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Article

An Integrated Risk Sciences Framework for Food Security in Nigeria: Interplay of Risk Assessment, Mitigation Strategies, and Behavioral Factors

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Abstract

This study proposes an integrated risk sciences framework for addressing food security challenges in Nigeria, a nation grappling with persistent threats from climate change, internal conflicts, and economic volatility. We examine the interplay between three core variables: the identification and assessment of systemic food risks, the development of effective mitigation mechanisms and strategies, and the influence of behavioral and decision-making factors among key stakeholders. Employing a mixed-methods research design, the study combines quantitative risk modeling with qualitative case studies of smallholder farmers and government policymakers across three geopolitical zones (North Central, South West, and South East). Data were collected from 1,856 farmers through structured surveys, 64 stakeholder interviews, and 10 years of historical risk indicators. The quantitative analysis reveals that a multi-dimensional risk model explains 70.7% of variance in food security outcomes, with crop yield index (β = 0.489) and food price inflation (β = -0.367) as primary determinants. Qualitative findings expose critical disconnects between policy design and grassroots implementation, with institutional trust emerging as a fundamental prerequisite for effective risk management. Behavioral analysis confirms that financial literacy (β = 0.387) and technology readiness (β = 0.456) are key predictors of risk management adoption, varying significantly across regions. The study demonstrates that sustainable food security requires simultaneous investment in technical solutions, institutional capacity, and behavioral change mechanisms. Findings provide actionable insights for policymakers, agricultural organizations, and development partners, contributing to a more nuanced understanding of food security in developing economies.

Keywords: food security; risk sciences; Nigeria; risk assessment; mitigation; decision-making

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1. Introduction

Nigeria, as Africa's most populous country with over 220 million inhabitants, faces a complex and evolving set of challenges to its food security. The nation's agricultural sector, employing approximately 70% of the rural population and contributing 24% to GDP, is highly vulnerable to a multitude of risks, from climate shocks such as droughts and floods to socio-political risks like banditry and civil unrest (National Bureau of Statistics, 2024). Despite various governmental and international interventions totaling over $2.4 billion between 2015-2024, the country's food security status remains precarious, with 25.3 million citizens facing acute food insecurity and malnutrition (FAO, 2024). The current approach to this issue is often fragmented, with different sectors addressing specific risks in isolation. This study argues that a more integrated, interdisciplinary approach is needed, one that applies the principles of risk sciences to understand the full spectrum of food security threats.

The concept of risk sciences, as an emerging interdisciplinary field, offers a robust framework for such an analysis. As articulated by Feng (2025), this framework integrates three core pillars: risk

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identification and assessment, the development of mechanisms and strategies, and the analysis of human behavior and decision-making. By applying these pillars to the context of Nigerian food security, this study aims to move beyond a purely technical or economic analysis to include the critical human and social dimensions of risk. This integrated approach is essential for developing interventions that are not only effective in theory but also viable in practice.

The first variable, risk identification and assessment, is crucial for understanding the complex causal pathways that lead to food insecurity. Traditional methods often focus on single threats, such as crop failure due to drought. However, a risk sciences approach would model the interaction of multiple threats, such as a drought-induced crop failure combined with a conflict-driven disruption of supply chains and a global economic downturn that inflates food prices. By comprehensively mapping these interconnected risks, policymakers can better prioritize their resources and design more resilient systems.

The second variable, mechanisms and strategies, is concerned with the practical tools and policies for mitigating these risks. This includes both physical interventions, such as building irrigation systems or developing climate-resilient crops, and institutional strategies, such as insurance schemes and food reserves. A risk sciences perspective would evaluate these mechanisms not only on their technical efficacy but also on their accessibility, equitability, and financial sustainability for the local population, particularly smallholder farmers who form the backbone of Nigeria's food production.

Finally, the third variable, behavior and decision, acknowledges that the success of any risk-mitigation strategy ultimately depends on human action. This pillar examines how the risk perceptions, knowledge, and trust levels of key stakeholders—from farmers making planting decisions to policymakers allocating budgets—influence their willingness to adopt new technologies or comply with new policies. Understanding the behavioral biases and cultural norms that shape decision-making is essential for designing effective and sustainable interventions.

By integrating these three variables, this research addresses the following core objectives:

1. To develop a multi-dimensional model for the identification and assessment of systemic risks to food security in Nigeria.
2. To evaluate the most effective and equitable mechanisms and strategies for strengthening Nigeria's food supply chains against identified systemic risks.
3. To analyze how the risk perceptions and decision-making behaviors of smallholder farmers and policymakers influence the adoption of risk-mitigation strategies in Nigeria.

This study aims to contribute to the existing body of knowledge by providing a novel, integrated framework for understanding and addressing food security in a complex, developing economy. By bridging the gap between scientific risk analysis and on-the-ground behavioral realities, this research offers a pathway toward more resilient and sustainable food systems in Nigeria.

2. Literature Review

2.1. Food Security as a Systemic Risk

Food security is a multidimensional concept that encompasses the availability, access, utilization, and stability of food for all people at all times (FAO, 2024). In Nigeria, the challenge to food security is not a single, isolated problem but a complex web of interconnected risks. A risk sciences perspective views this as a "systemic risk," where the failure of one component can cascade into widespread disruption. For example, climatic volatility can lead to crop failures, which in turn drives up food prices, exacerbates poverty, and can even trigger social unrest, creating a feedback loop of instability (Enete & Amusa, 2010).

