CLIMATE CHANGE, NATURAL DISASTERS, AND VULNERABILITY IN BANGLADESH: A COMPLEX NEXUS

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ABSTRACT

Bangladesh, located in a low-lying delta, confronts a multifaceted challenge arising from the convergence of climate change, natural disasters, and vulnerability. This abstract offers a concise overview of the intricate relationships at play in this intricate nexus. With the escalating impacts of climate change, Bangladesh is witnessing rising sea levels, elevated temperatures, shifting precipitation patterns, and an uptick in extreme weather events, which further amplify preexisting vulnerabilities. This study thoroughly explores the interplay between climate-induced changes and natural disasters, examining their effects on socio-economic, environmental, and infrastructural vulnerabilities in Bangladesh. It delves into the compounded consequences of these factors on the livelihoods, health, and general well-being of the population. Employing a multidisciplinary approach, the research integrates data from meteorological, geological, and socio-economic sources to gain a comprehensive understanding of the dynamics within this complex nexus. Key findings highlight that climate change-induced events, such as sea-level rise and cyclones, disproportionately impact the coastal regions of Bangladesh, resulting in population displacement, loss of life, and significant damage to critical infrastructure. Additionally, the paper explores the adaptive and mitigative strategies implemented by both the government and local communities in response to these challenges. Furthermore, this study examines the implications of this intricate nexus for policy development and international cooperation aimed at addressing climate change and reducing disaster risks in Bangladesh. It emphasizes the imperative need for holistic, sustainable solutions that acknowledge the interdependence of climate change, natural disasters, and vulnerability. In conclusion, the nexus of climate change, natural disasters, and vulnerability in Bangladesh presents a substantial challenge that demands comprehensive and innovative strategies. This research aims to enhance comprehension of this issue, fostering meaningful discourse and decisive action to build a more resilient and sustainable future for Bangladesh and its populace.

Keywords: *climate change, DM, natural disasters, BBS, KPA.*

1. INTRODUCTION

In the twenty-first century, climate change is a major issue that the entire globe is dealing with. This worldwide issue cuts beyond national boundaries, affecting environmental systems as well as national lifestyles, means of subsistence, and vulnerability [1]. There is a complicated and complex relationship between climate change, natural catastrophes, and human vulnerability that requires us to conduct a thorough analysis and look for a complete picture [2]. Deforestation and greenhouse gas emissions are just two of the many human activities contributing to climate change, which has become the most significant issue of our time. It is causing changes in weather patterns, changing the atmosphere of the planet, increasing the frequency of natural disasters, and causing biodiversity to disappear [3]. These enormous shifts affect every region of the world and are not limited by geography. Natural catastrophes are observable indicators of a changing climate. Examples of these include hurricanes, floods, wildfires, earthquakes, and droughts [4]. They act as sharp reminders of how human frailty and environmental factors interact. Communities and countries are finding it difficult to deal with the terrible aftermath of increasingly frequent and severe disasters [5]. The expenses are enormous and go well beyond the lives lost; they also include harm to infrastructure, property, and economic stability. The dynamic and complex landscape of human vulnerability to natural disasters and climate change is described throughout [6]. Numerous variables, such as socioeconomic status, geographic location, infrastructure quality, educational attainment, governance systems, and resource accessibility, influence this risk factor [7]. Environmental disasters have far-reaching effects, with marginalized and impoverished groups sometimes bearing the brunt of their effects [8].

