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Scenario-based risk analytics for managing cascading disasters

A pathway to manage risks and protect people in South Asia

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Executive summary

South Asia is facing an increasing complex and expanding disaster riskscape- one of the highest in the Asia Pacific region. Each year, people in the sub-region suffer from various climate hazards such as floods, droughts, tropical cyclones, and heat waves. This is continuing 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 fact, following any meteorological (that is cyclones, floods, tornadoes) or geophysical (earthquakes, volcanic eruptions) disaster that displaces large numbers of people, epidemic diseases such as diarrheal diseases, Hepatitis A and E, measles, meningitis, acute respiratory infections, malaria or dengue often emerge.[1] 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 a single hazard, single sector perspective to a multihazard, multi-sectoral and systemic risk perspective. To achieve this, building multiple and complex risk scenarios that take the converging biological and natural hazard risks will be a priority. This study is a step in this direction. Through the integration of data from multiple sources, this study extends the riskscape of the region and examines the cascading risks that are arising and will arise in the future from the impacts of natural and biological hazards. Specifically, the study provides a methodology for building an integrated scenario assessment for strategic management and policy development in South Asia.

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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Part I: The need to build cascading risk scenarios

Introduction

The Asia-Pacific region faces a daunting spectrum of hazards emanating from various sources including both natural and biological. Indeed, the region is the most disaster prone in world and comprises of countries that are close to reaching a tipping point, beyond which disaster risk, fueled by climate change, exceeds their capacity to respond. The overlaps of underlying risks drivers such as poverty, inequality, and unemployment, coupled with multiple and increasing natural and biological hazards are leading to regressing of the sustainable development goals in many countries.[2]

With the region already at risk, the advent of the COVID-19 pandemic has thoroughly taxed existing resources and capacities of both health and disaster management systems. The pandemic has very quickly shown the very real systemic gaps in integrated crisis management and mitigation 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 with significant impacts on vulnerable groups and livelihoods that also suffer 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.

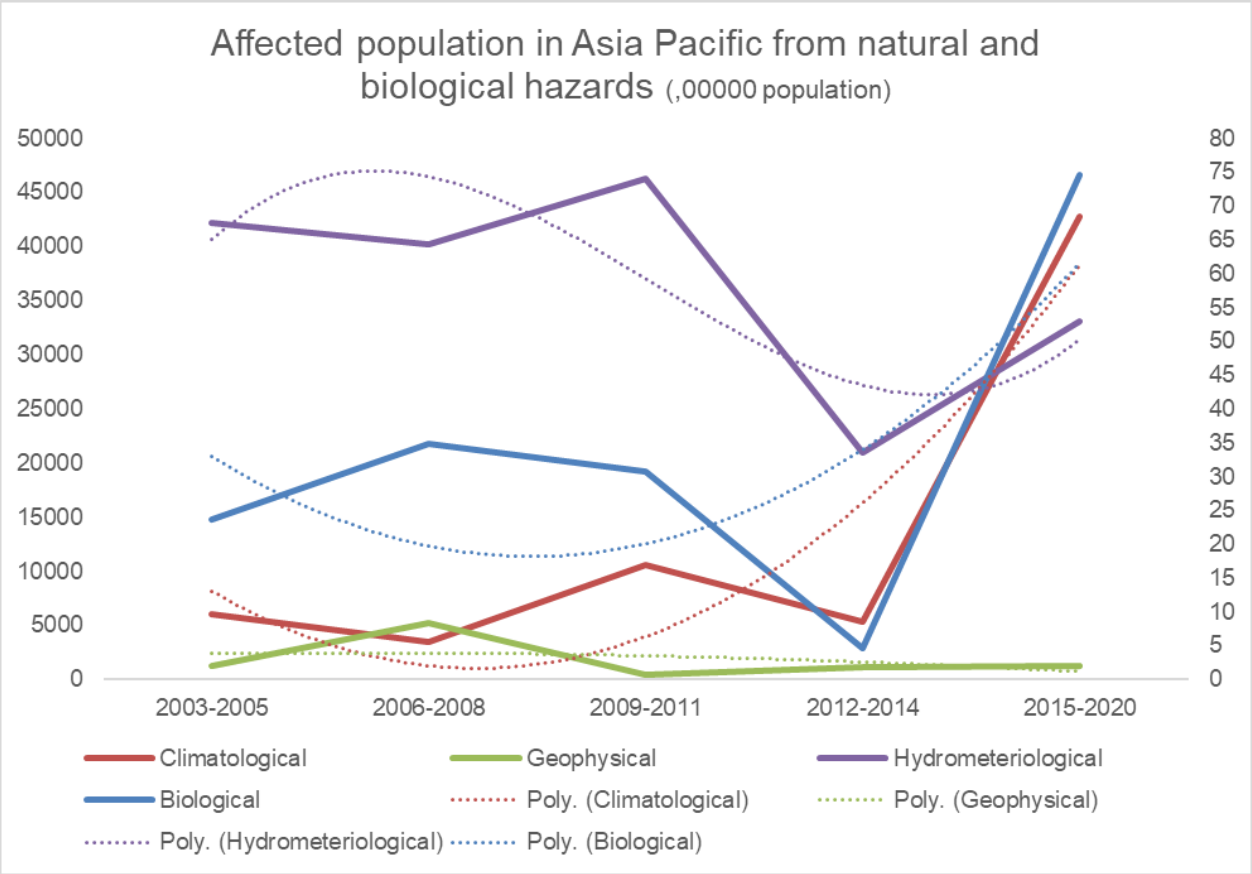
While the integration of disaster risk reduction and management sector with the health sector is the call of the hour,[3] there are multiple challenges that need to be overcome to advance this call from rhetoric to reality. One challenge noted by both health and disaster management policymakers is the understanding of the systemic risks that are emerging from the convergence of multiple disasters, both natural and biological, considering existing socio-economic vulnerabilities, and quantifying multi-sectoral impacts. [4] This can support policymakers in making evidence-based decisions, prioritize areas of investments, and protect people from the impacts of cascading disasters. A key pathway to address this challenge lies in developing comprehensive and complex risk scenarios in various timescales which provide information on systemic risks while aggregating elements of hazard, vulnerability, and exposure in the models.

This study demonstrates how developing complex and cascading risk scenarios can support policymakers in their commitment to protect people. The study *first* shows the cascading risks hotspots emerging from the convergence of multiple hazards and risk drivers in the Asia Pacific region, *second*, develops a novel methodology to build multi-time-scale complex risk scenarios for at-risk countries within the hotspots to address the systemic nature of current and future risks, and *third*, presents a pathway that integrated biological disasters into climate services to people, economies and the region's development goals.

Convergence of natural, biological risks and risk drivers in Asia-Pacific region

For the last several decades, the Asia-Pacific region has experienced the greatest human and economic impacts reported from the 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. The region is also a hotspot infectious disease emergence.[5] Recent data from EM-DAT shows that the region is experience increasing impacts of climate related hydrometeorological hazards as well as various biological hazards including vector borne diseases. (*Figure 1*).

Figure 1: Increase in affected populations from climate-related and biological hazards



Source: EM-DAT, Accessed 12 August 2020

Hazard risks in Asia-Pacific

Floods/Monsoons

Floods constitute 52 percent of the total number of disaster events occurring in the region in the past 2 decades (*Figure 2*). Additionally, the region's disaster riskscape[6] shows that floods contribute to 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.

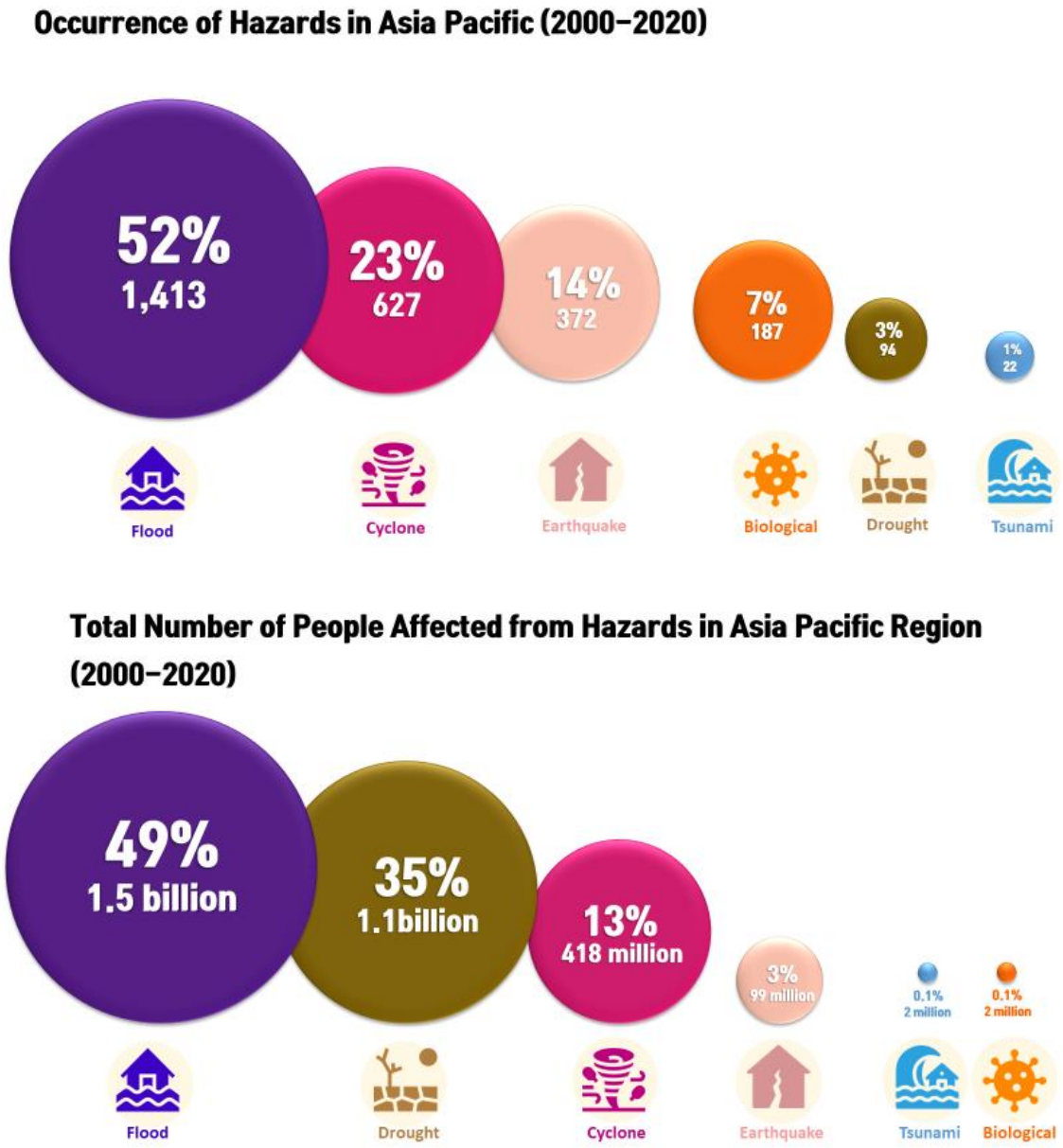
Climate change

The region has seen an increased proportion of climate related disasters comprising of droughts, extreme temperatures, flood and storms[7]. 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

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. Biological hazards account for almost 7 percent of the total number of disasters recorded in the Asia Pacific region from 2000 to 2020. 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). [8]

Figure 2 Summary of hazard profile in Asia Pacific



Source: Authors based on EM-DAT, Accessed 12 August 2020

Examining the sub-regions in Asia Pacific (*Figure 3*), South and South-West Asia and South East Asia are the most impacted subregions in terms of number of occurrences and people affected from hydrometeorological and biological hazards. This has been well demonstrated in the past. Floods, for example, have been shown to increase water-related infectious diseases, such as diarrhoea, 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.[9] In Viet Nam, for example, a study of 4,645 reports of typhoons and floods found significant increases in communicable diseases both pre- and post-disasters.

