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**COVID-19 pandemic, dengue epidemic, and climate change vulnerability in Bangladesh:
Scenario assessment for strategic management and policy implications**

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Abstract:

Bangladesh is one of the most vulnerable countries to climate change impacts also struck by the COVID-19 pandemic. The lockdown measures were ineffective with no sign of flattening the curve. Therefore, the high risk of transmission is evident with an increasing number of affected people. Under this circumstance, a multiple hazards scenario can be developed in this country due to climatic hazards such as cyclones, floods, landslides, heat waves, and the outbreak of infectious diseases such as dengue, cholera, and diarrhoea. The country experiences simultaneously the global pandemic, exceptionally prolonged flood along with the recovery stage from the damages due to the cyclone (Amphan). Therefore, these multiple factors have been putting pressure on losing millions of homes, livelihoods, and agricultural crops. This study

aimed to assess the potential impact of a simultaneous strike of climatic hazards and infectious disease outbreaks and their possible strategic management in Bangladesh under different scenarios. A mixed methodological approach was followed in this study including a questionnaire survey, in-depth discussion with experts, and extensive literature review to assess the multi-hazard scenario in a resource-limited setting with high population density. A set of statistical techniques were used to analyze the responses (n=1590) from different social groups (healthcare professionals, academicians, students, Government and NGO officials, and businessman) under three scenarios. The results revealed the high possibility of aggravating the impact of COVID-19 pandemic if there is a climatic hazard such as flood, cyclone have appeared. The majority of the respondents agreed that the situation will become more devastating if there is another outbreak of diseases such as dengue, cholera, and diarrhea. The poor and fragile healthcare system of this country cannot bear such unprecedented pressure. The lack of risk assessment and communication, lack of sectoral coordination might restrict the contingency plan of the government. Therefore, considering the unprecedented worst cases a stringent strategic plan for emergency response, short term and long-term management should have to be formulated. Resilience building through proactive planning and implementation of integrated, inclusive and sustainable strategies will be effective to ensure the health and socio-economic security for multi-hazard threats in the country.

Keywords: vulnerability, dengue, climatic hazards, climate change and health

46

47 **1. Introduction**

48 The novel coronavirus disease (COVID-19) has been taking a devastating toll from all over the
 49 world. An amazingly fast forward of a couple of months, the world finds an unbelievable and
 50 unprecedented situation; the COVID-19 pandemic, a Public Health Emergency of International
 51 Concern (PHEIC) as well as an economic crisis. As of 30 July 2020, more than 17 million people
 52 worldwide confirmed COVID-19 affected with about 0.67 million of death. The USA, Brazil,
 53 India, Russia, South Africa, Mexico, and Peru have been facing the worst ever situation in the
 54 near past.

55 Bangladesh witnessed the first confirmed COVID-19 infected Italian migrant on 8 March 2020
 56 (IEDCR/DGHS/GOB, 2020). However, the country declared a nationwide lockdown including
 57 all educational institutes, and government and private offices effective from 26 March 2020 to
 58 prevent human transmission. So far 221,178 COVID-19 infections were detected from the entire
 59 country with reported death toll of 2,874 until 25 July 2020 and the rate of infection against the
 60 total tests is more than 20 % (**Figure-1**). In Bangladesh, so far only a single COVID-19 detection
 61 method has been using, the reverse transcriptase-polymerase chain reaction (RT-PCR). This
 62 method can produce maximum sensitivity (67 %) within the first week of infection and then
 63 decreased to 45 % 2 weeks after the infection (Shormin and Yusuf, 2020). This is highly specific
 64 to the viral RNA, therefore this method is not suitable for the asymptomatic virus carriers and
 65 recovered patients. A combined approach of both molecular detection techniques along with
 66 immunological methods could produce a real COVID-19 scenario in Bangladesh.

67 The government of Bangladesh (GoB) took a set of quick response to tackle the COVID-19 and
 68 support its citizens, and economies by relief, financial stimulus packages, emergency health

services, increasing healthcare facilities etc. However, the declared contingency plan likely to be at the risks of cyclones, nor' westers, tornadoes, floods, landslides like natural hazards in Bangladesh in the context of COVID-19 (HCTT, 2020). These natural hazards during the COVID-19 pandemic might aggravate the people's vulnerability and the impact could be synergistically devastating. Especially, the vulnerable population groups and areas such as slum dwellers, refugees and low-income people living in climate-vulnerable areas are most expose and extremely sensitive population in the country. However, considering the population density, environmental factors, social structure, cultural norms, health care capacity and climate change vulnerability of Bangladesh, it is certainly hard to lock down the people for a long period (Tareq et al., 2020). Besides, Bangladesh has estimated a large number of a vulnerable population (more than 13 million) which need exclusive supports to counter the COVID-19 pandemic but along with the climatic hazards, the vulnerable population number might be almost doubled from the pandemic alone (22.5 million) which covers 25 districts out of 64 which might fall under the severely affected areas in the country (HCTT, 2020). Moreover, the unprecedented climatic vulnerability may also arise during this situation for instance a super cyclone (Amphan) struck the country devastatingly on May 20, 2020. It took a huge toll on lives and properties from the affected areas of Bangladesh. Preliminary estimated aftermath of the super cyclone counted about 11 billion BDT (The Daily Star, 2020). The cyclone forced to move about 2.4 million people to 14,636 cyclone shelters from 19 coastal districts of Bangladesh and damaged about 176,007 hectares of crops, coastal embankments, loss of houses and cattle (BRAC, 2020).

According to the reports of The Intergovernmental Panel on Climate Change (IPCC, 2014) due to the present trend of climate change there are a lot of challenges will be faced including water security, poverty, conflicts, and infectious disease epidemics (IPCC, 2014). The climate change has been a focal issue for centuries, but even more so in the last decade, with much focus in

recent months (Damani, 2020). About more than 300 peer-reviewed studies have been demonstrated the extreme weathers worldwide and the potential impact from anthropogenic activities for the induction of such events. Heatwaves are the major contributing events followed by drought, rainfalls, and floods (Carbon Brief, 2020). World meteorological organization declared the last decade (2010-2019) as the ‘decade of exceptional global heat’ (WMO, 2019) and it reported that the climate vulnerability and extreme events as the key drivers for elevating of the global hunger (WMO, 2019). A line of evidence suggested the impact of climate change on public health issues including malnutrition, diarrhoea, malaria, dengue fever, injuries and deaths (IPCC, 2014; Tong et al., 2016; Watts et al., 2018; Zhang et al., 2019; Yang et al., 2020).

In 2019, the largest dengue outbreak was observed in Bangladesh with 101,354 confirmed dengue patients (IEDCR, 2019). However, from 2000 to 2018 (19 years) the total dengue confirmed cases were 50,674 (IEDCR, 2019). Along with the new serotypical factor (DENV-3) the unusually high rainfall before the normal monsoon time in Bangladesh was thought be a significant factor for the high outbreak of dengue in 2019 (Ahsan et al., 2020). In addition, studies reported that the water-prone districts in Bangladesh having the high diarrhoea prevalence rate. For instance, the southern coastal area which is vulnerable to salinity and low water quality and the north-eastern districts, vulnerable to flash flood and monsoon floods (Das et al., 2019). Das et al. (2019) identified several districts with a doubled diarrhoea incidence rate compared to the national average (6%) such as in Madaripur (13.4 %), Stakhira (11.4 %), Meherpur (11.3 %), Bhola (12.7 %), Cox’s Bazar (12.2 %), and Nawabgonj (12.3 %). The high diarrhoea incidence rate was reported to be associated with climatic variables such as temperature variation, rainfall episodes, degree of salinity, drought in different local level studies (CCC, 2009; Rana, 2013). In addition, cholera (*Vibrio cholerae*) can be manifested with the climatic variability such as warming of sea surface may aggravate the risk of cholera outbreak in the coastal regions as the Bay of Bengal was the potential sources of several waves of cholera epidemic (Baker-Austin et al., 2018). Due to lack of available data cholera infection most of the experts rely on the past surveillance and demography survey to predict the potential impacts of climatic events such as droughts, floods, coastal storms on cholera infection. It was suggested that approximately 66 million people in Bangladesh is at risk of cholera infection (GHI, 2018). However, it was also found that about 300,000 cholera cases/year occur having an estimated

4,500 deaths (Qadri et al., 2015). Martinez et al. (2017) reported the potential teleconnection between the El Niño-Southern Oscillation (ENSO) and cholera in Bangladesh and demonstrated the post-monsoon (August-November) risk of the disease outbreak. The variability of rainfall and river discharge was also reported as risk factor for cholera epidemic in Bangladesh. Hasizume et al. (2008) found that both low and high rainfall are significantly correlated with the increase rate of cholera in Bangladesh. The bacteria show variable growing patterns during the floods and draughts, and experts warn about the outbreak of cholera in Bangladesh due to global warming (Dhaka Tribune, 2018). Despite the obvious teleconnection between the climatic variability, ambient environment, and the infectious diseases, there is a clear gap in formulating climate-based surveillance system in the policy papers for preventing these disease burden globally including Bangladesh (Ali et al., 2014).

Bangladesh has been considering as one of the most vulnerable countries and a set of the climate change impacts have already been identified such as extreme temperature, erratic rainfall, salinity intrusion, sea-level rise, and increased intensity of floods, flash floods, droughts, and cyclones (Islam et al., 2019 and Rahman and Islam, 2019). And these hazards have significant negative impacts on livelihoods, food and nutritional security, water and sanitation and overall on public health.

Considering the geographic location, weather pattern, frequency and intensity of natural disasters, erratic rainfall pattern and heat stress, water quality and availability, forest and land availability, agricultural and infrastructural vulnerability, livelihood and poverty situation determinants 41 districts out of 64 districts of Bangladesh have been identifying as most vulnerable districts to climate change impacts (**Figure-2**) (MoEFCC 2018). The vulnerable areas are the coastal regions, hill tracts, Barind tracts, Haor basins and the fast-growing urban areas in Bangladesh (MoEFCC 2018). For instance, during a regular monsoon flood, it covers about 20% of the country while in a severe situation about more than 60% of the country get inundated with disrupting life and causing deaths (NPDM, 2017; Islam et al., 2020).

This year amid COVID-19, a super cyclone (Amphan) struck the country devastatingly on May 20, 2020. It took a huge toll on lives and properties from the affected areas of Bangladesh. Preliminary estimated after math of the super cyclone counted about 11 billion BDT (The Daily Star, 2020). The cyclone forced to move about 2.4 million people to 14,636 cyclone shelters from 19 coastal districts of Bangladesh and damaged about 176,007 hectares of crops, coastal embankments, loss of houses and cattle (BRAC, 2020). Moreover, the monsoon flood due to torrential rainfall and huge water flow from the upstream already hit Bangladesh severely with huge tolls on livelihoods and lives. Report said about 26 districts (out of 64) have inundated and more about 3 million people are directly affected by the flood (BRAC, 2020, The Business Standard, 2020). So far total 62 died and about 68,000 people took shelter and about 172000 hectares cropland is damaged (BRAC, 2020). During this time, it would become a havoc as there are multiple risks to spread water and food borne diseases along with the COVID-19 transmission risks (Figure-3).

Therefore, food security, water availability, public health, agriculture, and livelihoods vulnerability leads the people to below the poverty line, leading to unprecedented human displacements and increased intergroup conflict (World Bank, 2018).

