vulnerability feedback loop is created when rapid, poorly regulated urban growth leads to extensive construction on natural floodplains. This human intervention degrades the environment, removing natural vegetation and reducing soil permeability. When an extreme precipitation event occurs, the altered ecosystem cannot absorb the shock, increasing surface runoff and generating high-velocity flash floods.

This environmental hazard feeds back into the social system, driving a poverty-vulnerability trap. To survive immediate asset depletion after a flood, impoverished farming households often resort to coping strategies that further damage the local ecosystem, such as clearing riparian trees for fuelwood or practicing unstable bank-side cultivation as waters recede. These survival choices increase soil erosion and siltation within the Kaduna River channel. A silted channel has a lower water-carrying capacity, meaning that subsequent rainy seasons require far less rainfall to trigger an even more severe flood event.

1.6. **Methodology**

Research Design and Study Area

This study utilized a cross-sectional survey design combining quantitative and qualitative rapid-appraisal instruments. This design allowed for the collection of data across a broad spectrum of farming households at a specific point in time, matching structured survey metrics with qualitative focus group insights.

The study area was Kaduna South LGA, purposively selected due to its high concentration of Fadama vegetable farming along the riparian corridors of the Kaduna River basin. Positioned between latitudes 10∘25′N and 10∘36′N and longitudes 7∘23′E and 7∘29′E, this zone experiences a tropical wet and dry climate, with a rainy season spanning from May to October. Its low-lying topography and high concentration of concrete surfaces make it a geographic funnel highly vulnerable to seasonal river overflows.

1.7 Population and Sampling Technique

The target population comprised all smallholder vegetable farmers operating within the high-risk floodplains of Kaduna South LGA. Because the exact total population of informal cultivators fluctuates seasonally, agricultural extension records were used to estimate a finite population of approximately 2,900 active farmers. A representative sample size of 350 respondents was determined using the Yamane (1967) formula:

n=1+N(e)2N

Where:

n = the derived sample size required for statistical reliability.

N = the estimated finite population of vegetable farmers (2,900).

e = the allowable margin of error, set at a strict confidence threshold of 5% (0.05).

A multi-stage sampling technique was utilized across three stages:

Stage 1 (Purposive Selection): Five specific wards bordering the Kaduna River with histories of severe flooding were selected: Barnawa, Makera, Kakuri, Tudun Wada, and Sabon Gari.

Stage 2 (Proportional Allocation): The sample size of 350 was distributed proportionally across the five wards based on their respective farmer populations to prevent data skewing.

Stage 3 (Probability Randomization): Within each ward, systematic random sampling was applied using localized farmer association registers to select individual households along spatial transects.

1.8 Data Collection and Analysis

Quantitative data were captured using a structured questionnaire based on a 4-point Likert scale, with response options ranging from Strongly Agree (4) to Strongly Disagree (1). The questionnaire integrated modules modeled on the Food Insecurity Experience Scale (FIES) to evaluate experiences across the five food security pillars. Qualitative depth was obtained via five Focus Group Discussions (FGDs) one per targeted ward composed of 8 to 12 farmers, alongside semi-structured interviews with community leaders and agricultural extension agents. Content validity was verified by a panel of senior agricultural economists and climate adaptation experts. Reliability testing via a pre-test with 35 farmers in an adjacent LGA yielded a Cronbach's alpha (α) coefficient of 0.84, confirming internal consistency.

Quantitative analysis was conducted using SPSS version 27, utilizing descriptive statistics such as frequency distributions, percentages, and mean scores. For the Likert scale items, a mean score threshold of 2.50 was established as the benchmark for decision-making, where scores ≥2.50 indicated significant agreement or impact. Qualitative transcriptions from the interviews and FGDs were evaluated using thematic analysis to code, categorize, and contextualize the quantitative findings.

1.9 Findings and Discussion

Impact on Food Availability and Accessibility

Field data revealed that 88% of the surveyed smallholder vegetable farmers experienced total crop failure at least once during the 2022–2025 flood cycles. When the Kaduna River breaches its banks, the physical destruction of high-value horticultural fields directly undermines the availability pillar. Fragile, non-woody horticultural species like tomatoes and peppers are highly sensitive to soil waterlogging. The quantitative data indicated that a 48-hour period of submergence triggers root rot and total crop death due to anaerobic soil conditions, creating localized production deficits across all five targeted wards.

Simultaneously, the accessibility pillar is disrupted by infrastructure damage. Submerged rural feeder roads and collapsed culverts form a transport bottleneck that isolates fresh produce at the farm gate. Because these low-lying routes lack adequate drainage, transport operators either refuse to enter flooded farming areas or sharply raise transport fees to compensate for potential vehicle damage. Consequently, fresh produce frequently rots on-site before reaching the Central Market Kaduna. This situation supports Sen's argument that acute food insecurity can occur due to a physical and geographic failure of market connectivity, even when food exists at the point of production.

