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Climate Vulnerability, Livelihood Assets, and Adaptive Capacity of Rain-Fed Smallholder Farming Systems in Kaduna State, Nigeria: A Mixed-Methods Analysis

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ABSTRACT
Smallholder farming systems in Kaduna State, northern Nigeria, are increasingly exposed to climate stressors including rainfall variability, drought, flooding and rising temperature. Yet the intersection of climate vulnerability and livelihood assets, two analytically distinct but practically inseparable dimensions remains underexplored at the sub-national level. This study integrates Climate Vulnerability Theory (CVT) and Sustainable Livelihoods Theory (SLT) to examine how climate change affects the five livelihood asset categories of smallholder farmers and what this means for adaptive capacity and agricultural resilience. A convergent mixed-methods design was employed: structured questionnaires were administered to 180 smallholder farmers across three agro-ecological zones of Kaduna State, supplemented by key informant interviews with extension officers and institutional stakeholders. Quantitative data were analysed using descriptive statistics and the chi-square test; qualitative data were thematically analysed. Findings reveal that financial and natural capital are most severely eroded by climate stress (84% and 78% of respondents, respectively), while irrigation adoption, the most effective adaptation strategy reaches only 29% of farmers. Finance access emerged as the dominant barrier (89%), followed by poor extension coverage (76%) and weak climate information reach (71%). The study concludes that adaptive capacity among Kaduna's smallholders is structurally constrained, not individually deficient, and calls for institutional reforms targeting the finance-extension-information nexus. The findings contribute a theoretically grounded, empirically derived framework for strengthening climate-resilient smallholder agriculture in Nigeria's climate-vulnerable north.

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INTRODUCTION

Across sub-Saharan Africa, smallholder farming systems shoulder a disproportionate share of climate change impacts. In northern Nigeria, an agrarian region where over 80% of rural households depend on rain-fed agriculture; this burden is particularly acute. Kaduna State, straddling the Guinea and Sudan savannah transition zones, exemplifies the paradox facing many climate-exposed states: high agricultural potential, high climate sensitivity, and weak adaptive infrastructure. Rising temperatures, erratic rainfall onset and cessation, periodic drought, and increasingly destructive flooding have disrupted planting calendars, destabilised yields, and eroded rural livelihoods (IPCC, 2022; World Bank, 2021; NiMet, 2025).

Despite growing scholarly and policy attention to climate-agriculture interactions in Nigeria, most published work operates at the national or regional level, treating vulnerability as a broad aggregate. What is less understood and what this study addresses is how climate

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stress moves through specific livelihood asset categories to constrain farmers' adaptive decisions. Two bodies of theory are directly relevant here: Climate Vulnerability Theory (CVT), which explains why particular communities face heightened risk based on exposure, sensitivity, and adaptive capacity (Adger, 2006; IPCC, 2022); and Sustainable Livelihoods Theory (SLT), which maps how households mobilise five asset types; natural, financial, human, physical, and social capital; to survive and recover from shocks (Chambers & Conway, 1992; DFID, 1999). Individually, each theory offers a partial lens. Together, they provide an integrated framework capable of connecting environmental hazard to livelihood outcome.

This paper develops and tests that integrated framework empirically. Using a convergent mixed-methods design across three agro-ecological zones in Kaduna State, it asks: which livelihood assets are most severely eroded by climate stress? Which adaptation strategies do farmers adopt and perceive as effective? And what structural barriers prevent more farmers from adapting? The answers have implications not only for Kaduna, but for the wider belt of climate-exposed smallholder farming systems stretching across Nigeria's north.

THEORETICAL FRAMEWORK

Climate Vulnerability Theory (CVT)

CVT conceptualises vulnerability as a function of three interacting dimensions: exposure to climate hazards, sensitivity of the system being affected, and adaptive capacity, the ability to adjust, moderate, or recover (Smit & Wandel, 2006; IPCC, 2022). Critically, the theory holds that climate impacts are socially differentiated: two farmers facing the same drought can suffer vastly different outcomes depending on their access to resources and institutions. In Kaduna State, where irrigation coverage is sparse, extension services under-resourced, and rural poverty persistent, the adaptive capacity component of the CVT triangle is structurally weak for most smallholders.