Amidst the traumatic situation of nation's anxiety and fear due to COVID-19 pandemic (Shammi et al., 2020), the possibility of climate change induced disasters including tropical cyclone, prolonged floods and its preparedness, the rising of dengue fevers cases and seasonal influenza, and other forms of infections should not be overlooked in Bangladesh. This year the dengue outbreak is thought to be more intense than the previous as expert's prediction and already the reported cases are 3 to 4 times higher at the same time of the previous years (Dhaka Tribune, 2020) (**Figure-4**). The monsoon season is very crucial for Bangladesh which is lasting from May

to August in terms of climatic hazards and infectious outbreak. Furthermore, the consequences of disposal of used PPE without proper treatment in the landfill or the dumps unconventionally will just arise more disease transmission and environmental disasters leaving the country at stake. The major gap to visualize the actual risk of climatic hazards along with the pandemic is to get satisfactory information on the COVID-19 and its tolls on life, goods, societies, and finance. Therefore, this study seeks to fill these gaps in the existing literature. In such a circumstance, this study is, thus, planned to analyze the COVID-19 pandemic in the light with the unprecedented climatic hazards, (cyclone, floods and landslides) other infectious diseases especially dengue under a set of scenarios through the public perception and literature surveys in Bangladesh. This assessment might be useful for the government and policymakers of countries with a similar socioeconomic and cultural structure like Bangladesh.

2. Methodology

2.1. Study procedure

Bangladesh is a low-lying river deltaic country in South Asia with a unique hydrogeographic setting and high population growth to make this nation more vulnerable (Rahman et al., 2019). The country is geographically located in a vulnerable position to easily exposed to a set of multiple natural hazards around the years. More specifically, from April, it usually exposes to numerous natural thrusts such as the outbreak of infectious disease (dengue and malaria), floods and flash floods, nor'westers, tornadoes, cyclones, landslides, and heatwaves (**Figure-5**) (MoEFCC, 2018). Therefore, the outbreak of COVID-19 makes the situation more sophisticated for the country in terms of disaster response and management with limited resources and

preparedness. Thus, this study is designed to explore the potential challenges due to multi-hazard exposure risk to tackle numerous socio-economic and health crisis in Bangladesh.

Considering the impact of current COVID-19 outbreak, climate change vulnerability and dengue epidemic in Bangladesh, this study identified three scenarios based on the country's current situation, expert consultation and literature review. The scenarios were validated by multi-disciplinary expert group consisting of policymakers, researchers, practitioners and sectoral experts in a group meeting through rigorous discussion. The scenarios are:

Scenario-1: Climate change-induced unprecedented disasters (flood or cyclone etc.) during or after COVID19 situation in Bangladesh (OS1)

Scenario 2: Dengue and other infectious diseases outbreak during or after COVID-19 pandemic in Bangladesh (OS2)

Scenario-3: Simultaneous multi-hazards risk of the COVID-19 pandemic, climatic disasters, and other infectious diseases (dengue, cholera, diarrhoea, and malaria) in Bangladesh (OS3)

Further, scenario-based literature review (Bodrud-Doza et al., 2020) and expert consultation were considered to set and validate scenario-related 43 statements for getting perceptions from a different group of people including health professionals, academicians, government officials, political leaders, NGO officials, researchers, students, and business persons. Google Form based online questionnaire was prepared to conduct the survey. An online database of target participants was prepared by reviewing the relevant websites and online social platforms of different expert groups in Bangladesh, considering their current activities, responsibilities and engagement related to COVID-19 response, disaster preparedness and response, socio-economic sector, climate change adaptation and health sector, country-level planning and policymaking. The prepared questionnaire with an introductory paragraph outlining the purpose of the study

was shared through Email, Facebook, LinkedIn, and WhatsApp with selective and relevant people considering the purposive sampling method. The questionnaire survey was conducted from 09 April to 20 April 2020.

In addition, one to one in-depth discussion with sectoral experts were also done in this study. The discussion was guided by a set of pre-selected questions mostly open-ended focusing the major multi-hazard challenges, policy gaps, obstructions and the interactions among the hazards with COVID-19 in Bangladesh. However, the schedule of discussion was very flexible and free.

2.2. Research sample and population

The target population was general Bangladeshi citizens age 18 years or older. The inclusion of the respondents was different social groups like university faculty and scholars, Government officials, development worker or practitioner, doctors, engineers and technologist, youth leaders and students, businessman and industry officials, banking and finance corporates, researchers, and others. The answers to the survey questionnaires are the voluntary basis. Data from 1590 participants were collected via a cross-sectional sampling survey method. A five-point (1 to 5) scenario-based Likert scale was employed to test whether each understands the statement descriptions that ranged from strongly disagree to strongly agreed with the statements. Total 43 statements were used to conduct the scenario-based impact assessment and management of COVID-19 outbreak in Bangladesh considering climate change vulnerability and dengue epidemic.

The ratio of male to female participants was 3:1, while the composition of age groups was 44% (18–25 years old), 41% (26–35 years old), and 15% (36–55 years old), respectively. However, the average age of the respondents (n=1590) was 28.44 years (SD±6.51). More than half of the participants were males (71%) and remaining (29%) females.

In-depth interviewees were purposely selected, considering their knowledge about the topic of COVID-19, dengue and climate change and a balance of gender, age, profession and work experience. A total of 41 completed the interviews, including 8 university professors teaching climate change public health and economic, 9 health experts, 8 Government officials involved in policy making, 7 practitioners in the field of disaster risk reduction and climate change adaptation, and 11 researchers conducted research on relevant issues.

2.3. Data analysis

The descriptive statistics (e.g., frequencies, percentages, mean and standard deviation) were used to understand the participant's characteristics. Applying the Statistical Package for the Social Science (SPSS) v. 25.0, datasets were analyzed via a set of statistical tools such as Classical Test Theory (CTT), principal component analysis (PCA), hierarchical cluster analysis (HCA), Pearson's correlation coefficient (PCC) and multiple regression analysis (MRA). PCA is one of the population data reduction techniques that indicate each potentiality of variables and their significance level in a huge sample size. Before conducting the PCA, Kaiser-Maier -Olkin (KMO) and Bartlett's sphericity tests were applied to confirm the necessity of this analysis. The results of the KMO >0.5 (the KMO value was 0.917 in this research) and the significance of Bartlett's sphericity test at $p<0.01$ verified our datasets to be fitted for the PCA (Islam et al., 2020). The number of factors chosen was based on the Kaiser's normalization principle, where the only factors with eigenvalues >1.0 were regarded. From the CTT analysis, Cronbach's alpha was employed to test the consistency and reliability of the factor loadings in this study. Cronbach's alpha validation values ranged from 0.965 to 0.967 indicating (**Table-1**) that these statements are appropriate in social science study (DeVellis, 1991). The hierarchical cluster analysis (HCA) is a crucial means of identifying relationships among all psychosocial and

environmental variables. The HCA assists to classify a population into different groups based on the similar characteristics of a set of the dataset that may show causes, effects, and or the source of any undetected psychosocial and environmental crisis. Furthermore, hierarchical clustering was adopted to determine the possible number of clusters.

2.4 Ethics statement

Informed consent was obtained formally before data were amassed from the participants. All the participants were informed before data collection about the specific objective of this study. Participants were able to complete the survey only once and were allowed to terminate the survey at any time they desired.

3. Results and Discussion

3.1 Scenario-1: Climate change-induced unprecedented disasters (flood or cyclone etc.) during or after COVID19 situation in Bangladesh (OS1)

Under the scenario-1 a set of interconnected statements (OS1S1-6) was developed through analysis of literature, technical papers of the GoB, expert opinion, and situation papers by different stakeholders. These statements encompass the risk to food security, loss of lives and properties, potential threats to vulnerable groups, socio-economic crisis, and rising of the poverty level due to climatic change induced extreme events (**Table 2**). The results summarized, 61.6% of respondents strongly agreed that the country will face another physiological shock with a mean value of 4.53 ± 0.719 , 69.8% agreed that poor and vulnerable communities living in the climate-vulnerable hotspots will be in the most affected groups with a mean value of 4.64 ± 0.621 . Almost 77.4% agreed that extra effort to increase agricultural production to combat the future food crisis with a mean value of 4.74 ± 0.533 . Overall, the respondents had a positive

view about OS1 to likely to the outbreak of COVID-19. These findings agree with the different other reports that the climatic hazards might be happening with elevated risk on vulnerable areas of the country. For instance, May, June July, and August possess a high possibility of flash flood and flood, as well as a cyclone in May, June and October in Bangladesh (MoEFCC, 2018). On May 20, 2020 the country experienced a super cyclone (Amphan) originated in the Bay of Bengal and made it landfall in Bangladesh with devastating toll of lives and properties. Huge damage has been done by the cyclone in different sectors such agriculture including fisheries and food crops, infrastructures including houses, coastal embankments, roads, bridges, and culverts (BRAC, 2020). About 2.4 million people had to evacuate from the coastal districts to the shelters which impose challenges to maintain the social as well as physical distancing due to COVID-19 pandemic (BRAC, 2020). Already the situation become a double whammy for Bangladesh as the cyclone put its trail on 26 districts which includes 19 most climate vulnerable. The GoB has already taken response actions such as distribution of relief, money and other necessary items. Besides, infectious disease such as dengue, diarrhoea, and cholera possess the highest risk in the monsoon months of June, July, August, and September. Along with this heavy rainfall can trigger landslides risks considerably high in June and July in the hill tract districts in Bangladesh (MoEFCC, 2018, HCTT, 2020). Early monsoon flood has inundated about 24 % (34,000 km²) of the total land area in Bangladesh which covers about 26 districts. Since its onset in June more than 3 million people have been affected with 90 reported death including 41 children, and thousands of people have been shifted to 1,086 flood shelters (Flood List, 2020, The Business Standard, 2020). The affected areas are suffering from different degrees of damages including loss of homes, safe water sources, croplands and communications. This situation aggravates the risk of waterborne and foodborne diseases risk for the affected people.

3.1.1 Potential impacts analysis of scenario-1:

As the potential risk of climatic hazards and other infectious diseases might appear during the COVID-19 pandemic, it warrants to analyze the probable impacts of such hazardous events. From the classical test theory (CTT) outcomes, according to the corrected inter-item correlation analysis, among 11 statements in the scenario 1 (OS1) with its management strategies, all statements have high corrected item-total correlation values (>0.55) indicating the acceptable corrected item-total correlation and were applied for further analysis. Each pair of variables exhibited significant positive associations in the Pearson correlation (**Table-S1, S2**). The country will face another physiological shock (OS1S1) had a strong positive correlation with food insecurity will increase in the whole country (OS1S2, $r=0.757$, $p<0.01$) and loss and damage of lives and properties (OS1S3, $r=0.757$, $p<0.01$) and increase of poverty level (OS1S6, $r=0.507$, $p<0.01$). Moreover, the loss and damage of lives and properties (OS1S3) had a moderate positive correlation with a severe socio-economic crisis will increase (OS1S5, $r=0.681$, $p<0.01$). A severe socio-economic crisis will increase (OS1S5) had a strong positive correlation with poverty level will increase (OS1S6, $r=0.759$, $p<0.01$). From this analysis, it is noticeably clear that the climatic hazards along with COVID-19 pandemic have greater potential on negative impacts on livelihoods, properties, goods, and food security of the country. Due to the effects of COVID-19 the poverty rate may raise to 40.9% in Bangladesh if the pandemic could reduce the family income by 25%, which might have a significant negative impact on the successes in poverty alleviation activities over the last decades (Global Times, 2020). It is also forecasted that about 24 million will be losing their jobs due to the pandemic in this country. Therefore, the climatic hazards and COVID-19 might induce a double whammy from the management point of views that will urge for international cooperation (The Daily Star, 2020; Bodrud-Doza et al., 2020).