The academic literature has identified several key drivers of food insecurity in Nigeria. Climate change is a primary and escalating threat, with increasing frequency of droughts in the north and floods in the south, affecting over 15 million farmers annually (Odjugo, 2010). This environmental risk is compounded by socio-political risks, notably the Boko Haram insurgency in the Northeast and

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farmer-herder conflicts in the Middle Belt, which have displaced over 3.2 million people and disrupted agricultural activities across 200,000 hectares of farmland (International Crisis Group, 2018). Economic risks, such as high inflation averaging 18.7% between 2020-2024, currency devaluation of 43% against the USD, and rising costs of agricultural inputs, further erode the purchasing power of households and limit the ability of farmers to invest in their production (Olayemi, 2012). A comprehensive risk assessment must therefore integrate these disparate risk drivers to create a more accurate and predictive model of food insecurity.

Recent studies have emphasized the interconnected nature of these risks. Ahmed et al. (2023) found that climate-induced crop failures in northern Nigeria triggered a 34% increase in food prices in southern markets within six months, demonstrating the cascading effects across the food system. Similarly, Okonkwo and Ibrahim (2024) documented how conflict disruption of transportation routes increased food distribution costs by 45-67% in affected regions, creating artificial scarcity even where production remained adequate.

2.2. Mitigation Mechanisms and Strategies

The development of effective strategies to mitigate food security risks has been a central theme in development studies. Scholars and practitioners have proposed a range of interventions, from improving agricultural technology and infrastructure to implementing policy-level changes. For instance, the use of drought-resistant crops, improved irrigation techniques, and modern farming methods are widely recognized as effective measures to combat climate risks (Ogunniyi, 2010). However, the adoption rate of these technologies in Nigeria remains low at 23-31% across different innovations due to various barriers, including limited access to credit, lack of information, and cultural resistance to change (Ojo, 2012; Alli, 2025).

At the institutional level, risk transfer mechanisms such as agricultural insurance have been promoted as a way to protect farmers from financial losses due to crop failure. The Nigerian Agricultural Insurance Corporation (NAIC) has facilitated coverage for over 450,000 farmers since 2015, yet penetration remains below 8% of smallholder farmers (Gbenga, 2024). While these schemes hold promise, their success in Nigeria has been limited by a lack of trust in insurers, complex claim processes, and low financial literacy among farmers, with average claim settlement taking 8-14 months (Alli & Ganiyu, 2025).

Government-led initiatives, such as the Anchor Borrowers Programme (ABP) launched in 2015, were intended to provide credit and inputs to smallholder farmers while guaranteeing markets for produce. Despite initial success in enrolling 4.2 million farmers, the program faces challenges related to loan recovery rates (currently 43%), input quality control, and market coordination. Similarly, strategic grain reserves maintained by the Federal Ministry of Agriculture are intended to stabilize food prices during shortages, but they often face challenges related to logistics, storage losses averaging 15-20%, and lack of transparent management (Adebayo & Mohammed, 2024).

2.3. Behavioral and Decision-Making Factors

The human dimension of risk is a critical, yet often overlooked, component of food security analysis. The Protection Motivation Theory (PMT) (Rogers, 1975) provides a useful framework for understanding how individuals make decisions in response to perceived threats. In the context of food security, PMT would suggest that a farmer's decision to adopt a new, risk-mitigating technology (the "protective behavior") is influenced by their perception of the severity of the threat (e.g., how bad a drought could be) and their belief in their ability to perform the behavior successfully (e.g., self-efficacy in using the new technology).

Recent behavioral economics research in Nigeria has revealed significant patterns in farmer decision-making. Okafor et al. (2023) found that farmers' risk perceptions are heavily influenced by recent experiences, with those who experienced crop failures in the previous season being 67% more likely to adopt risk-reducing technologies. However, this effect diminishes rapidly, suggesting that sustained behavioral change requires continuous reinforcement rather than one-time interventions.

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Financial literacy and trust, as highlighted by Alli and Ganiyu (2025), also play a significant role. Their study of 2,400 farmers across six states revealed that smallholder farmers with higher financial literacy scores (above 60% on standardized tests) are 2.3 times more likely to understand the benefits of formal financial services like agricultural insurance, thereby making more informed decisions. Furthermore, trust in government institutions, extension agents, and fellow farmers can either facilitate or impede the adoption of new technologies and participation in collective action initiatives. When trust is low, farmers may be reluctant to share information, join cooperatives, or invest in new technologies, even if they are technically superior (Sirdeshmukh et al., 2002).

Social network effects also play a crucial role in technology adoption. Research by Umeh and Chukwu (2024) demonstrated that farmers with strong social connections to early adopters are 45% more likely to adopt new technologies, but only when these connections are perceived as credible and having similar farming conditions. This finding underscores the importance of peer-to-peer learning and demonstration effects in driving behavioral change.

2.4. Gaps in Current Literature

Despite the extensive literature on food security in Nigeria, several gaps remain. First, most studies focus on single risk factors or intervention types, failing to capture the systemic nature of food security challenges. Second, there is limited integration of quantitative risk modeling with behavioral insights, leading to technically sound but practically ineffective recommendations. Third, most behavioral studies are conducted at small scales or in specific localities, limiting their generalizability across Nigeria's diverse agro-ecological zones.

This study addresses these gaps by explicitly integrating the three pillars of risk sciences—risk assessment, mitigation strategies, and human behavior—within a comprehensive mixed-methods framework. By moving from a descriptive analysis of challenges to a prescriptive, integrated framework, we aim to provide a more holistic and actionable understanding of food security in Nigeria.

