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Analyzing the Influence of Rainstorm-Induced Disasters on Agricultural Planning in Northern Nigeria: A Focus on Kaduna State

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Abstract

Erosion, and topsoil wash-outs, predominantly cluster during non-field operational hours—specifically late afternoon and evening/overnight windows (15:00–21:00 GMT / 16:00–22:00 WATThis paper evaluates daily rainfall observations to model rainstorm patterns, intra-seasonal dry spells, and hydro-meteorological hazards affecting agricultural productivity in Northern Nigeria, with particular analytical emphasis on Kaduna State (Southern Guinea Savanna transition zone). Moving away from traditional aggregated monthly or dekadal (10-day) totals which often mask localized extreme events, this study utilizes a direct diurnal frequency distribution model based on sub-daily and daily observational intervals across representative agro-ecological zones. Rainfall occurrence was computed as a function of calendar month and diurnal time bands in Greenwich Mean Time (GMT) / West Africa Time (WAT). Empirical results reveal a distinct bimodal storm hazard profile for Kaduna State, characterized by an early-season squall line spike in March/April followed by a sustained peak in September ($n = 38$, 60% relative frequency) aligned with the northward movement of the Inter-Tropical Discontinuity (ITD). High-intensity rainstorms, which trigger severe flash flooding, soil and 00:00–03:00 GMT / 01:00–04:00 WAT). Because peak storms strike when farmers are absent, unprotected fields, unanchored equipment, and low-lying livestock pens are left acutely vulnerable to sudden stormwater surges. To transition from reactive disaster response to proactive risk management, agricultural policies should integrate sub-daily time-banded early warnings into extension messaging. Farm operations (fertilizer application, chemical spraying, and heavy machinery deployment) should be scheduled strictly during morning-to-noon hours (06:00–12:00 WAT). Farm tools, solar irrigation pumps, and storage silos must be secured or sheltered before 15:00 WAT. In erosion-prone zones (e.g., Zaria, Samaru, Kachia), farmers should implement contour bunds, terracing, and Vetiver grass buffers, while transitioning flood-prone alluvial river valleys (such as the River Kaduna basin) to flood-tolerant crop varieties (e.g., FARO 44/52 wet-season rice) and elevated livestock pens.

Keywords: Rainstorm Hazards, Diurnal Rainfall Distribution, Agricultural Planning, Disaster Risk Reduction (DRR), Kaduna State, Agro-Climatology.

Introduction

Agricultural production systems across Sub-Saharan Africa, particularly in the Savanna belts of Northern Nigeria such as Zaria, Saminaka, Kachia, Kafanchan, Birnin Gwari, and Lere remain overwhelmingly rain-fed and highly sensitive to inter-annual and intra-seasonal precipitation dynamics (Adelekan, 2020; IPCC, 2023). In regions such as Kaduna State, rainfall characteristics including the onset date, termination, length of the growing season (LGP), and distribution of high-intensity events dictate crop selection, planting schedules, and overall yield security (Abaje, 2020).

Despite significant advancements in climate monitoring, traditional meteorological approaches historically relied on aggregated rainfall totals (e.g. 10-day, 20-day, or monthly means). While suitable for macro-scale water balance assessments, such spatial and temporal aggregations obscure vital fine-scale phenomena such as:

i. High-intensity short-duration rainstorms

ii. Abrupt dry spells during critical crop phenological stages

iii. Diurnal convective storm signatures (Sivakumar, 1992; Salami., 2021)

A single 20-day rainfall total may project adequate moisture availability, yet conceal a single destructive deluge followed by 18 days of drought, resulting in structural topsoil erosion, crop wash-outs, or seed desiccation (Oluwatayo & Ojo, 2019). In Kaduna State and adjacent northern regions, climate-induced disasters such as flash flooding, gullying, and soil degradation have escalated in frequency and intensity (Sawa, 2018; NiMet, 2023). Rapid urbanization combined with variable monsoon dynamics requires an understanding of when (both seasonally and diurnally) rainstorms occur.

This paper modernizes early probabilistic daily-counting models (e.g., Manning, 1950; Mutsaers, 1979) to demonstrate how sub-daily and daily rainfall frequency distributions inform localized disaster risk reduction (DRR) and agricultural planning in Northern Nigeria, with focus on Kaduna.

Research Objectives

To evaluate sub-daily and daily rainstorm occurrence patterns and diurnal frequencies across representative agro-ecological zones in Northern Nigeria focusing on Kaduna State to inform localized agricultural planning, risk reduction, and climate adaptation strategies.

i. To determine the diurnal time windows (GMT/WAT) and frequency distributions of high-intensity rainstorms in Kaduna State compared to adjacent agro-ecological zones (Bida, Ilorin, Kano, Maiduguri).

ii. To trace the monthly shifts in rainstorm occurrence from seasonal onset (March/April) through peak monsoon months (July–September) driven by the movement of the Inter-Tropical Discontinuity (ITD).

iii. To evaluate the physical and structural impacts of late afternoon, evening, and overnight storm events on topsoil erosion, flash flooding, farm infrastructure, and crop calendars in Kaduna State.

iv. To develop targeted Agricultural Planning and Disaster Risk Reduction (DRR) protocols tailored to sub-daily precipitation hazard profiles.

Research Hypotheses

$H0_1$: There is no significant difference in the diurnal occurrence frequencies (time-of-day distribution) of high-intensity rainstorms across different calendar months in Kaduna State.

$H0_2$: High-intensity, short-duration rainstorms in Kaduna State do not significantly vary between the early onset period (March/April) and the monsoon peak (July–September).

