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**Title:** **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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**Tables**: 3

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**Abstract: (Target: 274 words -max 300 words)**

**Background:** Dengue, caused by the mosquit (*Aedes spp*) -borne dengue virus (DENV) is endemic in over 100 countries worldwide. The aim of this study were to study trends, mortality, seasonality, and impact of climatic conditions 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. Comparisons between the first and second decades (2000-2011 vs 2012-2022) were made. Mann-Kendall and Sen’s slop tests were used for trends and variations and fitted a time series Poisson regression model to identify the impact of meteorological factors on the incidence of dengue cases. 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 792 deaths (Case fatality ratio [CFR] =0.32%). The annual number of dengue cases increased by eight-fold during the second decade, 2216 cases during 2000-2011 vs. 18,321 , 2012-2022, with a steepThe annual CFR also doubled. The mean monthly cases reached a peak in August with the monthly growth factor remaining above one significantly during April-July, which coincides with the hot and rainy season of the country. Monthly mean temperature (Incidence risk ratio [IRR]: 1.26), first-lagged rainfall (IRR: 1.08), and second-lagged rainfall (IRR: 1.17) were found to be significantly (P=??) associated with monthly dengue incidence in Bangladesh.

**Conclusions:** Over two decades, Bangladesh has experienced an increasing burden of dengue cases with regular intermittent outbreaks. The increased local temperature and unusual rainfall might have contributed to this increased incidence of dengue cases in Bangladesh. Vector control and vaccine rollout remain essential public health interventions

**Introduction:**

Dengue, caused by the arthropod- (*Aedes spp*) borne dengue virus (DENV) is endemic in over 100 countries and the number of cases globally being reported to the WHO continue to increase every year (WHO, 2023). Dengue fever is caused by four distinct serotypes of the dengue virus (DENV:1-4) of the Flaviviridae family (WHO 2009). DENV is transmitted to humans primarily by two species of Aedes mosquito: *Ae. aegypti* and *Ae. albopictus* (WHO 2009, CDC 2019). Whilst most human DENV infections (>80%) are self-limiting presenting with subclinical or mild clinical manifestations (WHO-Bangladesh 2022), 20% of DENV infections may result in severe dengue with significant morbidity (Teo et al. 2023). An estimated 390 million dengue infections per year globally including 96 million clinical cases are reported to the WHO (Murray et al. 2013, WHO 2023). Currently, South and Southeast Asia is considered to be the hotspot of dengue infection with more than 50% of cases recorded in the regions (WHO South-East Asia 2023).

Since dengue is transmitted through bites of the mosquito *Aedes spp*, climate change including changes in precipitation, temperature, and humidity, as well as rapid unplanned urbanization, were identified as strong predictors of an ecological imbalance that has led to an increase in dengue cases in Bangladesh (Mutsuddy et al. 2019). This suggests that the dengue transmission season could eventually extend year-round, with a higher chance of outbreaks occurring at any time. In this study, we aim to i) compare the annual and monthly cases in the first [2000-2010] and recent decade [2011-2022], ii) identify the trend and seasonality of dengue cases, and iii) quantify the impact of climatic factors for the monthly incidence of dengue cases in the country. 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.

**Methods:**

**Data sources:**

The data on the number of reported dengue‐infected people have been extracted 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, which was discussed in our earlier article (Ahsan et al. 2021). We collected three-hourly temperature and daily rainfall data from Bangladesh Meteorological Department (BMD) over the period 2000–2022 (BMD 2023) for the meteorological station located in Mirpur, Dhaka.

**Variables**

The monthly number of dengue cases was used as the main outcome variable. Two climatic variables- temperature and rainfall are used as the covariates for the regression analysis. In addition, two lagged variables rainfall in lag 1 and lag 2 have also been used as the predictors for the analysis to capture the actual impact of those meteorological elements. We also used monthly mortality data for comparison between two decades.

**Statistical analysis**

We analyzed the monthly dengue incidence and meteorological data for the period of 2000-2022. In the first stage, descriptive analysis is conducted to determine the characteristics of confirmed dengue cases and deaths with mean, and standard deviation in each year and each month for the entire period. Then, we compared dengue cases, deaths, and weather parameters in two decades (2000-2010 and 2011-2022) using paired sample t-test. Next, we calculated the monthly growth factor (GF) of dengue cases by dividing the number of dengue cases reported in a given 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 is skewed; therefore, we used the first natural log transformation before the data was further examined. However, we have also performed a reverse transformation of the log (GF) values by exponentiating values to convert them to the original scale for ease of interpretation(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). To select the appropriate autoregressive and moving average orders, the autocorrelation function (ACF) and partial autocorrelation function (PACF) are examined. Additionally, the differencing parameter, represented by "d," indicates the number of times the time series is differenced 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 (Haider, Hasan, Guitian, et al. 2023). 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. We also performed the Sen's slope test to assess variations in annual dengue cases and deaths.

