SPECIAL ASSESSMENT

CORRELATION AND LAG ANALYSIS BETWEEN PRECIPITATION LEVEL AND DENGUE CASES AMONG ASEAN MEMBER STATES

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ABSTRACT

ASEAN Member States have tropical climates that favor *Aedes aegypti* breeding, yet the timing of rainfall-related changes in dengue incidence may differ substantially among countries. This exploratory study assessed country-specific associations between precipitation and reported dengue cases, including temporal lags. National dengue surveillance data were paired with NASA POWER precipitation estimates and aggregated to each country's reporting frequency. Pearson correlation coefficients were calculated for 11 ASEAN Member States across lags of 0-6 months for monthly series and 0-12 weeks for weekly series. Lag patterns were heterogeneous. Viet Nam showed the strongest monthly short-lag association, peaking at 1 month (r = 0.72). Among weekly series, Lao PDR and Thailand peaked at 5 weeks (r = 0.68 and 0.47, respectively), whereas Myanmar peaked at 2-3 weeks (r = 0.53). Timor-Leste remained positively correlated across all evaluated lags (r = 0.48-0.68). Brunei Darussalam, Cambodia, and Indonesia showed weaker associations; Malaysia showed little consistent positive association; and Singapore showed negative correlations throughout the evaluated lag window. Estimates for the Philippines were unstable because of its short observation period and the small number of paired observations at longer lags. No single precipitation-dengue lag pattern applied across the region. Because inferential testing was not performed, the results should be interpreted as hypothesis-generating rather than causal. These findings support country-specific, multivariable early-warning models using longer time series, subnational exposure data, harmonized temporal scales, and methods that address seasonality, autocorrelation, nonlinear effects, and uncertainty.

Keywords: dengue; precipitation; ASEAN; lag correlation analysis

BACKGROUND

Dengue is the most rapidly spreading mosquito-borne viral disease worldwide, and Association of Southeast Asian Nations (ASEAN) member states bear a disproportionately high burden. An estimated 70% of the global population at risk lives in Asia, and hyperendemic transmission occurs across ASEAN countries[1]. The principal vector, *Aedes aegypti*, depends on water-filled containers for oviposition and larval development[2]. Rainfall can therefore increase dengue risk by creating additional mosquito breeding sites. However, this effect is not immediate. The mosquito's aquatic life cycle typically takes 7–10 days; the extrinsic incubation period of the dengue virus within the mosquito lasts 8–12 days; and additional delays arise from human incubation, illness onset, healthcare-seeking behaviour, and case reporting. As a result, changes in precipitation are often reflected in reported dengue cases only after a lag of one to several months[3].

Previous studies have shown that climate-dengue relationships are delayed and spatially heterogeneous across several ASEAN countries. In Thailand, Tipayamongkholgul et al. (2009) used Poisson autoregressive models and found that El Nino-Southern Oscillation indices predicted dengue epidemics over lags of 1-11 months, with effects that varied among provinces; precipitation was not included because rainfall records were incomplete[4]. In Malaysia, Cheong et al. (2013) applied distributed lag non-linear models and found that high bi-weekly accumulated rainfall had its largest estimated effect after approximately 26-28 days[5]. A systematic review by Naish et al. (2014) found that dengue transmission is sensitive to climatic conditions, particularly temperature, rainfall, and relative humidity[6]. In the Philippines, Cruz et al. (2024) reported that meteorological associations with dengue incidence varied among study sites, with significant lagged effects persisting for approximately one to two months in some locations[7]. Together, these findings suggest that climate-related dengue risk may emerge after a delay, although the timing and magnitude depend on local ecological conditions, vector control activities, population behaviour, and surveillance practices.

Although national-level studies provide important evidence, regional comparisons remain limited. Existing research is fragmented by country, covers different time periods, and often uses inconsistent case definitions and lag-estimation methods. These differences make it difficult to compare precipitation and dengue associations across ASEAN member states. A harmonised regional correlation and lag analysis using a unified dataset and methodology could address this gap by identifying shared temporal patterns, measuring differences in lag structures across countries, and strengthening the evidence base for climate-informed dengue early warning systems.