Sustainable Livelihoods Theory (SLT)

SLT, as operationalised through the DFID (1999) framework, identifies five livelihood capital categories: natural capital (land, water, soil), financial capital (income, savings, credit), human capital (skills, labour, knowledge), physical capital (tools, roads, irrigation infrastructure), and social capital (networks, cooperatives, communal norms). A livelihood is sustainable when these assets are sufficient to cope with shocks and recover without undermining the asset base. Climate change threatens all five categories, but not equally, and not independently. Drought depletes natural capital; crop failure erodes financial capital; declining extension services weaken human capital. SLT provides the vocabulary to trace these pathways systematically.

Integration and Analytical Framework

The paper integrates CVT and SLT by treating livelihood asset erosion as the primary mechanism through which climate vulnerability translates into constrained adaptive capacity. Where CVT asks "why are these farmers vulnerable?", SLT asks "what have they lost and what remains?". Together, they direct empirical attention to the specific assets most depleted by climate stress, and to the institutional conditions; finance access, extension reach, information flow; that determine whether adaptation strategies can bridge the gap. Figure 1 in the results section operationalises this framework for Kaduna State.

METHODOLOGY

Kaduna State lies between latitudes 9°02'N–11°32'N and longitudes 6°15'E–8°38'E in north-western Nigeria, covering approximately 46,053 km². Its ecological diversity from Guinea savannah in the south to Sudan savannah in the north produces distinct rainfall regimes (1,733 mm to 1,032 mm annually) and correspondingly varied climate risk profiles across farming communities. This makes the state analytically useful: a single study area that contains meaningful agro-ecological variation without the generalisation problems of national-level analysis.

A convergent mixed-methods design was adopted, in which quantitative and qualitative data are collected in parallel, analysed separately, and integrated at the

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interpretation stage (Creswell & Plano Clark, 2018). This design is appropriate because climate vulnerability involves both measurable outcomes (yield losses, adoption rates) and lived realities (how farmers experience risk, why they do or do not adopt strategies) that resist purely quantitative capture.

A structured questionnaire was administered to **180 smallholder farmers** selected via stratified random sampling across three agro-ecological zones (southern, central, and northern Kaduna). Stratification ensured representation across rainfall gradients and crop system diversity. In parallel, **key informant interviews** were conducted with 14 respondents including extension officers, NiMet representatives, and Kaduna Agricultural Development Agency (KADA) officials. Quantitative data were analysed using descriptive statistics and chi-square tests; qualitative data were processed through thematic analysis following Braun and Clarke (2006).

RESULTS AND DISCUSSION

Climate Vulnerability across Livelihood Asset Categories

The first major finding concerns which livelihood assets are most severely affected by climate stress. Figure 1 presents respondents' self-rated asset vulnerability across the five SLT capital categories.

Figure 1: Climate Vulnerability Across Livelihood Asset Categories (Smallholder Farmers, Kaduna State, n=180)