The impacts are ascertaining by the regression analysis (**Table-S3**). The multiple linear regression model was used to estimate scenario 1 (OS1) performance for model 1. The results indicate that the independent variables OS1S3 (Loss and damage of lives and properties) and OS1S2 (Food insecurity will increase in the whole country) were statistically significant and had a positive influence on OS1S1 (The country will face another physiological shock). The independent variables in the regression model sufficiently described in the influence of dependent variables ($R^2 = 0.643$). After the strike of Amphan about 176,006 hectares of croplands were damaged, 85 points in the different coastal embankments were broken, which requires immediate response as well as long term planning to construct a strong and permanent embankment to avoid future risk (BRAC, 2020). Mass evacuation put extra pressure to ensure social and physical distancing in the cyclone centers as well as the availability of personal hygiene stuffs was also hard to reach. Unfortunately, during the recovery stage of the cyclone, the early monsoon flood appeared in Bangladesh with about 1/3 of the country become inundated, which damages the houses, road communications, drinking water sources, sanitation facilities, education institutes, and croplands in the affected areas (Flood List, 2020). Different water and foodborne disease might aggravate during this flood event and also the maternal, newborn, and infant mortality will likely to be increased due to the unavailability of skilled midwives and doctors.

3.1.2 Management strategies for scenario-1:

For scenarios like development of climate change-induced unprecedented disasters (flood or cyclone etc.) during or after COVID19 situation, a clear suggestion came for the Government of Bangladesh to start preparing for the climatic disasters and shelter planning to

avoid contacts and further transmission. Bangladesh is at 113 positions in the global health security index (GHSI) out of 195 countries depicting the weakness of the health sector (HCCT, 2020). Lack of PPE will likely increase the transmission of diseases to the newborn and mortality. Responders suggested to take immediate steps to ensure future food security and maintain the food chain by taking the safest measure. Responders also suggested for strong collaboration among the ministry of health and family welfare (MHFW), ministry of disaster management and relief, ministry of Finance, Ministry of public administration and headed by ministry of planning (MP) and office of the prime minister. Coordination of the government, private sector and law enforcement were suggested to implement extra resources to tackle any natural disasters beforehand. The steps taken by the policymakers and planners must be swift, timely and transparent and people who are the most vulnerable must be treated at first. The associated loss from COVID-19 will hamper our economic growth for a long time. Even a small-scale disaster will be very costly for the country. After the strike of the super cyclone most important matter came to light is the most needed construction of permanent embankment to protect the coastal settlements. Huge damage in the water points and toilets need to be fixed within shortly to prevent further waterborne diseases in the vulnerable districts. Therefore, post-COVID-19 Response plan needs to consider those issues associated with other disasters especially for natural disasters including those which are related to climate change such as cyclones and flooding.

At the time of cyclone or flood event, the vulnerable community are encouraged to stay in the cyclone or flood shelters constructed in different regions of Bangladesh for savings lives of millions. Considering the COVID-19 human to human transmission risk, accommodating communities in the shelters would create more health risk. Therefore, along with relief support,

adequate water facilities, hygiene kits, PPE and other tools should be making available in the shelters during the disaster period. Community awareness should be created for ensuring social distancing measures during the time of cyclone and floods.

In Bangladesh, the very event for food security was done successfully with the harvesting of major crops avoiding potential flashflood in north-east haor region this year. However, there might be some riverine flood risks in the floodplain areas and coastal flooding after cyclone. Under these circumstances, special standing order can be implemented to ensure the availability of agriculture labor, mechanical harvesters with no or minimum cost. The GoB can buy the rice directly from the farmers to avoid the involvement of middleman to ensure the proper price of rice in this pandemic situation. Otherwise, this may lead to serious flaws in the response strategy against the COVID-19. For the long term management strategy a set of preparatory and preventive action plans can be formulated such as prioritizing the climate-smart agricultural options equipped with early warning system, community based food bank, awareness development programs, customization of microfinance tools for developing digitalized climate smart financial inclusion system to reach the vulnerable communities, implementation of water related adaptation technologies, adaptive and digitalized social safety net system and develop a strong waste management system in urban areas. Besides, some best practices can be followed such as in dealing with Covid-19, the states like Kerala in India, other successful nations such as Vietnam, New Zealand, South Korea, Germany (The Daily Star, 2020). They are heavily confident in informing their people about their strategy and plan of actions rather than suddenly imposing the decisions. For a vulnerable country like Bangladesh, this might be very crucial to let its people know the strategy and plan so that the people could prepare for the unprecedented situation. A set of suggestions are listed here based on the results of this study including

paradigm shifting to proactive emergency response management, prioritizing climate smart agriculture, building resilience house rather than shelters, inclusive and universal public health support systems, focusing nature-based solutions, and ensuring poverty reduction and secure livelihood in the vulnerable areas. However, without an informed and engaged population, this climate-vulnerable country cannot fight either the COVID-19 pandemic or the climate change emergency.

3.2 Scenario 2: Dengue and other infectious disease outbreak during or after COVID-19 pandemic in Bangladesh (OS2)

This scenario focuses on the possible outbreak of dengue, chikungunya, and other infectious diseases in Bangladesh. This country is the highest level of vulnerability to the outbreak of infectious disease from May to September. Therefore, a set of 9 statements (5 for identifying the risks and 4 for management implications) were picked up for this study to get public perceptions.

Based on the perception of the respondents in total, 67.9% of respondents in this study agreed that the country will face another physiological shock due to dengue and other disease outbreak during or after COVID19 situation with a mean value of 4.59 ± 0.695 , 75.5% agreed that the health sector will face the double burden (Epidemic after Pandemic) which will disrupt its system to provide health supports with a mean value of 4.68 ± 0.659 . About 78% strongly agreed that city corporations should take strong preparations and actions with a mean value of 4.74 ± 0.53 (**Table-2**). Overall, the respondents had also a positive view about OS2 to an outbreak of COVID-19 pandemic in Bangladesh. It was already reported in the national daily that the dengue case is about 3-4 times higher in 2020 than the previous year at the same month April (The Dhaka Tribune, 2020), the most potentially vulnerable month to the severe outbreak of dengue is

thought to be in August. A recent study reported a significant link between outbreak of dengue and high rainfall in Dhaka city (Ahsan et al., 2020).

3.2.1 Potential impacts analysis related to the scenario-2:

From Pearson correlation analysis, the country will face another physiological shock (OS2S1) had a moderately correlated with the severe socio-economic crisis will increase (OS2S4, $r=0.741$, $p<0.01$) (**Table-S1, S2**). The health sector will face the double burden (Epidemic after Pandemic) which will disrupt its system to provide health supports (OS2S2) had a moderate positive correlation with many people will die due to several health complications including COVID19-like pandemic and Dengue-like epidemic (OS2S3, $r=0.668$, $p<0.01$). Furthermore, OS2S3 had a strong positive correlation with the severe socio-economic crisis will increase (OS2S4, $r=0.779$, $p<0.01$). Also, OS2S4 had a moderate positive correlation with poverty level will increase (OS2S5, $r=0.706$, $p<0.01$). These findings suggest some severe potential impacts of the outbreak is on the country's health system, the extent of infections and death, loss of livelihoods, rise the poverty levels due to social and financial crisis in Bangladesh.

Moreover, for model 2 in the regression analysis, the results indicate that the health system will be disrupted (OS2S2) due to the outbreak of COVID-19 and dengue. This will lead to the severe socio-economic crisis (OS2S4) in Bangladesh (**Table-S3**). This means multiple stressors will be developed with the outbreak of dengue along with the COVID-19 in Bangladesh.

3.2.2 Management strategies for scenario 2

City and metropolitan areas are more vulnerable than the rural communities as far as dengue outbreak is concerned. Along with the metropolitan cities, the hill tract districts are also at a

vulnerable condition to the infectious disease outbreak. Those areas need to be in the priority list to take precautions before an outbreak happens. Regular cleaning activities and larvicidal spray can be an option to prevent such an outbreak in Bangladesh. In the perception analysis, the statement, many people will die due to several health complications including COVID19-like pandemic and Dengue-like epidemic (OS2S3, $r=0.668$, $p<0.01$) and massive awareness and preventions measures should be taken before dengue outbreak (OS2M1, $r=0.673$, $p<0.01$). An integrated task force can be prepared to have an expert group from each vulnerable area (OS3M7, $r=0.514$, $p<0.01$). Massive awareness and prevention measures should be taken before the dengue outbreak (OS2M1) had a moderate positive correlation with stringent collaboration among all the respective sectors that are in utmost importance (OS3M3, $r=0.532$, $p<0.01$). There was a moderate positive relationship between providing technical and financial supports in the health sector (OS2M2), city corporations should take strong preparations and actions (OS2M4, $r=0.639$, $p<0.01$) and the need to set the priority sectors and ensure timely preparedness (OS3M5, $r=0.571$, $p<0.01$) (**Table-S1, S2**). The city corporations must have to come forward with other related stakeholders to start working to kill the mosquito larvae. They should aware people to stay home and act on water clogging and clean their home and surroundings. Suggestions also came that weak governance in city corporations will always fail to manage this dengue situation. In terms of healthcare supports, hospitals must be prepared for the outbreak risks. Also, reformation and creation of new hospitals specialized in infectious disease treatment should be considered nationwide. Special training and capacity building of the health care workers should be considered regarding dengue and COVID-19 outbreak treatment and management. Further, regular monitoring of cases, increasing the number of tests, identification of disease hotspots and implementation of lockdown, isolation and waste management is

necessary. As the health system of Bangladesh is in a fragile state and overwhelming in COVID-19 tackle, the dengue, chikungunya, cholera, diarrhoea, and malaria outbreak must not be overlooked. Especially, the slum dwellers in the urban area are the most vulnerable group, so a suitable strategy should be communicated with the peoples to let them aware of the risk and response strategy.

3.3 Scenario 3: Simultaneous multi-hazards risk of the COVID-19 pandemic, climatic disasters, and other infectious diseases (dengue, chikungunya, and malaria) in Bangladesh (OS3)

Scenario 3 was established considering the worst possible cases in Bangladesh. Total 23 statements (13 for identifying the risks and 10 for management implications) were thought to get public perceptions. On a whole, 71.1% of the respondents in this work agreed that prolonged and severe health, psychosocial and socio-economic crisis with a mean value of 4.67 ± 0.57 , 73.4% agreed that prolonged food insecurity in the whole country with a mean value of 4.67 ± 0.601 . For management purposes, 70.4% thought that need strong volunteer groups with proper coordination, training, and equipment with a mean value of 4.66 ± 0.594 (**Table-2**). In summary, the participants had a positive viewpoint about OS3 due to COVID-19 spread out in Bangladesh. This means the worst scenario can happen in Bangladesh. The vulnerable group such as women, children and aged people will suffer a lot. The nation's targets for achieving sustainable development goals will also be severely affected. In average, more than 50% of the respondents strongly agreed with 13 statements regarding the simultaneous strikes from multi-hazards in Bangladesh.