METHODS

Dengue Case Data Source

Dengue data for ASEAN Member States in this report were compiled by the ASEAN Biological Threat Surveillance Centre (ABVC) from official national, regional, and publicly available surveillance sources. These include Ministries of Health in Brunei Darussalam, Indonesia, Myanmar, and Timor-Leste; WHO Western-Pacific Regional Office dengue surveillance data for Cambodia, Lao PDR, Malaysia, and Viet Nam; the Philippines Department of Health EB Weekly Surveillance Report; Singapore's Weekly Infectious Disease Bulletin; and Thailand's Bureau of Epidemiology under the Department of Disease Control. The sources were retrieved on July 21, 2026, and the report indicated that official reporting may have a 2-8 week delay, so the data should be interpreted cautiously.

The report presents dengue data from 2023 to Epi-week 28 of 2026, however most of data cover from 2024 to 2026 due to difference availability of data. For the year-to-date regional summary, the reporting period covers January 1 to July 18, 2026. During this period, ASEAN Member States reported 221,148 cumulative dengue cases and 431 deaths, corresponding to a case fatality rate of 0.19%. In Epi-week 28 alone, the region reported 1,845 new dengue cases.

Precipitation Data Source

Precipitation data were obtained as daily estimates from the NASA POWER meteorological dataset, which derives its meteorological parameters primarily from NASA GMAO's MERRA-2 reanalysis system. The dataset covered the period from 1 January 2020 to 18 July 2026 and was extracted at the available native resolution for each country reference point. Country-level coordinates were generated in R using spatial tools from the `tmaptools` package (version 3.3) by identifying the geometric centroid of each country.

Statistical Analysis

Dengue cases and precipitation were aligned by country and aggregated to the reporting frequency of the dengue series. Brunei Darussalam, Indonesia, Malaysia, and Viet Nam were analysed at monthly resolution, whereas Cambodia, Lao PDR, Myanmar, the Philippines, Singapore, Thailand, and Timor-Leste were analysed at weekly resolution. Pearson correlation coefficients were calculated between dengue cases in period t and precipitation in period t-l, with positive lags indicating that precipitation preceded reported cases. Lags of 0-6 months were assessed for monthly series and 0-12 weeks for weekly series, using complete observation pairs. For each country, the lag with the largest observed coefficient was identified descriptively. Because the analysis did not estimate confidence intervals, p-values, or corrections for testing multiple lags, the coefficients were interpreted as exploratory measures of temporal association rather than evidence of statistical significance or causation.