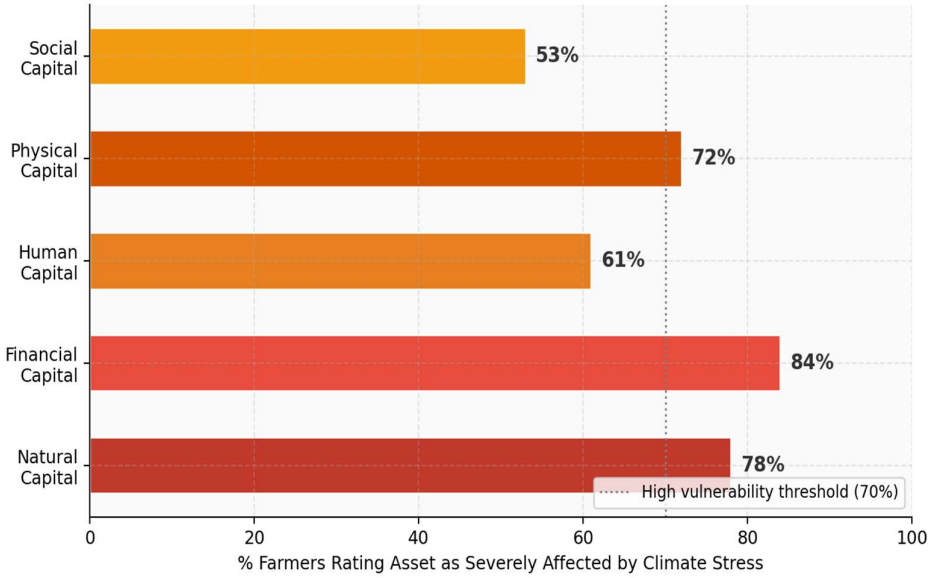


Figure 1: Climate Vulnerability Across Livelihood Asset Categories (n=180)

Financial capital emerged as the most severely affected asset, with 84% of respondents rating climate stress as having a high or very high negative impact on their income, savings, and credit access. This is consistent with CVT's prediction that adaptive capacity is weakest where poverty interacts with climate exposure: when crop failure reduces income, farmers simultaneously lose the financial means to invest in the adaptive technologies; irrigation, improved seeds, crop insurance; that would reduce their vulnerability in subsequent seasons. The result is a self-reinforcing vulnerability trap.

Natural capital was the second most affected category (78%), reflecting the centrality of soil moisture, land quality, and water availability to rain-fed farming. Prolonged dry spells deplete soil moisture; flooding causes erosion and nutrient loss; heat stress reduces

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soil biological activity. These are not episodic disruptions but cumulative degradations that reduce land productivity over time. Physical capital (72%) was affected primarily through flood damage to rural roads and the absence of irrigation infrastructure, while human capital impacts (61%) were concentrated in the loss of traditional planting calendar knowledge as seasonal patterns become less predictable. Social capital was the least affected (53%), with farmers noting that community mutual aid and cooperative structures retained some resilience even as individual asset bases eroded a finding consistent with SLT's recognition of social capital as a buffer when other assets fail.

The chi-square test confirmed that climate change has a statistically significant effect on smallholder farming systems in Kaduna State ($\chi^2 = 28.74$, df = 4, $p < 0.001$). This finding aligns with national-level evidence: FAO (2024) projected 33.1 million Nigerians at high food insecurity risk during the 2025 lean season, with climate shocks identified as a primary driver.

Adoption and Effectiveness of Adaptation Strategies

Figure 2 presents the adoption rates and self-rated effectiveness of six major adaptation strategies identified among respondents. The patterns reveal a significant disconnect between what farmers use and what works.

Figure 2: Adoption and Effectiveness of Climate Adaptation Strategies (Smallholder Farmers, Kaduna State, n=180)

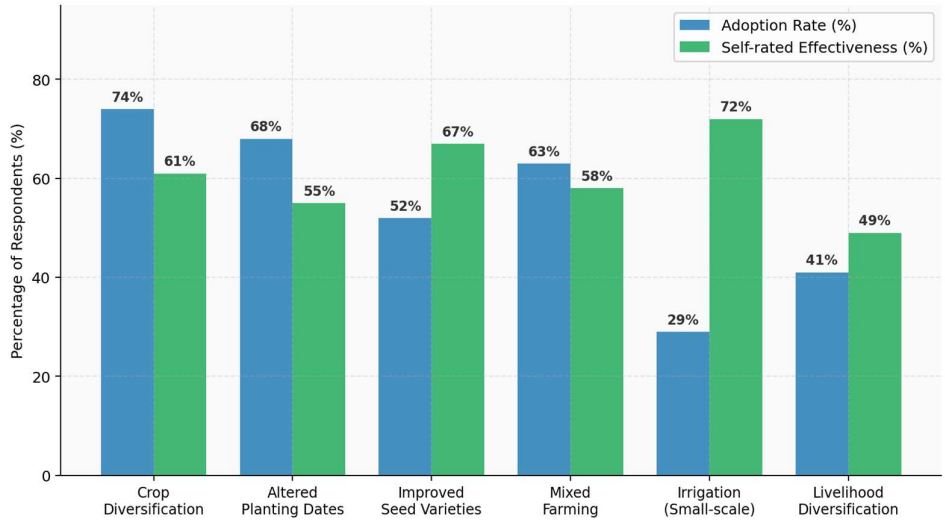


Figure 2: Adoption and Effectiveness of Climate Adaptation Strategies (n=180)