Impact on Affordability, Stability, and Utilization

The supply shocks and transport bottlenecks directly affect consumer markets, undermining affordability. Localized shortages caused a post-flood price shock, with the market cost of a standard basket of tomatoes increasing by 45% in late 2024. Because vegetables are a primary source of essential micronutrients for urban households, this lack of affordability forces low-income consumers to adjust their purchasing habits. Focus group data revealed that households frequently adapt by reducing their fresh vegetable intake and substituting cheaper, carbohydrate-dense but nutrient-poor staple foods. While this shift fulfills short-term caloric requirements, it leads to an increase in micronutrient deficiencies, or "hidden hunger," across the urban population.

Long-term system stability is also undermined by structural volatility. Traditional planting calendars, which farmers historically relied on to maximize yields, have been disrupted by erratic rainfall patterns and unseasonal flash floods. Farmers reported that planting too early risks losing capital inputs to late-season floods, whereas planting too late exposes fragile seedlings to dry-season heat stress without adequate irrigation support. This high level of uncertainty discourages long-term investment in soil health or high-quality inputs, keeping producers caught in a cycle of low inputs and low yields.

Finally, the utilization pillar is degraded by environmental contamination. Focus group discussions revealed that seasonal inundation causes overflowing pit latrines and open drainage channels to mix directly with shallow wells used for domestic consumption and crop washing. This contamination drives surges in waterborne pathogens like cholera and typhoid within farming households. The resulting physiological stress and enteric illnesses reduce nutrient absorption, meaning that even if dietary intake is maintained, illness prevents the body from properly utilizing those calories. This circular vulnerability confirms Social-Ecological Systems theory by illustrating how environmental degradation directly undermines human health and nutritional security.

1.10 Synthesis and Policy Implications

Synthesis of Findings

The empirical evidence demonstrating how flooding systematically impacts the five pillars of food security is summarized in Table 1.

Table 1: Empirical Mapping of Flood Impacts Across Food Security Pillars

Food Security Pillar	Specific Field Evidence from Kaduna South LGA	Supporting Theoretical Context
Availability	88% of farmers reported total crop failure; 75% of Fadama lands submerged.	Production-Based Entitlement Failure: Direct physical destruction of fragile horticultural crops by flood hazards.
Accessibility	Rural feeder roads flooded; transport costs increased; produce isolated at farm gate.	Market Access Failure: Infrastructure breakdowns block the farm-to-market trade corridor.
Affordability	Vegetable prices rose by 45% in late 2024, reducing household purchasing power.	Trade-Based Entitlement Failure: Market supply shocks cause rapid spikes in local food prices.
Stability	Traditional planting calendars disrupted by erratic weather patterns.	Systemic Volatility: Increased climate variability reduces long-term agrarian investment and stability.
Utilization	Well water contaminated; increased incidence of waterborne cholera and typhoid.	Biological Absorption Failure: Pathogen spikes in flooded soil and water impair nutrient utilization.

Note: Formulated based on statistical results and qualitative field data from the five target wards (2026).

This synthesis highlights that the situation in Kaduna South is part of an integrated cycle where each failure triggers the next. The physical loss of crops leads directly to transport blockages, which drives up market prices, creates long-term planning uncertainty, and spreads waterborne illness. Addressing this cycle requires moving away from short-term disaster relief toward comprehensive, climate-resilient agricultural and infrastructural planning.

1.11 Policy Implications

The policy implications of these findings indicate that food security cannot be achieved independently of water management and urban spatial planning. For decades, agricultural line ministries have operated within separate institutional silos, largely disconnected from environmental protection agencies, water resources boards, and municipal planning authorities. This study demonstrates that food insecurity among peri-urban vegetable farmers is not fundamentally an agricultural problem; it is a spatial planning and hydrological crisis.

The Spatial Planning and Hydrological Nexus

The expansion of concrete surfaces and informal settlements within Kaduna South has altered the natural hydrology of the Kaduna River basin. When municipal authorities permit infrastructure development on natural floodplains without enforcing stormwater management regulations, they reduce the catchment's water retention capability. This increase in surface runoff ensures that subsequent rain events will submerge downstream vegetable plots. Consequently, food systems planning must be integrated into municipal zoning frameworks, protecting the Fadama agricultural zones through strict enforcement of riparian buffer zones where construction is prohibited.

The Limitations of Reactive Disaster Governance

The institutional reliance on post-disaster food distribution and short-term emergency relief represents an inefficient model of governance. Distributing palliatives after a flood has already devastated thousands of hectares of vegetables does nothing to repair the underlying production system. It treats the symptom while ignoring the disease. Policy must transition toward proactive risk management frameworks, building capacity in predictive meteorological forecasting, hydrological modeling, and early-warning communication networks that can reach smallholders in time to execute early-harvest strategies.

