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Coastal Hazards in Asian Countries in the Context of Climate Change

Nandini Sanyal*,[1] and Sakib Rahman Siddique Shuvo*

Abstract – *The paper carried out a comparative assessment of coastal hazards and their resultant impacts on communities and physical systems/resources in the countries located in the Asian coastal regions and maritime areas. Only those natural hazards were considered in the assessment which pawned from climate change-induced phenomena. At the outset, the coastal countries including Bangladesh are grouped into three categories based on their exposure to natural hazards, the degree of vulnerability of the communities, socio-economic contexts and technological advancements to cope with the challenges. Then the state, nature, pattern of coastal hazards, and their resultant consequences have been analyzed. Secondary research materials, especially the National Communication (NC) reports of the countries submitted to the United Nations Framework Convention on Climate Change (UNFCCC) were used to undertake the study. The results suggest that the pattern of impacts and their consequences are somewhere identical and, in many areas, different that suggest cross-country understanding combined with local knowledge is crucial for taking effective policies for adaptation or mitigation planning in respective countries.*

Keywords – *Asian coastal hazards, climate change impact, National Communications to UNFCCC, vulnerability.*

1. INTRODUCTION

Coastal regions are the place where global and local events and processes make the interface, sometimes overlie and intermingle when variables like climate, hydrology, geomorphology, water currents, biological habitats are considered and put together in the context. Sometimes, natural hazards cause disturbance in all of these functions and processes and destabilize the whole system. Therefore, proper understanding of the coastal environment and associated hazards is important so that informed actions can be taken towards reducing vulnerabilities of coastal regains. This paper took efforts to examine vulnerabilities of Asian coastal countries in the contexts of climate change. The countries which are surrounded by the seas and which possess significant coastal regions such as India, Bangladesh, Sri Lanka, Maldives, Pakistan, Myanmar, Thailand, Malaysia, Indonesia, Philippines, Cambodia, Vietnam, Singapore, Japan, South, and North Korea were taken into consideration for the assessment. The article is written primarily depending on secondary information and a detail review is undertaken for examining the vulnerabilities of coastal communities of these aforementioned countries due to natural hazards induced by climate change. The National Communication reports of respective countries that were submitted to UNFCCC to meet their signatory obligation were examined to make a comparative and critical assessment.

The work aims to provide a continental scale overview of the vulnerabilities and sectoral impacts of coastal hazards induced by climate change. The climate-vulnerable countries are currently giving efforts in planning and developing diversified approaches like reforming institutions, mainstreaming adaptation projects into regular development programs, developing fiscal frameworks and necessary instruments to address the challenges posed by climate change induced hazards and disasters. A deep understanding of the pertinent issues from different countries combined with local knowledge may help countries to set up their appropriate strategies in this regard. This paper, in this backdrop, made a comparative assessment on the ways countries conceptualized their risk and vulnerabilities from climate change-induced challenges and at the same time learnings received by them while implementing programs to reduce vulnerabilities of different forms.

2. PEOPLE, ENVIRONMENT, AND HAZARDS IN COASTAL REGIONS

The coastal environment plays vital roles in supporting people's lives and livelihoods by facilitating them with different types of endowments in almost all the Asian countries which possess significant coastal areas. These coastal endowments may be classified as biotic and abiotic resources. These resources are generated from coastal ecological systems and depend on the complex physical processes. The physical processes include tidal systems, offshore currents, and waves, geomorphological processes like erosion and accretion phenomenon that develop various kinds of coastal landforms like offshore islands, beach environment, and dunes, spillover fans, and tidal channels, lagoon wetlands. Human communities interact with all these physical systems/processes in a very intricate manner to make their living and ensure their physical, social,

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cultural, and economic wellbeing [1]. Besides, several large, medium, and small-sized cities have also developed in the coastal areas in Asian countries because (i) the water-based communication facilities for supporting trade and commerce are better in those areas, (ii) various types of livelihoods supporting options exist there. More than half of the world's population live in the coastal areas and the rate of concentration is increasing [2].

The complex and interconnected human-nature interface in the coastal areas evolved based on the long-term knowledge, understanding, and familiarity of the coastal communities with the systems and resources they are settled in. People are even familiar with the unusual physical threats and risks that sometimes cause the collapse of the composition, and they generally know how to cope with those uncertainties. However, in recent times, climate change induced threats make those century-old, known patterns of risks and threats more strange, and people become unfamiliar with those to deal with [3]. Some of these threats are slow and progressive like sea-level rise, salinity intrusion, while some others are strong, sudden and rapid like cyclones with strong winds, water surge, tidal bore etc. [4]. Both the types of hazards cause the coastal systems collapsed and resources degraded or destroyed. Impacts of these destructions radiate into different sectors/areas of life, causing immediate and far-reaching, short and long-term chain-of-effects on coastal communities. It is observed that one impact triggers many new forms of consequences, and finally, communities find it difficult to return to their original state. In these circumstances, communities sustain by exercising and accommodating a continuous form of adaptation mechanism to cope with new conditions [5].

3. COASTAL HAZARDS IN THE CLIMATE CHANGE CONTEXTS

Asian coastal countries assessed their vulnerability in the context of climate change and reported to UNFCCC by submitting their National Communication (NC) papers. These documents thoroughly examined the physical and social contexts and showed how climate change exacerbated the existing hazard conditions and focused on the upcoming threats that climate change may cause to happen. Most of the countries refer to IPCC's (Intergovernmental Panel on Climate Change) predictions about climate change and accordingly presented their vulnerabilities, impacts, and response from formal and informal sectors. Countries like India, China, Thailand, Bangladesh, Maldives, Malaysia, Indonesia, Singapore, Republic of Korea, carried out assessments primarily focusing on sectoral impact scenarios. The studies were concentrated on the four areas closely related to the national economy, namely, water resources, agriculture, terrestrial ecosystem, and coastal regions, including offshore marine ecosystems. Countries like India, Thailand, China urged that the projections should be appropriate for scales (e.g., regional, local) to ascertain and understand the intricate dynamics of impacts. However, some countries depend on the PRECIS model to understand regional-scale climate change projections, and most of them started working on climate change induced impacts in the 1990s. It is important to note that the early assessments (reflected in the Initial National Communication, INC reports) of the impacts of climate change were mostly qualitative studies focused on the sensitivity of social and physical systems under incremental scenarios. In recent years, the study has been carried out based on the quantitative models linked up with projected outputs of the global climate models (GCMs) under greenhouse gases (GHGs) emission scenarios.

