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Analysis of Drought Impacts and Adaptation Strategies of Smallholder Crop Farmers In Southern Kaduna, Nigeria

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ABSTRACT
This study examines drought impacts and adaptation strategies among smallholder crop farmers in Southern Kaduna, Nigeria. The region, a major producer of ginger, maize, sorghum, and soybean, has experienced increasingly erratic rainfall over the past decade. Data were collected from 400 farmers across four Local Government Areas (Zangon Kataf, Kachia, Jema'a, and Kagarko) using structured questionnaires, focus group discussions, and key informant interviews, alongside historical meteorological data (2014–2023) from the Nigerian Meteorological Agency. Results show severe drought spells significantly reduced crop yields: maize and ginger fell by 44% and 36%, sorghum and soybean by 31% and 28%. These losses pushed 67% of surveyed households below the poverty line during drought years, with estimated annual economic losses of ₦12.4 billion across the four LGAs. Farmers adopted various coping mechanisms, including altering planting dates (82%), using early-maturing varieties (78%), crop diversification (65%), mulching (58%), and soil and water conservation (45%). However, capital-intensive adaptations like irrigation remained low (35%) due to financial constraints and poor institutional support. Social networks and cooperatives (52%) played significant roles in facilitating adaptation. The study concludes that indigenous strategies are insufficient to buffer severe drought shocks. It recommends increased government investment in small-scale irrigation, improved access to climate-resilient seeds, timely weather information dissemination, crop insurance schemes, and strengthened farmer cooperatives to enhance resilience against climate change

Keywords: Drought, Smallholder farmers, Adaptation strategies, Crop yield loss, Food security, Southern Kaduna, Nigeria, Climate change resilience, Indigenous coping mechanisms, Irrigation infrastructure, Farmer cooperatives, Crop insurance, Climate-resilient seeds

INTRODUCTION

Southern Kaduna is seeing more frequent and intense droughts, but the real impact on smallholder livelihoods has not been well documented. Existing studies (Adebooye *et al.,* 2020; Ojo *et al.,* 2021) have focused primarily on northern Nigeria or the Sahel region, with insufficient attention to the specific agro-ecological and socio-economic contexts of the Guinea Savanna zone. While farmers have figured out their own adaptation methods, there has been little assessment of how well they perform, what limits their use, or how far they could spread.

The gap between climate science and agricultural policy implementation is particularly pronounced at the local level. Farmers often lack access to timely climate information, improved seed varieties, and irrigation infrastructure necessary to adapt effectively. Numerous studies have documented the devastating effects of drought on African agriculture. Lobell *et al.* (2011) estimated that drought and heat stress reduced global maize production by 3.8% between 1980 and 2008, with sub-Saharan Africa experiencing losses exceeding 10%. Adebooye *et al.* (2020) found that drought events in northern Nigeria reduced sorghum yields by 25–40% and millet yields by 30–45% between 2000 and 2018. Ojo *et al.* (2021) reported that maize farmers in Kano State experienced yield declines of 35–50% during drought years, with smallholders (<1 ha) disproportionately affected. Ayanlade & Jegede (2016) analyzed rainfall variability in southwestern Nigeria and found that a 100mm decrease in seasonal rainfall corresponded to a 15–20% reduction in cassava yields.

Ginger, a high-value cash crop in Southern Kaduna, is particularly sensitive to water stress. According to Okwuowulu *et al.* (2015), ginger requires steady soil moisture (60–80% field capacity) during rhizome development; water deficits during this critical stage can reduce yields by 40–60% and affect rhizome quality (size, fiber content, essential oil concentration).

Farmers across Africa have developed various adaptation approaches to cope with drought. In Nigeria specifically Onyeneke *et al.* (2020) found that 72% of rice farmers in Anambra State adjusted planting dates in response to rainfall variability. Nwankwo *et al.* (2022) reported that sorghum farmers in Borno State adopted early-maturing varieties (65%), intercropping (58%), and mulching (42%) as primary adaptation strategies. Fadairo *et al.* (2023) documented that only 12% of farmers in Oyo State had access to irrigation, despite 78% expressing interest if subsidized equipment were available.