Figure 3 Summary of hazard profile for Asia Pacific Subregions

Source: Authors based on EM-DAT, Accessed 12 August 2020

Underlying risk drivers in Asia-Pacific

The underlying risk drivers that exacerbate the impacts of natural and biological hazards include poverty, inequality climate change and related extreme weather, unplanned and rapid urbanization, and the lack of disaster risk considerations in land management and environmental and natural resource management, as well as compounding factors such as demographic change, unsustainable uses of natural resources, declining and fragile ecosystems, pandemics and epidemics.

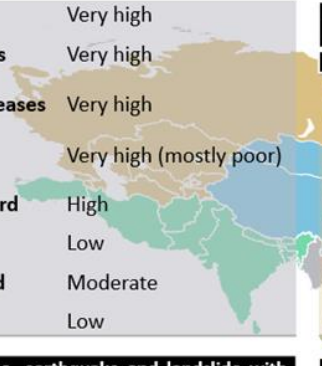
Climate change, especially, is not only a hazard in and of itself but is also risk driver which can exacerbates interactions between biological and natural hazards. IPCC's sixth assessment report notes that climatic variations will not only increase floods, monsoons, and drought but will also create new ecological niches for both vector borne and zoonotic diseases hence altering temporal and spatial distribution of the disease.[10] [11] Risks from some vector-borne diseases, such as malaria and dengue fever, will not only increase with warming from 1.5°C to 2°C, but also have potential shifts in their geographic range.[12]

Climate change induced seasonal flooding, for example, 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 putting them at risk for moderate and severe malnutrition. Now, those shifted to temporary shelters due to flood evacuation also run the risk of measles on top of COVID-19. Future drought situations will also 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. 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. Additionally, global warning will increase the frequency and severity of heatwaves with large increases in the number of people exposed to extreme heat, which, in turn, will increase illnesses such as heat exhaustion, heat cramps, heat strokes, cardiovascular and respiratory disorders.[13]

The Asia Pacific Disaster Report 2019[12] identifies four distinct hotspots where fragile environments are converging with critical socio-economic vulnerabilities to create potential cascading crises. The first is located within the transboundary river basins of South and South-East Asia, where poverty, hunger and undernourishment are combined with exposure to intensifying floods that alternate with prolonged droughts. The second surrounds the Pacific Ring of Fire, a path along the Pacific Ocean where major cities, transport and information and communications technology (ICT) infrastructure and poor populations are exposed to typhoons and seismic and tsunami hazards. The third is the Pacific Small Islands Developing States (SIDS), where vulnerable populations, fragile ecosystems and critical infrastructure are exposed to climate-related hazards of increasing intensities. A fourth emerging hotspot is the sand and dust storm risk corridor which covers parts of South, South-West, and Central Asia.

Adding the new available exposure data from COVID-19 and disease data from Inform Risk Index[14] demonstrates that South and South-West Asia is at a particularly vulnerable situation with high impacts from natural hazards, COVID-19, and other biological disasters (*Figure 4*). The next section will provide a brief overview of why this subregion can benefit from using integrated risk scenarios for policy making.

Figure 4 Four hotspots of converging vulnerabilities



Hotspot 1: Flood and drought prone areas/Transboundary river basins with COVID-19 and biological hazards

South and South-east Asia	
Population exposure- COVID 19	Very high
Population exposure- zoonotic diseases	Very high
Population exposure- vector borne diseases	Very high
Population exposure-natural hazard	Very high (mostly poor)
Economic stock exposure- natural hazard	High
Infrastructure, energy- natural hazard	Low
Infrastructure transport- natural hazard	Moderate
Infrastructure, ICT- natural hazard	Low

Hotspot 2: Ring of fire/Earthquake, Landslides, tsunami, and typhoon tracks with COVID-19 and biological hazards

North and North-east Asia, some South-east Asia	
Population exposure- COVID 19	Low
Population exposure- zoonotic diseases	Low
Population exposure- vector borne diseases	Moderate
Population exposure-natural hazard	Very high (mostly poor)
Economic stock exposure	High
Infrastructure, energy	Low
Infrastructure transport	Moderate
Infrastructure, ICT	Low

Hotspot 3: Tropical cyclone, El Nino, earthquake and landslide with COVID-19 and biological hazards

Pacific small island developing States	
Population exposure- COVID 19	Low
Population exposure- zoonotic diseases	Low
Population exposure- vector borne diseases	Moderate
Population exposure-natural hazard	Very high (mostly poor)
Economic stock exposure	High
Infrastructure, energy	High
Infrastructure, transport	Moderate
Infrastructure, ICT	Low

Hotspot 4: Sand and dust storm risk corridors with COVID-19 and biological hazards

South and South West Asia and Central Asia	
Population exposure- COVID 19	Very high in South Asia and context specific in the rest
Population exposure- zoonotic diseases	Very high
Population exposure- vector borne diseases	Very high
Population exposure-natural hazard	High (mostly poor)
Economic stock exposure	High
Infrastructure, energy	Moderate
Infrastructure transport	Moderate
Infrastructure, ICT	Low

Source: Authors based on Asia Pacific Disaster Report, 2019 and EM-DAT, Accessed 12 August 2020

Part II: South Asia- a hotspot of critical and converging vulnerabilities

While much of the Asia-Pacific region is at risk from the convergence of natural and biological hazards, the sub-regions of South and South West Asia and South East Asia shows the highest likelihood of overlapping disasters from natural and biological hazards (*Figure 1*). South and South West Asia, in particular, is at an extremely high risk from the convergence. Not only does the sub-region have high losses from natural disasters, it also shows high losses from biological disasters, quantified by the Disability-Adjusted Life Year (DALY) (*Figure 5*). South Asia contributes to almost 42 percent of total (DALY) lost worldwide.

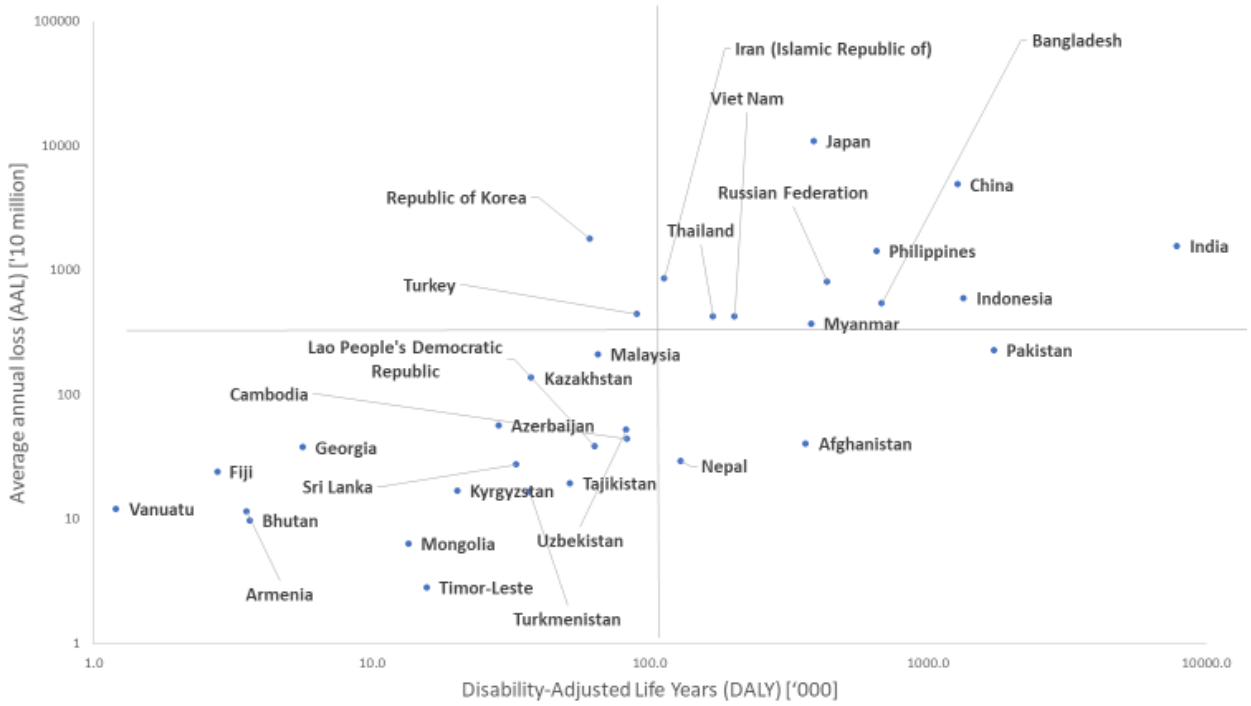
Disability-Adjusted Life Year (DALY)

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.

