MATHEMATICAL AND STATISTICAL INSIGHTS INTO CLIMATE-INDUCED HEALTH CONSEQUENCES IN BANGLADESH

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ABSTRACT

This study offers a comprehensive exploration of the consequences of climate alteration on people's health in Bangladesh, employing mathematical and statistical analyses. The global concern of climate alteration and its profound effects on public health are becoming increasingly urgent. Bangladesh, due to its vulnerability to a variety of climate-related challenges, serves as a crucial focal point for assessing the physiological and psychological health implications brought about by a shifting climate. By leveraging a robust dataset and employing rigorous mathematical and statistical methodologies, we investigate the intricate connections between climate-related variables and health outcomes in Bangladesh. We assess various aspects of physiological health, including heat-related illnesses, vector-borne diseases, and malnutrition, in conjunction with the evaluation of psychological well-being, which encompasses stress, anxiety, and mental health disorders. Our study uncovers persuasive evidence of climate alteration's adverse effects on the overall health of the Bangladeshi population. Elevated temperatures are associated with a rise in heat-related illnesses, and alterations in rainfall patterns are linked to the proliferation of vector-borne diseases. Furthermore, shifts in food security and access to clean water have far-reaching consequences for malnutrition rates. On the psychological front, our analysis highlights a significant correlation between climate-induced stressors and the prevalence of mental health disorders. This underscores the intricate interplay between environmental stressors and psychological well-being. The findings from this research lay the groundwork for a quantitative understanding of the multifaceted implications of climate alteration on health in Bangladesh. As climate alteration continues to exacerbate health challenges, the insights presented herein provide indispensable guidance for policymakers and public health professionals, aiding them in devising adaptive strategies and interventions aimed at safeguarding the well-being of the Bangladeshi population amidst an evolving climate landscape.

Keywords: *Climate alteration, health, ASAT, BBS, SDG*

1. INTRODUCTION

Climate alteration is a global phenomenon that affects every region of the world and poses a wide range of difficult issues with far-reaching effects [1]. Bangladesh is one of the countries in the region most vulnerable to the various effects of climate alteration [2]. Bangladesh, a country in South Asia, is particularly susceptible to the negative consequences of climate change, which makes it an important field of research for comprehending how changing environmental circumstances impact human health [3]. Bangladesh is especially vulnerable to climate change due to its geographic location. This low-lying nation is naturally vulnerable to rising sea levels, harsh weather, and changing patterns of rainfall since it is situated in the delta of three main river systems: the Ganges, Brahmaputra, and Meghna [4]. The effects of the altering climate are manifold, including rising average temperatures, more frequent and severe cyclones, floods, and droughts, as well as irregular monsoon seasons [5]. The ecology and the people living in Bangladesh may suffer greatly as a result of these changes [6].

There is growing worry about the complex relationship between the health of Bangladesh and climate alteration. The well-being and health of the public are significantly impacted by changing precipitation patterns, rising temperatures, and an increase in the frequency of natural disasters [7]. These repercussions cover both immediate and delayed health effects. Heat stress and heat-related disorders can result from rising temperatures, particularly in susceptible populations [8]. Changes in temperature and precipitation patterns have the potential to modify the range of disease-carrying vectors, including mosquitoes, hence increasing the spread of diseases like dengue, chikungunya, and malaria [9]. Extreme weather and flooding can contaminate water supplies, increasing the risk of waterborne illnesses such as cholera and diarrhea [10]. Crop yields and food availability can be impacted by climate alterations, which may result in hunger and related health problems [11]. Affected communities may experience higher levels of stress, anxiety, and mental health issues as a result of recurrent natural catastrophes and the loss of livelihoods brought on by climate-related variables [12].

Understanding the complex connections between climate alteration and health in Bangladesh requires a focus on mathematical and statistical methods [13]. These fields offer a framework for data analysis and modeling that helps to spot patterns, forecast outcomes, and guide the development of evidence-based treatments and policies [14]. To find patterns and relationships between climate change and health outcomes, mathematical approaches are applied to historical climate data, health records, and other pertinent information [15]. To evaluate the effects of climate alteration on disease transmission and the efficacy of different interventions, statistical models, such as epidemiological models, can be used [16]. In order to assist with preparedness and mitigation initiatives, probability and risk analysis are used to predict the likelihood of various health impacts in various climatic scenarios [17]. Designing public health policies and adaption strategies that effectively address the new health issues brought on by climate change need statistical knowledge [18].

