**Two Decades of Endemic Dengue in Bangladesh (2000-2022): Trends, Seasonality, and Impact of Temperature and Rainfall Patterns on Transmission Dynamics**

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**Abstract:**

**Background:** The objectives of this study were to compare dengue virus (DENV) infection, deaths, case-fatality ratio, and meteorological parameters between the first and the recent decade (2000-2010 vs. 2011-2022) and to understand the trends, seasonality, and impact of change of temperature and rainfall patterns on transmission dynamics of dengue in Bangladesh

**Methods:** For the period 2000-2022, dengue cases and death data from Bangladesh’s Ministry of Health and Family Welfare’s website, and meteorological data from the Bangladesh Meteorological Department were analyzed. A Poisson regression model was performed to identify the impact of meteorological parameters on the monthly dengue incidence. A forecast of dengue cases was performed using an autoregressive integrated moving average model.

**Results:** Over the past 22 years, a total of 244,246 dengue cases were reported including 849 deaths (Case fatality ratio [CFR] =0.34%). The mean annual number of dengue cases increased eight times during the second decade, with 2,216 cases during 2000-2010 vs. 18,321 cases during 2011-2022. The mean annual number of deaths doubled (21 vs. 46), but the overall CFR has decreased by one-third (0.69% vs 0.23%). Concurrently, the annual mean temperature increased by 0.49 °C, and rainfall decreased by 314 mm. Monthly mean temperature (Incidence risk ratio [IRR]: 1.26), first-lagged rainfall (IRR: 1.08), and second-lagged rainfall (IRR: 1.17) were significantly associated with monthly dengue case incidence.

**Conclusions:** The increased local temperature and decreased rainfall might have contributed to the increased incidence of DENV infection in Bangladesh. Effective strategies such as community engagement, vector control, and eliminating mosquito breeding habitats are crucial in addressing and managing the dengue outbreak exacerbated by these environmental changes.

**Keywords:** Dengue, Bangladesh, Climate change, Temperature, Rainfall

**Introduction:**

Dengue fever is a mosquito-borne disease (MVD) caused by four distinct serotypes of the dengue virus (DENV) within the family *Flaviviridae* (WHO 2009). DENV is transmitted to humans by bites of *Aedes aegypti (L.)* and *Aedes albopictus (*Skuse*)* (WHO 2009, CDC 2019). DENV is endemic in over 125 countries, and the number of cases globally reported to WHO continues to increase yearly (WHO 2023a). Annually, an estimated 390 million dengue infections are estimated worldwide, including 96 million clinical cases making DENV one of the most important vector-borne diseases (VBDs) (Murray et al. 2013, WHO 2023b). Most infections (>80%) are self-limiting with no or mild clinical manifestation resulting in lifelong immunity for that serotype (WHO-Bangladesh 2022). However reinfection with different serotypes, known as secondary or tertiary dengue infection, may result in severe dengue, including increasing the risk of fatal outcomes (Teo et al. 2023).

Currently, South and Southeast Asia are ‘hotspots’ of DENV infection, with more than 50% of cases recorded in these regions (WHO South-East Asia 2023). The first DENV outbreak in Bangladesh was reported in 2000, and since then, dengue has become endemic in the country posing a significant health challenge (Sharmin et al. 2015). Over the past few years, the number of dengue cases has been steadily increasing, with significant seasonal and regional variations. Analysis of data from 2000 to 2017 revealed that almost half of the dengue cases occurred during the monsoon (May-August) and the post-monsoon (September-December) seasons (Mutsuddy et al. 2019). However, a shift in seasonal patterns has been observed since 2014, with dengue cases being reported during the pre-and-post monsoon seasons (Mutsuddy et al. 2019). During 2015-2017, the number of dengue cases during the pre-monsoon season was more than seven times higher compared to the previous 14 years (Mutsuddy et al. 2019). The annual incidence of DENV infection started to increase sharply after the introduction of serotype DENV-3 in 2019 into Bangladesh (Haider et al. 2021).