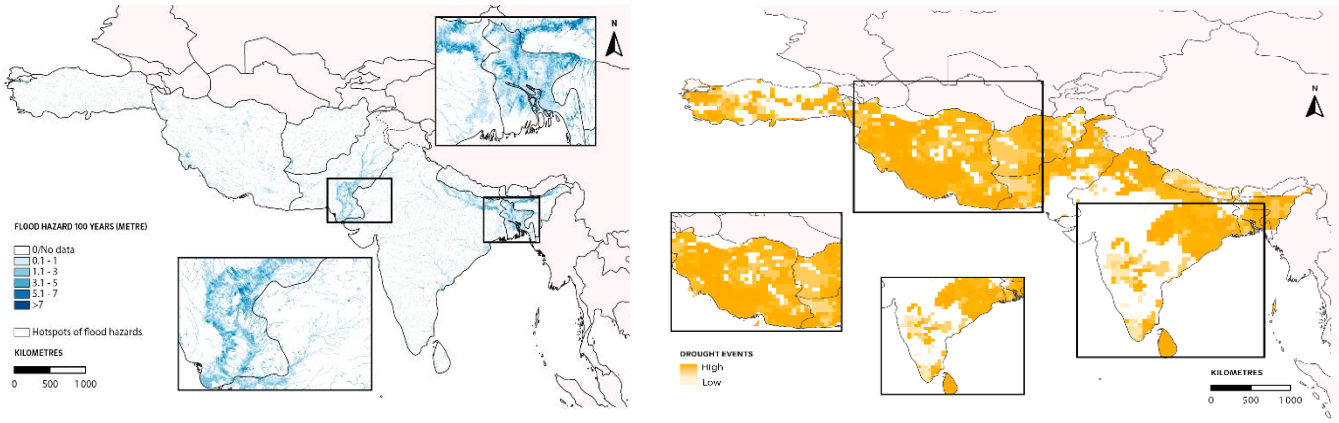
Figure 5 Overlap of Disability-adjusted life year (DALY) with Average annual loss (AAL) in Asia Pacific



Source: Authors based on Asia Pacific Disaster Report, 2019 and WHO Health Statistics and information systems , Accessed 12 August 2020

Additionally, 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. [15] 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 6*). 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. [16]

Figure 6Hotspots of flood and drought risk



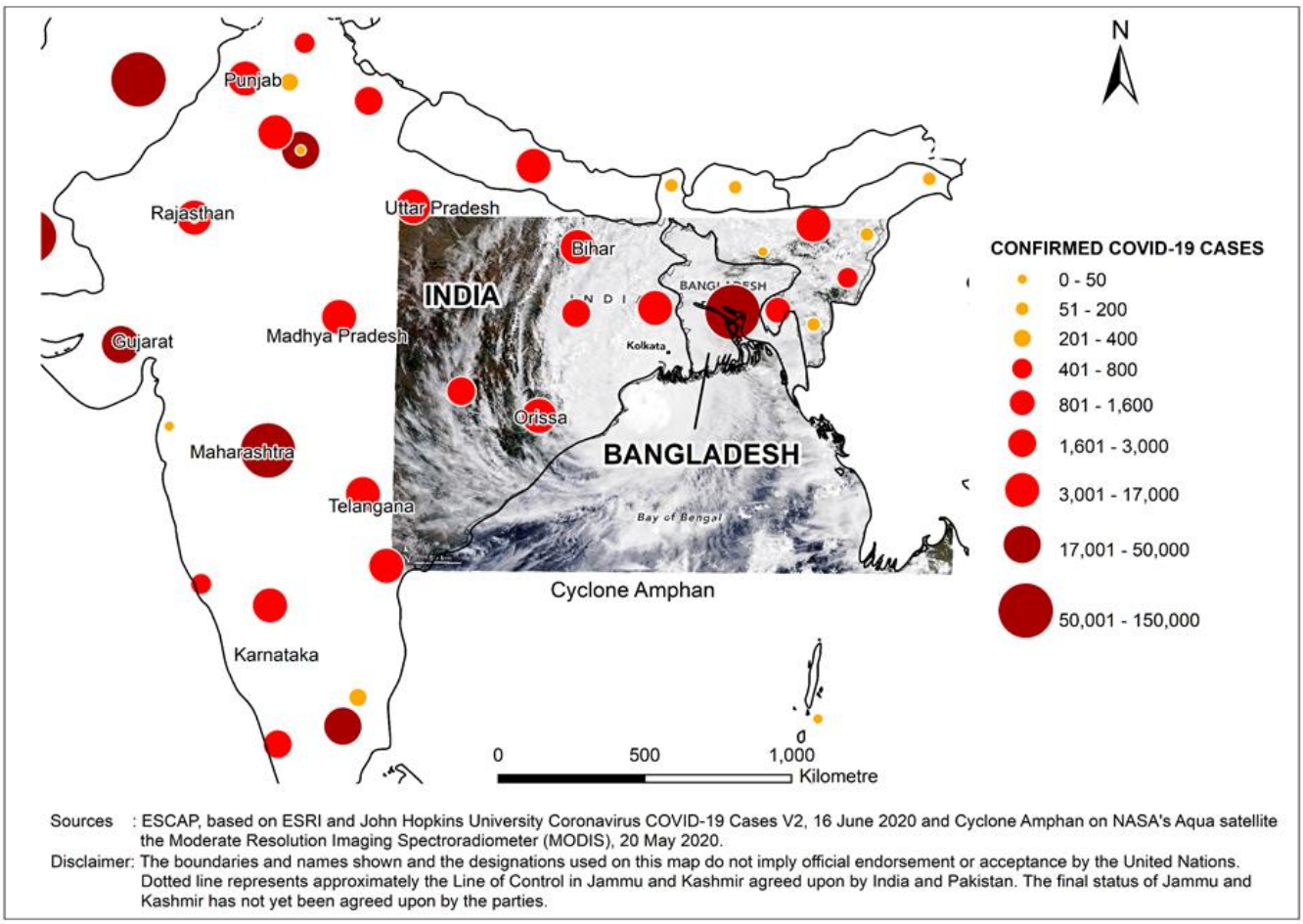
Source: Asia Pacific Disaster Report, 2019

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.[17]

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 7*. 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).[18]

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 summarized in *Table 1*.[19] 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.[20, 21]

Figure 7 Collision of cyclone Amphan with COVID-19



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.[22] Water reservoirs have been depleted due to receding glaciers in the mountain ranges of India and Nepal leading to rising temperatures and reduced snowfall.[23] This naturally affects activities around water, sanitation and hygiene that aids development in the sub-region.[24]

Table 1 Emerging biological risks posed by climate change (1°C rise) and related extreme weather events

	Climate Related Risks	Biological and Health Risks
Afghanistan	Annual average temperature rise will cause increased **precipitation** and **drought**	• Warming will affect the timing and availability of water resources • Increased incidence of cholera, typhoid, diarrhea, and ascariasis • Increased incidence of malaria and leishmaniasis
Bangladesh	Increase **Flooding** Increase **Cyclones**	• Increase diarrhoeal incidence rates by 5.6 percent • Increase in dengue and leishmaniasis
Bhutan	Glacial lake outburst floods, landslides, and flash floods	• Increased incidence of malaria, dengue, Japanese encephalitis, and chikungunya
India	Increase **Heatwaves** Increase **Flooding** in some areas Increase **Drought** in some areas	• Increase in heatwaves related health risks (heatstrokes etc.) • Increase in malaria, dengue, Japanese encephalitis, leishmaniasis • Diarrhoeal incidences expected to increase by 13.1 per cent by 2041 • Undernutrition due to food insecurity
Maldives	Decreasing **rainfall** and number of rainfall days Increase **Drought**	• Increase in dengue, chikungunya, scrub typhus along with newly emerging diseases such as Zika virus infection • Undernutrition due to food insecurity
Nepal	Increase **Drought** in some areas 1 cm increase in **rainfall**	• Increase diarrhoeal incidence rates by 0.28-4.39 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
Pakistan	Warming temperature will cause 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
Sri Lanka	Increase **Drought** in some areas Increase **Flooding** from sea level rise	• Increases in malaria, dengue, and heat related diseases

To address the growing risk of hazard complexities and their cascading nature, first 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. Second, the hotspot analysis needs to be downscaled at the national level as the distinguishing features of hotspots vary not only from sub-region to sub-region but also from country to country. South-Asia shares many vulnerabilities, but the nations also needs to prioritize building new and complex disaster risk scenarios that are downscaled prepared for cascading risks in the future.

Part III: Developing methodologies and prototypes for cascading risks scenarios in South Asia

Introduction

One of the key barriers to building integrated disaster-health risk scenarios is that these are data intensive and require data diverse data sources (Box 1). They need a wide range of data from multiple disciplines and sectors to provide the analytics that can support impact forecasting and risk informed early warning, indexing, and creating combined risk matrices to target at risk communities and vulnerable locations.

The cascading scenarios need to not only consider each individual hazard risk, but also note where the hazards intersect and locate the highest likelihood of cascading risks zones given existing risk drivers. This is critical to identifying the most vulnerable populations during cascading crises. *Figure 8* demonstrates a conceptual scenario planning for current, short term, and long-term disaster impacts.

Figure 8 shows the individual hazards, when overlapping, produce a cascading set of impacts on economies and populations. These hazards include the baseline risk drivers, natural hazards, recurring biological hazards, and novel hazards (such as another pandemic or other black swan events). These scenarios can occur at different time scales and the intersections and overlaps of these scenarios produce cascading risks. 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.

BOX 1: Challenges in developing cascading risk scenarios

Data

Challenges of **dealing with large variety of heterogeneous data** from different data sources- from sensors to crowdsourcing, including time series, semi-structured and invalidated data, and textural data as well as noise and misinformation.