It is critical to comprehend how Bangladeshi health and climate alteration are related for a number of reasons. First off, Bangladesh has one of the densest populations in the world, and its sensitivity to climate alteration emphasizes how urgent it is to solve these issues. Second, the knowledge gathered from this study may prove beneficial not only for Bangladesh but also for other areas dealing with related problems. In order to shed light on this urgent topic, this research explores the complex relationship between climate alteration and health outcomes in Bangladesh, using statistical and mathematical insights. It can act as a guide for creating evidence-based plans to lessen the negative effects of climate alteration on human health.

2. METHODOLOGY

This study uses statistical and mathematical methods to provide a thorough examination of the health effects caused by climate alteration in Bangladesh. The main goals of this study are to identify the most common diseases associated with alterations in the climate in Bangladesh, measure the impact of climate factors on the prevalence of these diseases, and identify the regional distribution of the health impacts associated with climate alteration. In order to accomplish these objectives, we have collected quantitative information on natural disasters and climate change from the World Bank and Bangladesh Bureau of Statistics (BBS) databases. The aforementioned data forms the basis for an analysis of the changing trends and patterns related to climate alteration and natural disasters in Bangladesh, along with their impact on the health of the most susceptible individuals and communities. We used Microsoft Excel 365 for graphical data visualization as part of our investigation, and SPSS Version 25 was used for correlation and regression analysis. Based on a cutoff p-value of < 0.05, statistical significance is evaluated. The partial correlation coefficient ($r_{uv.w}$) between two variables U and V while controlling for a third variable W is given by:

$$r_{uv.w} = \frac{r_{uv} - r_{uw}r_{vw}}{\sqrt{(1 - r_{uw}^2)\,(1 - r_{vw}^2)}}$$

The partial correlation coefficient statistically eliminates the impact of the third variable W while assessing the direction and intensity of the association between U and V. After taking into consideration the relationship that both U and V have with W, it aids in evaluating the direct association between U and V. An outcome variable (O) and two or more explanatory variables (E_1,E_2,E_3,...,Ec) are modeled using multiple linear regression. Finding the coefficients (ζ_0,ζ_1,ζ_2,ζ_3,...,ζc) that minimize the sum of squared errors is the aim of multiple linear regression. This process results in a model that most closely matches the data and may be utilized to forecast or comprehend the relationships between the variables. The degree and direction of the correlations between each independent variable and the dependent variable are revealed by the coefficients. Mathematically:

$$E(O) = \zeta_0 + \zeta_1 E_1 + \zeta_2 E_2 + \zeta_3 E_3 + \ldots + \zeta c Ec$$

Analyses of correlation and regression are essential for examining the health effects of climate change in Bangladesh. They produce insightful information, strong evidence, and quantitative measurements that support informed decision-making, public health intervention design, and methods to lessen the negative consequences of climate change on population health. These analytical techniques enable scientists and decision-makers to determine if climatic variables—such as temperature, precipitation, and air quality—and health outcomes—such as illness incidence and mortality rates—have a statistically significant association. They illuminate the direct impacts of climate-induced alterations on public health.

These analyses enable the accurate assessment of the direction and strength of the correlations between climate parameters and health indicators through the use of regression and correlation coefficients. This quantitative basis enables a thorough evaluation of the impact of climate on health outcomes. The conclusions drawn from these analyses provide empirical support for policy decisions in the areas of public health, healthcare, and government. This data backs up the planning of healthcare services, the distribution of resources, and the implementation of actions meant to reduce the health risks associated with climate change. Additionally, correlation and regression analysis might identify particular Bangladeshi regions or population groups that are particularly vulnerable to the negative health effects of climate alteration. Through proactive planning and early intervention techniques to address possible health hazards, these assessments allow the development of predictive models that predict how future climatic shifts may effect health outcomes. The outcomes of these assessments can also be used to direct the development of evidence-based policies designed to lessen the negative effects of climate alteration on health. These policies can include programs to improve public health awareness, support disaster preparedness, and improve healthcare infrastructure.

