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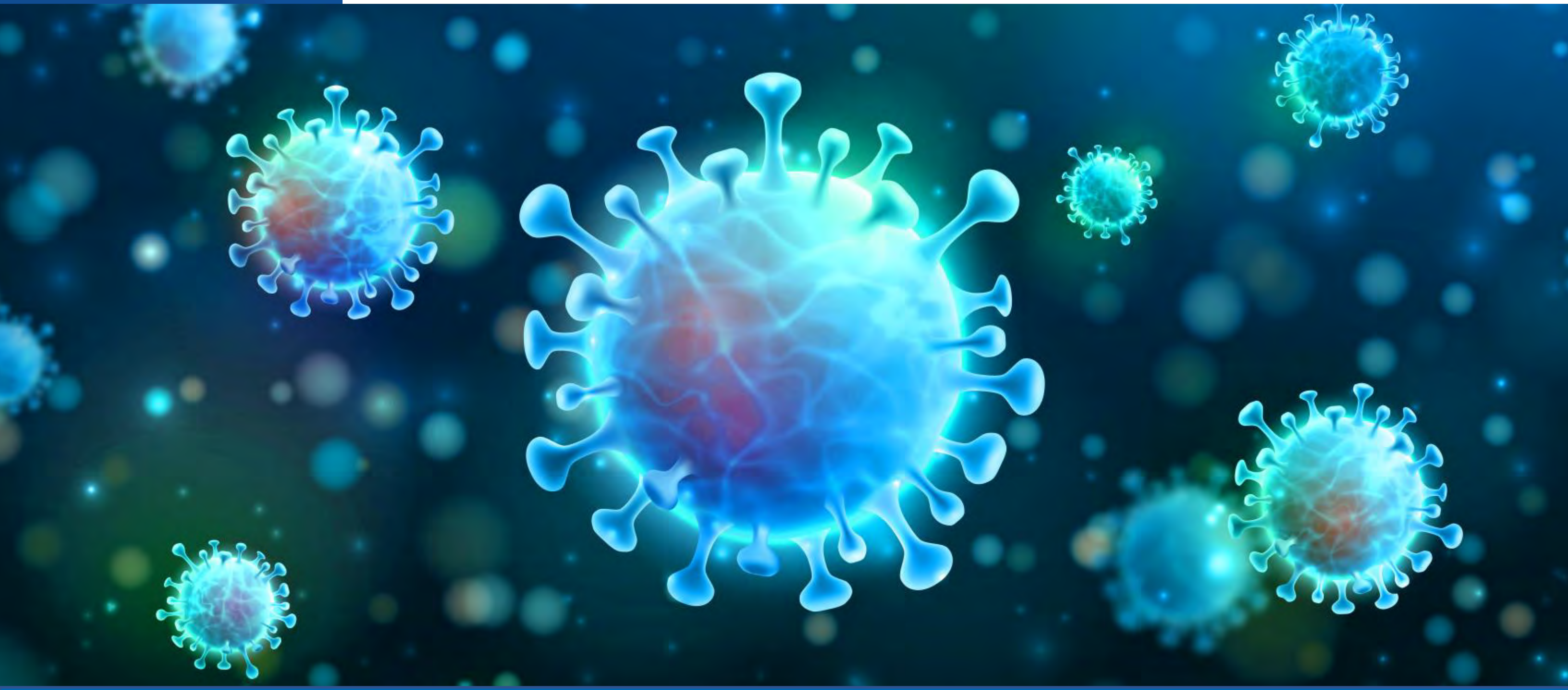

Developing cascading risk scenarios for complex disasters

Pathways to manage risk and protect people

Policy Study (4/2020)

Asia Pacific Disaster Resilience Network

COVID-19 RESPONSE

UNITED NATIONS ESCAP

Economic and Social Commission for Asia and the Pacific

Executive Summary

The Asia and the Pacific region facing an increasing complex and expanding disaster riskscape. Each year, people in the region suffer from various climate hazards such as floods, droughts, tropical cyclones, and heat waves. This is likely to continue this year in the middle of the COVID-19 pandemic. The pandemic is demonstrating that that the traditional demarcation between health and disaster hazards are arbitrary at best. Managing disaster risks amidst the pandemic requires very different approaches from what used to be done.

It has long been known that biological and natural hazards intersect with each other and increase the complexity of overall disaster impacts on populations and economies. But disaster management and risk analytics have been slow to capture the intersections of natural and biological hazards or capture the dimensions of interconnectedness and cascading effects to the social, economic, and environmental ecosystems.

In South Asia, in particular, the convergence of COVID-19 with natural hazards has created a hitherto unseen complex, compounding, and cascading risk landscape with spillover impacts on numerous sectors. The capacity of disaster management and public health systems to respond to these converging risks will inform the recovery for COVID-19 and beyond.

These challenging times call for a reformulation and paradigm shift from considering only short- and medium-term risk management to long-term understanding and addressal of cascading and systemic risks to support resilience building. The South Asia sub-region needs to prioritize building new and complex disaster risk scenarios supported by integrated approaches for risk assessments to address these risks. There is an opportunity now to build the knowledge base of how risks are compounded and to augment interdisciplinary interaction between health, disaster management and sectors impacted by the nature of cascading risks.

Building multiple and complex risk scenarios that take the converging biological and natural hazard risks into account will strengthen the much-needed systematic integration of health considerations into disaster risk reduction policies. In the era of COVID-19, developing the next generation of integrated risk scenarios will build a resilient South Asia that is prepared to face complex and cascading challenges and protect both lives and livelihoods.

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Contents

Figures and Tables

Introduction

The Asia-Pacific region faces a daunting spectrum of natural hazards. Indeed, many countries could be reaching a tipping point beyond which disaster risk, fueled by climate change, exceeds their capacity to respond. The 2019 Asia Pacific Disaster Report has expanded the understanding of the riskscape faced by the Asia Pacific region, including those emanating from slow-onset disasters. It also demonstrated how disasters are closely linked, interact with, and feed into inequalities of income and opportunity and the pathways through which it increases poverty levels in the region. However, the riskscape has yet to address the risk from biological hazards. While slow to be operationalized at the policy level, it has long been known that biological and natural hazards intersect with each other and increase the complexity of overall disaster impacts on populations and economies.

This has been starkly demonstrated by the impacts of the novel coronavirus COVID-19 which has added to the risks that prevail in region. The COVID-19 crisis has very quickly shown the very real systemic gaps in disaster management and countries are recognizing that the demarcations between natural, biological, and other hazards, are at best, arbitrary. The risk transmission pathways of biological hazards like COVID-19 and natural hazard events are very different, but they share the same geographical space and time in several countries. The virus now, is proliferating in high population density areas and having significant impacts on vulnerable groups and livelihoods that are also at risk from the impacts of natural disasters. With the increasing number and intensity of weather extremes foreshadowed by climate change, another pandemic could decimate the already shaky social systems including those related to health and disaster management.

However, in the development agenda of the region, the disaster risk reduction and management sector and the health sector, particularly the public health-care system, remain siloed. [1] In addition to the changing epidemiological and disease profile (double burden of infectious and noncommunicable diseases), there are challenges in integrating the health sector's emergency preparedness with the overall national disaster preparedness and response agencies and plans. This calls for a systems approach where a parallel effort of policy integration moves in line with preparing healthcare workers to work with limited resources and challenging situations.

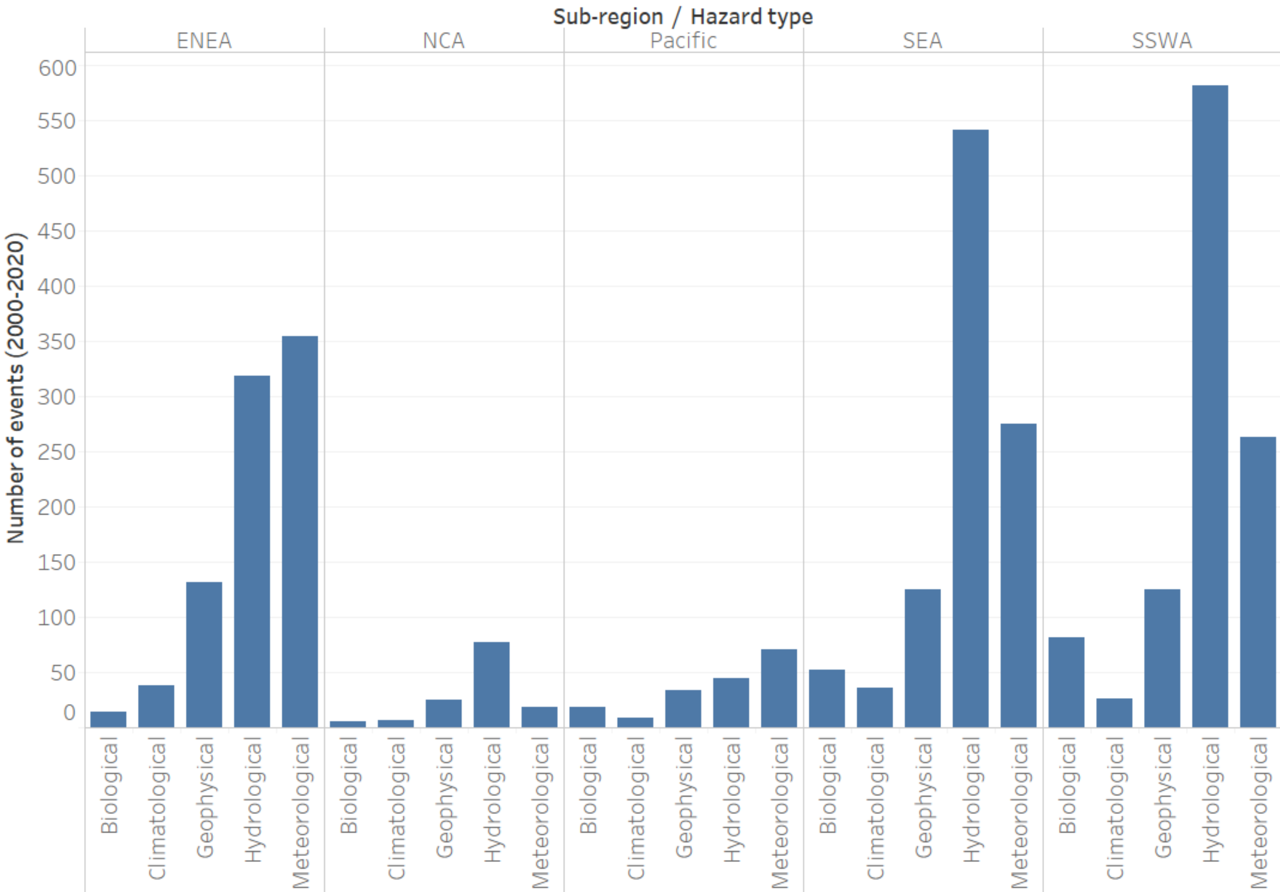
One of the key barriers to integration is that building integrated disaster-health risk scenarios are complex. They need a wide range of analytics from multiple disciplines and sectors that cover impact forecasting and risk informed early warning, indexing, and creating combined risk matrices to target at risk communities and vulnerable locations. Understanding the cascading scenarios from complex disasters will be key to protecting vulnerable communities from becoming new epicentres of the pandemic.

This policy study is a step in the direction to achieve this goal. The paper lays out the extended riskscape of the Asia Pacific region and examines the cascading risks that are arising and will arise from the impacts of natural and biological hazards. Specifically, the study provides a methodology for building an integrated risk analytics framework and demonstrates a protype for India and Bangladesh to show the cascading risk scenarios and provide a pathway to capture the systemic nature of cascading disasters.

The disaster risk landscape in Asia Pacific: complex, interconnect and cascading hazards with sub-regional specificities

For the last several decades, the Asia-Pacific region has experienced the greatest human and economic impacts reported from natural disasters. This partly corresponds to its size – Asia and the Pacific has 60 per cent of the world's people and 40 per cent of the landmass, as well as 36 per cent of global GDP. But even taking the region's size into account, a person living in Asia and the Pacific is much more likely to be affected by natural disasters.[2] Overall, the South and South west Asia subregion of Asia Pacific are the most impacted by biological, climatological and hydrological hazards (*Figure 1*).

Figure 1 Disaster events by hazard type among Asia Pacific sub-regions



Natural hazards

Floods — The riskscape shows that the hazard contributes almost 13 percent to the total annual average loss from natural hazards including drought. The countries with the highest flood risk are Myanmar, Lao People's Democratic Republic, Cambodia, and Bangladesh. Floods have also taken a greater share of fatalities over this period, with multiple incidences occurring in India, Afghanistan, China, the Democratic Republic of Korea, Japan, Lao People's Democratic Republic, and other countries in 2018.

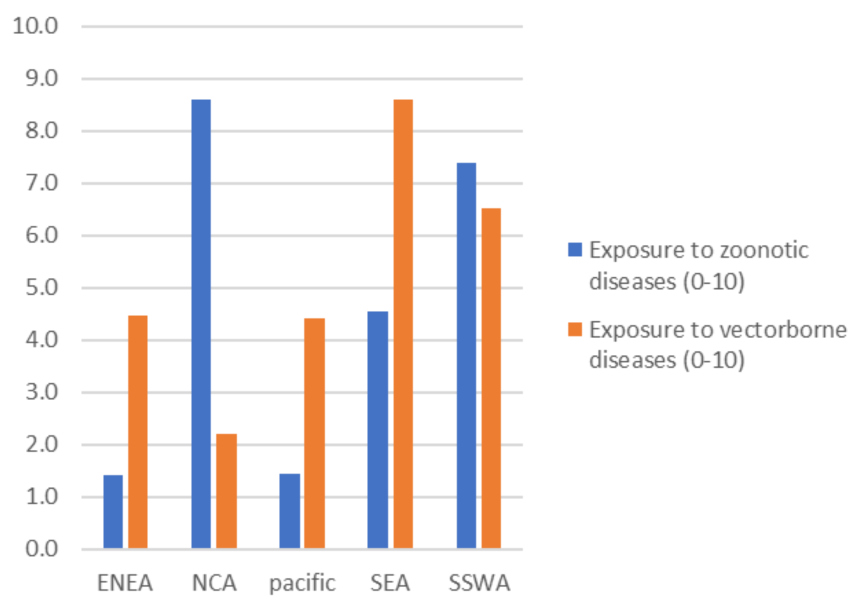
Tropical cyclones — Tropical cyclones contribute to almost 32 percent of the regional average annual loss. Higher income countries as well as countries in the Pacific Small Island Developing States have the highest risk from Tropical Cyclones. However, changing tropical cyclone tracks from climate variable have also led to more cyclone impacts in countries like Bangladesh and India. The most recent tropical cyclones, namely Cyclone Amphan and Cyclone Nisarga attest to these changing hydrometeorological events.