Climate change, including changes in precipitation, temperature, and humidity, as well as rapid unplanned urbanization, were identified as strong indicators of an ecological imbalance that has led to an increase in dengue cases in Bangladesh (Mutsuddy et al. 2019). These changes suggest that the dengue transmission season could eventually extend year-round, with a chance of outbreaks occurring at any time of the year. Identifying trends and seasonality in dengue cases can aid health authorities and relevant public and private administrations in effectively allocating resources to control the spread of the DENV through vector control. The objectives of our current study were to: i) compare the number of annual and monthly cases occurring during the first [2000-2010] and recent decade [2011-2022], ii) identify the overall trend and seasonality of dengue cases, iii) quantify the impact of weather parameters on the monthly incidence of dengue cases, and iv) forecast the annual incidence of dengue cases for the next decade.

**Methods:**

**Data sources:**

The Communicable Disease Control (CDC) typically oversees the monitoring of the spread of communicable diseases across the country by gathering data through its central control room. Established in 1983 in collaboration with the International Centre for Diarrheal Disease Research, Bangladesh (icddr,b), under the Epidemic Control Preparedness Program (ECPP) with the Ministry of Health and Family Welfare, Bangladesh, the Control Room of the Directorate General of Health Services operates 24/7. Its main focus is to collect information on dengue, diarrhea, and various other health-related emergencies. This control room cell is now officially recognized as the National Health Crisis Management Centre (NHCMC), DGHS (https://www.hindawi.com/journals/cjidmm/2019/3516284/). The data on the number of reported dengue‐infected people were obtained from the Directorate General of Health Services (DGHS)'s website from January 2000 to December 2022 (DGHS 2023). We used the definition of dengue cases used by the Ministry of Health and Family Welfare, Bangladesh. Dengue cases were identified based on clinical symptoms (including fever and rash) and/or laboratory tests for IgM or IgG antibodies to DENV, and nonstructural 1 protein (NS-1) of DENV, which was discussed elaborately in our earlier article (Ahsan et al. 2021). We used three-hourly temperature and daily rainfall data from only Dhaka, as most of the cases reported from Dhaka. We collected those data from Bangladesh Meteorological Department (BMD) over the period 2000–2022 (BMD 2023) for the meteorological station located in Mirpur, Dhaka.

**Procedures**

The monthly number of dengue cases was used as the primary outcome variable. Dengue monitoring primarily involves proactive efforts, including direct communication with public and private healthcare facilities and passive approaches through a daily 'Hot Line.' Additionally, each facility compiles a comprehensive report summarizing the morbidity and mortality related to dengue at the end of each month, which is then submitted to the CDC. Two weather variables- temperature and rainfall are used as the covariates for the regression analysis. In addition, two lagged variables monthly rainfall in lag 1 and lag 2 were also used as predictors for the incidence of monthly dengue cases to capture the impact of those meteorological parameters. A lagged variable refers to a value from a prior time point. When studying the meteorological impact on Dengue cases, it's crucial to focus on lag variables. Two critical stages for lag effects should be considered: mosquito development and parasite incubation within the mosquito. The lag times for these stages can vary based on climate, creating a diverse lag distribution at the population level. In the context of monthly data, lag 1 refers to the data from the preceding month, and lag 2 pertains to the data from two months prior. We also compared monthly mortality data between the two decades.

**Statistical analysis**

We analyzed the monthly dengue incidence and meteorological data for the period of 2000-2022. In the first stage, descriptive analyses were conducted to determine the characteristics of confirmed dengue cases and deaths with mean, and interquartile range (IQR) in each year and each month for the entire period. Then, we compared the number of dengue cases, deaths, and weather parameters in two decades (2000-2010 and 2011-2022) using paired sample t-test, aimed at examining and comparing trends, developments, and changes over specific periods. Next, we calculated the monthly growth factor (GF) of dengue cases by dividing the number of dengue cases reported in each month by the number of dengue cases reported in the previous month and repeating this process for each month from 2000 to 2022 (Haider et al. 2021). The formula for the growth factor can be given by

where indicates the number of dengue cases in th month. To avoid the occurrence of zeros in some months, we added 1 to the total number of cases for each month. This allows us to obtain a real-valued measurement of the GF for the above equation. The distribution of GF was skewed; therefore, we used the log10 transformation before the data was further examined. However, we have also performed a reverse transformation of the log10 (GF) values by back-transforming values to the original scale for ease of interpretation. GF greater than 1 indicates a high transmission period and less than 1 indicates a low transmission period (Haider et al. 2021).