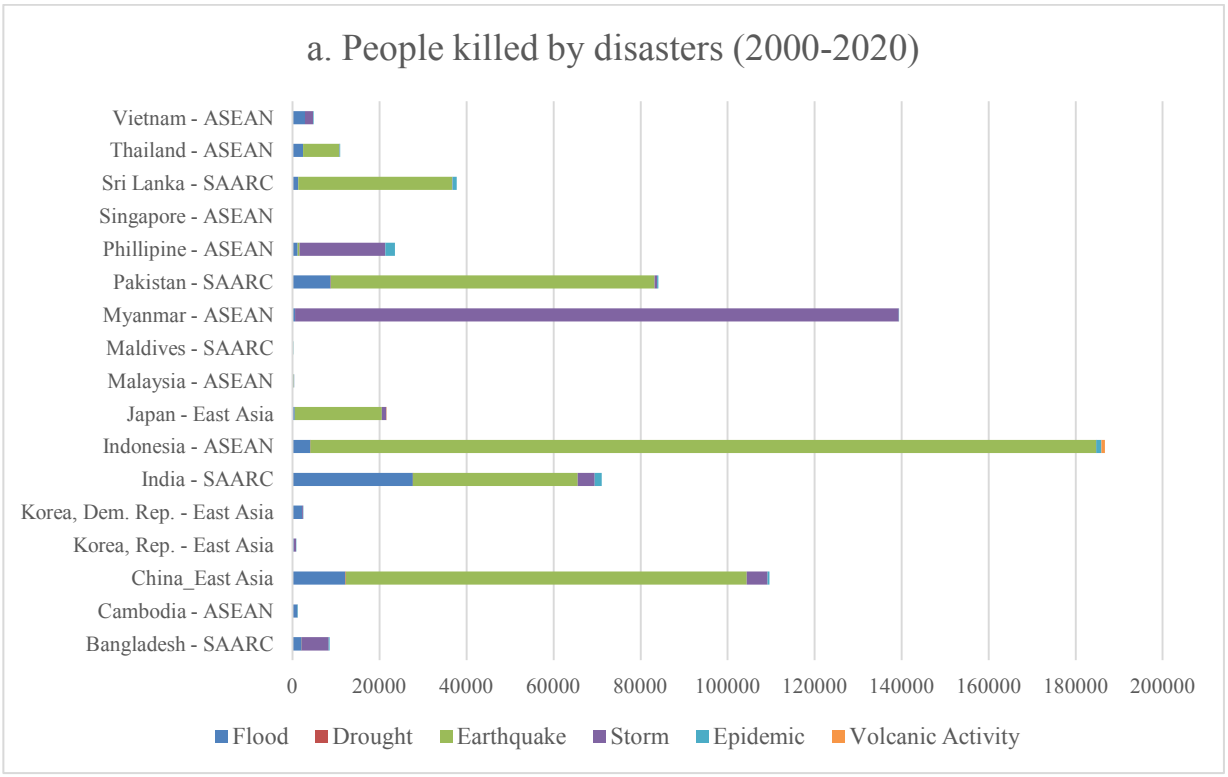
The types of coastal hazards reported by the countries are almost identical; these are sea-level rise, cyclonic disturbances with strong wind/gusts, coastal flooding or water surges, salinity intrusion in both soil and water, coastal erosion, increase in the sea surface temperature and resultant coral bleaching. However, sea-level rise is considered by the most of the Asian coastal countries as one of the severe threats, since sea-level rise will have long term and big impacts on the country's economic production, livelihoods security, environment, infrastructure, public health, and threaten the achievements of poverty reduction, food, and energy security, sustainable development, as well as the fulfillment of the Sustainable Development Goals.

The global disaster and emergency database managed by *Universite Catholique de Louvain*, Belgium, has become a vital source of information in present times in this regard. Data retrieved from this source separately on the number of people killed and the number of affected from the recent disasters for respective countries and graphically presented in Figure 1a and Figure 1b. Both the Figures depict that the hazards that Asian coastal countries are facing are mainly related to climate. It emerges from the Figures that storms, *i.e.* the cyclonic disasters, are more deadly for almost all the countries (Figure 1a). The mortality rate appeared higher from cyclonic events as it takes place with strong winds, huge rain and often accompanied by water surge, requiring huge number of emergency evacuation.

On the other hand, a flood is a slow-occurring phenomenon and lasts for a longer duration cause great suffering and leave millions of people in trouble in almost all the countries, though the death toll could be less (Figure 1b). However, the risk of losses from a particular hazard depends on three factors, *i.e.* hazard, elements at risk and vulnerability [6]. These elements at risk could be human, property, infrastructure etc. On the other hand, vulnerability indicates the likelihood of any community to be affected by any upcoming crisis that can damage its life, property, infrastructure and other kinds of resources on which their life and livelihood depend [7]. Thus the degree of vulnerability of the countries in question to specific hazards varies with the

variation of (i) the physical location of the countries, (ii) the socio-economic context of the country within which the community operates themselves and (iii) technological advancement of the country and the strength of the overall governance by which they can better handle the risk factors. Depending on these elements the studied countries were grouped into three distinct categories for this exercise (Table 1), *i.e.*

- The most vulnerable countries
- The countries with moderate vulnerability, and
- Less vulnerable countries.