Climate change— The region has seen an increased proportion of climate related disasters comprising of droughts, extreme temperatures, flood and storms[3]. Climate change is a main driver for changes in the disaster riskscape.[8] Recent climate-related extremes have been threatening people's well-being and their livelihoods.[9, 10] Climate change is expected to increase, droughts, flooding and cyclone intensity in many parts of South and Southeast Asia. [11, 12] An increase in extreme rainfall is a danger for countries with major river basins in South and South-West Asia. Climate change will also have multiple socioeconomic impacts, increasing uncertainties in livelihood, food security, and nutrition.[16]

Biological hazards[4]

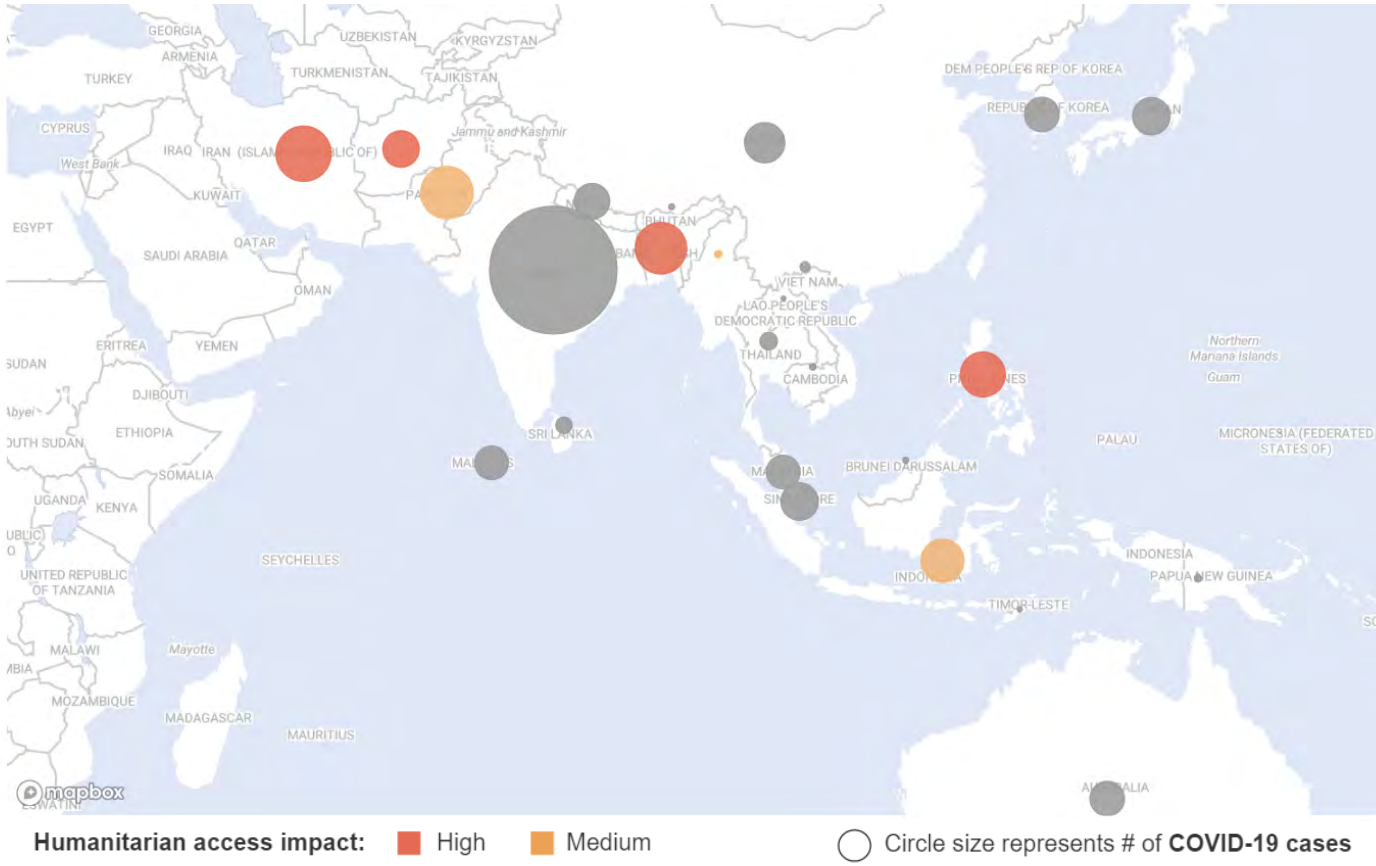
In addition to natural hazards, the region is constantly exposed to outbreaks and epidemics of emerging and re-emerging diseases including waterborne, vector-borne, vaccine-preventable, respiratory, and zoonotic infections like the current COVID-19. Along with the epidemics, and pandemics there is the high endemicity of dengue, typhoid, tuberculosis, and chikungunya. WHO assessing the region's vulnerability to biological hazards, notes that the largest biological threats to the region are Middle East respiratory syndrome (MERS), Diarrheal Diseases, Crimean–Congo hemorrhagic fever (CCHF), Japanese encephalitis (JE) Zika virus disease (ZVD). Biological disasters have a great impact in this region as several countries—especially in the South Asia subregion—are overpopulated and still developing, besides facing a severe human resource crunch among health care professionals which becomes an indirect threat among the already existing cascading threats. Analysis from the 2020 Inform Index data shows that ESCAP's South and South-West Asia region is the most exposed to both zoonotic and vector-borne diseases (*Figure 2*). This has been shown in the case of COVID-19 where the South and South West region has been highly exposed to the virus (*Figure 3).*

Figure 2 Sub-regional exposure to zoonotic and Vector-borne diseases



Source: Inform Index 2020

Figure 3 COVID-19 impacts in the Asia-Pacific region



Source: UNOCHA (2020). Asia Pacific COVID-19: Humanitarian Data Portal

Similar to natural disasters, a serious impact through infectious diseases is the economic burden on communities and nations, which is far more severe and disproportionate among countries in Asia Pacific than elsewhere. The complex interplay of biological, social, ecological, and technological drivers in the region enables microorganisms to exploit ecological niches, putting the entire region at high risk from emerging infectious diseases (EIDs). The burden of infectious diseases in the Asia Pacific region, and its specific sub-regions particularly South Asia, contributes to almost 42 percent of total disability-adjusted life years (DALYs)[1] lost worldwide.

Within the Asia Pacific sub-regions, South and South West Asia have the highest DALY (*Figure 4*) and has been considered a hotspot for emerging infectious diseases including those with pandemic potential.[5] In addition to COVID-19, the sub-region has witnessed several outbreaks of new and emerging infections as new microorganisms appear and existing ones alter their characteristics to promote their survival at the expense of human health. Japanese encephalitis, Nipah virus disease, leptospirosis, drug- resistant microbes such as New Delhi metallo-beta-lactamase 1 (NDM-1) and artemisinin-resistant malaria are a few of the emerging and re-emerging infectious diseases that have appeared recently and have now established endemicity.[6]

[1] The disability-adjusted life year (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. It was developed in the 1990s as a way of comparing the overall health and life expectancy of different countries.

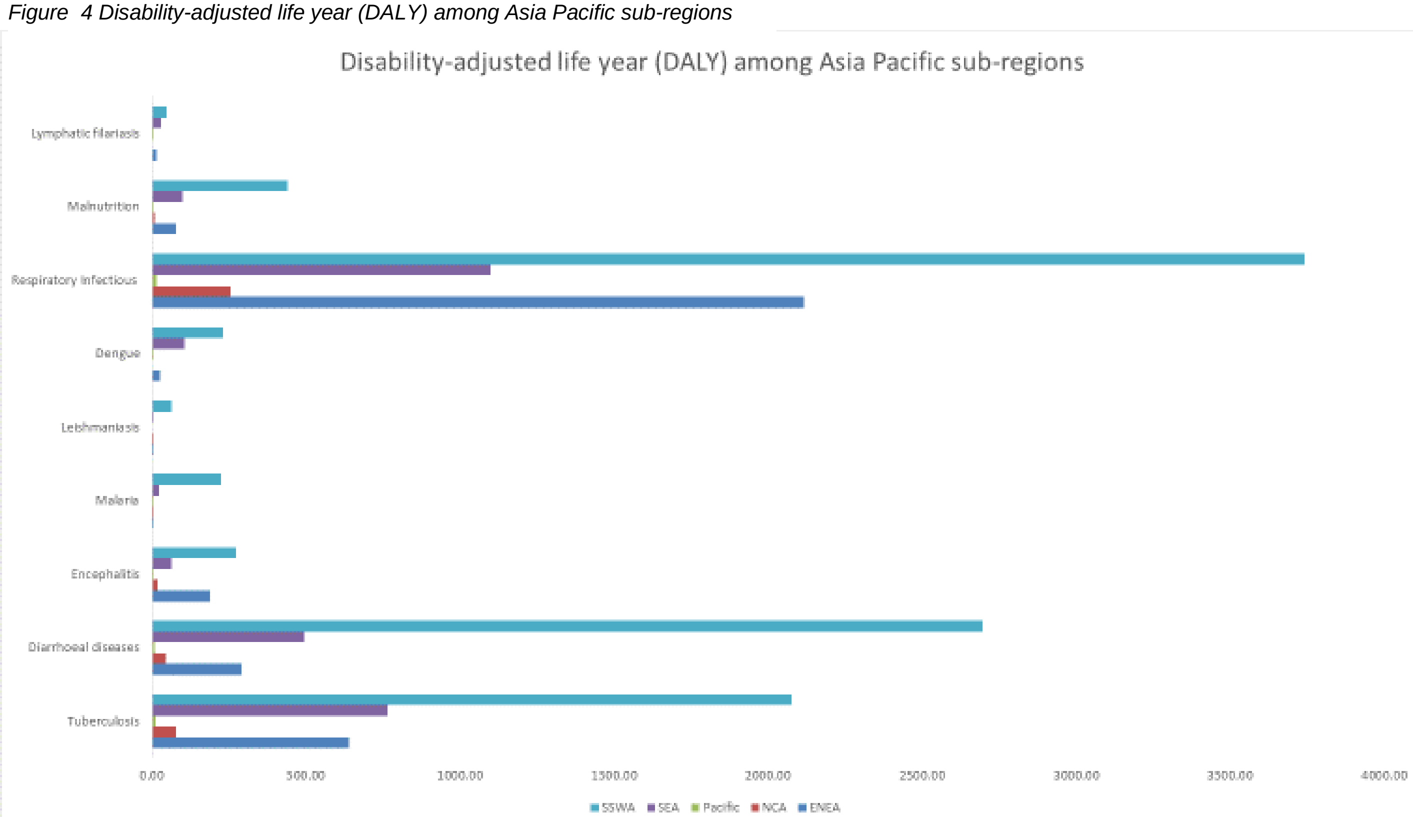
Disability-Adjusted Life Year (DALY)

Quantifying the Burden of Disease from mortality and morbidity

One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.

DALYs for a disease or health condition are calculated as the sum of the Years of Life Lost (YLL) due to premature mortality in the population and the Years Lost due to Disability (YLD) for people living with the health condition or its consequences.

Figure 4 Disability-adjusted life year (DALY) among Asia Pacific sub-regions



Source: World Health Organization, Global Health Estimates Summary Tables, 2018

Hotspots of interactions between biological and natural hazards

While slow to be operationalized at the policy level, it has long been known that biological and natural hazards intersect with each other and increase the complexity of disaster impacts. Floods, for example, have been shown to increase water-related infectious diseases, such as diarrhea, due to water contamination at drainage sites and damage to water systems. Floods and cyclones also increase the number of breeding sites for mosquito vectors and facilitate transmission of diseases such as leptospirosis.[7] In Viet Nam, for example, a study of 4,645 reports of typhoons, earthquakes and floods found significant increases in communicable diseases both pre- and post-disasters. Using the most recent EM-DAT data shows that biological, climatological and hydrometeorological hazards are impacting more and more populations in the region while the impact of the geological hazards has remained constant (*Figure 5*). In addition, the livelihood impacts in these countries from both biological and natural hazard intersects. *Figure 6* shows, that countries in South Asia, particularly India, Bangladesh, and Pakistan are at very high risk from losses for both natural hazards (measured in term of average annual loss or AAL) and disease burdens (measured by DALY).

Figure 5 Increasing affected populations from climate-related and biological hazards (,00000 population)