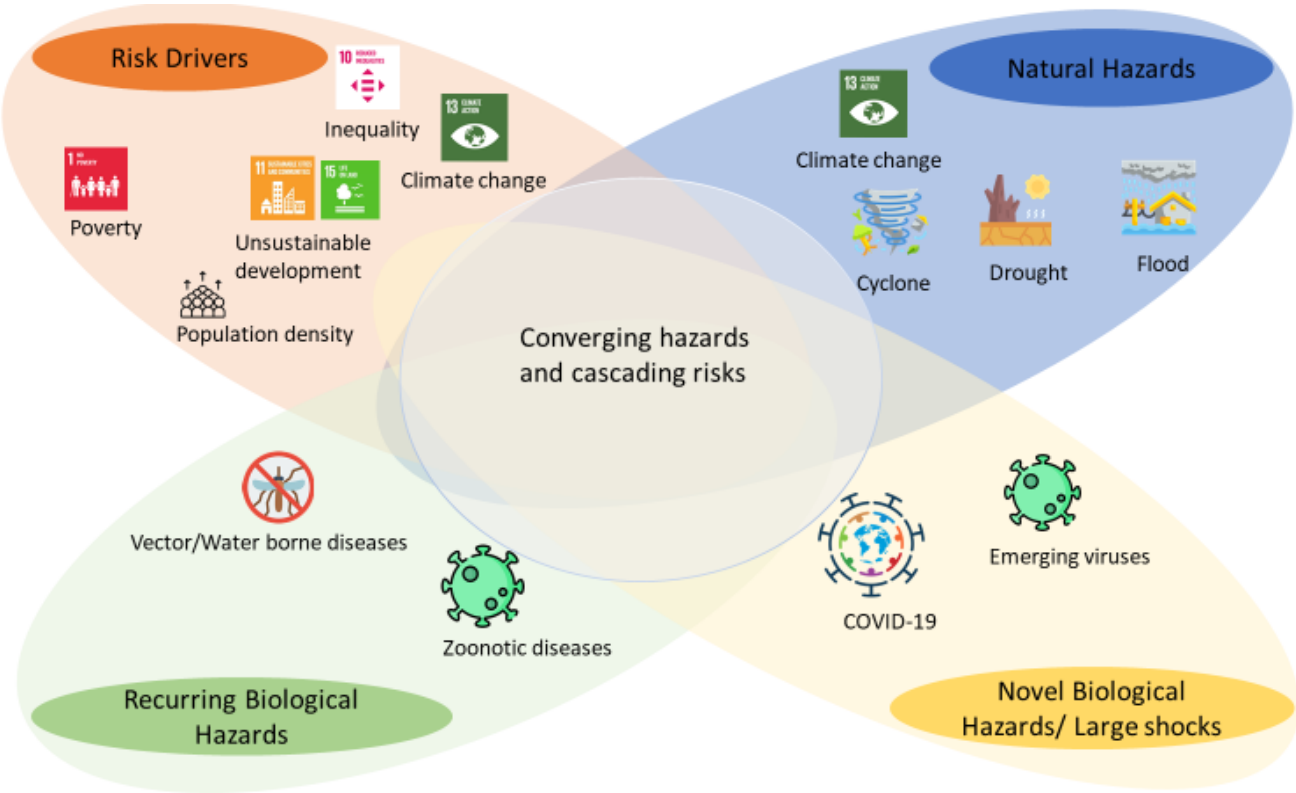
Analytics

Analytic methodologies are yet to **integrate reliably and accurately crowdsourced data**, from the disaster affected people, **into the physical sensing data** (e.g., satellite, UAV) **and authoritative data** (e.g., terrain data, census data).

Digital infrastructures

It is important to effectively **integrate huge data from multiple sources for real-time decision making** in the context of the emerging data volume of streaming videos, fast data transfer, and intuitive data visualization.

Figure 8 Cascading scenario planning- intersections of multiple hazards



A method for developing cascading risk scenarios: Prototypes for India and Bangladesh

To model these risk scenarios and the cascading risk from natural and biological hazards, this study uses Bangladesh and India as examples. Data for each individual hazard was gathered through various datasets consisting of heterogenous data. These data were combined using GIS-based analyses to examine the multi-hazard vulnerabilities for key sector in India and Bangladesh.

Risk Drivers: The study used the Human Development Index (HDI) as a proxy for the baseline risk drivers of poverty, inequality, and deprivation.[1] For India, the SDG India Index and Dashboard 2019-2020 provides SDG progress data at the province level and the India subnational SDG rank 2019 was used as a proxy for baseline risk drivers.[25]

***Natural Hazards*:** Here, two timescales of flooding were used. First, the scenario modeled the current seasonal floods and their impacts where data was extracted from the VIIRS sensor of NOAA-20 satellite between 20 June to 19 July for Southern Asia. To model a longer-term scenario, the GAR 2015 projected flood risk data is used with a return period of 50 years.

Recurring biological hazards*:* 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

[1] 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.

exposure data for malaria for India were gathered from various sources provided in the data reference section.

***Novel biological hazards/large shocks*:** For the novel shocks, 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.

The two country prototypes for cascading risks models in India and Bangladesh quantify number of at-risk population and healthcare infrastructure for three separate scenarios:

I. **Scenario 1:** A short-term scenario showing current cascading risks from floods during COVID-19 situation with baseline risk drivers.

II. **Scenario 2:** A medium-term scenario showing upcoming cascading risks from dengue, malaria and other infectious disease outbreaks during floods and COVID-19 pandemic with baseline risk drivers.

III. **Scenario 3:** A long-term scenario showing future cascading risks of climatic flooding and infectious diseases (dengue, malaria).

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 key sectors including the health sector, particularly healthcare infrastructure is assessed. To model the integrated scenarios the follow risk variables are used for each individual scenario in *Figure 9*.

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. Provinces with the lowest HDI are Bihar, Uttar Pradesh, Orissa, Jharkhand, and Madhya Pradesh.

In terms of seasonal and future floods, the provinces with the highest population exposure levels to flooding in order are Bihar, Uttar Pradesh, West Bengal, Assam, and Punjab. India also has a recurrence of biological hazards. 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. Lastly the COVID-19 cases have been rising steadily in India with Maharashtra, Tamil Nadu, Andhra Pradesh, Karnataka, and Delhi having the highest exposed populations.

India: Cascading risk scenarios

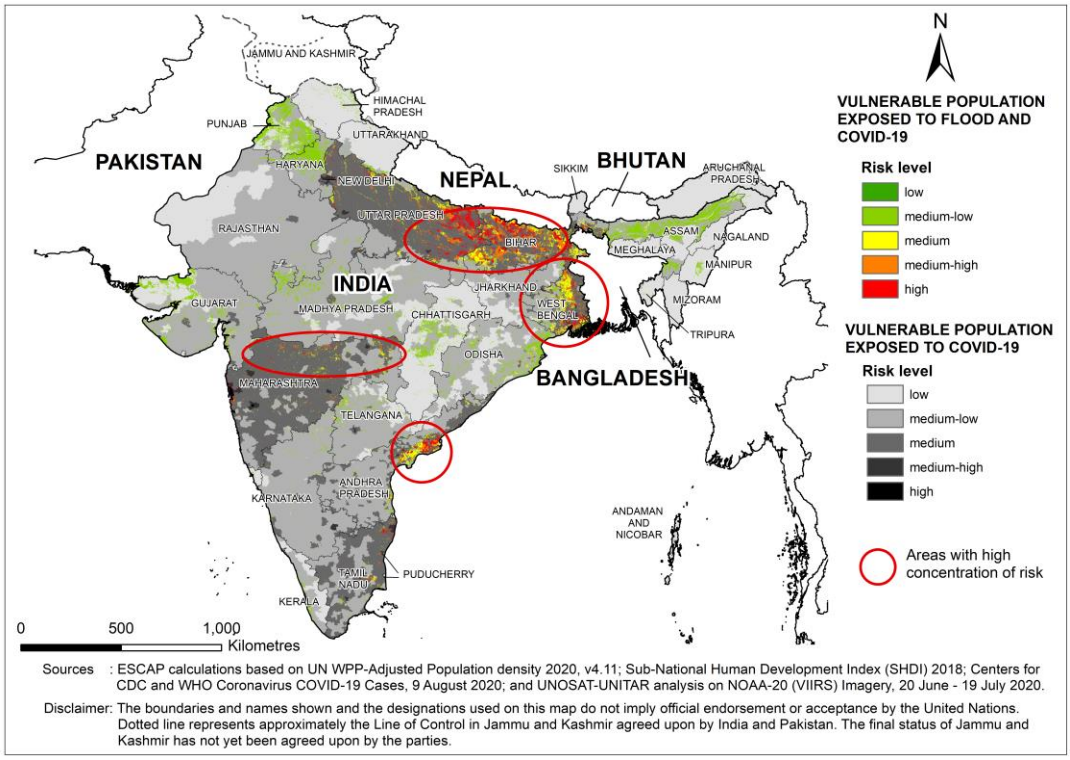
To model the cascading scenarios in the short-term timescale, the study used a combination of likelihood and impact probability of the simultaneous hazards to shows which provinces need immediate policy attention depending on their integrated risk level scores. The accompanying map shows the exact zones in the country where the risk of cascading disaster is at its highest.

Scenario 1: Short-term, hotspots of COVID-19, 2020 Seasonal floods and Socioeconomic risk drivers

The short-term cascading risk scenario in India is projected from the current COVID-19 pandemic, along with the recent monsoon floods, population density, and HDI. The matrix in *Figure 9* 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 9 India provinces ranked by likelihood and impact of cascading disasters in the Short-term timescale

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.

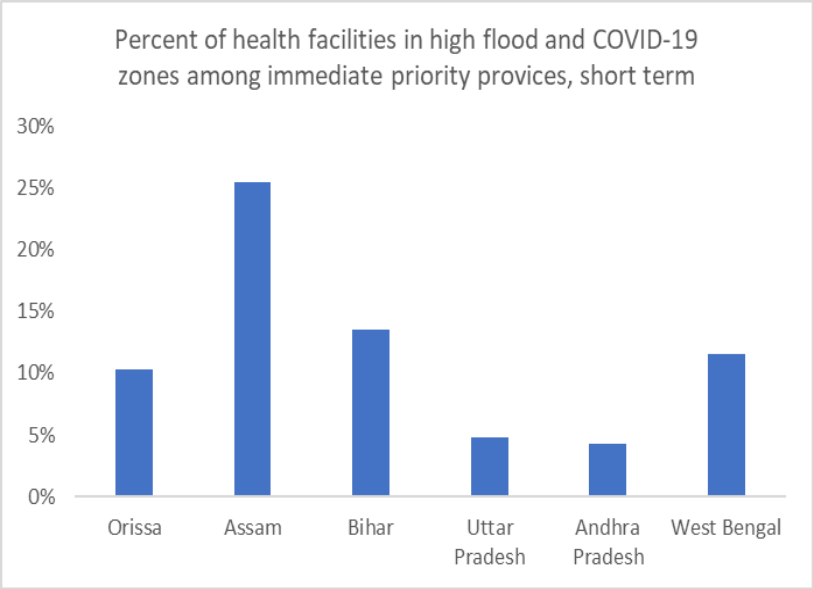
Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations. Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir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

Impacts and policy measures for key sectors

The implication of the cascading disasters on the highest risk zones are high with key sectors exposed to multiple disasters at a single time.

Healthcare- 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 10*). 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.

Figure10 At-risk healthcare infrastructure



Disaster management- In the high-risk zones, priority should be given to ensuring that COVID-19 patients can access hospitals which may be inaccessible due to the flooding. Additional evacuation shelters maintaining the necessary norms for COVID-19 should also be constructed near these hospitals to support further flood evacuation measures. COVID-19 restrictions have severely hampered and slowed down relief operations for floods as warehouses are declared containment zones.[26] Priority should be given in red-zone areas to make sure that aid reaches those in need.

Social and livelihood: The intersection of COVID-19 with flooding and monsoon has impacted existing vulnerable populations. In Orrisa, for example, the lockdowns from COIV-19 impeded farmers from harvesting crops while the monsoon floods destroyed the crops.[27] In turn, this can affect food security and malnutrition. In the red-zone districts, an integrated response has to be delivered to ensure that the measures taken to contain the virus do not jeopardize agricultural output and food security. The triple whammy of COVID-19, income loss from the lockdown and lost possessions from flooding for women especially requires targeted solutions, since a large portion of women's income are home-based.