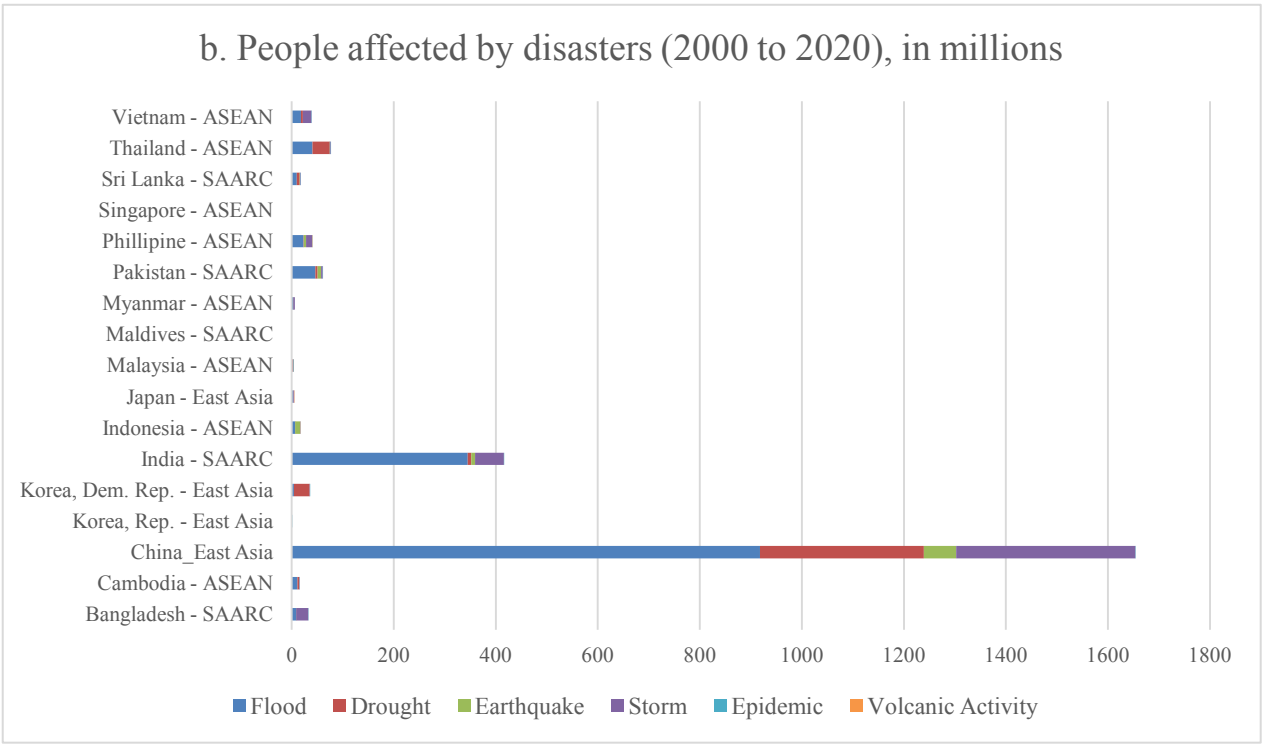


Fig. 1. (a) People died in disasters from 2000 to 2020 (b) People affected in disasters from 2000 to 2020.

Table 1. Types of natural hazards in Asian coastal countries and categories based on exposures to hazards (as reported in UNFCCC National Communication documents).

Groups of countries	Characterizing the hazards and impacts
Group – 1: Most vulnerable countries (*Indonesia, Malaysia, Philippines, Vietnam, Bangladesh, Maldives, Srilanka*)	• The proportion of coastal areas is high compared to the total land areas in these countries that means more people and large parts of economic activities are exposed to the threats of natural hazards. • Sea-level rise related coastal inundation, typhoon impacts, wave action, changes in the storm intensity, coral bleaching as an impact of seawater temperature increase. Oil and gas exploration, transportation, the transmission may be affected. Increased rainfall may cause landslides in some mountainous coastal areas.
Group – 2: Moderate vulnerable countries *(China, India, Thailand)*	• The proportion of coastal areas is less compared to the total land areas in these countries. The impacts are generally concentrated in local coastal regions, not pervasive like Category 1, most vulnerable countries. • Storm surge, sea-level rise related coastal inundation, coastal erosion, saltwater intrusion, death of coral caused by increased seawater temperature, destruction of mangroves, high waves, changes in the pattern of precipitation.
Group – 3: Less vulnerable countries *(Myanmar, Cambodia, Pakistan, Singapore, Japan and both South and North Korea)*	• Two different characteristics differentiate these countries from Group 1 and 2; Firstly, these countries have fewer coastlines like Myanmar, Pakistan and Cambodia. Secondly, some countries are technologically advanced to cope with coastal hazards like Japan, Singapore and Korea. • Flood is the main problem; coastal erosion, salinity intrusion, destruction of coastal forests also happens.

Reflecting on the categorization mentioned above, a comparative assessment of hazard proneness of the Asian coastal countries is given in the following sections.

4. VULNERABILITIES IN ASIAN COASTAL COUNTRIES AS REPORTED IN THE NATIONAL COMMUNICATION REPORTS

4.1 Most Vulnerable Countries

The countries that are most likely to be affected by coastal hazards are mainly the South East Asian (ASEAN) archipelago countries and some of the countries from South Asia. The archipelago countries composed of thousands of islands that include the Philippines, Indonesia, Malaysia, Vietnam; and the countries from South Asia such as Bangladesh, Maldives, Sri Lanka fall into this category. These countries suffer the most from coastal hazards compared to other Asian coastal countries. It is important to mention that although the Maldives does not have any record of great sufferings from coastal hazards but the country is highly susceptible to sea-level rise induced inundation. This reason made the rationale to include the Maldives into the most vulnerable countries.