3.3.1 Potential impact analysis of scenario-3 in Bangladesh

The country will face massive physiological shock (OS3S1) had moderately correlated with prolonged food insecurity in the whole country (OS3S2, $r=0.663$, $p<0.01$) (**Table-S1, S2**). Also, OS3S2 had a moderate positive correlation with the total economy disruption (OS2S4, $r=0.714$, $p<0.01$). The education system will face an irreversible system loss (OS3S3) had a moderate positive correlation with prolonged and severe health, psychosocial and socio-economic crisis (OS3S5, $r=0.618$, $p<0.01$). However, there was a moderate relationship between the total economy will be disrupted (OS3S4) and prolonged and severe health, psychosocial and socio-economic crisis (OS3S5, $r=0.713$, $p<0.01$). The young generation will become mentally depressed (OS3S7) had a moderate positive correlation with small and medium enterprises will collapse (OS3S9, $r=0.518$, $p<0.01$). There was a moderate positive relationship between the poverty level and the number of ultra-poor population will increase (OS3S8) and SDGs and other national targets will not be achieved as it planned (OS2S13, $r=0.507$, $p<0.01$). Small and medium enterprises will collapse (OS3S9) had a moderate positive correlation with the maternal and physical health status of the country will decrease (OS3S11, $r=0.633$, $p<0.01$). Child mortality rate will increase drastically (OS3S10) had a moderate correlation with social conflict, illegal activities, gender-based violence and crimes will increase (OS3S12, $r=0.660$, $p<0.01$).

For model 3 (**Table-S3**), prolonged and severe health, psychosocial and socio-economic crisis (OS1S5) will disrupt the total economy (OS3S4) which will create unemployed populations (OS3S6). There was significant evidence ($R^2 = >0.677$) that the independent variables in the proposed model adequately described in the influence of dependent variables. Despite the multiple risk factors, the GoB yet to show the coordinated efforts to fight the emergency.

3.3.2 Management strategies for scenario 3

The high population density, climate change vulnerability and weak health sectors along with ignorant citizens might exert pressure simultaneously to further worsen the COVID-19 and climate change emergency. Bangladesh is particularly exposed to the potential risk of a tropical cyclone during the month of April-August, and a dengue epidemic is usually common this time and already reported a high number of dengue cases, and floods from the upstream river basin are already forecasted. In a whole, some of the respondents had a positive view about other scenario-3 if COVID-19, climatic disasters, and dengue occur in the same year. A strong policy can be taken for the citizens to learn the basic primary healthcare and sanitation, destruction of Aedes mosquito habitats, cleanliness, and proper preparedness with sectoral collaborative approaches. However, such collaborative approaches were absent in this emergency. A national technical advisory committee has been formed to tackle COVID-19 in Bangladesh, unfortunately, that team only contains doctors which is not suitable approach rather that team can be comprised with doctors, public health experts, disaster management experts, emergency crisis management experts, education experts and economists. Long-term environmental and urban management plans should be considered. Slums should be given special emphasis. A special response, as well as risk-assessment task force, can be developed involving specialists from every prioritized sector as well as local stakeholders from the vulnerable communities to identify the gaps and needs, which should be integrated, accountable and transparent. From the peoples' perception analysis it was found that the categorized rapid risk assessment is required such as short, medium and long term (OS3M1) had a moderate relationship with the need to set the priority sectors and ensure preparedness early on (OS3M5, $r=0.692$, $p<0.01$). The special action plan should be drawn to implement mass awareness and measures for both Dengue epidemic, disasters and COVID-19 pandemic in a single umbrella (OS3M2) had a moderate association

with an integrated task force can be prepared to have an expert group from each vulnerable area (OS3M7, $r=0.604$, $p<0.01$). Long-term health policy to combat the prolonged psychosocial and socio-economic crisis (OS3M8) had a moderate relationship with Microfinance program for the unemployed and small-interest credits for the agricultural/IT/industry-based start-ups to create employment and business (OS3M9, $r=0.642$, $p<0.01$). The government must have to achieve public trust from grassroots to an upper level. Rehabilitation and reconstruction plan must be developed which should be transparent and communicative towards people. Private sector medical services must be involved in the emergency. It might be effective if the GoB dedicated some private hospitals to tackle other medical issues including Dengue patients. For long-term sustainability, substantial research and development budgets should be increased. Online agent banking, microfinancing and credit can be provided for new entrepreneurs to create employment and incentives for the business organizations as well as the agriculture sector. Farmers should be encouraged to grow more crops and foods and they should be given agricultural loans easily. Educational institutes will suffer from session jams and already national and board examinations must reschedule due to the prolonged closure of the pandemics. College and university students who rely on tuition and part-time jobs to support themselves, their families and education will likely suffer more by losing income and it will have devastating impacts on their minds. Due to the long-term closure of all educational institutes, it will create depression among the children and younger people and affect their physical and mental well-being. Mental and physical health and well-being of people during the emergency periods must be communicated and address by virtual activities. Psychosocial counselling through social and electronic media can be effective to reduce family violence and abuse, particularly to women and children.

3.4 Overall relationship assessment for effective management, policy implications and governance

The appraisal for effective management activities through policy formulation and governance, PCA, and Cluster analysis was performed. PCA showed a significant level of controlling factors in Bangladesh COVID-19 pandemic and how these statements are linked to the various scenarios. Eight principal components (PCs) were originated based on standard eigenvalues (surpassed 1) that extracted 72.276% of the total variance as outlined in **Table-S4**. However, before PCA employing in the tested data, the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests of Sphericity were conducted to appropriateness for this study. The findings of the KMO value in our work was 0.917 (>0.50), the confidence level of Bartlett's sphericity (BS) test was zero at $p<0.01$, suggesting the tested data was fit for PCA analysis.

The scree plot was used to identify the number of PCs to be retained to an understanding of the inherent variable structure (**Figure 6**). The loading scores were classified into three groups of weak (0.50–0.30), moderate (0.75–0.50) and strong (> 0.75) respectively (Liu et al., 2003; Islam et al., 2017). The PC1 (First) explained 14.992% of the variance as it encompassed the strongly significant positive loading of an integrated task force can be prepared to have an expert group from each vulnerable area (OS3M7: 0.771) and long-term health policy to combat the prolonged psychosocial and socio-economic crisis (OS3M8:0.828). This finding indicates the necessity of forming a national task force to handle the possible worst situation due to COVID-19 in Bangladesh. Similarly, this PC1 was also moderate positively loaded of categorized rapid risk assessment is required such as short, medium and long term and need to set the priority sectors and ensure preparedness early on the scenarios 3 and respective management in Bangladesh (OS3M1-OS3M6, OS3S9-OS3M10: 0.604-0.718).

The PC2 (Second) elucidated 10.93% of the total variance, and was loaded with moderate positive loading of scenarios 2 such as the health sector will face the double burden (Dengue, chikungunya, and other epidemics after the COVID-19 pandemic) which will disrupt its system to provide health supports and the severe socio-economic crisis will be increased (OS2S1-OS2S5: 0.621-0.72). In Bangladesh, the climatic hazards and human health consequences are not well explored. However, the poor health system management in this country may induce severe threats from the occurrence of COVID-19 with other infectious diseases. The lack of proper policy to tackle such threats may aggravate the unprecedented worst situation. Therefore, stringent response preparedness, short term and long-term recovery and management strategies must be needed to sustain the development activities for the achievement of SDGs.

The PC3 (Third) explained 10.645% of the variance and was strong positively loaded with the country will face another physiological shock and loss and damage of lives and properties (OS1S1-OS1S3: 0.764-0.827) in the scenario 1 over Bangladesh. Besides, the PC3 was moderately loaded of poor and vulnerable communities living in the climate-vulnerable hotspots will be in the most affected groups and poverty level will increase (OS1S4-OS1S6: 0.511-0.668). There is no alternative to set priority areas and special need allocation to counteract the potential hazards. It is evident that despite the vulnerability of the country (Syvitski et al., 2009) to climate change impacts there is huge knowledge gaps as well as national policy concerns towards the interrelation between climate change and human health (Rahman et al., 2019).

The PC4 (Four) responsible for 9.114% of the total variance and was strongly loaded of the education system will face an irreversible system loss and the total economy will be disrupted (OS3S3-S4: 0.757-0.779) and was moderately loaded with the country will face the massive

physiological shock and Prolonged food insecurity in the whole country (OS3S1-S2 and OS3S5: 0.549-0.645).

The PC5 (Five) elucidated 7.086% of the variance and was strong positively loaded of child mortality rate will increase drastically (OS3S10: 0.801) and social conflict, illegal activities, gender-based violence and crimes will increase (OS3S12:0.824).

PC6 (Six) and PC7 (Seven) accounted for 6.809% and 26.033% of the total variances, respectively and were strong positive loading of extra effort to increase agricultural production to combat the future food crisis (OS1M4:0.805) and the young generation will become mentally depressed (OS3S7: 0.77). The PC8 (Eight) explained 5.947% of the variance and was moderate positive loaded of massive awareness and preventions measures should be taken before dengue outbreak (OS2M1: 0.616) and city corporations should take strong preparations and actions (OS2M4: 0.587). As there is a lack of health system facility to meet up the requirements during any unprecedented outbreaks, therefore it is a must to have a proper contingency plan to protect the vulnerable population of the country. The outcome of the climate model projections put a horrifying picture for Bangladesh, as it is particularly vulnerable to the negative impacts of climate change (Alam et al., 2017). Besides, due to multi-hazards cooccurrence such as extreme weather events, rising temperatures, public health issues (mortality, injury), the spread of infectious diseases, damage to healthcare infrastructure and public health services can be further deteriorated (Shultz et al., 2005). Our results confirm the presence of COVID-19 pandemic and common climatic disasters and other infectious diseases heterogeneity that facilitates this virus attributable deaths caused by the elevated levels of confirmed cases which is similar to other earlier studies (Shammi et al., 2020a; 2020b; Bodrud-doza et al., 2020).

Cluster analysis further identified **the** total status of scenario variations, and how these scenarios influence the socio-economic, health and livelihoods of the country in terms of management aspects (**Figure 7**). All the statements were categorized into four major classes: cluster-1(C1), cluster-2 (C2), cluster-3(C3), and cluster-4(C4). C1 consisted of three sub-clusters of C1-A, B, and C; C1-A composed of the country will face another physiological shock, and poverty level will increase (OS1S1-S6). C1-B comprised of the country will face another physiological shock and many people will die due to several health complications including COVID19-like pandemic and dengue-like epidemic (OS2S1-S4). C1-C comprised of the health sector will face the double burden (epidemic after pandemic) which will disrupt its system to provide health supports, and city corporations should take strong preparations and actions (OS2S2, and OS2M1-4). C2-A comprised of poor and vulnerable communities living in the climate-vulnerable hotspots will be in the most affected groups and Prepare for the uncertain climate change-induced disasters (OS1S4, and OS1M1). C2-B comprised of making a proper response plan to face the upcoming challenge and customization of social safety net programs for the most vulnerable (OS1M2-5). C3 consisted of three sub-clusters of C2-A, B and C. C3-A consists of an integrated task force can be prepared to have an expert group from each vulnerable area and Long-term health policy to combat the prolonged psychosocial and socio-economic crisis (OS3M7-8). C3-B consists of Categorized rapid risk assessment is required such as short, medium and long term and Microfinance program for the unemployed and small-interest credits for the agricultural/IT/industry-based start-ups to create employment and business (OS3M1-5 and OS3M9). C3-C consists of Need strong volunteer groups with proper coordination, training and equipment and Special counselling for the affected persons, their family and the unemployed to overcome the crisis (OS3S4, OS3S6 and OS3S10). C4 consisted of three sub-clusters of C3-A,

B, C and C. C4-A contained the number of unemployed populations will increase due to COVID-19 pandemic, poverty level and the number of ultra-poor population will increase and small and medium enterprises will collapse OS3S6, OS3S8 and OS3S9. C4-B consisted of the country will face the massive physiological shock and Prolonged and severe health, psychosocial and socio-economic crisis (OS3S1-S5). C4-C composed of the young generation will become mentally depressed and Child mortality rate will increase drastically and SDGs and other national targets will not be achieved as it planned (OS3S7, OS3S10-S13).