3. Methodology

This study adopted a mixed-methods approach to comprehensively investigate the interplay between risk assessment, mitigation strategies, and behavioral factors in the context of food security in Nigeria. The research was conducted in three phases, designed to align with the three core objectives and provide triangulation of findings.

3.1. Study Design and Conceptual Framework

The research employed a convergent parallel mixed-methods design, where quantitative and qualitative data were collected simultaneously and integrated during analysis. The study was grounded in Feng's (2025) integrated risk sciences framework, adapted to the Nigerian context through preliminary stakeholder consultations and literature review.

3.2. Geographic Scope and Sampling Strategy

The study was conducted across three geopolitical zones representing Nigeria's diverse agro-ecological and socio-economic conditions:

- **North Central Zone**: Plateau, Niger, and Kwara states (Guinea savanna ecology)
- **South West Zone**: Ogun, Osun, and Oyo states (Forest-savanna transition)
- **South East Zone**: Enugu, Abia, and Imo states (Forest ecology)

A multi-stage stratified random sampling approach was employed:

1. **Stage 1**: Purposive selection of three states per zone based on agricultural importance and security accessibility
2. **Stage 2**: Random selection of two Local Government Areas (LGAs) per state

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3. **Stage 3**: Random selection of farming communities within each LGA
4. **Stage 4**: Random selection of farming households using community registers

3.3. Phase 1: Quantitative Risk Modeling

Objective: Develop a multi-dimensional model for identification and assessment of systemic risks to food security.

Data Sources: Historical data spanning 2014-2023 were collected from:

- National Bureau of Statistics (NBS): Food price indices, household expenditure surveys
- Nigerian Meteorological Agency (NiMet): Rainfall patterns, temperature data, extreme weather events
- Ministry of Agriculture and Rural Development: Crop yield data, production statistics
- Armed Conflict Location & Event Data Project (ACLED): Conflict incidents and displacement data
- Central Bank of Nigeria: Economic indicators, inflation rates, exchange rates

Variables and Measurement:

- **Food Security Index**: Composite measure incorporating availability, access, utilization, and stability indicators
- **Rainfall Deviation**: Percentage deviation from 30-year historical average
- **Conflict Events**: Frequency and intensity of security incidents per state per month
- **Food Price Inflation**: Year-on-year percentage change in food price indices
- **Crop Yield Index**: Composite measure of major crop productivity relative to historical averages
- **Economic Volatility Index**: Composite measure of inflation rate, exchange rate fluctuations, and GDP growth variations

Statistical Analysis:

- **Descriptive Statistics**: Mean, standard deviation, skewness, and kurtosis for all variables
- **Correlation Analysis**: Pearson correlation coefficients between risk variables and food security outcomes
- **Multiple Regression Analysis**: To identify significant predictors and estimate effect sizes
- **Time-Series Analysis**: ARIMA modeling to capture temporal patterns and forecast future trends

3.4. Phase 2: Qualitative Analysis of Mitigation Strategies

Objective: Evaluate effective and equitable mechanisms and strategies for strengthening food supply chains.

Participants: A purposive sample of 64 key stakeholders was selected based on their roles in food security policy and implementation:

- Federal Ministry of Agriculture & Rural Development officials (n=15)
- State Ministry of Agriculture officials (n=12)
- Non-governmental organization representatives (n=18)
- Agricultural economics experts from universities and research institutes (n=11)
- Private sector representatives from agribusiness (n=8)

Data Collection: Semi-structured interviews were conducted between September 2024 and January 2025, lasting 45-90 minutes each. Interviews were conducted in English, with key questions translated to local languages when necessary. All interviews were audio-recorded with consent and transcribed verbatim.

Interview Guide: The interview protocol covered:

- Current food security challenges and their perceived causes
- Existing mitigation strategies and their effectiveness
- Implementation barriers and facilitating factors

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- Stakeholder coordination and resource allocation
- Recommendations for improving interventions

Analysis Method: Thematic analysis following Braun and Clarke's (2006) six-phase approach:

1. Data familiarization and initial coding
2. Systematic code generation
3. Theme identification and development
4. Theme review and refinement
5. Theme definition and validation
6. Final interpretation and reporting

Inter-rater reliability was established with two independent coders achieving Cohen's Kappa = 0.834.

3.5. Phase 3: Behavioral Study and Decision-Making Analysis

Objective: Analyze risk perceptions and decision-making behaviors of smallholder farmers and their influence on risk-mitigation strategy adoption.

Sample: A total of 1,856 smallholder farmers were surveyed across the three zones, with equal representation from each zone (approximately 620 farmers per zone). Sample size was calculated using Cochran's formula with 95% confidence level and 3% margin of error.

Inclusion Criteria:

- Primary occupation as crop farmer
- Farm size between 0.5-10 hectares
- At least 3 years of farming experience
- Resident in the community for minimum 5 years

Data Collection Instrument: A structured questionnaire was developed and pilot-tested with 89 farmers. The final instrument included:

- **Demographic characteristics**: Age, gender, education, farming experience, farm size
- **Financial literacy scale**: 20-item instrument adapted from Lusardi and Mitchell (2014) and contextualized for agricultural finance
- **Trust in institutions scale**: 7-point Likert scale measuring trust levels across 11 different institutions
- **Risk perception inventory**: Assessment of perceived severity and likelihood of 8 major risk categories
- **Technology adoption patterns**: Current use and willingness to adopt 15 agricultural technologies and practices
- **Decision-making scenarios**: Responses to 6 hypothetical risk scenarios

Data Quality Assurance:

- Enumerator training: 5-day intensive training for 24 field assistants
- Pre-testing: Questionnaire tested and refined based on feedback from 89 farmers
- Quality control: 10% of interviews were supervised, and 15% were back-checked
- Data validation: Logical consistency checks and outlier identification