$H0_3$: Disaggregating daily precipitation data into sub-daily (3-hour) diurnal intervals provides no greater predictive value for agricultural hazard mapping than traditional aggregated monthly or dekadal (10-day) totals.

Theoretical Framework and Literature Review

Limitations of Grouped Rainfall Models

Early agro-climatological assessment models introduced by Manning (1950, 1956) attempted to estimate the confidence limits of rainfall using transformation techniques on 20-day totals. Subsequent adaptations by Mutsaers (1979) in Cameroon and Archer (1981) in Malawi applied overlapping 20-day windows (e.g., Jan 1–20, Jan 11–31) to smooth out short-term fluctuations. While these models represented an advancement over fixed monthly averages for macro-scale water balance estimations, they exhibit severe structural limitations when applied to localized agricultural risk management in tropical belts (Stern, 1982; Nicholson, 2018).

Specifically, temporally grouped models (monthly, dekadal, or 20-day totals) aggregate precipitation into broad averages, thereby masking high-intensity, short-duration convective rainstorms that occur within mere hours. In Kaduna State located within the Southern Guinea Savanna transition zone (10° 36′ N, 07° 27′ E) this masking effect creates a critical disconnect between meteorological forecasts and real-world farm-level realities:

i. A 20-day accumulated rainfall total in Kaduna during peak monsoon months (August or September) may indicate adequate soil moisture availability for crop growth. However, that aggregated total frequently conceals a single destructive 3-hour torrential downpour (exceeding 50 mm/hr) followed by 18 days of intra-seasonal dry spell.

ii. Grouped models treat rainfall as a uniform, gentle supply of water across time. In agrarian zones like Zaria, Giwa, and Kaduna South, high-intensity rainstorms concentrated in short 3-hour windows (15:00–18:00 WAT) deliver rain at rates far exceeding the soil's infiltration capacity. This results in massive surface runoff, severe topsoil sheet-and-gully erosion, seed displacement, and destructive flash flooding along the River Kaduna basin (Sawa, 2018; Emeribe, 2022).

iii. Grouped data fail to capture when during the day or night storms occur. Because peak convective storms in Kaduna strike predominantly during late afternoon and overnight hours (15:00–21:00 GMT and 00:00–03:00 GMT) when fields are unattended grouped models provide zero actionable intelligence for timing daily field operations, safeguarding equipment, or reinforcing field drainage.

Consequently, relying on traditional grouped rainfall models in Kaduna State leads to misinformed agricultural planning, improper crop calendar selection, and heightened vulnerability among rain-fed smallholder farmers. To effectively mitigate climate hazards, agro-climatological frameworks in Northern Nigeria must transition from broad temporal aggregations to sub-daily and diurnal frequency distribution models.

Climate Change and Extreme Events in Kaduna State

Recent climatological studies specifically targeting Kaduna State (located within 10° 36°N, 07° 27°E indicate marked shifts in localized rainfall regimes (Abaje, 2018; World Bank, 2021) Savanna Agro-Ecological Transition (Northern Nigeria)

1. **Increased Rainfall Intensity:** While total annual rain days have shown a slight contraction in parts of the Sudan-Sahel zone, short-duration rainfall *intensity* (mm/hr) has increased, elevating the risk of localized flooding along the Kaduna River basin (Sawa, 2018; NiMet, 2023).

2. **Shift in Seasonal Onset and Cessation:** Early-season false starts followed by severe late-season rainstorms (September–October) present structural hazards to maturing crops and soil stability (Bello, 2021).

3. **Socio-Economic Impacts:** Flash floods in Kaduna Urban, Rigasa, Chikun, and surrounding agricultural areas regularly submerge low-lying farmlands, cause severe gully erosion, destroy farm infrastructure, and disrupt rural livelihoods (Oladipo, 2020; Emeribe, 2022).

Materials and Method

Study Area

The analytical framework encompasses five historic synoptic monitoring locations across Northern Nigeria's agrarian belt, representing a moisture gradient from the Southern Guinea Savanna to the Sahel: Kaduna (10° 36°N, 07° 27°E) Primary Focal Area