The Southeast Asian archipelago countries such as the Philippines, Indonesia and Malaysia are situated in the narrow strait between the Indian and the Pacific Ocean in their west-to-east arch and having Australia and Asian landmass in their south and northern parts. This spatial location and geometric form make the region highly vulnerable to typhoon risks generated mainly in the Pacific Ocean. There is a tendency that the typhoons that are spawned in the Pacific generally follow this narrow path. However, in addition to typhoons, sea-level rise, an increase of seawater temperature, landward intrusion of saline water, change in the physical processes, and coastal and marine ecosystems are some significant physical hazards that these countries face. In general, these south East Asian countries have a humid equatorial climate marked by high temperatures and heavy annual rainfall. The countries located in the region experience ascending air and widespread equatorial cloudiness. The length of the discontinuous coastline of these countries is quite extensive because scores of islands form these, and many of the islands are having rugged surface terrains. The long coastline *vis-à-vis* large coastal areas caused to increase in the vulnerability of the human communities, ecosystems, coastal infrastructures to coastal hazards. The settlement clusters of these countries, in the form of cities and urban places, are mostly developed in coastal areas. For instance, the Philippines has 32,400 kilometers of coastline exposed to the sea, and about eighty percent of the provinces and sixty-five percent of the cities and municipalities are located in the coastal areas [9].

Table 2. Land erosion along the Malaysian coastlines [8].

State	Eroded Coastline (km)	Category 1		Category 2		Category 3	
		Critical Erosion		Significant Erosion		Acceptable Erosion	
		No. of Areas	Aggregate Length (km)	No. of Areas	Aggregate Length (km)	No. of Areas	Aggregate Length (km)
Johor	64.7	0	0	30	38.1	42	26.8
Kedah	26.8	4	1.9	28	13.6	90	11.3
Kelantan	19.8	2	2	2	2.5	43	15.3
Melaka	3.7	1	0.2	6	1.7	3	1.8
Negeri Sembilan	9.8	6	5.5	9	4.1	2	0.2
Pahang	61.8	2	1.5	14	16.9	58	43.4
Pulau Pinang	16.3	7	4.7	13	5	31	6.6
Perak	95.1	1	0.3	21	33.8	105	61.2
Perlis	0.1	0	0	0	0	2	0.1
Selangor	76.4	2	4.8	16	18.6	156	51.2
Terengganu	48.7	8	12.3	20	15.4	115	21
Sarawak	492.5	7	18.6	78	144.8	566	329.1
Sabah	429.3	3	3	63	79.1	1120	347.2
Labuan	4.4	1	0.6	9	2.5	11	1.3
TOTAL	1,349.30	44	55.4	309	376.1	2,344	916.5

In the National Communication papers, the Philippines and Malaysia [8],[9] mentioned that sea-level rise, increased sea surface temperature, storms, heavy rainfall, increased tropical cyclonic activities and associated storm surges are major threats in the coastal regions. The Philippines has shown concern that these hydro-meteorological irregularities may impact on freshwater availability, disrupt agricultural activities and food production, destabilize physical and biological systems (*i.e.*, coral bleaching, loss of sea-grass, mangrove area loss) in the coastal and marine areas. The bleaching and degradation in the coral ecosystems (by expelling the single-celled *zooxanthellae* living within coral polyps) as a consequence of sea temperature increase is a significant worry for the Philippines and Malaysia since coral reefs provide fish catch opportunities and thus ensured livelihoods security for millions of people in these the countries. Malaysia mentioned that eighty-five percent of the reefs are threatened by this phenomenon as coral bleaching reached 40-60% in 2016. Malaysia also claimed [8] that the renowned diving sites would be eroded if more coral bleaching occurs. Malaysia mentioned that sea-level rise is expected to cause, (i) inundation of coastal areas resulting in socio-economic loss or changes, (ii) saline intrusion that will affect agriculture and (iii) changes in the salinity of coastal waters that will impact upon marine and aquatic life as well as aquaculture.

Philippines National Communication papers claimed that 1964 is the cut off the year [9], from which a rising trend in sea-level can be detected. In terms of the occurrence of typhoons, the northern parts of the Philippines receive most of the devastating typhoons compared to the southern parts of the country. These typhoons are stronger, faster, carry more moisture, track differently, and will be aggravated by sea-level rise [10]. Similar to the Philippines, S-shaped extended coastal areas in Vietnam also received seven to eight out of twelve to sixteen active typhoons or tropical cyclones in the South China Sea every year. Sea-level rise would cause serious devastations for Mekong river floodplains and delta, the Red River delta, and the central coast of Vietnam, as claimed in the National Communication paper of Vietnam [11]. In Figure 2, the flooding risk of Vietnam's largest cities has been shown.

Vietnam expects saltwater intrusion in the floodplains aggravating agricultural production, causing severe economic and social consequences. The country also stated about higher risks of saltwater intrusion into the rivers and underground water resources caused by sea-level rise resulting in severe social and economic losses. Increased coastal flooding along with sea-level rise will also affect coastal infrastructures and communities, interrupt the waste management procedures and landfill plants; climate change may have

severe impacts on coastal ecosystems and coastal forests.

The impact scenario for Indonesia is almost identical to Malaysia, the Philippines, and Vietnam but for Indonesia, most death records are reported by non-climatic hazards like earthquakes and eruption of volcanoes (Figure 1). Figure 3 shows the likely loss of Indonesia due to sea-level rise.