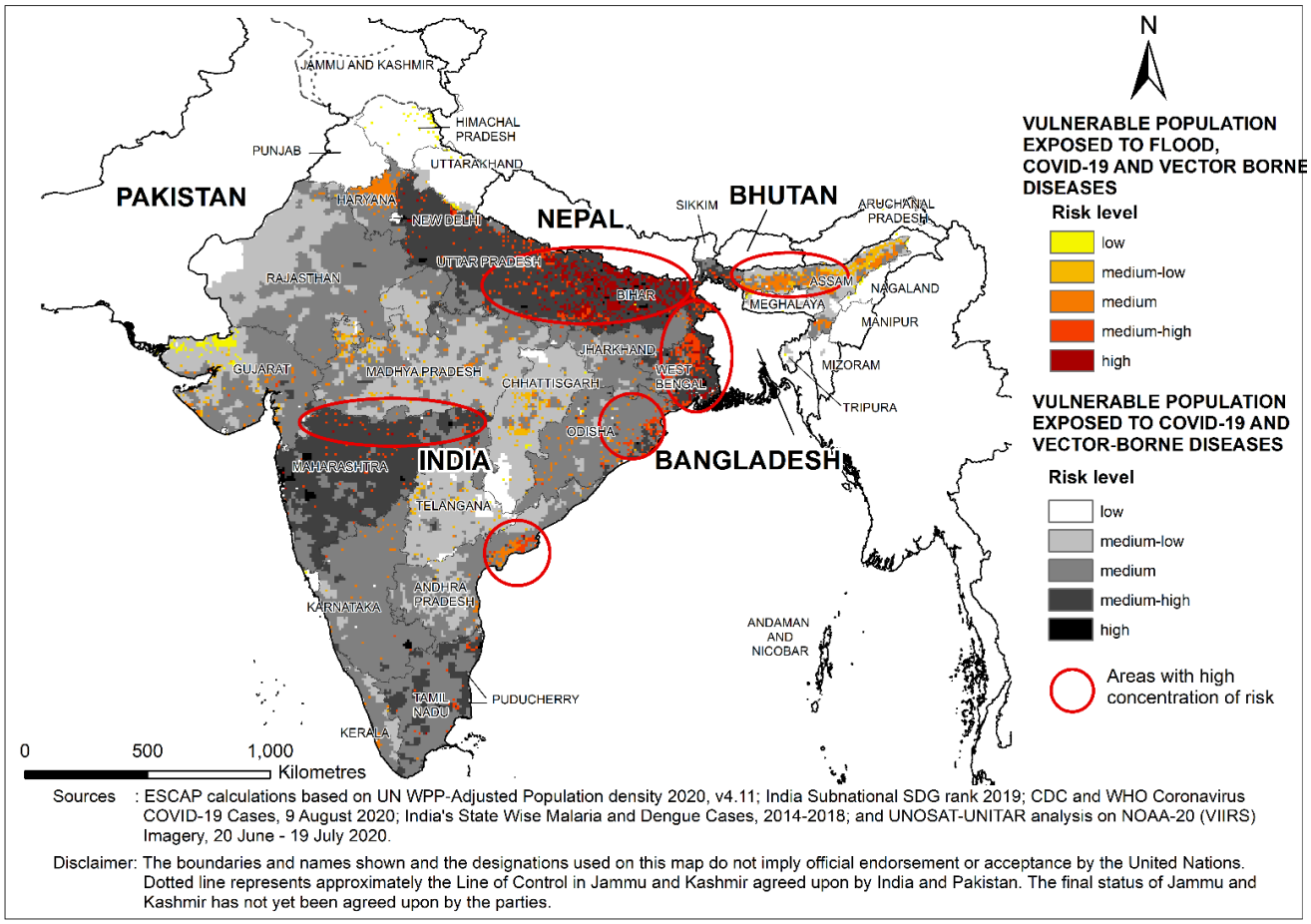
Scenario 2: Medium-term, Hotspots of COVID-19, Recurring biological hazards, Flood inundation, and socioeconomic risk drivers

The monsoon season floods mean a high proportion of the population in India is vulnerable to diseases such as dengue, malaria, leptospirosis, and cholera. The upcoming cascading risks in India therefore include the risk of diarrheal 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 11*) 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 11 India provinces ranked by likelihood and impact of natural and biological hazards, medium-term timescale

Impact severity on population						
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		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 current floods, COVID-19, Dengue, and Malaria				
		Immediate action	Urgent action	Some action	Monitor	No action



Impacts and policy measures for key sectors

Healthcare- The 150 million people who are at the highest risk in these provinces in the medium-term scenario are served by around 20,000 hospitals, almost 6 percent of which are currently under flooded areas (*Figure 12*). The map in *Figure 13* shows where these hospitals are located. These hospitals are not only stretched thin from the increasing COVID-19 numbers, but will also have potential flood related damages, and need to support the increasing incidences of dengue and malaria that will occur with the floods. While social distancing norms still need to be maintained as in the short-term scenario, these hospitals need to have enough medication for dengue and malaria.

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.

Figure12 At risk healthcare infrastructure, medium term

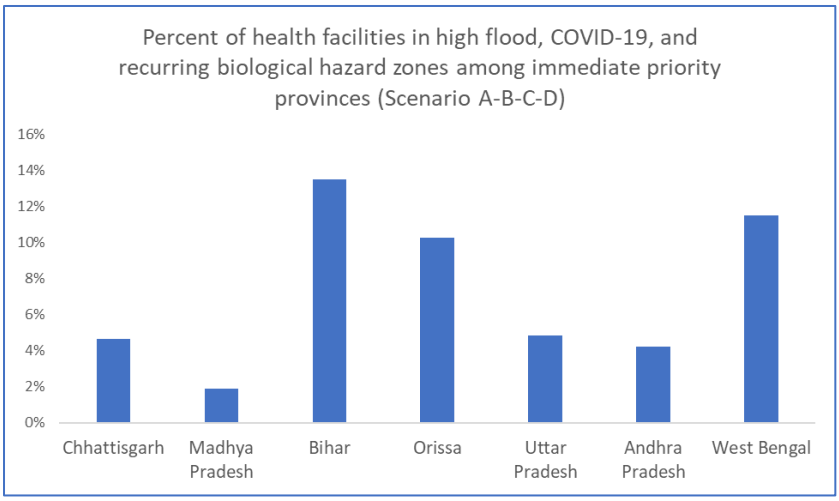
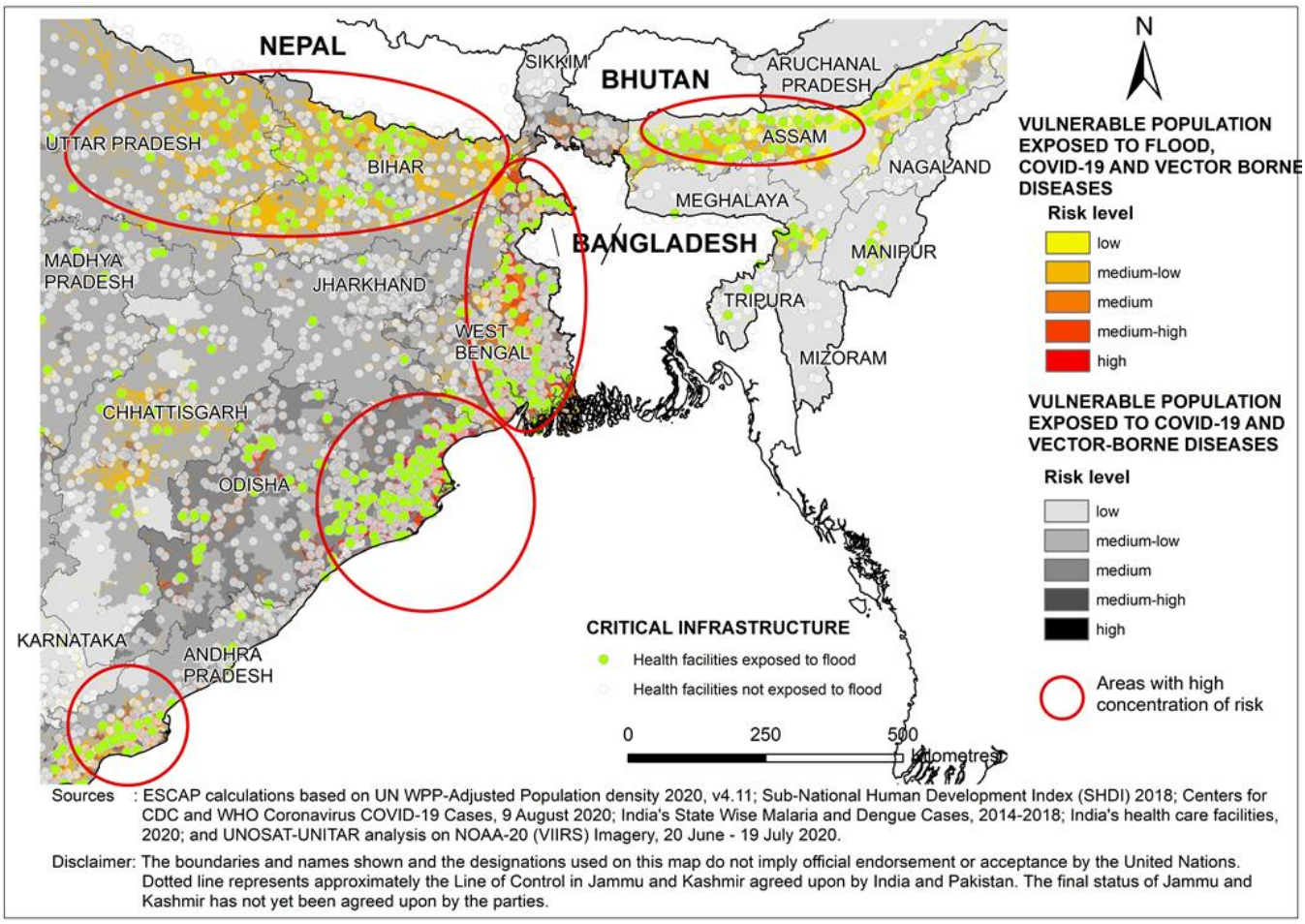


Figure 13 Hospitals at risk from flooding



Disaster Management: From a disaster management perspective, 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.