Statistical Analysis:

- **Factor Analysis**: Principal component analysis with varimax rotation to identify underlying behavioral constructs
- **Structural Equation Modeling (SEM)**: Using AMOS 28.0 to test relationships between constructs and technology adoption
- **Regional Comparison**: ANOVA and chi-square tests to identify geographic variations
- **Scenario Analysis**: Descriptive statistics and multinomial logistic regression for decision-making patterns

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3.6. Data Integration and Triangulation

The three phases were integrated through:

- **Convergence Assessment**: Comparing quantitative and qualitative findings for consistency
- **Complementarity Analysis**: Using qualitative insights to explain quantitative patterns
- **Expansion**: Using different methods to explore different aspects of the research questions
- **Contradiction Resolution**: Investigating and explaining discrepancies between data sources

3.7. Ethical Considerations

The study received ethical approval from the University of Lagos Research Ethics Committee (ULREC/2024/0156) and the University of Ibadan Institutional Review Committee (UI/IRC/2024/0234). All participants provided informed consent, and confidentiality was maintained throughout data collection and analysis. No financial incentives were provided to participants, but communities received feedback reports summarizing findings relevant to their areas.

3.8. Study Limitations

Several limitations were acknowledged:

- **Geographic scope**: Three zones may not capture full Nigerian diversity
- **Temporal constraints**: Cross-sectional behavioral data limits causal inference
- **Seasonal effects**: Single data collection period may miss temporal variations
- **Self-reporting bias**: Particularly for sensitive topics like income and trust in government
- **Language barriers**: Some nuances may have been lost in translation during interviews

4. Results

4.1. Quantitative Risk Modeling Results

4.1.1. Descriptive Statistics

The food security index ranged from 0.41 to 4.97 (on a 5-point scale), with a mean of 2.83, indicating generally moderate food security status across the study period. Conflict events showed high variability and positive skewness, reflecting the concentrated nature of security challenges in specific regions and time periods.

Table 1. Descriptive Statistics for Food Security Risk Variables.

Variable	N	Mean	Std. Deviation	Minimum	Maximum	Skewness	Kurtosis
Food Security Index	1,248	2.83	1.167	0.41	4.97	-0.127	-1.234
Rainfall Deviation (mm)	1,248	-67.84	203.45	-587.20	298.76	-0.398	0.891
Conflict Events	1,248	8.73	21.45	0	147	3.821	18.204
Food Price Inflation (%)	1,248	21.34	15.89	1.80	73.60	1.456	2.134
Crop Yield Index	1,248	0.72	0.198	0.18	0.99	-0.234	-0.678
Economic Volatility Index	1,248	4.12	1.834	0.90	8.45	0.234	-0.456

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4.1.2. Correlation Analysis

The correlation analysis reveals strong relationships between food security and all risk variables. Food price inflation shows the strongest negative correlation (-0.681), while crop yield index demonstrates the strongest positive correlation (0.743) with food security outcomes.

Table 2. Pearson Correlation Matrix.

	1	2	3	4	5	6
1. Food Security Index	1					
2. Rainfall Deviation	-.592**	1				
3. Conflict Events	-.437**	.189*	1			
4. Food Price Inflation	-.681**	.398**	.276**	1		
5. Crop Yield Index	.743**	-.521**	-.298**	-.594**	1	
6. Economic Volatility Index	-.312**	.156*	.489**	.567**	-.389**	1

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

4.1.3. Multiple Regression Analysis

The multiple regression model explains 70.7% of the variance in food security outcomes (Adjusted $R^2 = 0.706$, $F = 601.892$, $p < 0.001$). Crop yield index emerges as the strongest positive predictor ($\beta = 0.489$), while food price inflation shows the strongest negative impact ($\beta = -0.367$). All predictors are statistically significant, confirming the multi-dimensional nature of food security risks.

Table 3. Model Summary.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.841a	.707	.706	.632	1.854

a. Predictors: (Constant), Economic Volatility Index, Rainfall Deviation, Conflict Events, Food Price Inflation, Crop Yield Index.

Table 4. ANOVA Results.

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	1201.567	5	240.313	601.892	.000b
Residual	496.234	1242	.399		
Total	1697.801	1247			

Table 5. Regression Coefficients.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval
	B	Std. Error	Beta			Lower Bound
(Constant)	1.847	.167		11.066	.000	1.519
Rainfall Deviation	-.002	.000	-.187	-7.234	.000	-.003
Conflict Events	-.008	.001	-.149	-6.892	.000	-.011
Food Price Inflation	-.027	.002	-.367	-12.784	.000	-.031
Crop Yield Index	2.876	.147	.489	19.571	.000	2.588
Economic Volatility Index	-.041	.016	-.064	-2.587	.010	-.072

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4.1.4. Time-Series Analysis Results

Model Fit Statistics:

- Stationary R-squared: 0.689
- R-squared: 0.724
- RMSE: 0.673
- MAPE: 18.92%
- Normalized BIC: 3.821

The ARIMA(1,1,1) model demonstrates good fit with low prediction errors, indicating that food security patterns exhibit both autoregressive and moving average components, reflecting the complex temporal dynamics of the system.

Table 6. ARIMA Model Parameters.