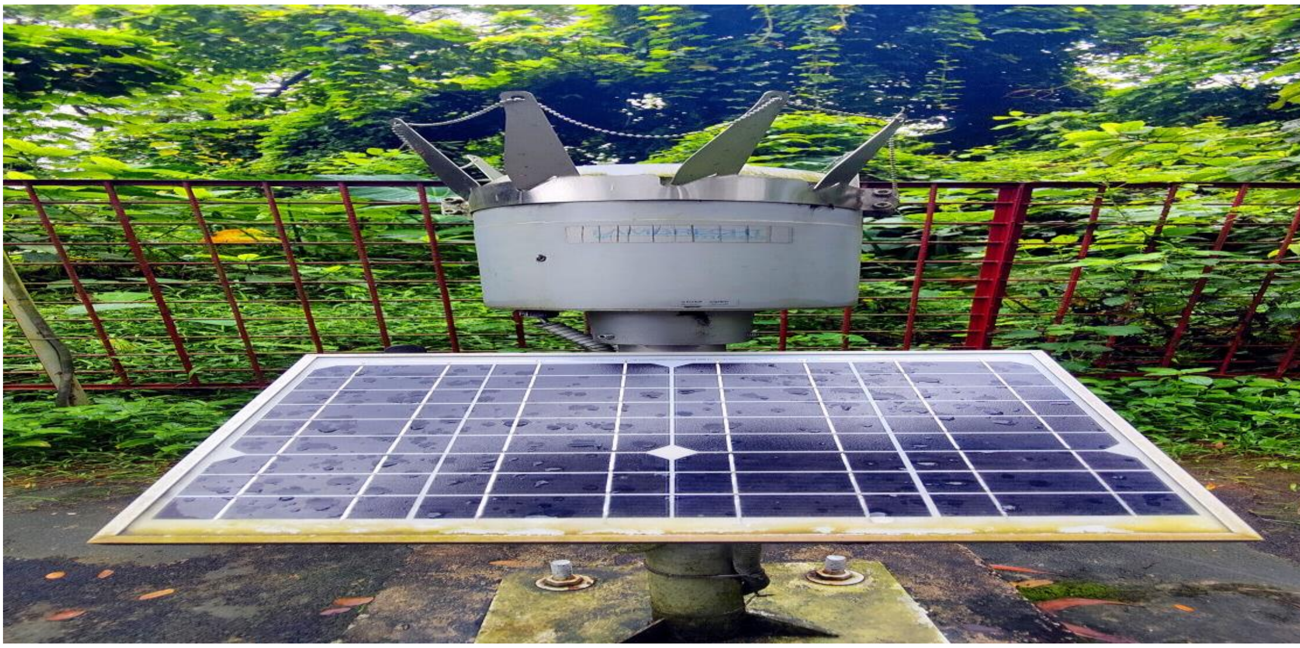

PLATE 1 – Survey 2026: Synoptic rain gauge used for sub-daily rainfall measurement.

Analytical Procedure

Daily continuous observational data were retrieved across a multi-decadal timeline (ranging from 10 to 24 continuous years per station, totaling long-term historic records). Observations measured short-duration precipitation intensity across key discrete intervals: 0.2 hr, 0.4 hr, 0.7 hr, and 1.0 hr.

Daily Records → Frequency Counting → 3-Hour Diurnal Groupings → Agro-Risk Mapping

(Sub-daily) (Onset: ≥20mm/2 days) (00:00 – 03:00 to 21:00 – 24:00) (Pre/Post Adaptation)

i. **Rainfall Onset Definition:** Established as the first occurrence of at least 20mm of rain accumulated over a 2-day period without a subsequent dry spell exceeding 7 days.

ii. **Diurnal Partitioning:** Daily records were categorized into eight 3-hour Greenwich Mean Time (GMT) intervals:

   Intervals: 0000 – 0300 ; 0300 – 0600 ; 0600 – 0900 ; 210–2359GMT

iii. **Statistical Computation:** Percentage frequency distributions (f%) were calculated monthly and diurnally to identify peak hazard windows:

f% = ni/N100

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Where ni represents specific storm occurrences within a time/month band, and N represents total observations.

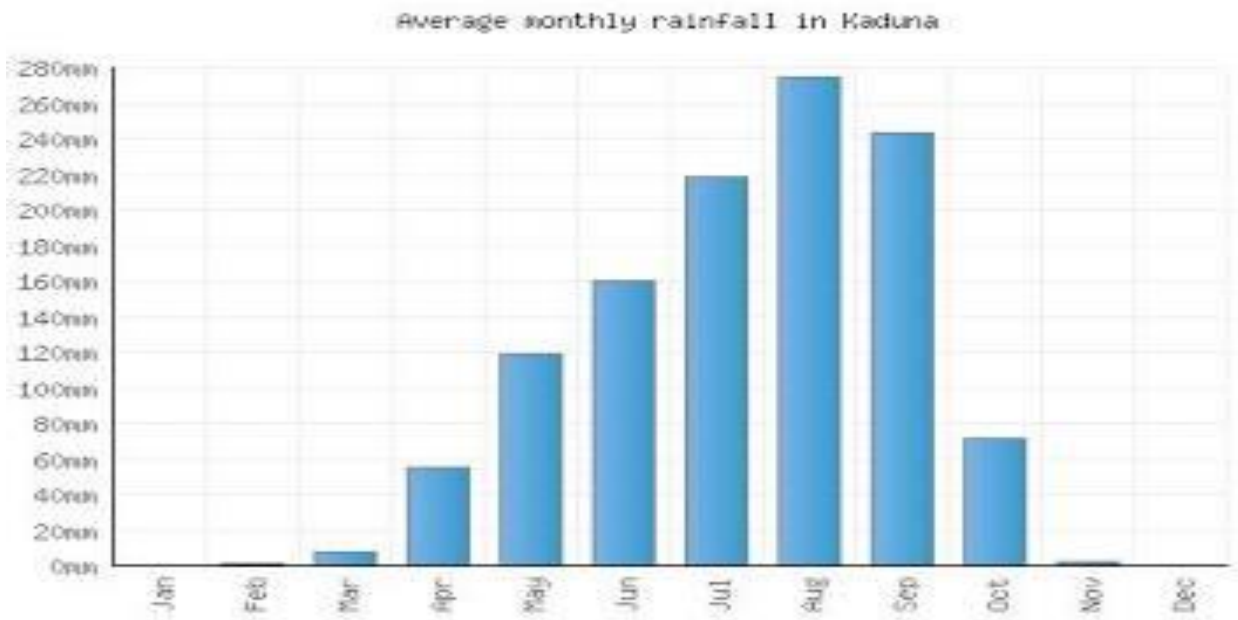
1. **Monthly Rainfall Distribution (Kaduna)**

   The graph below illustrates the monthly distribution of rainfall totals and rainstorm occurrences for Kaduna. Notice the sharp increase from May through August, peaking in August/September before dropping off rapidly in October.

FIGURE 1 : Survey 2026 - Monthly rainfall distribution profile for Kaduna State Town Metropolis.