We performed forecasting using the autoregressive integrated moving average (ARIMA) model. The ARIMA model is a data-driven, exploratory strategy that enables us to fit a suitable model and forecast values. The ARIMA model consists of autoregressive (p) terms, differencing (d) terms, and moving average (q) operations, and it is denoted as ARIMA (p, d, q) (Kumar and Susan 2020). To select the appropriate autoregressive and moving average orders, the autocorrelation function (ACF) and partial autocorrelation function (PACF) were examined. Additionally, the differencing parameter, represented by "d," indicated the number of times the time series was different to achieve stationarity. An ARIMA (p, d, q) process refers to an autoregressive moving average (ARMA) model that has been differenced "d" times to obtain stationarity ( Hasan et al. 2021). By removing high-frequency noise from the data, the model discovers local patterns by assuming that the time series values are linearly related. We also conducted a Mann-Kendall (M-K) trend analysis to determine possible upward or downward trends (Yue and Pilon 2004). The null hypothesis posits no monotonic trend, while the alternative hypothesis suggests the presence of a trend, which could be positive, negative, or non-null. We also performed Sen's slope test to assess variations in annual dengue cases and deaths. The slope greater than 0 indicates an upward trend and less than 0 indicates a downward trend of a given period (Sen 1968).

We, then used a time series count generalized linear model (GLM), more specifically, a time-series Poisson regression model to determine whether the meteorological factors were associated with the change in dengue cases over time (Sumi et al. 2021). The non-normality, heteroscedasticity, and non-linearity that characterize count data can be fitted using GLMs. The time-series observations may possess autocorrelation and they might be nonnegative integers, and thus GLM is useful in overcoming both issues (Quddus 2008, Fokianos 2012). Monthly dengue cases were utilized as the outcome variable in this model, along with data from the Bangladesh Meteorological Department (BMD) on temperature and rainfall. To capture the actual impact of rainfall on dengue incidence across time, we additionally employed two lagged variables of meteorological elements, mainly rainfall in lag 1 and 2. After eliminating predictors (average temperature with lag 1, lag 2 and rainfall with lag 0) with a higher multicollinear relationship, we arrived at average temperature, rainfall (in lag 1), and rainfall (in lag 2) as the final set of predictors for monthly dengue incidence in Bangladesh. We used the statistical program RStudio, version 3.5.2.2 for the analyses (R Core Team 2022).

**Results:**

Between 2000 and 2022, DGHS reported a total of 244,246 dengue cases, with an annual mean of 10,619 cases (interquartile range [IQR]: 859.5-5805.5), including 849 fatal outcomes with a case-fatality ratio (CFR) of 0.34%. Between 2000 to 2010, the mean annual number of dengue cases was 2,216 (IQR: 480-3182) which increased by 8 times in the following decade (2011-2022) at 18,321 (IQR: 1405-28429) **(Table 1)**. Between these two periods, the mean number of annual deaths due to DENV infection increased by 2.2 times, from 21.2 to 46.6 cases. However, the CFR of DENV infection decreased from 0.69% to 0.23% (**Table 1)**.

The highest monthly average number of cases was recorded in August (n=3,407 cases) and the lowest was in March (n=6.7 cases) **(Fig 1B)**. The highest number of annual cases was reported in 2019 with 101,354. The highest number of deaths was recorded in 2022 with 281 deaths, which was 35% of total deaths recorded in the past 23 years in Bangladesh **(Fig 1)**. Most of the dengue-related deaths were recorded after 2018, with more than 65% (n=550) deaths recorded during this time **(Fig 1)**.

