PLOS ONE

Climatic Risk Factors for the Transmission of Dengue Fever: Bangladesh Perspective

--Manuscript Draft--

Manuscript Number:	PONE-D-23-15182R1
Article Type:	Research Article
Full Title:	Climatic Risk Factors for the Transmission of Dengue Fever: Bangladesh Perspective
Short Title:	Climatic Risk Factors for the Transmission of Dengue Fever
Corresponding Author:	Md Rezaul Karim Jahangirnagar University Savar, Select an option… BANGLADESH
Keywords:	Bayesian Inferences; Markov chain Monte Carlo; Gibbs sampling; Dengue; Bangladesh
Abstract:	Dengue fever has become a major global public health concern. A significant global public health risk is dengue disease. Predicting how climatic factors will affect the spread of vector-borne diseases is difficult. However, the link is non-linear, geographically localized, and involves considerable lag periods between predictors and disease outbreaks. This disease spreads swiftly in Bangladesh due to its dense population and complex health policy setting. It is crucial to investigate the impact of climatic risk factors on Dengue transmission because it is an infectious disease spread by mosquitoes. In anticipating the occurrence or extent of each dengue outbreak, the methodology integrates confirmed Dengue cases and seasonal variables such as precipitation, temperature, humidity, wind speed, and lag duration of up to two years. The main objective is to examine how climatic risk variables affect dengue epidemics using Bayesian inference. Bayesian inference is drawn using MCMC with Gibbs sampling, which is carried out in the WinBUGS software. According to the study, less precipitation reduces infected cases and fatalities from Dengue. Furthermore, the spread of Dengue has diminished due to high temperatures, which have also affected the virus's ability to survive and spread.
Order of Authors:	Md Rezaul Karim
	Nazmin Akter, MS
Response to Reviewers:	Responses to all reviewers of "Climatic Risk Factors for the Transmission of Dengue Fever: Bangladesh Perspective" (Manuscript PONE-D-23-15182) We would like to thank the Editor-in-Chief and two anonymous reviewers for their detailed reading and valuable comments on the original version of the manuscript. In this revision we addressed all the points raised in the reports. A point-to-point reply to all comments raised in the review reports are provided below and on the enclosed separate pages. Review Comments to the Author Reviewer #1 Comment: Summary: The paper investigates "Climatic Risk Factors for the Transmission of Dengue Fever: Bangladesh Perspective". Despite being a significant public health concern for Bangladesh, this topic has already received considerable attention from numerous earlier and recently published studies. The purpose of the study has also been used in the past to explore comparable issues utilizing earlier data on Bangladesh. As a result, the paper's main original addition appears to be its application of this study to this study's "Bayesian Approach", and its conclusions/discussion largely—and not surprisingly—reflect those of previous research. The discussion failed to explain properly the objective of the study. The paper needs to be thoroughly proofread by a professional or expert. It is not

Powered by Editorial Manager® and ProduXion Manager® from Aries Systems Corporation

written to a high degree for academic writing, and there are several grammatical/spelling errors, which frequently make claims and arguments less clear. Additionally, the authors ought to eliminate any similarities from this work. Numerous times, the way that statistical results are interpreted is also ambiguous. The paper also neglected to mention or cite comparable but equally significant published studies from the nearest countries. The introduction fails to effectively justify the need for studying the issue, tables and results are not focused on the title, and objectives seem different in several parts of the manuscript. The tables and their interpretations are not similar, and the paper's findings by themselves are insufficient to support the discussion and conclusions.

Below are some comments with more information: Please include the line number in the main manuscript next time. However, to review purposes I inserted them. To track and resolve my comments please insert line number first.
Reply: Thanks for the query. We have now used the latex template of the journal for writing the revised version of our manuscript with additional corrections. The corrections are specified below subsections.
Abstract:
Please re-write the abstract. Authors take so many introductory sentences before the objective.
Page 1, Line 28: “According to the study, less precipitation reduces infected cases and fatalities from Dengue.” Need some data/statistics to validate it. As the reader will study this abstract first. Please explain, which information take you to support this statement. Also, for this, “Furthermore, the spread of Dengue has diminished due to high temperatures, which have also affected the virus’s ability to survive and spread.”
Reply: Thank you for this comment. The abstract is rewritten specifying the objectives and results. We have also added the outcome of the study which validates our study as well.
Introduction:
I am requesting to authors to check the serial of the citation in the whole manuscript. If possible, please use the citation manager.

Page 1, Lines 47-48: “In the middle of the epidemic, the Directorate General of Health in Bangladesh recorded 1026 confirmed cases in 2020, and 20,000 in 2021”. Reviewers seem that it is an old reference and is also confusing. Please update this information from a recently published manuscript: https://academic.oup.com/jme/advance-article/doi/10.1093/jme/tjad057/7172758
Page 1, Lines 50-51: “The Ministry of Health & Family Welfare of Bangladesh has reported 52,807 laboratory-confirmed dengue cases overall as of 20 November 2022, with 230 deaths associated with the disease”. Authors should update this information before submitting again.
Page 2, Lines 86-88: “Only a small amount of research has been executed so far on how weather influences the weight of ailment, appreciably dengue in South Asia.” Reviewers seem that the statement is not true. Some recent manuscripts in Bangladesh related to weather factors: https://academic.oup.com/jme/advance-article/doi/10.1093/jme/tjad057/7172758, https://www.mdpi.com/1660-4601/20/6/5152, as this is the middle of 2023. There are a lot of published papers similar to this topic. Please cite them before submitting them again.

Page 2, Lines 91-93: Statistically, it appears that most investigations utilized either very simple correlational techniques [12, 19, 23] or regression modeling [5, 37], or both.”. The author stated or try to explain that all of the cited references are from Bangladesh, because of the previous line. But reviewers seem all are from outside of Bangladesh. Either please change the previous line or change the citation from the stated references.

Page 2, Lines 90-101: Reviewers hope that this paragraph will provide more and only about other’s methods with findings and details about the Bayesian Regression Method and its pros and cons, as this study seems trying to focus more on the methodology (benefit) of this model.
Page 2, Lines 95-101: “Moreover, Bangladesh’s lack of preparedness, including weak public health infrastructure and ineffective vector-control programs, increases the impact of dengue virus importation, resulting in rising outbreaks. Anorexia, nausea, vomiting, pharyngitis, upper respiratory tract symptoms, relative bradycardia,

prostration, depression, hyperesthesia, lymphadenopathy, and rash are some of the symptoms and signs of dengue [13]. Other symptoms and signs include fever, backache, arthralgia, headache, generalized pain, eye pain, lacrimation, scleral injection, and rash. Since 2000, med- ical professionals in Bangladesh have clinically identified dengue following WHO guidelines." As symptoms are not our concerned variables, all these statements are not necessary for the introduction. Reviews and readers will hope for some literature review of findings related to climatic factors in this place. Page 2, Line 106: "Following are the research's main contributions" No need to explain it. Page 2, Lines 103-104 and Lines 114-116: "This study examines how key meteorological variables such as precipitation, heat, moisture, and wind speed may promote Dengue incidence in Bangladesh." And "In order to develop and provide a better knowledge of the complicated relationship between climate and health, this study aims to assess the impact of climatic risk variables on dengue incidence in Bangladesh." Reviewers seem to both sentences are trying to share the same statement, please keep only one.
Reply: Thank you for your reply. We appreciate your kind suggestions. All the mentioned information is now updated using the provided reference. Also the unnecessary lines are deducted from the manuscript.
Materials:
Page 3, Lines 125-127: "The weather variables of temperature (measured in ◦C), humidity (measured in %), precipitation (measured in mm), and wind speed (measured in km/h) were collected from Bangladesh Meteorological Department." The authors provided a link that does not take the reviewers to the BMD website. As per reviewers' knowledge, BMD data is not free to use. Please explain the real source and how you collect them. The authors also should explain how climatic factors from one station can represent the whole country. As dengue data was collected from the whole country.
Page 3-4: More details are needed about the dependent and independent variables. Authors should provide more details about the real/practical use of the models they used. More citations are needed in most methodological parts. Also, explain how time series data is appropriate in your models.
Reply: Thanks for your comment. The data source and website link are specified in our revised manuscript. As our daily data was collected from a free access website, where the maximum unit of representative data of Bangladesh was given, and the total daily dengue cases were also recorded by the Ministry of Health and Family Welfare, we believe that this information can represent the whole country. Moreover, Time series model is not used in our study but we may think about it in our next research.
Results:
Page 5, Line 13: "The fastest recorded speed occurred in May 2020." Please include the word "wind".

Page 5, Line 13-15: "These findings indicate that all climatic parameters contribute to a conducive environment, increasing mosquito breeding and dengue transmission rates which is also supported by". Place this statement in discussion. In addition, this statement is not correct and also not possible from your available results/findings. Please, re-write it or provide some evidence to support your statement.

Page 5, Line 37-39: "It is hypothesized that a skewed distribution would be more accurate in forecasting the values of this variable based on a comparison of the distributional shape of the number of Dengue cases.". Reviewers didn't notice the objective of forecasting, please mention in the objective if you want to try forecasting.

Page 6, Line 56-58: "To carries our Bayesian inference on the statistical problems using MCMC methods, we used the most popular Bayesian software. Three WinBUGS tools are required to obtain posterior samples: (a) the specification tool, (b) the sample monitor tool, and (c) the update tool.". Please replace this statement in the methods section.
Reply: Thank you for these comments. We have now replaced some sentence in methodology section with additional changes in results section.
Discussion:
Page 11, Lines 59-60: "Figure 5 shows that the posterior distribution for the parameters is well examined and that they appear to be regularly distributed." Reviewers seem that the statement you used first time here. I am concerned about the use of graphs in the discussion part. Please replace this graph in the result part and discuss the findings in the "discussion" part.

Powered by Editorial Manager® and ProduXion Manager® from Aries Systems Corporation

Page 11, Lines 65-66: “Low precipitation increases the propagation of dengue, according to empirical research.”. Need citations.

Page 11, Lines 65-66: “Dengue has been demonstrated to spread less frequently in high temperatures, which reduces the virus’s ability to survive and spread.”. Please refer to this finding from your result section.

Page 11, Lines 67-68: “Instead, freezing conditions give coronaviruses a secure haven that hastens their survival and spread.”. Please recheck this statement. Why coronaviruses are here?
Page 11, Lines 68-71: “It may be concluded that the climate has a substantial impact on the risk factors for virus transmission in Bangladesh. We came to the conclusion that the Bayesian tech- nique performed well and is easier to understand than traditional regression approaches in the literature on the basis of a variety of information criteria and the selection of influential elements.”. Please refer to this finding from your result section.

Page 11: No reference for fig. 6. Please replace this figure in the result part with a proper explanation.

The discussion part should be rewritten and should focus on the used variables from the study. Discussion should discuss with Authors’ findings with others. As this is a theory/methodological-based study, you should discuss other findings with various methodological aspects. Authors should explain the significance and the difference of these methods with others. This part should support the result but there is some discrepancy between the result and the discussion. Please cited others in the discussion.
Reply: Thank you for your suggestions. We have interchanged the position of graphs in our final manuscript where Figure 5 is kept in result section and Figure 6 is replaced in Appendix section. “Low precipitation increase the propagation of dengue, according to empirical research”, In this line we have now added 2 latest citations. Some sentences are now moderated in our manuscript, and some spellings are also corrected.
Conclusion:
Page 12, Lines 83-84: “Despite the fact that the majority of recent studies have concentrated on a correlation approach between meteorological parameters and pandemic data.” Is Dengue Pandemic in Bangladesh? The authors should check that.
Page 12, Lines 87-88: “This study used a number of statistical techniques, and the model revealed a substantial causal link between climatic variables and the spread of dengue.” Is Dengue Pandemic in Bangladesh? The authors should provide valid evidence to state this.
The conclusion needs to be more specific and highlight key findings. This should support the result. Suggested providing less discussion in the conclusion. Reviewers didn’t find so much to conclude the whole results and discussion in the “conclusion” part. Much information is redundant in the discussion and conclusion.
Reply: Thanks for your comment. The conclusion part is now more specified according to the reviewer.

Reviewer #2

This manuscript addressed the climatic risk factors of dengue transmission in Bangladesh country based on the data over a 2-year period. The authors examined how the climatic variables affect dengue epidemics in the study area by adopting Bayesian inference through MCMC with Gibbs sampling. However, in my opinion, the paper has some shortcomings and the manuscript needs a few points of consideration.
Comment#1
As this research work aimed at providing support to decision making, I believe the duration of the study period and the data used in the present study is not adequate to serve the purpose.
Reply: Thank you for the comment. We used the most recent data available when we did this research. We believe this study still has enough merits to serve the purpose.
Comment#2
Introduction part is very lengthy and not well organized. Suggest rewriting to maintain continuity.
Reply: Thanks for your comment. The Introduction part is revised to maintain its

continuity.
Comment#3
Introduction: Since the study is oriented in Bangladesh perspective, suggest including a paragraph citing the climate scenario, and dengue vector complexity in Bangladesh.
Reply: Thanks for your comment. In our final manuscript more citations are now added.

Comment#4
The authors did not provide recent literature and mentioned only about the tradition correlation and regression models. However, there are many other models like Bayesian geo statistical models which studied the role of climate variability on dengue transmission. Please mention the recent models and explain the superiority of the present Bayesian Poisson regression models when compared.
Reply: Thanks for your comment. One Resent literature about Bayesian Poisson model is mentioned in introduction part with appropriate citation.
Comment#5
The authors mentioned that the climatic variables influence dengue transmission, however, they have not established how different climatic factors affect the vector and virus behavioral traits.
Reply: Thanks for your comment. In this study, we showed the relationship of climatic risk variables with dengue epidemics using Bayesian inference. How different climatic factors affect the vector and virus behavioral traits, that was not our research purpose.
Comment#6
The methods and algorithms in the methods and material section are explained comprehensively and contain unwanted information. Simplify this section.
Reply: Thanks for your comment. The method section is now more simplified and some sentence are also deducted.
Comment#7
Results: table-1: mention the units of variables and check the spelling of Skewness.
Reply: Thanks for your suggestions. The unit of the variable are added in table 1 and the spelling is corrected.
Comment#8
Figure-2: The title of the figure is wrongly labelled. Plot a & b are labelled with the same title.
Reply: Thanks for your comment. The label of Plot a & b are titled correctly in final manuscript.
Comment#9
The estimated Bayesian Poisson model equation is refereed in terms of log cases, however, the cases were not log-transformed in figure 1& 2.
Reply: Thanks for your comment. The estimated Model is written according to Bayesian Poisson regression model equation 2. Figure 1 and 2 are plotted for descriptive data representation.

Comment#10
The MCMC iteration was specified as 30,000 in the update tool and beg was set between 10,000 – 30,000 in the sample monitor tool. What id beg here? And the description of why this value was chosen is non-informative. Was sensitivity analysis performed for the threshold limits? This information would be useful for future decision making in future research.
Reply: Thanks for your comment. Id “beg” (to the Sample Monitor Tool) instructs WinBUGS to discard the first 10000 simulations to get past any initial transients. And No sensitivity analysis was performed here for the threshold limits.
Comment#11
Why the effective sample size for posterior distribution and diagnostic test was different. Please explain.
Reply: Thanks for your comment. The effective sample size for posterior distribution and diagnostic test results are tabulated using WINBUGS, the size is found different. These happened for large number of iteration, as we assume it from 10000 to 30000.
Comment#12
The authors did not use cross validation to construct the model during the development phase. To improve the model's performance, it is recommended to use a cross validation method.
Reply: Thanks for your suggestion. In our research, we only used Bayesian Poisson regression model to assess the relationship between Dengue outbreak and Climatic factors. Cross Validation method will be applied to improve the model's performance in

Powered by Editorial Manager® and ProduXion Manager® from Aries Systems Corporation

	our next work. Comment#13 Conclusion part is very prolonged, simply removing the unnecessary information. Reply: Thanks for your comment. The conclusion part is made simple than earlier in revised version. Comment#14 In the discussion part it is mentioned as “Instead, freezing conditions give coronaviruses a secure haven that hastens their survival and spread.” I feel it is irrelevantly mentioned about the coronaviruses. Please check the context and modify the sentence. Reply: Thanks for your comment. The correction of this line is added in our revised manuscript. Comment#15 Provide a paragraph summarizing the limitations of the study. Reply: Thanks for your suggestion. The limitation of the study paragraph is added just before the conclusions.
Additional Information:	
Question	**Response**
Financial Disclosure Enter a financial disclosure statement that describes the sources of funding for the work included in this submission. Review the submission guidelines for detailed requirements. View published research articles from *PLOS ONE* for specific examples. This statement is required for submission and **will appear in the published article** if the submission is accepted. Please make sure it is accurate. **Unfunded studies** Enter: *The author(s) received no specific funding for this work.* **Funded studies** Enter a statement with the following details: • Initials of the authors who received each award • Grant numbers awarded to each author • The full name of each funder • URL of each funder website • Did the sponsors or funders play any role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript? • **NO** - Include this sentence at the end of your statement: *The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.* • **YES** - Specify the role(s) played.	It is important to mention that we received funds from Jahangirnagar University to conduct this research. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

* typeset	
Competing Interests Use the instructions below to enter a competing interest statement for this submission. On behalf of all authors, disclose any competing interests that could be perceived to bias this work—acknowledging all financial support and any other relevant financial or non-financial competing interests. This statement is required for submission and **will appear in the published article** if the submission is accepted. Please make sure it is accurate and that any funding sources listed in your Funding Information later in the submission form are also declared in your Financial Disclosure statement. View published research articles from *PLOS ONE* for specific examples. **NO authors have competing interests** Enter: *The authors have declared that no competing interests exist.* **Authors with competing interests** Enter competing interest details beginning with this statement: *I have read the journal's policy and the authors of this manuscript have the following competing interests: [insert competing interests here]* * typeset	The authors have declared that no competing interests exist.
Ethics Statement Enter an ethics statement for this submission. This statement is required if the study involved:	Field Research