We, then used a time series count generalized linear model (GLM), more specifically, a time-series Poisson regression model to determine whether the climatic factors are associated with the dengue cases over time (Sumi et al. 2021). The non-normality, heteroscedasticity, and non-linearity that characterize count data can be fitted easily using GLMs. The time-series observations may possess autocorrelation and they might be nonnegative integers, and thus GLM is useful in overcoming both issues [20, 21, 22]. 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 with a higher multicollinear relationship, we have arrived at average temperature, rainfall (in lag 1), and rainfall (in lag 2) as the final set of predictors for the 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, Bangladesh reported a total of 244,246 dengue cases with 792 fatal outcomes (case-fatality ratio: 0.32%). The mean annual number of dengue cases detected in Bangladesh was 10,619 (standard deviation [SD]=23,971). The highest number of annual cases was reported in 2019 with 101,354 and the highest number of deaths was recorded in 2022 with 281 deaths, which is 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 69% (n=550) deaths recorded during this time. Out of the 23 years, there were no deaths recorded in 16 years including the years between 2007 and 2018 **(Fig 1)**.

Between 2000 to 2010, the mean annual number of dengue cases was 2,216 (±2,123) which has increased over eight times compared to the following decade (2011-2022) at 18,321 (±31,778) **(Table 1)**. Between these two periods, the mean number of annual deaths due to dengue infection has increased by 2.2 times (21.18 cases vs 46.58 cases) **(Table 1)**. The highest average number of cases was recorded in August (3407 cases) and the lowest was in February (7.3 cases) **(Fig 1)**.

The average annual temperature was 26.35 °C (SD=3.72) during the first decade (2000-2010) and 26.84 °C (SD=3.76) during the recent decade (2011-2022) (**Table 1**). The increase of 0.4 ° C temperature is equivalent to 3504 degree-hour/year of heat (365 days X 24 hours X 0.4 ° C). The annual rainfall had decreased by 314 mm between two decades (2078.66 mm vs. 1764.50 mm) (**Table 1**), however during the non-monsoon period, the rainfall has decreased only 6 mm.

Compared to the first decade (2000-2010), an unusually higher amount of rain has been observed in the second decade with most of the months recording extreme rainfall in some years (**Fig 2**).

The overall mean GF from month to 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 years, 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 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 results suggest that dengue cases would rise by 26% for 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: 1.07-1.09]), and in the second lagged month increase the cases by 17% [IRR=1. 17 (95% CI: 1. 16 -1.18)] **(Table 3)**.

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

**Discussion:**

Dengue is currently a worrying and important public health challenge for Bangladesh. Our study found that the number of cases has increased eight times and deaths have doubled between the first and second decade of this century in Bangladesh. Between these decades, the annual temperature increased by 0.4 °C, and annual rainfall decreased by 314 mm. Although the amount of annual rainfall had decreased, the pattern of rainfall has changed significantly with unusually early or late rainfall outside the typical monsoon season in Bangladesh (July-October) (Haider et al. 2014). The monthly growth factor remains above one significantly for four months (April to July) which overlaps the hot and humid period of the year.

The first dengue outbreak in Bangladesh was reported in 1964 (formerly, East Pakistan), and the term "Dacca fever" was coined. Thereafter a lengthy period followed with no reports of dengue outbreak in the country. Subsequently, Bangladesh was reported an outbreak in 2000, and since then, dengue has become endemic in the country, posing a significant health challenge (Sharmin et al. 2015). However, the reported number seems to be only a fraction of the total infected cases (Ahsan et al. 2021, Haider, Hasan, Khalil, et al. 2023). The country has witnessed a significant increase in dengue incidence in recent years, with an estimated 40 million people being infected nationally and 2.4 million annual infections (Salje et al. 2019a). The largest dengue outbreak in Bangladesh occurred in 2019, with over 101,000 cases and 164 deaths reported (Ahsan et al. 2021). In 2020, the number of cases dramatically decreased to 1,405 with only three confirmed deaths possibly a consequence of lockdown-related measures during the first year of the COVID-19 pandemic (Ahsan et al. 2021, Haider, Hasan, Khalil, et al. 2023). In 2021, there was a sharp increase in dengue cases again, with over 28,000 cases and 105 reported deaths (Hsan et al. 2019, Kayesh et al. 2023). In 2022, Bangladesh reported the highest number of dengue-related deaths (n=281) in the country (DGHS 2023). The 2022 outbreak is characterized by a late onset with the highest ever reported number of deaths, partly attributed to the occurrence of a new serotype (DENV-4) in the country (Haider, Hasan, Khalil, et al. 2023).