Financial Inclusivity and Credit Traps

Because traditional commercial banks view floodplain farming as an uninsurable, high-risk venture, vegetable farmers are locked out of formal credit systems. When a flood occurs, they are forced to borrow from informal moneylenders at high interest rates to purchase inputs for the next cycle. This creates a credit trap where smallholders spend their productive cycles paying off debts incurred from past climate disasters. Policy frameworks must focus on establishing state-backed, weather-indexed micro-insurance schemes to absorb the economic shock of crop losses, providing immediate cash payouts to farmers post-flood so they can replant without falling into permanent poverty traps.

1.12 Conclusion

The empirical findings lead to a definitive structural conclusion: climate-induced flooding is no longer a peripheral threat but an embedded determinant of food insecurity in Kaduna South. The historical paradigm that framed flooding as an isolated environmental anomaly occurring once a decade has been invalidated by field realities. Between 2022 and 2025, the recurrent nature of these hydrological shocks demonstrated that flooding has become a chronic disruptor targeting the foundational pillars of the agrarian economy simultaneously. The physical erasure of Fadama crops systematically destroys production and trade entitlements, driving down local availability while triggering price shocks that compromise affordability for the urban poor.

Simultaneously, the physical closing of transit routes breaks accessibility, while the contamination of groundwater resources directly degrades human health, neutralizing nutritional utilization. Proactive climate adaptation and integrated policy planning are necessary to safeguard the peri-urban vegetable sector from the risk of permanent collapse.

1.13 Recommendations

Based on the empirical findings, the following actionable recommendations are proposed:

1. **Physical Infrastructure and Hydrological Engineering:** The Kaduna State Ministry of Environment, in coordination with the Federal Ministry of Water Resources and the Kaduna State Environmental Protection Authority (KEPA), should prioritize the extensive dredging of the urban stretches of the Kaduna River to lower riverbed levels and restore natural channel capacity. Earthen ditches in the farming belts of Barnawa, Makera, Kakuri, Tudun Wada, and Sabon Gari must be replaced with reinforced concrete drainage channels and retaining embankments designed to withstand high-velocity floods. Furthermore, municipal authorities must construct elevated, culvert-supported rural feeder roads to ensure smallholders can transport fresh harvests to the Central Market Kaduna during flood events.

2. **Agricultural Extension and Climate-Smart Innovations:** The Kaduna State Agricultural Development Agency (KADADP) should partner with regional research hubs, such as the Institute for Agricultural Research (IAR) at Ahmadu Bello University, Zaria, to develop and distribute early-maturing, short-cycle, and flood-tolerant vegetable cultivars. Introducing crop varieties that reach maturity within a shorter window allows farmers to harvest entirely within the safe planting window before

seasonal peak floods occur. Additionally, extension agents must train farmers in advanced water management methods, raised cultivation beds, and decentralized water purification protocols to ensure water used for crop washing and drinking is free from flood-borne pathogens.

3. **Institutional Financial Safety Nets and Risk Transfer:** The Kaduna State Government should establish a public-private partnership with specialized agricultural insurers, such as the Nigerian Agricultural Insurance Corporation (NAIC), to design and scale a dedicated Weather-Index Insurance (WII) framework for Fadama producers. This framework should utilize automated, rapid financial payouts triggered when satellite and meteorological data verify that river-gauge metrics have crossed a pre-set hydrological threshold. To lower entry barriers, the state should subsidize a portion of the premium payments using its dedicated climate adaptation and ecological funds, tying these insurance products directly to input credit programs to provide replacement packages of high-quality seeds and fertilizers post-flood.

4. **Integrated Early Warning Communication Networks:** The Kaduna State Emergency Management Agency (SEMA) must collaborate with the Nigerian Meteorological Agency (NiMet) to build a localized, community-level Early Warning System (EWS). The state should invest in automated river-gauge monitors along the Kaduna River basin to track real-time changes in water levels and link this data to a decentralized communication network that sends automated, local-language SMS alerts and radio broadcasts directly to farmer cooperatives. This early warning information

will allow smallholders to harvest mature produce early and move portable irrigation pumps to safety.

5. **Urban Zoning Reform and Environmental Enforcement:** The Kaduna State Urban Planning and Development Authority (KASUPDA) must execute structural reforms regarding urban land allocation and floodplain management. The authority must strictly enforce existing environmental regulations, halting unauthorized construction within designated riparian buffers along the Kaduna River corridor and clearing buildings that block natural urban stormwater channels. Urban planners must officially register the Fadama agricultural zones as protected green infrastructure and urban food security reserves to shield these crucial peri-urban belts from speculative real estate expansion.

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