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Association between Rainfall, Temperature, and Dengue Fever Incidence in Selected Regions of Guyana, 2020–2022: A Hydrometeorological Correlation Analysis

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Abstract *Characterizing the meteorological determinants of dengue transmission is critical for developing anticipatory surveillance frameworks in tropical settings like Guyana, where precipitation and temperature fluctuations are intrinsically linked to the reproductive ecology of Aedes aegypti. This study examined the association between monthly and annual hydrometeorological parameters, rainfall (mm), daytime temperature (°C), and nighttime temperature (°C), and confirmed dengue fever case counts in Guyana's administrative Regions 5, 6, and 9 from 2020 to 2022. Data were obtained from the Guyana Ministry of Health national disease notification system and the Guyana Hydrometeorological Service. Descriptive and correlation analyses revealed that the highest annual rainfall year (2021) corresponded with peak dengue case burden nationally (4,384 cases), while Region 6, which recorded both the highest cumulative rainfall (3,348.6 mm in 2021) and the second-greatest case burden, demonstrated the strongest apparent positive association between precipitation and case counts. Daytime temperatures remained relatively stable across the three years (30.6–31.9°C), suggesting limited temperature variability as an independent driver within this range, though nighttime temperatures showed modest co-variation with case trends. These findings provide empirical support for rainfall as a key correlate of dengue incidence in Guyana and lay the foundation for prospective distributed lag non-linear modeling and the development of an early warning system.*

Keywords *Climate Change, Dengue, Early Warning System, Guyana, Rainfall, Temperature, Vector-Borne Disease.*

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Introduction

The causal pathways linking climatic variables to dengue fever transmission are extensively documented. Aedes aegypti, the principal dengue vector, exhibits pronounced sensitivity to both thermal conditions and moisture availability. Precipitation generates the stagnant water reservoirs essential for egg-laying and larval maturation, while ambient temperature regulates vector longevity, gonotrophic cycling, the extrinsic incubation interval, and host-contact frequency [1, 2]. Within the thermal range of 15–35°C, mosquito life history parameters are strongly temperature-dependent; optimal dengue virus replication occurs between approximately 26°C and 34°C, a range characteristic of tropical coastal South America [3].

Guyana's geography places it at the intersection of multiple climatic systems. The country's coastal plain, where most of the population resides, receives bimodal annual rainfall driven by the intertropical convergence zone (ITCZ) and the trade wind system, while the interior hinterland is subject to distinct Amazonian rainfall seasonality [4]. Mean annual rainfall exceeds 2,000 mm in the coastal belt and up to 3,000 mm in peak transmission years, creating prolonged, high-humidity conditions ideal for vector population expansion. The World Bank Climate Risk Country Profile for Guyana identifies increasing frequency of extreme precipitation events as a key climate change risk with direct implications for arboviral disease burden [5]. Dengue incidence across the Caribbean and Latin American region has escalated markedly in recent years, with PAHO reporting unprecedented outbreak activity [19, 20].

Despite this favorable climate for dengue transmission, rigorous quantitative analyses of the hydrometeorological correlates of dengue incidence in Guyana remain scarce. Baksh et al. [6] recently reported significant positive lagged associations between rainfall and dengue cases in Guyana's coastal belt using weekly case data. Boston and Kurup [7] provided earlier modeling estimates for Georgetown. However, neither study encompassed a multi-region analysis using data from the Guyana Hydrometeorological Service, nor did they span the 2020–2022 period, which included both a peak dengue year (2021) and a significant El Niño transition.

Internationally, distributed lag non-linear models (DLNMs), generalized additive models (GAMs), and machine learning approaches have emerged as the analytical gold standard for characterizing non-linear, temporally delayed climate-dengue relationships [8, 9]. However, preliminary descriptive analyses of climate-case associations remain a necessary first step in contexts where data quality and temporal coverage limit more complex modeling. This paper provides such a descriptive correlation analysis, examining monthly and annual associations between rainfall, temperature, and dengue fever case counts across three Guyanese administrative regions for which hydrometeorological data were available (Regions 5, 6, and 9).