Social and livelihood: The convergence of floods with dengue and malaria every year with the added impacts of COVID-19 this year will add to community vulnerabilities robbing people of their homes and livelihoods. The mounting risk of more deadly disease outbreaks when health resources are stretched to breaking point by COVID-19 will add to cycles of poverty and impact livelihoods of the most vulnerable populations.[28] Since, hospital are stretched thin and resources have diverted to COVID-19 response, recurring diseases like dengue, malaria, and diarrheal diseases will remain untreated causing increase losses in income, missed school days, and potential malnutrition among children under 5. In the red-zone provinces, priority needs to be given to increasing healthcare coverage for at-risk populations while also potentially providing social protection coverage for missed income from flood damage.

Scenario 3: Long-term, Hotspots of climate-related natural and biological hazards

While the short-term and medium-term scenarios 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 from climate change and climate related natural hazards, a 50-year flood forecasting data from the Global Annual Report (GAR 2015) was used to show future risk for flooding.

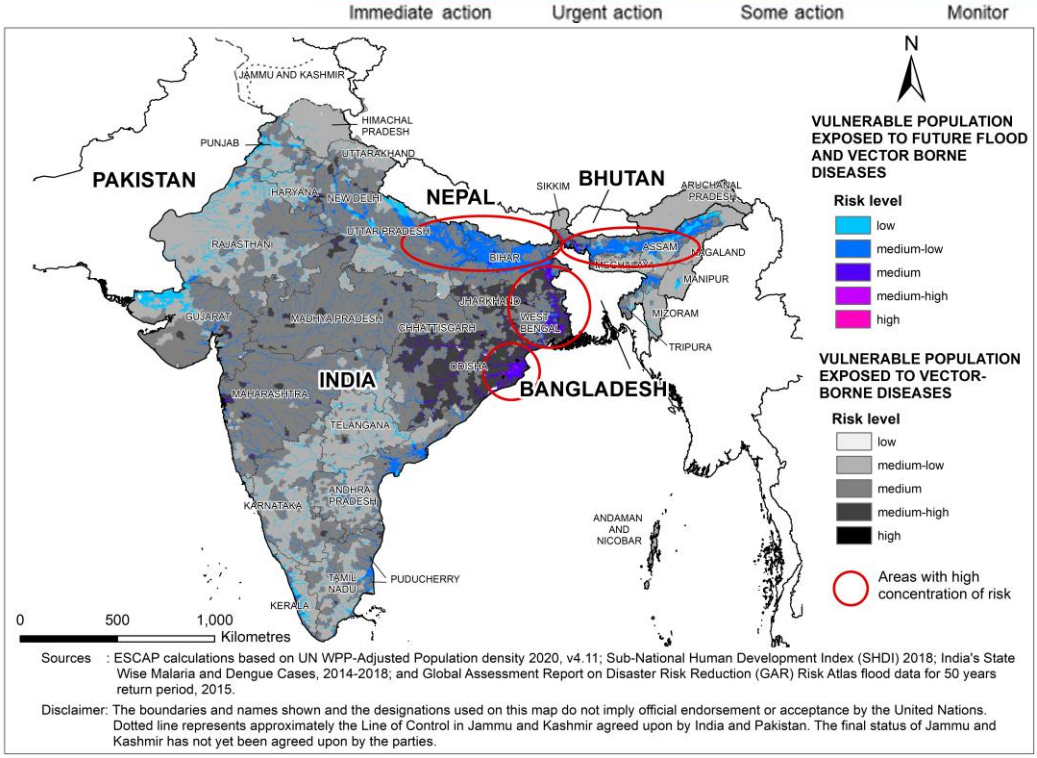
In addition, while the baseline risk drivers of poverty, inequality, and deprivation and HDI was expected to improve there is much variability for future HDI depending on the continuing impacts of COVID-19. South Asia's sub-regional economy is likely to shrink for the first time in four decades and the loss of jobs and livelihoods could push up to 132 million people into extreme poverty.[29] 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, Uttar Pradesh, and West Bengal 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 cascading disasters in the long-term timescale

Impact severity on population						
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	
		1 Lowest	2 Low	3 Medium	4 High	5 Very High
		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.

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.

Bangladesh: Cascading risk scenarios

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.

The provinces with the lowest HDI are Habiganj, Rangpur, Suamganj, Bandarban, and Cox's Bazaar. The most recent flood inundation maps (from 20 June- 19 July 2020), which show the current flood extent in the country with Sylhet, Tangail, Sirajganj, Sumanganj, Faridpur, Gaiband and Jamalpur. 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. The COVID-19 cases have been rising slowly in Bangladesh with Dhaka, Chittagong, Narayanganj, Comilla, and Bogra having the highest exposed populations.

Scenario 1: Short-term, hotspots of COVID-19, 2020 Seasonal floods and Socioeconomic 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.

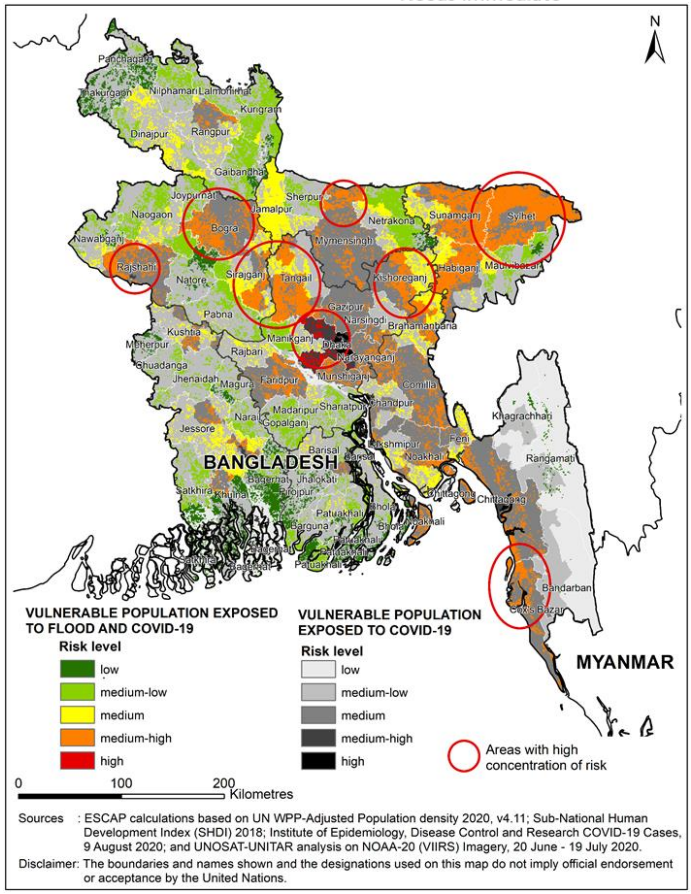
The integrated matrix (*Figure 15*) shows that 15 districts in the red zones with almost 12 million people are at the highest risk from cascading disasters and need immediate policy actions and measures to mitigate disaster impacts on the populations at risk.

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 provinces ranked by likelihood and impact of cascading disasters in the short-term timescale

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	Bogra Narayanganj Sylhet	Faridpur Gaibandha
	Low	2	Jhalokati	Bagerhat Madaripur Rajbari Sherpur Thakurgaon	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



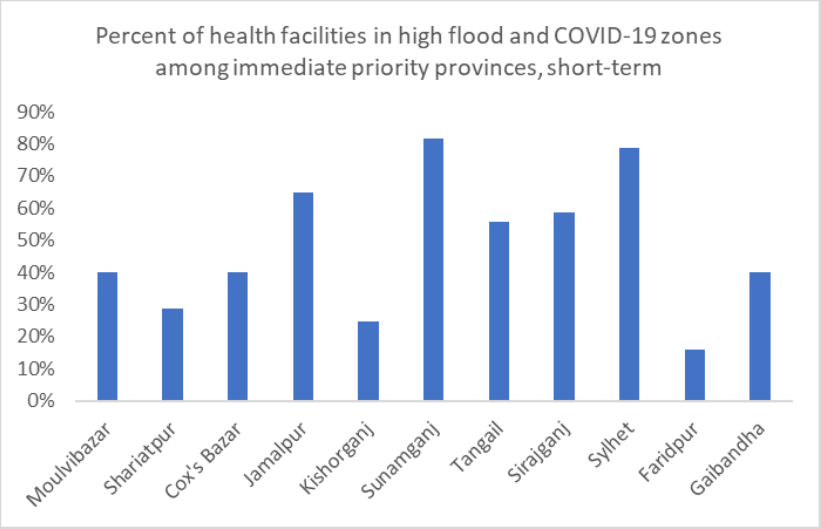
Impacts and policy measures for key sectors

Healthcare- In the immediate term, 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. Additionally, the closure of healthcare facilities due to the floods have increased pressure on those facilities that are still operational.[30] These hospitals should be given the highest priority to ensure that social distancing norms are maintained, and enough hospital beds and related equipment is available to treat people from both COVID-19 and floods.

Disaster management- In the red zone districts, priority should be given to ensuring that COVID-19 patients can access hospitals which may be inaccessible due to the flooding, since almost 1 million people have been isolated by floodwaters.[31] A majority of roads are underwater, and many people are without transportation means due to lack of availability and financial accessibility to boats.[32] Close to one-third of the country was flooded in July and additional evacuation shelters maintaining the necessary norms for COVID-19 should also be constructed near these hospitals to support further flood evacuation measures. Priority should be given in red-zone areas to make sure that aid reaches those in need.