RESULTS

Descriptive patterns of dengue cases and precipitation

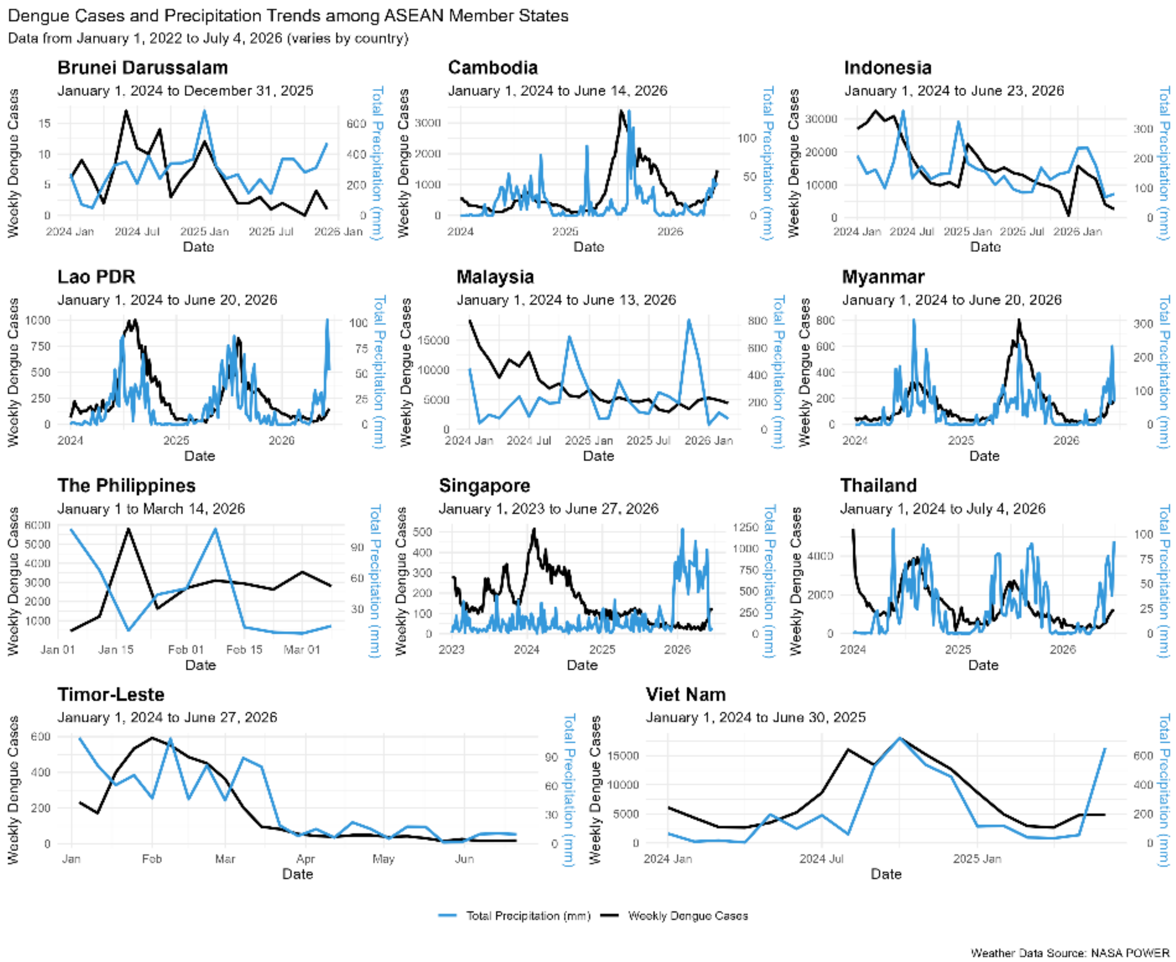

Figure 1. Dengue case and precipitation time series for ASEAN Member States. The observation window and reporting frequency vary by country; dengue cases are shown in black and total precipitation in blue.

The time-series plots in figure 1 showed marked between-country variation in the magnitude and timing of dengue activity. Several countries, including Cambodia, Lao PDR, Myanmar, and Thailand, displayed recurrent rises in cases during or after wetter periods. In contrast, the alignment was less consistent in Brunei Darussalam, Indonesia, Malaysia, Singapore, and the Philippines. The plots also highlighted major differences in data coverage: some series spanned multiple years, whereas the Philippines series covered only a short part of 2026. These differences constrain direct comparison of both disease burden and apparent climate-response timing across countries.