The average annual temperature was 26.35 °C (SD=0.49) during the first decade (2000-2010) and 26.84 °C (SD=0.37) during the recent decade (2011-2022) (**Table 1**). The increase of 0.49 ° C temperature was equivalent to 4292 degree-hours/year of heat (365 days X 24 hours X 0.49 ° C). The annual total rainfall decreased by 314 mm between two decades, from 2078.6 mm to 1764.5 mm (**Table 1**), of which 308 mm decreased during the monsoon (July-October) season and only 6 mm decreased during the non-monsoon period. However, during pre-and-post monsoon season, rainfall (more than 3rd quantile value of monthly rainfall for the decade) increased in the second decade **(Fig 2)**.

The overall mean GF for the number of dengue cases per month was 1.37 (SD=0.86). However, in four months (April-July), the monthly GF was above one (lower 95% confidence interval >1), while for the rest of the months, the monthly GF was less than 1 (95% confidence interval crossed 1). More than 77% (71/92) of months between April and July for the period 2000–2022 had mean monthly GF > 1 compared to only 16% (30/184) of months between August and March of the same period. June had the highest GF with a mean value of 3.47 indicating that cases would be more than three times higher in the next month (July). The lowest GF was recorded in December with a mean of 0.54 (95% CI: 0.40 to 0.69) indicating that cases in January would be halved compared to the number of cases recorded in December (**Fig. 3**). In the M-K trend analysis, we found a positive trend of reported dengue cases (p <0.001 and tau = 0.26). In Sen’s slope test, the slope was 171.67 (95% CI: -46 to 687) indicating an upward trend in upcoming months (**Table 2**).

In the GLM, the estimated effect of each variable is presented as the incidence risk ratio (IRR). The model indicates that dengue cases would rise by 26% with a one-degree centigrade (°C) temperature increase. For each additional centimeter (cm) of rainfall in the first lagged month, the number of dengue cases increased by 8% (IRR= 1.08 [95% CI: 1.08-1.09]), and in the second lagged month increases in cases would be by 17% [IRR=1. 17 (95% CI: 1. 17 -1.18)] **(Table 3)**.

In the ARIMA model, we detected an increasing trend for the first few years, which then started to decline. However, a strong rise in cases was observed after 2018 except for 2020 (the first year of the Covid-19 pandemic). The forecasted value showed a continuously increasing trend in the number of DENV infections in Bangladesh **(Fig 4)**.

**Discussion:**

Dengue is currently an important public health challenge for Bangladesh. Our analysis showed that the number of DENV infections has increased eight times and deaths have doubled, and the CFR dropped to one-third between the first and second decades of this century in Bangladesh. Between these periods, the annual temperature increased by 0.49 °C, and annual rainfall decreased by 314 mm, despite changes in rainfall patterns with unusually early or late rainfall outside the typical monsoon season (July-October) (Haider et al. 2014). The monthly growth factor remained above one for four months (April to July) which overlapped the hot and humid period of the year. Monthly mean temperature, monthly first-lagged rainfall, and second-lagged rainfall played a critical role in monthly dengue incidence in Bangladesh.

The increase of 0.49 °C temperature adds approximately 4292-degree-hours of equivalent heat per year. This additional heat would favor VBD transmission. For dengue virus transmission, approximately 305-degree-hours equivalent heat is needed to accomplish the extrinsic incubation period in *Aedes* mosquitoes at 26° C (Focks et al. 1995). Therefore the addition 0.49°C temperature will add the burden of more than 14 generations of infectious mosquitoes in the environment of Bangladesh. An 8-fold increase in dengue cases is an indication of such changes in temperature in the country. Our model identified a significant role of monthly mean temperature with an additional 1 °C temperature increasing the monthly cases by 26%. Earlier studies showed that for every 1 °C increase in temperature, dengue cases increased by 61% in Australia, 12-22% in Cambodia, 5% in Vietnam, and 2.6% in Mexico (Soneja et al. 2021).