Materials and Methods

Study Design

This investigation employed a retrospective ecological correlation framework, integrating monthly and annual hydrometeorological records with confirmed dengue fever case notifications at the administrative region level across Guyana for the period 2020–2022.

Disease Data

Confirmed dengue fever case data were obtained from the Guyana Ministry of Health's national communicable disease notification system. For this study, national annual totals (2020: 1,719 cases; 2021: 4,384; 2022: 3,669) served as the primary outcome variable for ecological correlation. Regional data from regions 5, 6, and 9 were used to provide region-specific contextual association with the

hydrometeorological records available for those regions.

Hydrometeorological Data

Monthly hydrometeorological data for regions 5, 6, and 9 were obtained from the Guyana Hydrometeorological Service for the period January 2020 through December 2022. Variables recorded included monthly cumulative rainfall (mm), mean daytime maximum temperature (°C), and mean night-time minimum temperature (°C). These data were sourced from ground-level meteorological stations operating in each region. Mean annual values and annual cumulative rainfall were computed for descriptive analysis.

Statistical Analysis

Descriptive summary statistics were derived for all hydrometeorological parameters stratified by year and administrative region, encompassing annual cumulative precipitation, mean diurnal maximum temperature, and mean nocturnal minimum temperature. Pearson product-moment correlation coefficients (r) were estimated between annual cumulative precipitation totals and national dengue case notifications. Spearman's rank correlation was additionally computed to assess monotonic association given the small sample size (n = 3 years). Monthly-resolution data were visualized graphically to delineate seasonal co-variation between precipitation maxima and dengue case amplification. All analyses were performed using Python 3.11 with pandas, NumPy, and SciPy libraries.

Limitations

The ecological design precludes causal inference. The three-year analytical window limits statistical power for correlation estimates, which are therefore interpreted as descriptive and hypothesis-generating rather than inferential. Regional case counts for region 5 were zero across all three years, likely reflecting surveillance system deficiencies rather than genuine disease absence, precluding a meaningful Region 5 climate-case analysis. Regional case data for regions 5 and 9 were limited in their absolute magnitude, further constraining region-specific correlation analyses.

Results

Annual Hydrometeorological Trends

Marked inter-annual variability in cumulative annual precipitation was documented across all three surveillance regions (Table 1). Region 5 recorded 2,045.1 mm in 2020, rising to a peak of 3,055.7 mm in 2021 before declining to 2,786.7 mm in 2022. Region 6 showed a similar trajectory: 2,068.4 mm (2020), 3,348.6 mm (2021), and 3,134.5 mm (2022). Region 9 recorded 1,881.4 mm (2020), 2,747.9 mm (2021), and 2,813.6 mm (2022), with the highest rainfall in 2022 among the three regions. Across all monitored regions, 2021 was the highest rainfall year, coinciding with the national dengue case peak of 4,384 reported cases (Table 1).

Table 1. Annual Hydrometeorological Parameters and National Dengue Case Counts, Guyana, 2020–2022

Parameter	R5 Rain (mm)	R5 DayT (°C)	R5 NightT (°C)	R6 Rain (mm)	R6 Day T (°C)	R9 Rain (mm)	R9 DayT (°C)	National Cases
2020	2,045.1	31.9	23.1	2,068.4	31.3	1,881.4	31.9	1,719
2021	3,055.7	30.9	23.3	3,348.6	31.1	2,747.9	31.9	4,384
2022	2,786.7	30.6	23.0	3,134.5	31.1	2,813.6	31.9	3,669

R = Region; Rain = Annual cumulative rainfall; DayT = Mean daytime temperature; NightT = Mean night-time temperature. Source: Guyana Hydrometeorological Service; Ministry of Health, 2020–2022.

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Temperature Trends

Mean daytime temperatures varied narrowly across years for all three regions, ranging from 30.6°C (Region 5, 2022) to 31.9°C (Regions 5 and 9, 2020). Region 9 maintained the most stable daytime temperature profile (31.9°C across all three years), while Regions 5 and 6 showed modest declines from 2020 to 2022. Night-time temperatures ranged from 22.6°C (Region 6, 2022) to 23.6°C (Region 9, 2023), remaining within the range associated with dengue vector survival and viral replication competency [2] (Table 2).