The world community is facing a critical turning point as it deals with the complex issues brought about by climate change, an occurrence that transcends national borders and has an impact on every aspect of the ecosystems on our planet [9]. Bangladesh is one country that provides a powerful example of the complex relationships that exist between natural catastrophes, climate change, and human vulnerability. Bangladesh, a low-lying, heavily populated country in South Asia, is at the center of the global climate tragedy [10]. The Bangladeshi historical narrative is tightly linked to nationwide vulnerability to the relentless assault of climate change and natural disasters [11]. A lengthy struggle for independence and autonomy, which finally concluded in 1971, has outlined the path of the country. But since independence, many difficulties have emerged, including widespread poverty, unstable governance structures, and fast population expansion [12]. Due to these historical bases, the nation is ill-prepared to deal with the increasingly severe effects of climate change, which has resulted in a complex web of vulnerabilities. The Bangladeshi geographic composition contributes significantly to its susceptibility [13]. Numerous rivers, such as the Ganges, Brahmaputra, and Meghna, which all originate in the Himalayan ranges, crisscross this deltaic geography. Bangladesh is vulnerable to frequent, severe flooding during the monsoon season because of its topography. Millions of people live in low-lying coastal areas, making the national coastal regions particularly vulnerable to cyclones and sea level rise [14]. The vulnerabilities that Bangladesh already faces are exacerbated by climate change. Rising temperatures around the world cause the Himalayan glaciers to melt, which increases river flow and increases the risk of flooding. Sea level rise causes saltwater infiltration into freshwater sources and coastal community erosion [15]. Furthermore, the increased frequency and intensity of cyclones brought on by climate change cause catastrophic loss of life and livelihoods. Bangladesh is vulnerable in a wide range of socioeconomic ways. A region roughly the size of Iowa is home to over 160 million people, which puts a heavy strain on the limited resources of the country [16]. The problems brought on by climate change and natural disasters are made worse by poverty, dense population, and inadequate infrastructure [17]. Vulnerable populations, which include marginalized groups like women, children, and the elderly, experience an excessive amount of hardship because they lack the resources and ability to properly adjust and recover [18]. The government has recognized that addressing climate change is critically important in light of these difficulties. It has put in place several adaptation and mitigation strategies, such as sustainable farming methods, cyclone shelters, and early warning systems [19]. Bangladesh has additionally actively engaged in global climate negotiations, promoting the interests of countries that are vulnerable to climate change [20].

The correlation among climate change, natural calamities, and human vulnerability emphasizes the necessity of comprehensive understanding. Complex feedback loops arise from the intersection of these elements, with each factor intensifying the others. This complex relationship has global implications

that extend beyond national borders [21]. Resource conflicts, migration brought on by climate change, and environmental degradation have an impact on international relations and security issues. To tackle this global issue, cooperative efforts, international collaboration, and fair responsibility sharing are required. This thorough analysis lays a strong basis for a more in-depth examination of the intricate interactions that exist in Bangladesh among natural disasters, climate change, and human vulnerability. By delving deeper into the complex facets of this relationship, we can acquire a deeper comprehension of the difficulties facing this country and the priceless lessons it teaches the international community about tackling the far-reaching effects of climate change.

2. METHODOLOGY

The intricate relationship between climate change, natural disasters, and vulnerability in Bangladesh will be examined in this study. The following major research questions will be its main focus:

- How is the frequency and intensity of natural disasters in Bangladesh being exacerbated by climate change?
- What socioeconomic elements put Bangladesh at a higher risk of natural disasters and climate change?
- What impact do climate change and natural disasters have on the most vulnerable people and communities in Bangladesh?
- What coping and adaptation strategies are currently in place in Bangladesh to deal with climate change and natural disasters?
- What are the weaknesses and obstacles in the current policies and programs, and what more needs to be done to make Bangladesh less susceptible to natural disasters and climate change?

We have gathered quantitative information about natural disasters and climate change from databases maintained by the Bangladesh Bureau of Statistics (BBS) and the World Bank. This information is used to analyze how climate change and natural disasters are changing in Bangladesh and how they affect the most vulnerable people and communities. In our analysis, Microsoft Excel 365 is used to visualize the data graphically. Additionally, we used SPSS V.25 software to carry out correlation analysis. The assessment of statistical significance has been based on a threshold p-value of ≤ 0.05.

$$Correlation\ coefficient\ = \frac{SP(Temperature*Rainfall)}{\sqrt{SS(Temperature)\ SS(Rainfall)}} \quad (1)$$

Where,

$$SS(Temperature) = \sum Temperature^2 - \frac{(\sum Temperature)^2}{Number\ of\ data\ points}$$

$$SS(Rainfall) = \sum Rainfall^2 - \frac{(\sum Rainfall)^2}{Number\ of\ data\ points}$$

$$SP(Temperature * Rainfall) = \sum Temperature * Rainfall - \frac{\sum Temperature\ \sum Rainfall}{Number\ of\ data\ points}$$