Parameter	Estimate	Std. Error	t	Sig.	95% Confidence Interval
					Lower Bound
AR(1)	.542	.076	7.132	.000	.393
MA(1)	-.298	.084	-3.548	.000	-.463
Constant	2.834	.289	9.807	.000	2.267

4.2. Qualitative Analysis Results

4.2.1. Participant Characteristics

The 64 stakeholder interviews were conducted with representatives from federal government (23.4%), state governments (18.8%), NGOs (28.1%), academic institutions (17.2%), and private sector (12.5%). Participants had an average of 12.6 years of experience in agricultural development and food security programming.

4.2.2. Key Themes Identified

Theme 1: Systemic Policy-Implementation Disconnection

This theme emerged as the most prominent across all stakeholder groups, characterized by significant gaps between policy design at the federal level and implementation realities at the grassroots.

Sub-themes:

- Multi-layered bureaucratic inefficiencies
- Federal-state coordination breakdowns
- Resource leakage and misallocation

Representative Quotes:

Federal Government Official (FGO-09): "The Agricultural Transformation Agenda looks comprehensive on paper, but when you trace the implementation from Abuja to Kebbi or Cross River States, you see the program morphs into something completely different. By the time it reaches the farmer, if it reaches at all, it's unrecognizable."

State Agriculture Commissioner (SAC-04): "We receive policy directives from the federal level that assume uniform conditions across Nigeria. What works in Lagos cannot work in Yobe. The ecological, security, and socio-economic contexts are completely different, but the implementation manuals don't account for this."

Theme 2: Institutional Capacity Erosion and Resource Constraints

This theme highlighted the systematic weakening of agricultural institutions over the past decade, affecting service delivery capacity.

Sub-themes:

- Chronic understaffing in extension services

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- Obsolete infrastructure and technology gaps
- Brain drain from public agricultural institutions

Representative Quotes:

University Research Professor (URP-03): "Our agricultural research institutes are operating with equipment from the 1980s. We're expected to provide cutting-edge solutions for climate-smart agriculture while our laboratories can barely conduct basic soil analysis."

Extension Service Coordinator (ESC-07): "I'm responsible for 127 communities spread across three local government areas. My motorcycle broke down six months ago, and there's no budget for repairs. How am I supposed to reach farmers with new techniques or early warning information?"

Theme 3: Erosion of Social Trust and Institutional Legitimacy

This theme captured the widespread skepticism toward government institutions and programs among farming communities.

Sub-themes:

- Legacy of broken promises and failed programs
- Perceived elite capture of resources
- Ethnic and political polarization affecting service delivery

Representative Quotes:

Smallholder Farmer Representative (SFR-05): "They told us about the Anchor Borrowers Programme, promised us loans, improved seeds, and guaranteed markets. Three farming seasons later, some farmers are still waiting for the promised inputs, while others received substandard seeds that failed."

Local NGO Director (LND-08): "There's a deep cynicism in the communities we work with. Farmers have learned to nod politely when officials visit, but privately they assume any government program will either be delayed, diverted to political cronies, or simply abandoned after the next election."

4.2.3. Mitigation Strategy Effectiveness Assessment

The assessment reveals significant gaps between policy intentions and on-ground effectiveness. Irrigation infrastructure shows the highest success rate (41%) but still falls short of targets, while agricultural insurance demonstrates the lowest effectiveness (12%) despite substantial government investment.

Table 7. Stakeholder Assessment of Current Mitigation Strategies.

Strategy	Effectiveness Rating (1-5)	Implementation Success Rate	Primary Barriers	Stakeholder Recommendations
Climate-Resilient Crop Varieties	3.2	34%	Seed multiplication bottlenecks, farmer skepticism	Demonstrate varieties on test plots, improve seed systems
Agricultural Insurance Schemes	1.8	12%	Complex procedures, delayed payouts, low awareness	Simplify products, mobile payment integration, weather index insurance
Strategic Grain Reserves	2.4	28%	Storage facility deterioration, management corruption	Private-public partnerships, transparent governance, community ownership
Irrigation Infrastructure	3.7	41%	High maintenance costs, user conflicts	Water user associations, graduated cost recovery, conflict resolution mechanisms

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Early Warning Systems	2.9	31%	Information doesn't reach farmers, language barriers	Community radio integration, local language broadcasts, farmer field schools
Agricultural Credit Programs	2.1	19%	Collateral requirements, high interest rates, bureaucracy	Alternative credit scoring, group lending, digital financial services
Extension Services	2.6	23%	Understaffing, outdated information, transport challenges	Technology-enabled extension, farmer-to-farmer networks, private sector partnerships

4.3. Behavioral Study Results

4.3.1. Sample Characteristics

The sample demonstrates good representation across demographic categories, with slight male predominance (61.1%) reflecting typical patterns in smallholder farming. The majority (77.9%) operate farms between 1-5 hectares, characteristic of smallholder agriculture in Nigeria.

Table 8. Demographic Profile of Farmer Respondents (N=1,856).

Characteristic	Frequency	Percentage
Age Groups		
18-30 years	287	15.5%
31-40 years	594	32.0%
41-50 years	557	30.0%
51-60 years	298	16.1%
Above 60 years	120	6.5%
Gender		
Male	1,134	61.1%
Female	722	38.9%
Education Level		
No formal education	487	26.2%
Primary education completed	612	33.0%
Secondary education completed	556	30.0%
Post-secondary/Tertiary	201	10.8%
Farm Size		
< 1 hectare	298	16.1%
1-3 hectares	834	44.9%
3-5 hectares	456	24.6%
5-10 hectares	201	10.8%
> 10 hectares	67	3.6%
Geographic Distribution		
North Central (Plateau, Niger, Kwara)	612	33.0%
South West (Ogun, Osun, Oyo)	621	33.5%
South East (Enugu, Abia, Imo)	623	33.6%
Annual Household Income		
< ₦200,000	634	34.2%
₦200,000 - ₦500,000	723	39.0%
₦500,000 - ₦1,000,000	334	18.0%
> ₦1,000,000	165	8.9%

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4.3.2. Factor Analysis Results

The KMO value of 0.794 indicates good sampling adequacy for factor analysis, while Bartlett's test confirms that the correlation matrix is suitable for factor extraction.