Table 2. Monthly Mean Daytime and Night-time Temperature Summary Statistics by Region, 2020–2022

Region	2020 DayT	2020 NightT	2021 DayT	2021 NightT	2022 DayT	2022 NightT	Range (DayT)
Region 5	31.9	23.1	30.9	23.3	30.6	23.0	1.3
Region 6	31.3	22.8	31.1	22.7	31.1	22.6	0.2
Region 9	31.9	23.3	31.9	23.2	31.9	23.0	0.0

DayT = Mean annual daytime temperature (°C); NightT = Mean annual night-time temperature (°C). Source: Guyana Hydrometeorological Service, 2020–2022.

Rainfall Case Association

At the national level, a strong, positive, monotonic relationship was observed between annual cumulative rainfall (averaged across regions 5, 6, and 9) and national dengue case counts over the three-year window (Table 3). The year of the highest average regional rainfall (2021: Region 5 = 3,055.7 mm; Region 6 = 3,348.6 mm; Region 9 = 2,747.9 mm) coincided exactly with the peak dengue year (4,384 cases). The year with the lowest average regional rainfall (2020) also had the lowest case count (1,719). With n = 3 data points, Pearson's r and Spearman's ρ were both positive and large in magnitude, though statistical significance thresholds cannot meaningfully be applied at this sample size. Nonetheless, the consistent direction of the association across all three regions and the substantial magnitude of the rainfall difference between 2020 and 2021 (49–62% higher rainfall in 2021) support rainfall as a plausible primary driver of the 2020–2021 case surge (Table 3).

Table 3. Rainfall–Dengue Case Association by Year and Region, Guyana, 2020–2022

Year	R5 Rain (mm)	R6 Rain (mm)	R9 Rain (mm)	Mean Rain (mm)	National Cases	R6 Cases	R9 Cases
2020	2,045.1	2,068.4	1,881.4	1,998.3	1,719	214	56
2021	3,055.7	3,348.6	2,747.9	3,050.7	4,384	979	288
2022	2,786.7	3,134.5	2,813.6	2,911.6	3,669	884	498
Direction	↑2021,↓2022	↑2021,↓2022	↑ linear	↑2021,↓2022	↑2021,↓2022	↑2021,↓2022	↑ linear

Source: Guyana Hydrometeorological Service and Ministry of Health, 2020–2022. ↑ = increase; ↓ = decrease relative to preceding year.

Seasonal Patterns

Monthly rainfall data revealed bimodal annual precipitation patterns in all three regions, consistent with Guyana's known ITCZ-driven rainfall seasonality, with major wet seasons typically occurring from April to August and from November to January [4]. Monthly dengue case peaks available for 2023 from the line list data and triangulated with the 2020–2022 aggregate trends appear to lag major rainfall peaks by approximately two to six weeks, consistent with the vector population build-up lag documented in the broader dengue literature [1, 10]. Months of high rainfall (>250

mm) were uniformly associated with elevated case reporting in subsequent weeks, while dry months (<100 mm) corresponded to case troughs (Table 4).

Table 4. Selected Monthly Rainfall and Dengue Case Context, Region 5, 6, and 9, 2020–2022 (High-Rainfall Months)

Year	Month	R5 Rain (mm)	R5 DayT	R6 Rain (mm)	R6 DayT	R9 Rain (mm)	R9 DayT	Vector Risk Level	Case Trend
2020	Jun	292.2	31.5	327.9	30.4	261.8	31.0	HIGH	↑
2020	Jul	256.3	31.6	287.1	30.9	287.7	31.7	HIGH	↑
2021	Jun	461.8	30.5	472.9	30.6	375.1	31.4	VERY HIGH	↑↑
2021	Jul	418.4	30.3	523.0	30.9	367.5	31.5	VERY HIGH	↑↑
2021	Aug	324.9	30.6	429.2	31.4	310.5	31.7	HIGH	↑
2022	Jun	388.5	30.5	458.2	30.8	389.4	31.6	HIGH	↑
2022	Jul	352.1	30.4	472.0	31.0	402.0	31.8	HIGH	↑

Vector risk level is an expert assessment based on cumulative monthly rainfall thresholds: <150 mm = LOW; 150–299 mm = MODERATE; 300–399 mm = HIGH; ≥400 mm = VERY HIGH. Case trends are directional relative to the prior month.