Lagged correlations between precipitation and dengue cases

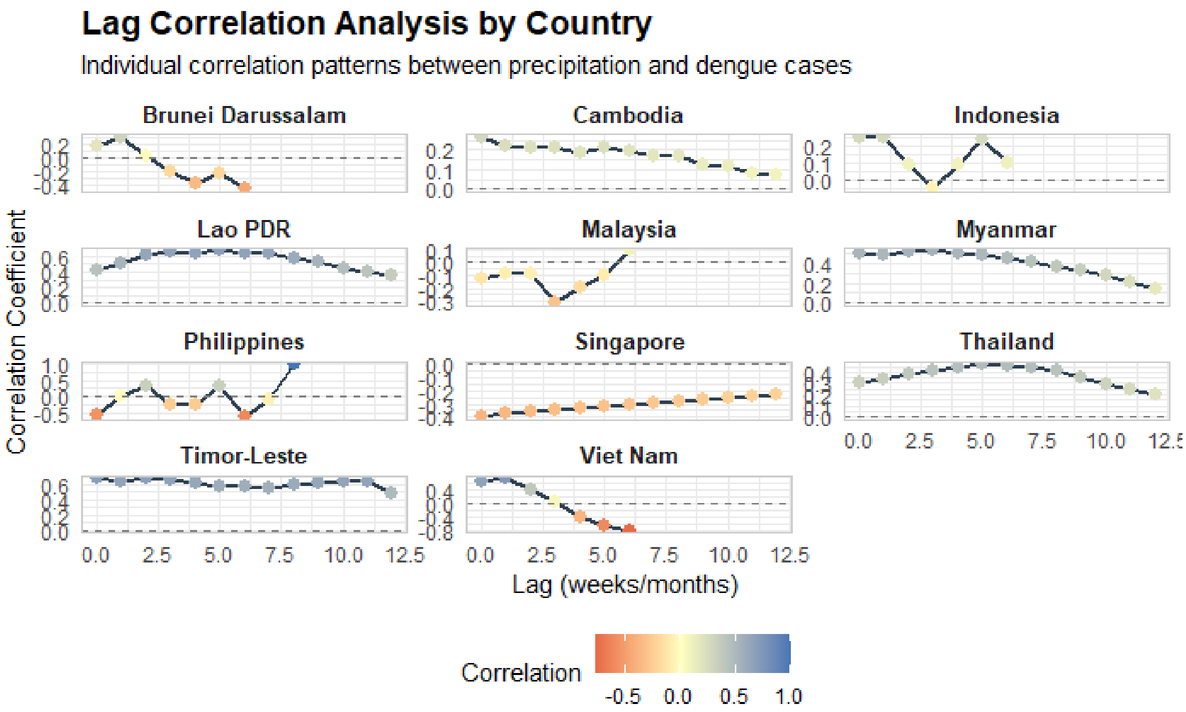

Figure 2. Country-specific Pearson correlation coefficients across precipitation lags. Lag units are months for Brunei Darussalam, Indonesia, Malaysia, and Viet Nam, and weeks for the other countries.

The lag analysis revealed substantial heterogeneity rather than a single regional lag structure as can be seen in figure 2. Among the monthly series, Viet Nam showed the clearest short-lag pattern in figure 3: the coefficient increased from r = 0.65 at lag 0 to a maximum of r = 0.72 at lag 1 month, then declined and became negative at lags 4-6 months. Brunei Darussalam had a modest maximum at lag 1 month (r = 0.30), while Indonesia showed only weak positive coefficients, with a maximum of r = 0.26 at lags 0-1 month. Malaysia was weakly negative at most lags and reached only r = 0.09 at lag 6 months in lag correlation heatmap.