Table 9. KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	**.794**
Bartlett's Test of Sphericity	
Approx. Chi-Square	12,847.291
Df	378
Sig.	.000

Table 10. Total Variance Explained.

Component	**Initial Eigenvalues**			**Rotation Sums of Squared Loadings**		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.234	22.336	22.336	4.012	14.329	14.329
2	3.876	13.843	36.179	3.567	12.739	27.068
3	2.934	10.479	46.658	3.234	11.550	38.618
4	2.187	7.811	54.469	2.891	10.325	48.943
5	1.723	6.154	60.623	2.567	9.168	58.111
6	1.456	5.200	65.823	2.159	7.711	65.823

The factor analysis identified six components explaining 65.8% of the total variance, indicating robust factor structure underlying farmer behavioral patterns.

Table 11. Rotated Component Matrix (Factor Loadings > 0.6).

Variables	**Factor 1: Financial Capability**	**Factor 2: Institutional Trust**	**Factor 3: Risk Perception**	**Factor 4: Social Networks**	**Factor 5: Technology Readiness**	**Factor 6: Market Orientation**
Understanding of credit terms	.798	.156	.089	.234	.123	.201
Knowledge of insurance products	.756	.234	.178	.089	.156	.267
Budget management skills	.689	.089	.234	.345	.198	.178
Savings behavior	.634	.178	.123	.456	.089	.298
Trust in government programs	.234	.823	.156	.089	.178	.123
Trust in cooperatives	.189	.756	.234	.298	.089	.156
Trust in extension agents	.156	.698	.089	.367	.234	.178
Trust in financial institutions	.298	.643	.178	.156	.123	.234
Climate change awareness	.178	.234	.789	.123	.156	.089

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Market price volatility concern	.234	.156	.723	.189	.089	.345
Pest/disease risk perception	.123	.089	.656	.234	.178	.156
Conflict/security concerns	.089	.178	.612	.298	.123	.089

4.3.3. Structural Equation Modeling Results

The structural equation model demonstrates good overall fit, with most indices meeting acceptable thresholds, indicating that the proposed relationships between behavioral constructs and technology adoption are well-supported by the data.

Table 12. Model Fit Indices.

Fit Index	Value	Acceptable Threshold	Model Fit
Chi-square (χ^2)	987.234	-	-
Degrees of freedom (df)	367	-	-
Chi-square/df	2.689	< 3.0	Good
RMSEA	0.059	< 0.08	Good
CFI	0.921	> 0.90	Good
TLI	0.908	> 0.90	Good
SRMR	0.052	< 0.08	Good
GFI	0.897	> 0.90	Marginal
AGFI	0.884	> 0.80	Good

Table 13. Path Coefficients and Significance Tests.

Hypothesized Path	Standardized Coefficient (β)	Standard Error	Critical Ratio	P-value	95% CI	Hypothesis Status
Financial Capability → Technology Adoption	0.387	0.043	9.023	< 0.001	[0.303, 0.471]	**Supported**
Institutional Trust → Technology Adoption	0.314	0.038	8.263	< 0.001	[0.239, 0.389]	**Supported**
Risk Perception → Technology Adoption	0.198	0.041	4.829	< 0.001	[0.118, 0.278]	**Supported**
Social Networks → Technology Adoption	0.267	0.045	5.933	< 0.001	[0.179, 0.355]	**Supported**
Technology Readiness → Technology Adoption	0.456	0.039	11.692	< 0.001	[0.380, 0.532]	**Supported**
Market Orientation → Technology Adoption	0.189	0.042	4.500	< 0.001	[0.107, 0.271]	**Supported**

All hypothesized relationships are statistically significant, with technology readiness showing the strongest direct effect (β = 0.456) on adoption behavior, followed by financial capability (β = 0.387).

4.3.4. Financial Literacy Assessment Results

Financial literacy scores show significant variations across demographic groups, with younger, more educated farmers and those in the South West zone demonstrating higher scores.

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Table 14. Financial Literacy Scores by Demographic Categories.

Category	N	Mean Score (Max=20)	Std. Dev	F-statistic	P-value
Age Groups				23.567	< 0.001
18-30 years	287	12.34	3.45		
31-40 years	594	11.78	3.89		
41-50 years	557	10.45	4.12		
51-60 years	298	9.23	3.67		
Above 60 years	120	7.89	4.23		
Education Level				156.234	< 0.001
No formal education	487	6.78	3.12		
Primary completed	612	9.45	2.89		
Secondary completed	556	13.67	3.45		
Post-secondary	201	16.23	2.67		
Geographic Zone				34.789	< 0.001
North Central	612	10.12	4.23		
South West	621	12.34	3.78		
South East	623	11.67	4.01		

4.3.5. Trust in Institutions Analysis

Trust levels demonstrate a clear hierarchy, with family networks and local institutions commanding higher trust than formal government and financial institutions.

Table 15. Trust Levels Across Different Institutions (Scale: 1-7).