An effective way to evaluate the relationship between temperature and rainfall in Bangladesh is to find the correlation coefficient between these two variables. It facilitates the understanding of the intricate connections between temperature and rainfall by climatologists and researchers. For the purpose of forecasting weather patterns, the effects of climate change, and related hazards, this knowledge is essential. This correlation can be used by policymakers to help them decide how best to allocate resources, plant crops, and provide irrigation. Strategies for adjusting to a changing climate can be influenced by a significant positive or negative correlation. It offers information that is necessary for research on climate change. Changes in climate patterns and their effects on the area can be detected by tracking correlations between rainfall and temperature over time. It is crucial to emphasize, however, that a correlation does not establish a cause. Strong correlations between temperature and rainfall do not always indicate a direct cause-and-effect relationship between changes in one variable and changes in the other. The analysis must also take other variables and factors into account. Disaster management organizations can use the correlation coefficient to predict extreme weather events. For example, a high positive correlation might suggest that there is a greater chance of droughts during times of low rainfall

and high temperatures. It acts as a foundation for academic research and evidence-based policymaking. Government policies about sustainable development, disaster relief, and climate adaptation are informed by it.

3. ILLUSTRATIONS

The average monthly temperature and rainfall patterns in Bangladesh show a clear seasonal variation that has remained relatively constant over time, with the exception of some interannual variability. Its average monthly temperature and rainfall trends over time are displayed in Figure 1. It provides useful data regarding long-term trends in temperature and rainfall in Bangladesh. These historical records help us understand nationwide climatic trends and how they have changed over time. Bangladesh has its coolest and driest weather from January to March. Though there can be minor variations from year to year, average temperatures are generally consistent. The winter season begins during this time. Even though it could change, the temperature usually stays in this range. There is little to no rainfall during the winter and early spring. During this season, rainfall varies very little from year to year. As spring turns into early summer, April and May see an increase in temperature. Temperature fluctuations are possible, but overall trends don't change. As the nation enters the monsoon season in April and May, rainfall starts to rise. During these transitional months, rainfall variability is more apparent, with some years seeing heavier pre-monsoon showers. Although there may be some variations during the monsoon season, which runs from June to September, the warm and muggy weather is a yearly occurrence. Rainfall during the monsoon season is heavy and continuous. Every year is different when it comes to the amount of rainfall; some years have stronger monsoons than others. October is still quite warm. The temperature can fluctuate a little, but it usually stays in this range. October sees high but progressively decreasing rainfall as the monsoon ends. It is also noted that post-monsoon rainfall varies between years. Compared to the peak of summer, the months of November through December have milder and more comfortable weather. There are not many temperature variations. Low rainfall occurs in November and December, marking the start of the dry season. During this dry season, rainfall variability is minimal.

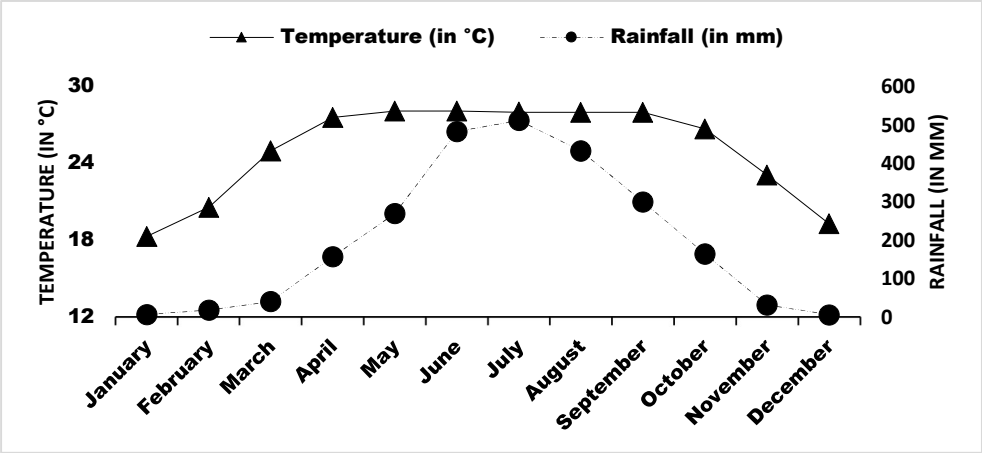

Figure 1: Temperature and rainfall trends (monthly average) in Bangladesh [Source: World Bank]