Despite the prevalence of indigenous strategies, significant barriers limit effective adaptation includes Financial constraints (High costs of improved seeds, fertilizers, and irrigation equipment (Deressa *et al.,* 2009)), Information gaps

(Limited access to weather forecasts, extension services, and market information (Hansen *et al.,* 2019)), Institutional failures (Weak agricultural policies, poor infrastructure, and inadequate credit facilities (Morton, 2007)), Land tenure insecurity (Communal land systems and inheritance disputes discourage long-term investments (Place, 2009)) and Gender disparities (Female farmers face additional constraints including limited land rights, labor burdens, and exclusion from decision-making (Doss, 2014)).

MATERIALS AND METHODS

Study Area

Southern Kaduna is located between latitudes 9°00'N and 11°00'N and longitudes 7°00'E and 8°30'E in Kaduna State, north-central Nigeria. The region covers approximately 26,000 km² and comprises 12 LGAs. Four LGAs were selected for this study based on their high agricultural productivity and reported vulnerability to drought as shown in Table 1 below.

Table 1: Agricultural Productivity in four (4) states (Zango Kataf, Kachia, Jema'a and Kagarko)

LGA	Area (km²)	Population (2022 est.)	Major Crops	Elevation (m)
Zangon Kataf	2,668	408,000	Ginger, maize, sorghum	750–1,200
Kachia	4,570	312,000	Maize, soybean, ginger	600–900
Jema'a	1,912	278,000	Ginger, yam, maize	800–1,400
Kagarko	3,526	195,000	Sorghum, maize, cowpea	500–800

The region experiences a tropical wet-and-dry climate, with mean annual rainfall of 1,000–1,300 mm, intense between May and October. The dry season (November–April) is characterized by the Harmattan winds, low humidity, and high evapotranspiration rates (5–7 mm/day).

Research Design

A mixed-methods approach combining quantitative and qualitative techniques was used. The quantitative component consists structured questionnaire surveys, while the qualitative component applied focus group discussions (FGDs), key informant interviews (KIIs), and direct field observations.

Sampling Technique

A multi-stage random sampling technique was used as indicated in table 2:

Stage 1: Four LGAs was selected based on agricultural significance and reported drought vulnerability.

Stage 2: Five farming communities randomly selected per LGA using simple random sampling from a list of communities obtained from the Kaduna State Agricultural Development Project (KADP).

Stage 3: Twenty(20) smallholder farmers randomly selected from each community using systematic random sampling from community household lists, concluding in a sample size of 400 respondents.

Table 2: Sample Distribution

LGA	Communities	Farmers per Community	Total Farmers
Zangon Kataf	5	20	100
Kachia	5	20	100
Jema'a	5	20	100
Kagarko	5	20	100
Total	**20**	—	**400**

Data Collection

Primary Data

Structured questionnaires was administered to 400 farmers, covering socio-economic characteristics, farming practices, drought experiences, adaptation strategies, and constraints.
Eight Focus Group Discussions (FGDs): was conducted (2 per LGA), with 8–12 participants each, to discover community-level insights and collective adaptation mechanisms.

i. Key Informant Interviews (KIIs): 16 KIIs with agricultural extension officers, community leaders, and NiMet officials.

Secondary Data

i. Historical rainfall records (2014–2023) from NiMet stations in Kaduna and Zaria.
ii. Crop yield data from Kaduna State Ministry of Agriculture (2014–2023).
iii. Satellite-derived vegetation indices (NDVI) from MODIS Terra for vegetation monitoring.

Data Analysis

Quantitative data was analyzed using:

i. Descriptive statistics: Frequencies, percentages, means, and standard deviations.
ii. Inferential statistics: Chi-square tests for independence, ANOVA for yield comparisons, and binary logistic regression for adoption determinants.
iii. Drought indices: Standardized Precipitation Index (SPI) and Palmer Drought Severity Index (PDSI) calculated from rainfall data.

Qualitative data was analyzed using thematic content analysis.
Drought severity was classified using the SPI as show in Table 3.