While considering the South Asian region, Bangladesh, Sri Lanka, and the Maldives would face severe impacts from coastal hazards. All these countries are concerned about climate change induced sea-level rise, anticipating that inundation of low-lying areas would occur, coastal erosion and change in the coastal and marine ecosystems would cause serious uncertainties among coastal communities. However, it is imperative to mention that the coastal hazards of Bangladesh are a little different from other Asian countries. Large-scale coastal inundation problems were initially thought [13] to be the primary concern for Bangladesh, but gross inundation of coastal lands is no longer considered a serious threat in recent times. Increase of temperature and salinity, rise in the frequency and magnitude of cyclones and floods, sediment deposition in the river channel are the major threats in Bangladesh reported in the Third National Communication [14, 15, 16] report. The most characteristic phenomenon for the Bangladesh coast is the continuously changing nature of the geometric shape of the landform. This unstable nature of landform does not allow the coastal lands to settle permanently to develop topsoil and finally to establish vegetation climax and ready for agricultural production based on which people can rely on for their food and livelihoods security. Climate change induced threats is aggravating the situations further.

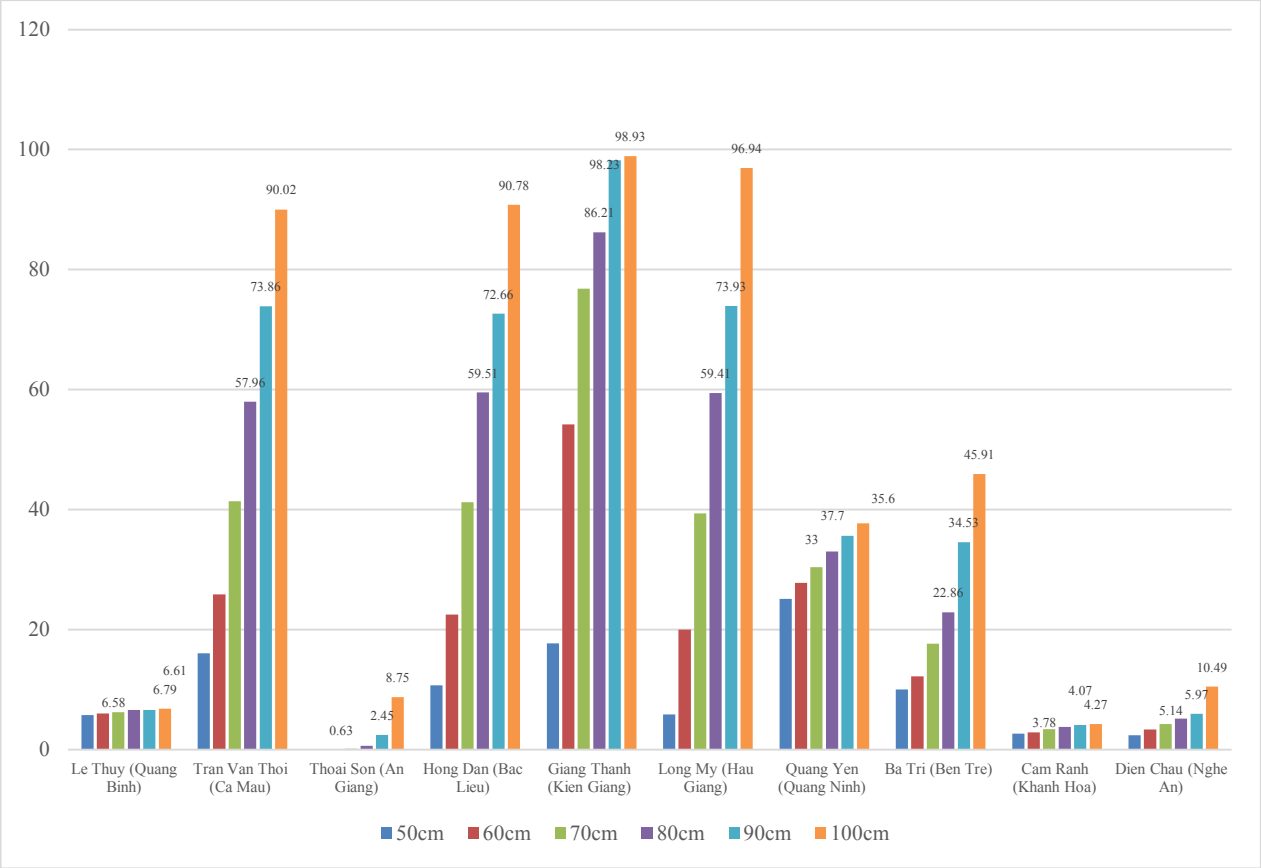


Fig. 2. Risk of flooding concerning sea level rises (% area) of the ten largest coastal regions of Vietnam [11].

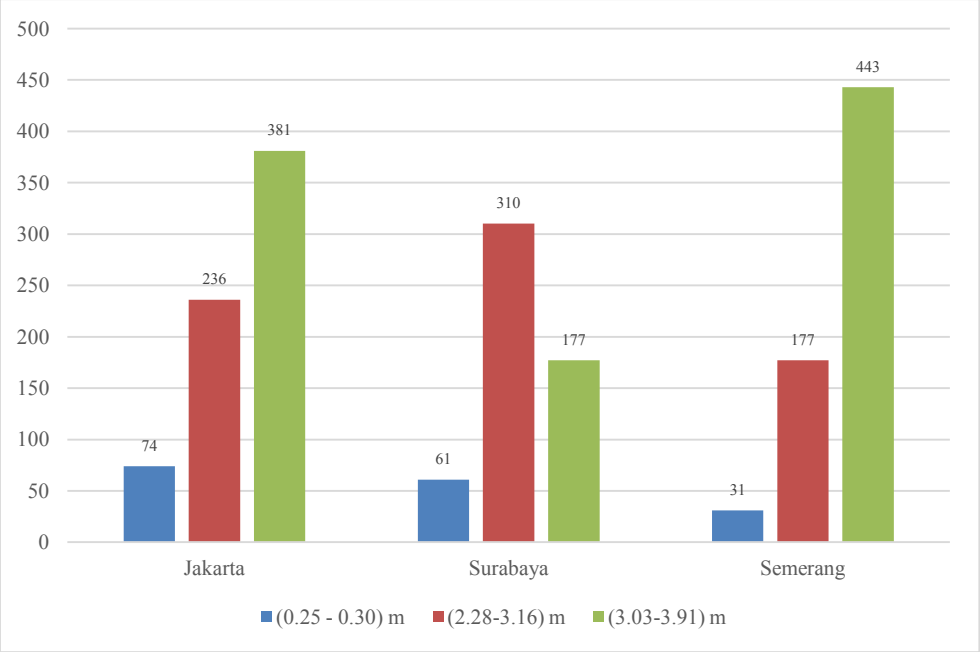


Fig. 3. Potential impact of sea level rise in three big cities of Indonesia (in '000); number of people affected due to sea level rise in three big cities of Indonesia (in '000). [12].