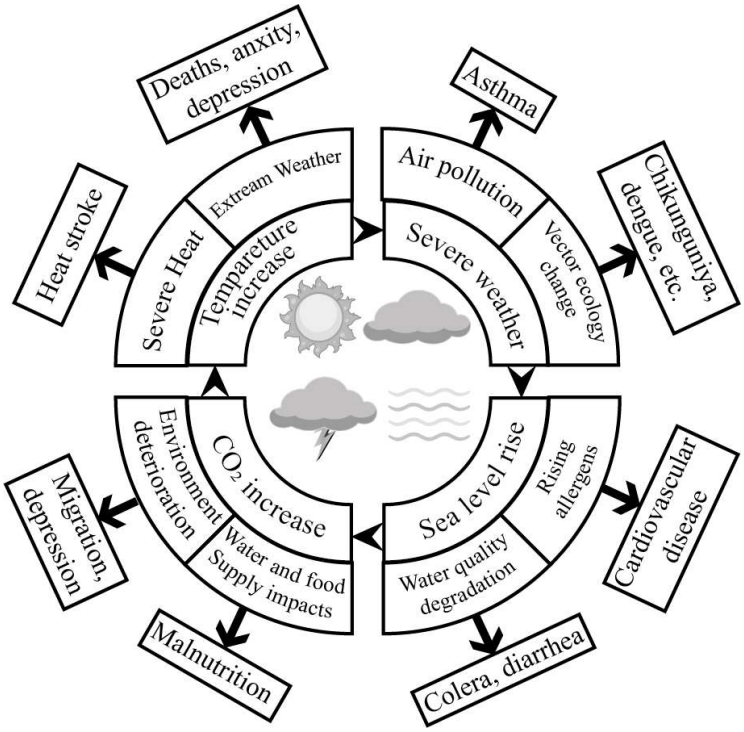

Figure 1: Theoretical framework [Source: World Bank]

3. RESULTS AND DISCUSSIONS

Over the past few decades, climate alteration has become a more urgent issue in Bangladesh, giving rise to a number of visible trends and patterns connected to this worldwide concern. Among these, the increase in temperature is one of the most notable and extensively studied. Temperatures have been rising both throughout the day and at night, which has increased discomfort and heat stress. In addition to potentially worsening heat-related health issues, these higher temperatures might also negatively impact the national agriculture industry. Notably, the steady increase in average yearly temperatures is one of the most noticeable trends in climate alteration in Bangladesh. Average Surface Air Temperatures (ASAT) have been steadily rising since 1901, both at the minimum and highest levels.

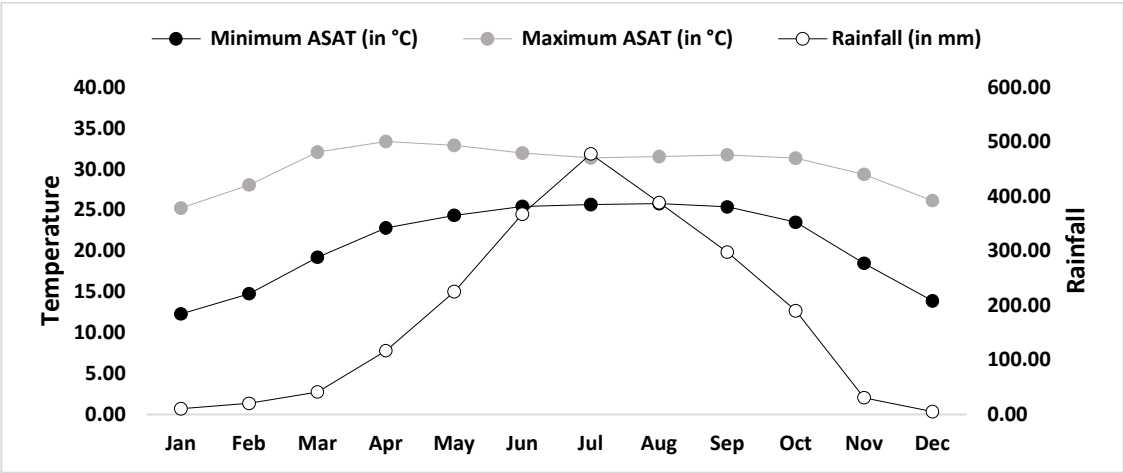

Figure 2: Monthly average temperature and rainfall between 1901 to 2022 in Bangladesh [Source: BBS]

Bangladesh is heavily dependent on the monsoon season, particularly in terms of water resources and agriculture. There are now inconsistencies in the timing and distribution of rainfall due to the disruption of traditional monsoon patterns caused by climate alteration. This can therefore contribute to both droughts and floods by causing longer stretches of dry weather as well as heavier, more concentrated rainfall. A number of reasons, such as changes in atmospheric circulation patterns, decreased moisture availability, and increased evaporation rates owing to rising temperatures, can be combined to explain the diminishing rainfall.