Crop diversification was the most widely adopted strategy (74%), followed by altered planting dates (68%) and mixed farming (63%). These are low-cost strategies that require knowledge adjustment rather than capital investment, consistent with a population whose financial capital is severely eroded. However, their self-rated effectiveness was moderate at best (61%, 55%, and 58% respectively).

The most striking finding is the inverse relationship between adoption and effectiveness for irrigation. Small-scale irrigation was rated the most effective strategy (72% perceived effectiveness), yet reached only 29% of farmers, the lowest adoption rate of any strategy measured. This gap is analytically significant: it signals not a lack of farmer awareness or aspiration, but a structural barrier rooted in the financial, physical, and institutional capital deficits identified in Section 4.1. As one extension officer noted during key informant interviews: "Farmers know irrigation works. What they cannot do is buy the pump, pay for

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fuel, or find a borehole that was properly maintained."

Improved seed varieties showed the opposite pattern: moderate adoption (52%) but high perceived effectiveness (67%). This suggests a specific bottleneck, likely seed access and cost, rather than a fundamental incompatibility with farming systems. Livelihood diversification had low adoption (41%) and low perceived effectiveness (49%), which qualitative data attributed partly to limited non-farm opportunities in rural Kaduna and partly to the time and capital costs of establishing alternative income streams during a farming season already compromised by climate stress.

Barriers to Adaptation

Figure 3 maps the severity of six barriers to climate adaptation as rated by respondents. Three barriers crossed the 70% "critical" threshold established for this analysis.

Figure 3: Severity of Barriers to Climate Change Adaptation (Smallholder Farmers, Kaduna State, n=180)

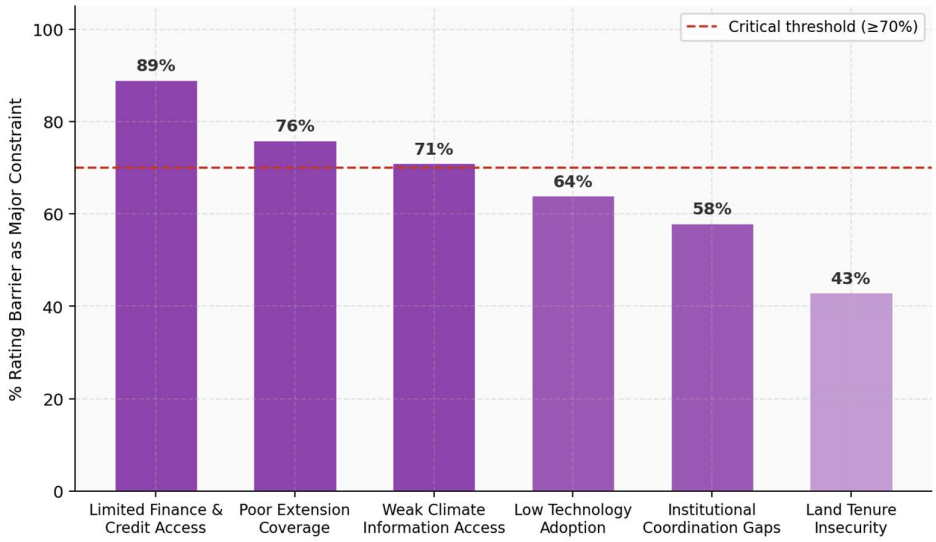


Figure 3: Severity of Barriers to Climate Change Adaptation (n=180)

Limited access to finance and credit was the dominant barrier (89%), reinforcing the financial capital vulnerability identified in Figure 1. This is not a new finding in the literature, but its severity in Kaduna State is notable. Even farmers who understand climate-smart practices and want to adopt them cannot mobilise the capital to do so. Formal credit institutions are largely absent from rural Kaduna; informal credit carries prohibitive interest rates; and agricultural micro-finance programmes remain limited in reach.