• Human participants • Human specimens or tissue • Vertebrate animals or cephalopods • Vertebrate embryos or tissues • Field research Write "N/A" if the submission does not require an ethics statement. General guidance is provided below. Consult the submission guidelines for detailed instructions. **Make sure that all information entered here is included in the Methods section of the manuscript.**	

Powered by Editorial Manager® and ProduXion Manager® from Aries Systems Corporation

Format for specific study types **Human Subject Research (involving human participants and/or tissue)** • Give the name of the institutional review board or ethics committee that approved the study • Include the approval number and/or a statement indicating approval of this research • Indicate the form of consent obtained (written/oral) or the reason that consent was not obtained (e.g. the data were analyzed anonymously) **Animal Research (involving vertebrate animals, embryos or tissues)** • Provide the name of the Institutional Animal Care and Use Committee (IACUC) or other relevant ethics board that reviewed the study protocol, and indicate whether they approved this research or granted a formal waiver of ethical approval • Include an approval number if one was obtained • If the study involved *non-human primates*, add *additional details* about animal welfare and steps taken to ameliorate suffering • If anesthesia, euthanasia, or any kind of animal sacrifice is part of the study, include briefly which substances and/or methods were applied **Field Research** Include the following details if this study involves the collection of plant, animal, or other materials from a natural setting: • Field permit number • Name of the institution or relevant body that granted permission	
Data Availability Authors are required to make all data underlying the findings described fully available, without restriction, and from the time of publication. PLOS allows rare exceptions to address legal and ethical concerns. See the PLOS Data Policy and FAQ for detailed information.	Yes - all data are fully available without restriction

A Data Availability Statement describing where the data can be found is required at submission. Your answers to this question constitute the Data Availability Statement and **will be published in the article**, if accepted. **Important:** Stating 'data available on request from the author' is not sufficient. If your data are only available upon request, select 'No' for the first question and explain your exceptional situation in the text box. Do the authors confirm that all data underlying the findings described in their manuscript are fully available without restriction?	
Describe where the data may be found in full sentences. If you are copying our sample text, replace any instances of XXX with the appropriate details. • If the data are **held or will be held in a public repository**, include URLs, accession numbers or DOIs. If this information will only be available after acceptance, indicate this by ticking the box below. For example: *All XXX files are available from the XXX database (accession number(s) XXX, XXX.*). • If the data are all contained **within the manuscript and/or Supporting Information files**, enter the following: *All relevant data are within the manuscript and its Supporting Information files.* • If neither of these applies but you are able to provide **details of access elsewhere**, with or without limitations, please do so. For example: *Data cannot be shared publicly because of [XXX]. Data are available from the XXX Institutional Data Access / Ethics Committee (contact via XXX) for researchers who meet the criteria for access to confidential data.* *The data underlying the results presented in the study are available from (include the name of the third party*	All relevant data are within the manuscript and its Supporting Information files.

and contact information or URL). • This text is appropriate if the data are owned by a third party and authors do not have permission to share the data. * typeset	
Additional data availability information:	Tick here if the URLs/accession numbers/DOIs will be available only after acceptance of the manuscript for publication so that we can ensure their inclusion before publication.; Tick here if your circumstances are not covered by the questions above and you need the journal's help to make your data available.

Powered by Editorial Manager® and ProduXion Manager® from Aries Systems Corporation

Manuscript Click here to access/download;Manuscript;Manuscript.pdf

Climatic Risk Factors for the Transmission of Dengue Fever: Bangladesh Perspective

Md. Rezaul Karim[1], Nazmin Akter[1]

1 Department of Statistics, Jahangirnagar University, Bangladesh.

*rezaul.juniv.edu; nazmin.swarna194@gmail.com

Abstract

Dengue fever has become a major global public health concern. A significant global public health risk is dengue disease. Predicting how climatic factors will affect the spread of vector-borne diseases is difficult. However, the link is non-linear, geographically localized, and involves considerable lag periods between predictors and disease outbreaks. This disease spreads swiftly in Bangladesh due to its dense population and complex health policy setting. It is crucial to investigate the impact of climatic risk factors on Dengue transmission because it is an infectious disease spread by mosquitoes. In anticipating the occurrence or extent of each dengue outbreak, the methodology integrates confirmed Dengue cases and seasonal variables such as precipitation, temperature, humidity, wind speed, and lag duration of up to two years. The main objective is to examine how climatic risk variables affect dengue epidemics using Bayesian inference. Bayesian inference is drawn using MCMC with Gibbs sampling, which is carried out in the WinBUGS software. According to the study, less precipitation reduces infected cases and fatalities from Dengue. Furthermore, the spread of Dengue has diminished due to high temperatures, which have also affected the virus's ability to survive and spread.

Keywords:Bayesian Inferences, Markov Chain Monte Carlo, Gibbs sampling, Dengue, Bangladesh.

Introduction

The Dengue virus, one of the viral pathogens, predominantly affects tropical and subtropical areas where it produces classical Dengue fever (DF) and Dengue Hemorrhagic fever (DHF). Dengue fever is a mosquito-borne disorder that affects millions of people each year [1, 2]. The *Aedes aegypti* mosquito transmits Dengue illnesses. The *Aedes* mosquito may transmit the dengue virus without the need for an intermediary animal vector. Often found in metropolitan areas, the *Aedes* mosquito maintains a man-mosquito-man interaction. Bangladesh is a country that suffers the most from dengue practically every year [3] and its tropical environment has made it an excellent place for the dengue virus to spread. Bangladesh witnessed occasional dengue virus transmission from 1964 to 1999, but The country is experiencing its worst dengue outbreak since 2000, with widespread dread of fatality as the illness spreads throughout the country, disproportionately impacting children, pregnant women, and the elderly [4–7] and mainly in the capital city of Dhaka. The country experienced its greatest epidemic in history in 2019, with over 100,000 reported illnesses and almost 120 deaths [8]. In the middle of the epidemic, the Directorate General of Health in

Bangladesh recorded 1026 confirmed cases in 2020, and 20,000 in 2021 [8]. We again spotlight the dengue outbreak in Bangladesh in 2022, thus far is the third most cases reported in a year since the first cases were reported in 2000. The Ministry of Health & Family Welfare of Bangladesh has reported 52,807 laboratory-confirmed dengue cases overall as of 20 November 2022, with 230 deaths associated with the disease [9].

Dengue fever is common in tropical and subtropical regions, but the epidemic in Bangladesh warrants additional investigation. What's inflicting this unusual boom in dengue cases? The concept that weather modifications make it easier for illnesses to unfold to new populations has substantially heightened humans' worry approximately the arrival and reemergence of infectious diseases [10]. Bangladesh's outbreak is being exacerbated by way of poor water, sanitation, and hygiene structures, in addition to a congested population, climatic trade, unplanned speedy urbanization, and building, poor vector manipulation strategies, and Bangladesh's faltering healthcare gadget all contribute to the extent and severity of dengue epidemics [11–15]. Additional causes might be drainage issues, stagnant water and rubbish anywhere, weak immune reputation, bodily weak spot, unplanned market, wetland occupation, the habit of gardening, polluted waterbody, [16] and so on. Climate change increases the opportunity for Dengue epidemics as it strengthens the hyperlink between the vector and the virus [17, 18]. The majority of research on this topic focuses on climate-related factors (rainfall or humidity). This tendency may be detected in quite early studies, such as Moore's [19], which showed that both the amount of rain and the persistence of rainfall were good predictors since when rainfall has continued to provide the most reliable early warning indicator [20]. Geographic location peak [20, 21] and trough weather events, such as highest and lowest temperatures [21], abnormal climatic occurrence, and running averages [22] have all been added to the list of variables used in the literature. Choudhury et al. evolved a Seasonal Autoregressive incorporated transferring average (SARIMA) model, especially for Dhaka, Bangladesh. While this look stated that it does now not take into consideration weather elements, it does remember seasonality, which axiomatically captures primary climatic characteristics [23]. Karim et al. evolved models with the use of simple linear regression and Pearson's correlation, utilizing a spread of environmental parameters including month-to-month rainfall, humidity, maximum, and lowest temperature, and determined that meteorological parameters may are expecting month-to-month dengue incidence with an excessive degree of accuracy [24]. However, the predictor variable glaringly deviated from the normal distribution. In some other studies, Kanchanapairoj, McNeil, and Thammapalo provided conflicting evidence that demonstrates the connection between dengue incidence and climatic situations is still up for debate [25]. Only a small amount of research has been executed so far on how weather influences the weight of ailment, appreciably dengue in South Asia.

The latest study, in addition to addressing the topic of climatic predictors of dengue in Bangladesh, employs a broader variety of statistical tactics. Statistically, it appears that most investigations utilized either very simple correlational techniques [24, 26, 27] or regression modeling [20, 28], or both. We employed the Bayesian Regression Method in this study. This generates a vast number of factors, including seasonal aspects, that allow researchers to investigate plausible links between scientifically quantifiable climate change and dengue transmission. Moreover, Bangladesh's lack of preparedness, including weak public health infrastructure and ineffective vector-control programs, increases the impact of dengue virus importation, resulting in rising outbreaks. Anorexia, nausea, vomiting, pharyngitis, upper respiratory tract symptoms, relative bradycardia, prostration, depression, hyperesthesia, lymphadenopathy, and rash are some of the symptoms and signs of dengue [16]. Other symptoms and signs include fever, backache, arthralgia, headache, generalized pain, eye pain, lacrimation, scleral

injection, and rash. Since 2000, medical professionals in Bangladesh have clinically identified dengue following WHO guidelines.

This study examines how key meteorological variables such as precipitation, heat, moisture, and wind speed may promote Dengue incidence in Bangladesh. Here, we present the findings of a study conducted across Bangladesh, using a Bayesian regression approach to estimate the prevalence of Dengue and pinpoint significant risk variables for infection. Following are the research's main contributions. Then, using the Gibbs sampling (MCMC) algorithm to estimate the posterior distribution, future observations will be predicted. First, we will summarize measures for the location and variability of Dengue cases with additional risk factors and investigate the non-linear relationship between Dengue case counts and climatic factors for the dataset. To structure this article, there are four more sections. In Section 2, the fundamental formulation of the Bayesian model and the design of the Gibbs sampling technique, including the data sources, are discussed. In Section 3, the distributions for modeling daily Dengue cases are described, and the method's application to a specific example of daily Dengue cases data is examined. Finally, Sections 4 and Section 5 give a general discussion and conclusion, respectively. In order to develop and provide a better knowledge of the complicated relationship between climate and health, this study aims to assess the impact of climatic risk variables on dengue incidence in Bangladesh. Health professionals who create efficient plans to enhance public health may find this material to be useful.

Materials and methods

Data Sources

The weather variables of temperature (measured in °C), humidity (measured in %), precipitation (measured in mm), and wind speed (measured in km/h) were collected from Bangladesh Meteorological Department. Data are available on the website `www.timeanddate.com/weather/bangladesh/dhaka/ext`. Daily dengue data were obtained from the Directorate General of Health Services (DGHS) of the Ministry of Health and Family Welfare [8].

Bayesian Poisson Regression

To represent discrete event counts that occur over predetermined intervals of time or space, the Poisson model can be employed. The Poisson model is especially useful when counts are right-skewed and cannot be reasonably approximated by a Normal model. Fitting a Bayesian Poisson regression model to the frequency of Dengue infected cases, say Y with density

$$Y_i|\lambda_i \sim \text{Poission}(\lambda_i)$$

where, $Y_i = 0, 1, 2, \ldots$ is the random variable and λ is the rate parameter, $\lambda > 0$.The mean and variance of the density are generally known to be equal to λ_i. As a result, the typical value of Y should approximately reflect its variability given the predictors X. The Poisson regression model is defined as ([29]):

$$E(Y = y/x) = \exp\left(\beta_0 + x_1\beta_1 + x_2\beta_2\right) \ldots x_p\beta_p) \tag{1}$$

where y is the response variable, x's are the independent variable, p is the number of independent variables and β's are regression parameters.

Likelihood Distribution

Assume that λ_i can be expressed as a linear combination of X predictors, we can write

$$\text{data:} \quad Y_i|\beta_0, \beta_1, \beta_2\beta_3, \beta_4 \sim \text{Poission}(\lambda_i) \quad \text{with} \quad \log(\lambda_i) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4. \tag{2}$$

where β represents the regression coefficients and X_i's are the covariates as X_i= precipitation, temperature, humidity, wind speed. The likelihood function $Pr(Y|X_i, \beta) = \text{Poisson}(\lambda_i)$. where, $Pr(\cdot|\cdot)$ denotes a conditional probability function. The five parameters $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$ is the intercept, precipitation, temperature, humidity and wind speed effect respectively.

Specifying the Priors Distribution

Assume the following prior distribution is applied to a parameter, where $\pi(.)$ represents a prior distribution.

$$\pi(\beta_0) = \text{uniform}(0, 1) \quad \text{and} \quad \pi(\beta_1).\pi(\beta_2).\pi(\beta_3).\pi(\beta_4) = \text{normal}(0, \sigma^2)$$

To build the Bayesian model, we must express our prior knowledge of regression coefficients$(\beta_0, \beta_1, \beta_2, \beta_3, \beta_4)$. Again, using Normal priors makes sense because each of these coefficients can take on any value along the real line. We'll also suppose that these priors—that is, our prior knowledge of the model coefficients—are independent. The complete Poisson regression model depiction of Y_i is as follows.

$$\begin{aligned} \text{prior:} \quad \beta_0 &\sim \text{U}(0, 1) \\ \beta_1 &\sim \text{N}(0, \tau_1) \\ \beta_2 &\sim \text{N}(0, \tau_2) \\ \beta_3 &\sim \text{N}(0, \tau_3) \\ \beta_4 &\sim \text{N}(0, \tau_4) \end{aligned}$$

where $\tau_1, \tau_2, \tau_3, \tau_4 \sim \exp(0.1)$ are precision of priors (i.e.precision= 1/variance). The posterior distribution of $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$ is determined by the likelihood function and prior distribution using the Bayes theorem.The likelihood and data-driven prior are multiplied to arrive at the posterior distribution. Consequently, we demonstrate the posterior distribution using the likelihood and prior distributions which are as follows:

$$P(\lambda/Y) = \exp[-\sum_{i=1}^{n} \log y_i! + n\bar{Y} \log \lambda - n\lambda] \times \frac{1}{\sqrt{2\pi\sigma^2}} \exp[\frac{x^2}{2\sigma^2}] \tag{3}$$

A prior is multiplied by a likelihood based on data to create the posterior distribution, which is then used as a prior in further modeling. Finally, these Bayesian probability distributions were employed for the data on Dengue cases in the Bayesian regression model.

Markov Chain Monte Carlo (MCMC) Method

The posterior inference result is increasingly difficult to assess and study the more variables we include in our model. The MCMC method is then utilized in this situation. The MCMC approach imitates the posterior in order to examine it. Inferences about the model and its parameters can then be made using the results. There are numerous MCMC approaches available. One of the most significant MCMC algorithms is the *Gibbs sampler*, which transformed Bayesian statistics and dramatically revived the Bayesian philosophy by offering solutions to real-world problems.

Gibbs Sampling

Using a combined probability distribution of two or more random variables, Gibbs sampling generates a series of samples as a form of probabilistic inference ([30]). In order to study the Gibbs distribution, the Gibbs sampler was first introduced in the context of image processing by [31]. The Gibbs sampler, on the other hand, didn't become well-known in the statistical community until [32] showed that it could deal with complex estimating concerns in a Bayesian fashion.

The observable data (Y) is the beginning condition for the Gibbs sampler. Gibbs sampling necessitates the usage of an unnamed vector of pertinent variables. Gibbs sampling seeks estimates for the parameters of interest (Y) to ascertain how well the observable data fits the model of interest and whether or not data independent of the observed data matches the model given by the observed data ([33]). The Gibbs sampler method does not compute the density before selecting random variables from a distribution. The Gibbs sampler needs very large sets (on the order of 15 or more sequences) for poorly preserved patterns to reach statistical significance ([33]). In order to avoid the considerably more challenging calculations, we can instead build a succession of simpler ones.

Basic Algorithm of Gibbs Sampling: Assuming a starting location $\beta^0 = (\beta_0^0, \beta_1^0, \beta_2^0, \ldots, \beta_d^0)^T$,The multivariate Gibbs sampler uses an iterative technique, as seen below. The sampling process performs the following d steps at iteration $(k+1)$:

(1). Sample β_0^{k+1} from $p(\beta_0|\beta_1^k, \beta_2^k, \ldots, \beta_{d-1}^k, \beta_d^k, \mathbf{y})$;

(2). Sample β_1^{k+1} from $p(\beta_1|\beta_0^{k+1}, \beta_2^k, \beta_3^k, \ldots, \beta_d^k, \mathbf{y})$;
... ...

(d). Sample β_d^{k+1} from $p(\beta_d|\beta_0^{k+1}, \beta_1^{k+1}, \ldots, \beta_{d-2}^{k+1}, \beta_{d-1}^{k+1}, \mathbf{y})$.

The conditional distributions $p(\beta_j|\beta_0^k, \beta_1^k, \beta_2^k, \ldots, \beta_{j-1}^k, \beta_{j+1}^k, \ldots, \beta_{d-1}^k, \beta_d^k, \mathbf{y})$ are reffered to as full conditional distributions, because β_j depends on all other parameters.

The open-source MCMC application WINBUGS makes it straightforward to implement the Gibbs sampling algorithm. It can handle models with both common and unusual parameters because it is flexible enough. It can therefore be used in a variety of contexts, such as with insurance claim data, and is easy adaptable to enable more distributions (see [34]).