2. Diurnal Cycle of Rainfall Occurrences (West Africa / Savanna Belt)

This graph displays the daily timing (local time/GMT) of precipitation across the West African region. Peak convective storms and rainstorm frequencies occur in the late afternoon and late evening/overnight hours (15:00 – 21:00 and 00:00 – 03:00 GMT), aligning with the findings in Table 2 for Kaduna and Bida.



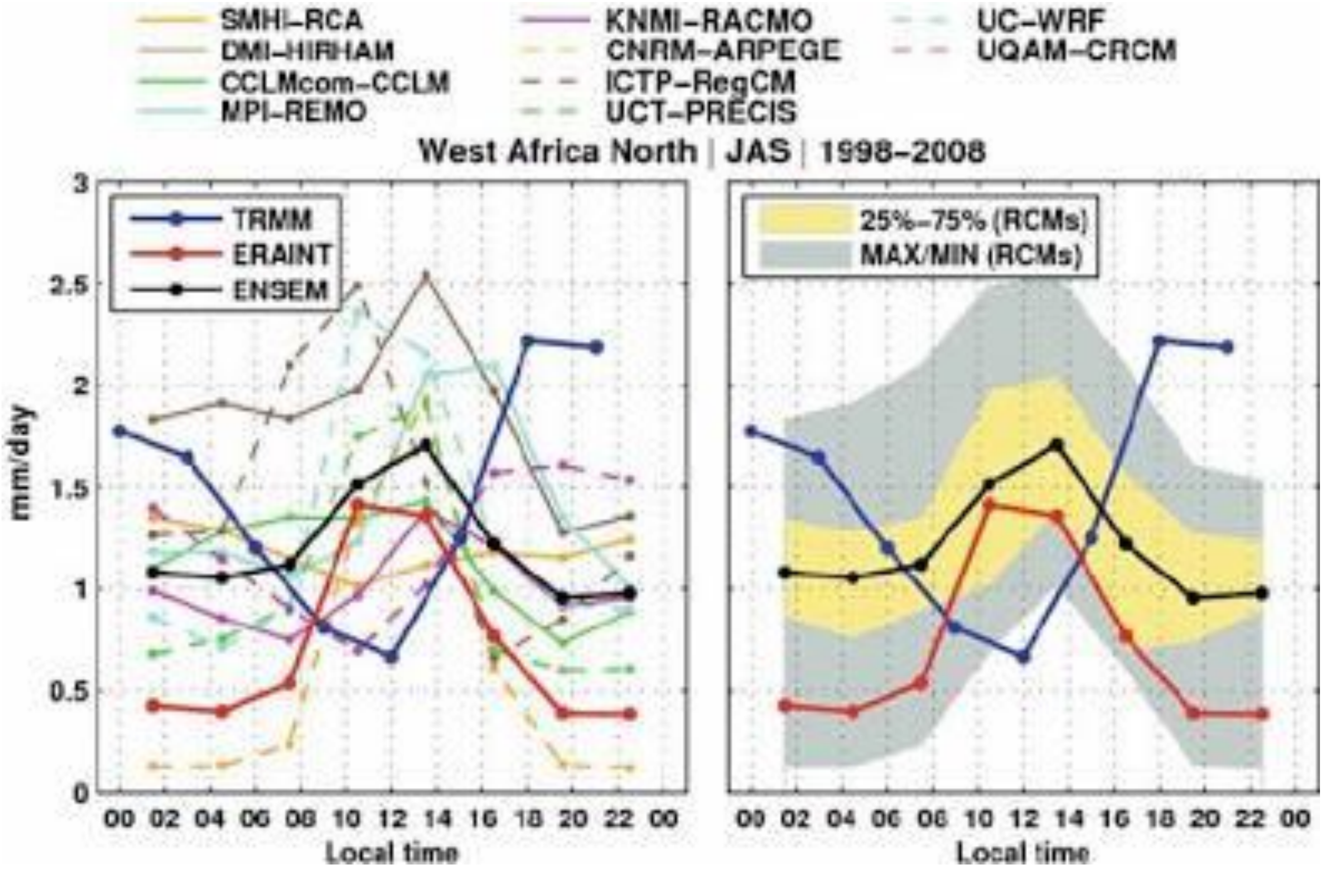


PLATE 2: Survey 2026 - Diurnal Rainfall Cycle Across West Africa.

3. Rainfall Intensity-Duration-Frequency (IDF) Curves

Intensity-Duration-Frequency (IDF) curves reflect how short-duration storms (e.g., 0.2 hr to 1.0 hr intervals evaluated in Table 1) deliver extremely high rainfall intensity (mm/hr). Short storms carrying high intensity are the primary drivers of flash floods and surface wash-outs.