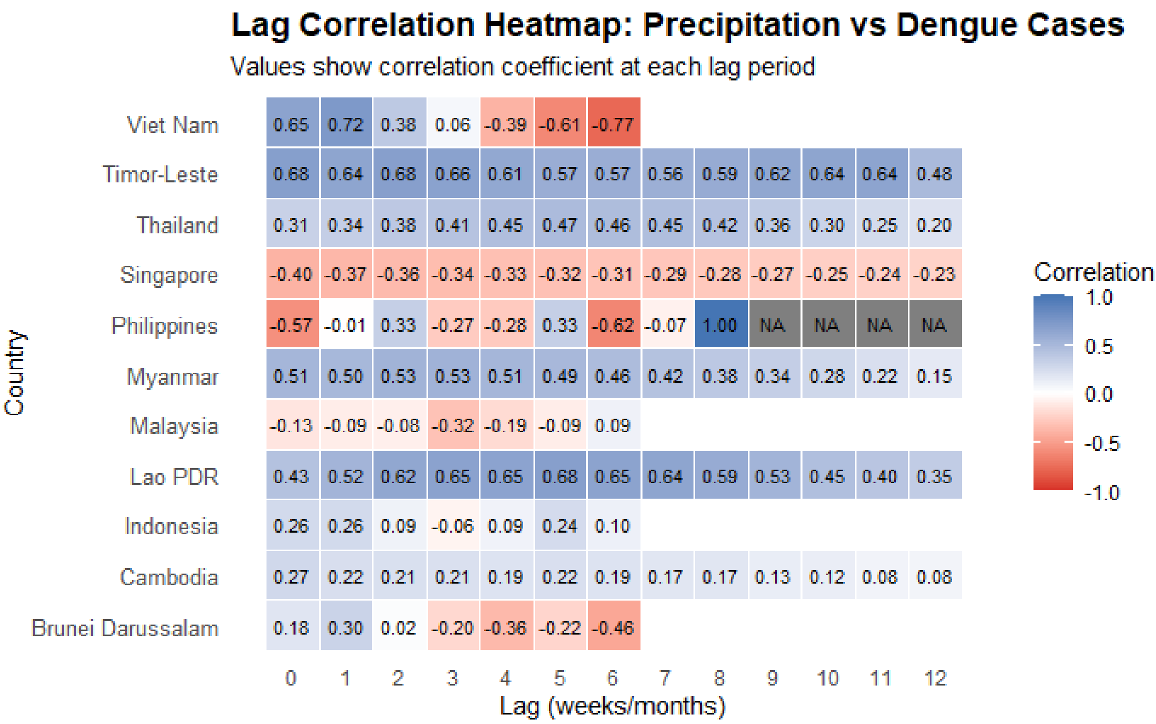

Figure 3. Heatmap of precipitation-dengue correlation coefficients by country and lag. Positive lags indicate that precipitation preceded dengue cases; blank cells indicate that a coefficient could not be estimated.

Among the weekly series, in figure 3, Lao PDR showed a sustained positive pattern that peaked at lag 5 weeks (r = 0.68). Thailand similarly rose from r = 0.31 at lag 0 to r = 0.47 at lag 5 weeks before gradually declining. Myanmar had moderately positive contemporaneous and short-lag coefficients, peaking at r = 0.53 at lags 2-3 weeks. Timor-Leste remained positively correlated across all evaluated lags (r = 0.48-0.68), with maxima at lags 0 and 2 weeks. Cambodia showed a weak contemporaneous association (r = 0.27) that generally diminished with increasing lag.

On the other hand, Singapore differed from these patterns, with negative coefficients throughout the 0-12-week range (r = -0.40 to -0.23). Moreover, in figure 3, The Philippine coefficients fluctuated sharply from negative to positive values, including an isolated r = 1.00 at lag 8 weeks, after which lags 9-12 could not be estimated. Given the short of the Philippines observation window and rapidly diminishing number of paired observations at longer lags, this extreme coefficient was considered unstable and was not interpreted as evidence of a perfect precipitation-dengue relationship.

DISCUSSION

This regional analysis indicates that the association between precipitation and dengue is context dependent. Overall, he most coherent short-lag positive patterns occurred in Viet Nam, Lao PDR, Thailand, and Myanmar, whereas Brunei Darussalam, Cambodia, and Indonesia showed weaker associations, Malaysia showed little consistent positive association, and Singapore showed negative correlations throughout the evaluated lag window. The findings therefore do not support a single precipitation threshold or lag that can be applied uniformly across ASEAN Member States. Evidently, finding strong association between climate factors and dengue cases is by evaluating and analysing longer period of surveillance data which showed by van Panhuis, W. G., et al. (2015) where they collected and analysed 18 years of monthly dengue surveillance reports [8].

Interpretation of country-specific lag patterns

The positive associations at short lags are biologically plausible. Rainfall can increase the availability of water-filled larval habitats, after which time is required for mosquito development, viral amplification within the mosquito, human incubation, care seeking, and case reporting[3]. The peaks at approximately 1 month in Viet Nam and 5 weeks in Lao PDR and Thailand are consistent with this delayed pathway and with earlier evidence that rainfall-related dengue effects often occur within one to three months[4]-[7]. Myanmar's relatively high coefficients at lag 0 and 2-3 weeks may reflect a faster local response, shared seasonal timing, or aggregation of exposure and case reporting within the same weekly periods.

The weak, negative, or changing correlations in other countries should not be interpreted as evidence that precipitation is irrelevant. Rainfall-dengue relationships may be nonlinear. There is several factors that may contribute this phenomenon: moderate rainfall can create breeding habitat, whereas intense rainfall may flush containers or occur during periods when temperature, immunity, human mobility, or vector-control activities limit transmission[3],[6]. National aggregation can also obscure local associations, particularly in geographically large or climatically diverse countries such as Indonesia. Singapore's persistently negative pattern may similarly reflect urban control interventions, container ecology, drainage, or seasonal factors that are not captured by precipitation alone.

The comparison with previous country studies reinforces the need for cautious interpretation. Based on our analysis, Thailand's peak at about 5 weeks, however it cannot be directly compared with other study done by Tipayamongkholgul et al.[4], which evaluated El Nino South Oscilation (ENSO), temperature, and relative humidity rather than precipitation, but both analyses demonstrate that climate-dengue timing varies across settings. In Malaysia, the weak correlations in the present analysis contrast with the approximately 26-28-day rainfall effect reported in a subnational distributed-lag analysis [5], suggesting that national monthly aggregation or the restricted study window may mask local signals. The irregular Philippines pattern also differs from previously reported meteorological associations persisting for one to two months at some study sites[7]; however, the short series used here provides too few stable long-lag comparisons to evaluate that discrepancy reliably.

Implications for surveillance and early warning

Precipitation could contribute to climate-informed dengue surveillance, but the results favour country-specific models rather than a common regional rule. In countries with coherent short-lag patterns, recent rainfall could be incorporated as an early-warning covariate alongside temperature, humidity, historical dengue activity, vector indices, and surveillance indicators. Operational thresholds should be developed and validated separately for each country and, where possible, at subnational level. The observed lag windows may help define the period during which vector control, risk communication, clinical preparedness, and supply planning are intensified, but prospective validation is required before these correlations are used for prediction.

Strengths and limitations

A strength of this study is the use of a common analytical procedure to compare precipitation-dengue timing across multiple ASEAN settings. Nevertheless, several limitations materially affect interpretation. Dengue data sources, case definitions, reporting delays, observation windows, and reporting frequencies differed by country. Weekly and monthly lag coefficients are not directly equivalent, and national case counts were not standardised by population. Precipitation was represented by a country reference point, which may poorly capture spatial variability within large or archipelagic states. Pearson correlation assumes a linear relationship and does not account for nonlinearity, long-term trends, seasonality, autocorrelation, temperature, humidity, population immunity, serotype dynamics, mobility, or vector-control activities. Testing several lags and selecting the largest coefficient can also overstate apparent associations, especially in short series. No confidence intervals, p-values, or out-of-sample validation were available; therefore, the results should be considered hypothesis generating and cannot establish causality.

Conclusion

Precipitation and dengue cases exhibited heterogeneous lagged associations across ASEAN Member States. Viet Nam, Lao PDR, Thailand, and Myanmar showed the clearest short-lag positive patterns, while several other countries showed weak, negative, or unstable coefficients. These findings support further development of locally calibrated, multivariable early-warning models using harmonised time scales, longer series, subnational exposure estimates, and methods that explicitly address seasonality, autocorrelation, nonlinear effects, and uncertainty. Additionaly, these analysis provide reproducible methods for analysing relationship between precipitation level and dengue cases in respective countries. Also this analysis could be continued with time series analysis to investigate causality of weather variables with dengue cases in respective countries.

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