Temperature and rainfall have a significant positive correlation according to the SPSS correlation analysis ($r = 0.7$, p-value = 0.00). This strong positive correlation coefficient shows that rainfall increases in combination with rising temperatures, and that falling temperatures are correlated with decreasing rainfall. In simpler terms, a decrease in rainfall is expected when temperatures drop and a rise in precipitation is highly likely when temperatures rise. The extremely low p-value for this correlation emphasizes how unlikely it is that this relationship is a coincidence and instead indicates that this is a statistically significant finding. This shows that rather than being a random occurrence, the correlation between temperature and rainfall that has been observed is a meaningful and consistent relationship. This strong positive correlation has important implications for the Bangladeshi climate. It suggests a strong and direct correlation between temperature and rainfall in the area. Rising temperatures can cause more evaporation, which would raise the amount of moisture in the atmosphere and possibly result in more rainfall. Managing the Bangladeshi rainy and dry seasons effectively requires an understanding of this relationship. For example, high temperatures during the monsoon season may cause more frequent and heavy rainfall, which can have a big effect on agricultural practices and flooding. On the other hand, lower temperatures during the dry season might result in less rainfall, which could have an impact on crop cultivation and water resources. There are significant implications for agriculture and the environment from this correlation. Crop growth and ecosystem health depend on these climatic factors existing in a harmonious balance.

Determining the strength of this relationship provides decision-makers with important information about agricultural practices, flood control measures, and the management of water resources. This correlation takes on even more significance when considered in the larger context of climate change, where global temperatures are rising. High temperatures may lead to changes in the Bangladeshi patterns of precipitation, which could affect what happens during the monsoon and dry seasons. This necessitates a proactive approach to the management and adaptation of the region to climate change.

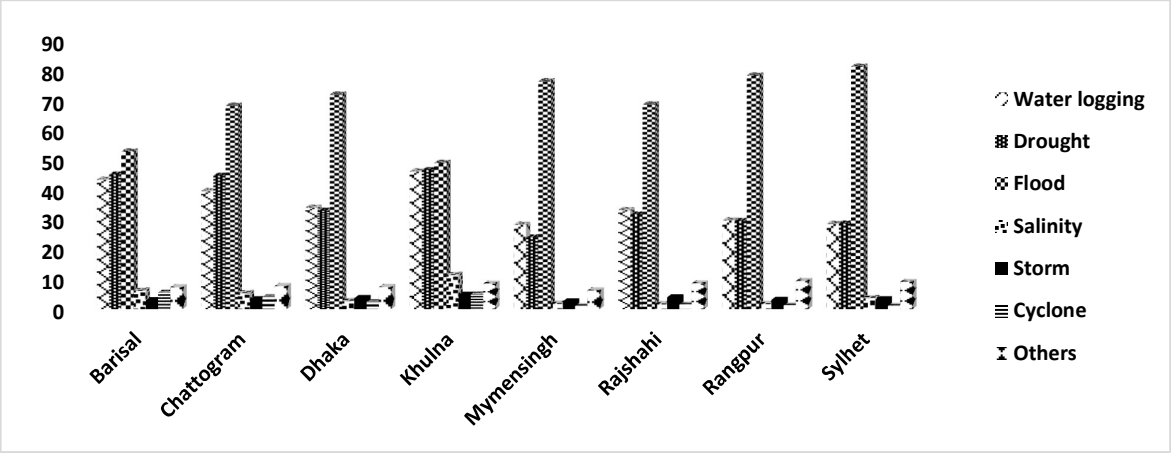

Figure 2: Ratios (%) of people by KPA on climate change effects across divisions in 2021 [22]