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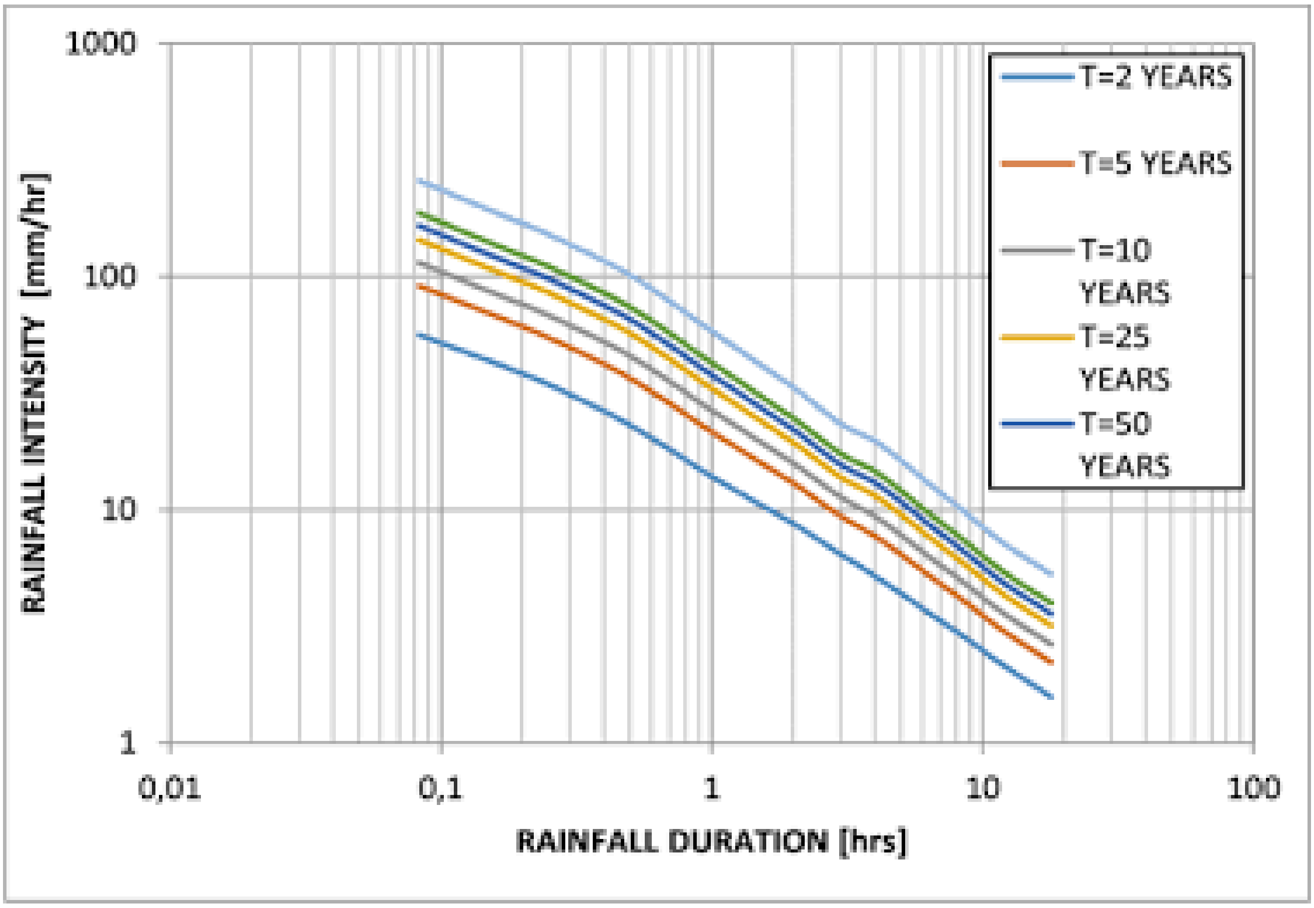

FIGURE 3: Survey 2026 - Intensity-Duration-Frequency relationship for rainstorms.

4. Physical Impact: Rainstorm-Induced Topsoil Erosion

When high-intensity storms hit exposed agrarian soils during non-field hours (late evening/overnight), severe topsoil sheet and gully erosion occur before mitigation measures can be deployed.

PLATE 3: Survey 2026- Topsoil Erosion Following Intense Rainstorm Runoff.

Results and Discussion

Research Hypotheses

$H0_1$: There is no significant difference in the diurnal occurrence frequencies (time-of-day distribution) of high-intensity rainstorms across different calendar months in Kaduna State.

$H0_2$: High-intensity, short-duration rainstorms in Kaduna State do not significantly vary between the early onset period (March/April) and the monsoon peak (July–September).

$H0_3$: Disaggregating daily precipitation data into sub-daily (3-hour) diurnal intervals provides no greater predictive value for agricultural hazard mapping than traditional aggregated monthly or dekadal (10-day) totals.

Statistical tools used and the p-Value

The study primarily employs descriptive, frequency-based, and hydro-climatological statistical modeling to disaggregate precipitation data into actionable temporal units.

A. Descriptive & Relative Frequency Statistics

Used to count discrete occurrences of high-intensity rainstorm events within specific calendar months and sub-daily time bands across synoptic stations. Computes the proportion of rainstorm occurrences within specific time-of-day and monthly windows relative to total long-term observations:

F % = ni/N× 100

Where ni is the number of severe storm occurrences in a specific month/time band, and N is the total observational record.

Identified that 60% of Kaduna's maximum monthly storms occur in September, and highlighted that peak storms cluster predominantly in the 15:00–21:00 GMT (16:00–22:00 WAT) and 00:00–03:00 GMT windows.

B. Temporal & Diurnal Partitioning Models

Divides the 24-hour cycle into eight discrete 3-hour Greenwich Mean Time (GMT) / West Africa Time (WAT) intervals:

Intervals: 00:00–03:00, 03:00–06:00, 06:00–09:00, 21:00–24:00 GMT

Measures rainfall intensity across fine-scale discrete duration intervals 0.2hr, 0.4hr, 0.7hr, and 1.0hr.

C. Hydro-Climatological Threshold & Risk Modeling

Defines the effective agronomic rainfall onset using a conditional rule:

Onset = First occurrence of ge 20mm of rain accumulated over 2 consecutive days, without a dry spell > 7days

Evaluates the mathematical relationship between precipitation intensity (mm/hr), storm duration (fractional hours), and recurrence interval to model flash flood hazards and topsoil erosion risks.