The Maldives, on the other hand, comprised of almost 1192 coral islands situated in the Indian Ocean is under serious threat of seal level rise [17] since almost eighty percent of the areas exist within one meter of mean sea level. The IPCC projected sea-level rise at the end of this century may cause wiping out the country from the map of the world. Beach erosion, bleaching of corals are the major coastal problems in Maldives. The Maldives is not located in a region of cyclonic disturbance, but the northern parts are affected by storms generated in the Arabian Sea and Indian Ocean [18]. Coastal erosion is a concern for Sri Lanka; the country reported that coastal erosion is taking place at a rate of about 0.03 to 0.35 meter per year [19]. Sea level rise, storms, floods, saline intrusion and coastal retreat are common hazards in Sri Lanka which will result in changes in habitat and species distribution, landward migration of coastal species and may cause coastal infrastructural damage [19].

4.2 Coastal Countries with Moderate Vulnerability

The countries that have comparatively less coastal areas are generally less vulnerable because only a part of the whole population live in coastal areas and the concentration of economic activities is less (Table 1). These countries are also prone to coastal hazards and are categorized as the second most vulnerable countries. Countries like China, India, Thailand lie in this group. The types of coastal hazards faced by these countries are almost similar to those faced by the most vulnerable (Group I) countries. Sea level rise, increased frequency of tropical cyclones, coastal erosion, flooding, saline intrusion, destruction of coastal and marine ecosystems are the major types of coastal hazards in these countries. The countries reported that these natural hazards are not new rather they existed from time immemorial. But the strength and severity, frequency of occurrence, the unpredictability of these hazards have increased significantly in recent years.

India, a country of having a coastline of about 7500 kilometers, is susceptible to different types of coastal hazards, though the types of coastal hazards are location specific. For instance, the Bay of Bengal (West Bengal) and Gulf of Kutch coasts anticipate the highest level of sea-level rise, accounted for 0.4 to 2.0 mm per year [20]. In contrast, sea-level in the coastal areas of Karnataka undergoes a relative decrease. The overall estimation of sea-level rise between 1990 to 2100 is about 3.5 to 34.6 inches [21]. India expects that a one-meter sea-level rise would cause to displace approximately 7.1 million people in India, and about 5,764 square kilometers of the land area will be lost, along with 4,200 km of road networks. Indian government expressed their concern about the future state of coastal wetlands and mangrove forests as a result of climate change induced sea level rise, the temperature increase in the coastal areas, change in the brackish water environment, and increased frequency of storm surges. The mangroves located in the mouth of Ganges-Brahmaputra in West Bengal, Mahanadi mangrove forests in Orissa, the Godavari and Krishna mangroves in Andhra Pradesh, the Pichavaram and Muthupet mangroves in the Cauvery delta of Tamil Nadu, the mangroves in the Gulf of Kutchh in Gujarat, and those in the Andaman and Nicobar islands are in great danger of coastal hazards. Besides, increased sea surface temperature causes severe bleaching of corals in Indian coastal areas. Three major metropolitan areas, such as Kolkata, Mumbai, Chennai, and eighteen urban centers, having a population of one million are located in coastal areas [20]. These urban agglomerations and

associated infrastructures are under threat of cyclonic events. Table 3 depicts the spatial and temporal pattern of cyclonic events in the Indian coastal areas.

China is mostly concerned about sea-level rise. The sea-level rise in the Yangtze and Pearl river delta would create a severe impact on agricultural production and human habitation. In the coming 30 years, marked as critical coastal economic belts, these areas will be the most vulnerable zone and face a high risk of flooding due to rising sea level which has happened at an average rate of 3.3 millimeters/year between 1980 and 2017 [22]. Currently, the Yangtze and Pearl river delta areas are experiencing a rate of 3.1 and 1.7 mm per annum increase in the sea levels respectively [23]. The general trend of the change in sea level is that the change along the southern coast is relatively significant, while that along the northern coast small; among the coastal provinces, a significant level of the rise was recorded along the coastal regions of Hainan and Guangdong provinces, while the smallest along coastal regions in Tianjin, Hebei and Liaoning provinces. Decadal change of sea surface temperature indicates a rising trend. The increase in the temperature of coastal waters were estimated to be as 0.55, 0.35, and 0.25 degree Celsius per decade for winter, spring-autumn and summer respectively [22] which may cause coastal bleaching.

Thailand experiences cyclonic disturbances in the forms of depressions, monsoon, and typhoons in their coastal areas. Based on the historical trend analysis, the Department of Disaster Prevention and Mitigation of Thailand reported that Thailand would face an increased number of cyclonic hazards over the upcoming years (Table 4). However, Thailand expressed concerns about understanding local level climate change impacts based on the global scale modeling results [24]. Their National Communication paper mentioned that more local scale research is needed to understand the precise nature of climate change induced coastal hazards.

Table 3: Cyclonic events in Indian coasts.

The spatial pattern of cyclone incidences and the fact (data from 1877 to 1990)
- 1474 cyclones originated in the Bay of Bengal and the Arabian Sea during this period.
- 964 cyclones crossed Indian coastline; of these 3 districts in West Bengal received 174, seven districts in Orissa received 422, nine districts in Andhra Pradesh received 203 and 15 districts in Tamil Nadu received 100 cyclonic events. The remaining 65 cyclones are received by Indian west coastal areas.