There is a significant variation in the knowledge, performance, and awareness (KPA) of the consequences of climate change among the different regions of Bangladesh. Numerous factors, such as geographic location, socioeconomic circumstances, and information access, have been identified for this divergence. People in coastal divisions like Khulna, Barisal, and Chittagong are more likely to be aware of the effects of climate change because of their increased susceptibility to coastal flooding, cyclones, and sea level rise. Locals in these areas usually have a better understanding of the risks associated with climate change and how to adapt to them. Additionally, they are more likely to take an active role in adapting to climate change through the construction of homes that can withstand flooding, aquaculture, and the cultivation of crops that can withstand salt. The active support of government and non-governmental organizations for these endeavors raises awareness. On the other hand, inland areas such as Dhaka and Rajshahi are comparatively less directly exposed to the effects of climate change. Fewer people may be aware of these effects as a result. Urban areas within these divisions, however, typically have better access to climate change education and information. Because the immediate threats are not as readily apparent at hand, inland divisions tend to perform less well in terms of adaptation and mitigation measures for climate change. However, urban areas frequently have more advanced infrastructure and government initiatives aimed at tackling climate change issues. There is also variation in awareness levels, with urban areas usually having higher awareness than rural areas. To increase public awareness of the effects of climate change and the need for both mitigation and adaptation measures, education and outreach programs are essential. Large-scale national initiatives are in progress to improve knowledge, performance, and awareness (KPA) about climate change in all regions of Bangladesh. These initiatives include policy changes, awareness-raising campaigns, and educational programs all geared toward reducing the vulnerability of the nation to climate change. Nonetheless, obstacles such as scarce resources, impoverishment, and unstable political environments could hinder the thorough examination of KPA differences among various sectors.

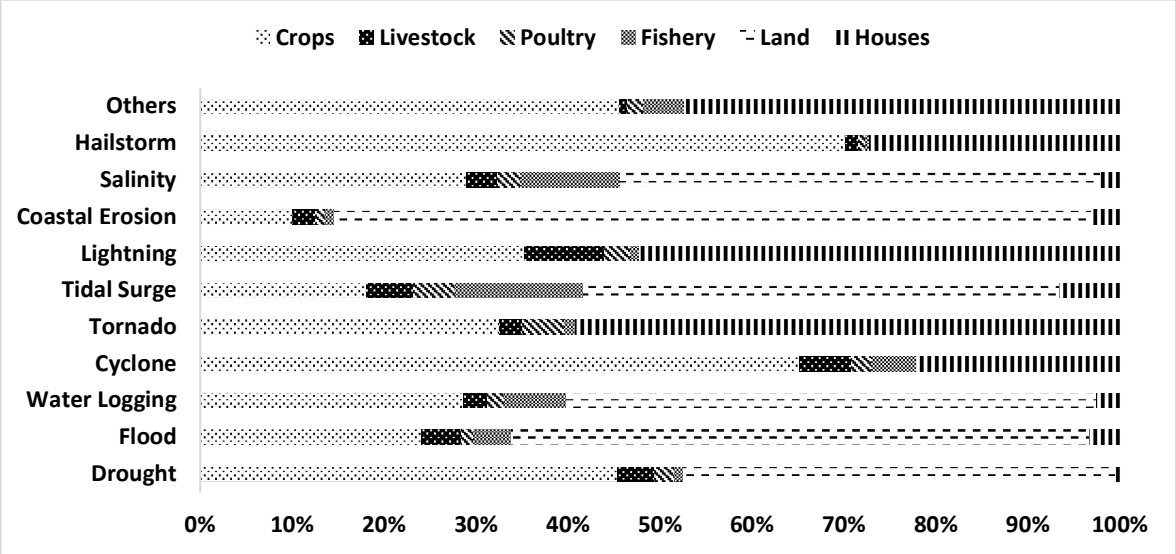

Figure 3: Losses from natural disasters in Bangladesh (2015-20) by types and sectors [22]

Natural disasters that affect Bangladesh include cyclones, floods, landslides, erosion of riverbanks, earthquakes, tornadoes, and salinity intrusion. These challenges have a significant impact on the environment, the economy, and society, highlighting the critical need for disaster preparedness and climate change adaptation in the country. Bangladesh suffered a wide range of losses as a result of these environmental hazards between 2015 and 2020, revealing its vulnerability to various risks. The most destructive natural disasters were cyclones, followed by floods, drought, saline intrusion, and coastal erosion. Numerous industries were affected by these losses, but the agriculture sector was hardest hit, followed by the housing, fishing, and livestock industries.