These results are consistent with outcomes of other recent studies and may assist to make a scenario-based strategic plan against COVID-19 pandemic in various regions of the globe (Tobais, 2020; Iqbal et al., 2020; Sun et al., 2020; Kissler et al., 2020; Bodrud-doza et al., 2020). For example, Kraemer et al., (2020) reported that drastic control measures including travel restriction implemented substantially offset the spread of COVID-10 pandemic in China. Ahmadi et al. (2020) stated that climate-induced migration and population displacement are also likely to have an impact on the spread of infectious diseases like dengue, SARS-CoV-2, as human mobility and density are key drivers of disease dynamics. Further, Kissler et al. (2020) stated that social distancing, critical care capacity, and effective therapy would improve the COVID-19 pandemic control.

Wider socio-economic effects will likely continue for several months to years across the world which will also significantly impact on the economy of Bangladesh. Both the import of important goods and exports related to the ready-made garment sector and others extremely likely be affected for income and employment, therefore the financial protection during an outbreak is a matter of great concern. At the initial stage of the COVID-19 epidemic, out-of-pocket expenditure posed a substantial financial burden for the poor populations with severe

symptoms, even for those under coverage by the social health insurance scheme (Wang & Tang, 2020). People marginally above the poverty level particularly the low-income families, daily and informal low wage earners, ethnic community groups, people with disabilities, returnee migrant workers are already started falling below the poverty line due to loss of income and employment. BRAC an international Bangladeshi NGO survey report confirmed to increase 60% rise in poverty amidst the COVID-19 pandemic (BRAC 2020).

Human adaptation to climate change may influence the likelihood of infectious other coronaviruses, like influenzas viruses, SARS transmission (Baker-Austin et al., 2018; Rahman et al., 2019). Bodrud-Doza et al. (2020) showed that there is a likelihood of a climate change-induced disaster and infectious diseases like dengue during/after the COVID-19 situation, which will create severe food insecurity and a further healthcare crisis in Bangladesh. It suggests that climate change strategy and action plan (BCCSAP) should be implemented by the concerned authorities based on the existing and emerging infectious diseases scenario assessment. If earlier spreads of SARS are a basis, we are only in the foothills of a new SARS-CoV-2 disease that could continue to spread for forthcoming months. So, the government must put in place control measures of the COVID-19 pandemic by practicing self-hygiene and social distancing. A rapid acceleration in the number of COVID-19 cases could quickly overwhelm already vulnerable healthcare systems in Bangladesh. This work suggests that swift action to containment further spreads of the coronavirus, and to improve the emergency response capabilities of the most affected regions in Bangladesh is thus urgent.

After the lockdown measures the resumption of economic activities are taking place in Bangladesh, therefore, the public health and safety now become an individual and to some extent social concern. The RMG industries are in their regular production, which created scopes to mass

gathering that may trigger the risk of COVID-19 transmission. Despite, many RMG workers already lost their jobs and did not receive their salary of the previous months. At this condition, middle-income families are relying on their savings. The negative coping mechanism includes skipping meals and nutrition and distressing the whole family. Due to the movement restriction, the agricultural products in the urban areas are selling at a high price while the farmers are not getting the fair price of the product in agricultural districts. Moreover, the agricultural crops in the vulnerable areas are lost due to flooding and cyclone. All these will likely to impose further impacts on food production and crop supply chains. To protect the country from famine, the Bangladesh government should consider a set of interventions such as the stimulus package for the farmers with 2% agricultural loan to continue cropping and agricultural production, making of a national digital farmer database, digital emergency support platform for root-level farmers, modern agricultural technology introduction, increase crop storage facilities, enlarge the seed bank capacity, the introduction of crop insurance in climate-vulnerable areas, encourage the development of urban cultivation of food crops.

This study highlighted the importance of multi-hazards scenarios when examining the recent climatic disasters like floods, cyclone, landslides and the elevated risk of infectious diseases such as dengue fever, diarrhoea and cholera. Findings from this study should have significant implications for future epidemiological studies on weather factors and dengue fever, cholera, malaria as well as other infectious diseases. When analyzing the scenarios without considering the multi-hazards approaches, the results may be inappropriate or underestimated.

Aside from this, the country has serious threats from the outbreak of Dengue fever. The symptoms of COVID-19 and dengue fever has some similarities. Therefore, detection and isolation might become a real challenge. Although the GoB stakeholder claimed well preparation

for the dengue, the available health service facilities are not in agreement with such claims. Thus, a clear and stringent management plan must be announced for its people to ensure basic and advance health support under such multi-hazard scenario in Bangladesh. This study proposes some interventions for strengthening the health facilities including proposing community-based health facility, increasing online-based health support system, universal health insurance for every citizen, and increasing the health support staffs, continuous awareness development program on hygiene practice, ensure proper sanitation facilities, household and/ or community-based water management and forecasting system.

4. Concluding remarks

The socio-economic and psychosocial impacts, and the food insecurity, as well as rising poverty due to COVID-19 at the community level, needs to be coordinated well along with the coming disasters of cyclones, floods and landslides of monsoon seasons and the rising risk of dengue fever, diarrhoea, cholera in Bangladesh. All these might further aggravate the humanitarian needs of the most vulnerable groups in the country in the coming months to be followed. The Government of Bangladesh has already mobilized a noteworthy stimulus package to support the affected industries and community people which need to be coordinated over a longer period of 12-18 months and maybe for another 5-year plans. Moreover, humanitarian support should reach to the most vulnerable communities which need to be targeted, outlined, and delivered. Some very specific points should be taken care of are as follows:

- Economic implications should be subjected to the spatial and geographical locations based on the vulnerabilities.

- Proper risk assessment and risk communication for the deadly multiple climate change induced hazards should be performed.
- Vulnerable hotspots should be identified with proper preventive and response measures.
- A comprehensive climate-based disease surveillance system can be initiated to ensure minimum damage with quick recovery policy.
- Climate-based disaster and health insurance system can be initiated.
- Disease related data should be archived properly with maximize its accessibility.
- Climate financing should reach to the most vulnerable and special research fund should be allocated to study the impacts of climatic variations on public health.
- There is a huge gap in the environmental diseases related study in Bangladesh, thus a special focus should be created to strengthen understanding of this crucial issue.
- Natural disaster, public health, and diseases related surveillance system and data should be made available as real-time to facilitate disaster risk reduction steps.
- Proactive, inclusive and integrated humanitarian response to the climatic extreme events amid COVID-19 and implementation of context specific, effective, and sustainable interventions for building resilience.
- The long-term strategic plan can be integrated into Bangladesh delta plans (BDP 2100) and National Adaptation Plan (NAP) for better strategic management.

Finally, there is no alternative to strengthen the health care facilities and preparedness for the potential humanitarian crisis. Whatever will be the scenario, emergency preparedness for initial response and proper implementation of initiatives for resilience building must be ensured. Strong strategic inclusive planning, proper financing and multi-sectoral collaboration including integrated supports from the private sectors and international bodies are necessary.

761

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764 **Conflict of Interests**

765 None

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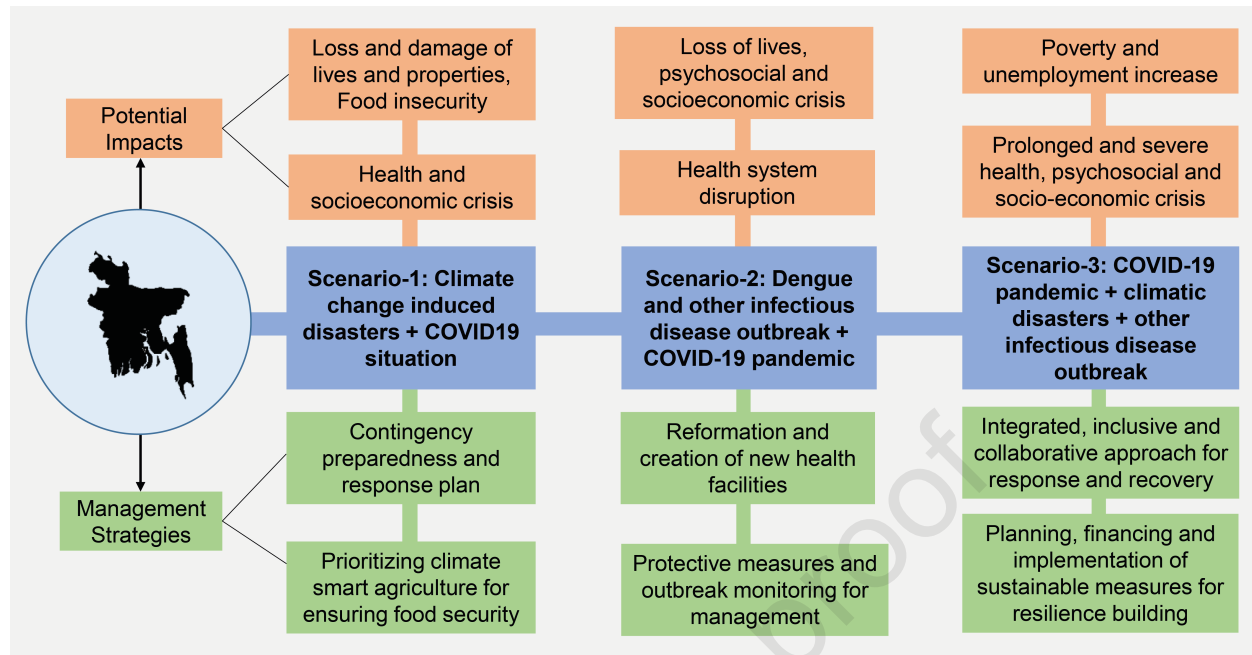


Table-1: Cronbach's alpha value.