Rainfall provides oviposition and larval developmental sites and thereby plays an important role in mosquito-borne pathogen transmission. Although we found a 15% reduction in annual rainfall in the recent decade from the immediate past decade, we detected an increase in unusually high rainfall in pre-and-post monsoon seasons, therebyextending the season for mosquitoes and other arthropod vectors. Our model showed that both the first and the second lagged month’s rainfall increased monthly cases by 8% and 17%, respectively. These findings were consistent with earlier studies in Bangladesh that showed that peak dengue cases occurred two months after the peak rainfall (Salje et al. 2016) or an additional rainy day per month increased dengue cases by 6% in the succeeding month (Rahman et al. 2020). Similar findings were reported in Vietnam with dengue incidence being associated with both first and second-lagged months (Cuong et al. 2011). In Timor-Leste, a 47% increase in dengue incidence was recorded with an additional 1 mm seasonal rainfall increase (Wangdi et al. 2018). These findings are biologically plausible as rainfall allows approximately two generations of dengue cases over a month. A generation interval is a time difference between a primary human infection and a second human infection originating from the first human case through two bites of the mosquitoes (Siraj et al. 2017). To accomplish a generation interval the virus and mosquito undergo several phases including the intrinsic incubation period in humans, human-mosquito transmission (first bite), blood digestion and the extrinsic incubation period in mosquitoes, and finally mosquitoes-to-human transmission (2nd bite) (Siraj et al. 2017). Ideally, for DENV, the generation interval completes at around 16 days at 28-32 °C (Siraj et al. 2017).

Bangladesh’s dengue season is characterized by hot and wet periods between June to August. This is the period with the highest amount of rainfall facilitating *Aedes* abundance in the country (Haider et al. 2023). The monthly mean growth factor above 1 for April – June indicates that for each of these months, the incidence of dengue cases will surpass the previous month. Thus, we suggest starting vector control intervention in April in Bangladesh.

Globally and regionally in South and Southeast Asia, dengue cases are increasing. DENV infection increased by more than 46% between 2015 and 2019 in the region (WHO South-East Asia 2023). Through 31 May 2023, a total of 1,515,460 DENV infections were recorded in Brazil with 387 deaths(European CDC 2023). In Malaysia, a total of 43,619 DENV infections have been recorded by 21 May 2023(European CDC 2023). We found an increasing trend of DENV cases in Bangladesh. This increasing trend was much more pronounced after the serotype DENV-3 was introduced in the country in 2018 (Ahsan et al. 2021). This increased trend was possibly linked with climate change in the region attributed to increased temperature and unusual rainfall, as well as urbanization, population growth, inadequate water supply and storage practice, poor sewer, and waste management system, rise in global commerce and tourism (WHO South-East Asia 2023).

The case fatality ratio (CFR) of primary dengue infection is very low with an estimation of 0.018% - 0.1% (Huits and Schwartz 2021). However, the CFR of secondary or tertiary DENV infection is high. Although precise estimates were not available, some studies showed more than 1% and up to 4% (Liu et al. 2020). Bangladesh’s overall CFR of dengue infection (0.34%) seems slightly higher considering the overall CFR reported in other South and Southeast Asian countries (WHO South-East Asia 2023). However, more than 65% of dengue-related deaths in Bangladesh were recorded after the introduction of the serotype DENV-3 in 2019. Earlier, DENV serotypes 1-3 had been reported over different years between 2000 and 2019 (Rahim et al. 2021) and DENV-4 had reappeared in 2022 (Haider et al. 2023). Thus, secondary, or tertiary infections are likely contributing to higher dengue-related deaths in Bangladesh. In addition, the CFR of the dengue virus infection might have been affected by a reduction in active surveillance and failure to detect mild and asymptomatic cases outside the public hospitals and few selected private hospitals in Bangladesh or a weaker health care system in the country (Ahsan et al. 2021). In some years, the CFR was very high, for example, in 2003, the CFR was 2.1 (total cases 486), in 2000, 1.68 (total cases 5,551), and in 2022, 0.45 (total cases 62,382). The CFR of DENV infection decreased in the second decade in Bangladesh. This improvement is probably associated with improved access to the health care system, a better understanding of the treatment protocol including the availability of clinical management guidelines and training for the health care providers, better availability of Information, Education, and Communication (IEC) materials, community engagement and expansion of surveillance system to more hospitals in the surveillance system across the county in the recent years, and overall improvement of the economic condition of the country (Diseases Control Division (DGHS) 2013, WHO 2017, Albis et al. 2019).