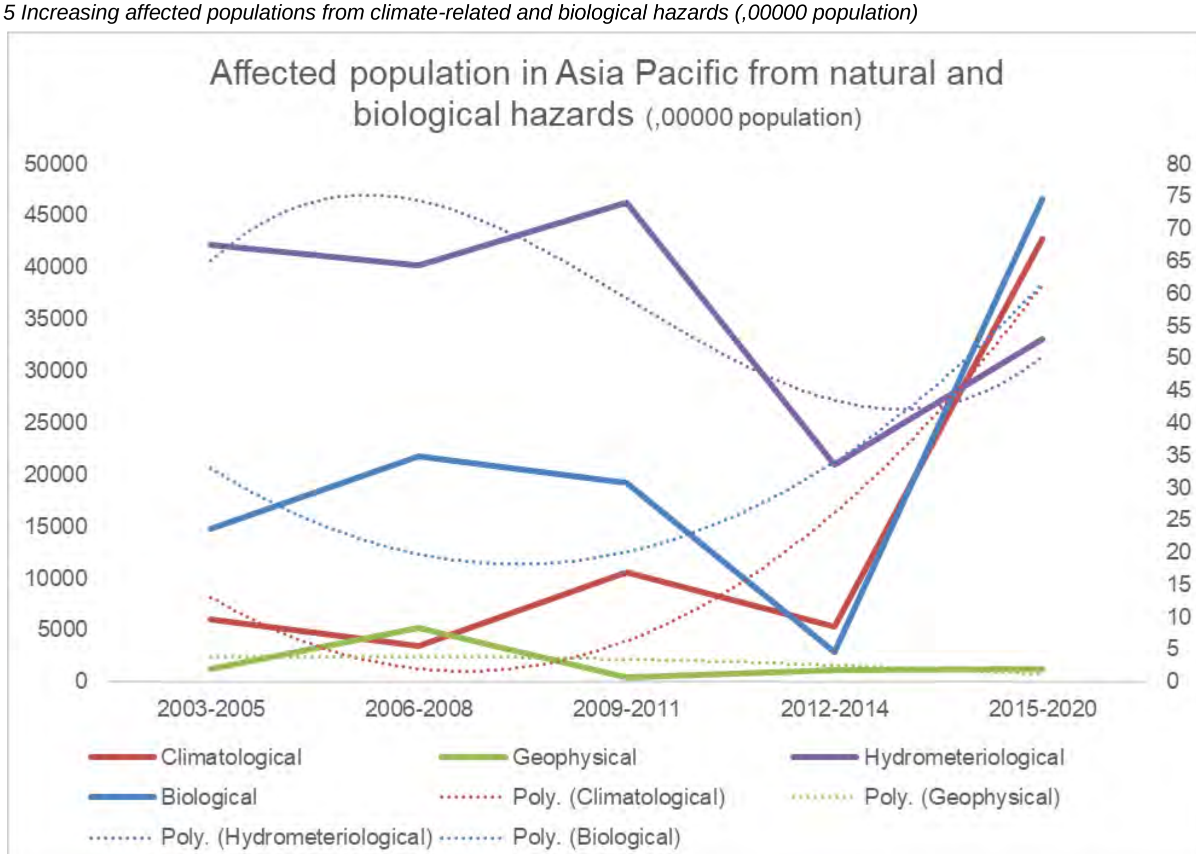
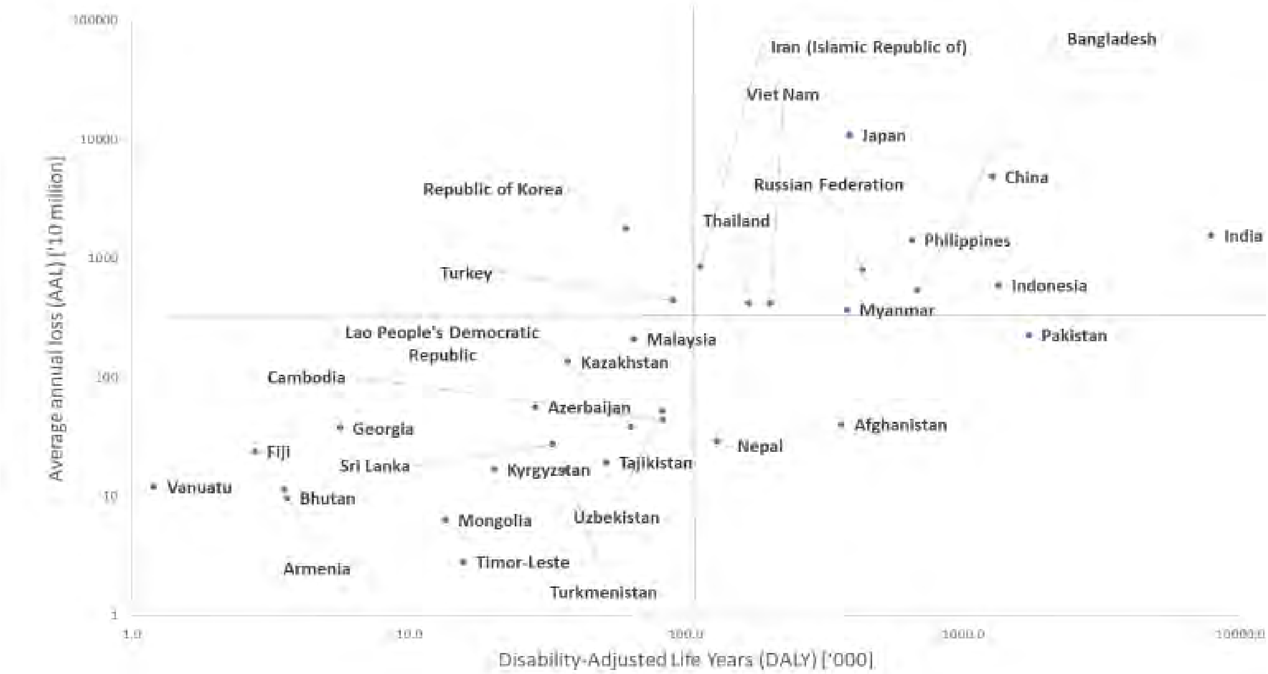


Figure 6 Overlap of Disability-adjusted life year (DALY) with Average annual loss (AAL) in Asia Pacific



Climate change is also set to increase these interactions. IPCC's sixth assessment report notes that climatic variations create new ecological niches for both vector borne and zoonotic diseases hence altering temporal and spatial distribution of the disease.[8] In addition, increase in temperature can also increase vector densities 30-32°C. [9] The effect of global warming can be seen in leishmaniasis transmission with sandflies as vectors. Sandflies are more active at higher temperatures and take more frequent bloodmeals, which in turn increases transmission.[10].

Seasonal flooding is already exposing more and more human lives to diarrhoeal disease outbreak among under five children and to some extent among adults where drainage systems contaminate clean water sources. This also naturally disrupts the chain of nutritional growth required among under five children puttingthem at risk for moderate and severe malnutrition where they enter into the bracket of 3SD and 4SD (standard deviation) from normal if supply chain recovery is not fast enough besides being complemented with catch-up growth diet at the household level. Now, those shifted to temporary shelters due to flood evacuation also run the risk of measles on top of COVID-19.

Additionally, future drought situations will drive the cycle of malnutrition among rural populations due to food insecurity crippling developmental efforts to eradicate Severe Acute Malnutrition (SAM). In floods, droughts, and pandemics, human health takes a beating, compromising growth, impacting the immune system, adding to mental health woes and psychosocial imbalance, and deepening existing inequalities, besides overwhelming health systems based on the intensity of the disaster and the existing local capacities. Additionally patients with chronic diseases like Diabetes, Hypertension, Kidney ailments end up being affected due to supply chain disruption which is an outcome of prolonged flooding, irregular transportation and follow up care in endemic/pandemic situations which calls for plugging leakages through risk informed policy and sectoral integration.

The Asia Pacific Disaster Report 2019, notes that within the realm of natural hazards, there are four distinct hotspots in the Asia Pacific region where fragile environments are converging with critical socio-economic vulnerabilities to create potential cascading crises (*Table 1*).[11] This study added the exposure to zoonotic and vector borne diseases from the Inform Index analysis in Figure 2 to the natural hazard risk matrix to present the integrated hotspots of natural and biological hazards. The table notes that South and South West Asia, followed by South East Asia are overall, highly exposed to both natural and biological disasters.

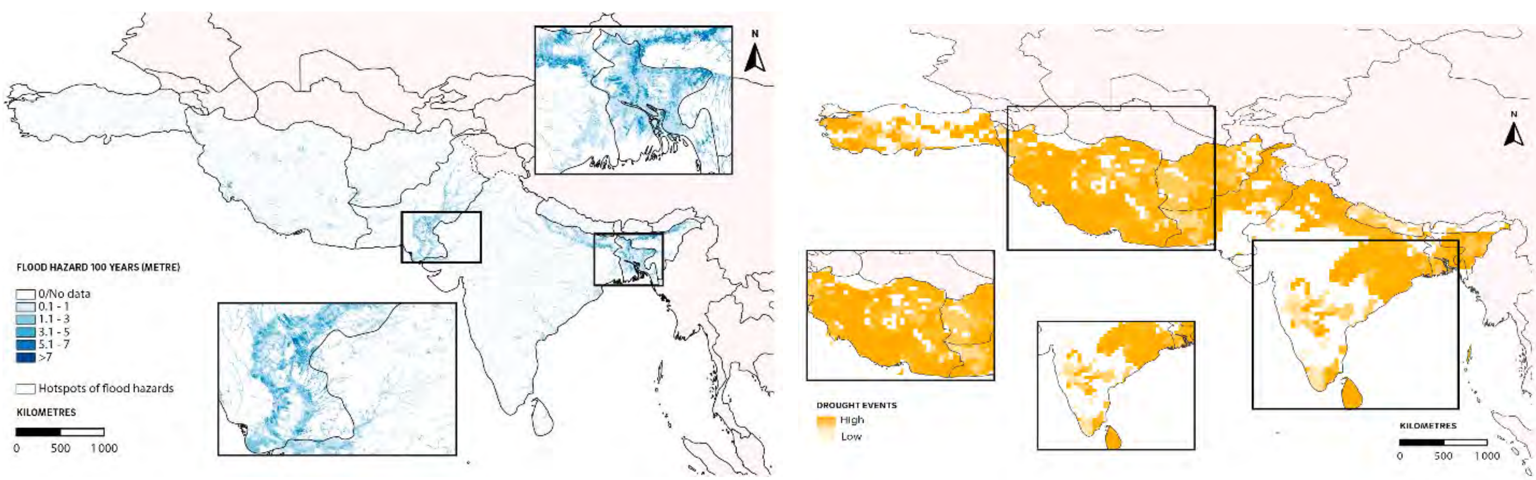
Table 1 Locating cascading and complex disaster risk hotspots (natural hazards, COVID-19, biological hazards)

Hotspot 1: Flood and drought prone areas/Transboundary river basins with COVID-19 and biological hazards		*Hotspot 2: Ring of fire/Earthquake, Landslides, tsunami, and typhoon tracks with COVID-19 and biological hazards*	
South and South-east Asia		*North and North-east Asia, some South-east Asia*	
Population exposure- COVID 19	Very high	Population exposure- COVID 19	Low
Population exposure- zoonotic diseases	Very high	Population exposure- zoonotic diseases	Low
Population exposure- vector borne diseases	Very high	Population exposure- vector borne diseases	Moderate
Population exposure-natural hazard	Very high (mostly poor)	Population exposure-natural hazard	Very high (mostly poor)
Economic stock exposure- natural hazard	High	Economic stock exposure	High
Infrastructure, energy- natural hazard	Low	Infrastructure, energy	Low
Infrastructure transport- natural hazard	Moderate	Infrastructure transport	Moderate
Infrastructure, ICT- natural hazard	Low	Infrastructure, ICT	Low
Hotspot 3: Tropical cyclone, El Nino, earthquake and landslide with COVID-19 and biological hazards		*Hotspot 4: Sand and dust storm risk corridors with COVID-19 and biological hazards*	
Pacific small island developing States		*South and South West Asia and Central Asia*	
Population exposure- COVID 19	Low	Population exposure- COVID 19	Very high and context specific
Population exposure- zoonotic diseases	Low	Population exposure- zoonotic diseases	Very high
Population exposure- vector borne diseases	Moderate	Population exposure- vector borne diseases	Very high
Population exposure-natural hazard	Very high (mostly poor)	Population exposure-natural hazard	High mostly poor)
Economic stock exposure	High	Economic stock exposure	High
Infrastructure, energy	High	Infrastructure, energy	Moderate
Infrastructure, transport	Moderate	Infrastructure transport	Moderate
Infrastructure, ICT	Low	Infrastructure, ICT	Low

South Asia: Where interactions between risk drivers, climate hazards and biological hazards lead to cascading disasters

Of all the ESCAP subregions, Table 1 shows that South Asia is where overlaps between disaster and socioeconomic risks and vulnerability are at their most complex with grave implications for achieving the sustainable development goals in the sub-region. In this subregion more than any other, records of major disasters show that social sectors suffer impacts that perpetuate inequality of opportunity. Almost 43 per cent and 38 per cent of disaster impacts were on the social and livelihood and productive sectors, respectively. [12] These recurring losses represent an ongoing erosion of development assets and reduce the potential to invest the dividends of economic growth into human development. Climate related disasters, mainly floods and drought, make up almost 90 per cent of the losses from natural disasters (*Figure 7*). The region is also home to the world's largest river basin, the Ganges–Brahmaputra–Meghna (GBM)river basin, shared by four South Asian countries Bangladesh, Nepal, India and Bhutan which also accounts for the largest concentration of poverty in the world. [13]

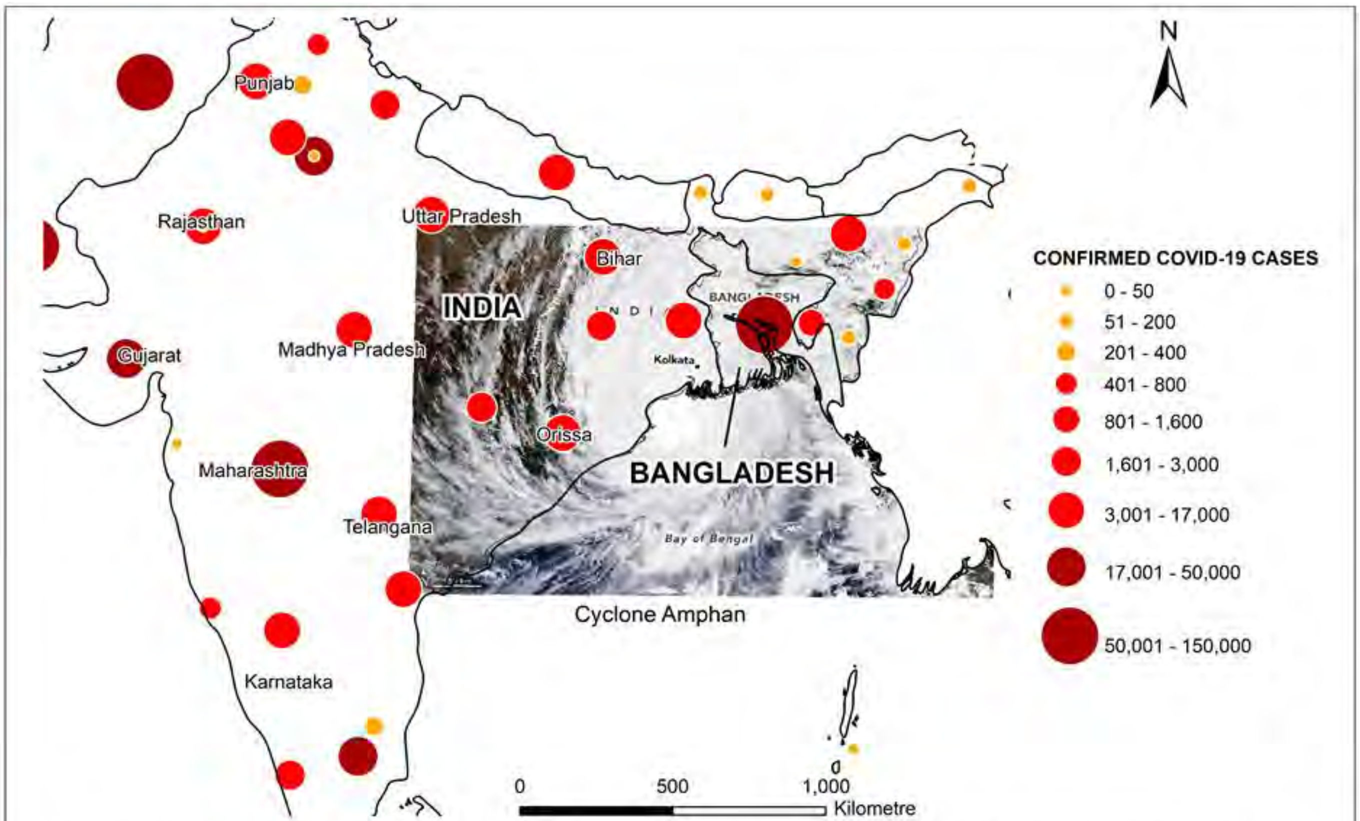
Figure 7 Hotspots of flood and drought risk



India, Bangladesh, Pakistan, Nepal, and others in South Asia with endemic risks of widespread poverty, poor sanitation, and poor public health facilities, are also suffering from high impacts of diseases. Recent years have seen new disease outbreaks and emerging infectious diseases (EID) assuming pandemic proportions, causing social and economic disruption and ultimately becoming endemic. The standard of living and the health status of people regarding their nutrition and immunity, as well as sanitation problems that arise especially in overcrowded urban areas amplify the impacts of these diseases. These risk drivers, along with growing urbanization, allow vectors to breed in both rural and urban areas and reduces the gap between rural and urban distribution of water and vector borne diseases. An increased incidence of malaria at higher altitudes in India, expansion of Japanese Encephalitis from Terai regions to Kathmandu valley in Nepal and spillover of dengue to Bhutan from Sikkim in India all foreshadow the expanding threat of vector borne diseases from climate change, urbanization and unsustainable land-use practices.[14]

The convergence of COVID-19 with natural hazards in South Asia is a perfect example of how endemic risks are driving the impacts of both biological and natural hazards. For example, amidst the COVID-19 pandemic, South Asian countries are being hit by cyclones, floods, landslides and locust infestations as shown in *Figure 8*. The pandemic demonstrates the cascading risks that occur when increasing climate-related weather extreme intersect with an ongoing pandemic along with the existing risk drivers that are endemic to South Asia. For example, In August 2020, Mumbai city in India received 198 mm of rain in four hours- the heaviest since 2005; it came at a time where more than half the residents of slums including Dharavi, the largest slum in the world, tested positive for COVID-19 (only 16 per cent of people living outside slums in the same areas were found to be exposed to the infection).[15]

Figure 8 Collision of cyclone Amphan with COVID-19



Sources : ESCAP, based on ESRI and John Hopkins University Coronavirus COVID-19 Cases V2, 16 June 2020 and Cyclone Amphan on NASA's Aqua satellite the Moderate Resolution Imaging Spectroradiometer (MODIS), 20 May 2020.

Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

The COVID-19 crisis is also foreshadowing that climate change will be a key factor in future natural hazards and vector distribution for biological hazards. The specific health risks posed by climatic disasters and climate change in South Asia is provided in *Table 2*. India, Nepal, Bangladesh and Pakistan will face greater flooding in coming days due to extreme weather events and this will increase the incidence and prevalence of diarrheal diseases, vector borne diseases and increase the issues revolving around food security thereby indirectly also facilitating the risk of further slipping improved populations into moderate and severely acute malnutrition and weakening their immune response.[16] Afghanistan, Maldives, Bhutan, Sri Lanka also face similar challenges and the health systems that presently exist are not sufficient enough to mitigate and prepare for cascading risks. South Asia, as such, faces a severe human resource shortage both at a tertiary care level and also at a primary healthcare level. This is further complicated by hilly terrains and mountain ranges which make healthcare inaccessible and also unaffordable at times due to which health seeking behaviour is comparatively not very strong. Most of South Asia has over time cultivated grass-root healthcare workers who have been assigned basic duties in community healthcare and are called by different names in different countries, but these grass-root healthcare workers are not placed at the center of discussing emerging from health and disasters and have little or no knowledge with regard to addressing or mitigating cascading risks from a systems approach.

Additionally, salt water that intrudes from sea levels and drought induced loss of cultivable land will aggravate a food shortage crisis in the middle of already very high rates of undernutrition among children in South Asian nations.[17] Water reservoirs have been depleted due to receding glaciers in the mountain ranges of India and Nepal leading to rising temperatures and reduced snowfall.[18] This naturally affects activities around water, sanitation and hygiene that aids development in the sub-region.[19]

Table 2 Emerging biological risks posed by climate change and extreme weather events

	Climate related risks	*Biological and health risks*
Bangladesh	1°C rise in temperature Increase in extreme weather events	Increase diarrhoeal incidence rates by 5.6 per cent Increase in dengue and leishmaniasis
India	1°C rise in temperature Flooding Drought	Increase in malaria, dengue, Japanese encephalitis, leishmaniasis Diarrhoeal incidences expected to increase by 13.1 per cent by 2041 Undernutrition due to food insecurity
Nepal	1°C rise in temperature 1 cm rainfall increase	Increase diarrhoeal incidence rates by 4.39 per cent; Mosquito vectors of malaria, chikungunya, and dengue and lymphatic filariasis and Japanese encephalitis can now be found at 2000 m above mean sea level in Nepal; Zika virus threat emerging Increase diarrhoeal incidence rates by 0.28 per cent
Sri Lanka	Increased flooding from sea level rise	Increases in malaria, dengue, and heat related diseases
Pakistan	Melting glaciers in the Himalayas threaten river flows, increased frequency and severity of monsoons and cyclones, and saline intrusion	Increase in geographical range and incidence of vector-borne diseases Increase in water-borne diseases and malnutrition
Maldives	Decreasing rainfall and number of rainfall days Drought	Increase in dengue, chikungunya, scrub typhus along with newly emerging diseases such as Zika virus infection Undernutrition due to food insecurity
Afghanistan	Rise in temperature, drought and flooding	Increased incidence of cholera, typhoid, diarrhoea, and ascariasis Increased incidence of malaria and leishmaniasis
Bhutan	Glacial lake outburst floods, landslides, and flash floods	Increased incidence of malaria, dengue, Japanese encephalitis, and chikungunya

To address the growing risk of hazard complexities and their cascading nature, there needs to be a paradigm shift from considering only short- and medium-term risk management to long-term understanding and addressal of cascading and systemic risks to support resilience building efforts.

Towards this, the sub-region needs to prioritize building new and complex disaster risk scenarios supported by integrated approaches for risk assessments to be prepared for cascading risks in the future.

A method for developing complex risk scenarios for cascading hazards: prototype for India and Bangladesh

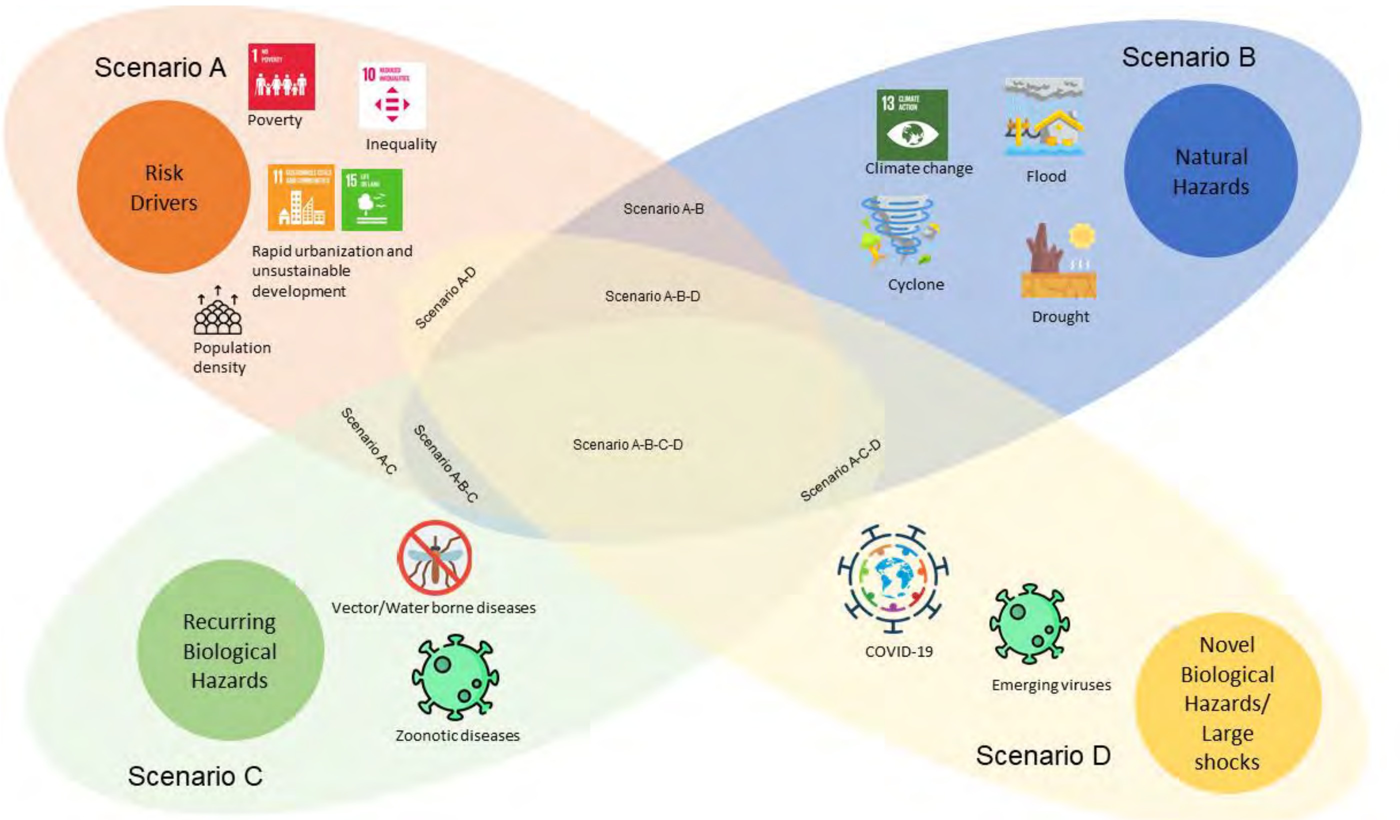
There is a limited knowledge base of how natural and biological hazard risks are compounded. Building multiple and complex risk scenarios that take the converging biological and natural hazard risks into account will strengthen the much-needed systematic integration of health considerations into disaster risk reduction policies.[20] These complex scenarios should not only consider each individual risk but also account for and locate the highest likelihood of cascading risks zones. This is critical to identifying the most vulnerable populations during cascading crises.

Figure 9 demonstrates a conceptual scenario planning for the current pandemic along with likely disasters both natural and other biological disaster that can potentially occur in the long-term or near future. For example, Scenario A-B is probably the most familiar and recurring scenario for disaster management agencies and both the impacts and probability of occurrence are somewhat known from historical record. Here, advances in early warning systems along with other technological and community level preparedness will potentially provide people with enough lead time to into evacuation shelters and save lives. Similarly, Scenario A-C is probably well known to health agencies and systems where they have adequate supplies to treat populations, even those who are vulnerable. However, the current pandemic under Scenario A-D is new and therefore, preparedness measures have not been in place. When natural hazard risks are added to the scenario as in Scenario A-B-D, this becomes a cascading disaster; here the lead time developed under Scenario A-B may not be sufficient due to the restrictions in travel or the newly implemented social distancing measures.

Therefore, to become resilient to hazards, all scenarios need to be modeled with their corresponding impacts on populations and sectors as well as the corresponding probabilities. In addition, these scenarios can also be developed for future cascading risks through time-based analysis. To develop these cascading scenarios, the interactions between agencies that are needed as well as the data requirement for the scenarios has been distilled from the various literature and is given in Appendix A.

To model the cascading risk scenarios from natural and biological hazards, this study uses Bangladesh and India as examples. The prototype shows (a) the simple hazard wise risk and (b) the intersections of hazard risk to model simple to complex risk scenarios with two separate time periods: a short-term scenario and a long-term scenario. The risk scenarios are demonstrated through an integrated matrix that captures the impact and probability of multiple hazards at the sub-national level for each district or province and categorized the province according to their risks from cascading and multiple hazards. This is accompanied by maps which locate the risk zones within the district. Using the prototype, impacts on the health sector, particularly on health infrastructure is assessed. To model the integrated scenarios the follow risk variables are used for each individual scenario in Figure 9. The datasets are provided in Appendix B and C.

Figure 9 Cascading scenario planning



Scenario A: The baseline risk drivers of poverty, inequality and deprivation is calculated with the Human Development Index (HDI). The HDI is a statistic composite index of life expectancy, education, and per capita income indicators, which are used to rank countries into four tiers of human development. A country scores a higher HDI when the lifespan is higher, the education level is higher, and the gross national income GNI (PPP) per capita is higher. Populations living in low HDI areas are more likely to be impacted by hazards, both biological and natural due to the lack in systemic coping capacities.[21]

Scenario B: The prototype focuses on flooding as the key natural hazard. For understanding the short-term scenario, the most recent flood extent was extracted from the VIIRS sensor of NOAA-20 satellite between 20 June to 19 July for Southern Asia. For the long-term scenario, the GAR 2015 projected flood risk data is used with a return period of 50 years.

Scenario C: The recurring biological hazard data focused on dengue and malaria exposure. Both dengue and malaria hit India and Bangladesh with regular frequency. Exposure data for dengue for Bangladesh and India and exposure data for malaria for India were gathered from various sources provided in the data reference section.

Scenario D: The most recent COVID-19 exposure data (India, 6 August 2020; Bangladesh, 9 August, 2020) enumerating the number of cases is taken from Johns Hopkins.

India: Prototype of a cascading risk scenario model

A. Individual hazard risks [Simple Scenarios A, B, C, D]

Scenario A: India's overall country HDI value for 2018 is 0.647— which puts the country in the medium human development category. However, there are differences in HDI within India, which impacts the transmission of cascading disaster risks. Appendix B provides the individual province level risks and notes that the provinces with the lowest HDI are Bihar, Uttar Pradesh, Orissa, Jharkhand, and Madhya Pradesh.

Scenario B: The prototype uses the most recent flood inundation maps for short term risks and the 50 year flood return period for long term risk. Appendix B notes the provinces with the highest population exposure levels to flooding in order are Bihar, Uttar Pradesh, West Bengal, Assam, and Punjab.

Scenario C: India has a recurrence of biological hazards. Appendix B shows that the provinces with the highest population exposure levels to dengue in order are West Bengal, Punjab, Maharashtra, Kerala, and Delhi and the provinces with the highest population exposure levels to malaria in order are Orissa, Chhattisgarh, Jharkhand, Madhya Pradesh, and Uttaranchal.

Scenario D: The COVID-19 cases have been rising steadily in India. Appendix B shows that Maharashtra, Tamil Nadu, Andhra Pradesh, Karnataka, and Delhi have the highest exposed populations.

B. Risk scenarios for current and upcoming cascading risks [Short-term]

The simple scenario analysis notes the greatest at-risk provinces if only one risk was happening at one time. However, these scenarios are taking place simultaneously. What is needed now is to understand how these risks are intersecting with one another and which populations in which provinces will be the most impacted. To model an integrated risk matrix, the study used a combination of likelihood and impact probability of multiple disasters *from both natural and biological hazards* to shows which provinces need immediate policy attention depending on their integrated risk level scores. The accompanying map shows the exact zones in the country where the risk of cascading disaster is at its highest.