Results

Exploratory Data Analysis

Table 1 and Figure **??** shows the daily mean rainfall, temperature, humidity, wind speed readings, and dengue incidence in Bangladesh, respectively. Dengue incidences in Bangladesh ranged from 0 to 1224 over a two-year period (1st January 2020 to 31st December 2021), with the peak incidence (1224 cases) occurring in December 2020. The daily mean precipitation ranged from 0 to 118 millimeters, with the maximum recorded measurement in April 2020. The daily mean temperature ranged from 15.10°C to 34.0 °C, with the maximum recorded temperature being in May 2020. The daily mean humidity ranged from 27% to 100%. The highest temperature ever recorded was in June 2021. The daily mean wind speed values ranged from 0.00 to 32.0 units. The fastest recorded speed occurred in May 2020. These findings indicate that all climatic parameters contribute to a conducive environment, increasing mosquito breeding and dengue transmission rates which is also supported by [21].

Table 1. Descriptive statistics of Number of Dengue-infected people, precipitation, temperature, humidity, and wind speed for January 01, 2022, to 31 December 2022.

Variables	Infected case	Precipitation	Temperature	Humidity	Wind speed
Mean (SD)	274.80 (287.51)	5.08 (12.26)	26.94(4.23)	73.67(15.06)	4.02 (4.32)
Skewnwss	1.69	4.11	-0.73	-0.64	2.10
25th Percentile	41.50	0.00	23.50	63.50	1.00
Median	232.0	0.00	28.40	76.50	2.50
75th Percentile	357.00	3.40	30.30	85.50	5.50
90th Percentile	607.00	16.00	31.30	91.00	8.50
99th Percentile	1209.00	59.10	32.65	97.35	19.50
Min	0.00	0.00	15.10	27.00	0.00
Max	1224.0	118.00	34.00	100.0	32.00

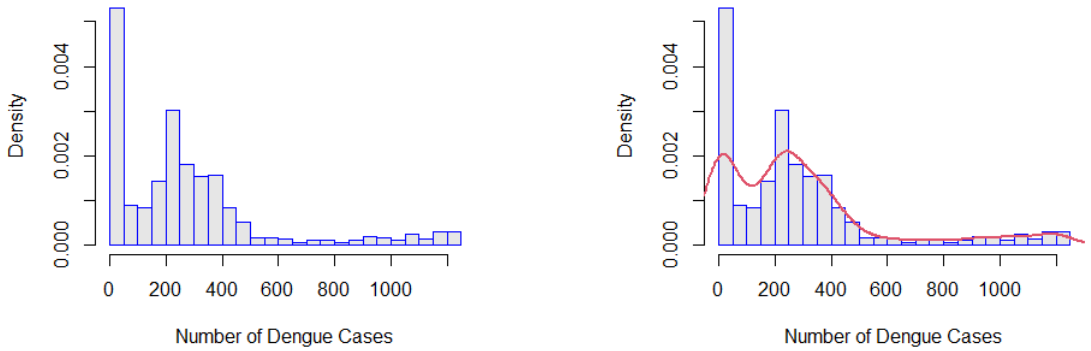


Fig 1. *(a).Histogram of Number of Infected Dengue Cases ; (b). Distribution of the number of Dengue Cases, during the period* 1^{st} *January 2020–* 31^{st} *December 2021.*

A kernel density plot of the infected dengue cases brought on by dengue fever is shown on a histogram in Figure 1. It demonstrates that one of the most accurate probabilistic models for this variable is the bell-shaped distribution by showing that the number of confirmed Dengue cases appears to have a symmetric distributional form. It is hypothesized that a skewed distribution would be more accurate in forecasting the values of this variable based on a comparison of the distributional shape of the number of Dengue cases.

Bayesian Poisson Regression Model

To carries our Bayesian inference on the statistical problems using MCMC methods, we used the most popular Bayesian software. Three $WinBUGS$ tools are required to obtain posterior samples: (a) the specification tool, (b) the sample monitor tool, and (c) the update tool. Since our model had four initial values, we set the *number of chains* = *4* in order to get the appropriate posterior information. Furthermore, the MCMC iteration is specified as $30,000$ in the update tool. In the sampling monitor tool, we specified *beg* from $10,000$ and ended with $30,000$ for updating the model. However the *thin* number was taken as 10 out there. We have got the summary statistics, trace, and density plot by clicking the option of these toolbars. The posterior summary measurements are displayed using the density and stat settings. Table 2 gives the sample, start iteration, posterior mean and SD, MC error, $2.5\%, 50\%, and 97.5\%$

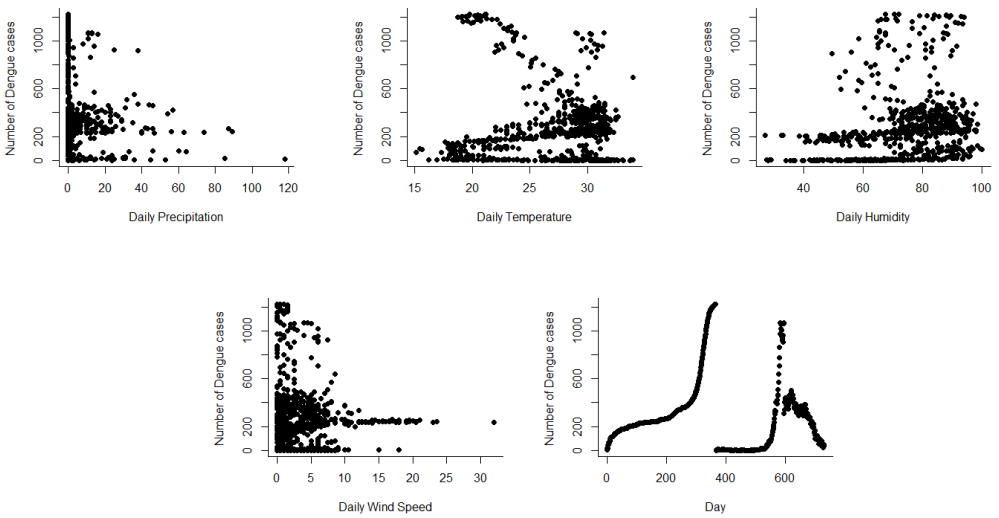


Fig 2. *Scatter diagram (a). The daily number of Dengue Cases vs. Daily Precipitation; (b). The daily number of Dengue Cases vs. Daily Precipitation; (c). The daily number of Dengue Cases vs. Daily Temperature; (d). The daily number of Dengue Cases vs. Daily Humidity; (e). The daily number of Dengue Cases vs. Daily Wind Speed during the period* 1^{st} *January 2020–* 31^{st} *December 2021.*

posterior quantiles. Hence the estimated model is

$$\log(\lambda_i) = 3.781 - 0.007 \times \text{precipitation}_{i-19} + 0.015 \times \text{temperature}_i + 0.021 \times \text{humidity}_i - 0.037 \times \text{wind speed}_i. \quad (4)$$

Table 2. Summary statistics of the posterior distribution.

Parameter	mean	SD	MC error	2.5%	median	97.5%	start	samples
β_0	3.781	0.02108	2.882×10^{-4}	3.74	3.781	3.822	10000	8000
β_1	-0.006777	2.135×10^{-4}	2.568×10^{-6}	-0.0072	-0.006774	-0.006356	10000	8000
β_2	0.01527	5.724×10^{-4}	6.822×10^{-6}	0.01415	0.01527	0.01639	10000	8000
β_3	0.02116	1.731×10^{-4}	2.20×10^{-6}	0.02082	0.02115	0.0215	10000	8000
β_4	-0.03779	6.406×10^{-4}	7.275×10^{-6}	-0.03906	-0.0378	-0.03654	10000	8000
τ_1	15.22	12.52	0.139	1.1	11.94	47.03	10000	8000
τ_2	14.84	12.06	0.1311	1.153	11.73	46.53	10000	8000
τ_3	15.2	12.49	0.1529	0.9981	11.94	47.49	10000	8000
τ_4	14.83	12.2	0.1445	1.077	11.72	47.95	10000	8000

Interpreting the Posterior

To simulate the Poisson posterior regression model, we employ MCMC trace graphs, density plots, and autocorrelation plots 4 and show that our simulation has stabilized. From 1 January 2020 to 31 December 2021, only nine posterior simulations of Dengue case data had ACF histograms with skew, range, and trend that match the observed data. Think about the precipitation coefficient $beta_1$, which has a posterior median that is roughly -0.007. This suggests that we should expect roughly one time as much precipitation if it increases by one mm or 0.993% more, anti-discrimination laws: $e^{-0.007} = 0.993$ and the posterior median is around 0.015 for the temperature coefficient $beta_2$. It implies that if the temperature rises by one unit, we might anticipate 1.02

times as many anti-discrimination measures, or 1.02 percent more: $e^{0.0152} = 1.0153$. The posterior median for the humidity coefficient $beta_3$ is around 0.02115. This means that if the humidity increases by one unit, we should expect it to have 1.02 times as many, or 1.02 percent, more, likewise for the posterior median of the wind speed coefficient $beta_4$, which is -0.0378. This means that if the wind speed increases by one km/h, we should anticipate 0.96 times as many, or 0.96 percent, more.

Graphically Checking

Initially, the Markov chain distribution's trace and autocorrelation plots were used to visually assess convergence. 10,000 iterations of each of the four chains were investigated. For all parameters except $beta_0$, the trace plots 3 show a horizontal strip indicating stationarity and well mixing of the chains which indicates slow mixing of the chains.

Initially, convergence was evaluated visually using the trace and autocorrelation plots of the Markov chain distribution. We looked at 10,000 iterations of each of the four chains. The trace plots given in 3 display a horizontal strip suggesting stationarity and well mixing of the chains for all parameters except $beta_0$, which indicates slow mixing of the chains. Furthermore, the autocorrelation plot 4 indicates that the current position of the chains does not predict the future position of the chains, indicating that the posterior distribution for parameters is extensively investigated. According to the autocorrelation plots in the 4, there is a decreased correlation between lengthy lags, which indicates that the chains were poor mixed.

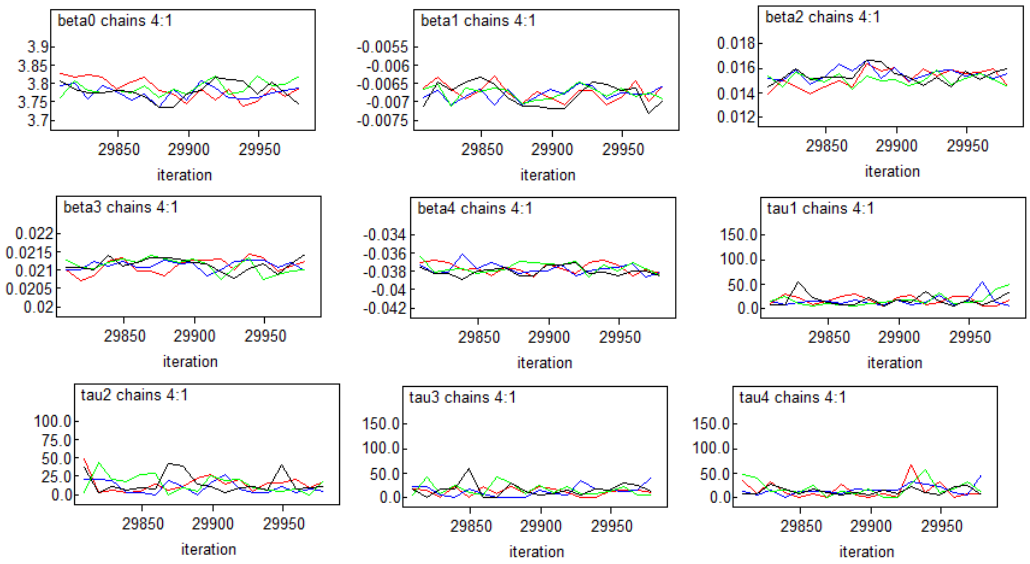


Fig 3. *Trace plots of parameters (β) and variance of random effects*

Formal Diagnostic Test

Three diagnostic tests are performed in order to confirm the stationarity, accuracy, and convergence: the Brooks-Gelman-Rubin (BGR) diagnostic approach developed by Geweke, HeidelbergerWelch, and. Table 3 details the official diagnostic tests for the 4 model with random intercept and slope.

With default settings of 10% (first part of a chain) and 50% (second part of a chain), the Geweke diagnostic test demonstrated stationarity for all parameters with the exception of the estimated variance of the random intercepts, presuming that all

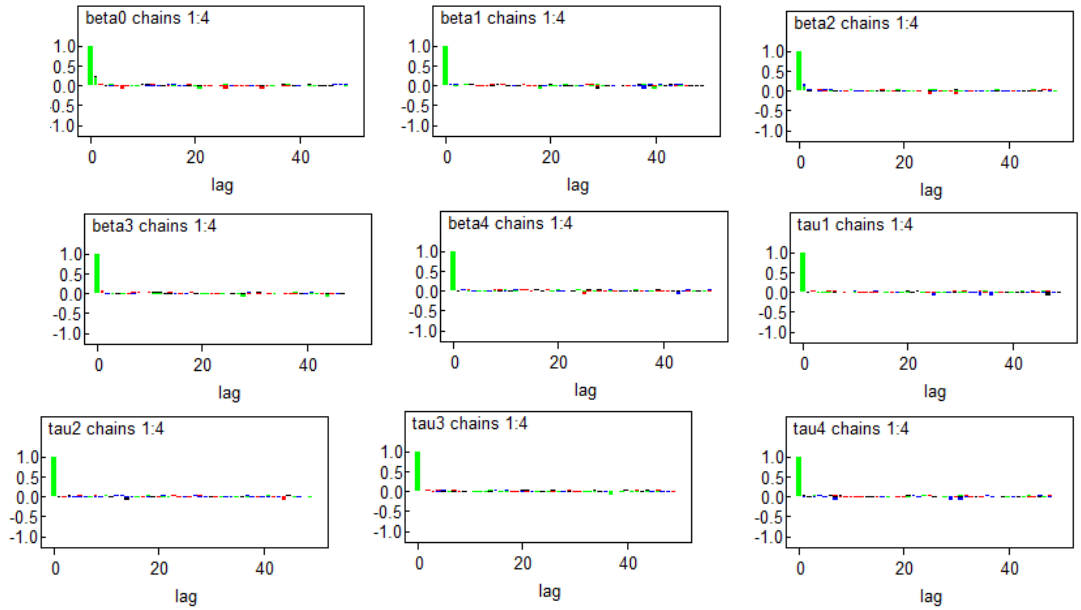


Fig 4. *Auto-correlation plots of parameters (β) and variance of random effects*

Table 3. Formal diagnostic tests for a bayesian regression model with random intercept and slope

parameter	Geweke	Heidelberger-Welch	BGR	effective sample size
Intercept (β_0)	0.285	0.850	1.000	3353.017
Precipitation (β_1)	0.827	0.387	1.000	3000.000
Temperature (β_2)	0.113	0.230	1.000	3816.157
Humidity (β_3)	-0.928	0.775	1.000	3000.000
Wind Speed (β_4)	0.348	0.060	1.000	3000.000
Deviance (σ^2)	1.425	0.567	1.000	3000.000

Z-values for the parameters are constrained between -1.96 and 1.96. Heidelberger-diagnostic Welch's also showed that every parameter passed the convergence test, leading to the conclusion that the length of the chain is sufficient to ensure the accuracy of the posterior means of the parameters. Figure 3 shows the Brooks-Gelman-Rubin (BGR) diagnostic, which is the sole convergence diagnostic test based on the four chains.

Poor chain mixing was discovered to be the cause of the huge sample size disparity between the effective sample size and the MCMC simulation sample size (totaling 30,000). Additionally, it was found that $beta_2$ had a large discrepancy, which suggested considerable autocorrelation. Significant results suggest non-randomness when evaluating the correlation between a variable's most recent and previous values using autocorrelation.

For model evaluation purposes, different measures to check the model's fit are shown in table 4. It is clear that the model has a larger posterior predictive value (PD), a discrepancy metric that indicates complexity. In Table 4 $\bar{D}$ is the posterior mean of $-2logL$ and $\hat{D} = -2logL$ at a posterior mean of stochastic parameters.

In figure 5, The model's intercept, slope, and precision density plots are shown. The distribution of posterior information appears to be normally distributed.