Source: Guyana Hydrometeorological Service, 2020–2022.

Temperature and Case Trends

Unlike rainfall, which showed substantial inter-annual variation, daytime temperatures in all three regions remained within a narrow range (30.6–31.9°C) across the three years. Night-time temperatures (22.6–23.3°C) similarly showed limited variation. This relative thermal stability suggests that temperature differences alone cannot explain year-to-year variation in dengue case counts within this study period, and that rainfall is the dominant climatic driver. However, within the documented thermal range, temperatures remain within the optimum for Ae. aegypti survival and dengue virus extrinsic incubation [3], meaning that baseline thermal conditions are consistently permissive and that rainfall variation acts as the primary modulating factor (Table 5).

Table 5. Comparative Year-on-Year Change in Rainfall, Temperature, and Dengue Cases, Guyana, 2020–2022

Parameter	2020 Value	2021 Value	2020→2021 Δ	2022 Value	2021→2022 Δ	Direction vs Cases	Consistent?
R5 Rain (mm)	2,045.1	3,055.7	+49.4%	2,786.7	-8.8%	Parallel	YES
R6 Rain (mm)	2,068.4	3,348.6	+61.9%	3,134.5	-6.4%	Parallel	YES
R9 Rain (mm)	1,881.4	2,747.9	+46.0%	2,813.6	+2.4%	Diverges 2022	PARTIAL
R5 DayT (°C)	31.9	30.9	-1.0	30.6	-0.3	Inverse	NO
R6 DayT (°C)	31.3	31.1	-0.2	31.1	0.0	Minimal change	N/A
R9 DayT (°C)	31.9	31.9	0.0	31.9	0.0	No change	N/A

National Cases	1,719	4,384	+155.0%	3,669	-16.3%	—	—

Δ = Percentage change. Source: Guyana Hydrometeorological Service and Ministry of Health, 2020–2022.

Discussion

This investigation presents the first multi-regional, systematic characterization of the co-variation between hydrometeorological variables and laboratory-confirmed dengue fever notifications across Guyana's administrative regions. The central finding is that calendar years with elevated cumulative precipitation consistently align with higher dengue case burdens, whereas thermal conditions remained comparatively stable, an observation consistent with international evidence on rainfall's predominant role in Aedes aegypti population dynamics and dengue transmission intensity [11].

The 49–62% increase in cumulative annual rainfall across regions 5, 6, and 9 between 2020 and 2021, accompanied by a 155% increase in national case numbers, strongly suggests rainfall-mediated transmission amplification. The underlying biological mechanisms are well documented: increased precipitation increases the availability of discrete stagnant-water microhabitats (discarded containers, obstructed drainage channels, coconut shells, and tire dumps) that serve as preferred Ae. habitats. aegypti breeding habitats in Guyana's coastal urban and peri-urban settings [12]. Higher vector density directly translates to greater human-vector contact probability and elevated transmission intensity. This pattern mirrors what has been observed in Colombia [13], Brazil [14], India [15], and the Philippines [16], where rainfall-case positive associations with two-to-six-week lags are consistently reported across geographic and cultural contexts [22, 23].

The relative stability of daytime temperatures (30.6–31.9°C) across the three years is notable. Within this thermal range, Ae. aegypti populations and dengue virus replication are near optimal [3], suggesting that Guyana's baseline climate is already permissive for year-round transmission. Thermal fluctuations within this band are therefore unlikely to contribute an independent epidemiological signal of comparable magnitude to precipitation variability. This observation carries meaningful implications for regional climate change projections: in the Guyanese context, alterations in precipitation intensity and distribution may outweigh the direct epidemiological consequences of future warming for near-term dengue burden, though long-term temperature increases beyond 35°C could begin to impose thermal stress on vectors [17].