The temporal pattern of cyclone incidences
- Depressions have a distinct peaks in the month of August
- Storms have two distinct peaks in June and October
- Severe storms have distinct peaks in May and November
- The total number of tropical cyclones seasonality follow the path of the depression

Average based on the facts
- 8.45 cyclones cross Indian coastline every year
- 5.15 depressions cross Indian coastline on n average per year
- 1.93 storms occur on an average per year
- 1.35 severe storms occur on an average per year

Table 4. Trends in the intensity of depressions, monsoons, and typhoons in Thailand and forecasts over the next 30 years (2013 to 2043).

Storm	1963 to 1982		1983 to 1997		2013 to 2043	
	Number	%	Number	%	Number	%
Depression	8	54	6	46	6	40
Monsoon	5	33	4	31	5	33
Typhoon	2	13	3	23	4	27
Total	15	100	13	100	15	100

4.3 Less Vulnerable Countries

The countries having significant coastal areas but comparatively better protected from coastal hazards are categorized in this group (Group 3). The countries are better protected because of their locational advantage or the countries are technologically and financially capable to put safeguard efforts for minimizing the negative consequences of natural hazards. Countries like Myanmar, Cambodia, Pakistan, Singapore, Japan and both South and North Korea fall into this category. The comparatively safer geographical position of the countries such as Myanmar, Cambodia and Pakistan and the technological and financial advancement of Singapore, both the Korean states and Japan fall into this group. For instance, the eastern parts of Myanmar are protected by Thailand and the southern adjoining Gulf of Martaban is comparatively shallower than the Andaman sea or the adjoining Bay of Bengal. This shallow depth of continental shelf areas contributes to softening the impacts of cyclones or tsunamis and give Myanmar better natural protection from coastal hazards.

Table 5 indicates that only cyclone Nargis, struck in Myanmar coast on 02 May 2008 caused 138 thousand deaths; the death toll in the rest of other coastal disasters is less. The high death toll in cyclone Nargis took place because of lack of preparation to deal with this disaster, where almost similar kind of cyclones struck in Bangladesh coast in 2007 and 2009 (cyclone Sidr and Aila respectively) causing death below 5000 people in each disaster because of better preparedness were put in place.

Table 5. Top 10 disasters in Myanmar in terms of number of people killed.

Disaster	Date	No of people killed
Storm	May 2008	138,366
Storm	May 1926	2700
Storm	May 1968	1070
Storm	April 1936	1000
Storm	May 1902	600
Earthquake	May 1930	500
Storm	May 2004	236
Storm	May 1975	200
Storm	October 1967	178
Flood	October -2011	151

Source: EM-DAT: The OFDA/CRED International Disaster Database, www.em-dat.net – Universite Catholique de Louvain – Brussels – Belgium". Data created on June 23, 2020.

On the other hand, Cambodia is protected by Thailand, Laos, and Vietnam in eastern, northern and eastern parts, respectively; only the southern parts are open to the Gulf of Thailand. But this coastal part is also protected by mountain ranges from coastal hazards. These physical barriers put Cambodia in a relatively safer position from coastal hazards. National Communication report of Cambodia also mentioned that the country rarely suffers from extreme weather events such as typhoons [25]. However, recent studies confirmed that this country is threatened by a sea-level rise which may threaten seaports, beach resorts, coastal fisheries and coastal land use patterns. Recent analysis showed that 25000 and 38000 hectares of lands will be inundated permanently if sea level rise happens 1m and 2m respectively [26]. Eighty percent of lands may go under water in the low-lying areas of Koh Kong province if sea level rise takes place by 1 meter and eleven percent in Prah Sihanouk Province. The coastal mangrove forests, grasslands and shrimp farms in these coastal plains would be destroyed as an effect of sea-level rise [26]. Large parts of Mekong river delta and Combodia's 435 km shoreline could be affected by sea level rise [27].

Pakistan also reported climate change induced vulnerates in variety of forms [24]. A small part of Pakistan (the Indus valley and port city Karachi), stretches over 990 kilometers, is situated along the Arabian sea, more specifically along the Gulf of Oman. These coastal areas are susceptible to coastal hazards like cyclones. Almost seventy five percent of the cyclones that spawned in the Arabian Sea generally end up at the Omani coast on the western Arabian sea, and the remaining twenty five percent cross Pakistan coast as reported in Pakistan's National Communication report [28]. Sea level rise becomes a significant concern for Pakistan. Pakistan anticipates that the very physical processes and sediment dynamics will be impacted as a consequence of sea-level rise, resulting in disturbances to coastal mangroves.

On the other hand, South Korea, North Korea, Japan and Singapore remain under threats of coastal hazards, but they are better prepared to face those events. Japan gives protection to both the Korean states from cyclonic hazards as Japan situates directly in the eastern sides of Korean states. Korean countries are rather worried about the rise of the water temperature and increase in the sea level in the surrounding waters of the Korean Peninsula, which will ultimately cause changes in the ocean circulation pattern and seawater characteristics resulting to the change of the marine ecosystems and impacting on the distribution of fisheries resources in adjoining coastal areas.

However, Japan is one of the worst affected countries from cyclone hazard, but the country has demonstrated tremendous success in reducing vulnerability by strengthening community capacity and making evacuation efforts efficient. This statement is also true for Singapore since the country has protected about eighty percent of her coastline from hazards by erecting hard walls and stone embankments. Mangrove forests protect the remaining areas. However, Singapore showed their concern as sea level rise may cause saltwater intrusion into their water reservoirs [29]. However, Singapore is getting prepared to deal with climate change induced coastal hazards by accommodating adaptation measures in its *Sustainable Singapore Blueprint* and took necessary steps towards its implementation.