Scenario A-B-D [Current risk: COVID-19, Floods, Endemic Risk drivers]

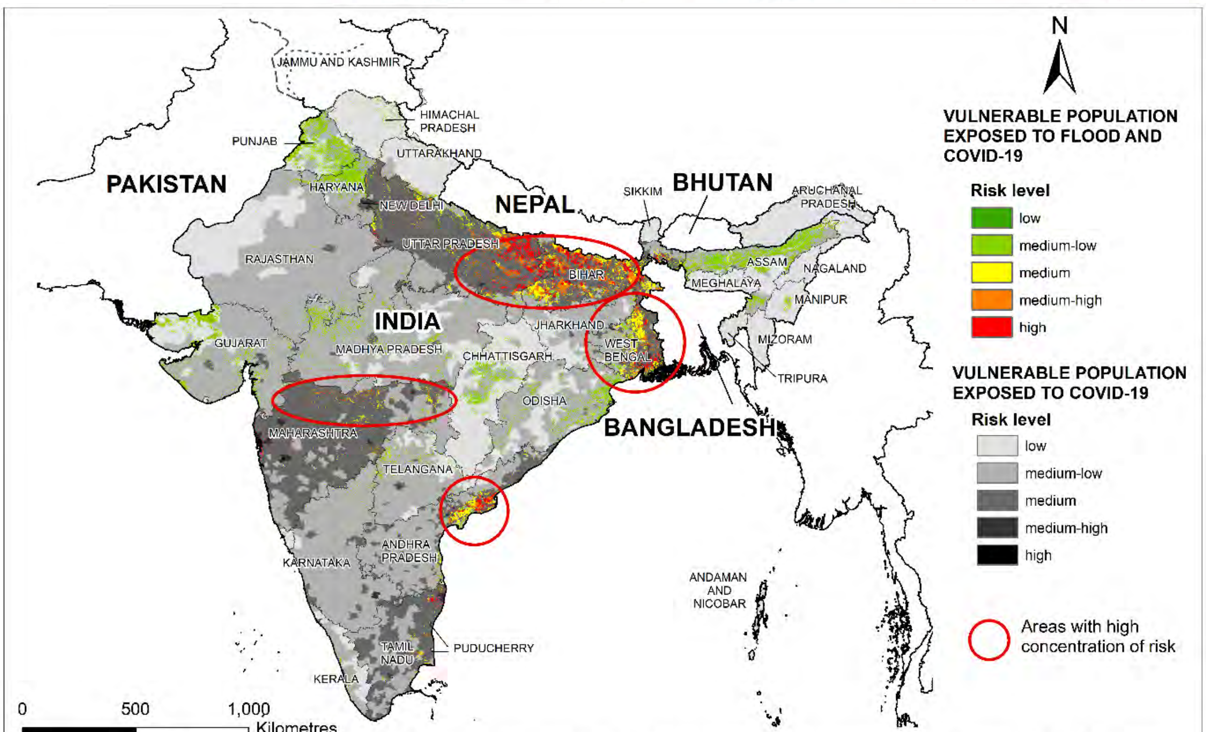
The current cascading risk scenario in India stem from the current COVID-19 pandemic, along with the recent monsoon floods, as well as the endemic risk drivers of poverty, inequality, and population density. The matrix in *Figure 10* shows Orissa, Assam, Bihar, Uttar Pradesh, and West Bengal are at the highest risk from cascading disasters with almost 14 million people exposed and need immediate policy actions and measures to mitigate disaster impacts on the populations at risk. The accompanying map shows the exact zones that at highest risk of cascading disasters.

Figure 10 India provinces ranked by likelihood and impact of natural and biological hazards (Scenario A-B-D, Time: Short-term current)

Impact severity on population			1 Lowest	2 Low	3 Medium	4 High	5 Very High
	Very High	5		Chhattisgarh Jharkhand	Madhya Pradesh	Orissa	Assam Bihar Uttar Pradesh
	High	4	Arunachal Pradesh Dadra and Nagar Haveli Meghalaya Tripura		Rajasthan		Andhra Pradesh West Bengal
	Medium	3	Jammu and Kashmir Manipur Nagaland	Uttaranchal	Telangana	Gujarat Karnataka	Maharashtra
	Low	2	Daman and Diu Himachal Pradesh Mizoram Sikkim			Haryana Punjab	Tamil Nadu
	Lowest	1	Andaman and Nicobar Chandigarh Goa Lakshadweep Puducherry	Kerala		Delhi	

Likelihood of population exposure to floods and COVID-19

Immediate action | Urgent action | Some action | Monitor | No action



Sources : ESCAP calculations based on UN WPP-Adjusted Population density 2020, v4.11; Sub-National Human Development Index (SHDI) 2018; Centers for CDC and WHO Coronavirus COVID-19 Cases, 9 August 2020; and UNOSAT-UNITAR analysis on NOAA-20 (VIIRS) Imagery, 20 June - 19 July 2020.

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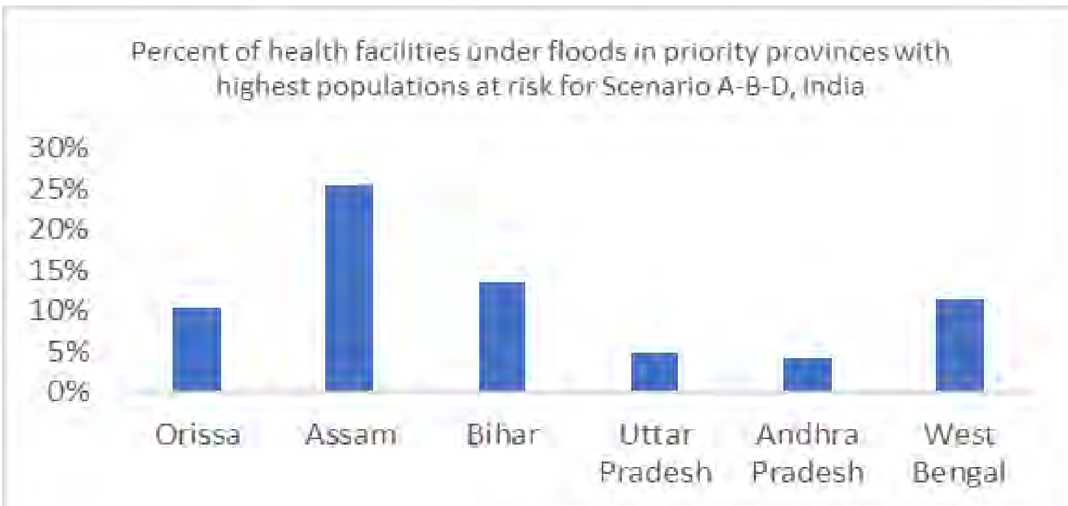
Considerations for the health sector and health infrastructure in the current cascading risk

The 14 million people who are at the highest risk in these provinces are served by around 15,000 hospitals, almost 10 percent of which are currently under flooded areas (*Figure 11*). These hospitals are not only stretched thin from the increasing COVID-19 numbers along with populations with low resources but are now exposed to the infrastructure damage that may occur from large scale flooding. These hospitals should be given the highest priority to ensure that social distancing norms are maintained, personal protective gears made available, and the hospitals have enough equipment to treat people from both COVID-19 and floods. Additional evacuation shelters maintaining the necessary norms for COVID-19 should also be constructed near these hospitals to support further flood evacuation measures.

Figure 11 At risk healthcare infrastructure



Scenario A-B-C-D [Upcoming risk: COVID-19, Floods, Recurring biological hazards, Endemic risk drivers]

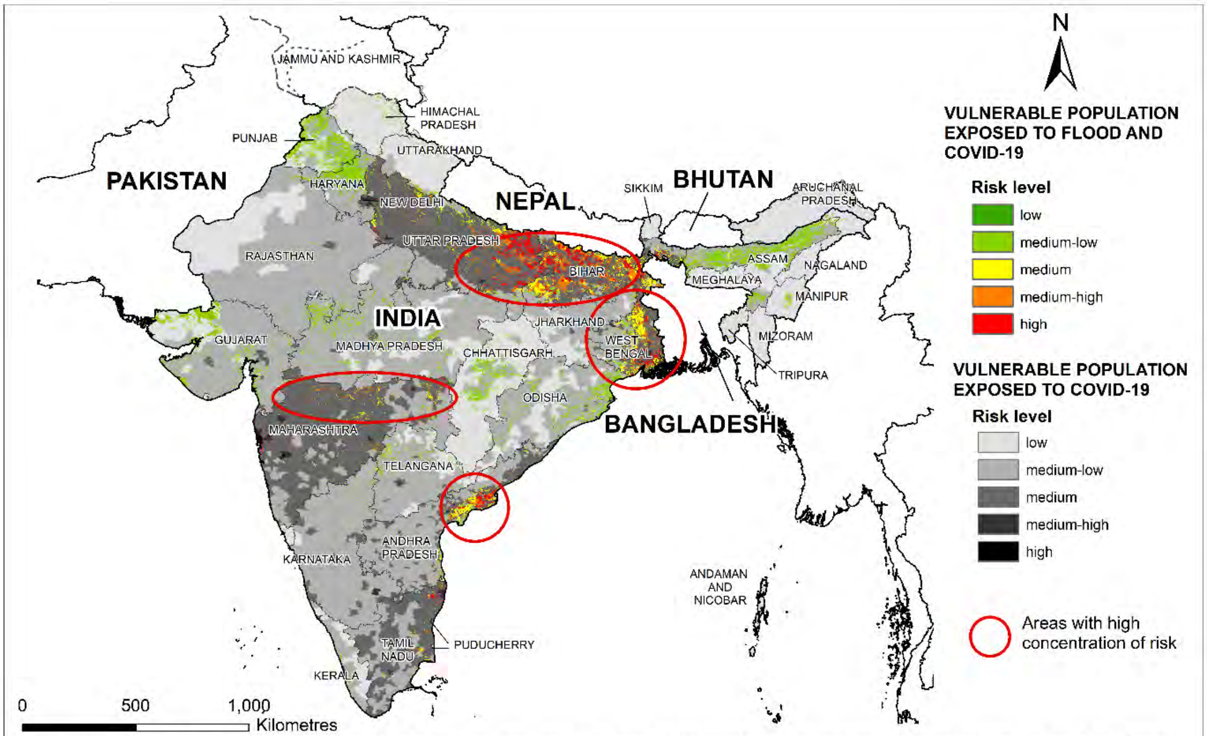
The upcoming cascading risks in India will also include the risk of diarrhoeal diseases, dengue and malaria as water and vector borne diseases are projected to occur from the large-scale flooding. The recurring disease runs parallel with the incoming floods from the monsoon season. Therefore, the upcoming riskscape of India will stem from the current COVID-19 pandemic, along with the recent monsoon floods, recurring biological hazards as well as the endemic risk drivers of poverty, inequality, and population density. The integrated matrix and the accompanying map (*Figure 12*) show that Bihar, Orissa, Uttar Pradesh, Andhra Pradesh, West Bengal, Chhattisgarh, and Madhya Pradesh are at the highest risk from the most complex cascading disasters with almost 150 million people exposed and need immediate policy actions and measures to mitigate disaster impacts on the populations at risk.

Figure 12 India provinces ranked by likelihood and impact of natural and biological hazards (Scenario A-B-C-D, Time: Short-term upcoming)

Impact severity on population							
	Very High	5		Chhattisgarh Jharkhand	Madhya Pradesh	Orissa	Assam Bihar Uttar Pradesh
	High	4	Arunachal Pradesh Dadra and Nagar Haveli Meghalaya Tripura		Rajasthan		Andhra Pradesh West Bengal
	Medium	3	Jammu and Kashmir Manipur Nagaland	Uttaranchal	Telangana	Gujarat Karnataka	Maharashtra
	Low	2	Daman and Diu Himachal Pradesh Mizoram Sikkim			Haryana Punjab	Tamil Nadu
	Lowest	1	Andaman and Nicobar Chandigarh Goa Lakshadweep Puducherry	Kerala		Delhi	
			1 Lowest	2 Low	3 Medium	4 High	5 Very High

Likelihood of population exposure to floods and COVID-19

Immediate action | Urgent action | Some action | Monitor | No action



Sources : ESCAP calculations based on UN WPP-Adjusted Population density 2020, v4.11; Sub-National Human Development Index (SHDI) 2018; Centers for CDC and WHO Coronavirus COVID-19 Cases, 9 August 2020; and UNOSAT-UNITAR analysis on NOAA-20 (VIIRS) Imagery, 20 June - 19 July 2020.

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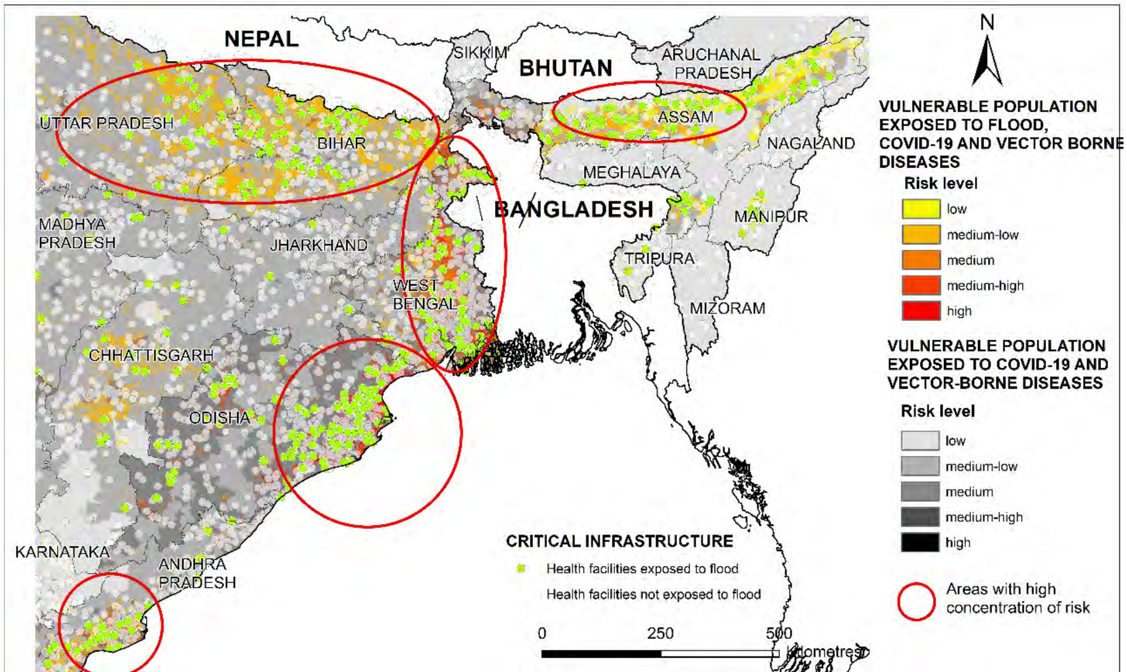
Considerations for the health sector and health infrastructure in the upcoming cascading risk scenario

The 150 million people who are at the highest risk in these provinces are served by around 20,000 hospitals, almost 6 percent of which are currently under flooded areas (*Figure 13*). The map in shows where these hospitals are located. These hospitals are not only stretched thin from the increasing COVID-19 numbers along with populations with low resources but are now exposed to the infrastructure damage that may occur from large scale flooding and need to support the increasing incidences of dengue and malaria that will occur with the floods. These hospitals should be given the highest priority to ensure that social distancing norms are maintained, along with personal protective gears made available, and the hospitals have adequate flood mitigation measures and enough equipment to treat people from COVID-19, dengue, and malaria. Additional evacuation shelters maintaining the necessary norms for COVID-19 should also be constructed near these hospitals to support further flood evacuation measures.