Table 1: Correlations among temperature, rainfall, and dengue prevalence in Bangladesh

		Rainfall	Temperature	Dengue prevalence
Rainfall	Correlation coefficient	1	0.76	0.69
	p-value		0.01*	0.03*
Temperature	Correlation coefficient	0.76	1	0.46
	p-value	0.01*		0.02*
Dengue prevalence	Correlation coefficient	0.69	0.46	1
	p-value	0.03*	0.02*	

The data shown in Table 1 clearly show a significant positive association between dengue prevalence and rainfall in Bangladesh. This suggests that the prevalence of dengue fever tends to increase along with rising rainfall. Furthermore, a strong positive correlation has been found throughout the nation between dengue prevalence and temperature, indicating that rising temperatures are linked to a rise in dengue prevalence. The results align with earlier research [19–21].

Table 2: Linear regression among temperature, rainfall, and dengue prevalence in Bangladesh

Model's efficacy				
R		R^2	Adjusted R^2	Standard error
0.93		0.86	0.77	81.54
ANOVA – Analysis of variance				
Sum of Squares	Degrees of freedom	Mean Square	F	$p-value$
SS (regression) = 127163.57	2	63581.78	9.56	0.04*
SS (residual) = 19945.26	3	6648.42		
Regression coefficients				
	Coefficients	Standard error	t	$p-value$
Constant	31.86	56.25	0.56	0.60
Rainfall	1.05	0.31	3.41	0.02*
Temperature	36.01	9.56	3.76	0.02*

Dengue prevalence is equal to 31.86 + 1.05 (rainfall) + 36.01 (temperature) in the relevant model. Because of the strong positive correlation, there is a discernible relationship between rising rainfall and rising dengue prevalence. The establishment of breeding grounds for Aedes mosquitoes, which transmit the dengue virus, is thought to be the cause of this link. Increased rainfall causes stagnant water to build up, which creates the perfect environment for mosquito reproduction. Consequently, dengue transmission risk is raised in places with higher rainfall due to higher mosquito populations. In a similar vein, rising temperatures are strongly connected with an increase in dengue prevalence in Bangladesh, according to a statistically positive association with temperature. This relationship can be explained by how temperature affects the life cycle and activity of mosquitoes. Increased mosquito activity and faster mosquito development result from warmer temperatures, which raise the risk of dengue transmission. Higher temperatures can also decrease the dengue virus's incubation period in mosquitoes, increasing the virus' contagiousness and likelihood of infecting humans.

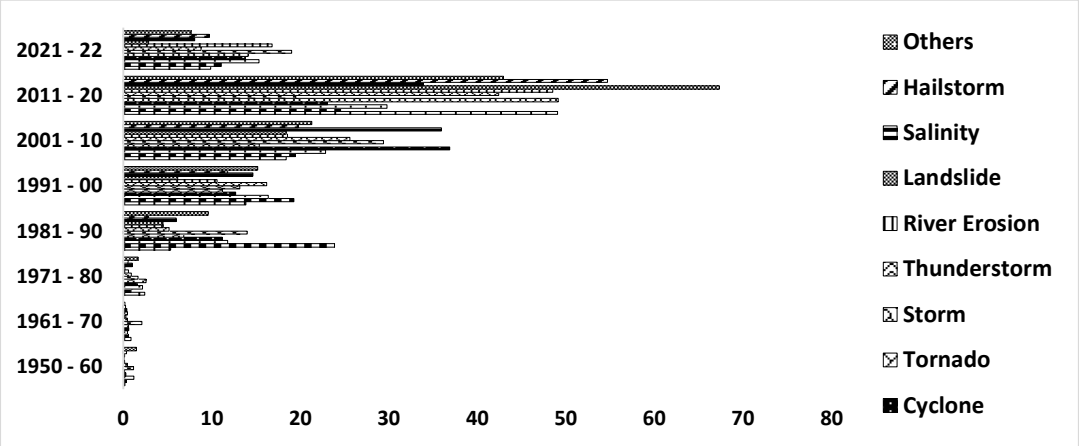

Figure 3: Natural disaster trends between 1950 to 2022 in Bangladesh [Source: BBS]