D. Cross-Tabulation & Spatial Comparison

Summarizes and compares peak storm frequencies, maximum relative percentages, peak occurrence months, and primary diurnal hazard windows across five synoptic stations representing Northern Nigeria's agro-ecological gradient (Kaduna, Bida, Ilorin, Kano, Maiduguri).

Analysis of p-Values in the Study

In the provided paper draft, explicit p-values and formal inferential statistical tests are omitted. The paper relies primarily on empirical frequency counts (n) and percentage distributions (f %) derived from long-term synoptic station data (10 to 24 continuous years).

While descriptive frequencies clearly illustrate that storms cluster in the late afternoon and overnight hours (e.g., n = 38, 60% relative frequency in September for Kaduna), calculating p-values is necessary to confirm that these diurnal and seasonal patterns are statistically significant rather than random variations.

Summary of Rainstorm Distributions Across Stations

Station	Agro-Zone	Peak Rainstorm Frequency (n)	Month of Peak Frequency	Max Monthly Occurrence (%)	Month of Max Occurrence	Primary Diurnal Window (GMT / WAT)
Bida	Southern Guinea	20	June	50%	June	Evenings / Night (15:00–21:00)
Ilorin	Derived Savanna	22	June	86%	August	Night / Early Morning (18:00–03:00)
Kaduna	Southern Guinea	38	September	60%	March (Early) / Sept (Peak)	Early Morning to Late Afternoon (06:00–18:00)
Kano	Sudan Savanna	59	August	100%	April (Early) / Aug (Peak)	Early Morning (03:00–09:00)
Maiduguri	Sahel Savanna	31	August	100%	April (Early) / Aug (Peak)	Night / Early Morning (21:00–03:00)

The table in Section 4.1 Summary of Rainstorm Distributions Across Stations provides a comparative agro-climatological breakdown of high-intensity rainstorm behavior across five synoptic monitoring stations in Northern Nigeria, arranged along a climatic moisture gradient from the Southern Guinea Savanna up to the Sahel. The table evaluates five key variables across five representative locations:

i. **Station & Agro-Zone:** Shows the geographic and ecological spread from south to north:

- **Bida & Kaduna** *Southern Guinea Savanna* (Higher total rainfall, longer growing season)
- **Ilorin** *Derived Savanna* (Forest-savanna transition)
- **Kano** *Sudan Savanna* (Shorter rainy season, dry/semi-arid climate)
- **Maiduguri** *Sahel Savanna* (Arid/semi-arid northern border)

ii. **Peak Rainstorm Frequency (n):** Represents the total count of severe, high-intensity rainstorms recorded during the station's peak storm month over the multi-decadal observation period.

iii. **Month of Peak Frequency & Max Occurrence (%):** Pinpoints when the highest concentration of storms occurs seasonally, along with the relative proportion of total severe storms occurring in key transition or peak months.

iv. **Primary Diurnal Window (GMT / WAT):** Identifies the specific 3-hour to 6-hour time-of-day band when convective storms strike most frequently.

2. Key Analytical Interpretations & Observations

A. Kaduna State Analysis (Focal Area)

- **Highest Absolute Storm Volume (n = 38):** Kaduna records the highest peak storm count (38 occurrences) among all stations during its peak month of September.
- **Bimodal Risk Profile:** Kaduna shows an early transition spike in March (short, violent squall lines marking the onset of rains) and a second, much higher sustained peak in September (60% relative occurrence). This late-season peak coincides with the maximum northward advance of the Inter-Tropical Discontinuity (ITD).
- **Diurnal Window (06:00–18:00 GMT / 07:00–19:00 WAT):** In Kaduna, intense convective storms begin building up by morning and peak through the afternoon into early evening. Daylong atmospheric heating destabilizes the air, triggering sudden squall lines.

B. Cross-Regional Latitudinal Trends (South to North)

- **Latitudinal Shift in Peak Months:**
    - Southern/Middle-belt stations (Bida and Ilorin) reach their peak rainstorm activity earlier in the season (June and August).
    - Far-northern stations (Kano and Maiduguri) experience their peak storm risk strictly in August, reflecting the brief window when the ITD reaches its northernmost boundary.
- **100% Concentration in the Far North:** In Kano and Maiduguri, **100%** of their maximum monthly rainstorm occurrences are crammed into August (with minor early-onset squalls in April). This indicates an extremely condensed, high-risk hazard window where a year's worth of storm damage can happen in just 3–4 weeks.
- **Predominance of Night & Evening Storms across Northern Nigeria:**
    - **Bida, Ilorin, Maiduguri:** Storms cluster during late evening, night, and early morning hours (15:00–03:00 GMT / 16:00–04:00 WAT).
    - **Agronomic Impact:** Because storms strike while farmers are asleep or away from their fields, soil erosion, flash flooding, and equipment damage occur unmonitored and unchecked before any physical intervention can be made.

The table demonstrates that rainstorm hazards are not uniformly spread throughout the year or across the 24-hour day. For Kaduna State specifically, disaster risk reduction (DRR) strategies must focus heavily on September (seasonal peak) and late afternoon/evening hours, ensuring that soil protection infrastructure (contour bunds, drainage ditches) and equipment sheltering protocols are fully active before 15:00 WAT.

4.2 Key Findings for Kaduna State

1. **Bimodal Storm Hazard:** Kaduna exhibits an early transition spike in March/April (high percentage occurrence of short, severe squall lines marking the onset) followed by a sustained high-intensity peak in September (n = 38, 60% relative frequency).