Poor extension coverage (76%) and weak climate information access (71%) together constitute what this study terms the "information-advice gap", the distance between what NiMet and research institutions know about seasonal conditions and what reaches individual farmers in actionable form. NiMet's 2025 Seasonal Climate Prediction projected delayed rainfall onset in parts of Kaduna, information that is directly relevant to planting decisions (NiMet, 2025). Yet key informant interviews revealed that this information reaches less than one in three farmers through formal channels; most rely on community word-of-mouth or personal observation. This finding aligns with Bello et al. (2025), who found that 80.5% of respondents in Kaduna North LGA had not adopted any practices to address water availability changes.

Low technology adoption (64%) and institutional coordination gaps (58%) reflect the weak physical and social capital dimensions of

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the vulnerability picture. Land tenure insecurity (43%), while below the critical threshold, was notably higher among farmers in the northern zone and among those with no documented land rights, consistent with findings from climate-tenure interaction studies in northern Nigeria.

Integrated Discussion: The CVT-SLT Interface

Taken together, the three figures reveal a coherent pattern that neither CVT nor SLT alone could fully capture. Climate stress most severely erodes financial and natural capital (CVT: high sensitivity + low adaptive capacity). The assets most depleted are precisely those required to adopt the most effective adaptation strategies; irrigation and improved seeds require capital, physical infrastructure, and institutional support (SLT: capital erosion constrains adaptation choice). The result is a structural adaptation deficit in which the farmers most exposed to climate stress are least able to respond, not because of individual failure but because of systematic institutional gaps in the finance-extension-information nexus.

This finding has a practical implication that goes beyond Kaduna: it suggests that adaptation programmes targeting farmer behaviour alone, promoting "climate-smart" practices without addressing the capital and institutional conditions required for adoption are unlikely to shift the underlying vulnerability pattern. What is needed is a parallel institutional reform agenda.

CONCLUSIONS AND POLICY IMPLICATIONS

This study set out to examine how climate vulnerability moves through livelihood asset categories to constrain adaptive capacity among smallholder farmers in Kaduna State. The integrated CVT-SLT framework proved analytically productive: it clarified not just that farmers are vulnerable, but where in the livelihood asset structure vulnerability is concentrated, and how that concentration forecloses specific adaptation pathways.

Three conclusions warrant emphasis. First, climate change erodes financial and natural capital most severely among Kaduna's smallholders, eroding the very assets that underwrite adaptive investment. Second, the adaptation strategies that farmers most value (irrigation, improved seeds) are systematically under-adopted due to capital constraints, not ignorance. Third, the barriers most cited; finance, extension, and climate information are institutional rather than individual, pointing toward systemic solutions over farmer-level interventions.

The policy implications are specific. The state government should expand agricultural micro-finance access in rural zones, prioritising smallholders in the Sudan savannah northern belt where financial capital is most depleted. The Kaduna Agricultural Development Agency (KADA) needs increased staffing, mobility support, and climate-specific training to close the extension coverage gap. NiMet's Seasonal Climate Predictions need local-language radio dissemination partnerships to reach the 70%+ of farmers currently excluded from the information loop. At the federal level, the Climate Change Act 2021 provides the legal mandate, but implementation in states like Kaduna requires dedicated adaptation financing and inter-institutional coordination mechanisms.

Future research should pursue longitudinal tracking of livelihood asset trajectories across climate shock events, spatial mapping of vulnerability hotspots within Kaduna's agro-ecological zones, and evaluation of specific micro-finance and extension programme designs. The integrated CVT-SLT framework deployed here is transferable to other climate-exposed smallholder contexts across Nigeria and sub-Saharan Africa.

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