Social and livelihood: The intersection of COVID-19 with flooding and monsoon has impacted existing vulnerable populations. The socio-economic impact of the pandemic is worsening due to flooding and pushing people into poverty. A majority of the population had become unemployed due to the pandemic, with vulnerable groups, such as daily wage workers, particularly impacted. Recent floods have left agricultural lands under water, and most of the crops have been damaged. People are not able to meet basic needs such as food and water due to income loss.[33] In the districts of Faridpur and Gaibandha for example, surveys conducted by the Union Disaster Management Committees (UDMC) found that the monsoon season impacted communities more severely this year by compounding annual floods with the socio-economic and health risks from the COVID-19 crisis and reported challenges in access to food. In the red-zone districts, an integrated response has to be delivered to ensure that the measures taken to contain the virus do not jeopardize agricultural output and food security. In addition, disaster management and social welfare agencies need to ensure financial access for people who have been forced to sell valuable assets and cattle due to the floods.[34]

Figure 16 At-risk healthcare infrastructure



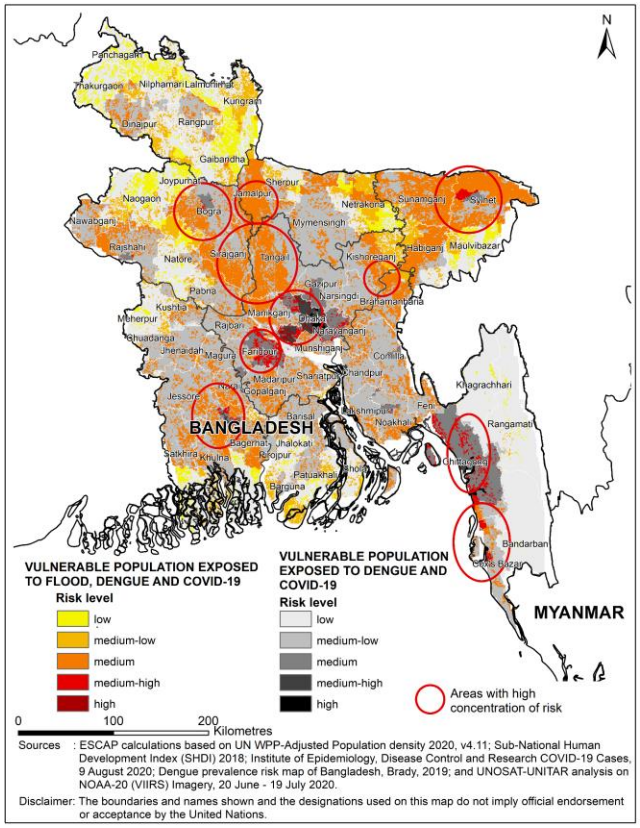
Scenario 2: Medium-term, Hotspots of COVID-19, Recurring biological hazards, Flood inundation, and Socioeconomic risk drivers

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 17 Bangladesh provinces ranked by likelihood and impact of cascading disasters in the medium-term timescale

Impact severity on population							
	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
			1 Lowest	2 Low	3 Medium	4 High	5 Very High
			Likelihood of population exposure to current floods, COVID-19, and Dengue				
			Immediate action	Urgent action	Some action	Monitor	No action



Impacts and policy measures for key sectors

Healthcare: 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*) and will be under stress in the coming months. The accompanying map shows where these hospitals under stress will be 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. This is critical since in 2019, In 2019, the largest dengue outbreak was observed in Bangladesh with 101,354 confirmed dengue patients.[35] 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.

Figure 18 At risk healthcare infrastructure

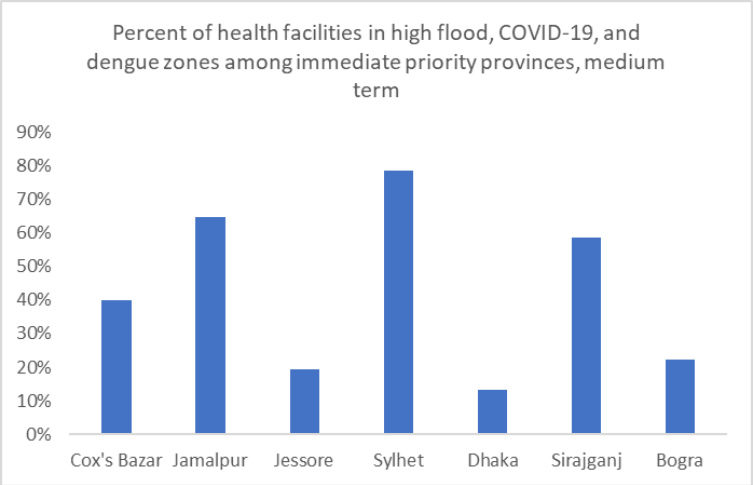
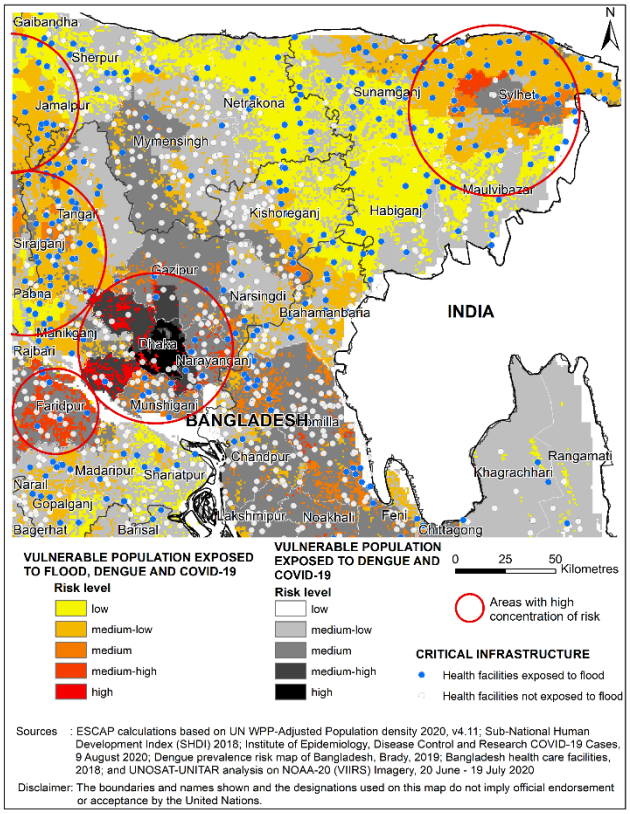


Figure 19 Hospitals at risk from flooding



Disaster Risk Management: As in the India case, ensuring access and integrity healthcare systems to respond to the potential crises stemming from floods, dengue and malaria while tackling COVID-19 calls for an integrated co-operation from the line ministry of health, home affairs, women and child and rural development as well. 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 relevant NGOs to support government systems in building resilient processes and boosting community health needs.

Social and livelihood: The convergence of floods with dengue and malaria every year with the added impacts of COVID-19 this year will add to community vulnerabilities robbing people of their homes and livelihoods, especially if the water and food borne diseases spread alongside the COVID-19 transmission risks. In 2021, it is projected that the dengue outbreak will be more severe than in previous years and the upcoming monsoon season in the coming year is critical for Bangladesh in terms of climatic hazards and infectious outbreaks.[36] In the medium-term scenario, the red-zone provinces

in particular need to be given priority for increased healthcare coverage for at-risk populations while also potentially providing social protection coverage for missed income from flood damage.

Scenario 3: Long-term, Hotspots of climate-related natural and biological hazards

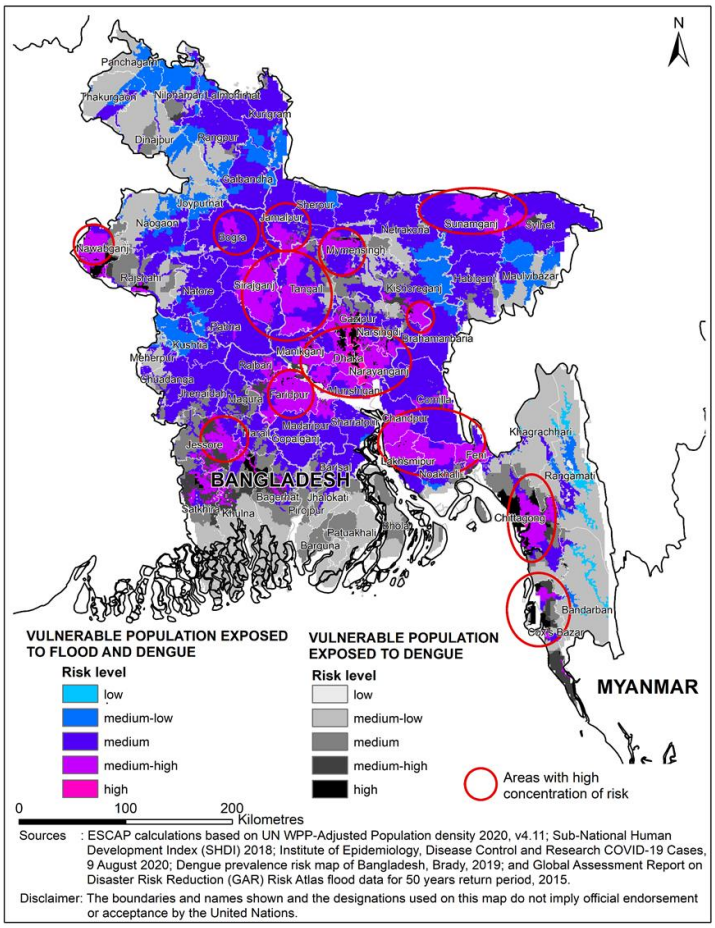
The long-term cascading risks in Bangladesh will stem from climate related weather extremes- especially increasing floods, increasing vector/water borne diseases as well as the endemic risk drivers of poverty, inequality, unemployment, and population density.

For this analysis, GAR 2015 flood data for 50-year flood return period is used. *Figure 20* 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. The map in *Figure 20* 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 20 Bangladesh provinces ranked by likelihood and impact of cascading disasters in the long-term timescale

Impact severity on population						
	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
			1 Lowest	2 Low	3 Medium	4 High	5 Very High
			Likelihood of population exposure to future floods and recurring biological hazard (dengue)				
			Immediate action	Urgent action	Some action	Monitor	No action



Part IV: Integrating cascading risk scenarios into multi-hazard early warning systems and climate services for resilience

The storm of cascading disasters and biological risks demonstrates the need for new algorithms to combine current public health emergency preparedness with disaster risk reduction strategies and management. Estimating risks, vulnerabilities, and capacities from multiple hazards simultaneously and developing different risk scenarios based on the analysis, is the only way to pre-empt natural and health induced disasters. Without appropriate and comprehensive risk profiles and analytics, actions for resilience may be less effective, miss the target, or remain inefficient. This requires both the adaptation of existing preparedness systems as well as additional investments and resources in preparedness, risk estimation and risk reduction (pre-event phases), including developing composite risk matrices which identify and stratify vulnerable populations and locations to understand the differential needs and capacities. Developing these risk matrices will mean a shift from a compartmentalized, or hazard by hazard approach to comprehensive risk assessments with different sectors coming together to improve the common understanding of the complex systems and risks presented and to collectively identify solutions to improve efficiency, reduce duplication of efforts, and allow for integrated policy actions. The COVID-19 crisis now offers an opportunity to fast-track development of these complex risk analytics. The new analytics can form the backbone of post-COVID 19 standard operating procedures (SOPs), local, state, national and policies, and regional cooperation efforts.

The integrated risk scenarios described in this paper are a new way to approach both multi-hazard early warning systems and the larger development of climate services which includes all hazards- biological and natural.

First, the integration of biological disasters into existing early warning systems is critical to develop comprehensive early warning systems. Infact, SDG 3 specifically notes that by 2030, countries need to strengthen early warning for national and global heath risk[37] and the Sendai Framework already has component of biological hazards through the Health Emergency and Disaster Risk Mangement Framework (EDRM)[38]. A comprehensive climate-based disease surveillance system can be initiated to ensure better monitoring and intergrated strategies. While there are early warning systems both in the health sector and the disaster management sector, these have yet to be integrated- however, there are good practice examples that can be scaled up. Box 1, for example, provides methodology for how climate sensitive early health warning systems can be used to provide climate-health outlooks with almost a 2-week lead time.