Scenario	Number of items	Reliability	Validity
OS1	11	0.905	0.906
OS2	9	0.927	0.929
OS3	23	0.937	0.942
Total	43	0.965	0.967

Table-2: Descriptive statistics and item-total correlation

Scenarios	Statements	Denotes	Strongly disagree % (n)	Disagree % (n)	Neither agree nor disagree % (n)	Agree % (n)	Strongly agree % (n)	Mean	Std. Deviation	Variance	Skewness	Kurtosis	Corrected Item-Total Correlation
Scenario-1: Climate change-induced unprecedented disasters (flood or cyclone etc.) during or after COVID19 situation in Bangladesh (OS1)	The country will face another physiological shock	OS1S1	1.3 (21)	0.6 (10)	3.8 (60)	32.7 (520)	61.6 (979)	4.53	0.719	0.517	-2.12	6.61	0.58
	Food insecurity will increase in the whole country	OS1S2	0.6 (10)	1.3 (21)	3.1 (49)	30.8 (490)	64.2 (1020)	4.57	0.68	0.462	-2.016	5.772	0.58
	Loss and damage of lives and properties	OS1S3	0.6 (10)	0.6 (10)	3.8 (60)	30.8 (490)	64.2 (1020)	4.57	0.66	0.436	-1.939	5.649	0.67
	Poor and vulnerable communities living in the climate-vulnerable hotspots will be in the most affected groups	OS1S4	0 (0)	1.3 (21)	3.8 (60)	25.2 (400)	69.8 (1109)	4.64	0.621	0.385	-1.816	3.496	0.59
	A severe socio-economic crisis will increase	OS1S5	0 (0)	0.6 (9)	5.7 (91)	27 (429)	66.7 (1061)	4.6	0.628	0.394	-1.464	1.704	0.73
	Poverty level will increase	OS1S6	0 (0)	0 (0)	4.4 (70)	26.4 (420)	69.2 (1100)	4.65	0.564	0.318	-1.354	0.883	0.68
Management strategies for Scenario-1	Prepare for the uncertain climate change-induced disasters	OS1M1	0.6 (10)	1.9 (30)	5.7 (90)	34 (540)	57.9 (920)	4.47	0.744	0.554	-1.651	3.505	0.58
	Make a proper response plan to face the upcoming challenge	OS1M2	0 (0)	0.6 (10)	3.1 (49)	29.6 (471)	66.7 (1060)	4.62	0.581	0.338	-1.471	2.198	0.64
	Coordination between government agencies, non-government organizations and private sectors to take the preparation and response initiatives	OS1M3	0 (0)	1.3 (21)	5.7 (90)	23.3 (370)	69.8 (1109)	4.62	0.654	0.428	-1.746	2.793	0.65
	Extra effort to increase agricultural production to combat the future food crisis	OS1M4	0 (0)	0.6 (10)	2.5 (40)	19.5 (310)	77.4 (1230)	4.74	0.533	0.284	-2.178	5.246	0.46
	Continuation and customization of social safety net programmes for the most vulnerable	OS1M5	0 (0)	1.3 (21)	5 (79)	27 (429)	66.7 (1061)	4.59	0.648	0.42	-1.615	2.508	0.55
Scenario 2: Dengue and other infectious	The country will face another physiological shock	OS2S1	0.6 (10)	1.3 (21)	4.4 (70)	25.8 (410)	67.9 (1079)	4.59	0.695	0.484	-2.103	5.635	0.70

disease outbreak during or after COVID-19 pandemic in Bangladesh (OS2)	The health sector will face the double burden (Epidemic after Pandemic) which will disrupt its system to provide health supports	OS2S2	0.6 (10)	1.3 (21)	3.1 (49)	19.5 (310)	75.5 (1200)	4.68	0.659	0.434	-2.635	8.574	0.69
	Many people will die due to several health complications including COVID19-like pandemic and Dengue-like epidemic	OS2S3	0 (0)	0.6 (10)	5.7 (90)	25.2 (400)	68.6 (1090)	4.62	0.624	0.39	-1.557	1.978	0.73
	The severe socio-economic crisis will increase	OS2S4	0 (0)	0.6 (10)	3.8 (60)	23.9 (380)	71.7 (1140)	4.67	0.581	0.338	-1.758	3.045	0.75
	Poverty level will increase	OS2S5	0 (0)	0.6 (10)	5.7 (90)	27 (430)	66.7 (1060)	4.6	0.628	0.394	-1.464	1.704	0.70
Management strategy for Scenario-2	Massive awareness and preventions measures should be taken before dengue outbreak	OS2M1	0 (0)	0 (0)	3.8 (60)	18.9 (300)	77.4 (1230)	4.74	0.521	0.272	-1.86	2.636	0.68
	Provide technical and financial supports in the health sector	OS2M2	0.6 (9)	0.6 (10)	1.3 (21)	18.2 (290)	79.2 (1260)	4.75	0.573	0.329	-3.206	14.147	0.68
	Provide intensive/ insurance support to the health workers	OS2M3	0 (0)	2.5 (40)	4.4 (70)	25.8 (410)	67.3 (1070)	4.58	0.697	0.486	-1.818	3.3	0.70
	City corporations should take strong preparations and actions	OS2M4	0 (0)	0.6 (10)	2.5 (40)	18.9 (300)	78 (1240)	4.74	0.53	0.281	-2.231	5.509	0.70
Scenario-3: Simultaneous multi-hazards risk of the COVID-19 pandemic, climatic disasters, and other infectious diseases in Bangladesh (OS3)	The country will face the massive physiological shock	OS3S1	0 (0)	0 (0)	5 (79)	15.1 (241)	79.9 (1270)	4.75	0.539	0.291	-2.077	3.382	0.65
	Prolonged food insecurity in the whole country	OS3S2	0 (0)	0.6 (10)	5 (79)	20.8 (330)	73.6 (1171)	4.67	0.601	0.361	-1.85	3.097	0.70
	The education system will face an irreversible system loss	OS3S3	1.3 (21)	1.9 (30)	8.8 (139)	23.9 (380)	64.2 (1020)	4.48	0.833	0.694	-1.825	3.52	0.57
	The total economy will be disrupted	OS3S4	0 (0)	3.1 (49)	2.5 (40)	22.6 (360)	71.7 (1141)	4.63	0.689	0.475	-2.176	4.937	0.64
	Prolonged and severe health, psychosocial and socio-economic crisis	OS3S5	0 (0)	0.6 (10)	3.1 (49)	25.2 (401)	71.1 (1130)	4.67	0.57	0.325	-1.723	3.073	0.69
	The number of unemployed populations will increase	OS3S6	0 (0)	0.6 (10)	4.4 (70)	30.2 (480)	64.8 (1030)	4.59	0.608	0.37	-1.382	1.687	0.72
	The young generation will become mentally depressed	OS3S7	1.9 (30)	1.3 (21)	5.7 (91)	26.4 (418)	64.8 (1030)	4.51	0.818	0.669	-2.173	5.601	0.41
	Poverty level and the number of ultra-poor population will increase	OS3S8	0 (0)	0 (0)	2.5 (40)	26.4 (420)	71.1 (1130)	4.69	0.517	0.268	-1.351	0.86	0.64
	Small and medium enterprises will collapse	OS3S9	0 (0)	0.6 (10)	8.8 (140)	30.8 (490)	59.7 (950)	4.5	0.683	0.467	-1.134	0.51	0.70
	Child mortality rate will increase drastically	OS3S10	0.6 (10)	4.4 (70)	18.2 (289)	32.7 (520)	44 (701)	4.15	0.915	0.838	-0.857	0.086	0.50
	Maternal and physical health status of the country will decrease	OS3S11	0.6 (10)	0.6 (10)	8.2 (130)	32.1 (510)	58.5 (930)	4.47	0.728	0.529	-1.499	2.888	0.60
	Social conflict, illegal activities, gender-based violence and crimes will increase	OS3S12	0.6 (10)	1.9 (30)	6.9 (110)	37.1 (590)	53.5 (850)	4.41	0.757	0.572	-1.462	2.79	0.56
	SDGs and other national targets will not be achieved as it	OS3S13	0.6 (10)	1.3 (21)	5.7 (91)	30.8 (489)	61.6 (979)	4.52	0.719	0.517	-1.762	4.052	0.57

	planned												
Management strategies for Scenario-3	Categorized rapid risk assessment is required such as short, medium and long term	OS3M1	0 (0)	0 (0)	3.8 (60)	32.1 (510)	64.2 (1020)	4.6	0.563	0.317	-1.066	0.153	0.65
	The special action plan should be drawn to implement mass awareness and measures for both Dengue epidemic, disasters and COVID-19 pandemic in a single umbrella	OS3M2	0 (0)	0.6 (10)	5.7 (91)	25.8 (410)	67.9 (1079)	4.61	0.626	0.391	-1.525	1.883	0.59
	Stringent collaboration among all the respective sectors are in utmost important	OS3M3	0 (0)	0 (0)	2.5 (40)	32.1 (510)	65.4 (1040)	4.63	0.534	0.285	-1.036	0.016	0.72
	Need strong volunteer groups with proper coordination, training and equipment	OS3M4	0.6 (10)	0 (0)	2.5 (39)	26.4 (421)	70.4 (1120)	4.66	0.594	0.352	-2.301	8.564	0.52
	Need to set the priority sectors and ensure preparedness early on	OS3M5	0 (0)	0 (0)	3.1 (49)	28.3 (450)	68.6 (1090)	4.65	0.539	0.291	-1.254	0.609	0.67
	National coordination committee can be formed headed by Prime Minister of Bangladesh	OS3M6	0.6 (10)	0 (0)	6.3 (100)	24.5 (390)	68.6 (1090)	4.6	0.666	0.443	-1.952	5.062	0.44
	An integrated task force can be prepared to have an expert group from each vulnerable area	OS3M7	0 (0)	0 (0)	3.1 (49)	32.7 (520)	64.2 (1021)	4.61	0.55	0.303	-1.025	0.039	0.68
	Long-term health policy to combat the prolonged psychosocial and socio-economic crisis	OS3M8	0 (0)	0 (0)	4.4 (70)	32.1 (510)	63.5 (1010)	4.59	0.576	0.332	-1.068	0.162	0.59
	Microfinance program for the unemployed and small-interest credits for the agricultural/IT/industry-based start-ups to create employment and business	OS3M9	0.6 (10)	0 (0)	6.3 (100)	32.1 (510)	61 (970)	4.53	0.673	0.453	-1.616	3.926	0.57
	Special counselling for the affected persons, their family and the unemployed to overcome the crisis	OS3M10	0 (0)	0 (0)	5 (80)	32.1 (510)	62.9 (1000)	4.58	0.589	0.347	-1.064	0.146	0.51

Figure-1: COVID-19 in Bangladesh (a) Cases (b) Deaths and (c) Percentage of cases per total test