Two large dengue outbreaks occurred in Bangladesh during 2019 and 2022, with both characterized by unusual weather patterns and the occurrence of two different DENV serotypes. The 2019 outbreak was characterized by early rainfall of 120 mm in February compared to a monthly mean of 20 mm precipitation, along with the introduction of a new serotype of DENV-3 in the country (Ahsan et al. 2021). The 2022 outbreak was characterized by the late onset of rainfall with 297 mm rainfall in October compared to a monthly mean of 156 mm that may have prolongedthe vector transmission season and by the introduction of a new serotype, DENV-4, in the country (Haider et al. 2023). The occurrence of a new serotype exposed a large naïve population in a densely populated country like Bangladesh. A large proportion of the population had already been infected with one or more serotypes of DENV with more than 80% of people living in Dhaka having antibodies against DENV (Salje et al. 2016). Another study predicted an estimated 40 million people had been infected with DENV nationally, with 2.4 million annual infections (Salje et al. 2019). Thus, any subsequent infections raise the risk of developing severe dengue hemorrhagic fever through antibody-dependent enhancement (ADE) (Teo et al. 2023). The deaths of many people in 2022 when DENV-4 was introduced were probably associated with secondary and/or tertiary DENV infection (Haider et al. 2023).

Controlling vector-borne diseases in tropical countries where temperatures, humidity, and rainfall remain favorable for mosquitoes during most periods of the year is a difficult task (Haider et al. 2023). Concerns have been raised over the development of insecticide resistance (Al-Amin et al. 2020, Ahsan et al. 2021) and the failure of developing a successful dengue vaccine (Wang et al. 2017). The prospect of *Wolbachia-*related intervention is still far from being applied on a national scale considering the expenses and associated technicalities. In this situation, an integrated and holistic vector management plan while engaging the local communities is key for controlling *Aedes*-borne diseases, especially in resource-limited countries. Regular destruction of mosquito developmental sites and increasing surveillance for detecting active cases are key to controlling dengue virus infection. Continuous activesurveillance for DENV infections will enable early detection of cases and outbreaks. Public health authorities will be able to identify areas where the disease is spreading, take immediate action to control mosquito populations, isolate infected patients, and implement public awareness campaigns to educate people about preventive measures. Early detection and response can help prevent the further spread of the disease and reduce its impact on individuals and communities.

Regular destruction of mosquito developmental habitats and increasing surveillance for detecting active cases should be prioritized for controlling DENV infection in Bangladesh. Policymakers need to design an *Aedes*-borne disease management plan by considering a range of pathogens that *Aedes* mosquito can transmit including dengue, chikungunya, , and Zika , , viruses (Haider et al. 2023).

Several weaknesses may have impacted our study. We relied on the reported number of cases from the Ministry of Health and Family Welfare’s website, which mainly relies on passive reporting systems from the selected health facilities in the country (Ahsan et al. 2021). These numbers seem to underestimate the actual number of infections and fever cases. A modeling study based on the national seroprevalence of DENV antibodies predicted an annual infection of 2.4 million people (Salje et al. 2019). Dengue infection is underestimated globally as it is difficult to detect asymptomatic or mild cases that never reach healthcare settings. Although mild cases are missed more frequently, the severe and fatal cases would likely visit the hospital and thus be counted as numerators in our estimation. Thus, our estimation did not overlook the worst-case scenario, but may have estimated a higher CFR because of the underestimation of the denominators. Another limitation pertains to our exclusive utilization of weather data from the Dhaka station. Given Bangladesh's relatively small size and the moderate climate variation across the country, we focused our data collection solely on the Dhaka station. Furthermore, a substantial proportion of historical dengue data originates from the Dhaka region.