Table 3: Drought Characterization

SPI Value	Drought Category	Frequency (2014–2023)
≥ 0	No drought	4 years
-0.99 to 0	Mild drought	2 years
-1.49 to -1.0	Moderate drought	2 years
-1.99 to -1.5	Severe drought	2 years
≤ -2.0	Extreme drought	0 years

RESULTS AND DISCUSSION

Socio-Economic Characteristics of Respondents

Table 4: Socio-Economic Characteristics of Respondents (n=400)

Variable	Category	Frequency	Percentage (%)
Gender	Male	285	71.25
	Female	115	28.75
Age	18 – 35 years	90	22.50
	36 – 55 years	210	52.50
	> 55 years	100	25.00
Marital Status	Married	342	85.50
	Single	38	9.50
	Widowed/Divorced	20	5.00
Household Size	1 – 4 members	95	23.75
	5 – 8 members	218	54.50
	> 8 members	87	21.75
Education Level	No formal education	112	28.00
	Primary education	98	24.50
	Secondary education	124	31.00
	Tertiary education	66	16.50
Farming Experience	< 10 years	85	21.25
	10 – 20 years	195	48.75
	> 20 years	120	30.00
Farm Size	< 1 hectare	148	37.00
	1 – 2 hectares	182	45.50
	> 2 hectares	70	17.50
Primary Income Source	Crop farming only	268	67.00
	Crop + Livestock	89	22.25
	Crop + Off-farm	43	10.75

As indicated in Table 4 above, the predominance of male farmers (71.25%) reflects traditional land tenure systems where men typically hold land titles, though women contribute significantly to labor. Over half (52.5%) of respondents are in the productive age bracket (36–55 years), indicating farming remains an occupation for the economically active population. Low educational attainment (28% no formal education) may limit access to climate information and technical knowledge. Small farm sizes (<2 ha for 82.5% of respondents) confirm the smallholder nature of agriculture in the region.

Drought Trends and Characteristics

Rainfall Variability

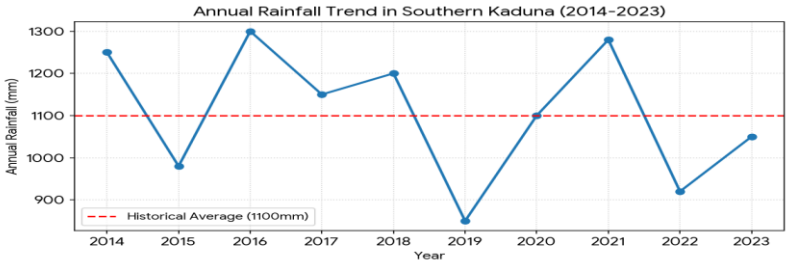

Figure 1: Annual Rainfall Trend in Southern Kaduna (2014–2023)

Figure 1 shows that three severe drought years (2015, 2019, 2022) recorded rainfall deficits of 25.4%, 30.9%, and 35.5%, respectively. Late onset (delayed by 15–31 days) and early cessation (advanced by 8–18 days) characterized drought years, reducing the growing season by 35–60 days. The 2022 drought was the most severe, with the shortest growing season (84 days) and highest rainfall deficit.

Dry Spell Analysis

The dry spell analysis is indicated in the Table 5 below.

Table 5: Frequency and Duration of Dry Spells During Growing Season

LGA	Normal Years (≤7 days)	Moderate (8–14 days)	Severe (>14 days)	Longest Dry Spell Recorded
Zangon Kataf	2–3	1–2	0–1	21 days (2019)
Kachia	2–3	1–2	0–1	18 days (2022)
Jema'a	3–4	1–2	0–1	24 days (2022)
Kagarko	2–3	2–3	1–2	19 days (2015)

Effects of Drought on Crop Production

Yield Reductions

Table 4: Average Crop Yields During Normal and Drought Years (t/ha)

Crop	Normal Year Yield	Drought Year Yield	Yield Reduction (%)	Significance (p<0.05)
Maize	2.50 ± 0.35	1.40 ± 0.28	**44.0**	***
Ginger	18.00 ± 2.10	11.50 ± 1.85	**36.1**	***
Sorghum	1.80 ± 0.25	1.24 ± 0.20	**31.1**	***
Soybean	1.20 ± 0.18	0.86 ± 0.15	**28.3**	***
Cowpea	0.85 ± 0.12	0.62 ± 0.10	**27.1**	**
Yam	12.50 ± 1.80	9.80 ± 1.50	**21.6**	**

***p < 0.001; **p < 0.01

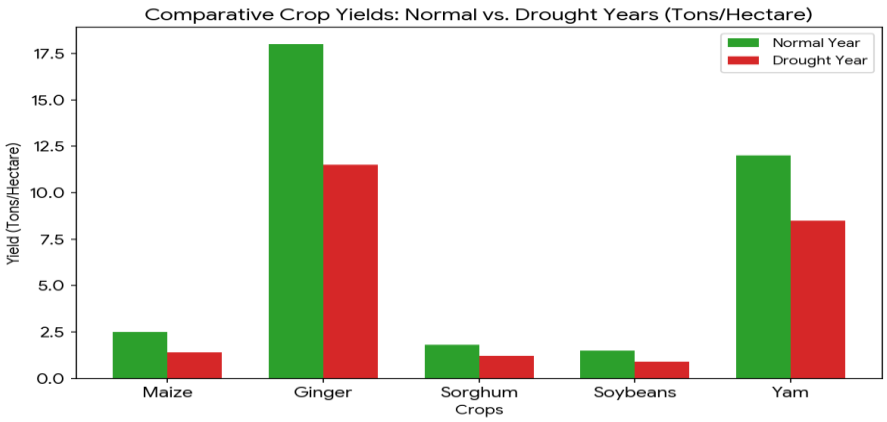

Figure 2: Comparative Crop Yields: Normal vs. Drought Years

Crop-Specific Impacts

Figure 2 shows the crop specific impacts and the interpretations are as follows;

Maize: The 44% yield reduction is attributed to water stress during the critical tasseling and silking stages (VT/R1). Drought at this stage causes pollen sterility, poor kernel set, and reduced grain filling. Farmers reported complete crop failure in 15% of maize fields during the 2022 drought.

Ginger: The 36% yield reduction reflects ginger's high water requirement during rhizome expansion (4–6 months after planting). Water stress during this period reduces rhizome size, essential oil content, and marketability. The 2019 drought was particularly devastating, with ginger prices rising by 120% due to supply shortages.

Sorghum: As a relatively drought-tolerant crop, sorghum showed lower yield reduction (31%). However, the quality of grains was affected, with smaller grain size and lower test weight reported.

Economic Impact Assessment

The estimated economic losses due to drought can be seen in Table 6 below while the household income and expenditure During Drought Years is indicated in Table 7

Table 6: Estimated Economic Losses Due to Drought (₦ Million, 2023 Prices)

LGA	Area Cultivated (ha)	Normal Year Gross Output (₦M)	Drought Year Gross Output (₦M)	Economic Loss (₦M)	Loss per Farmer (₦)
Zangon Kataf	45,000	8,550	5,130	3,420	85,500
Kachia	38,000	6,460	4,180	2,280	57,000
Jema'a	32,000	6,080	3,952	2,128	53,200
Kagarko	28,000	4,200	2,940	1,260	31,500
Total	**143,000**	**25,290**	**16,202**	**9,088**	**56,800**

Assumptions: Average farm size 1.5 ha; composite yield loss 35%; prices: maize ₦280,000/t, ginger ₦450,000/t, sorghum ₦250,000/t

Table 7: Household Income and Expenditure During Drought Years (n=400)

Indicator	Normal Year	Drought Year	Change (%)
Average household income (₦/year)	485,000	312,000	-35.7
Average farm income (₦/year)	385,000	218,000	-43.4
Average off-farm income (₦/year)	100,000	94,000	-6.0
Food expenditure as % of income	45%	62%	+37.8
School fees payment (full)	78%	43%	-44.9
Healthcare access (adequate)	65%	38%	-41.5
Households below poverty line	34%	67%	+97.1

Food Security Implications

The table 8 below shows the food security status for the respondent households.

Table 8: Food Security Status of Respondent Households

Food Security Indicator	Normal Year (%)	Drought Year (%)	Change
Food secure (adequate intake year-round)	48	18	-30 pp
Mildly food insecure (occasional shortages)	32	28	-4 pp
Moderately food insecure (frequent shortages)	15	35	+20 pp
Severely food insecure (chronic hunger)	5	19	+14 pp
Months of adequate household food provisioning	10.2	6.8	-3.4 months
Households relying on food purchases (vs. own production)	42	78	+36 pp

Adaptation Strategies Employed by Farmers

Indigenous and Scientific Adaptation Measures are shown in table 9 below and figure 3 also displays the Adoption Rate of Climate Adaptation Strategies in percentages.

Table 8: Adoption Rates of Climate Adaptation Strategies (n=400)

Adaptation Strategy	Description	Adoption Rate (%)	Effectiveness Rating (1-5)	Cost Category
Altering planting dates	Delaying sowing until rains are established	82	3.8	Low
Early-maturing varieties	Using 90–100 day maize, fast-ginger	78	4.2	Medium
Crop diversification	Mixing cereals, legumes, and tubers	65	4.0	Low
Mulching	Applying crop residues to conserve moisture	58	3.5	Low
Soil/water conservation	Contour bunding, zai pits, stone lines	45	3.9	Medium
Intercropping	Maize + cowpea, ginger + soybean	52	3.7	Low
Reduced tillage	Minimum tillage to preserve soil structure	38	3.2	Low
Fertilizer application	Organic and inorganic nutrient enhancement	42	3.6	Medium
Irrigation/Fadama farming	Dry season cultivation using water pumps	35	4.5	High
Tree planting	Agroforestry for shade and moisture	22	3.0	Low
Livestock integration	Small ruminants as drought buffer	48	3.4	Medium
Off-farm employment	Petty trading, construction, transport	55	3.3	—
Cooperative membership	Group savings, shared inputs, bulk marketing	52	4.1	Low
Weather information use	Listening to radio forecasts, farmer bulletins	40	3.8	Low

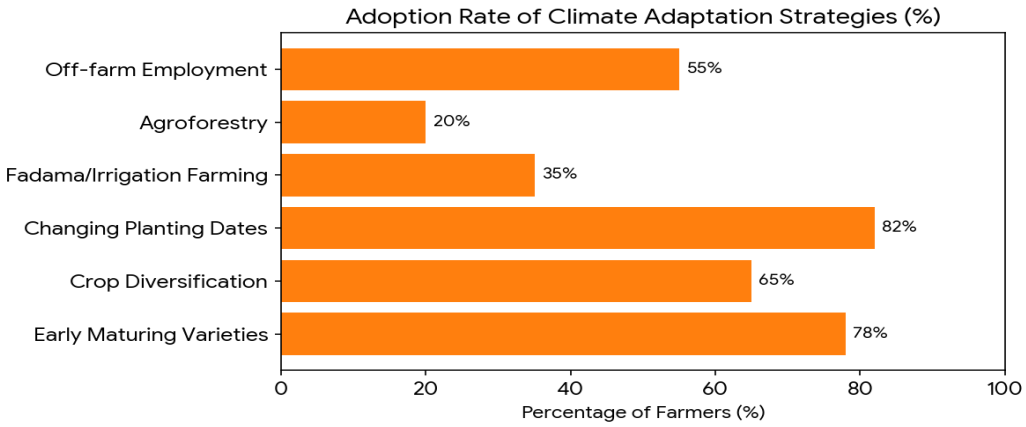

Figure 3: Adoption Rate of Climate Adaptation Strategies (%)

Detailed Analysis of Key Strategies

Altering Planting Dates (82% adoption): Farmers have shifted from fixed-calendar planting to rainfall-responsive planting. The traditional planting date (May 1–15) has been delayed to May 25–June 10 in recent years. However, this strategy carries risks: late planting exposes crops to early cessation of rains and pest pressure. In 2022, farmers who planted in late June experienced crop failure due to September drought.

Early-Maturing Varieties (78% adoption): Adoption of improved varieties has increased significantly:

1. **Maize:** TZL COMP1-W (95 days), Sammaz 16 (90 days), TELA Maize (Bt drought-tolerant)
2. **Ginger:** Improved Indian varieties with 7–8 month maturity vs. traditional 9–10 months
3. **Sorghum:** ICSV 400 (100 days), KSV8 (105 days)

Crop Diversification (65% adoption): Farmers now cultivate 3–5 crops simultaneously compared to 1–2 crops a decade ago. Common combinations:

1. Maize + cowpea + ginger
2. Sorghum + soybean + groundnut
3. Yam + maize + vegetables

Irrigation and Fadama Farming (35% adoption): Despite high effectiveness (4.5/5), adoption remains limited due to:

1. High initial investment (₦150,000–300,000 for pump set)
2. Fuel costs (₦800–1,000/liter petrol)
3. Limited water source access
4. Lack of technical knowledge

Determinants of Adaptation Adoption

This table 10 examines what factors predict whether a farmer adopts climate adaptation strategies.

Table 10: Binary Logistic Regression Results for Adaptation Adoption

Variable	Coefficient (B)	Standard Error	Wald	Significance	Odds Ratio
Age	-0.024	0.012	4.02	0.045*	0.976
Gender (Male=1)	0.682	0.312	4.78	0.029*	1.978
Education level	0.356	0.098	13.17	0.000***	1.428
Farm size	0.412	0.156	6.97	0.008**	1.510
Farming experience	0.018	0.011	2.68	0.102	1.018
Access to credit	1.245	0.342	13.24	0.000***	3.473
Extension contact	0.876	0.298	8.64	0.003**	2.402
Cooperative membership	0.934	0.276	11.46	0.001***	2.545
Climate information access	0.678	0.234	8.38	0.004**	1.970
Constant	-2.345	0.876	7.16	0.007**	0.096

*R^2 = 0.42 (Nagelkerke); Model χ^2 = 156.78, $p < 0.001$; *p<0.05, **p<0.01, ***p<0.001

Key Determinants:

1. ***Access to Credit (OR = 3.473):*** Farmers with credit access are 3.5 times more likely to adopt adaptation measures.
2. ***Cooperative Membership (OR = 2.545):*** Group membership facilitates knowledge sharing and input access.
3. ***Extension Contact (OR = 2.402):*** Regular extension visits significantly increase adoption.
4. ***Education (OR = 1.428):*** Each additional year of schooling increases adoption likelihood by 43%.

Constraints to Adaptation

Table 11 shows the constraints to the adaptation strategies while figure 4 shows Severity of Constraints to Adaptation.

Table 11: Constraints to Adaptation (Multiple Response, n=400)

Constraint	Frequency	Percentage (%)	Severity Ranking (1-5)
Financial constraints / Lack of credit	312	78.0	4.6
High cost of inputs (seeds, fertilizer, equipment)	298	74.5	4.5
Limited access to improved seed varieties	245	61.3	4.2
Inadequate extension services	228	57.0	4.0
Poor access to climate information	198	49.5	3.8
Lack of irrigation infrastructure	276	69.0	4.4
Land tenure insecurity	156	39.0	3.5
Labor shortage during peak seasons	178	44.5	3.6
Poor road infrastructure / Market access	198	49.5	3.7
Pest and disease pressure	134	33.5	3.2
Limited technical knowledge	212	53.0	3.9
Inadequate government support	256	64.0	4.3

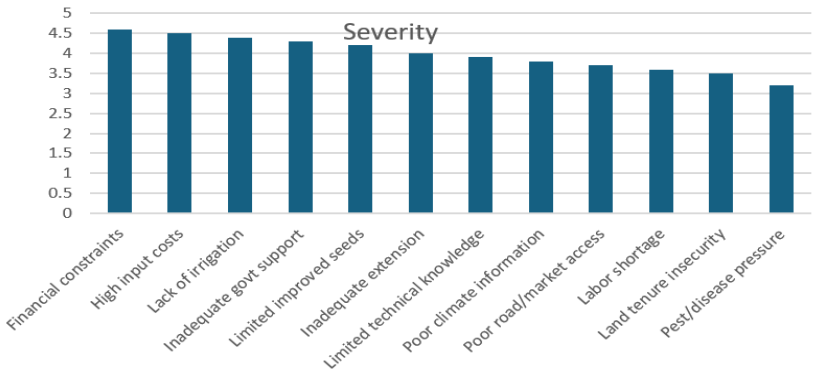

Figure 4: Severity of Constraints to Adaptation

Institutional and Policy Context
Table 12 below shows Farmer's assessment of institutional support

Table 11: Farmers' Assessment of Institutional Support

Institution/Program	Awareness (%)	Benefit Received (%)	Satisfaction (1-5)
Agricultural Development Project (KADP)	68	32	2.8
National Agricultural Insurance Scheme	22	8	2.2
Fadama III Project	45	18	2.6
Anchor Borrowers' Program (CBN)	38	15	2.9
Farmer Input Support Program	52	24	3.1
NiMet Weather Forecasts	40	12	2.4
NGO Programs (ActionAid, Oxfam)	28	14	3.4
Cooperative Societies	65	48	3.8

Discussion
This study confirms that drought poses a severe and increasing threat to agricultural livelihoods in Southern Kaduna. The 44% maize yield reduction and 36% ginger yield reduction align with findings from other drought-prone regions of Nigeria (Adebooye *et al.,* 2020; Ojo *et al.,* 2021) and exceed the IPCC (2021) projections for moderate warming situations. The economic losses estimated at ₦9.1 billion across four LGAs underscore the macroeconomic significance of drought impacts.

The prevalence of low-cost, indigenous adaptation strategies (altering planting dates, crop diversification, mulching) reflects rational decision-making under capital constraints. However, the low adoption of irrigation (35%) despite its high effectiveness highlights the "adaptation deficit" created by institutional and market failures. This finding corroborates Morton's (2007) observation that African smallholders are "trapped" in low-input, low-risk strategies that cannot buffer severe shocks.

Comparative Analysis
Table 12: Comparison with Other Nigerian Studies

Study	Location	Drought Impact	Key Adaptation	Adoption Rate
This study	Southern Kaduna	Maize -44%, Ginger -36%	Altered planting, early varieties	82%, 78%
Adebooye *et al.* (2020)	Northern Nigeria	Sorghum -35%, Millet -42%	Drought-tolerant varieties, zai pits	65%, 45%
Ojo *et al.* (2021)	Kano State	Maize -40%, Rice -28%	Irrigation, crop insurance	25%, 12%
Nwankwo *et al.* (2022)	Borno State	Sorghum -38%, Cowpea -32%	Early varieties, intercropping	70%, 58%
Onyeneke *et al.* (2020)	Anambra State	Rice -25%, Cassava -18%	Adjusted planting, water harvesting	72%, 35%

Table 13 indicates that Southern Kaduna shows higher yield losses than most comparison sites, likely due to the high water requirements of ginger (the dominant cash crop) and limited irrigation infrastructure compared to northern Nigeria's Fadama systems.

Theoretical Implications
The findings support the Sustainable Livelihoods Framework's emphasis on asset vulnerability. Drought simultaneously depletes natural capital (soil moisture, vegetation), physical capital (crop biomass), financial capital (income, savings), and human capital (nutrition, health). Social capital (cooperatives, kinship networks) emerges as the most resilient asset, facilitating risk-sharing and collective action.
However, the SLF's linear asset-strategy-outcome model requires modification for drought contexts. In Southern Kaduna, strategies are often reactive (coping) rather than proactive (adapting), and outcomes frequently involve erosion of asset bases rather than accumulation. This suggests the need for a "distress-adjusted" livelihood framework that accounts for shock-induced asset depletion.

CONCLUSION
This study has demonstrated that drought is a persistent and intensifying threat to smallholder agriculture in Southern Kaduna, Nigeria. Drought frequency and severity are increasing: Three severe droughts occurred between 2014 and 2023, with rainfall deficits exceeding 25% and growing seasons shortened by 35–60 days. Crop yields are severely affected: Maize and ginger yields declined by 44% and 36%, respectively, during drought years, with estimated economic losses of ₦9.1 billion across four LGAs. Food security is compromised: The proportion of food-secure households dropped from 48% to 18% during drought years, with 67% of households falling below the poverty line. Indigenous adaptations are prevalent but insufficient: While 82% of farmers altered planting dates and 78% adopted early-maturing varieties, these strategies cannot fully buffer severe droughts. Capital-intensive adaptations (irrigation) remain underutilized due to financial and institutional constraints. Institutional support is inadequate: Government programs reach less than one-third of farmers, with low satisfaction ratings indicating implementation failures.

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