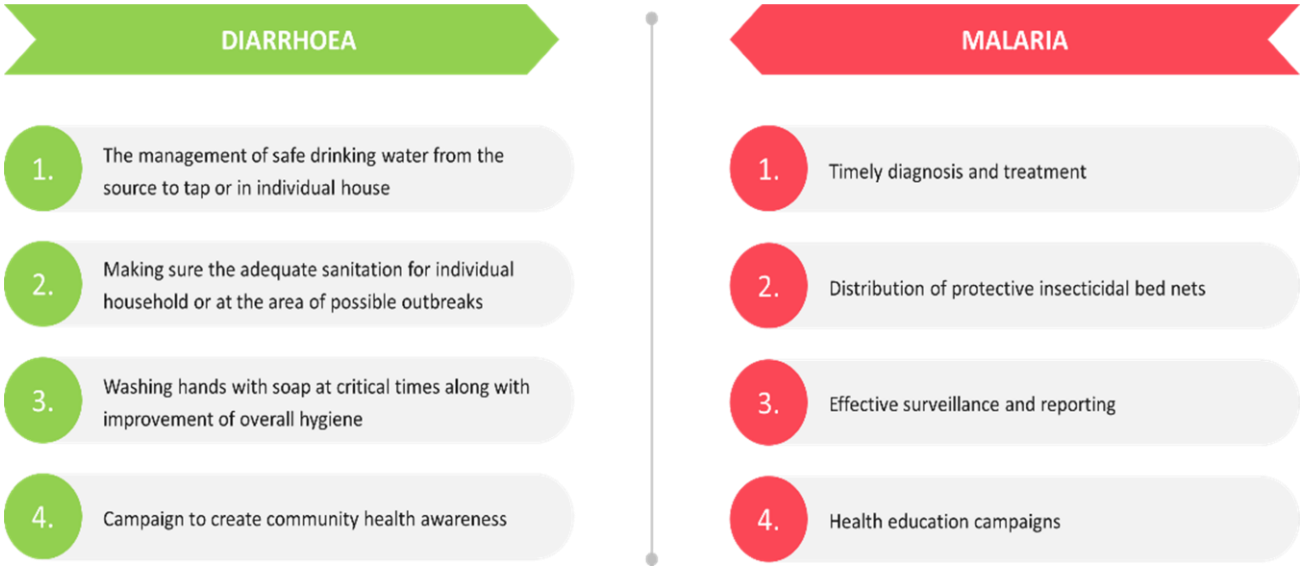
Second, managing climate and health disasters in the backdrop of COVID-19 pandemic and floods in South Asia has re-established the importance of climate services in overall preparedness and crisis management of all hazards. In South Asia, early warning systems have already advanced greatly to cope with hydrometeorological disasters using state of the art weather and climate models which are produced at different timescales (short, medium, extended, and seasonal) using advanced technology such as supercomputers, satellite imagery, and robust modelling systems.

However, translating climate model output to real life situations and applications and integrating them into health and disaster frameworks is the challenge and requires a sound understanding of the relationship between climate and health and the development of methodologies for complex risk scenarios. It is often a challenge for the public health community to access, recognize, understand, interpret, and apply available climate information. Likewise, the climate services community often does not fully appreciate all public health concerns and needs, and the role climate services can play to support public health. Establishment of a strong framework of collaboration between the public health authorities and the national meteorological organizations, can address these challenges and improve the national early warning and response systems for all hazards.

BOX 2: Advances in climate sensitive early health warning systems- a case study in India

Various weather parameters like temperature, precipitation, humidity etc. can directly or indirectly play a major role in the incidence of diseases like malaria and diarrhoea in many complex ways. In a country like India, these diseases have a large disease burden especially among children hence the introduction of a probabilistic forecasting algorithm which could predict and warn is imperative. Researchers have developed and employed probabilistic forecasting of the disease incidences in extended range time scale (2–3 weeks in advance) over India based on an unsupervised pattern recognition technique that uses meteorological parameters as inputs and which can be applied to any geographical location over India.

The study found that the increased probabilities of high (less) rainfall, high (low) minimum temperature and low (moderate) maximum temperature were more (less) conducive for both diseases over the two regions tested upon (Pune and Nagpur), but had different thresholds. The model performed reasonably well based on various measures and had great potential in capturing the variability during different seasons which in turn could give useful, realistic and scientific information for the policymakers about the potential incidence of these diseases. The study also had various suggestion for possible interventions after the climate related forecast of high incidences of malaria or diarrhoea which were:



Source: Sahai A.K., Mandal R., Joseph S, et.al. (2020). Development of a probabilistic early health warning system based on metereological parameters

Conclusion and Way Forward

While the global community is waking up to the notion of "build back better" it is an ingrained concept in disaster risk reduction and noted as one of four priority areas in the global agreement on disasters – the Sendai Framework for Disaster Risk Reduction. The disaster risk reduction community, thus, already has established strengths in understanding the mechanics of 'building back better.' Global and national frameworks already exist to support countries and can be adapted, implemented, and used to increase integrated capacities for disaster and health emergency risk management.

However, regional cooperation is needed to operationalize this conceptual framework. There are a number of existing regional and sub-regional cooperation mechanisms including the South Asian Association for Regional Cooperation (SAARC), the Bay of Bengal Initiative for Multi Sectoral Technical and Economic Cooperation (BIMSTEC), and ESCAP's Asia Pacific Disaster Resilience Network as well as the South Asia SDG Forum that can support countries in South Asia to scale up the integrated of biological hazards into existing climate services.

These cooperation mechanisms can be used to generate knowledge and advances in good practices across the region and can be optimized to establishing integrated multi-hazard early warning systems that address biological hazards, natural hazards, and the shared vulnerabilities of the region. The Asia Pacific Disaster Resilience Network (APDRN), in particular, has been established by ESCAP to support integrated multi-hazard early warning systems and close data gaps therein (*Figure 21*) and can be strengthened further. 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:

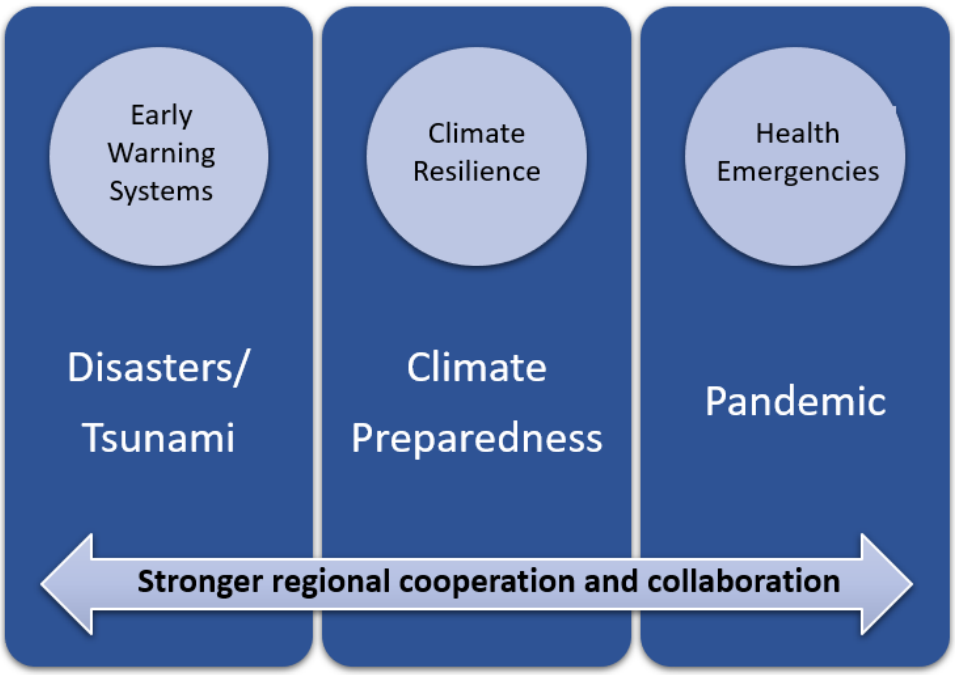
- The APDRN has already mobilized regional cooperation around early warning systems for tropical cyclones under the WMO/ESCAP Panel on Tropical Cyclones. It is also in the process of developing early warning systems for slow onset disasters such as floods and drought. Moving forward, under this workstream, the APDRN will include early warning systems for biological hazards.

- The network assembles geospatial information and services for disasters, disaster -related statistics, and big data analytics for disaster resilience under one platform to build a regional social innovation ecosystem. This platform can now include health related data and close the gaps in integrated analytics from multiple data sources.

- The network brings together space data applications, artificial intelligence applications and digital connectivity for disaster management- the components of this workstream can be expanded to include both health and disaster management.

- Under the network, ESCAP produced a host of thematic knowledge products including the biennial Asia Pacific Disaster Report. These thematic knowledge products can be broadened to include integrated natural and biological hazard risk analytics.

Figure 21 ESCAP's Regional Cooperation Mechanisms for pandemic preparedness, better recovery and resilience



- **Pooling of regional resources, technologies and innovations-risk analytics, telemedicine, tele-education and remote learning**
- **Complement regional/sub-regional initiatives for combatting the COVID-19**

The pandemic, while devastating, has given the world an incredible opportunity to reexamine existing systems and build back better. Disaster, climate, and health are all part of the cycle of systemic risks that impact the most vulnerable populations. But while disasters are addressed in several global frameworks that are also committed to reducing pandemics and health risks, operationalization. Within the Sustainable Development Goals (SDGs), SDG 3 is devoted to good health and well-being, with an emphasis on "early warning, risk reduction and management of national and global health risks." The Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR) has a more specific focus on biological risks – driven by the experiences of Ebola, Middle East respiratory syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS). The links between managing epidemics and disasters are further highlighted by the Bangkok Principles for the implementation of the health aspects of the SFDRR. Using these frameworks, now is the time to substantiate the often talked about 'multi-sectoral' approach and implement risk-informed decision making in all sectors. While this may be a challenge, this is also an opportunity to seize the moment to build back better a future that is resilient and includes all.

Appendix

Appendix A: Requirements for developing cascading risk scenarios

Integrated scenarios	*Stakeholders*	*Impacted sectors and populations*	*Required data to measure impact and probability*
Risk drivers with Natural hazards	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
Risk drivers with recurring Biological hazards	Planning ministries, health ministries	Health, WASH, populations with low human development index, children, women	Population counts, Subnational Human Development Index (HDI) Dengue cases
Risk drivers with Novel hazards	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
Risk drivers with Natural and recurring Biological hazards	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
Risk drivers with Natural, Biological, and other Novel hazards	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

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