These measures also call for an integrated co-operation from the line ministry of health, home affairs, women and child and rural development. Sectoral convergence at district levels, state levels and at the central level where the Disaster Management Authority works with the local health office in a structured and phased pattern will need to emerge. This will also involve related NGOs to support government systems in building resilient processes and boosting community health needs. Moreover, every district will have to identify zones for setting up field hospitals, prepare hospital administrators to handle surge capacity, establish a task force for outbreak investigation and epidemiological interventions like contact tracing, high risk zonal mapping besides primary health care continuity. While this happens, there will ought to be a clear demarcation of triaging during disaster and also during endemic times so that elective surgeries do not get postponed, patients requiring dialysis, chemotherapy do not remain at -risk or exposed, and those on chronic disease medications like diabetes, hypertension, depression, bi-polar mood disorders do not run out of medicines. The floods will lead to a sizeable growth in chronic disease exacerbation and these patients need to receive the right medical advice and follow up. Maintaining a database of patients in every district who are on dialysis support with seamless co-ordination for dialysis modification schedules and rescue treatments will become administratively essential as inadequately controlled chronic diseases will pose further complications in rescue and relief operations on the ground. Anti-biotic resistance is a growing challenge in the region and providing primary and tertiary care during the cascading hazards will require streamlining prescription drugs while practicing medicine.

Hospitals will need to regularly engage in capacity building sessions working along with disaster management authorities and local NGOs to establish a seamless stakeholder convergence which has a snowballing potential to mitigate risks to a great extent. The South Asian region in general faced with limited human resources in the medical community and cautiously drawn GDP investment will also need to tap digital innovation to collaborate with all stakeholders in reducing risk and shaping resilience to ensure that public health systems respond when needed the most.

Figure 13 At risk healthcare infrastructure



Sources : ESCAP calculations based on UN WPP-Adjusted Population density 2020, v4.11; Sub-National Human Development Index (SHDI) 2018; Centers for CDC and WHO Coronavirus COVID-19 Cases, 9 August 2020; India's State Wise Malaria and Dengue Cases, 2014-2018; India's health care facilities, 2020; and UNOSAT-UNITAR analysis on NOAA-20 (VIIRS) Imagery, 20 June - 19 July 2020.

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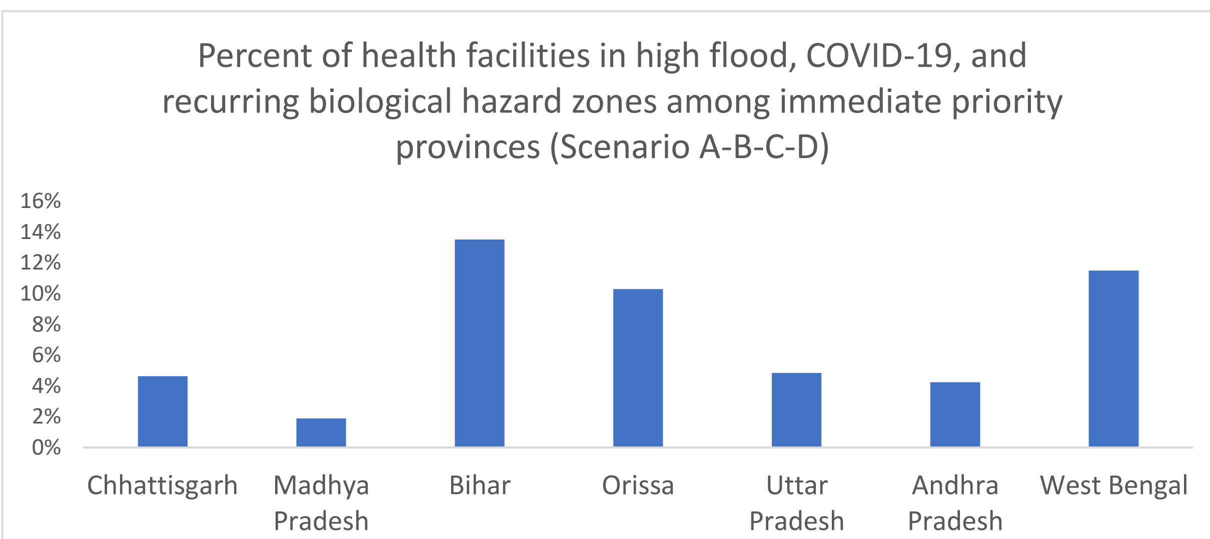


Long term risk scenarios from climate-related natural and biological hazards [Scenario A-B-C, future]

While short-term can be used for immediate mitigation measures, the increasing impacts of multiple and concurrent disasters necessitates a need to build long-term scenarios that consider future hazard projections. To understand the future risks of natural hazards, the study used the 50-year flood forecasting data from the Global Annual Report (GAR 2015) to show future risk for flooding.

In addition, while the baseline risk drivers of poverty, inequality, and deprivation and HDI was expected to improve there is much variability for future HDI depending on the continuing impacts of COVID-19. South Asia's sub-regional economy is likely to shrink for the first time in four decades and the loss of jobs and livelihoods could push up to 132 million people into extreme poverty.[22] For this scenario, the HDI will be kept at the 2019 level, but this is likely to change substantially in the future, given the impacts of the current cascading crises.

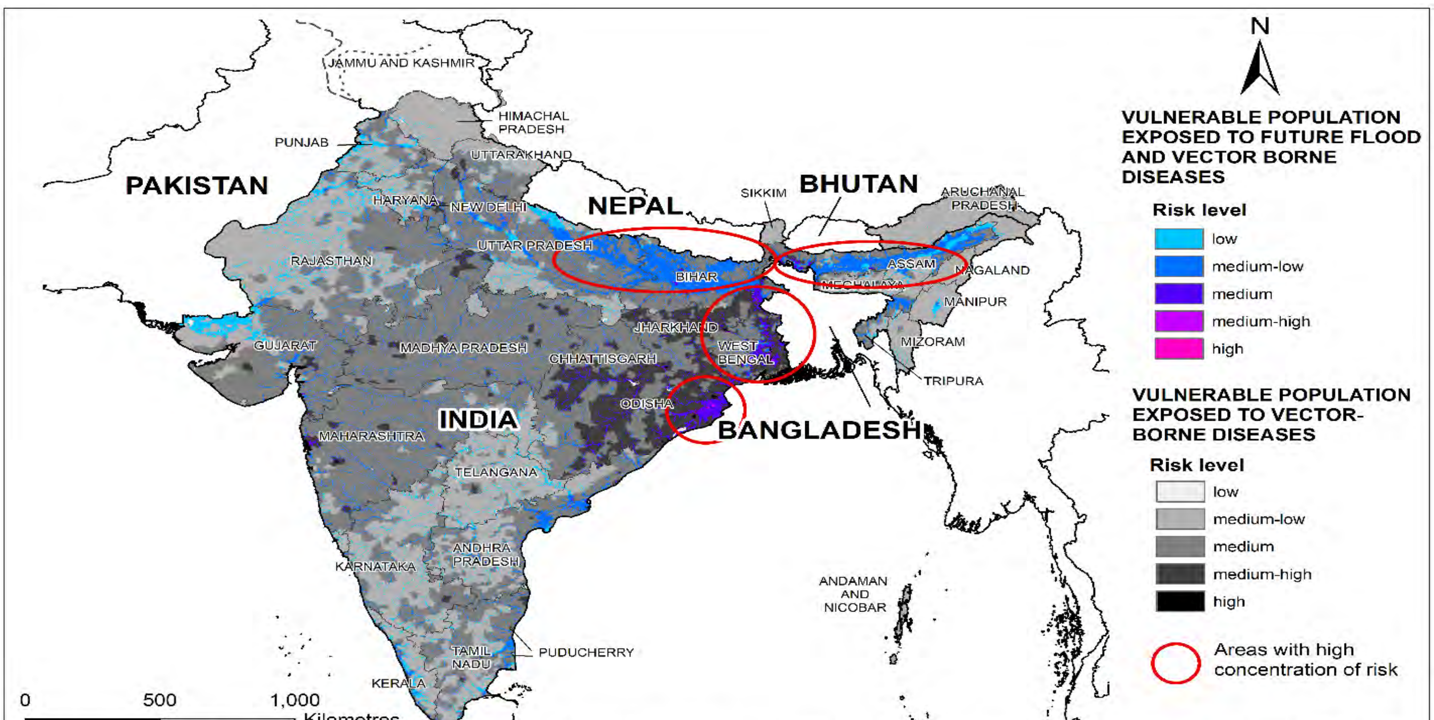
The long-term cascading risks in India will stem from climate related weather extremes- especially increasing floods and drought-like situation, increasing vector/water borne diseases as well as the endemic risk drivers of poverty, inequality, unemployment, and population density. The matrix and map in *Figure 14* shows that in the long term, the provinces of Bihar, Orrisa and Uttar Pradesh need priority actions to make them resilient to future natural and biological hazards. The actions taken to build resilience in these provinces and the high-risk zones need to be multi-sectoral involving multiple agencies in livelihood, healthcare, disaster management and national planning sectors.

Figure 14 India provinces ranked by likelihood and impact of natural and biological hazards (Scenario A-B-C, Time: Long-term)

Impact severity on population		1 Lowest	2 Low	3 Medium	4 High	5 Very High
Very High	5			Assam Jharkhand	Chhattisgarh Madhya Pradesh	Bihar Orissa Uttar Pradesh
High	4	Arunachal Pradesh Dadra and Nagar Haveli	Meghalaya Tripura	Rajasthan	Andhra Pradesh	West Bengal
Medium	3	Jammu and Kashmir Manipur Nagaland	Telangana	Uttaranchal	Gujarat Karnataka	Maharashtra
Low	2	Daman and Diu Himachal Pradesh Mizoram Sikkim				Tamil Nadu
Lowest	1	Andaman and Nicobar Chandigarh Goa Lakshadweep Puducherry			Delhi	

Likelihood of population exposure to future floods and recurring biological hazard (dengue, malaria)

Immediate action | Urgent action | Some action | Monitor | No action



Sources : ESCAP calculations based on UN WPP-Adjusted Population density 2020, v4.11; Sub-National Human Development Index (SHDI) 2018; India's State Wise Malaria and Dengue Cases, 2014-2018; and Global Assessment Report on Disaster Risk Reduction (GAR) Risk Atlas flood data for 50 years return period, 2015.

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Bangladesh: Prototype of a cascading risk scenario model

A. Individual hazard risks [Simple Scenarios A, B, C, D]

Scenario A: Bangladesh's overall country HDI value for 2018 is 0.614— which puts the country in the medium human development category. However, there are differences in HDI within Bangladesh, which impacts the transmission of cascading disaster risks. Appendix B notes that the provinces with the lowest HDI are Habiganj, Rangpur, Suamganj, Bandarban, and Cox's Bazaar.

Scenario B: To understand the most current risks, the prototype used the most recent flood inundation maps (from 20 June- 19 July 2020), which show the current flood extent in the country. The provinces with the highest population exposure levels to flooding in order are Sylhet, Tangail, Sirajganj, Sumanganj, and Jamalpur.

Scenario C: Bangladesh has a recurrence of biological hazards. The provinces with the highest population exposure levels to dengue in order are Dhaka, Chittagong, Gazipur, Mymensingh, and Comilla.

Scenario D: The COVID-19 cases have been rising slowly in Bangladesh. Appendix A shows that Dhaka, Chittagong, Nrayanganj, Comilla and Bogra have the highest exposed populations.

B. Risk scenarios for current and upcoming cascading risks [Short-term]

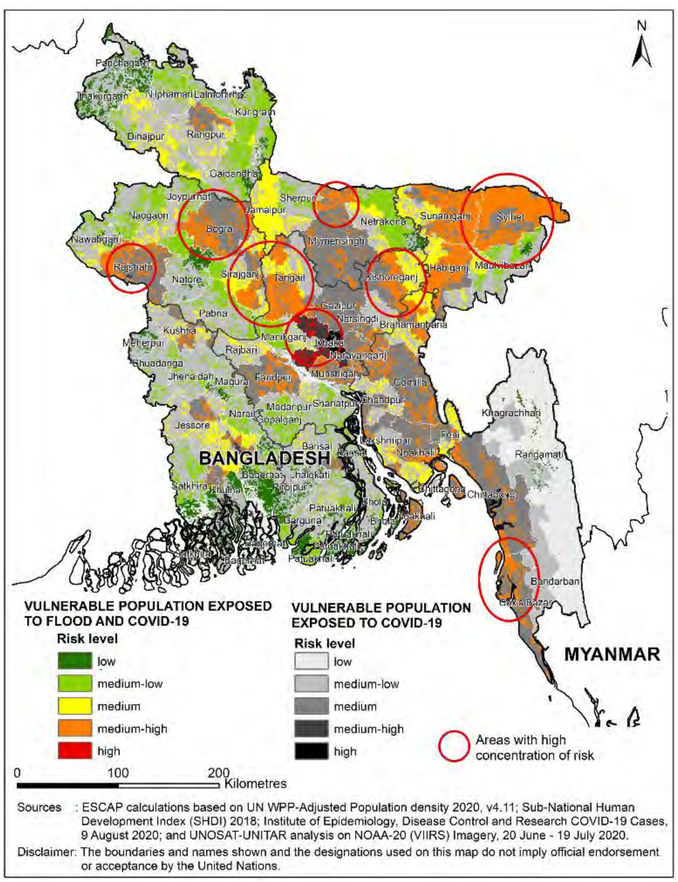
Scenario A-B-D [Current risk: COVID-19, Flood inundation 2020, Endemic Risk drivers]

The current cascading risk scenario in Bangladesh stem from the current COVID-19 pandemic, along with the recent monsoon floods, as well as the endemic risk drivers of poverty, inequality, and population density. The integrated matrix (*Figure 15*) shows that 15 districts in the red zones with almost 12 million people are at the highest risk from cascading disasters and need immediate policy actions and measures to mitigate disaster impacts on the populations at risk. In particular, the matrix show that Cox's Bazaar needs immediate intervention due to the impacts of cascading risks on one the most vulnerable populations in the sub-region. The map locates the exact zones that are at the highest risk of cascading disasters.

Figure 15 Bangladesh districts ranked by likelihood and impact of natural and biological hazards (Scenario A-B-D, Time: Short-term current)

Impact severity on population	Very High	5	Bandarban Narail Panchagarh Rangamati	Nawabganj	Maulvibazar Rangpur Shariatpur	Cox's Bazar Habiganj Mymensingh	Jamalpur Kishoreganj Sunamganj Tangail
	High	4	Barguna Khagrachhari Pirojpur	Bhola Lakshmipur Nilphamari	Naogaon Patuakhali	Kurigram	Sirajganj
	Medium	3	Chuadanga Magura	Joypurhat Natore Satkhira	Feni Kushtia Manikganj Narsingdi Pabna	Faridpur	Bogra Narayanganj Sylhet
	Low	2	Jhalokati	Bagerhat Madaripur Rajbari Sherpur Thakurgaon	Gaibandha Jessore	Dinajpur Khulna Netrakona	
	Lowest	1		Jhenaidah	Barisal Chandpur Gopalganj Munshiganj	Gazipur Noakhali Rajshahi	Brahamanbaria Chittagong Comilla Dhaka
			1 Lowest	2 Low	3 Medium	4 High	5 Very High
			Likelihood of population exposure to current floods and COVID-19				

Needs immediate action	Urgent action	Some action	Monitor	No action



Considerations for the health sector and health infrastructure in the current cascading risk scenario

The 12 million people who are at the highest risk in these provinces are served by around 610 hospitals, almost 40 percent of which are currently under flooded areas (*Figure 16*). These hospitals are not only stretched thin from the increasing COVID-19 numbers along with populations with low resources but are now exposed to the infrastructure damage that may occur from large scale flooding. These hospitals should be given the highest priority to ensure that social distancing norms are maintained, and the hospitals have enough equipment and protection gear to treat people from both COVID-19 and floods. Additional evacuation shelters maintaining the necessary norms for COVID-19 should also be constructed near these hospitals to support further flood evacuation measures.