Over the past few years, the number of dengue cases has been steadily increasing with significant variations in seasonal and regional patterns. Analysis of data from 2000 to 2017 revealed that almost half of the dengue cases occurred during the monsoon season (May-August) and the post-monsoon season (September-December) (Mutsuddy et al. 2019). However, a shift in seasonal patterns has been observed since 2014, with dengue cases being reported during the pre-monsoon season as well (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).

Temperature plays a critical role in the transmission of VBDs as the extrinsic incubation period of the virus, the biting and survival rate of the mosquitoes are highly dependent on environmental temperature(Haider 2018). The increase of 0.4 °C temperature adds ~3500-degree-hours equivalent heat per year in the country. This additional heat would favor mosquito-borne disease transmission. For DENV 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). Thus, the additional 0.4°C temperature will add the burden of more than 10 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 for every 1 °C increase in temperature dengue cases increase by 61% in Australia, 12-22% in Cambodia, 5% in Vietnam, and 2.6% in Mexico (Soneja et al. 2021).

Rainfall facilitates mosquito breeding and plays an important role in mosquito-borne disease transmission. Although we found a 15% reduction in annual rainfall in the recent decade compared to the earlier decade, we found an increase in unusually high rainfall in pre-and-post monsoon season. Our model shows that both the first and the second lagged month’s rainfall increase monthly cases by 8% and 17%, respectively). These findings are consistent with an earlier study in Bangladesh that showed that peak dengue cases occurred two months after the peak rainfall (Salje et al. 2016). Similar findings were reported in Vietnam with the 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 the mosquitoes(Siraj et al. 2017). To accomplish a generation interval the virus and mosquito undergo several phases including intrinsic incubation period in humans, human-mosquito transmission (first bite), extrinsic incubation period in mosquitoes, blood meal digestion period, 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).

Two large dengue outbreaks occurred in Bangladesh in the year 2019 and 2022 both characterized by unusual weather patterns and the occurrence of two different 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, and thus prolongation of vector transmission season along with the introduction of a new serotype, DENV-4 in the country (Haider, Hasan, Khalil, 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 is already infected with one of the serotypes of DENV with more than 80% of people living in Dhaka having antibodies against DENV (Salje et al. 2016). Thus, any subsequent infections raise the risk of developing severe dengue through antibody-dependent enhancement (ADE) (Teo et al. 2023). The deaths of many people in the year 2022 when the new serotype DENV-4 was introduced were probably associated with secondary dengue infection.

Bangladesh’s dengue season is characterized by hot and wet periods running between June to August. This is the period with the highest amount of rainfall in the country facilitating Aedes mosquito breeding in the country (Haider, Hasan, Khalil, et al. 2023). The monthly mean growth factor above 1 for April – June for 23 years indicates that for dengue cases for each subsequent month, the cases will surpass the number of cases of the current month as the growth factor is more than 1. However, the highest number of cases is reported in the month of August, one of the warm and humid months in the country [25].

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). We found an increasing trend in Bangladesh's reported number of dengue cases. This increasing trend was much stiffer after the serotype DENV-3 was introduced in the country in 2018 (Ahsan et al. 2021). This increased trend is possibly linked with climate change in the region attributed to increased temperature and unusual rainfall, 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 dengue infection is high, although precise estimates are not available, some studies show more than 1% and reaching up to 4% (Liu et al. 2020). Bangladesh’s overall CFR of dengue infection (0.32%) seems slightly higher considering the overall CFR reported in other South and Southeast Asian countries (WHO South-East Asia 2023). However, more than 69% of dengue-related deaths in Bangladesh were recorded after the introduction of the serotype DENV-3 in 2019. Thus, secondary infection is likely contributing to higher dengue-related deaths in Bangladesh. In addition, the CFR of the dengue virus infection might have been affected by a lack of active surveillance and missing the mild and asymptomatic cases, and not recording the cases outside the public hospital and few selected private hospitals in Bangladesh or weaker health care system in the country(Ahsan et al. 2021). In some years, the CFR was high. for example, in the year 2003, the CFR was 2.1 (total cases 486), in the year 2000, 1.68 (total cases 5,551), and in 2022, 0.45 (total cases 62,382).