In the history plot in figure 6, the well-mixed initials values have very small differences which indicates that the initial values of coefficients $\beta_o, \beta_1, \beta_2, \beta_3, \beta_4$ got

Table 4. Measure of fit for the Poisson regression model

Y	$\bar{D}$	$\hat{D}$	P_D	DIC
Cases	186650.0	186645.0	5.123	186656.0
Total	186650.0	186645.0	5.123	186656.0

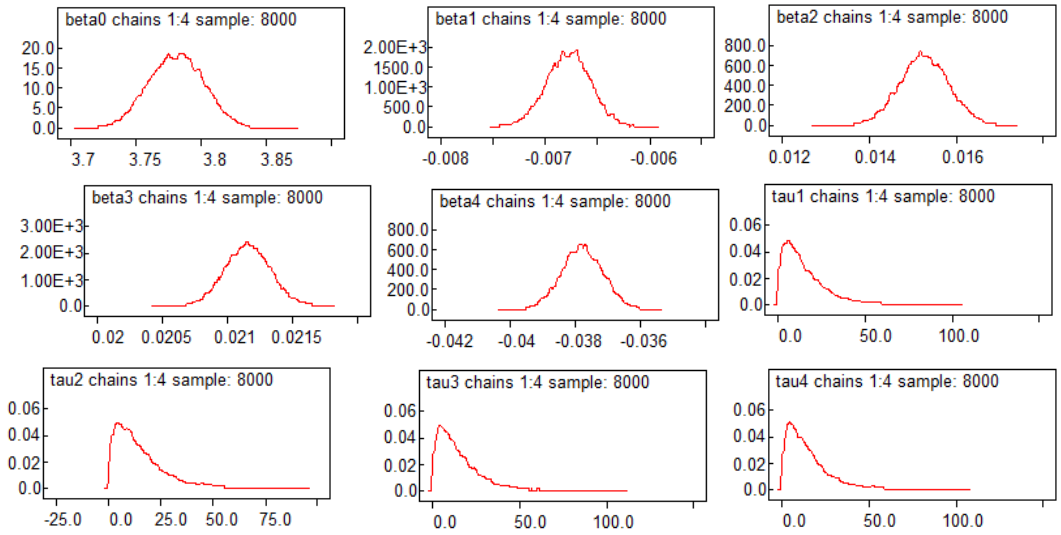


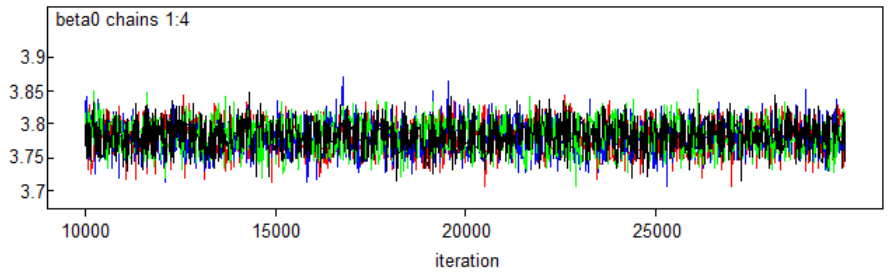
Fig 5. *Density plots for posterior distribution of parameters (β's) and precision*

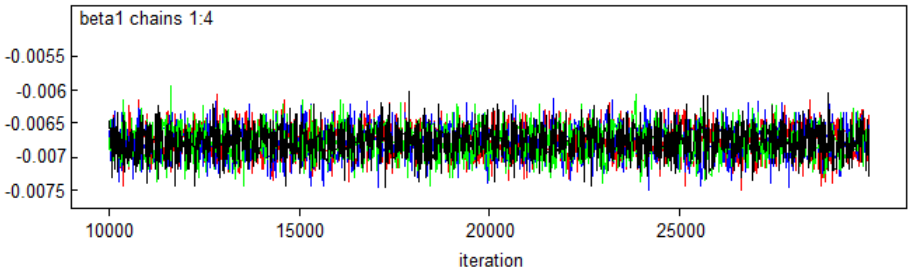
convergence.

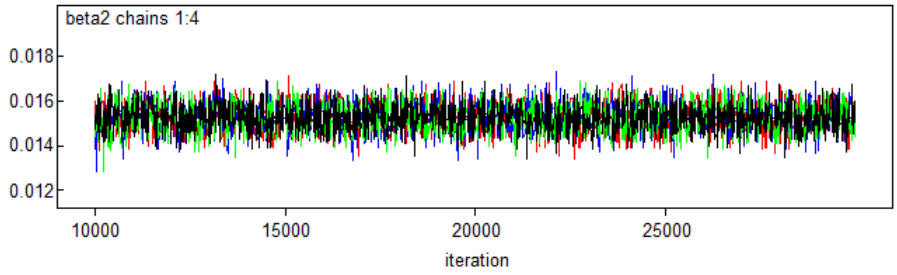
Discussion

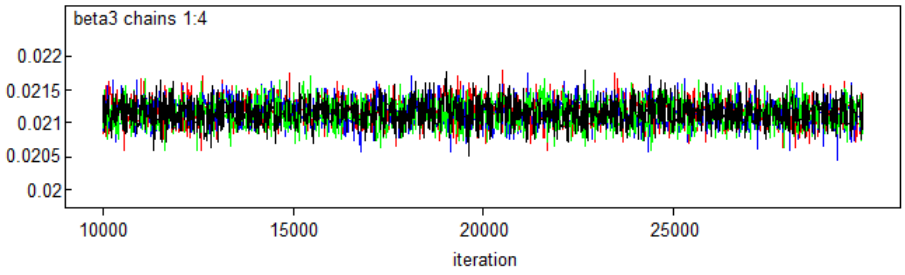
Dengue is a major hazard to public health and a significant economic burden in Bangladesh. An increasing body of evidence indicates that dengue imposes a massive socioeconomic cost on households, healthcare systems, and government health expenditures in endemic nations, particularly during outbreaks. An increasing number of initiatives are being made to relate relatively local-area factors like rainfall, humidity, and temperature to dengue incidence in order to increase public health relevance.

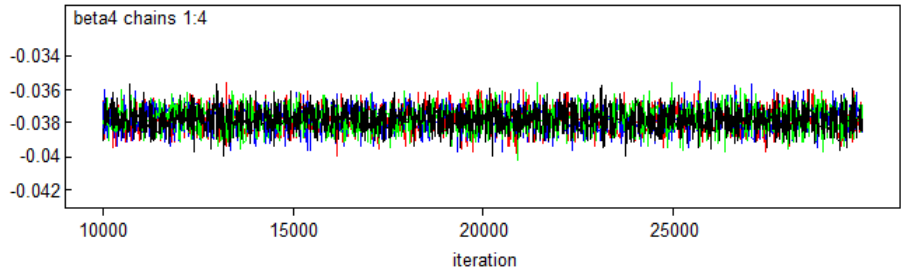
Since Dengue fever is a growing public health concern in Bangladesh, its identification of alterations in the climatic factor pattern will enhance case-finding from an environmental standpoint. Consequently, the purpose of this study was to provide insight into the altering climatic manifestation of dengue infections in Bangladesh. In this study, we examined the effect of meteorological risk factors on the severity of dengue transmission using the dengue confirm cases. However, we must employ Bayesian methods such as Markov Chain Monte Carlo (MCMC) in order to use the informative prior ([35]). For Bayesian regression modeling, we built the Poisson regression model using the Normal distribution as the prior. The aim of Bayesian Regression is not to find the single "best" value of the model parameters but rather to determine the posterior distribution for the model parameters. Not only is the response generated from a probability distribution but the model parameters are assumed to come from a distribution as well. In this respect, an attractive class of sampling algorithm, called MCMC method is explored to solve the practical problem in a Bayesian manner. This study demonstrated that the Gibbs sampling, a highly


beta0 chains 1:4
3.9
3.85
3.8
3.75
3.7
10000
15000
20000
25000
iteration


beta1 chains 1:4
-0.0055
-0.006
-0.0065
-0.007
-0.0075
10000
15000
20000
25000
iteration


beta2 chains 1:4
0.018
0.016
0.014
0.012
10000
15000
20000
25000
iteration


beta3 chains 1:4
0.022
0.0215
0.021
0.0205
0.02
10000
15000
20000
25000
iteration


beta4 chains 1:4
-0.034
-0.036
-0.038
-0.04
-0.042
10000
15000
20000
25000
iteration

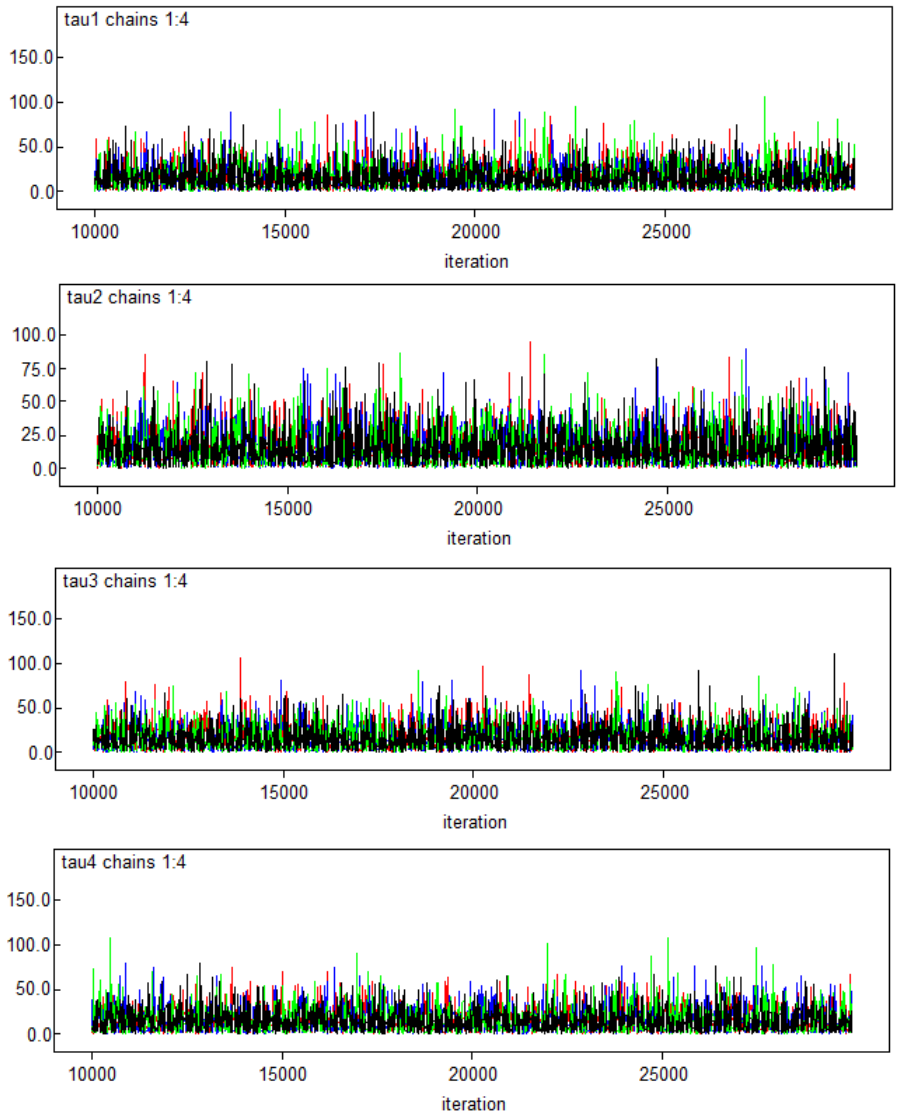


Fig 6. *History plots of parameters (β's) Obtained from WinBUGS after 30,000 iterations*

computationally efficient MCMC method [36], can generate accurate estimates of Bayesian regression coefficients for Dengue counts. In order to assess how well the observable data fits the model of interest and whether or not data independent of the observed data fit the model given by the observed data, Gibbs sampling is used to find estimates for the parameters of interest ([33]).

We proved the Bayesian discrete Poison model's applicability to data on medical domain counts. We examined data on the total number of afflicted cases caused by Dengue fever in order to generate statistical proof of the impact of climatic conditions on Dengue transmission. In the instances given, we concentrated on a daily count of all 731 Dengue causes from January 1, 2020, to December 31, 2021, which is discrete and has a right-skewed distribution, making the full conditional distribution of interest.

The important posterior knowledge of the parameters is obtained by assuming the previous information. Furthermore, Figure 5 shows that the posterior distribution for the parameters is well examined and that they appear to be regularly distributed. The model, which exhibits the presence of autocorrelation, likewise revealed a higher discrepancy. Additionally, we used a variety of diagnostic tests to evaluate the inference technique on actual data, demonstrating both the results' stationary nature and their convergence. In this regard, the diagnostic outcomes are also demonstrated, demonstrating the precision of the posterior parameters. The model also exhibits higher posterior density (HPD) with poor mixing convergence beginning values. Low precipitation increases the propagation of dengue, according to empirical research. Dengue has been demonstrated to spread less frequently in high temperatures, which reduces the virus's ability to survive and spread. Instead, freezing conditions give coronaviruses a secure haven that hastens their survival and spread. It may be concluded that the climate has a substantial impact on the risk factors for virus transmission in Bangladesh. We came to the conclusion that the Bayesian technique performed well and is easier to understand than traditional regression approaches in the literature on the basis of a variety of information criteria and the selection of influential elements.

Moreover, it is critical to investigate and describe these additional potential variables since they may have a significant influence on the frequency with which certain infectious diseases manifest and the long-term health and well-being of the general populace. Additionally, more study is needed to determine the genetic variations of dengue that are most prevalent as well as the effects of climate change on the biology of the vectors that spread these infectious diseases.

Conclusions

To sum up, we have given an overview of the Bayesian regression models used in count data analysis. Despite the fact that the majority of recent studies have concentrated on a correlation approach between meteorological parameters and pandemic data. Unfortunately, there haven't been any direct tests with dengue outbreaks in different environmental contexts. Our research revealed striking similarities in the effects of precipitation, temperature, humidity, and wind speed on the seasonal viability and severity of dengue fever. This study used a number of statistical techniques, and the model revealed a substantial causal link between climatic variables and the spread of dengue.

As it is throughout the world, dengue fever, an emerging disease, will continue to pose a serious threat to public health in Bangladesh. So, developing preventative and control measures is urgently needed in Bangladesh. Communities must take part in community-based initiatives to get rid of mosquito breeding sites. Every healthcare facility needs to have the necessary equipment, including diagnostic lab capabilities, to

make an early diagnosis of dengue illness. In order to reduce fatality rates, professionals in Bangladesh must receive training in the management of severe dengue disease. To stop the spread of an outbreak, institutions, non-governmental groups, policymakers, and government officials must launch short-term national measures. Important mosquito breeding places should be eliminated and pesticides sprayed. Water logging should be addressed, and canals, water tanks, rainwater collection tanks, downpipes, and gutters should be cleaned. In remote regions, the distribution of dengue detection kits to health centers and the training of health facilitators would be advantageous. Because personal apparel serves as a preventive strategy, schoolchildren should be given specific attention through the enhancement of school uniforms. The media might help by broadcasting information on dengue stages, the use of bed nets and insect repellents, and the wearing of light-colored, loose-fitting, long-sleeved, and breathable clothing [13]. Furthermore, a dengue virus vaccine could be introduced in the country, as it has been demonstrated to lower severity and hospital admissions by 80-90% in Asian youngsters [37].

We urge the creation of a nationwide dengue control program for clinical management of the virus, in addition to the already-existing national recommendations from the Directorate General of Health Services in Bangladesh, together with a broad community awareness campaign for better responses. Although the Bangladeshi government has launched various short-term initiatives, mostly in Dhaka, nationwide comprehensive action initiatives have fallen short. To stop preventable deaths and lessen the epidemic's disease burden, the government, and relevant stakeholders should give priority to this dengue outbreak and implement a comprehensive dengue control program. To entirely eradicate the *Ades* mosquito, numerous community-based awareness programs need to be launched and maintained. To address the catastrophic health burden caused by dengue infections, a number of social protection programs, including "Shasthyo Surokhsha Karmasuchi (SSK)" may be implemented in metropolitan cities for poor and vulnerable households.

Acknowledgments

Author Contributions

References

1. Islam MA, Ahmed MU, Begum N, Chowdhury NA, Khan AH, del Carmen Parquet M, et al. Molecular characterization and clinical evaluation of dengue outbreak in 2002 in Bangladesh. Japanese journal of infectious diseases. 2006;59(2):85.

2. Biswas R, Mohammed FR, Sengupta P, Ahmed HS, Rahman MM, Sarker MAS, et al. Dengue NS1 antigen: a tool in early detection of dengue virus infection. Journal of Medicine. 2014;15(1):28–30.

3. Akram A. Alarming turn of dengue fever in Dhaka city in 2019. Bangladesh Journal of Infectious Diseases. 2019;6(1):1–2.

4. Alam H. Dengue deaths so far: most were infected a second time. 2019; 2021.

5. Alam H. Dengue outside Dhaka: non-critical patients crowd dist hospitals (2019); 2021.

6. Dayaram S, Pokharel S. Bangladesh hit by worst dengue outbreak on record. CNNhealth July. 2019;30:2019.

7. Sharmin S, Viennet E, Glass K, Harley D. The emergence of dengue in Bangladesh: epidemiology, challenges, and future disease risk. Transactions of The Royal Society of Tropical Medicine and Hygiene. 2015;109(10):619–627.

8. Directorate General of Health Services (DGHS) GotPRoB Ministry of Health & Family Welfare. Disease Control Directorate;. https://old.dghs.gov.bd/index.php/bd/home/5200-daily-dengue-status-report.

9. (2022) WHO. Dengue–Bangladesh;. https://www.who.int/emergencies/disease-outbreak-news/item/2022-DON424.

10. Lindsay S, Birley M. Climate change and malaria transmission. Annals of Tropical Medicine & Parasitology. 1996;90(5):573–588.

11. Hsan K, Hossain MM, Sarwar MS, Wilder-Smith A, Gozal D. Unprecedented rise in dengue outbreaks in Bangladesh. The Lancet Infectious Diseases. 2019;19(12):1287.

12. Lindsay SW, Wilson A, Golding N, Scott TW, Takken W. Improving the built environment in urban areas to control Aedes aegypti-borne diseases. Bulletin of the world health organization. 2017;95(8):607.

13. Mone FH, Hossain S, Hasan MT, Tajkia G, Ahmed F. Sustainable actions needed to mitigate dengue outbreak in Bangladesh. The Lancet Infectious Diseases. 2019;19(11):1166–1167.

14. Simmons CP, Farrar JJ, van Vinh Chau N, Wills B. Dengue. New England Journal of Medicine. 2012;366(15):1423–1432.

15. Struchiner CJ, Rockloev J, Wilder-Smith A, Massad E. Increasing dengue incidence in Singapore over the past 40 years: population growth, climate and mobility. PloS one. 2015;10(8):e0136286.

16. Dhar-Chowdhury P, Haque CE, Driedger SM. Dengue disease risk mental models in the city of Dhaka, Bangladesh: juxtapositions and gaps between the public and experts. Risk Analysis. 2016;36(5):874–891.

17. Wiwanitkit V, et al. Strong correlation between rainfall and the prevalence of dengue in central region of Thailand in 2004. Journal of Rural and Tropical Public Health. 2005;4:41–42.

18. Guzman MG, Kouri G. Dengue and dengue hemorrhagic fever in the Americas: lessons and challenges. Journal of Clinical Virology. 2003;27(1):1–13.

19. Moore CG. Predicting Aedes aegypti abundance from climatologic data. 1985;.

20. Arcari P, Tapper N, Pfueller S. Regional variability in relationships between climate and dengue/DHF in Indonesia. Singapore Journal of Tropical Geography. 2007;28(3):251–272.

21. Promprou S, Jaroensutasinee M, Jaroensutasinee K. Climatic Factors Affecting Dengue Haemorrhagic Fever Incidence in Southern Thailand. 2005;.

22. Schreiber KV. An investigation of relationships between climate and dengue using a water budgeting technique. International Journal of Biometeorology. 2001;45:81–89.

23. Choudhury ZM, Banu S, Islam AM. Forecasting dengue incidence in Dhaka, Bangladesh: A time series analysis. 2008;.

24. Karim MN, Munshi SU, Anwar N, Alam MS. Climatic factors influencing dengue cases in Dhaka city: a model for dengue prediction. The Indian journal of medical research. 2012;136(1):32.

25. Kanchanapairoj K. Climatic Factors Influencing the Incidence of Dengue Haemorrhigic Fever in Southern Thailand. Prince of Songkla University, Pattani Campus; 1999.

26. Depradine C, Lovell E. Climatological variables and the incidence of Dengue fever in Barbados. International Journal of Environmental Health Research. 2004;14(6):429–441.

27. Hales S, Weinstein P, Souares Y, Woodward A. El Niño and the dynamics of vectorborne disease transmission. Environmental Health Perspectives. 1999;107(2):99–102.

28. Yi B, Zhang Z, Xu D, Xi Y. Relationship of dengue fever epidemic to Aedes density changed by climate factors in Guangdong Province. Wei sheng yan jiu= Journal of Hygiene Research. 2003;32(2):152–154.

29. Cameron AC, Trivedi PK. Regression analysis of count data. vol. 53. Cambridge university press; 2013.

30. Casella G, George EI. Explaining the Gibbs sampler. The American Statistician. 1992;46(3):167–174. doi:https://doi.org/10.2307/2685208.

31. Geman S, Geman D. Stochastic relaxation, Gibbs distributions, and the Bayesian restoration of images. IEEE Transactions on pattern analysis and machine intelligence. 1984;(6):721–741. doi:10.1109/TPAMI.1984.4767596.

32. Gelfand AE, Smith AF. Sampling-based approaches to calculating marginal densities. Journal of the American statistical association. 1990;85(410):398–409.

33. Rouchka EC. A brief overview of Gibbs sampling. Bioinformatics Technical Report Series, No TR-ULBL-2008-02, University of Louisville. 1997;9.

34. Katsis A, Ntzoufras I. Bayesian hypothesis testing for the distribution of insurance claim counts using the Gibbs sampler. Journal of Computational Methods in Sciences and Engineering. 2005;5(3):201–214. doi:10.3233/JCM-2005-5304.

35. Gelman A, Carlin J, Stern H, Dunson D, Vehtari A, Rubin D. Bayesian data analysis; 2013.

36. Ntzoufras I. Bayesian modeling using WinBUGS. vol. 698. John Wiley & Sons; 2011.

37. Capeding MR, Tran NH, Hadinegoro SRS, Ismail HIHM, Chotpitayasunondh T, Chua MN, et al. Clinical efficacy and safety of a novel tetravalent dengue vaccine in healthy children in Asia: a phase 3, randomised, observer-masked, placebo-controlled trial. The Lancet. 2014;384(9951):1358–1365.

Data File

Click here to access/download

Supporting Information

Dengue Data.csv

Revised Manuscript with Track Changes

Climatic Risk Factors for the Transmission of Dengue Fever: Bangladesh Perspective

Md. Rezaul Karim[1], Nazmin Akter[1]

1 Department of Statistics, Jahangirnagar University, Bangladesh.

*rezaul.juniv.edu; nazmin.swarna194@gmail.com

Abstract

A significant global public health risk is dengue disease. Predicting how climatic factors will affect the spread of vector-borne diseases such as Dengue is difficult. To investigate the impact of climatic risk factors on Dengue transmission because it is an infectious disease spread by mosquitoes. The main objective is to examine how climatic risk variables affect dengue epidemics using Bayesian inference. Bayesian inference is drawn using MCMC with Gibbs sampling, which is carried out in the WinBUGS software. In anticipating the occurrence or extent of each dengue outbreak, the methodology integrates confirmed Dengue cases and seasonal variables such as precipitation, temperature, humidity, wind speed, and lag duration of up to two years. According to the results we got less precipitation (posterior median, $\beta_1 = 0.993\%$) reduces infected cases and fatalities from Dengue. Furthermore, the spread of Dengue has diminished due to high temperatures (posterior median, $\beta_2 = 1.015\%$), which have also affected the virus's ability to survive and spread.

Keywords:Bayesian Inferences, Markov Chain Monte Carlo, Gibbs sampling, Dengue, Bangladesh.

Introduction

The Dengue virus, one of the viral pathogens, predominantly affects tropical and subtropical areas where it produces classical Dengue fever (DF) and Dengue Hemorrhagic fever (DHF). Dengue fever is a mosquito-borne disorder that affects millions of people each year [1, 2]. Bangladesh is a country that suffers the most from dengue practically every year [3] and its tropical environment has made it an excellent place for the Dengue virus to spread. Bangladesh witnessed occasional dengue virus transmission from 1964 to 1999, but the country is experiencing its worst dengue outbreak since 2000, with widespread dread of fatality as the illness spreads throughout the country, disproportionately impacting children, pregnant women, and the elderly [4–7] and mainly in the capital city of Dhaka. The country experienced its greatest epidemic in history in 2019, with over 100,000 reported illnesses and almost 120 deaths [8], an abnormally lengthy rainy season, and pesticide resistance were all mentioned as potential drivers of the outbreak ([9]). With COVID-19 pandemic-related lockdown measures in place for the years 2020 and 2021, the nation saw a comparatively reduced number of Dengue cases (1,405 and 28,429 cases, respectively) [8]. We again spotlight the Dengue outbreak in Bangladesh in 2022, thus far is the third most cases reported in a year since the first cases were reported in 2000. The Ministry of Health & Family Welfare of Bangladesh has reported 52,807 laboratory-confirmed dengue cases overall as of 20 November 2022, with 230 deaths associated with the disease [10].

Dengue fever is common in tropical and subtropical regions, but the epidemic in Bangladesh warrants additional investigation. What's inflicting this unusual boom in dengue cases? The concept that weather modifications make it easier for illnesses to unfold to new populations has substantially heightened humans' worry approximately the arrival and reemergence of infectious diseases [11]. Bangladesh's outbreak is being exacerbated by way of poor water, sanitation, and hygiene structures, in addition to a congested population, climatic trade, unplanned speedy urbanization, and building, poor vector manipulation strategies, and Bangladesh's faltering healthcare gadget all contribute to the extent and severity of dengue epidemics [12–16]. Additional causes might be drainage issues, stagnant water and rubbish anywhere, weak immune reputation, bodily weak spot, unplanned market, wetland occupation, the habit of gardening, polluted waterbody, [17] and so on. Climate change increases the opportunity for Dengue epidemics as it strengthens the hyperlink between the vector and the virus [18, 19]. A number of studies have been undertaken in order to build a weather-based dengue early warning system, see for example [20], [21], [22] . The majority of research on this topic focuses on climate-related factors (rainfall, temperature or humidity). This tendency may be detected in quite early studies, such as Moore's [23], which showed that both the amount of rain and the persistence of rainfall were good predictors since when rainfall has continued to provide the most reliable early warning indicator [24]. Geographic location peak [24, 25] and trough weather events, such as highest and lowest temperatures [25], abnormal climatic occurrence, and running averages [26] have all been added to the list of variables used in the literature. Choudhury et al. evolved a Seasonal Autoregressive incorporated transferring average (SARIMA) model, especially for Dhaka, Bangladesh. While this look stated that it does now not take into consideration weather elements, it does remember seasonality, which axiomatically captures primary climatic characteristics [27]. In anothothe study, Climate-based multivariate non-linear models were developed by [22], to assess the correlations between climate, *Aedes aegypti* vectors, and dengue outbreaks, with the maximum temperature and relative humidity serving as the best predictor variables. Karim et al. also evolved models with the use of simple linear regression and Pearson's correlation, utilizing a spread of environmental parameters including month-to-month rainfall, humidity, maximum, and lowest temperature, and determined that meteorological parameters may are expecting month-to-month dengue incidence with an excessive degree of accuracy [28]. However, the predictor variable glaringly deviated from the normal distribution. In some other studies, Kanchanapairoj, McNeil, and Thammapalo provided conflicting evidence that demonstrates the connection between dengue incidence and climatic situations is still up for debate [29].

The latest study, in addition to addressing the topic of climatic predictors of dengue in Bangladesh, employs a broader variety of statistical tactics. Statistically, it appears that most investigations utilized either very simple correlational techniques [28, 30, 31] or regression modeling [24, 32], or both. One Recent study showed the association through precipitation with dengue data using multivariate Poisson regression models in a Bayesian framework with a conditional autoregressive prior structure to quantify the relationship between dengue, climate with other socio-ecological factors [33]. In our research we employed the Bayesian Regression Method which generates a vast number of climatic factors, including seasonal aspects, that allow researchers to investigate plausible links between scientifically quantifiable climate change and Dengue transmission. In order to develop and provide a better knowledge of the complicated relationship between climate and health, this study aims to assess how key meteorological variables such as precipitation, heat, moisture, and wind speed may promote Dengue incidence in Bangladesh. Here, we present the findings of a study conducted across Bangladesh, using a Bayesian Poisson regression approach to estimate

the prevalence of Dengue and pinpoint significant risk variables for infection. Then, using the Gibbs sampling (MCMC) algorithm to estimate the posterior distribution hence future observations are predicted. First, we will summarize measures for the location and variability of Dengue cases with additional risk factors and investigate the non-linear relationship between Dengue case counts and climatic factors for the dataset. To structure this article, there are four more sections. In Section 2, the fundamental formulation of the Bayesian model and the design of the Gibbs sampling technique, including the data sources, are discussed. In Section 3, the distributions for modeling daily Dengue cases are described, and the method's application to a specific example of daily Dengue cases data is examined. Finally, Sections 4 and Section 5 give a general discussion and conclusion, respectively. Health professionals who create efficient plans to enhance public health may find this material to be useful.

Materials and methods

Data Sources

Data of Daily Dengue were obtained from the Directorate General of Health Services (DGHS) of the Ministry of Health and Family Welfare [8] during the period of 1st January 2020 to 31st December 2021. The weather variables of temperature (measured in °C), humidity (measured in %), precipitation (measured in mm), and wind speed (measured in km/h) were collected from website `www.timeanddate.com/weather/bangladesh/dhaka/ext`. All data are uploaded to the Kaggle website, which can be found in `https://www.kaggle.com/datasets/drmdrezaulkarim/researchdata`.

Bayesian Poisson Regression

To represent discrete event counts that occur over predetermined intervals of time or space, the Poisson model can be employed. The Poisson model is especially useful when counts are right-skewed and cannot be reasonably approximated by a Normal model. Fitting a Bayesian Poisson regression model to the frequency of Dengue infected cases, say Y with density

$$Y_i|\lambda_i \sim \text{Poission}(\lambda_i)$$

where, $Y_i = 0, 1, 2, \ldots$ is the random variable and λ is the rate parameter, $\lambda > 0$.The mean and variance of the density are generally known to be equal to λ_i. As a result, the typical value of Y should approximately reflect its variability given the predictors X. The Poisson regression model is defined as ([34]):

$$E(Y = y/x) = \exp\left(\beta_0 + x_1\beta_1 + x_2\beta_2\right)\ldots x_p\beta_p) \tag{1}$$

where y is the response variable, x's are the independent variable, p is the number of independent variables and β's are regression parameters.

Likelihood Distribution

Assume that λ_i can be expressed as a linear combination of X predictors, we can write

$$\text{data:}\quad Y_i|\beta_0, \beta_1, \beta_2\beta_3, \beta_4 \sim \text{Poission}(\lambda_i) \quad \text{with} \quad \log(\lambda_i) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4. \tag{2}$$

where β represents the regression coefficients and X_i's are the covariates as X_i= precipitation, temperature, humidity, wind speed. The likelihood function

$Pr(Y|X_i, \beta) = \text{Poisson}(\lambda_i)$. where, $Pr(\cdot|\cdot)$ denotes a conditional probability function. The five parameters $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$ is the intercept, precipitation, temperature, humidity and wind speed effect respectively.

Specifying the Priors Distribution

Assume the following prior distribution is applied to a parameter, where $\pi(.)$ represents a prior distribution.

$$\pi(\beta_0) = \text{uniform}(0, 1) \quad \text{and} \quad \pi(\beta_1).\pi(\beta_2).\pi(\beta_3).\pi(\beta_4) = \text{normal}(0, \sigma^2)$$

To build the Bayesian model, we must express our prior knowledge of regression coefficients($\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$). Again, using Normal priors makes sense because each of these coefficients can take on any value along the real line. We'll also suppose that these priors—that is, our prior knowledge of the model coefficients—are independent. The complete Poisson regression model depiction of Y_i is as follows.

$$\begin{aligned} \text{prior:} \quad \beta_0 &\sim \text{U}(0, 1) \\ \beta_1 &\sim \text{N}(0, \tau_1) \\ \beta_2 &\sim \text{N}(0, \tau_2) \\ \beta_3 &\sim \text{N}(0, \tau_3) \\ \beta_4 &\sim \text{N}(0, \tau_4) \end{aligned}$$

where $\tau_1, \tau_2, \tau_3, \tau_4 \sim \exp(0.1)$ are precision of priors (i.e.precision= 1/variance). The posterior distribution of $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$ is determined by the likelihood function and prior distribution using the Bayes theorem.The likelihood and data-driven prior are multiplied to arrive at the posterior distribution. Consequently, we demonstrate the posterior distribution using the likelihood and prior distributions which are as follows:

$$P(\lambda/Y) = \exp[-\sum_{i=1}^{n} \log y_i! + n\bar{Y} \log \lambda - n\lambda] \times \frac{1}{\sqrt{2\pi\sigma^2}} \exp[\frac{x^2}{2\sigma^2}] \tag{3}$$

A prior is multiplied by a likelihood based on data to create the posterior distribution, which is then used as a prior in further modeling. Finally, these Bayesian probability distributions were employed for the data on Dengue cases in the Bayesian regression model.

Markov Chain Monte Carlo (MCMC) Method

The posterior inference result is increasingly difficult to assess and study the more variables we include in our model. The MCMC method is then utilized in this situation. The MCMC approach imitates the posterior in order to examine it. There are numerous MCMC approaches available. One of the most significant MCMC algorithms is the *Gibbs sampler*, which transformed Bayesian statistics and dramatically revived the Bayesian philosophy by offering solutions to real-world problems.

Gibbs Sampling

Using a combined probability distribution of two or more random variables, Gibbs sampling generates a series of samples as a form of probabilistic inference ([35]). In order to study the Gibbs distribution, the Gibbs sampler was first introduced in the context of image processing by [36]. The Gibbs sampler, on the other hand, didn't become well-known in the statistical community until [37] showed that it could deal with complex estimating concerns in a Bayesian fashion.

Basic Algorithm of Gibbs Sampling: Assuming a starting location $\beta^0 = (\beta_0^0, \beta_1^0, \beta_2^0, \ldots, \beta_d^0)^T$,The multivariate Gibbs sampler uses an iterative technique, as seen below. The sampling process performs the following d steps at iteration $(k+1)$:

(1). Sample β_0^{k+1} from $p(\beta_0|\beta_1^k, \beta_2^k, \ldots, \beta_{d-1}^k, \beta_d^k, \mathbf{y})$;

(2). Sample β_1^{k+1} from $p(\beta_1|\beta_0^{k+1}, \beta_2^k, \beta_3^k, \ldots, \beta_d^k, \mathbf{y})$;

... ...

(d). Sample β_d^{k+1} from $p(\beta_d|\beta_0^{k+1}, \beta_1^{k+1}, \ldots, \beta_{d-2}^{k+1}, \beta_{d-1}^{k+1}, \mathbf{y})$.

The conditional distributions $p(\beta_j|\beta_0^k, \beta_1^k, \beta_2^k, \ldots, \beta_{j-1}^k, \beta_{j+1}^k, \ldots, \beta_{d-1}^k, \beta_d^k, \mathbf{y})$ are reffered to as full conditional distributions, because β_j depends on all other parameters.

The open-source MCMC application WINBUGS makes it straightforward to implement the Gibbs sampling algorithm. To carries our Bayesian inference on the statistical problems using MCMC methods, we used the most popular Bayesian software. Three *WinBUGS* tools are required to obtain posterior samples: (a) the specification tool, (b) the sample monitor tool, and (c) the update tool. It can handle models with both common and unusual parameters because it is flexible enough. It can therefore be used in a variety of contexts, such as with insurance claim data, and is easy adaptable to enable more distributions (see [38]).

Results

Exploratory Data Analysis

Table 1 and Figure 2 shows the daily mean rainfall, temperature, humidity, wind speed readings, and dengue incidence in Bangladesh, respectively. Dengue incidences in Bangladesh ranged from 0 to 1224 over a two-year period (1st January 2020 to 31st December 2021), with the peak incidence (1224 cases) occurring in December 2020. The daily mean precipitation ranged from 0 to 118 millimeters, with the maximum recorded measurement in April 2020. The daily mean temperature ranged from 15.10°C to 34.0 °C, with the maximum recorded temperature being in May 2020. The daily mean humidity ranged from 27% to 100%. The highest temperature ever recorded was in June 2021. The daily mean wind speed values ranged from 0.00 to 32.0 units. The fastest recorded wind speed occurred in May 2020.

Table 1. Descriptive statistics of Number of Dengue-infected people, precipitation, temperature, humidity, and wind speed for January 01, 2022, to 31 December 2022.

Variables	Infected case	Precipitation (mm)	Temperature (°C)	Humidity (%)	Wind speed (km/h)
Mean (SD)	274.80 (287.51)	5.08 (12.26)	26.94(4.23)	73.67(15.06)	4.02 (4.32)
Skewness	1.69	4.11	-0.73	-0.64	2.10
25th Percentile	41.50	0.00	23.50	63.50	1.00
Median	232.0	0.00	28.40	76.50	2.50
75th Percentile	357.00	3.40	30.30	85.50	5.50
90th Percentile	607.00	16.00	31.30	91.00	8.50
99th Percentile	1209.00	59.10	32.65	97.35	19.50
Min	0.00	0.00	15.10	27.00	0.00
Max	1224.0	118.00	34.00	100.0	32.00

A kernel density plot of the infected dengue cases brought on by dengue fever is shown on a histogram in Figure 1. It demonstrates that one of the most accurate probabilistic models for this variable is the bell-shaped distribution by showing that the

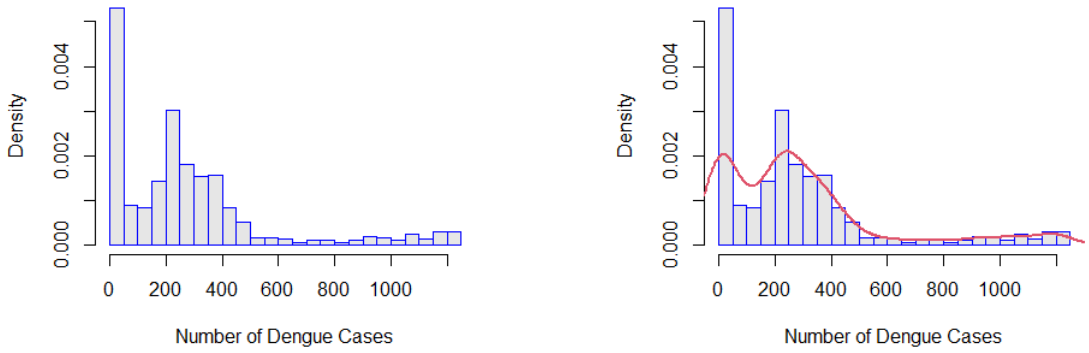


Fig 1. *(a).Histogram of Number of Infected Dengue Cases ; (b). Distribution of the number of Dengue Cases, during the period* 1^{st} *January 2020–* 31^{st} *December 2021.*

number of confirmed Dengue cases appears to have a symmetric distributional form. Based on a comparison of the distributional shape of the number of Dengue cases, it is hypothesised that a skewed distribution would be more accurate in predicting the values of this variable.

Bayesian Poisson Regression Model

Since our model had four initial values, we set the *number of chains* $= 4$ in order to get the appropriate posterior information. Furthermore, the MCMC iteration is specified as $30,000$ in the update tool. In the sampling monitor tool, we specified *beg* from $10,000$ and ended with $30,000$ for updating the model. However the *thin* number was taken as 10 out there. We have got the summary statistics, trace, and density plot by clicking the option of these toolbars. The posterior summary measurements are displayed using the density and stat settings. Table 2 gives the sample, start iteration, posterior mean and SD, MC error, $2.5\%, 50\%, 97.5\%$ posterior quantiles respectively. Hence the estimated model is

$$\log(\lambda_i) = 3.781 - 0.007 \times \text{precipitation}_{i-19} + 0.015 \times \text{temperature}_i + 0.021 \times \text{humidity}_i - 0.037 \times \text{wind speed}_i. \quad (4)$$

Table 2. Summary statistics of the posterior distribution.

Parameter	mean	SD	MC error	2.5%	median	97.5%	start	samples
β_0	3.781	0.02108	2.882×10^{-4}	3.74	3.781	3.822	10000	8000
β_1	-0.006777	2.135×10^{-4}	2.568×10^{-6}	-0.0072	-0.006774	-0.006356	10000	8000
β_2	0.01527	5.724×10^{-4}	6.822×10^{-6}	0.01415	0.01527	0.01639	10000	8000
β_3	0.02116	1.731×10^{-4}	2.20×10^{-6}	0.02082	0.02115	0.0215	10000	8000
β_4	-0.03779	6.406×10^{-4}	7.275×10^{-6}	-0.03906	-0.0378	-0.03654	10000	8000
τ_1	15.22	12.52	0.139	1.1	11.94	47.03	10000	8000
τ_2	14.84	12.06	0.1311	1.153	11.73	46.53	10000	8000
τ_3	15.2	12.49	0.1529	0.9981	11.94	47.49	10000	8000
τ_4	14.83	12.2	0.1445	1.077	11.72	47.95	10000	8000

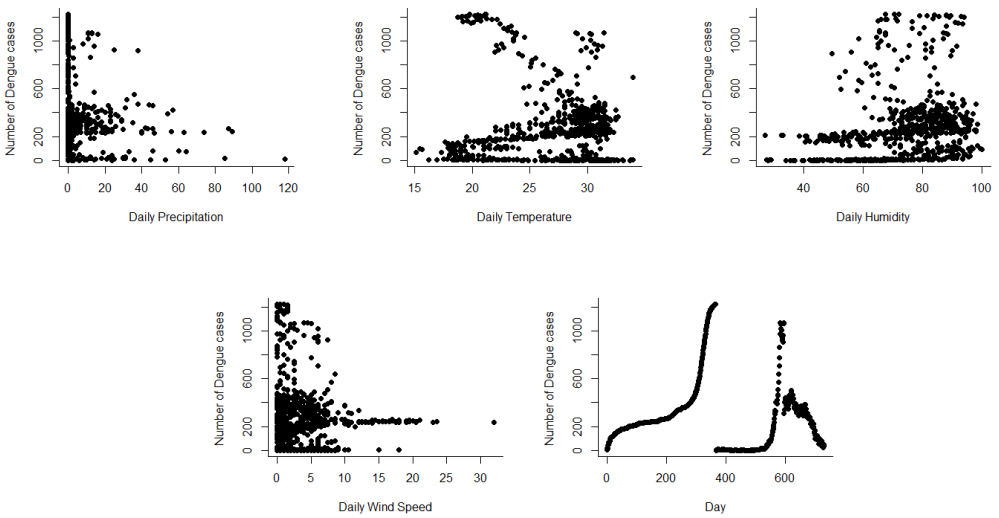


Fig 2. *Scatter diagram (a). The daily number of Dengue Cases vs. Daily Precipitation; (b). The daily number of Dengue Cases vs. Daily Temperature; (c). The daily number of Dengue Cases vs. Daily Humidity; (d). The daily number of Dengue Cases vs. Daily wind speed; (e). The daily number of Dengue Cases vs. Day during the period* 1^{st} *January 2020–* 31^{st} *December 2021.*

Interpreting the Posterior

To simulate the Poisson posterior regression model, we employ MCMC trace graphs, density plots, and autocorrelation plots 4 and show that our simulation has stabilized. From 1 January 2020 to 31 December 2021, only nine posterior simulations of Dengue case data had ACF histograms with skew, range, and trend that match the observed data. Think about the precipitation coefficient $beta_1$, which has a posterior median that is roughly -0.007. This suggests that we should expect roughly one time as much precipitation if it increases by one mm or 0.993% more, anti-discrimination laws: $e^{-0.007} = 0.993$ and the posterior median is around 0.015 for the temperature coefficient $beta_2$. It implies that if the temperature rises by one unit, we might anticipate 1.02 times as many anti-discrimination measures, or 1.02 percent more: $e^{0.0152} = 1.0153$. The posterior median for the humidity coefficient $beta_3$ is around 0.02115. This means that if the humidity increases by one unit, we should expect it to have 1.02 times as many, or 1.02 percent, more, likewise for the posterior median of the wind speed coefficient $beta_4$, which is -0.0378. This means that if the wind speed increases by one km/h, we should anticipate 0.96 times as many, or 0.96 percent, more.

Graphically Checking

Initially, the Markov chain distribution's trace and autocorrelation plots were used to visually assess convergence. 10,000 iterations of each of the four chains were investigated. For all parameters except $beta_0$, the trace plots 3 show a horizontal strip indicating stationarity and well mixing of the chains which indicates slow mixing of the chains.

Initially, convergence was evaluated visually using the trace and autocorrelation plots of the Markov chain distribution. We looked at 10,000 iterations of each of the four chains. The trace plots given in 3 display a horizontal strip suggesting stationarity and well mixing of the chains for all parameters except $beta_0$, which indicates slow

mixing of the chains. Furthermore, the autocorrelation plot 4 indicates that the current position of the chains does not predict the future position of the chains, indicating that the posterior distribution for parameters is extensively investigated. According to the autocorrelation plots in the 4, there is a decreased correlation between lengthy lags, which indicates that the chains were poor mixed.

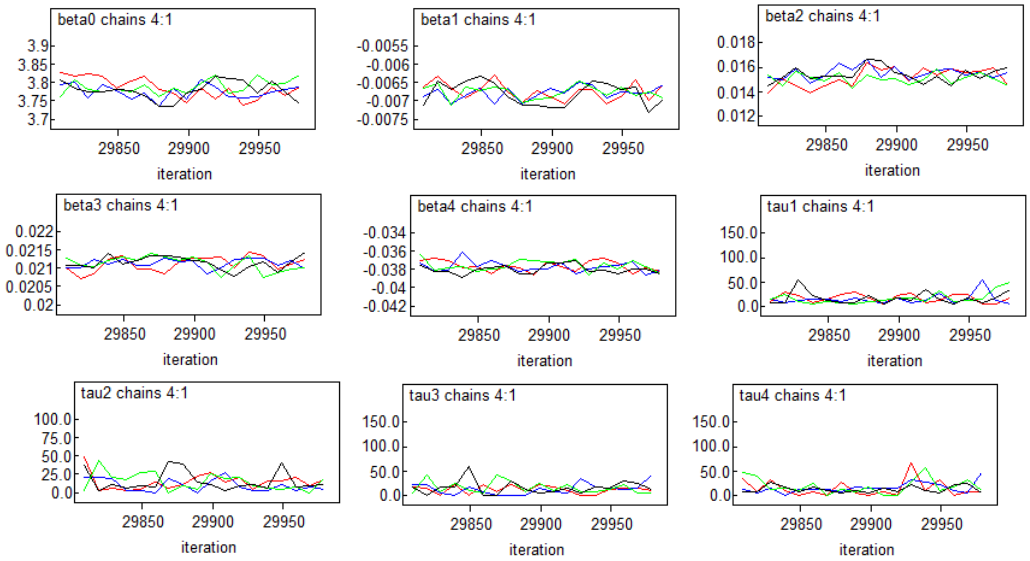


Fig 3. *Trace plots of parameters (β) and variance of random effects*

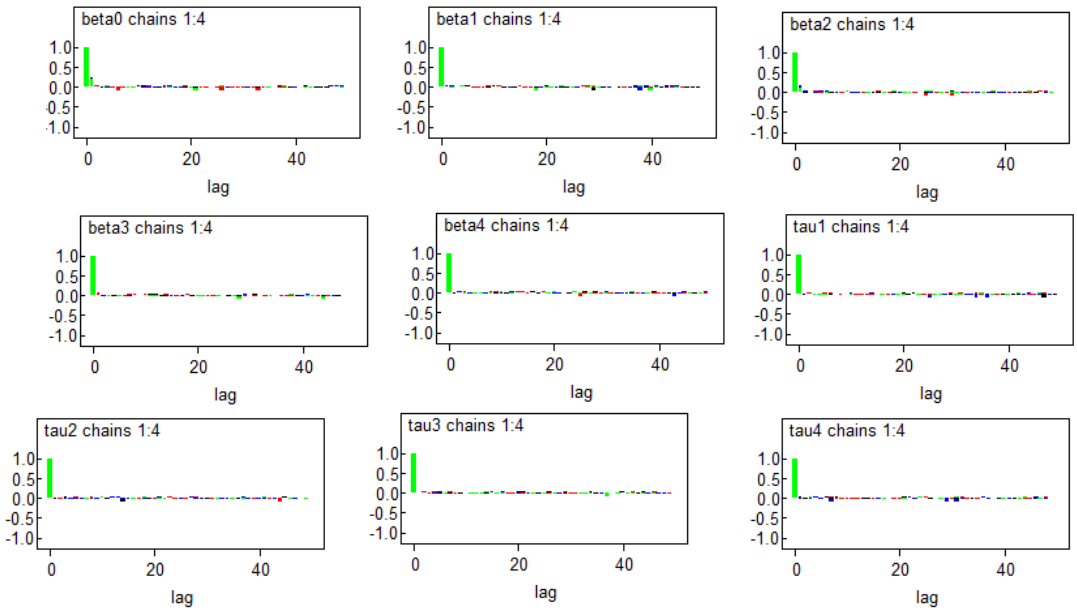


Fig 4. *Auto-correlation plots of parameters (β) and variance of random effects*

Formal Diagnostic Test

Three diagnostic tests are performed in order to confirm the stationarity, accuracy, and convergence: the Brooks-Gelman-Rubin (BGR) diagnostic approach developed by

Geweke, HeidelbergerWelch, and. Table 3 details the official diagnostic tests for the 4 model with random intercept and slope.

Table 3. Formal diagnostic tests for a bayesian regression model with random intercept and slope

parameter	Geweke	Heidelberger-Welch	BGR	effective sample size
Intercept (β_0)	0.285	0.850	1.000	3353.017
Precipitation (β_1)	0.827	0.387	1.000	3000.000
Temperature (β_2)	0.113	0.230	1.000	3816.157
Humidity (β_3)	-0.928	0.775	1.000	3000.000
Wind Speed (β_4)	0.348	0.060	1.000	3000.000
Deviance (σ^2)	1.425	0.567	1.000	3000.000

With default settings of 10% (first part of a chain) and 50% (second part of a chain), the Geweke diagnostic test demonstrated stationarity for all parameters with the exception of the estimated variance of the random intercepts, presuming that all Z-values for the parameters are constrained between -1.96 and 1.96. Heidelberger-diagnostic Welch's also showed that every parameter passed the convergence test, leading to the conclusion that the length of the chain is sufficient to ensure the accuracy of the posterior means of the parameters. Figure 3 shows the Brooks-Gelman-Rubin (BGR) diagnostic, which is the sole convergence diagnostic test based on the four chains.

Poor chain mixing was discovered to be the cause of the huge sample size disparity between the effective sample size and the MCMC simulation sample size (totaling 30,000). Additionally, it was found that $beta_2$ had a large discrepancy, which suggested considerable autocorrelation. Significant results suggest non-randomness when evaluating the correlation between a variable's most recent and previous values using autocorrelation.

For model evaluation purposes, different measures to check the model's fit are shown in table 4. It is clear that the model has a larger posterior predictive value (PD), a discrepancy metric that indicates complexity. In Table 4 $\bar{D}$ is the posterior mean of $-2logL$ and $\hat{D} = -2logL$ at a posterior mean of stochastic parameters.

Table 4. Measure of fit for the Poisson regression model

Y	$\bar{D}$	$\hat{D}$	P_D	DIC
Cases	186650.0	186645.0	5.123	186656.0
Total	186650.0	186645.0	5.123	186656.0

In figure 5, The model's intercept, slope, and precision density plots are shown. The distribution of posterior information appears to be normally distributed.

In the history plot in figure 6, the well-mixed initials values have very small differences which indicates that the initial values of coefficients $\beta_o, \beta_1, \beta_2, \beta_3, \beta_4$ got convergence. (see Appendicx)

Discussion

Dengue is a major hazard to public health and a significant economic burden in Bangladesh. An increasing body of evidence indicates that dengue imposes a massive socioeconomic cost on households, healthcare systems, and government health expenditures in endemic nations, particularly during outbreaks. An increasing number

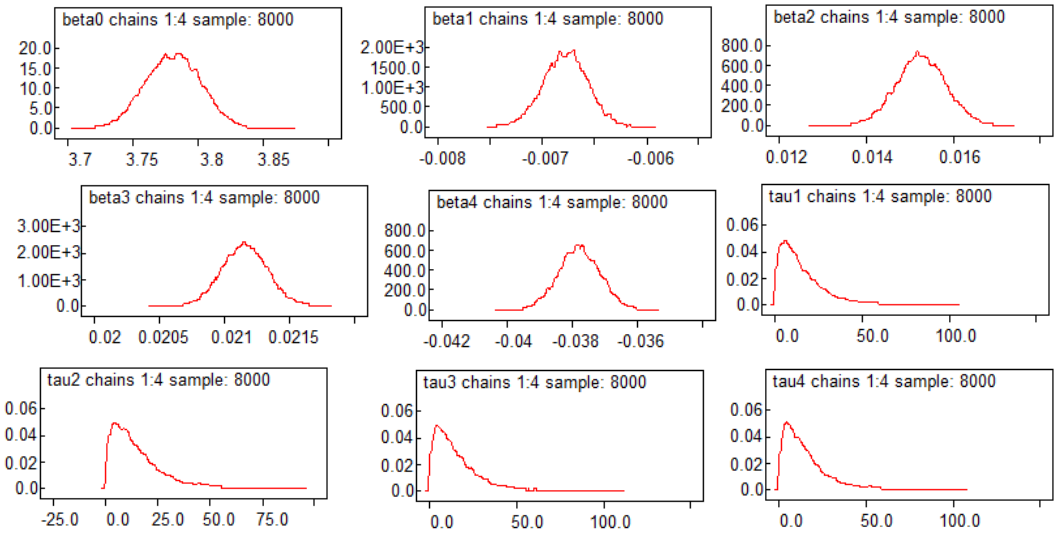


Fig 5. *Density plots for posterior distribution of parameters (β's) and precision*

of initiatives are being made to relate relatively local-area factors like rainfall, humidity, and temperature to dengue incidence in order to increase public health relevance.

Since Dengue fever is a growing public health concern in Bangladesh, its identification of alterations in the climatic factor pattern will enhance case-finding from an environmental standpoint. Consequently, the purpose of this study was to provide insight into the altering climatic manifestation of dengue infections in Bangladesh. In this study, we examined the effect of meteorological risk factors on the severity of dengue transmission using the dengue confirm cases. However, we must employ Bayesian methods such as Markov Chain Monte Carlo (MCMC) in order to use the informative prior ([39]). For Bayesian regression modeling, we built the Poisson regression model using the Normal distribution as the prior. The aim of Bayesian Regression is not to find the single "best" value of the model parameters but rather to determine the posterior distribution for the model parameters. Not only is the response generated from a probability distribution but the model parameters are assumed to come from a distribution as well. In this respect, an attractive class of sampling algorithm, called MCMC method is explored to solve the practical problem in a Bayesian manner. This study demonstrated that the Gibbs sampling, a highly computationally efficient MCMC method [40], can generate accurate estimates of Bayesian regression coefficients for Dengue counts. In order to assess how well the observable data fits the model of interest and whether or not data independent of the observed data fit the model given by the observed data, Gibbs sampling is used to find estimates for the parameters of interest ([41]).

We proved the Bayesian discrete Poison model's applicability to data on medical domain counts. We examined data on the total number of afflicted cases caused by Dengue fever in order to generate statistical proof of the impact of climatic conditions on Dengue transmission. In the instances given, we concentrated on a daily count of all 731 Dengue causes from January 1, 2020, to December 31, 2021, which is discrete and has a right-skewed distribution, making the full conditional distribution of interest.

The important posterior knowledge of the parameters is obtained by assuming the previous information. Furthermore, Figure 5 shows that the posterior distribution for the parameters is well examined and that they appear to be normally distributed. The model, which exhibits the presence of autocorrelation, likewise revealed a higher

discrepancy. Additionally, we used a variety of diagnostic tests to evaluate the inference technique on actual data, demonstrating both the results' stationary nature and their convergence. In this regard, the diagnostic outcomes are also demonstrated, demonstrating the precision of the posterior parameters. The model also exhibits higher posterior density (HPD) with poor mixing convergence beginning values. Low precipitation increases the propagation of dengue, according to empirical research [28, 42]. From our results, it might come to the conclusion that the Bayesian technique performed well and is easier to understand than traditional regression approaches in the literature on the basis of a variety of information criteria and the selection of influential elements.

Moreover, it is critical to investigate and describe these additional potential variables since they may have a significant influence on the frequency with which certain infectious diseases manifest and the long-term health and well-being of the general populace. Additionally, more study is needed to determine the genetic variations of dengue that are most prevalent as well as the effects of climate change on the biology of the vectors that spread these infectious diseases.

Conclusions

To sum up, we have given an overview of the Bayesian regression models used in count data analysis. Despite the fact that most current research has focused on a correlation approach between climatic characteristics and epidemic data. Unfortunately, there haven't been any direct tests with dengue outbreaks in different environmental contexts. Our research revealed striking similarities in the effects of precipitation, temperature, humidity, and wind speed on the seasonal viability and severity of dengue fever. This study contain a number of statistical techniques, and the Bayesian model revealed a substantial causal link between climatic variables and the spread of dengue.

As it is throughout the world, Dengue fever, an emerging disease, will continue to pose a serious threat to public health in Bangladesh. So, developing preventative and control measures is urgently needed in Bangladesh. To minimize the spread of an outbreak, institutions, non-governmental groups, policymakers, and government officials must launch short-term national measures. Important mosquito breeding places should be eliminated and pesticides sprayed. Water logging should be addressed, and canals, water tanks, rainwater collection tanks, downpipes, and gutters should be cleaned. In remote regions, the distribution of dengue detection kits to health centers and the training of health facilitators would be advantageous. Because personal apparel serves as a preventive strategy, schoolchildren should be given specific attention through the enhancement of school uniforms. The media might help by broadcasting information on dengue stages, the use of bed nets and insect repellents, and the wearing of light-colored, loose-fitting, long-sleeved, and breathable clothing [14]. Furthermore, a dengue virus vaccine could be introduced in the country, as it has been demonstrated to lower severity and hospital admissions by 80-90% in Asian youngsters [43].

We urge the creation of a nationwide dengue control program for clinical management of the virus, in addition to the already-existing national recommendations from the Directorate General of Health Services in Bangladesh, together with a broad community awareness campaign for better responses. Although the Bangladeshi government has launched various short-term initiatives, mostly in Dhaka, nationwide comprehensive action initiatives have fallen short. To stop preventable deaths and lessen the epidemic's disease burden, the government, and relevant stakeholders should give priority to this dengue outbreak and implement a comprehensive dengue control program. To entirely eradicate the *Ades* mosquito, numerous community-based awareness programs need to be launched and maintained. To address the catastrophic

health burden caused by dengue infections, a number of social protection programs, including "Shasthyo Surokhsha Karmasuchi (SSK)" may be implemented in metropolitan cities for poor and vulnerable households.

Limitation of the Study

This study focuses on the effects of climatic variables on Dengue epidemic in Bangladesh. Although this study is conducted based on Secondary data sources , this study have some limitations. The climatic data are not collected from individuals station of Meteorogical Department of Bangladesh (BMD), so it may not represent the whole country scenario. Moreover, When researcher conduced this study, the update data of Year 2022 was not published in Directorate General of Health Services (DGHS) of the Ministry of Health and Family Welfare [8]. Therefore, these results were not updated in this study. However, The study would be done through the utilization of questionnaire to the Dengue epidemic related to climatic risk factors.

References

1. Islam MA, Ahmed MU, Begum N, Chowdhury NA, Khan AH, del Carmen Parquet M, et al. Molecular characterization and clinical evaluation of dengue outbreak in 2002 in Bangladesh. Japanese journal of infectious diseases. 2006;59(2):85.

2. Biswas R, Mohammed FR, Sengupta P, Ahmed HS, Rahman MM, Sarker MAS, et al. Dengue NS1 antigen: a tool in early detection of dengue virus infection. Journal of Medicine. 2014;15(1):28–30.

3. Akram A. Alarming turn of dengue fever in Dhaka city in 2019. Bangladesh Journal of Infectious Diseases. 2019;6(1):1–2.

4. Alam H. Dengue deaths so far: most were infected a second time. 2019; 2021.

5. Alam H. Dengue outside Dhaka: non-critical patients crowd dist hospitals (2019); 2021.

6. Dayaram S, Pokharel S. Bangladesh hit by worst dengue outbreak on record. CNNhealth July. 2019;30:2019.

7. Sharmin S, Viennet E, Glass K, Harley D. The emergence of dengue in Bangladesh: epidemiology, challenges, and future disease risk. Transactions of The Royal Society of Tropical Medicine and Hygiene. 2015;109(10):619–627.

8. Directorate General of Health Services (DGHS) GotPRoB Ministry of Health & Family Welfare. Disease Control Directorate;. `https://old.dghs.gov.bd/index.php/bd/home/5200-daily-dengue-status-report`.

9. Ahsan A, Haider N, Kock R, Benfield C. Possible drivers of the 2019 dengue outbreak in Bangladesh: the need for a robust community-level surveillance system. Journal of medical entomology. 2021;58(1):37–39.

10. (2022) WHO. Dengue–Bangladesh;. `https://www.who.int/emergencies/disease-outbreak-news/item/2022-DON424`.

11. Lindsay S, Birley M. Climate change and malaria transmission. Annals of Tropical Medicine & Parasitology. 1996;90(5):573–588.

12. Hsan K, Hossain MM, Sarwar MS, Wilder-Smith A, Gozal D. Unprecedented rise in dengue outbreaks in Bangladesh. The Lancet Infectious Diseases. 2019;19(12):1287.

13. Lindsay SW, Wilson A, Golding N, Scott TW, Takken W. Improving the built environment in urban areas to control Aedes aegypti-borne diseases. Bulletin of the world health organization. 2017;95(8):607.

14. Mone FH, Hossain S, Hasan MT, Tajkia G, Ahmed F. Sustainable actions needed to mitigate dengue outbreak in Bangladesh. The Lancet Infectious Diseases. 2019;19(11):1166–1167.

15. Simmons CP, Farrar JJ, van Vinh Chau N, Wills B. Dengue. New England Journal of Medicine. 2012;366(15):1423–1432.

16. Struchiner CJ, Rockloev J, Wilder-Smith A, Massad E. Increasing dengue incidence in Singapore over the past 40 years: population growth, climate and mobility. PloS one. 2015;10(8):e0136286.

17. Dhar-Chowdhury P, Haque CE, Driedger SM. Dengue disease risk mental models in the city of Dhaka, Bangladesh: juxtapositions and gaps between the public and experts. Risk Analysis. 2016;36(5):874–891.

18. Wiwanitkit V, et al. Strong correlation between rainfall and the prevalence of dengue in central region of Thailand in 2004. Journal of Rural and Tropical Public Health. 2005;4:41–42.

19. Guzman MG, Kouri G. Dengue and dengue hemorrhagic fever in the Americas: lessons and challenges. Journal of Clinical Virology. 2003;27(1):1–13.

20. Gharbi M, Quenel P, Gustave J, Cassadou S, Ruche GL, Girdary L, et al. Time series analysis of dengue incidence in Guadeloupe, French West Indies: forecasting models using climate variables as predictors. BMC infectious diseases. 2011;11(1):1–13.

21. Eastin MD, Delmelle E, Casas I, Wexler J, Self C. Intra-and interseasonal autoregressive prediction of dengue outbreaks using local weather and regional climate for a tropical environment in Colombia. The American journal of tropical medicine and hygiene. 2014;91(3):598.

22. Descloux E, Mangeas M, Menkes CE, Lengaigne M, Leroy A, Tehei T, et al. Climate-based models for understanding and forecasting dengue epidemics. PLoS neglected tropical diseases. 2012;6(2):e1470.

23. Moore CG. Predicting Aedes aegypti abundance from climatologic data. 1985;.

24. Arcari P, Tapper N, Pfueller S. Regional variability in relationships between climate and dengue/DHF in Indonesia. Singapore Journal of Tropical Geography. 2007;28(3):251–272.

25. Promprou S, Jaroensutasinee M, Jaroensutasinee K. Climatic Factors Affecting Dengue Haemorrhagic Fever Incidence in Southern Thailand. 2005;.

26. Schreiber KV. An investigation of relationships between climate and dengue using a water budgeting technique. International Journal of Biometeorology. 2001;45:81–89.

27. Choudhury ZM, Banu S, Islam AM. Forecasting dengue incidence in Dhaka, Bangladesh: A time series analysis. 2008;.

28. Karim MN, Munshi SU, Anwar N, Alam MS. Climatic factors influencing dengue cases in Dhaka city: a model for dengue prediction. The Indian journal of medical research. 2012;136(1):32.

29. Kanchanapairoj K. Climatic Factors Influencing the Incidence of Dengue Haemorrhigic Fever in Southern Thailand. Prince of Songkla University, Pattani Campus; 1999.

30. Depradine C, Lovell E. Climatological variables and the incidence of Dengue fever in Barbados. International Journal of Environmental Health Research. 2004;14(6):429–441.

31. Hales S, Weinstein P, Souares Y, Woodward A. El Niño and the dynamics of vectorborne disease transmission. Environmental Health Perspectives. 1999;107(2):99–102.

32. Yi B, Zhang Z, Xu D, Xi Y. Relationship of dengue fever epidemic to Aedes density changed by climate factors in Guangdong Province. Wei sheng yan jiu= Journal of Hygiene Research. 2003;32(2):152–154.

33. Akter R, Hu W, Gatton M, Bambrick H, Cheng J, Tong S. Climate variability, socio-ecological factors and dengue transmission in tropical Queensland, Australia: a Bayesian spatial analysis. Environmental Research. 2021;195:110285.

34. Cameron AC, Trivedi PK. Regression analysis of count data. vol. 53. Cambridge university press; 2013.

35. Casella G, George EI. Explaining the Gibbs sampler. The American Statistician. 1992;46(3):167–174. doi:https://doi.org/10.2307/2685208.

36. Geman S, Geman D. Stochastic relaxation, Gibbs distributions, and the Bayesian restoration of images. IEEE Transactions on pattern analysis and machine intelligence. 1984;(6):721–741. doi:10.1109/TPAMI.1984.4767596.

37. Gelfand AE, Smith AF. Sampling-based approaches to calculating marginal densities. Journal of the American statistical association. 1990;85(410):398–409.

38. Katsis A, Ntzoufras I. Bayesian hypothesis testing for the distribution of insurance claim counts using the Gibbs sampler. Journal of Computational Methods in Sciences and Engineering. 2005;5(3):201–214. doi:10.3233/JCM-2005-5304.

39. Gelman A, Carlin J, Stern H, Dunson D, Vehtari A, Rubin D. Bayesian data analysis; 2013.

40. Ntzoufras I. Bayesian modeling using WinBUGS. vol. 698. John Wiley & Sons; 2011.

41. Rouchka EC. A brief overview of Gibbs sampling. Bioinformatics Technical Report Series, No TR-ULBL-2008-02, University of Louisville. 1997;9.

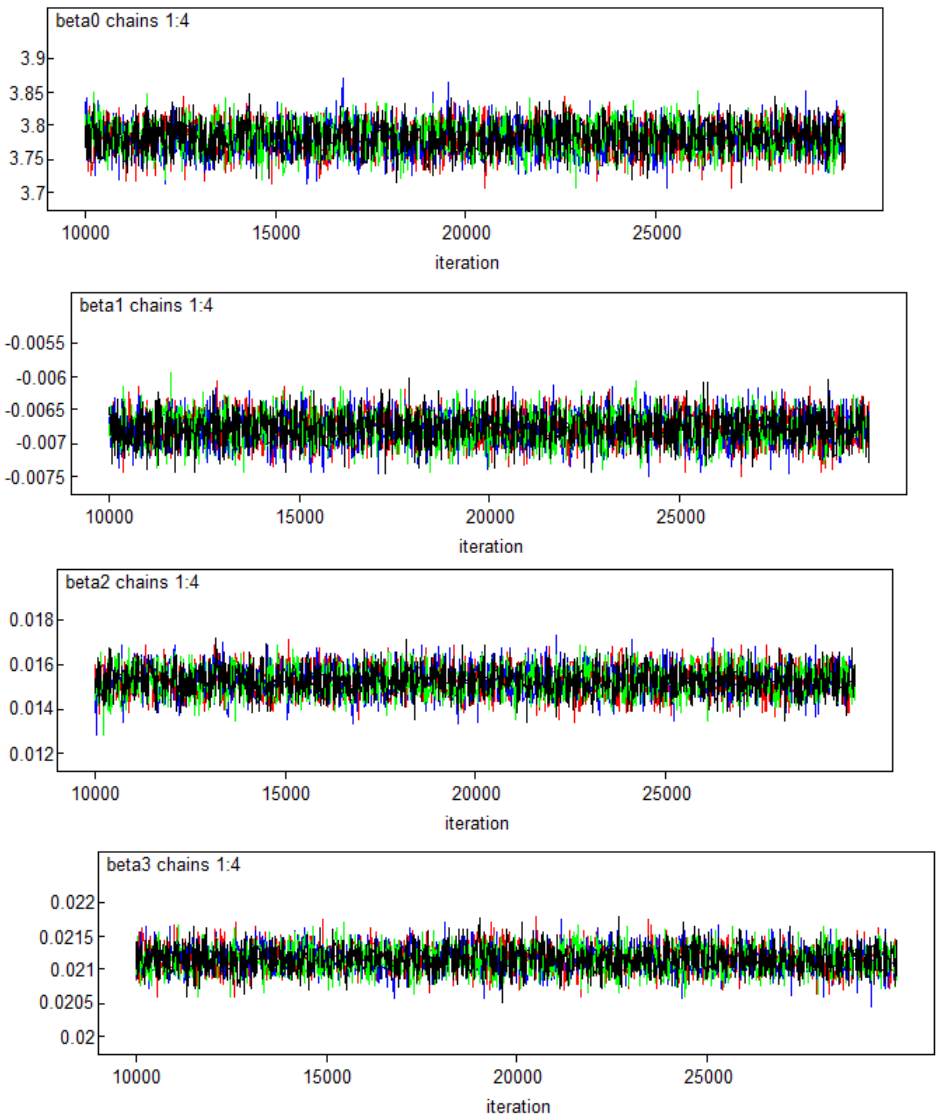
42. Sang S, Gu S, Bi P, Yang W, Yang Z, Xu L, et al. Predicting unprecedented dengue outbreak using imported cases and climatic factors in Guangzhou, 2014. PLoS neglected tropical diseases. 2015;9(5):e0003808.

43. Capeding MR, Tran NH, Hadinegoro SRS, Ismail HIHM, Chotpitayasunondh T, Chua MN, et al. Clinical efficacy and safety of a novel tetravalent dengue vaccine in healthy children in Asia: a phase 3, randomised, observer-masked, placebo-controlled trial. The Lancet. 2014;384(9951):1358–1365.

Supplementary Materials

All data are uploaded to the Kaggle website which can be found in `https://www.kaggle.com/datasets/drmdrezaulkarim/researchdata`.

Appendix



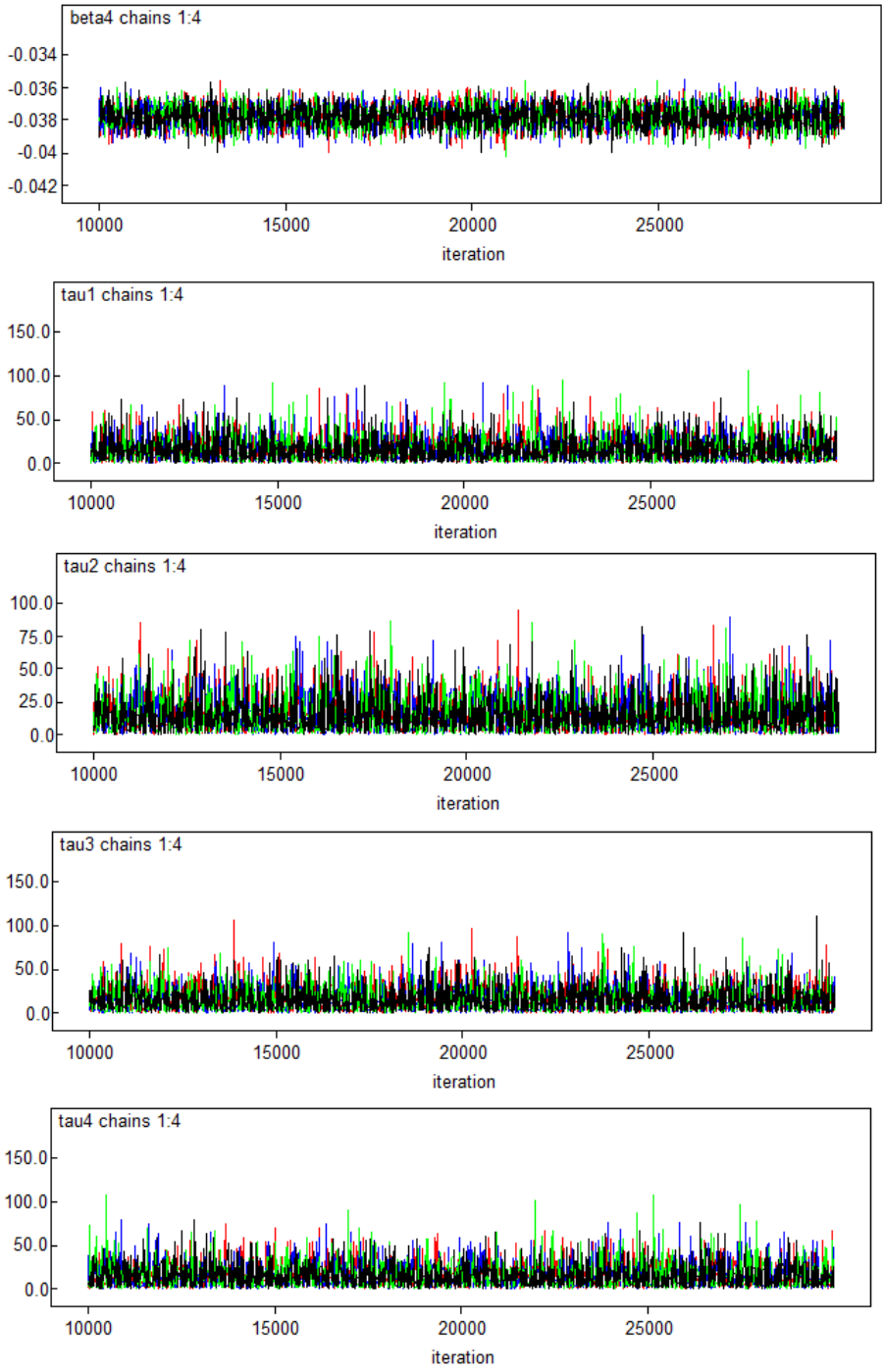


Fig 6. *History plots of parameters (β's) Obtained from WinBUGS after 30,000 iterations*

Responses to all reviewers of

“Climatic Risk Factors for the Transmission of Dengue Fever: Bangladesh Perspective”

(Manuscript PONE-D-23-15182)

We would like to thank the Editor-in-Chief and two anonymous reviewers for their detailed reading and valuable comments on the original version of the manuscript. In this revision we addressed all the points raised in the reports.

A point-to-point reply to all comments raised in the review reports are provided below and on the enclosed separate pages.

Review Comments to the Author
Reviewer #1

Comment:

Summary:

The paper investigates “Climatic Risk Factors for the Transmission of Dengue Fever: Bangladesh Perspective”. Despite being a significant public health concern for Bangladesh, this topic has already received considerable attention from numerous earlier and recently published studies. The purpose of the study has also been used in the past to explore comparable issues utilizing earlier data on Bangladesh. As a result, the paper's main original addition appears to be its application of this study to this study’s “Bayesian Approach”, and its conclusions/discussion largely—and not surprisingly—reflect those of previous research. The discussion failed to explain properly the objective of the study.

The paper needs to be thoroughly proofread by a professional or expert. It is not written to a high degree for academic writing, and there are several grammatical/spelling errors, which frequently make claims and arguments less clear. Additionally, the authors ought to eliminate any similarities from this work. Numerous times, the way that statistical results are interpreted is also ambiguous. The paper also neglected to mention or cite comparable but equally significant published studies from the nearest countries. The introduction fails to effectively justify the need for studying the issue, tables and results are not focused on the title, and objectives seem different in several parts of the manuscript. The tables and their interpretations are not similar, and the paper's findings by themselves are insufficient to support the discussion and conclusions.

Below are some comments with more information: Please include the line number in the main manuscript next time. However, to review purposes I inserted them. To track and resolve my comments please insert line number first.

Reply: Thanks for the query. We have now used the latex template of the journal for writing the revised version of our manuscript with additional corrections. The corrections are specified below subsections**.**

Abstract:

Please re-write the abstract. Authors take so many introductory sentences before the objective. Page 1, Line 28: "According to the study, less precipitation reduces infected cases and fatalities from Dengue." Need some data/statistics to validate it. As the reader will study this abstract first. Please explain, which information take you to support this statement. Also, for this, "Furthermore, the spread of Dengue has diminished due to high temperatures, which have also affected the virus's ability to survive and spread."

Reply: Thank you for this comment. The abstract is rewritten specifying the objectives and results. We have also added the outcome of the study which validates our study as well.

Introduction:

I am requesting to authors to check the serial of the citation in the whole manuscript. If possible, please use the citation manager.

Page 1, Lines 47-48: "In the middle of the epidemic, the Directorate General of Health in Bangladesh recorded 1026 confirmed cases in 2020, and 20,000 in 2021". Reviewers seem that it is an old reference and is also confusing. Please update this information from a recently published manuscript: https://academic.oup.com/jme/advance-article/doi/10.1093/jme/tjad057/7172758
Page 1, Lines 50-51: "The Ministry of Health & Family Welfare of Bangladesh has reported 52,807 laboratory-confirmed dengue cases overall as of 20 November 2022, with 230 deaths associated with the disease". Authors should update this information before submitting again.
Page 2, Lines 86-88: "Only a small amount of research has been executed so far on how weather influences the weight of ailment, appreciably dengue in South Asia." Reviewers seem that the statement is not true. Some recent manuscripts in Bangladesh related to weather factors: https://academic.oup.com/jme/advance-article/doi/10.1093/jme/tjad057/7172758, https://www.mdpi.com/1660-4601/20/6/5152, as this is the middle of 2023. There are a lot of published papers similar to this topic. Please cite them before submitting them again.

Page 2, Lines 91-93: Statistically, it appears that most investigations utilized either very simple correlational techniques [12, 19, 23] or regression modeling [5, 37], or both.". The author stated or try to explain that all of the cited references are from Bangladesh, because of the previous line.

But reviewers seem all are from outside of Bangladesh. Either please change the previous line or change the citation from the stated references.

Page 2, Lines 90-101: Reviewers hope that this paragraph will provide more and only about other's methods with findings and details about the Bayesian Regression Method and its pros and cons, as this study seems trying to focus more on the methodology (benefit) of this model. Page 2, Lines 95-101: "Moreover, Bangladesh's lack of preparedness, including weak public health infrastructure and ineffective vector-control programs, increases the impact of dengue virus importation, resulting in rising outbreaks. Anorexia, nausea, vomiting, pharyngitis, upper respiratory tract symptoms, relative bradycardia, prostration, depression, hyperesthesia, lymphadenopathy, and rash are some of the symptoms and signs of dengue [13]. Other symptoms and signs include fever, backache, arthralgia, headache, generalized pain, eye pain, lacrimation, scleral injection, and rash. Since 2000, med- ical professionals in Bangladesh have clinically identified dengue following WHO guidelines." As symptoms are not our concerned variables, all these statements are not necessary for the introduction. Reviews and readers will hope for some literature review of findings related to climatic factors in this place. Page 2, Line 106: "Following are the research's main contributions" No need to explain it. Page 2, Lines 103-104 and Lines 114-116: "This study examines how key meteorological variables such as precipitation, heat, moisture, and wind speed may promote Dengue incidence in Bangladesh." And "In order to develop and provide a better knowledge of the complicated relationship between climate and health, this study aims to assess the impact of climatic risk variables on dengue incidence in Bangladesh." Reviewers seem to both sentences are trying to share the same statement, please keep only one.

Reply: Thank you for your reply. We appreciate your kind suggestions. All the mentioned information is now updated using the provided reference. Also the unnecessary lines are deducted from the manuscript**.**

Materials:

Page 3, Lines 125-127: "The weather variables of temperature (measured in ◦C), humidity (measured in %), precipitation (measured in mm), and wind speed (measured in km/h) were collected from Bangladesh Meteorological Department." The authors provided a link that does not take the reviewers to the BMD website. As per reviewers' knowledge, BMD data is not free to use. Please explain the real source and how you collect them. The authors also should explain how climatic factors from one station can represent the whole country. As dengue data was collected from the whole country. Page 3-4: More details are needed about the dependent and independent variables. Authors should provide more details about the real/practical use of the models they used. More citations are needed in most methodological parts. Also, explain how time series data is appropriate in your models.

Reply: Thanks for your comment. The data source and website link are specified in our revised manuscript. As our daily data was collected from a free access website, where the maximum unit of representative data of Bangladesh was given, and the total daily dengue cases were also recorded by the Ministry of Health and Family Welfare, we believe that this information can represent the

whole country. Moreover, Time series model is not used in our study but we may think about it in our next research.

Results:

Page 5, Line 13: "The fastest recorded speed occurred in May 2020." Please include the word "wind".

Page 5, Line 13-15: "These findings indicate that all climatic parameters contribute to a conducive environment, increasing mosquito breeding and dengue transmission rates which is also supported by". Place this statement in discussion. In addition, this statement is not correct and also not possible from your available results/findings. Please, re-write it or provide some evidence to support your statement.

Page 5, Line 37-39: "It is hypothesized that a skewed distribution would be more accurate in forecasting the values of this variable based on a comparison of the distributional shape of the number of Dengue cases.". Reviewers didn't notice the objective of forecasting, please mention in the objective if you want to try forecasting.

Page 6, Line 56-58: "To carries our Bayesian inference on the statistical problems using MCMC methods, we used the most popular Bayesian software. Three WinBUGS tools are required to obtain posterior samples: (a) the specification tool, (b) the sample monitor tool, and (c) the update tool.". Please replace this statement in the methods section.

Reply: Thank you for these comments. We have now replaced some sentence in methodology section with additional changes in results section.

Discussion:

Page 11, Lines 59-60: "Figure 5 shows that the posterior distribution for the parameters is well examined and that they appear to be regularly distributed." Reviewers seem that the statement you used first time here. I am concerned about the use of graphs in the discussion part. Please replace this graph in the result part and discuss the findings in the "discussion" part.
Page 11, Lines 65-66: "Low precipitation increases the propagation of dengue, according to empirical research.". Need citations.

Page 11, Lines 65-66: "Dengue has been demonstrated to spread less frequently in high temperatures, which reduces the virus's ability to survive and spread.". Please refer to this finding from your result section.

Page 11, Lines 67-68: "Instead, freezing conditions give coronaviruses a secure haven that hastens their survival and spread.". Please recheck this statement. Why coronaviruses are here?
Page 11, Lines 68-71: "It may be concluded that the climate has a substantial impact on the risk

factors for virus transmission in Bangladesh. We came to the conclusion that the Bayesian technique performed well and is easier to understand than traditional regression approaches in the literature on the basis of a variety of information criteria and the selection of influential elements.". Please refer to this finding from your result section.

Page 11: No reference for fig. 6. Please replace this figure in the result part with a proper explanation.

The discussion part should be rewritten and should focus on the used variables from the study. Discussion should discuss with Authors' findings with others. As this is a theory/methodological-based study, you should discuss other findings with various methodological aspects. Authors should explain the significance and the difference of these methods with others. This part should support the result but there is some discrepancy between the result and the discussion. Please cited others in the discussion.

Reply: Thank you for your suggestions. We have interchanged the position of graphs in our final manuscript where Figure 5 is kept in result section and Figure 6 is replaced in Appendix section. "Low precipitation increase the propagation of dengue, according to empirical research", In this line we have now added 2 latest citations. Some sentences are now moderated in our manuscript, and some spellings are also corrected.

Conclusion:

Page 12, Lines 83-84: "Despite the fact that the majority of recent studies have concentrated on a correlation approach between meteorological parameters and pandemic data." Is Dengue Pandemic in Bangladesh? The authors should check that.
Page 12, Lines 87-88: "This study used a number of statistical techniques, and the model revealed a substantial causal link between climatic variables and the spread of dengue." Is Dengue Pandemic in Bangladesh? The authors should provide valid evidence to state this.
The conclusion needs to be more specific and highlight key findings. This should support the result. Suggested providing less discussion in the conclusion. Reviewers didn't find so much to conclude the whole results and discussion in the "conclusion" part. Much information is redundant in the discussion and conclusion.

Reply: Thanks for your comment. The conclusion part is now more specified according to the reviewer.

Reviewer #2

This manuscript addressed the climatic risk factors of dengue transmission in Bangladesh country based on the data over a 2-year period. The authors examined how the climatic variables affect dengue epidemics in the study area by adopting Bayesian inference through MCMC with Gibbs

sampling. However, in my opinion, the paper has some shortcomings and the manuscript needs a few points of consideration.

Comment#1

As this research work aimed at providing support to decision making, I believe the duration of the study period and the data used in the present study is not adequate to serve the purpose.

Reply: Thank you for the comment. We used the most recent data available when we did this research. We believe this study still has enough merits to serve the purpose**.**

Comment#2

Introduction part is very lengthy and not well organized. Suggest rewriting to maintain continuity.

Reply: Thanks for your comment. The Introduction part is revised to maintain its continuity.

Comment#3

Introduction: Since the study is oriented in Bangladesh perspective, suggest including a paragraph citing the climate scenario, and dengue vector complexity in Bangladesh.

Reply: Thanks for your comment. In our final manuscript more citations are now added.

Comment#4

The authors did not provide recent literature and mentioned only about the tradition correlation and regression models. However, there are many other models like Bayesian geo statistical models which studied the role of climate variability on dengue transmission. Please mention the recent models and explain the superiority of the present Bayesian Poisson regression models when compared.

Reply: Thanks for your comment. One Resent literature about Bayesian Poisson model is mentioned in introduction part with appropriate citation.

Comment#5

The authors mentioned that the climatic variables influence dengue transmission, however, they have not established how different climatic factors affect the vector and virus behavioral traits.

Reply: Thanks for your comment. In this study, we showed the relationship of climatic risk variables with dengue epidemics using Bayesian inference. How different climatic factors affect the vector and virus behavioral traits, that was not our research purpose.

Comment#6

The methods and algorithms in the methods and material section are explained comprehensively and contain unwanted information. Simplify this section.

Reply: Thanks for your comment. The method section is now more simplified and some sentence are also deducted.

Comment#7

Results: table-1: mention the units of variables and check the spelling of Skewness.

Reply: Thanks for your suggestions. The unit of the variable are added in table 1 and the spelling is corrected.

Comment#8

Figure-2: The title of the figure is wrongly labelled. Plot a & b are labelled with the same title.

Reply: Thanks for your comment. The label of Plot a & b are titled correctly in final manuscript.

Comment#9

The estimated Bayesian Poisson model equation is refereed in terms of log cases, however, the cases were not log-transformed in figure 1& 2.

Reply: Thanks for your comment. The estimated Model is written according to Bayesian Poisson regression model equation 2. Figure 1 and 2 are plotted for descriptive data representation**.**

Comment#10

The MCMC iteration was specified as 30,000 in the update tool and beg was set between 10,000 – 30,000 in the sample monitor tool. What id beg here? And the description of why this value was chosen is non-informative. Was sensitivity analysis performed for the threshold limits? This information would be useful for future decision making in future research.

Reply: Thanks for your comment. Id "*beg*" (to the Sample Monitor Tool) instructs WinBUGS to discard the first 10000 simulations to get past any initial transients. And No sensitivity analysis was performed here for the threshold limits.

Comment#11

Why the effective sample size for posterior distribution and diagnostic test was different. Please explain.

Reply: Thanks for your comment. The effective sample size for posterior distribution and diagnostic test results are tabulated using WINBUGS, the size is found different. These happened for large number of iteration, as we assume it from 10000 to 30000.

Comment#12

The authors did not use cross validation to construct the model during the development phase. To improve the model's performance, it is recommended to use a cross validation method.

Reply: Thanks for your suggestion. In our research, we only used Bayesian Poisson regression model to assess the relationship between Dengue outbreak and Climatic factors. Cross Validation method will be applied to improve the model's performance in our next work.

Comment#13

Conclusion part is very prolonged, simply removing the unnecessary information.

Reply: Thanks for your comment. The conclusion part is made simple than earlier in revised version**.**

Comment#14

In the discussion part it is mentioned as “Instead, freezing conditions give coronaviruses a secure haven that hastens their survival and spread.” I feel it is irrelevantly mentioned about the coronaviruses. Please check the context and modify the sentence.

Reply: Thanks for your comment. The correction of this line is added in our revised manuscript**.**

Comment#15

Provide a paragraph summarizing the limitations of the study.

Reply: Thanks for your suggestion. The limitation of the study paragraph is added just before the conclusions**.**

Data Review URL

Click here to download Data Review URL
http://www.kaggle.com/datasets/drmdrezaulkarim/researchdata