Scenario A-B-C-D [Upcoming risk: COVID-19, Flood inundation 2020, Recurring biological hazards, Endemic risk drivers]

The upcoming cascading risks in Bangladesh will also include the risk of dengue as water and vector borne diseases are projected to occur from the large-scale flooding in addition to the already continuing pandemic and the monsoon floods as well as the endemic risk drivers. The risk matrix (*Figure 17*) shows some difference between prior scenario of floods and COVID-19 and the more complex scenario of floods, COVID-19 and dengue. In this scenario, Sylhet's population as well as those of Jessore, Tangail, Cox's Bazaar and Bogra are at high risk of cascading disasters. These red zone areas located in the map are at the highest risk of being impacted by the most complex risk scenario and will need immediate policy attention for COVID-19 when dengue cases are on the rise from the recurring floods. Healthcare facilities in these districts need to be on high alert.

Figure 16 At risk healthcare infrastructure

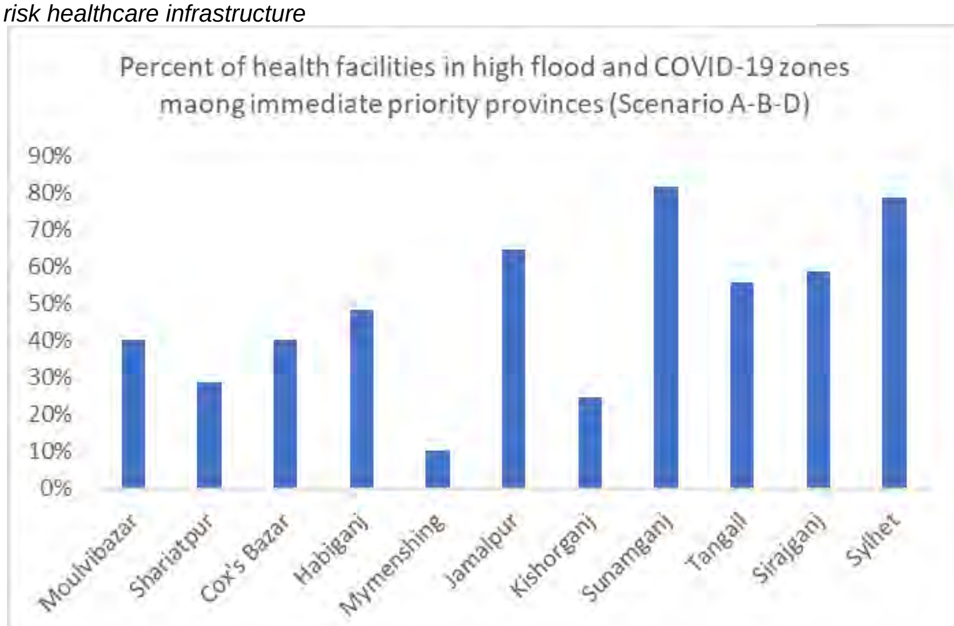
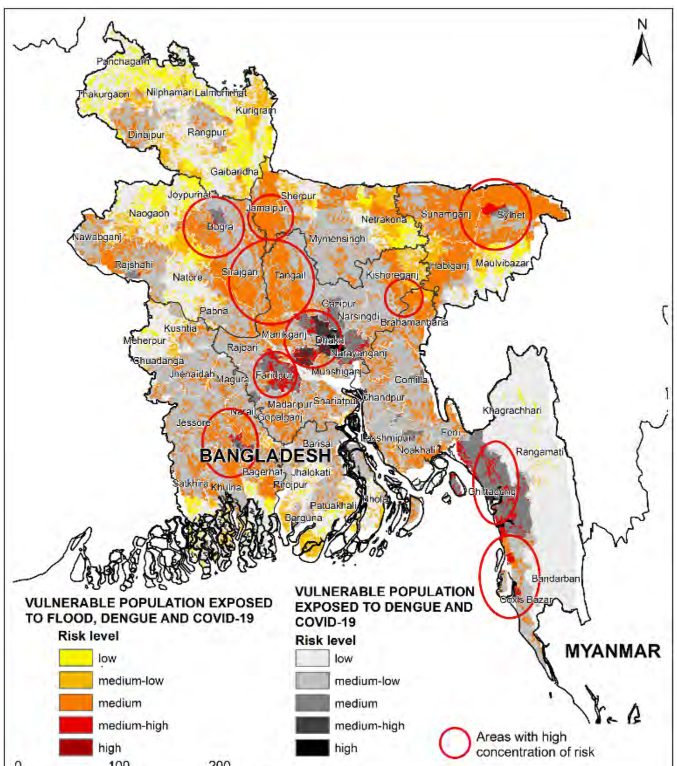


Figure 17 Bangladesh districts ranked by likelihood and impact of natural and biological hazards (Scenario A-B-C-D, Time: Short-term upcoming)

Impact severity on population			1 Lowest	2 Low	3 Medium	4 High	5 Very High
	Very High	5	Bandarban Narail Panchagarh Rangamati	Nawabganj	Maulvibazar Shariatpur	Cox's Bazar Jamalpur	Kishoreganj Sunamganj Tangail
	High	4	Barguna Bhola Khagrachhari Pirojpur		Habiganj Kurigram Lakshmipur Nilphamari Patuakhali	Jessore	Mymensingh Sirajganj Sylhet
	Medium	3	Chuadanga Joypurhat Magura	Natore Satkhira	Feni Kushtia Manikganj Narsingdi	Naogaon Pabna Rangpur	Bogra Dhaka Faridpur Khulna
	Low	2	Jhalokati	Bagerhat Madaripur Rajbari Sherpur Thakurgaon		Dinajpur Gaibandha Netrakona	Narayanganj
	Lowest	1	Lalmonirhat Meherpur	Gopalganj Jhenaidah	Barisal Chandpur Munshiganj	Noakhali Rajshahi	Brahamanbaria Chittagong Comilla Gazipur

Likelihood of population exposure to current floods, COVID-19, and Dengue

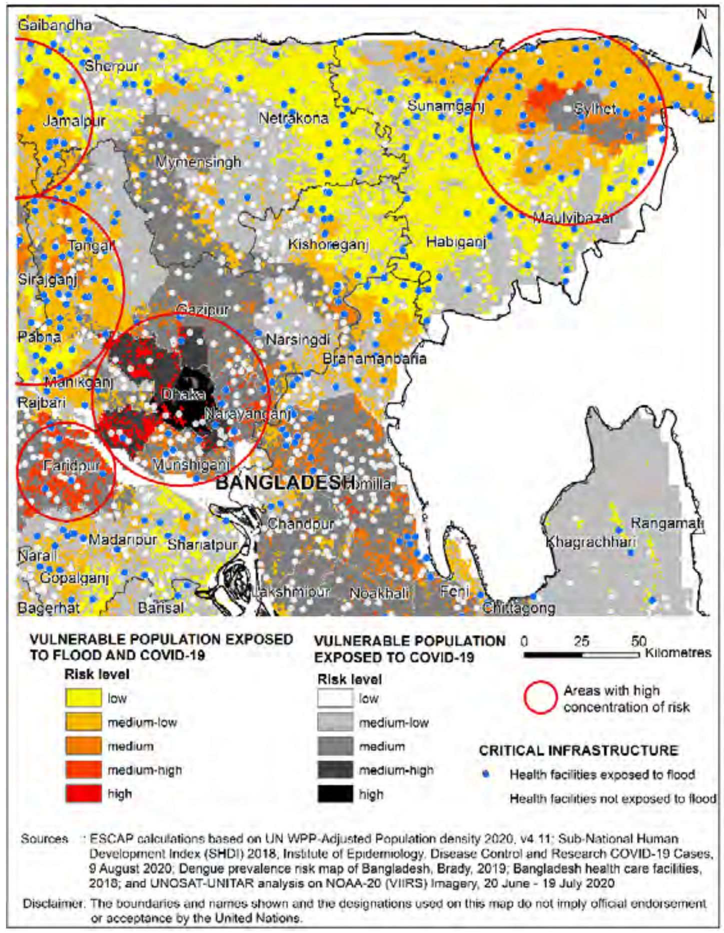
Immediate action	Urgent action	Some action	Monitor	No action



Sources : ESCAP calculations based on UN WPP-Adjusted Population density 2020, v4.11; Sub-National Human Development Index (SHDI) 2018; Institute of Epidemiology, Disease Control and Research COVID-19 Cases, 9 August 2020; Dengue prevalence risk map of Bangladesh, Brady, 2019; and UNOSAT-UNITAR analysis on NOAA-20 (VIIRS) Imagery, 20 June - 19 July 2020.

Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Considerations for the health sector and health infrastructure in the current cascading risk scenario



In the most complex scenario with floods, COVID-19 and potential dengue, almost 41 per cent of the hospitals red zone districts are currently under flooding situations (*Figure 18*). The accompanying map shows where these hospitals are located. These hospitals are not only stretched thin from the increasing COVID-19 numbers along with populations with low resources but are now exposed to the infrastructure damage that may occur from large scale flooding and need to support the increasing incidences of dengue that will occur with the floods. Hospitals in the "immediate action" districts should be given the highest priority to ensure that social distancing norms are maintained, and the hospitals have adequate flood mitigation measures and enough equipment to treat people from COVID-19, and dengue. Additional evacuation shelters maintaining the necessary norms for COVID-19 should also be constructed near these hospitals to support further flood evacuation measures.

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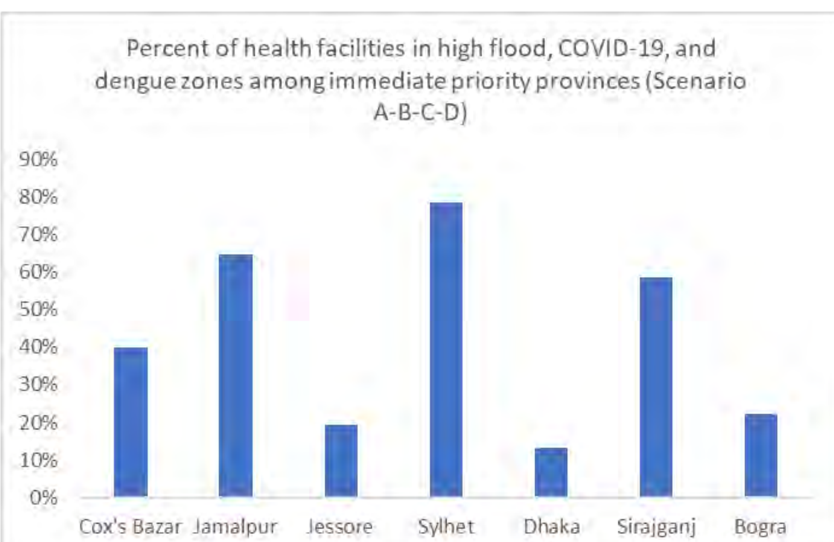
Figure 18 At risk healthcare infrastructure



Long term risk scenarios from climate-related natural and biological hazards [Scenario A-B-C, future]

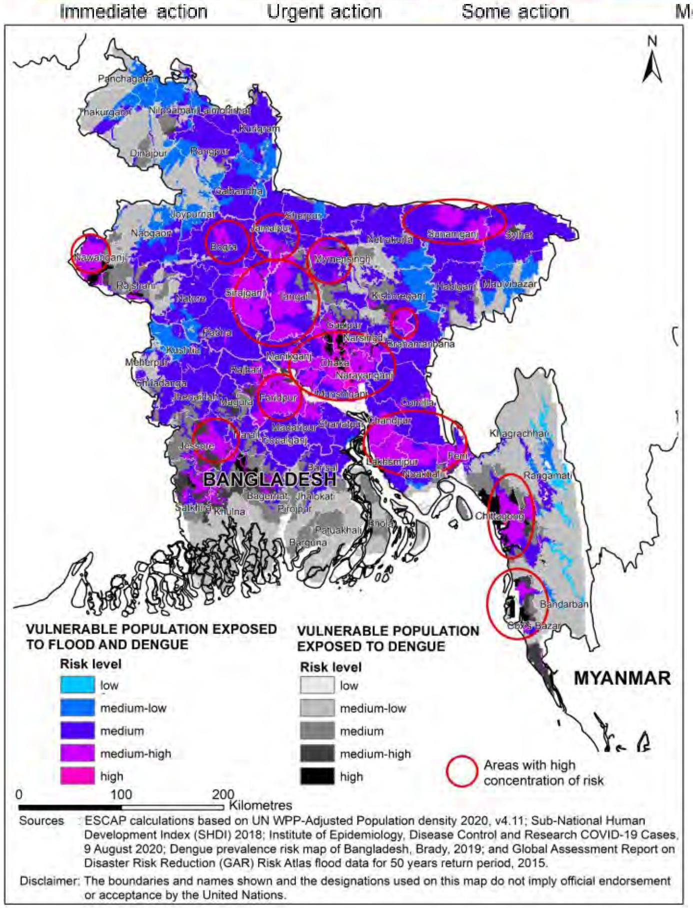
The long-term cascading risks in Bangladesh will stem from climate related weather extremes-especially increasing floods, increasing vector/water borne diseases as well as the endemic risk drivers of poverty, inequality, unemployment, and population density. For this analysis, GAR 2015 flood data for 50-year flood return period is used. *Figure 26* ranks provinces by a combination of likelihood and impact of the multiple natural and biological hazards that will potentially hit the region in the next 50 years. It shows that the regions under the highest stress from climate change and biological hazards include Dhaka, Cox's Bazaar, Bogra, and Sylhet. *Figure 27* shows the areas at highest risk from future cascading disasters. Additional multisectoral investment and focused scenario planning in each red-zone district with localized risk data is a needed priority to make these areas resilient to future natural and biological hazards. These actions need to be multi-sectoral involving multiple agencies to build resilience in livelihood, healthcare, disaster management and national planning sectors.