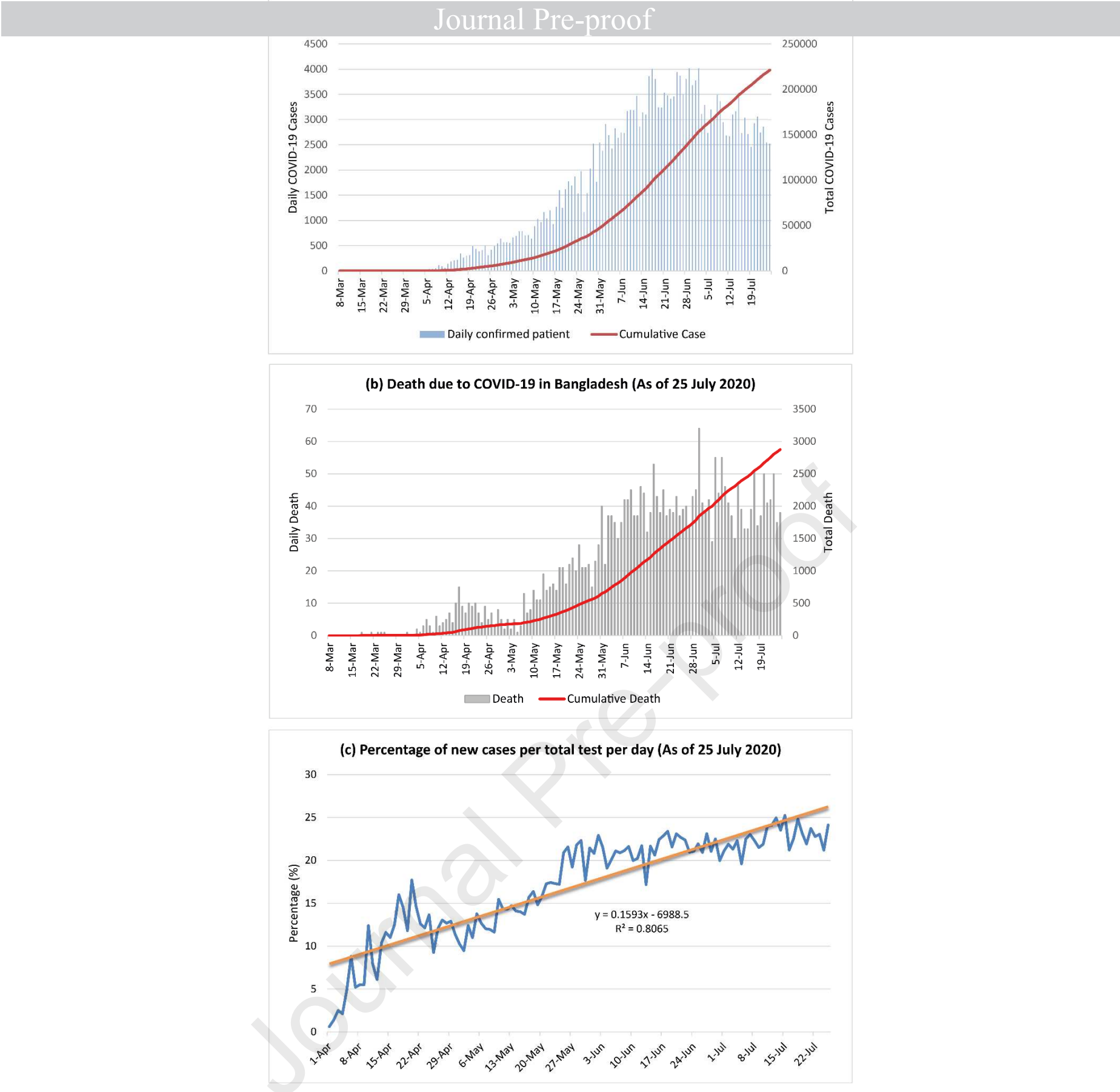


Figure-2: Most climate vulnerable districts and sub-districts (Modified after MoEFCC, 2018)

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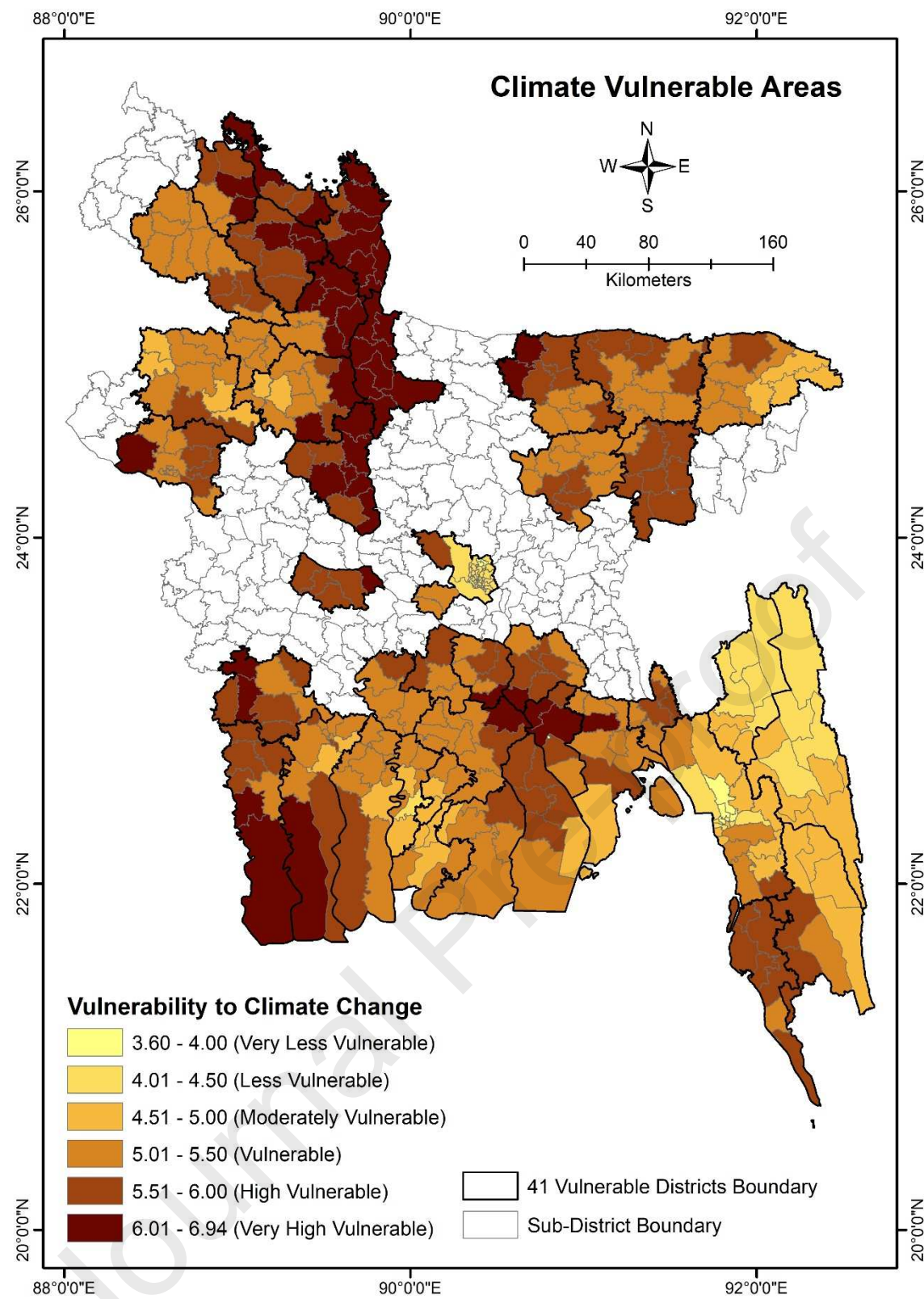