**Conclusions:**

Between the first (2000-2010) and the second decade (2011-2022), dengue cases have increased by 8.3 times, and annual deaths have increased by 2.2 times in Bangladesh. This growth of cases may partly be explained by global warming, with an increase of 0.49°C annual temperature as well as changes in duration and length of the rainy season. Unusual rain including early or late rain in and beyond the monsoon season likely contributed to extending the length of the dengue transmission season in Bangladesh. The monthly mean temperature and monthly total rainfall of the first-lagged month and second-lagged months showed a greater influence on the monthly incidence of DENV infection in Bangladesh. The mean monthly growth factor remained significantly above one during April-July, which coincided with the hot and rainy season of the country indicating an earlier vector control would benefit the country. The ARIMA model forecasted a continuously increasing trend of DENV infection for the next decade in Bangladesh. We recommend an integrated and holistic vector management plan while engaging the local communities in the elimination of mosquito larval habitats and increasing surveillance for detecting active dengue cases. Proactive surveillance, vector control, and vaccine rollout remain essential public health interventions. In the context of climate change, urbanization, trade, and the movement of infected people, there is a need to operationalize the One Health approach to address dengue fever and other vector-borne diseases in Bangladesh and beyond.

**Acknowledgments:**

We are grateful to the Ministry of Health and Family Welfare of Bangladesh for publicly sharing the dengue cases and deaths data. We acknowledge Bangladesh Meteorological Department for sharing the meteorological data. NH, and AZ, are part of the PANDORA-ID-NET Consortium (EDCTP 373 Reg/Grant RIA2016E-1609) funded by the European and Developing Countries Clinical Trials Partnership (EDCTP2) programme. NH is a member of the International Development Research Centre, Canada’s grant on West African One Health Actions for understanding, preventing, and mitigating outbreaks (109810-001). AZ is a National Institutes of Health Research senior investigator, and a Mahathir Science Award and Pascoal Mocumbi Award laureate.

**Author contribution statement:** NH ideated the study and all authors helped develop the study outline and protocol. MNH and IK collected the data. NH, MNH, MA and AZ analyzed the data. NH, IK and MNH prepared the first draft manuscript and all authors contributed to several drafts and finalization of the manuscript. All authors approved the final draft and submission of the manuscript.

**Financial Support:** There was no funding for this research.

**Conflict of interest:** The authors declare that they have no conflict of interest.

**Ethics statement:** This study does not include individual-level data and thus does not require ethical approval. We used publicly available data on Dengue cases and deaths.

**Data availability statement:** All the dengue data presented in this manuscript are publicly available on Bangladesh’s Ministry of Health and Family Welfare’s Directorate General of Health Services website (<https://dghs.gov.bd/> ). The meteorological data were purchased from Bangladesh Meteorological Department and are restricted to use for research purposes only and anyone interested in these data can request Bangladesh Meteorological Department (<https://live3.bmd.gov.bd/> ).

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**Tables and Figure Legends:**

**Tables:**

**Table 1: Comparison of dengue cases, deaths, and weather parameters between the first (2000-20210) and the recent decade (2011-2022) in Bangladesh**

**Table 2: The Mann-Kendell trend test for reported dengue cases in Bangladesh, 2000-2022**

**Table 3: The incidence risk ratio (IRR) of monthly average temperature and total rainfall for monthly incidence of dengue cases in Bangladesh using time-series count Generalized Linear Model for the period 2000-2022.**

**Figures:**

**Fig 1:** Top: Number of dengue cases and deaths over the period 2000-2022, Bangladesh. Bottom: Number of monthly dengue cases and deaths recorded in Bangladesh.

**Fig 2:** The boxplot compares monthly rainfall in Dhaka city, Bangladesh between two decades (2000-2010 vs 2011-2022). The bottom and top of the box indicate the first and third quantiles, the band inside the box is the median. The dots outside the box are individual outliers. Most of the months in the second decade had outlier rainfall whereas in the first decade, only the cooler months (Nov-Jan) had some extreme rainfall.

**Fig 3: Top:** Mean monthly growth factor for the period of 2000-2022. **Bottom:** The Monthly growth factor for the individual year 2000-2022. The horizontal line indicates monthly growth factor 1 (the same number of dengue cases in two subsequent months).

**Fig 4:** The observed and forecasted number of dengue cases in Bangladesh using the autoregressive moving average (ARIMA) model including a 95% confidence interval.