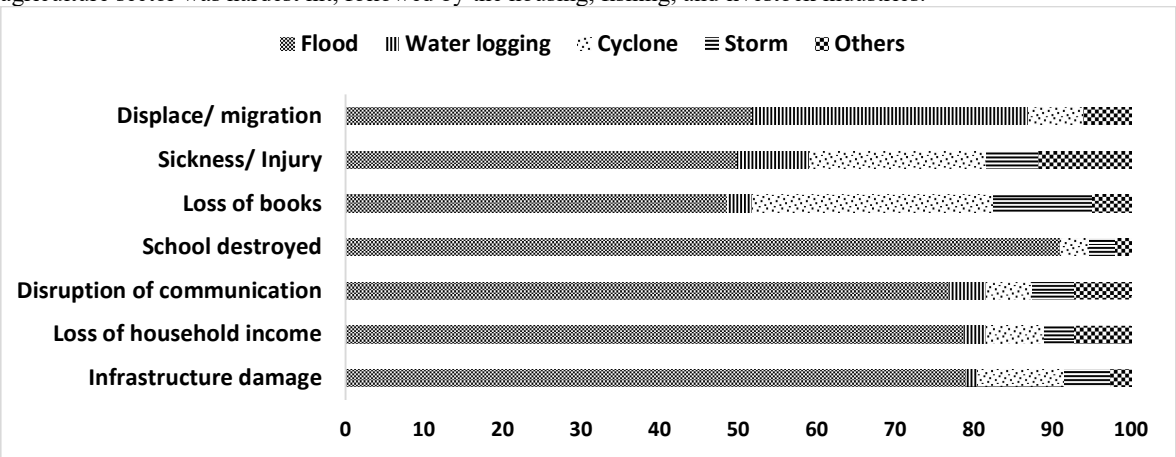

Figure 4: Distribution of children dropping school by disaster category and its effects in 2021 [22]

Depending on the kind of natural disaster a child experiences, the effects of their absence from school can change. In areas like Bangladesh, flooding is a common occurrence and frequently results in schools being submerged, making them unsafe and unusable. This calls for the temporary closure of schools, which has a negative impact on the attendance of students. On the other hand, school infrastructure, such as buildings and facilities, can sustain significant damage from cyclones and storm surges, sometimes rendering them unusable. Children are thus compelled to stay at home, which interferes with their ability to learn. Childhood travel can become hazardous in hilly and mountainous regions due to the possibility of landslides blocking road access to schools. Furthermore, school buildings may sustain direct damage from landslides, necessitating their closure. These interruptions have far-reaching effects. The immediate result is gaps in what the kids are learning because their education is disrupted. This may lead to higher dropout rates, particularly for vulnerable populations, since students who experience significant disruptions to their education are more likely to give up on their studies altogether. Children who are exposed to natural disasters may also suffer from trauma and psychological distress, which makes it difficult for them to concentrate on their schoolwork and frequently calls for support and counseling. A lack of education can have long-term negative effects on an individual and the economy of a community by reducing their options for

future employment and earning potential. In addition, children who lack access to education may be forced to work as minors to support their families, which would further jeopardize their chances of completing their education. Girls may be expected to take on household duties during and after disasters, which can disproportionately affect them and continue gender differences in educational achievement.