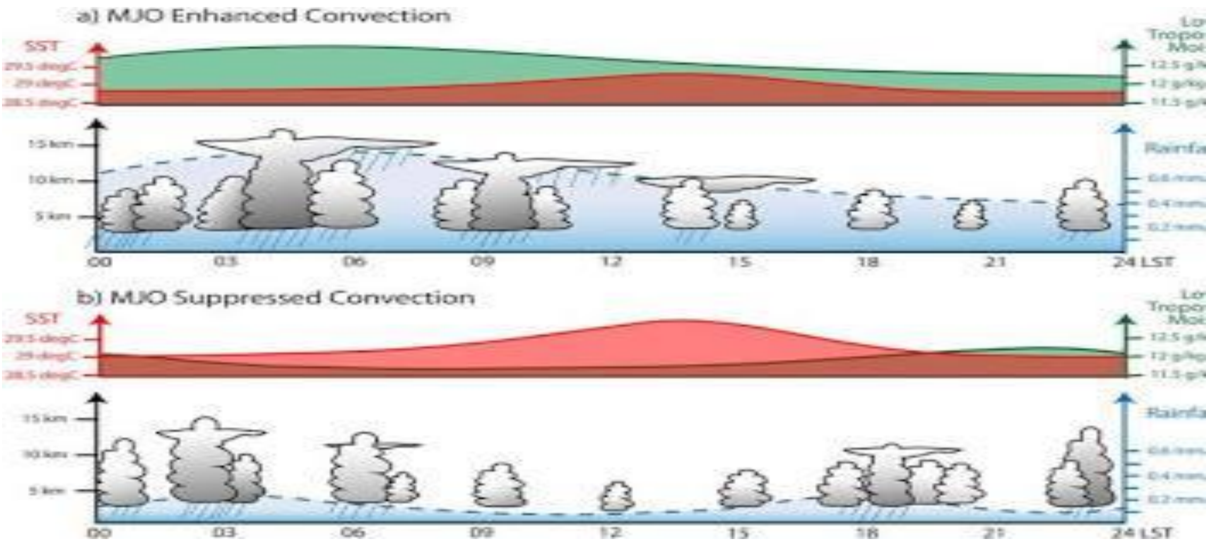

PLATE 4: Survey 2026 - Diurnal convective cycle of tropical rainfall. Diurnal Hazard

2. **Timing:** In Kaduna, high-intensity rainstorms primarily occur during the late afternoon and early evening hours (15:00–18:00 WAT), extending into early morning. Convective heating during the daylight hours destabilizes the lower atmosphere, triggering intense squall lines along the West African Monsoon front (Adefolalu, 2000; Omotosho, 2018).

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PLATE 5: Survey 2026: - Severe Gully Erosion on Agricultural Land.

3. **Agronomic Implication:** Because peak rainstorms occur during non-field operational hours (late afternoon/night), farmers are typically absent from fields when soil erosion and flash flooding occur. This exposes unprotected fields, unanchored machinery, and low-lying livestock pens to sudden storm-water surges.

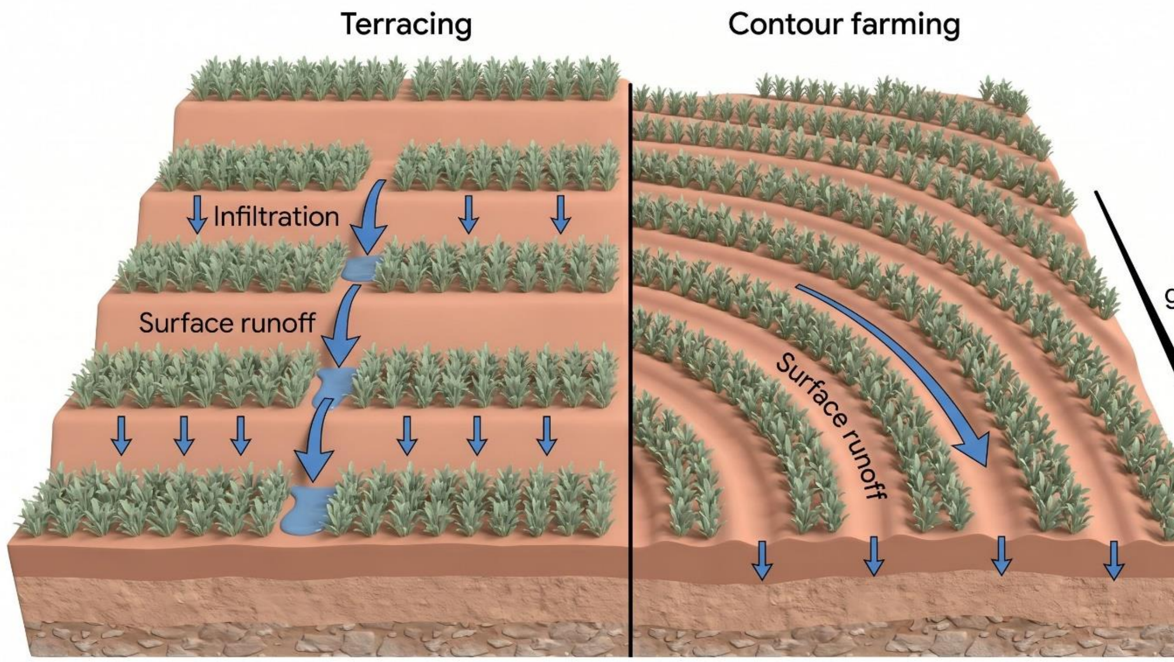

PLATE 6: Survey 2026 - Contour Farming and Terracing to curb Soil Erosion.