Figure 19 Bangladesh districts ranked by likelihood and impact of natural and biological hazards (Scenario A-B-C, Time: Long-term)

Impact severity on population			1 Lowest	2 Low	3 Medium	4 High	5 Very High
	Very High	5	Bandarban Narail Rangamati	Panchagarh Shariatpur	Nawabganj	Cox's Bazar Habiganj Jamalpur	Kishoreganj Mymensingh Rangpur Sunamganj Tangail
	High	4	Barguna Bhola Khagrachhari Patuakhali Pirojpur		Lakshmipur Nilphamari	Naogaon	Bogra Chittagong Dhaka Sirajganj
	Medium	3		Chuadanga Joypurhat Magura Satkhira	Feni Manikganj Maulvibazar Natore	Faridpur Kurigram Kushtia Narsingdi	Jessore Pabna Sylhet
	Low	2	Jhalokati	Bagerhat Madaripur Rajbari Thakurgaon	Dinajpur Khulna Sherpur	Gaibandha Netrakona	Narayanganj
	Lowest	1	Meherpur	Gopalganj Lalmonirhat	Barisal Jhenaidah Munshiganj Rajshahi	Chandpur	Brahamanbaria Comilla Gazipur Noakhali

Likelihood of population exposure to future floods and recurring biological hazard (dengue)

Immediate action	Urgent action	Some action	Monitor	No action



Conclusion and Way Forward

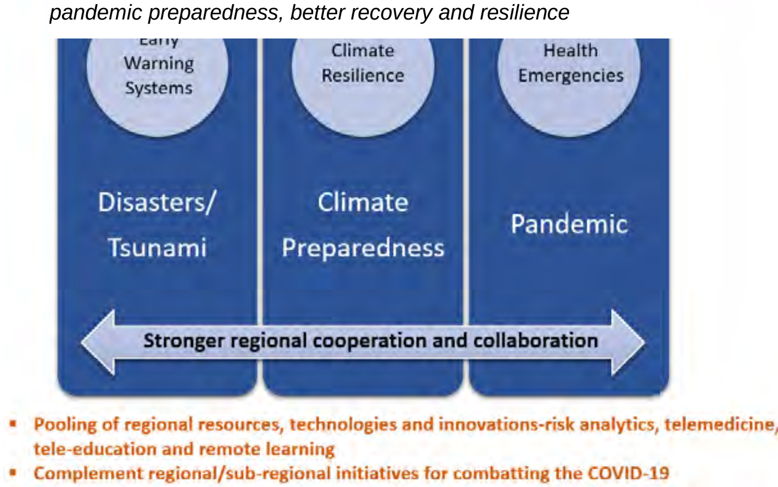
The complexity of cascading disasters requires an integrated approach for both health and disaster management. This study expanded the understanding of the disater risk hotpots in the Asia Pacific region through integrating biological hazard risk and demonstrated that natural disasters, health disaters, and endemic risk drivers interact, augment, and feed each other to create complex and cascading disasters that create cycles of underdevelopment, poverty and inequality. Considering this extended landscape of disaster risk, this section recommends three potential takeaway messages for policy development.

Message 1: Establishing multi-hazard early warning systems as a public good to address both biological and natural hazards

The concurrence of the pandemic, floods, cyclones, and upcoming biological hazards have shown that the seperation between hazards are, at best, arbitrary. Both natural and biological hazards are transboundary and impact the most vulnerable populations. With climate change, increasing incidences of floods, drought and other climate-related natural disasters will increase the incidence of water and vector borne diseases. Thus, early warning systems that provide accurate lead time for both biological and natural disaters need to be considered a public good. The 2019 Global Adaption Report underscored that the benefit-cost ratio of strengthening early warning systems is almost 10 to 1.[23]

While there are early warning systems both in the health sector and the disaster management sector, these need to be integrated. Infact, SDG 3 specifically notes that by 2030, countries need to strengthen early warning for national and global heath risk[24] and the Sendai Framework already has component of biological hazards through the Health Emergency and Disaster Risk Mangement Framework (EDRM)[25]. However, regional cooperation is needed to operationalize this conceptual framework. Therefore, multi-hazard early warning systems within the disaster realm need to be updated and have to including biological disaters moving forward. Exemplied by *Figure 20*, addressing the shared vulnerabilities of the region should be a priority for future regional cooperation.

Figure 20: ESCAP's Regional Cooperation Mechanisms for pandemic preparedness, better recovery and resilience



Message 2: Building resilient critical infrastructure should be seen a public good

The 2019 Global Adaption Report also notes that making new infrastructure resilient to disasters provides a benefit cost ratio of 5 to 1.[26] This must include making critical infrastructure like hospitals, schools, community centers, and evacuation shelters resilient to all hazards. Moving forward risk-informed infrastructure building needs to assess the risks from both natural and biological hazards, and should include measures that support additional space for social distancing, providing protective gear to medical personnel, and ensuring that transmission of recurring biological hazards like malaria, diarrhoeal diseases, and dengue are mitigated.

Message 3: Using the Asia Pacific Disaster Resilience Network (APDRN) to establish intergrated multihazard early warning systems and close data gaps

As a network of networks, the APDRN serves to mobilize expertise and resources to establish multi-hazard early warning systems. The network is built around four work streams which all support establishing multi-hazard early warning systems. First, the network has already mobilized regional cooperation around early warning systems for tropical cyclones under the WMO/ESCAP Panel on Tropical Cyclones. It is also in the process of developing early warning systems for slow onset disasters such as floods and drought. Moving forward, under this workstream, the APDRN will include early warning systems for biological hazards. Second, the network assembles geospatial information and services for disaters, disaster -related statisics, and big data analytics for disaster resilience under one platform to build a regional social innovation ecosystem. This platform will now include health related data and close the gaps in intergrated analytics from multiple data sources. Third, the network brings together space data applications, artificial intelligence applciations and digital connetivity for disaster management- the components of this workstream can be expanded to include both health and disaster management. Lastly, under the network, ESCAP produces a host of thematic knowledge products including the biennial Asia Pacific Disaster Report. These thematic knowledge products will be broaden to include integrated natural and biological hazard risk analytics.

Appendix

Appendix A: Requirements for developing cascading risk scenarios

Integrated Scenario	*Stakeholders*	*Impacted sectors and populations*	*Required data to measure impact and probability*
A-B	Disaster management agencies, Planning ministries	Social, agriculture, employment, education, populations with low human development index	Population counts, Flood extent map, Subnational Human Development Index (HDI) Infrastructure data
A-C	Planning ministries, health ministries	Health, WASH, populations with low human development index, children, women	Population counts, Subnational Human Development Index (HDI) Dengue cases
A-D	Planning ministries, Health ministries, Education ministries, Disaster management agencies	Health, WASH, employment, education, populations with low human development index	Population counts, Subnational Human Development Index (HDI) COVID cases
A-B-D	Disaster management agencies, Planning ministries, Health ministries, Education ministries	Health, Social, employment, education, health, WASH, agriculture and food security, populations with low human development index	Population counts, Flood extent map, Subnational Human Development Index (HDI) COVID cases Infrastructure data

A-B-C-D	Disaster management agencies, Planning ministries, Health ministries, Education ministries	Health, Social, employment, education, health, WASH, agriculture and food security, populations with low human development index, women, children	Population counts, Flood extent map, Subnational Human Development Index (HDI) Dengue cases COVID cases Infrastructure data

APPENDIX B: India population exposure and impact table for scenario building- Current risk

Province	COVID-19 population exposure	Floods 2020, population exposure	Dengue, population exposure	Malaria, population exposure	HDI 2018	Floods, 50 Year RT, population exposure	Floods 2020, hospital exposed to floods
Andaman and Nicobar	0%	0%	0%	0%	0.739	0%	4%
Andhra Pradesh	10%	4%	3%	2%	0.65	3%	2%
Arunachal Pradesh	0%	0%	0%	0%	0.66	0%	25%
Assam	1%	9%	2%	1%	0.614	8%	14%
Bihar	4%	24%	1%	0%	0.576	26%	0%
Chandigarh	0%	0%	1%	0%	0.775	0%	5%
Chhattisgarh	0%	2%	1%	14%	0.613	1%	0%
Dadra and Nagar Haveli	0%	0%	2%	0%	0.663	0%	33%
Daman and Diu	0%	0%	0%	0%	0.708	0%	0%
Delhi	8%	0%	7%	0%	0.746	4%	4%
Goa	0%	0%	0%	0%	0.761	0%	1%
Gujarat	4%	3%	5%	4%	0.672	2%	4%
Haryana	2%	4%	3%	1%	0.708	1%	1%
Himachal Pradesh	0%	0%	1%	0%	0.725	0%	3%
Jammu and Kashmir	0%	0%	0%	0%	0.688	1%	2%
Jharkhand	1%	1%	0%	11%	0.599	1%	0%
Karnataka	8%	0%	7%	1%	0.682	1%	3%
Kerala	2%	1%	7%	0%	0.779	3%	2%
Lakshadweep	0%	0%	0%	0%	0.75	0%	1%
Madhya Pradesh	2%	2%	3%	7%	0.606	2%	16%
Maharashtra	25%	3%	7%	4%	0.696	3%	3%
Manipur	0%	0%	0%	0%	0.696	0%	0%
Meghalaya	0%	0%	0%	3%	0.656	0%	0%
Mizoram	0%	0%	0%	2%	0.705	0%	10%
Nagaland	0%	0%	0%	0%	0.679	0%	1%
Orissa	2%	4%	5%	37%	0.606	4%	7%
Puducherry	0%	0%	1%	0%	0.738	0%	1%

Punjab	1%	7%	10%	0%	0.723	2%	0%
Rajasthan	3%	0%	5%	1%	0.629	2%	2%
Sikkim	0%	0%	0%	0%	0.716	0%	3%
Tamil Nadu	13%	2%	7%	1%	0.708	3%	4%
Telangana	3%	1%	3%	1%	0.669	1%	5%
Tripura	0%	0%	0%	2%	0.658	0%	1%
Uttar Pradesh	6%	16%	1%	0%	0.596	20%	11%
Uttaranchal	0%	1%	4%	5%	0.684	0%	4%
West Bengal	5%	14%	13%	3%	0.641	11%	2%

APPENDIX C: Bangladesh population exposure and impact table for scenario building- current risk

District	**COVID-19 population exposure**	**Floods 2020, population exposure**	**Dengue, population exposure**	**HDI 2018**	**Floods, 50 Year RT, population exposure**	**Floods 2020, hospital exposed to floods**
Bagerhat	0.4%	1.2%	0.8%	0.62	0.3%	29%
Bandarban	0.3%	0.0%	0.3%	0.538	0.1%	0%
Barguna	0.4%	0.5%	0.4%	0.586	0.0%	17%
Barisal	1.4%	0.8%	1.2%	0.672	1.0%	11%
Bhola	0.3%	0.8%	0.8%	0.586	0.0%	22%
Bogra	2.8%	2.4%	2.3%	0.614	3.3%	27%
Brahamanbaria	1.1%	3.5%	1.9%	0.632	2.9%	40%
Chandpur	1.0%	0.7%	1.3%	0.632	2.1%	6%
Chittagong	8.0%	2.3%	4.3%	0.648	2.6%	22%
Chuadanga	0.4%	0.4%	0.7%	0.61	0.8%	16%
Comilla	3.1%	2.8%	3.2%	0.632	5.2%	17%
Cox's Bazar	1.9%	1.6%	1.2%	0.538	0.5%	40%
Dhaka	35.4%	2.1%	9.7%	0.695	8.9%	13%
Dinajpur	0.9%	2.4%	2.0%	0.614	0.5%	34%
Faridpur	2.6%	1.3%	1.3%	0.596	1.7%	16%
Feni	0.7%	1.0%	0.8%	0.596	1.2%	21%
Gaibandha	0.4%	2.5%	1.6%	0.614	2.2%	40%
Gazipur	2.3%	1.1%	3.5%	0.649	3.0%	18%
Gopalganj	0.9%	0.9%	0.7%	0.636	1.0%	33%
Habiganj	0.7%	2.9%	1.4%	0.535	1.6%	48%
Jamalpur	0.5%	3.6%	1.5%	0.574	2.1%	65%
Jessore	1.2%	1.5%	1.8%	0.614	1.3%	19%
Jhalokati	0.3%	0.2%	0.4%	0.622	0.1%	21%
Jhenaidah	0.6%	0.7%	1.1%	0.672	1.4%	6%
Joypurhat	0.4%	0.8%	0.6%	0.61	0.5%	28%
Khagrachhari	0.3%	0.0%	0.4%	0.593	0.1%	21%

Khulna	2.2%	1.6%	1.5%	0.62	0.5%	31%
Kishoreganj	1.1%	2.9%	2.0%	0.562	2.1%	25%
Kurigram	0.3%	2.8%	1.3%	0.591	2.1%	68%
Kushtia	1.1%	1.0%	1.3%	0.61	1.8%	27%
Lakshmipur	0.8%	0.8%	1.1%	0.591	1.6%	18%
Lalmonirhat	0.2%	0.8%	0.8%	0.636	1.0%	9%
Madaripur	0.6%	0.7%	0.7%	0.622	1.1%	15%
Magura	0.3%	0.5%	0.6%	0.596	0.5%	19%
Manikganj	0.5%	1.5%	1.0%	0.61	1.3%	50%
Maulvibazar	0.6%	1.7%	1.1%	0.578	1.2%	17%
Meherpur	0.1%	0.2%	0.3%	0.649	0.3%	40%
Munshiganj	1.7%	1.2%	0.9%	0.649	1.6%	23%
Mymensingh	1.5%	2.2%	3.5%	0.578	3.2%	10%
Naogaon	0.5%	2.3%	1.6%	0.593	1.5%	24%
Narail	0.5%	0.5%	0.5%	0.562	0.5%	14%
Narayanganj	3.2%	1.4%	2.2%	0.614	3.2%	23%
Narsingdi	1.0%	1.2%	1.6%	0.596	1.8%	17%
Natore	0.3%	1.0%	1.1%	0.606	1.4%	18%
Nawabganj	0.3%	1.0%	0.9%	0.578	1.0%	14%
Netrakona	0.3%	2.9%	1.4%	0.614	1.7%	52%
Nilphamari	0.4%	1.2%	1.2%	0.586	1.0%	19%
Noakhali	1.9%	1.8%	1.7%	0.672	2.2%	6%
Pabna	0.5%	1.9%	1.7%	0.596	2.4%	11%
Panchagarh	0.2%	0.7%	0.6%	0.578	0.5%	29%
Patuakhali	0.6%	1.3%	0.7%	0.593	0.0%	26%
Pirojpur	0.4%	0.5%	0.6%	0.591	0.1%	15%
Rajbari	0.8%	0.5%	0.7%	0.62	1.0%	8%
Rajshahi	1.9%	1.8%	1.7%	0.636	1.0%	11%
Rangamati	0.4%	0.1%	0.4%	0.574	0.2%	11%
Rangpur	0.9%	1.5%	1.9%	0.535	2.3%	15%
Satkhira	0.4%	0.8%	1.2%	0.596	0.6%	30%
Shariatpur	0.6%	1.4%	0.6%	0.574	1.0%	29%
Sherpur	0.2%	1.0%	0.8%	0.614	1.2%	32%
Sirajganj	0.8%	4.2%	2.3%	0.592	3.3%	59%
Sunamganj	0.8%	4.2%	1.8%	0.535	2.6%	82%
Sylhet	2.4%	5.8%	2.6%	0.596	3.6%	79%
Tangail	1.0%	4.3%	2.3%	0.574	2.9%	56%
Thakurgaon	0.2%	1.0%	0.9%	0.614	0.4%	18%

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