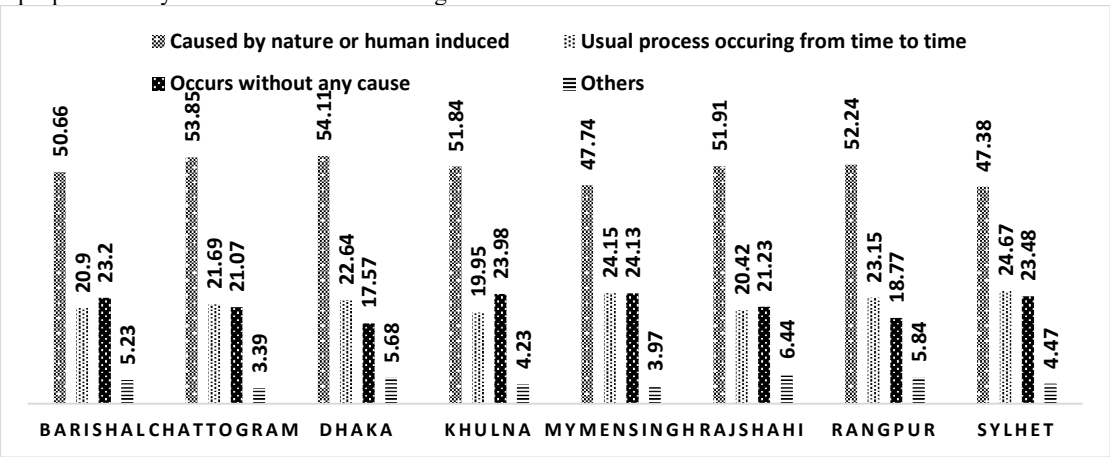

Figure 5: Ratios (%) of people by KPA on natural disasters across divisions [22]

Regarding natural disasters, KPA varies among Bangladeshi divisions. Because of their increased susceptibility to storm surges and cyclones, coastal communities frequently have a deeper awareness of these particular risks. Because there are shelters resistant to cyclones and early warning systems, they are well-versed in disaster preparedness and evacuation protocols. These communities keep well-established disaster response networks and actively participate in evacuation drills. First-hand experiences with cyclones and storm surges have led to heightened awareness, which has been further reinforced by local NGOs and government initiatives that promote preparedness and resilience. On the other hand, inland divisions usually have less knowledge about disasters that are specific to the coast, such as cyclones. Instead, in light of the environmental challenges specific to their region, they mainly concentrate on riverine floods and landslides. There is variation in the performance of preparedness for disasters; urban areas are better equipped with better response and infrastructure. On the other hand, rural areas in inland divisions might struggle with resource scarcity, which would hinder efficient disaster management. Levels of awareness also vary, with urban areas having easier access to resources for education and knowledge about different types of natural disasters. However, awareness and preparedness in rural areas are lower, mostly as a result of limited outreach and resource availability.

In Bangladesh, disaster management (DM) is an all-encompassing and crucial endeavor that aims to increase the resilience of the country while reducing the effects of both natural and human-caused disasters. Considering national vulnerability to various disasters, efficient disaster management becomes crucial.

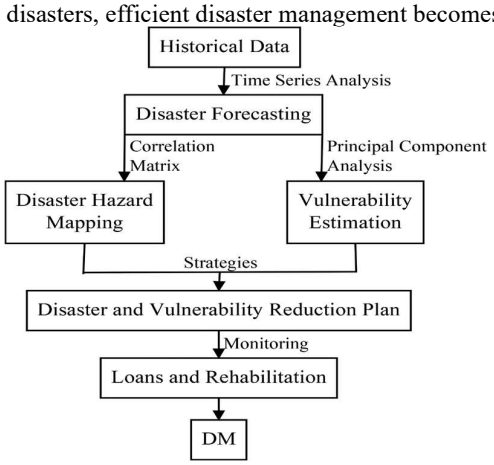

Figure 6: Proposed DM plan for Bangladesh

Bangladesh has made significant investments in early warning systems intended to deliver accurate and timely notifications for floods, cyclones, and other possible calamities. To provide these vital alerts and enable planning and evacuation, the Bangladesh Meteorological Department (BMD) and the Flood Forecasting and Warning Center (FFWC) are essential.

Bangladesh has built cyclone shelters strategically in coastal areas that are vulnerable to cyclones, providing residents with a safe haven during strong storms. Furthermore, precise evacuation strategies are developed and implemented to guarantee the secure and effective transfer of individuals to these shelters. Bangladesh also emphasizes the importance of local communities in its DM strategy. Communities actively participate in the creation and implementation of plans for disaster risk reduction, receiving education on preparedness and response strategies. When disasters occur, the government coordinates the mobilization of resources for prompt disaster response and relief efforts in coordination with non-governmental organizations and international entities. This includes providing those impacted by the disaster with vital relief supplies like food, shelter, and medical care. Government officials, first responders, and volunteers are the focus of training and capacity-building programs run by a wide range of agencies. By improving their DM and response skills, these programs hope to increase national overall resilience to disasters.