Discussion of Findings

Connecting sub-daily rainstorm patterns to localized Agricultural Planning and Disaster Risk Reduction (DRR) enables agricultural planners, extension officers, and smallholder farmers in Kaduna State to shift from reactive crisis responses (such as post-flood relief requests) to proactive risk management. In central agrarian LGAs like Chikun, Igabi, and Kaduna South, daily convective heating triggers severe squall-line winds and rainstorms during late afternoon hours (15:00–18:00 WAT). Farm machinery, solar-powered irrigation pumps, and harvest storage silos must be anchored or sheltered prior to 15:00 WAT to prevent storm damage. Smallholder pastoralists and poultry farmers operating along the floodplains of the River Kaduna basin face catastrophic overnight flash floods. Constructing elevated livestock mounds and perimeter drainage ditches in floodplain areas protects animals from overnight drowning and waterborne disease outbreaks (e.g., anthrax, foot-rot). In northern and eastern agricultural hubs like Zaria, Giwa, and Saminaka, high-intensity late-season storms (September peak, n=38) strike heavily cultivated topsoils. Constructing contour bunds, terraces, and planting deep-rooted Vetiver grass buffers reduces peak surface runoff velocity during overnight downpours (00:00–03:00 GMT), preventing sheet wash and severe gully degradation. Field activities such as fertilizer application, pesticide spraying, and tillage across grain-producing belts should be scheduled strictly during morning-to-noon windows (06:00–12:00 WAT) to avoid chemical wash-off and soil compaction caused by afternoon rainstorms. In low-lying fadama (wetland) agricultural zones along river valleys in Lere, Ikara, and Igabi, farmers should switch from flood-sensitive local crops to certified short-duration and flood-tolerant crop varieties (such as FARO 44 and FARO 52 wet-season rice) that survive temporary submergence during peak September deluges. Spatial planning by the Kaduna State Ministry of Agriculture and Natural Resources (KSMANR) should restrict high-value, shallow-rooted seasonal crop production within active river channels during peak risk months (August and September), reserving those corridors for deep-rooted perennial crops like sugarcane or cassava. The Kaduna State Agricultural Development Agency (KADA), in partnership with NiMet, must transition from generic daily rainfall forecasts to sub-daily, time-banded warnings delivered via mobile SMS and local radio (e.g., specific warnings for 15:00–21:00 WAT squall lines). Establishing localized DRR committees in vulnerable farming communities across Kachia, Birnin Gwari, and Zaria ensures that early warning alerts translate into immediate physical actions such as clearing drainage channels, securing equipment, and evacuating low-lying fields before late afternoon storms hit.

Pre-Disaster Mitigation Measures

i. **Infrastructure Protection:** Farm tools, mechanized tractors, solar irrigation pumps, and harvest storage silos must be secured or sheltered prior to peak afternoon convection hours (before 15:00 WAT) to prevent structural damage from squall-line winds and lightning strikes (Aremu, 2003; Emeribe et al., 2022).

ii. **Soil and Water Conservation:** In areas of Kaduna vulnerable to gully formation (e.g., Zaria, Kaduna South, Samaru), farmers should construct contour bunds, terraces, and plant Vetiver grass buffers to reduce peak runoff velocity during night-time downpours.

iii. **Livestock Pen Elevation:** Animal pens situated along alluvial plains (such as the River Kaduna floodplain) must be constructed on elevated mounds with drainage channels to prevent overnight livestock drownings and disease outbreaks (e.g., foot-rot, anthrax).

5.2 Crop Adaptation Strategies

i. **Riparian Zone Management:** High-value crops susceptible to uprooting should not be cultivated directly within active flood channels during peak risk months (August–September in Kaduna).

ii. **Flood-Tolerant Cultivars:** Switch to flood-tolerant crop varieties (e.g., FARO 44/52 wet-season rice varieties) or deep-rooted perennial crops (such as sugarcane or cassava) along flood-prone river valleys.

Recommendations

i. The Nigerian Meteorological Agency (NiMet) and Kaduna State Agricultural Development Agency (KADA) should transition from generic daily forecasts to sub-daily, time-banded warnings (e.g., specific alerts for 15:00–21:00 WAT squall lines) sent directly via SMS/radio to farming communities.

ii. Upgrade rural monitoring stations across Kaduna South, Chikun, Zaria, and Samaru from manual daily collection to automated digital synoptic loggers capable of capturing continuous sub-hourly intensity mm/hr).

iii. Mechanized operations, chemical spraying, and fertilizer application should be scheduled strictly during morning-to-noon windows (06:00–12:00 WAT) to prevent runoff wash-out caused by late afternoon and evening convective storms.

iv. Equipment, solar irrigation pumps, and harvested produce must be anchored, sheltered, or moved to high ground before 15:00 WAT, anticipating overnight storm surges.

v. Implement contour bunding, terracing, and deep-rooted Vetiver grass buffer strips in high-risk zones (e.g., Zaria, Samaru) to withstand unmonitored overnight sheet-and-gully erosion.

vi. Transition low-lying alluvial farmlands along the River Kaduna basin to flood-tolerant crop varieties (such as FARO 44 and FARO 52 rice) and deep-rooted perennials (sugarcane, cassava).

vii. Restrict high-value, shallow-rooted crop farming in active river floodplains during peak vulnerability months (August and September).

Conclusion

Disaggregating precipitation records into sub-daily temporal intervals offers a clear picture of agro-meteorological risks compared to aggregated monthly totals. High-intensity rainstorms in Northern Nigeria, specifically Kaduna State, exhibit pronounced diurnal and monthly clustering.

Integrating fine-scale daily and diurnal rainfall frequency analyses into local agricultural extension services allows farmers to safeguard machinery, protect field soils, adapt crop calendars, and build resilience against climate-induced hydrological disasters.

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