Bangladesh had a number of changes and advancements in the field of natural catastrophes brought on by climate alteration between 1950 and 2022. With over 70% of all natural disasters occurring in Bangladesh, floods are by far the most common type of disaster. Due to its large river system and low-lying topography, the country is extremely vulnerable to flooding. Floods have become more frequent and intense in recent decades, causing significant damage to lives, livelihoods, and infrastructure. Another major natural hazard that affects Bangladesh is cyclones, which usually originate in the Bay of Bengal. These powerful weather phenomena produce intense rain, strong gusts, and violent storm surges that cause extensive destruction. Cyclones have become more frequent and severe in recent years, and they are now more frequently making landfall in Bangladesh. In Bangladesh, the frequency of droughts is also increasing, with a particular focus on the country's western and northwest areas. These dry spells are caused by decreasing precipitation and increased evaporation rates brought on by high temperatures. Droughts have a disastrous effect on agriculture, causing severe food shortages and crop failures. In Bangladesh, river erosion is a significant problem that affects about 20% of the nation's geographical area. Due to increased rainfall and storm surges that cause riverbanks to expand and flood, climate alteration has enhanced the erosive force of rivers. This unwanted phenomena affects infrastructure, livelihoods, and agriculture, which heightens worries about the uprooting of local residents.

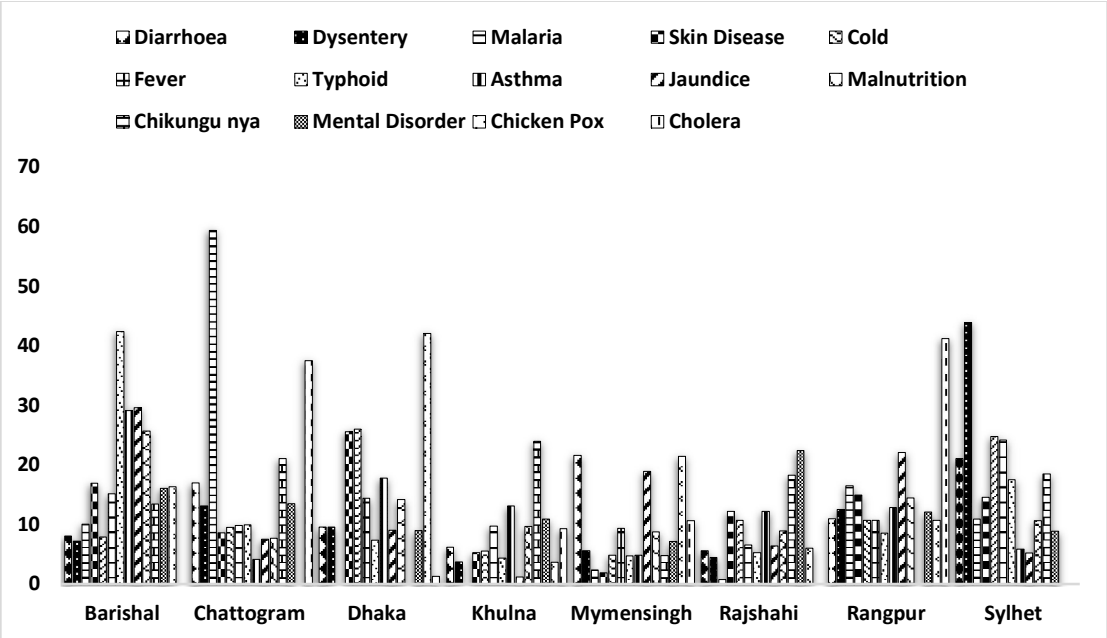

Figure 4: Divisional allocations of climate-induced diseases in Bangladesh [Source: BBS]

The incidence of diseases brought on by the climate varies throughout Bangladesh's administrative divisions, reflecting the unique environmental and climatic circumstances of each area. The coastal divisions—Khulna, Barisal, and Chittagong—are particularly vulnerable because of their low-lying topography, close proximity to bodies of water, and regular exposure to severe weather events like floods and cyclones. These circumstances provide mosquitoes with ideal hatching grounds, which aids in the spread of illnesses like dengue, malaria, and diarrhea. Bangladesh is home to the mosquito-borne viral illness dengue, which finds ideal circumstances for spreading along the shore. The major dengue vector, Aedes mosquitoes, find ideal breeding grounds in the regular flooding and accumulation of stagnant water. While malaria has been successfully eradicated in the majority of Bangladesh, it still poses a concern in coastal areas, particularly in the Sundarbans. The main vector of malaria, Anopheles mosquitoes, and extensive mangrove forests both contribute to the disease's continued prevalence. Droughts and heat waves are more common in the northern divisions of Rajshahi, Rangpur, and Sylhet, which might increase the prevalence of respiratory illnesses such lung infections and asthma. Warm weather and increased air pollution, which are frequently made worse by burning biomass in agriculture, can aggravate and precipitate asthma attacks. A lack of fresh water during periods of drought may force people to use contaminated sources, which increases the risk of contracting waterborne illnesses like typhoid and hepatitis A and exacerbates respiratory problems. On the other hand, floods can cause disruptions to water supply systems and sanitary facilities in the central and inland divisions of Dhaka, Mymensingh, and Narayanganj, leading to the emergence of diseases including diarrhea and cholera. Flooding can greatly increase the danger of cholera outbreaks, which are caused by contaminated water or food. Cholera is a waterborne bacterial disease. Watery diarrhea is a common and sometimes serious condition that arises during epidemics of waterborne diseases brought on by floods. It is caused by bacteria, viruses, or parasites.

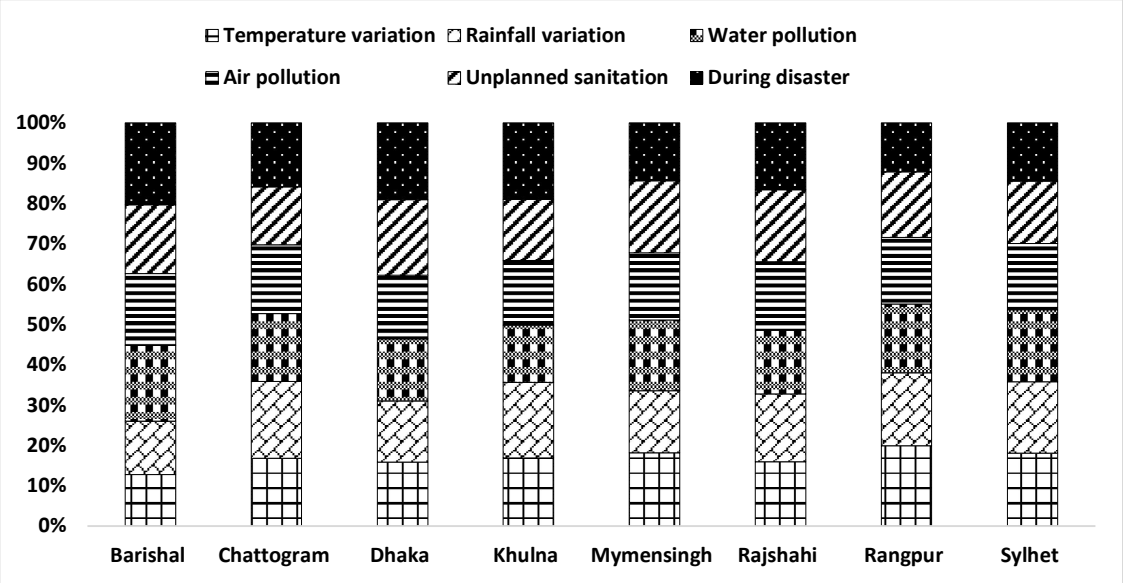

Figure 5: Divisional allocations of causes for climate-induced diseases in Bangladesh [Source: BBS]

Due to their low-lying terrain and close proximity to bodies of water, the coastal divisions are particularly vulnerable to diseases brought on by the climate. This makes them a perfect breeding ground for disease vectors, particularly mosquitoes. Frequent cyclones and floods in these areas cause standing water and increased mosquito breeding, which in turn spreads diseases like malaria and dengue. Furthermore, flooding and water stagnation increase the risk of waterborne illnesses including diarrhea. Extreme weather events can contaminate water supplies, which in turn can lead to outbreaks of waterborne illnesses. On the other hand, the northern divisions are more vulnerable to heat waves and droughts. When there is a drought, people turn to tainted water sources due to scarcity, which increases the risk of contracting waterborne illnesses. Furthermore, respiratory illnesses like lung infections and asthma are more common in these places due to high temperatures and worsened air

pollution from activities like burning biomass. Floods can cause major disruptions to water supply systems and sanitary facilities in the central and inland regions. An environment that is favorable to the spread of waterborne illnesses is created by this disruption. During floods, there is a higher chance of contracting cholera, a bacterial disease spread by contaminated water or food. Additionally, other bacteria cause a high prevalence of watery diarrhea in these divisions during outbreaks of waterborne diseases brought on by flooding.

A comprehensive set of policy suggestions is needed to address the health impacts of climate alteration in Bangladesh, with the aim of improving resilience and reducing the impact on public health. Here are some policy suggestions:

- Make investments in healthcare infrastructure that is climate resilient, particularly in coastal and flood-prone areas. To deliver timely medical aid, it is imperative that healthcare facilities be built to resist harsh weather events and continue to operate during emergencies.
- Enhance and broaden early warning systems for diseases brought on by climate alterations, paying special attention to vector-borne illnesses like malaria and dengue. The impact on public health can be minimized by managing and preventing illness outbreaks by early detection and prompt intervention.
- Develop community-based health education initiatives to raise knowledge of the health concerns associated with climate alteration and to encourage preventative measures. Communities with greater knowledge are better able to adopt preventative measures, which lowers the prevalence of diseases linked to climate alteration.
- Control mosquito populations in susceptible locations by implementing integrated vector management techniques. In areas where stagnant water is a problem, targeted vector control efforts can reduce the spread of diseases like dengue and malaria.
- Enhance the infrastructure for water and sanitation, particularly in areas that are prone to flooding and drought. During extreme weather events, having access to clean water and adequate sanitation is essential to preventing waterborne infections.
- To lessen the effects of climate alteration on food security and nutrition, encourage climate-resilient farming practices. Maintaining a steady food supply lowers the danger of malnutrition during climate-related emergencies and improves public health generally.
- Healthcare personnel should receive training and capacity building so they can manage and react to climate-related health issues with effectiveness. To handle the growing health burdens linked to climate alteration, a well-prepared healthcare workforce is necessary.
- To keep an eye on how diseases brought on by climate alteration are developing and how they are affecting public health, invest in research and surveillance systems. Policies must be regularly gathered and analyzed in order to be adjusted to changing health trends.
- Create community resilience initiatives that enable nearby communities to adjust to health issues linked to climate alteration. Building community resilience decreases the long-term effects of climate-related health effects and promotes self-sufficiency.
- To guarantee ongoing efforts and resources, cooperate with global organizations and pursue funding for climate health projects. Health issues brought on by climate change frequently call for teamwork, and assistance from other countries can increase the efficacy of mitigation and adaptation plans.

When combined and put into practice, these policy ideas can help Bangladesh create a robust healthcare system and reduce the negative health effects of climate alteration.

4. CONCLUSIONS

The study of statistics and quantitative insights into the health effects of climate alteration in Bangladesh clarifies the complex relationship between environmental alteration and public health. The urgent need to address the complex issues brought on by climate alteration in this sensitive region is highlighted by this study, which is based on actual evidence and thorough analysis. The statistical and mathematical methods used in this study provide a foundation for well-informed decision-making. The results can be used by public health officials and policymakers to create evidence-based plans and actions. Governments may better allocate resources, put early warning systems in place, and customize public health campaigns to address the developing health hazards by knowing the quantitative correlations between climatic variables and health outcomes. To sum up, the statistical and mathematical understanding of Bangladesh's climate-related health effects is evidence of the value of data and analysis in solving one of the most pressing issues of our day. This study is a clear call to action, highlighting the necessity of taking preventative action to protect public health in the face of climate change. It serves as a stark reminder that, with the right information and teamwork, we can lessen the negative effects of climate alteration on human health and create a more robust, adaptable, and sustainable future for Bangladesh and the entire globe.

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