Controlling vector-borne diseases in tropical countries where temperatures, humidity, and rainfall remain favorable for breeding mosquitoes during most periods of the year is a difficult task(Haider, Hasan, Khalil, et al. 2023). Researchers raised concern over the development of insecticide resistance (Haider, Hasan, Khalil, et al. 2023), and the failure of developing a successful dengue vaccine(Wang et al. 2017). The prospect of *Wolbachia-*related intervention is bright but still far from applying on a national scale considering the expenses and technicalities associated with this. 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 breeding sites and increasing surveillance for detecting active cases are key in controlling dengue virus infection. Continuous active dengue surveillance will enable early detection of cases and outbreaks by monitoring cases and trends. 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 breeding habitats and increasing surveillance for detecting active cases should prioritize in controlling dengue virus infection in Bangladesh. Policymakers need to design an *Aedes spp*-borne disease management plan by considering a range of diseases that Aedes mosquito can transmit including Chikungunya, yellow fever, Zika virus, West Nile, Japanese Encephalitis, Eastern Equine Encephalitis, Ross River, Rift Valley fever, and the LaCrosse virus (Haider, Hasan, Khalil, et al. 2023).

Our data should be viewed in lieu of several weaknesses of our study. We relied on the reported number of cases from the Ministry of Health and Family Welfare. These numbers seem to be an underestimation of actual cases. A modeling study based on the national seroprevalence of DENV antibodies predicted an annual infection of 2.4 million cases with 40 million cases nationwide (Salje et al. 2019b). However, dengue infection is underestimated globally as it is difficult to diagnose asymptomatic or mild cases that never reach healthcare settings. Although mild cases are missed more frequently, the severe 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, that is, our estimation, for example, estimated the higher CFR rather than lower possible estimates.

**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 is partly explained by the influence of global warming with an increase of 0.4°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 total rainfall of the first-lagged month and second-lagged rainfall showed a greater influence on monthly dengue incidence in Bangladesh. Our model estimated that for additional 1°C monthly temperature dengue cases will increase by 26%. The mean monthly growth factor remains above one significantly during April-July, which coincides with the hot and rainy season of the country indicating an earlier vector control would benefit the country. The ARIMA model forecasts 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 regular destruction of mosquito breeding sites and increasing surveillance for detecting active DENV-infected cases.

Proactive surveillance, vector control and vaccine rollout remain essential public health interventions.

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**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.

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

**Ethics statement:** This study does not include any individual-level data and thus does not require any ethical approval.

**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/> ).

**LEGENDS TO TABLES AND FIGURES:**

**LEGENDS TO 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 of dengue cases in Bangladesh

**Table 3**: The incidence risk ratio (IRR) of average temperature and rainfall to Dengue cases in Bangladesh using time-series count Generalized Linear Model.

**LEGENDS TO 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. 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 dotted horizontal line indicates monthly growth factor 1 (same number of cases in two subsequent months).

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

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

|  |  |  |  |
| --- | --- | --- | --- |
|  | First decade (2000-2010) | Recent decade (2011-2022) | p-value |
| Mean annual dengue cases (SD) | 2216.64 (±2123.62) | 18321.92 (±31,778.90) | 0.219 |
| Mean annual dengue deaths (SD) | 21.18 (±30.69) | 46.58 (±90.90) | 0.853 |
| Mean temperature °C (SD) | 26.35(±0.49) | 26.84 (±0.37) | <0.001 |
| Mean annual rainfall (SD) | 2078.66 (±459.68) [mm] | 1764.50 (±448.32) [mm] | 0.188 |

**Table 2: The Mann-Kendell trend test of dengue cases in Bangladesh**

|  |  |  |
| --- | --- | --- |
| **Test** |  | |
| ***Mann-Kendell trend analysis*** | **Tau** | **p-value** |
|  | 0.26 | 0.139 |
| *Sen’s Slop test* |  |  |
|  | Sen’s Slope | 95% Confidence Interval |
|  | 171.67 | -46 to 687 |

**Table 3: The incidence risk ratio (IRR) of average temperature and rainfall to Dengue cases in Bangladesh using time-series count Generalized Linear Model.**

|  |  |  |
| --- | --- | --- |
|  | IRR (95% CI) | P-value |
| Average temperature | 1.26 (1.258 – 1.265) | <0.001 |
| Rainfall (lag 1) in centimeter | 1.08 (1.079 – 1.086) | <0.001 |
| Rainfall (lag 2) in centimeter | 1.17 (1.168 – 1.175)) | <0.001 |

**Fig 1**



**Fig 2:**

****

**Fig 3:**



**Fig 4:**