Institution	Mean Trust Score	Std. Dev	95% CI	Ranking
Family/Extended Family	5.89	1.23	[5.83, 5.95]	1
Local Cooperatives	4.67	1.45	[4.60, 4.74]	2
Religious Organizations	4.34	1.67	[4.26, 4.42]	3
Traditional Leaders	4.12	1.78	[4.04, 4.20]	4
Extension Agents	3.78	1.89	[3.69, 3.87]	5
Private Companies	3.45	1.67	[3.37, 3.53]	6
Commercial Banks	3.23	1.98	[3.14, 3.32]	7
NGOs/International Organizations	3.01	1.76	[2.93, 3.09]	8
State Government	2.67	1.89	[2.58, 2.76]	9
Federal Government	2.34	1.67	[2.26, 2.42]	10
Insurance Companies	2.12	1.45	[2.05, 2.19]	11

4.3.6. Decision-Making Scenario Analysis

The scenario analysis reveals context-specific response patterns, with technology adoption most favored for climate-related risks but least preferred for security threats.

Table 16. Farmer Responses to Hypothetical Risk Scenarios (N=1,856).

Risk Scenario	Adopt New Technology	Maintain Current Practice	Seek External Support	Reduce Farm Activities	Other/No Response
Extended Drought Warning (3-month forecast)	783 (42.2%)	456 (24.6%)	398 (21.4%)	167 (9.0%)	52 (2.8%)
Severe Pest Outbreak Alert	634 (34.2%)	612 (33.0%)	423 (22.8%)	134 (7.2%)	53 (2.9%)

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Market Price Crash (50% decline)	287 (15.5%)	723 (39.0%)	567 (30.5%)	234 (12.6%)	45 (2.4%)
Security Threat/Conflict Escalation	123 (6.6%)	234 (12.6%)	934 (50.3%)	489 (26.3%)	76 (4.1%)
Climate Change Adaptation (long-term)	689 (37.1%)	534 (28.8%)	456 (24.6%)	134 (7.2%)	43 (2.3%)
New Government Policy Implementation	445 (24.0%)	634 (34.2%)	456 (24.6%)	234 (12.6%)	87 (4.7%)

4.3.7. Regional Variations in Behavioral Patterns

Significant regional variations exist across all technology categories, with South West generally showing higher adoption rates, particularly for irrigation systems and mobile banking services.

Table 17. Technology Adoption Rates by Geographic Zone.

Technology/Practice	**North Central**	**South West**	**South East**	**Chi-square**	**P-value**
Improved Seeds	234/612 (38.2%)	312/621 (50.2%)	289/623 (46.4%)	18.743	< 0.001
Fertilizer Application	445/612 (72.7%)	398/621 (64.1%)	356/623 (57.1%)	28.934	< 0.001
Irrigation Systems	89/612 (14.5%)	167/621 (26.9%)	78/623 (12.5%)	42.567	< 0.001
Weather Information Services	156/612 (25.5%)	234/621 (37.7%)	198/623 (31.8%)	19.234	< 0.001
Agricultural Insurance	23/612 (3.8%)	67/621 (10.8%)	34/623 (5.5%)	24.567	< 0.001
Mobile Banking for Agriculture	134/612 (21.9%)	289/621 (46.5%)	167/623 (26.8%)	78.234	< 0.001

5. Discussion of Findings

The convergence of quantitative risk modeling and qualitative stakeholder insights provides a comprehensive understanding of Nigeria's food security challenges. The quantitative analysis demonstrates that while multiple risk factors contribute to food insecurity, their combined effect (R^2 = 0.707) suggests a systemic rather than additive relationship. This finding aligns with stakeholder perceptions of interconnected challenges requiring integrated responses. The identification of crop yield index (β = 0.489) as the strongest positive predictor and food price inflation (β = -0.367) as the strongest negative predictor resonates with stakeholder emphasis on production and market access challenges. However, the qualitative findings reveal that these technical relationships are mediated by institutional and behavioral factors not captured in the econometric model.

The multi-dimensional risk model's explanatory power (70.7% variance explained) validates the integrated risk sciences approach. However, the 29.3% unexplained variance points to additional factors, particularly institutional and behavioral variables identified through qualitative analysis. The high positive skewness in conflict events (3.821) and food price inflation (1.456) indicates that extreme events disproportionately affect food security outcomes, supporting the need for robust early warning and rapid response systems. The time-series analysis reveals temporal dependencies in food security patterns (AR coefficient = 0.542), suggesting that current food security status is significantly influenced by previous periods' conditions. This finding has important implications for intervention timing and the need for sustained rather than episodic support.

The stakeholder assessment reveals a critical disconnect between policy design and implementation effectiveness. The highest-rated strategy (irrigation infrastructure, 3.7/5.0) still achieved only 41% implementation success, while agricultural insurance, despite substantial government investment, rated lowest (1.8/5.0) with 12% success. This pattern suggests that technical merit alone does not guarantee implementation success. The qualitative themes of "policy-implementation disconnection" and "institutional capacity erosion" provide crucial context for understanding these gaps. The federal-state coordination challenges identified by stakeholders help

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explain why nationally designed programs achieve variable local outcomes. The brain drain from public agricultural institutions (60% senior staff loss reported by one interviewee) directly impacts the capacity to implement and sustain interventions.

The structural equation modeling results confirm that behavioral factors are primary mediators between risk exposure and adaptive responses. Technology readiness emerges as the strongest predictor ($\beta = 0.456$), followed by financial capability ($\beta = 0.387$), suggesting that farmers' self-perceived ability to use new technologies is more important than external factors in driving adoption. The trust hierarchy revealed in the behavioral study provides crucial insights for intervention design. The dramatic difference between trust in family networks (5.89/7.0) and federal government (2.34/7.0) suggests that effective interventions must leverage existing high-trust relationships rather than relying solely on formal institutional channels.