Figure-3: COVID-19, Cyclone Amphan and Flood affected areas

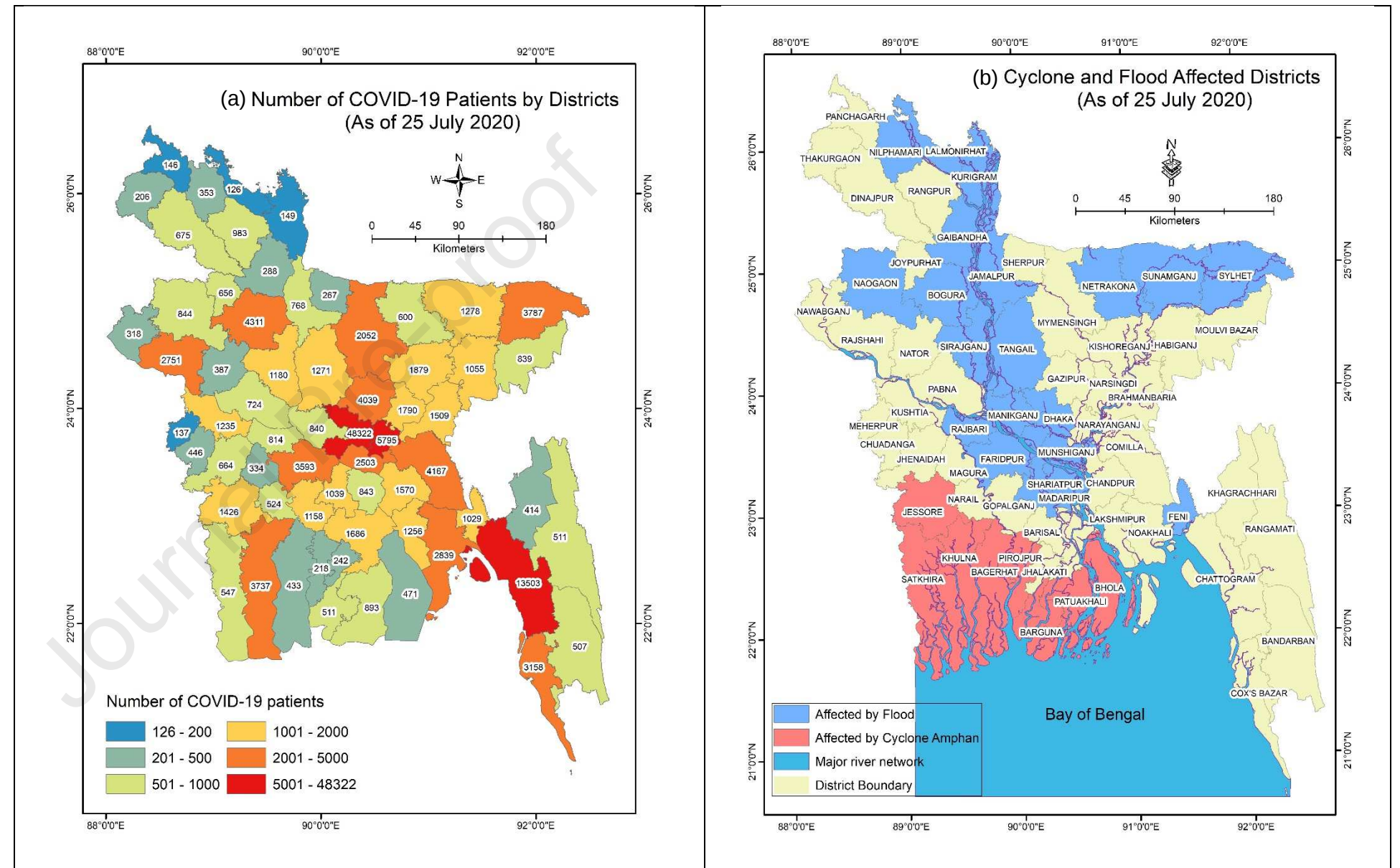


Figure 7. Annual Dengue fever reported cases and deaths in Bangladesh 2000-2019

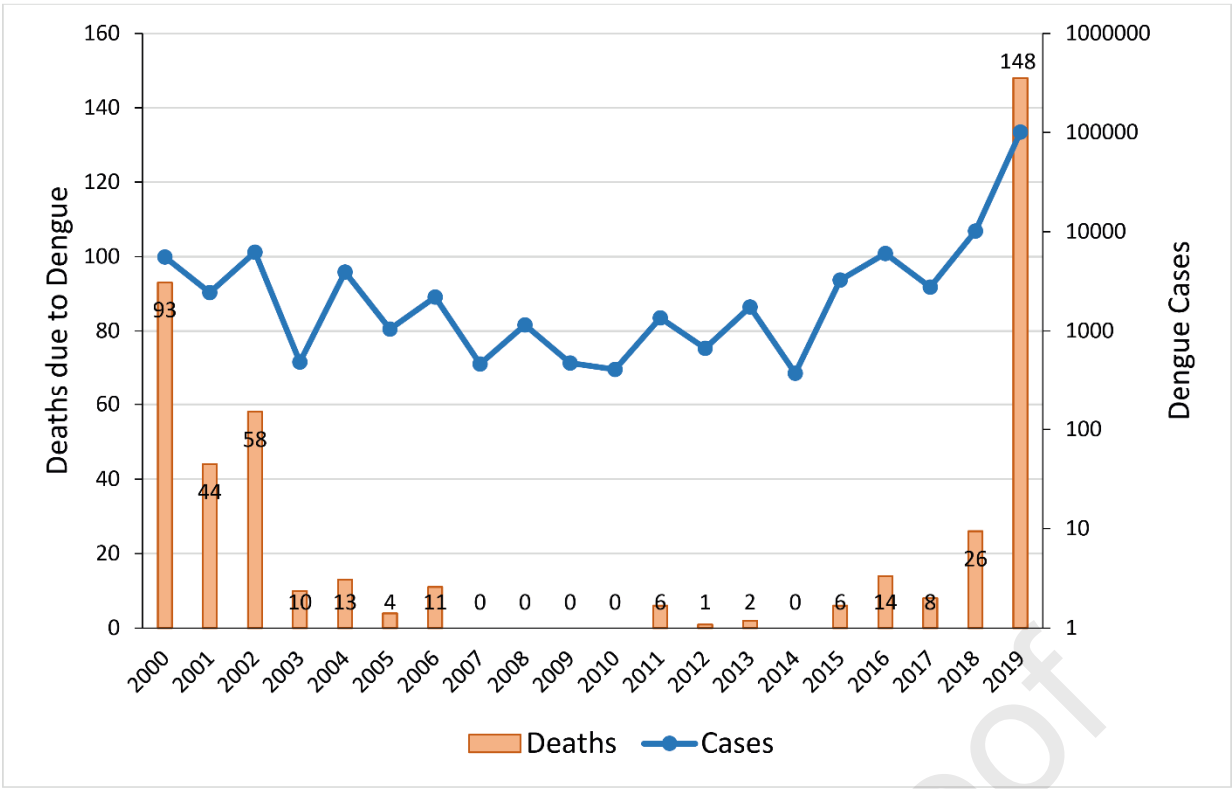


Figure 5: Monthly distribution of climatic extreme and slow-on set events

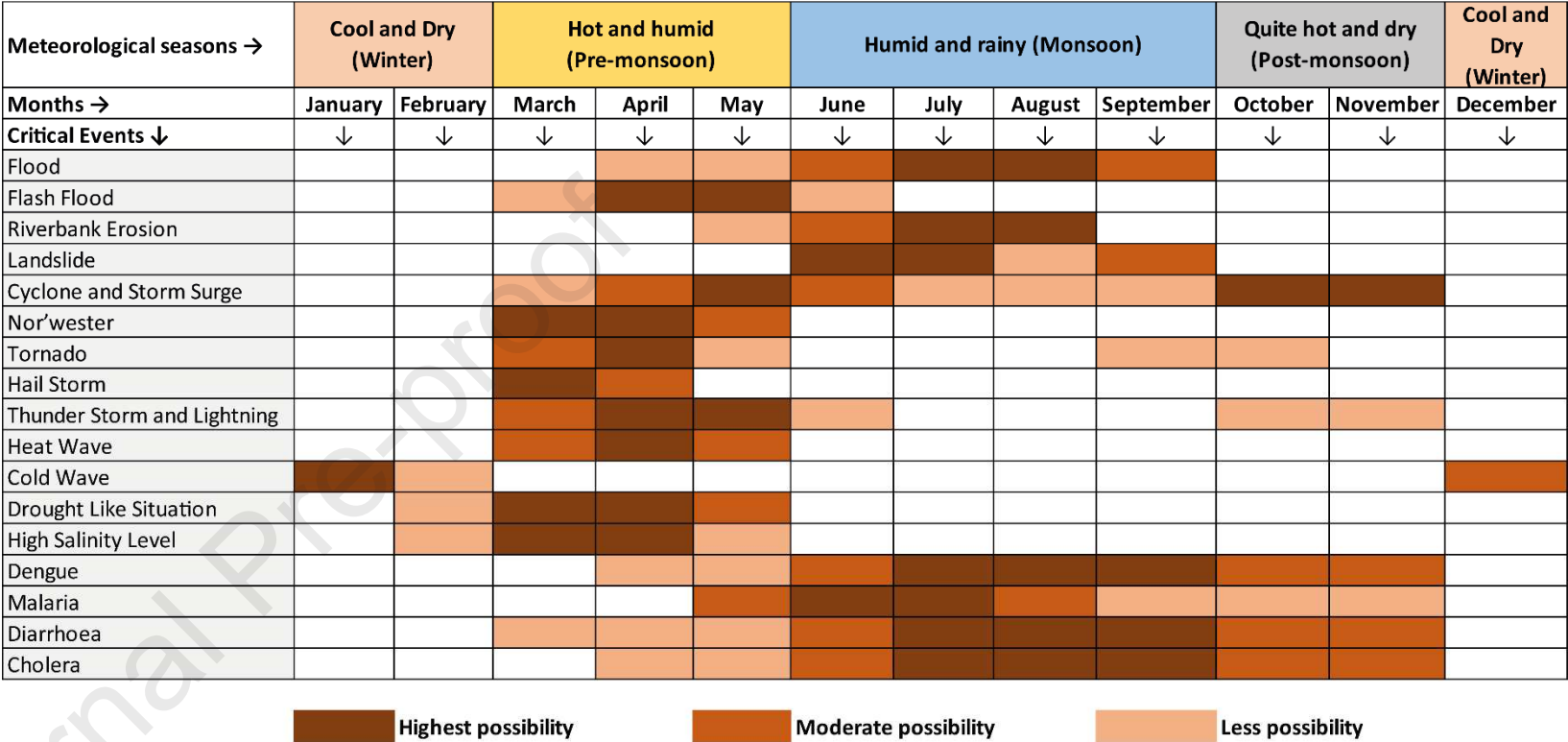


Figure-6: Scree plots of the eigenvalues of PCA

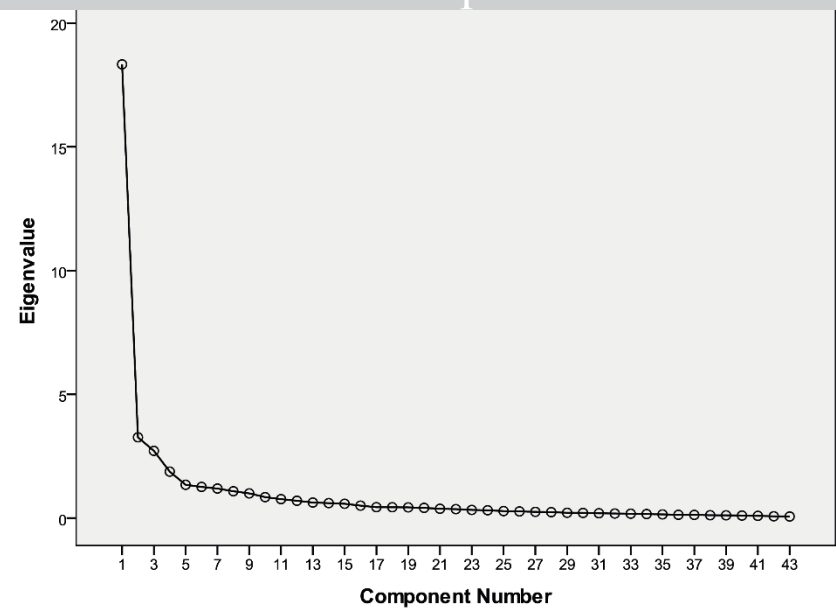
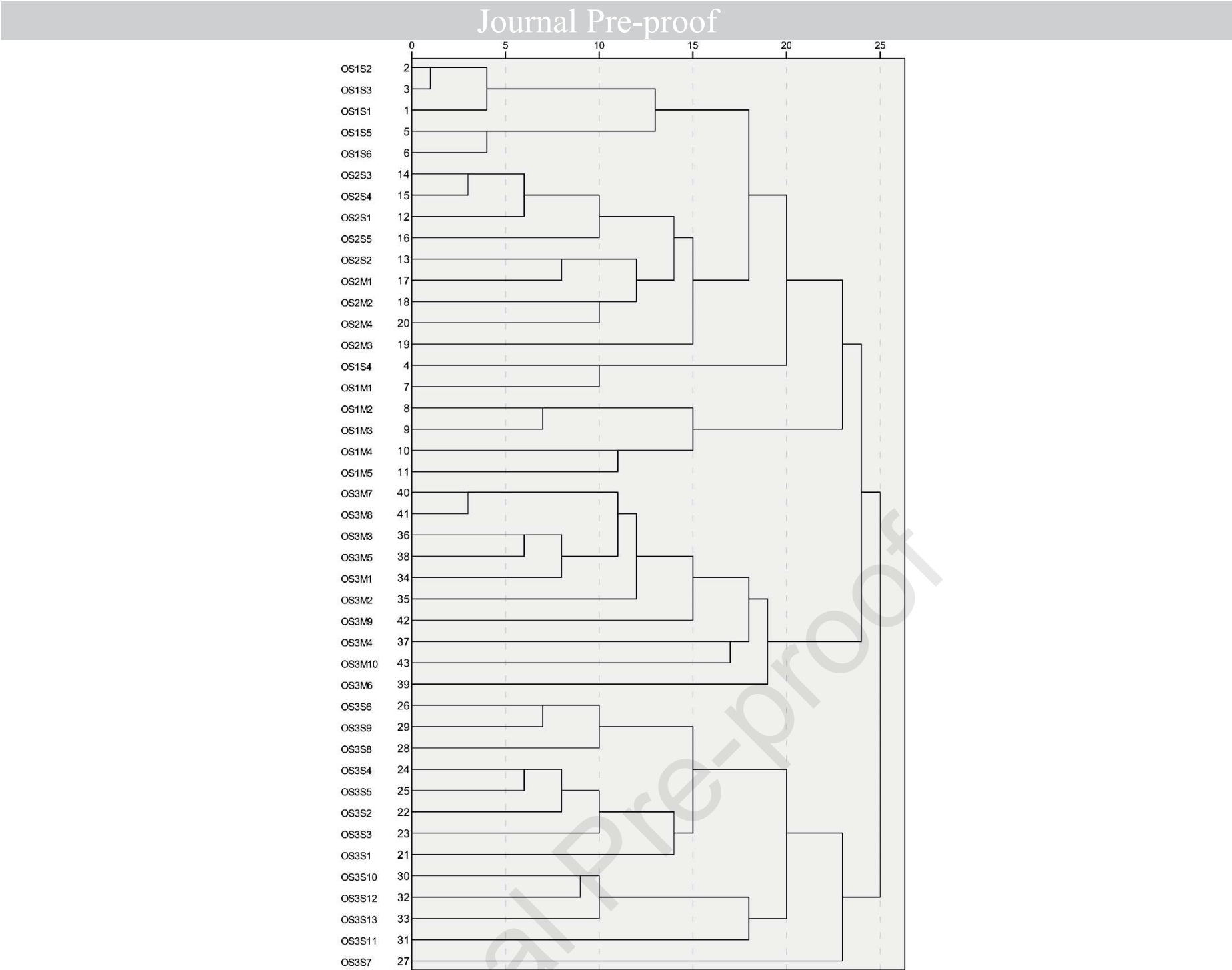


Figure-7: Dendrogram showing the clustering of people’s perceptions on different scenarios



Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: