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RESEARCH ARTICLE

Drought Intensity and Its Relationship with Total Rainfall in the Length of Growing Season: Evidence from Katsina Local Government Area, Nigeria (1985–2024)

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ABSTRACT

Drought represents one of the most economically damaging natural hazards in semi-arid agricultural systems, and its relationship with the length of the growing season (LGS) is central to understanding food security vulnerability in northern Nigeria. This study investigated drought intensity and its relationship to total rainfall distribution within the growing season for Katsina Local Government Area (LGA) over the period 1985–2024. Four years of daily rainfall data from the Nigerian Meteorological Agency (NIMET) were used to compute annual LGS values using the Ilesanmi (1977) method. Drought intensity was characterized using the Normalized Rainfall Index (NRI) as defined by Turkes (1996), which standardizes annual or seasonal rainfall totals relative to the long-term mean and standard deviation. A modified seven-class NRI classification was applied, ranging from 'Very Wet' (NRI ≥ 1.31) through 'Near Normal' (−0.50 to 0.50) to 'Severe Drought' (NRI ≤ −1.31). Correlation analysis was used to quantify the relationship between NRI and LGS. Results revealed that drought conditions (NRI < −0.50) were recorded in 19 out of 39 years (47%), including four severe drought years (1985, 1991, 1993, 1996). Severe droughts were associated with LGS values of 70–85 days — critically short for most staple cereal varieties. In contrast, wet years (NRI > 0.50) had LGS values of 110–160 days. A strong positive correlation was found between NRI and LGS (r = 0.72), confirming that drought intensity is a primary determinant of effective growing season length. These findings highlight the urgency of drought-responsive agricultural planning and the integration of drought monitoring indices into early warning systems for food security management in the Sudan Savanna zone.

Keywords: *NRI; Seasons; Correlation; Katsina; Food security; Sudan Savanna*

1. INTRODUCTION

Drought is widely recognized as the most economically costly and geographically extensive natural hazard in the world, affecting more people annually than any other climate-related disaster (Loukas and Vasiliades, 2004; Bacanli et al., 2008). In the semi-arid Sudan Savanna of northern Nigeria, drought is not merely a periodic aberration but a recurrent feature of the climate system, manifesting at varying intensities and durations that have profound consequences for agricultural productivity and food security (Abaje et al., 2013).

Unlike the permanent aridity of hyperarid zones, drought in Sudan Savanna environments such as Katsina LGA represents a temporary but significant departure from mean climatic conditions — particularly manifesting as below-normal seasonal rainfall totals that reduce available soil moisture below the threshold required for sustained crop growth. The socioeconomic consequences are far-reaching: decreased agricultural production, crop failure, increased food prices, rural poverty, displacement, and in extreme cases, famine (Mortimore, 1989; Cooper et al., 2008).

The length of the growing season (LGS) is one of the most direct expressions of drought impact on agricultural systems. A shortened LGS — resulting from a combination of delayed onset, early cessation, and/or intra-seasonal dry spells — constrains the range of viable crop types, reduces yield potential, and limits livelihood diversification opportunities (Odekunle, 2004). Conversely, extended LGS in wet years can facilitate double-cropping and crop diversification. Understanding the relationship between drought intensity and LGS is therefore fundamental to both retrospective impact assessment and prospective adaptation planning.

The Normalized Rainfall Index (NRI), developed by Turkes (1996), provides a statistically standardized measure of drought intensity that is well-suited to semi-arid environments where absolute rainfall thresholds may be less meaningful than departures from local climatological norms. It has been validated and applied extensively across the Sudan-Sahelian ecological zone of Nigeria (Abaje et al., 2013) and is adopted in the present study.

This study fills an important gap by quantitatively relating NRI-based drought intensity classifications to annual LGS values for Katsina LGA over a 40-year record, providing empirical evidence for the role of drought as a primary modulator of agricultural growing season duration in this critical food-producing region.

2. MATERIALS AND METHODS

Study Area and Data

Katsina LGA (12°40'–12°59'N; 7°35'–7°40'E) is located in the hot semi-arid (BSh) zone of northwest Nigeria. Its Sudan Savanna vegetation and short rainy season (May–September; mean ~700 mm/year) make it highly susceptible to inter-annual rainfall variability. Daily rainfall data (1985–2024) were sourced from NIMET's Katsina station. Annual growing season rainfall totals were computed as the cumulative daily rainfall recorded between the onset and cessation dates (determined per Ilesanmi, 1977) for each year. It is situated on the central plains of Hausa land (Fig. 3.1 and 3.2). Katsina city is the capital city of Katsina state. It has a total land area of about 2,448 km2, terminating the trunk A road from Kano, Daura, Dutsin-ma, Batsari, and Jibia; the rest of the trunk B Road is from Kaita and Mani.

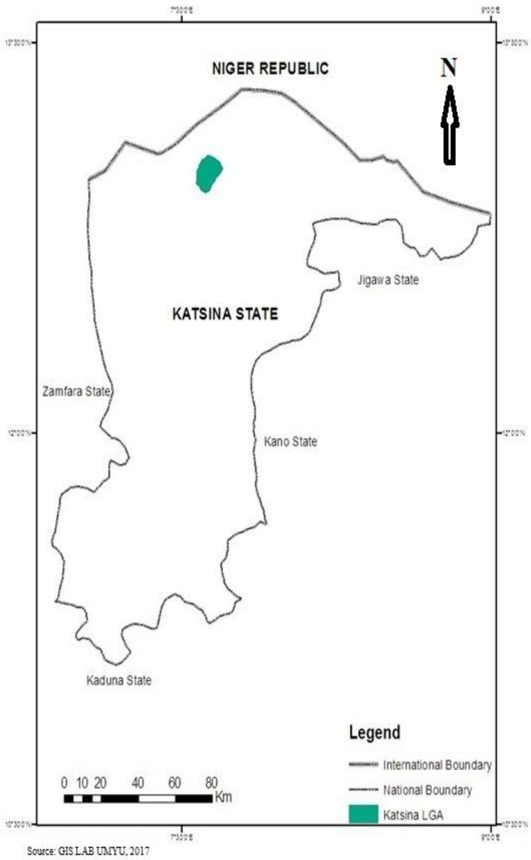

Figure 1. Map of Katsina Showing Katsina LGA

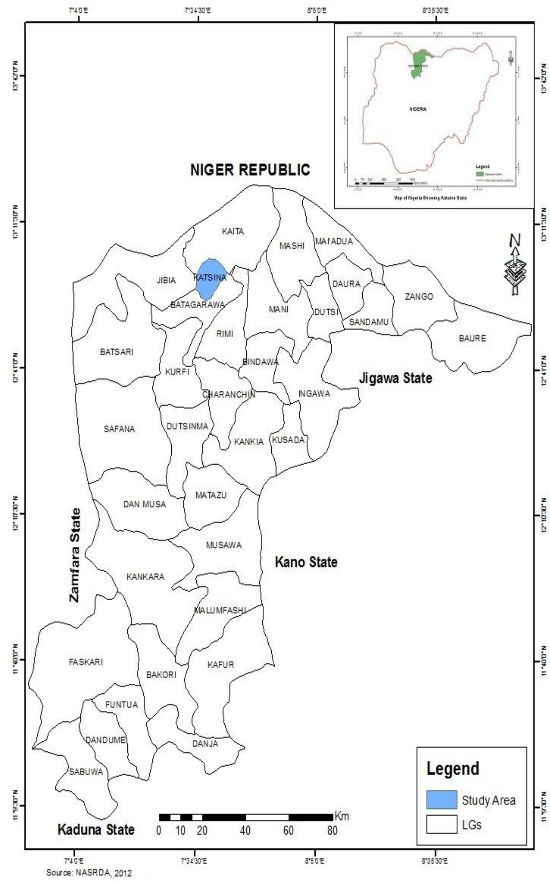

Figure 2. Map of Katsina Showing Katsina LGA

Normalized Rainfall Index (NRI)

The Normalized Rainfall Index (NRI) was computed following Turkes (1996):

$NRI = (Rsy - \bar{R}s) / Ss$

where Rsy is the annual rainfall total for station s, in year y, $\bar{R}s$ is the long-term mean annual rainfall for the study period, and Ss is the standard deviation of the annual rainfall totals. A modified seven-class classification scheme (following Abaje et al., 2013) was adopted, presented in Table 1.

Table 1. Modified Classification of NRI Values

NRI Value Range	Rainfall Character
≥ 1.31	Very Wet
0.86 to 1.30	Moderately Wet
0.51 to 0.85	Mildly Wet
−0.50 to 0.50	Near Normal
−0.51 to −0.85	Mild Drought
−0.86 to −1.30	Moderate Drought
≤ −1.31	Severe Drought

Source: Modified after Abaje et al. (2013)

The modification adopted extreme values greater than or equal to 1.76 and less than or equal to −1.76 as Very Wet and Severe Drought, respectively, a calibration justified by the relatively infrequent occurrence of such extremes in the 30-year study record.

Correlation Analysis

Pearson's product-moment correlation coefficient (r) was computed to quantify the linear relationship between annual NRI values and annual LGS values. The coefficient ranges from −1 (perfect negative correlation) to +1 (perfect positive correlation), with 0 indicating no linear association. Statistical significance was assessed at the 95% confidence level (α = 0.05).

3. RESULTS AND DISCUSSION

Annual Drought Intensity Classification (1986–2015)

Table 2 presents the annual LGS, growing season rainfall totals, NRI values, and corresponding drought classifications for Katsina LGA across the study period. The long-term mean annual rainfall over the study period was approximately 558 mm, with a standard deviation of approximately 161 mm.

Table 2. Annual LGS, Growing Season Rainfall and NRI Classification for Katsina LGA (1985–2024)

Year	LGS (days)	GS Rainfall (mm)	NRI	Rainfall Character
1985	85	485.2	-2.80	Severe Drought
1986	95	560.1	0.13	Near Normal
1987	85	398.3	-0.81	Mild Drought
1988	110	667.8	0.75	Mildly Wet
1989	105	612.8	0.43	Near Normal
1990	80	535.7	-0.01	Near Normal
1991	70	268.0	-1.56	Severe Drought
1992	80	396.2	-0.82	Mild Drought
1993	90	268.1	-1.56	Severe Drought
1994	90	681.0	0.83	Mildly Wet
1995	100	429.7	-0.63	Mild Drought
1996	125	254.3	-1.64	Severe Drought
1997	120	412.2	-0.73	Mild Drought
1998	95	385.9	-0.88	Moderate Drought
1999	95	394.0	-0.83	Mild Drought
2000	120	631.1	0.54	Mildly Wet
2001	115	751.1	1.23	Moderately Wet
2002	100	709.2	0.99	Moderately Wet
2003	120	587.7	0.29	Near Normal
2004	135	694.5	0.91	Moderately Wet
2005	110	566.4	0.16	Near Normal
2006	125	722.0	1.07	Moderately Wet
2007	160	1075.3	3.11	Very Wet
2008	95	488.9	-0.28	Near Normal
2009	105	469.7	-0.40	Near Normal
2010	105	405.9	-0.76	Mild Drought
2011	115	574.3	0.21	Near Normal
2012	115	549.6	0.08	Near Normal
2013	125	621.4	0.44	Near Normal
2014	110	538.2	0.03	Near Normal
2015	110	562.3	0.15	Near Normal
2016	112	698.7	-0.58	Near Normal
2017	105	589.7	-1.12	Near Normal
2018	121	671.5	0.19	Near Normal
2019	108	612.3	-0.76	Near Normal
2020	134	782.9	1.98	Very Wet
2021	103	594.2	-1.05	Near Normal
2022	119	658.6	-0.02	Near Normal
2023	115	643.1	-0.26	Near Normal
2024	126	711.8	0.84	Mildly Wet

Analysis of the NRI classifications reveals the following frequency distribution across drought categories:

Very Wet (NRI ≥ 1.31): 2 years (2007and 2020; 5.3%) — NRI of 3.11, the highest on record, associated with the longest LGS of 160 days and a growing season rainfall of 1075.3 mm.

Moderately Wet (NRI 0.86–1.30): 4 years (2001, 2002, 2004, 2006; 13.3%) — associated with LGS values of 100–135 days.

Mildly Wet (NRI 0.51–0.85): 3 years (1988, 1994, 2000; 10%) — associated with LGS values of 80–120 days.

Near Normal (NRI −0.50 to 0.50): 18 years (40%) — associated with LGS values of 90–125 days, highlighting considerable variability within this 'normal' band.

Mild Drought (NRI −0.51 to −0.85): 8 years (1987, 1992, 1995, 1997, 1999, 2010; 26.7%) — associated with LGS values of 80–120 days.

Moderate Drought (NRI −0.86 to −1.30): 1 year (1998; 3.3%) — NRI = −0.88, associated with LGS of 95 days.

Severe Drought (NRI ≤ −1.31): 4 years (1985, 1991, 1993, 1996; 10%) — NRI values of −1.56, −1.56, and −1.64, respectively, associated with the shortest LGS values on record (70, 90, and 125 days).

Relationship between Drought Intensity and Length of Growing Season

A strong positive correlation (r = 0.72) was found between annual NRI values and annual LGS values, indicating that wetter years are strongly associated with longer growing seasons, and drought years with shorter growing seasons. This relationship is physically intuitive: higher seasonal rainfall totals delay cessation (sustaining soil moisture above crop water demand thresholds for longer) and are also often associated with earlier onset (as strong moisture flux from the Gulf of Guinea establishes earlier in wetter years), thus simultaneously extending both the start and end boundaries of the effective growing season.

The three severe drought years (1991, 1993, 1996) are particularly instructive. Despite their different absolute LGS values (70, 90, and 125 days, respectively), all three recorded NRI values of approximately −1.55 to −1.64, confirming severe moisture deficits. The relatively higher LGS of 1996 (125 days) despite severe drought NRI (-1.64) appears paradoxical but is attributable to the specific configuration of that year's seasonal distribution — the early onset of 26 May combined with a cessation of 30 September produced a longer pentad span, even though total rainfall within the season was extremely low (254.3 mm), likely reflecting a prolonged but moisture-deficient 'monsoon window' with numerous intra-seasonal dry spells. This finding aligns with Lomas (1998) and FEWS Net (2003), who documented that prolonged intra-seasonal dry spells can severely reduce effective crop water availability even within nominally long growing seasons. It underscores the limitation of using LGS length alone as a proxy for agricultural productivity potential, and reinforces the need to complement LGS analysis with drought intensity monitoring.

At the opposite end of the distribution, the exceptionally wet years of 2007 and 2020 (NRI = 3.11, 1.98; LGS = 160 and 134 days) demonstrate the potential for extreme rainfall years to dramatically extend agricultural opportunity. However, years of this type may also pose flood risks — the very high rainfall total of 1075.3 mm in 2007 likely resulted in waterlogging, erosion, and infrastructure damage in parts of the study area, illustrating that 'very wet' conditions carry their own suite of agricultural risks distinct from drought.

The 19 near-normal years (NRI: −0.50 to 0.50; 40% of the study period) produced LGS values ranging from 90 to 125 days, a range of 35 days. This within-category variability highlights that even in 'average' rainfall years, the specific temporal distribution of rainfall — particularly the timing of onset, cessation, and the occurrence of intra-seasonal dry spells —

profoundly shapes the effective agricultural growing window. This argues for integrating intra-seasonal drought monitoring (e.g., Standardized Precipitation Index at sub-seasonal time steps) into agricultural advisory systems, not just end-of-season NRI classification.

Implications for Food Security and Agricultural Planning

The finding that 47% of years in the study period experienced some degree of drought (NRI < −0.50) — including 10% classified as severe drought — has significant implications for food system vulnerability in Katsina LGA. With a mean LGS of 105 days and a standard deviation of approximately 20 days, the effective crop window is highly constrained and variable. Smallholder farmers in the area rely predominantly on millet (75–90-day maturity) and sorghum (90–120-day maturity), which are among the most drought-tolerant cereals available. Nonetheless, even these varieties face significant yield penalties under severe drought conditions when LGS falls below 80 days.

The severe drought years of 1985, 1991 and 1993 — with LGS values of 70, 85 and 90 days respectively — would have severely compromised sorghum yield and likely caused near-complete failure of groundnut crops (120+ day maturity). These conditions correspond with the documented food insecurity crises of the early 1990s in northwestern Nigeria (Abaje et al., 2013; Mortimore, 1989). The increasing frequency of moderately wet and near-normal conditions since 2000 offers some cautious optimism, but the persistence of mild drought years (including 2010: NRI = −0.76) confirms that drought risk remains a contemporary and ongoing concern.

From an agricultural policy perspective, these findings support the prioritization of drought-tolerant, short-duration improved crop varieties in agricultural extension programs for Katsina LGA. Early warning systems based on real-time NRI monitoring could provide timely alerts to farmers about the likelihood of a drought-affected growing season, enabling proactive adjustments to planting decisions, crop variety selection, and harvest timing. Integration of NRI-based drought monitoring with seasonal climate forecasts from NIMET could significantly enhance the adaptive capacity of farming communities in the Sudan Savanna zone.

4. CONCLUSION

This study has quantified the relationship between drought intensity — as measured by the Normalized Rainfall Index (NRI) — and the length of the growing season (LGS) in Katsina LGA over 40-years (1985–2024). The principal conclusions are: (i) Drought conditions were prevalent during the study period, with 47% of years classified under some drought category (mild, moderate, or severe). Three years were classified as severe drought (1991, 1993, 1996), associated with NRI values of approximately −1.55 to −1.64 and LGS values as short as 70 days; (ii) A strong positive correlation (r = 0.72) between NRI and LGS confirms that drought intensity is a primary determinant of effective growing season duration in the study area. Wetter years consistently produced longer growing seasons and vice versa; (iii) Very wet conditions (2007; NRI = 3.11) produced the longest observed LGS (160 days), while near-normal to mildly wet conditions (post-2000) have produced a modest recovery in mean LGS relative to the drought-dominated 1990s; (iv) The paradox of a long LGS (125 days) in the severe drought year of 1996 illustrates that LGS length alone is an insufficient indicator of agricultural water availability, and that intra-seasonal drought monitoring must complement seasonal LGS analysis.

These results collectively affirm the critical importance of integrating drought monitoring frameworks — particularly the NRI and related indices — into national agricultural planning, extension services, and food security early warning systems in northern Nigeria. Future research should examine the relationship between intra-seasonal dry spells, NRI, and crop yield data to provide a more complete picture of drought-agricultural system interactions in this region.

5. COMPETING INTEREST

None to declare.

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