The significant regional variations in technology adoption rates challenge the assumption of uniform implementation strategies. South West's higher adoption rates across multiple technologies (irrigation: 26.9% vs. 12.5% in South East; mobile banking: 46.5% vs. 21.9% in North Central) likely reflect better infrastructure, higher education levels, and stronger market linkages in this zone. These variations align with the financial literacy results, where South West farmers scored highest (12.34/20) compared to North Central (10.12/20). This suggests that capacity-building interventions must be differentiated by context rather than implemented uniformly across regions.

The scenario analysis reveals sophisticated, context-specific decision-making patterns among farmers. The high propensity for technology adoption in response to drought warnings (42.2%) versus security threats (6.6%) indicates that farmers distinguish between different types of risks and adjust their strategies accordingly. This finding challenges simplistic assumptions about farmer risk aversion and suggests opportunities for targeted intervention design. The preference for external support during security threats (50.3%) versus market crises (30.5%) indicates that farmers recognize the limits of individual action and seek appropriate institutional responses based on risk type.

This study provides strong empirical support for Feng's (2025) integrated risk sciences framework in a developing country context. The three pillars—risk assessment, mitigation strategies, and behavioral factors—each contribute unique insights that would be missed by single-discipline approaches. However, the study also reveals the need for contextual adaptation of the framework. In resource-constrained settings like Nigeria, institutional trust becomes a foundational rather than supplementary variable, and social networks serve as critical buffers that partially compensate for weak formal institutions.

The findings contribute to development theory by demonstrating how quantitative risk assessment can be enriched through behavioral and institutional analysis. The mediation analysis showing that behavioral factors explain the relationship between risk exposure and outcomes challenges purely technical approaches to development interventions. For practice, the study suggests that sustainable development outcomes require simultaneous investment across technical, institutional, and behavioral dimensions. The finding that financial literacy and trust are stronger predictors of technology adoption than technical superiority has important implications for how development programs are designed and evaluated.

The successful integration of quantitative risk modeling, qualitative stakeholder analysis, and behavioral surveys demonstrates the value of mixed-methods approaches for complex development challenges. The triangulation achieved 73.4% convergence between quantitative and qualitative findings, providing confidence in the robustness of conclusions while highlighting areas where different methods reveal complementary insights. The geographic stratification across three zones captures important contextual variations while maintaining analytical rigor. The large sample size (1,856 farmers) provides statistical power while the qualitative depth (64 stakeholder interviews) offers rich contextual understanding.

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6. Conclusions

This study demonstrates that Nigeria's food security challenges require an integrated risk sciences approach that simultaneously addresses technical, institutional, and behavioral dimensions. The research validates Feng's (2025) integrated framework while revealing important contextual adaptations necessary for developing country applications.

6.1. Key Research Contributions

Theoretical Contributions:

- First comprehensive empirical validation of integrated risk sciences framework in Sub-Saharan African context
- Demonstration that behavioral factors mediate the relationship between risk exposure and food security outcomes
- Evidence that institutional trust serves as a foundational variable in resource-constrained settings

Methodological Contributions:

- Successful integration of quantitative risk modeling with qualitative stakeholder analysis and behavioral surveys
- Development of culturally adapted measurement instruments for financial literacy and institutional trust
- Demonstration of effective triangulation across multiple data sources and analytical approaches

Empirical Contributions:

- Multi-dimensional risk model explaining 70.7% of food security variance across Nigerian contexts
- Identification of technology readiness and financial capability as primary behavioral predictors
- Documentation of significant regional variations requiring differentiated intervention approaches

6.2. Policy and Practice Implications

The findings reveal that sustainable food security improvements require moving beyond sector-specific interventions to integrated risk management platforms. The critical role of institutional trust suggests that rebuilding confidence in public institutions must be a central component of any comprehensive strategy. The behavioral insights indicate that capacity-building interventions should focus on enhancing farmers' self-perceived ability to use new technologies (technology readiness) and their understanding of financial concepts (financial capability) rather than merely providing technical training. Regional variations suggest that one-size-fits-all approaches are likely to fail. Intervention design must account for local contexts, with South West's higher adoption rates suggesting potential for this region to serve as a demonstration hub for scaling successful practices.

6.3. Broader Implications for Development Practice

This research contributes to growing evidence that complex development challenges require systems approaches that integrate technical, institutional, and behavioral interventions. The finding that behavioral factors are primary mediators between risk exposure and outcomes challenges purely technical approaches to development programming. The study demonstrates that sustainable development outcomes in resource-constrained settings depend critically on institutional trust and social capital. This finding has implications beyond food security for how development interventions are designed and implemented across sectors.

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7. Recommendations

- Implement transparent, community-monitored pilot programs in high-risk areas across all three zones
- Launch mobile-based financial education targeting 100,000 smallholder farmers
- Conduct comprehensive audit of extension service capabilities and resource gaps
- Develop technology-enabled system linking early warning, insurance, and credit services
- Establish inter-ministerial task force with measurable accountability frameworks
- Redesign existing programs to account for behavioral predictors identified in the study
- Restructure agricultural service delivery to reduce federal-state-local coordination failures
- Establish agricultural leadership pipeline with retention incentives for public service
- Integrate climate resilience into all agricultural policies and programs
- Track farmer decision-making patterns across multiple seasons to establish causal relationships
- Conduct randomized controlled trials of integrated vs. single-sector interventions
- Develop low-cost, locally appropriate technologies aligned with farmers' technology readiness levels

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