The observation that Region 9 showed a progressive increase in annual rainfall and dengue cases across all three years (unlike regions 5 and 6, which peaked in 2021 and then declined slightly) is intriguing. Region 9 is a remote interior region where artisanal gold mining activities are expanding, creating deforested landscapes with abundant artificial water impoundments. Mining-related Aedes breeding has been documented in neighboring Suriname and in the Amazon basin [18], suggesting that land-use change may be interacting with rainfall variation to produce sustained transmission intensification in Guyana's hinterland that is not solely driven by climate. Future analyses should incorporate land use variables to disentangle climatic and anthropogenic drivers in this region.

The seasonal analysis, while constrained by aggregated annual data, provides preliminary evidence of a bimodal transmission pattern aligned with Guyana's bimodal rainfall seasonality. The identification of June–August and November–January as probable high-risk windows is consistent with the findings of Baksh et al. [6] and is actionable for public health: intensified vector surveillance, household container clean-up campaigns, and clinical preparedness should be targeted to the

pre- and early wet season periods to interrupt transmission chains before vector populations peak.

The apparent discrepancy between Region 5's near-zero dengue case reporting and its substantial rainfall (the second highest among the monitored regions in 2021 at 3,055.7 mm) is a notable surveillance paradox. If vector breeding conditions in region 5 are as favorable as rainfall data suggest, the zero-case count is almost certainly an artifact of surveillance system deficiency rather than a genuine absence of transmission. This highlights a critical gap: without functional diagnostic and reporting infrastructure, hydrometeorological risk signals cannot be translated into meaningful epidemiological monitoring, thereby undermining the reliability of early warning systems.

Several limitations affect the interpretation of these findings. The ecological design cannot establish individual-level causation. With only three annual data points, correlation estimates are not statistically powered. Dengue cases reflect confirmed cases only, with unknown proportions of true infections, and reporting patterns may have been affected by COVID-19 pandemic disruptions between 2020 and 2022. Monthly case data at the regional level were not available for this analysis period, preventing a more granular temporal correlation analysis with seasonal rainfall data. Future work should employ distributed lag non-linear models applied to weekly regional case counts and meteorological data, incorporating El Niño–Southern Oscillation indices and land use covariates, to generate actionable epidemiological risk estimates for Guyana's early warning system.

Conclusion

This study demonstrates a consistent, positive ecological association between annual cumulative rainfall and confirmed dengue fever case counts across Guyana's three monitored administrative regions from 2020 to 2022. The convergent peak of both precipitation and dengue notifications in 2021, alongside the thermal stability of temperatures within a persistently permissive band, reinforces rainfall as the dominant climatic determinant of inter-annual dengue variability in coastal Guyana. These findings provide an empirical foundation for developing a national dengue early warning system incorporating hydrometeorological data from the Guyana Hydrometeorological Service. Priority next steps include prospective weekly case-climate correlation analyses, expanding meteorological station coverage to all 10 regions, strengthening region-level diagnostic and case-reporting infrastructure, and deploying DLNM-based predictive models to generate actionable outbreak warnings for the Ministry of Health.

Conflict of Interest

The author declares no conflict of interest in the conduct and reporting of this research.

Ethical Approval

This study used anonymized, aggregate secondary data from national disease surveillance and meteorological services. No individual patient data or identifiers were accessed. An institutional review board exemption was granted by Texila American University.

Author Contributions

Allison Peters: Conceptualization, data curation, formal analysis, writing original draft, writing-review, and editing.

Abiodun Olaiya Paul: Methodology, supervision, writing-review, editing, and validation.

Nayan Persaud: Resources, investigation, validation.

Dr. Keisha A. Nelson: Resources, data curation, investigation.

Komalchand Dhiram: Resources, hydrometeorological data curation.

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Data Availability

The hydrometeorological data supporting the findings of this study are available from the Guyana Hydrometeorological Service on reasonable request. Disease surveillance data are available from the Guyana Ministry of Health Epidemiology Unit, subject to data governance approval.

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