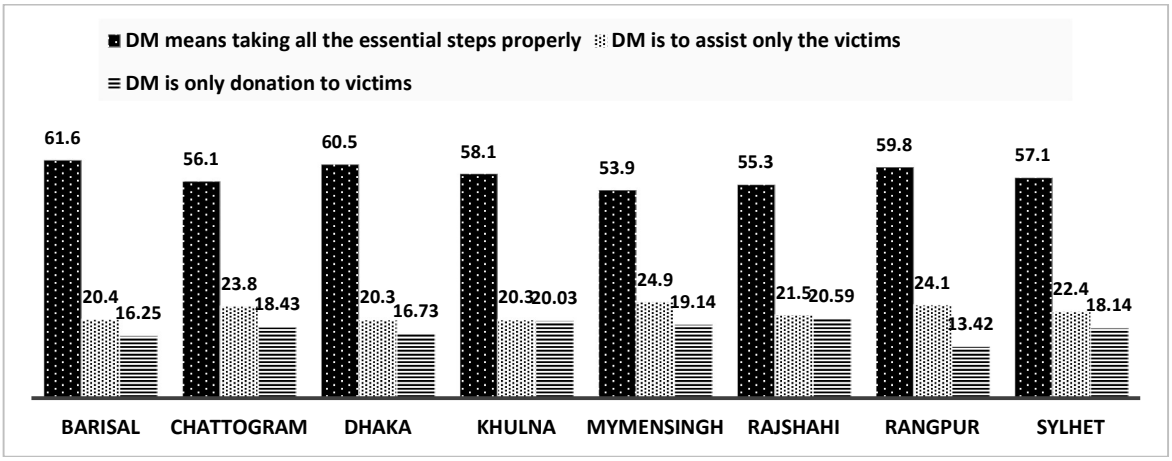

Figure 7: Ratios (%) of people by KPA on DM across divisions in 2021 [22]

Over 80% of people in Bangladesh are familiar with the term Disaster Management (DM), indicating a strong general understanding of the concept. Moreover, almost 74% of them are able to correctly identify at least one DM measure. However, there are differences between the regions, particularly the central and southern areas, which have higher levels of knowledge. It is also impressive how well people perform on DM-related tasks, like identifying evacuation routes and making a family disaster plan; nearly 80% of respondents answered at least one question correctly in these areas. There are some regional differences once more, with the central and southern regions having significantly higher performance levels. Nearly 90% of people are aware that there are risks associated with natural disasters. These risks can take many different forms. River erosion, cyclones, and floods are the most commonly mentioned hazards. Northern and coastal areas, which are more susceptible to natural disasters, have the highest levels of awareness.

4. CONCLUSIONS

This research represents a thorough investigation that reveals the complex and ever-changing network of difficulties encountered by a country at the forefront of the global climate emergency. As this study comes to an end, it is abundantly evident that the intricate interactions between climate change, natural disasters, and human vulnerability in Bangladesh are more than just a research project; rather, they serve as a sobering reminder of the complexity and urgency of climate-related issues on a worldwide basis. The takeaways from our painstaking investigation show that this relationship goes beyond national borders and captures the larger difficulties that humanity faces in a time of environmental change. The interdependence of climate change, natural disasters, and human vulnerability results in a continuous feedback loop where each influences and reinforces the other. Rising global temperatures lead to more frequent and severe natural disasters, which ironically make marginalized communities even more vulnerable. Bangladesh has several socioeconomic issues that make it unprepared to deal with the growing effects of climate change due to the historical legacies of colonization, political unrest, and the national arduous struggle for independence. This complex relationship has global resonance and transcends national boundaries. International relations and security are significantly impacted by migration brought on by climate change, resource-related conflicts, and environmental degradation. These factors highlight the critical need for a cooperative, global approach to combating climate change. In conclusion, the complex nexus of climate change, natural disasters, and vulnerability in Bangladesh serves as a poignant reminder that the repercussions of climate change are fundamentally human-centric. It screams out for teamwork, international solidarity, and

creative solutions to address the many problems facing our planet. The lessons learned from this study have global implications that extend well beyond the national borders. Specifically, they emphasize the urgency of taking significant action against climate change and the need for cooperation to safeguard the planet and its most vulnerable citizens from the long-term effects of these changes.

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