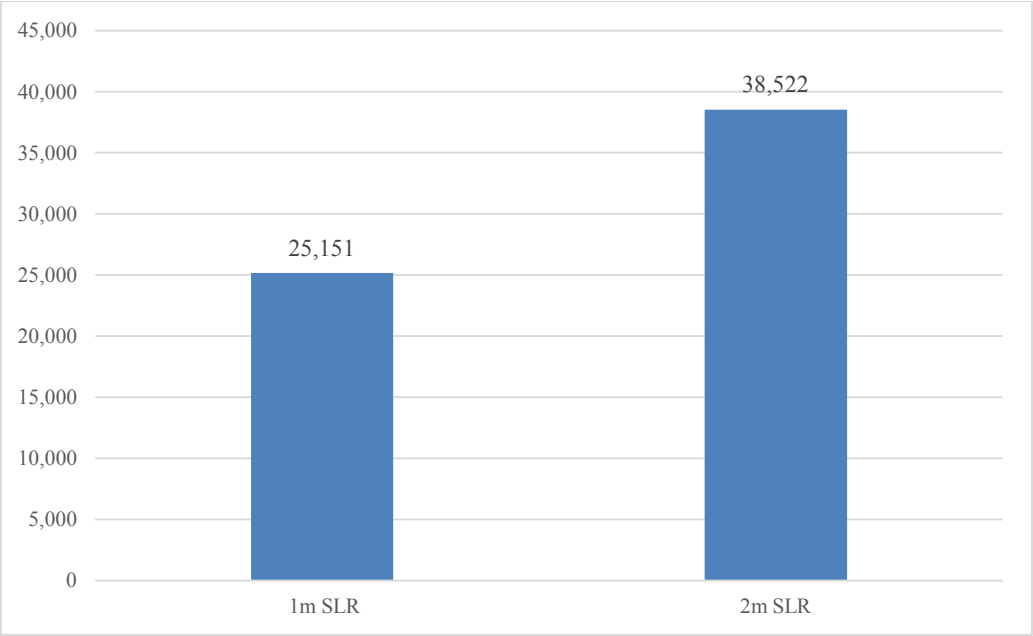


Fig. 4. Coastal areas (in hectares) under threat of inundation against 1m and 2 m sea level rise scenario in Cambodia [26].

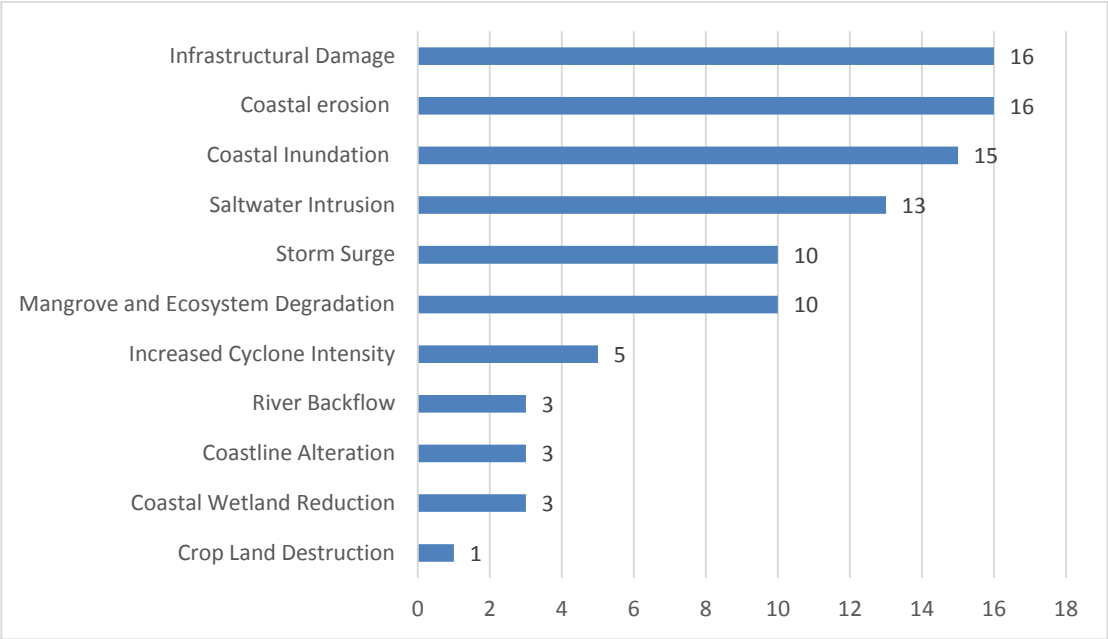


Fig. 5. Sectors of potential impacts of sea level rise and number of concerned countries.

5. CONSEQUENCES OF COASTAL HAZARDS

The review of the National Communication (NC) reports prepared by seventeen Asian coastal countries for UNFCCC gives the opportunity to make continental-scale comparative assessment on climate change induced threats and challenges. The countries reported a range of hazards those are currently occurring and also those which may occur in the upcoming years as results of change in the climate systems. The reported hazards are mostly identical but the degree of threats was reported to be variable in different countries (Table 6). It is found that cyclonic disturbances are common in all the countries which is deadly and rise in the sea level indicated by most of the countries as a potential threat (Figure 5) in the coastal systems (both economic and ecological). The countries mentioned (Table 6) that many hazards are localized but will become a potential challenge in the future under the influence of incremental changes of regional and global patterns of climatic systems. The concerns for hazards come from the fact that these will destroy infrastructure, local economy and destabilize the ecological processes vis-à-vis undermine the ecosystem services based on which coastal communities live and thrive.

6. LITERATURE BEYOND NATIONAL COMMUNICATIONS

This paper primarily focused on climate induced hazards and vulnerability that are narrated in the National Communication Reports (NCR) submitted to UNFCCC by 22 coastal countries of Asia. The results informed about the impacts and magnitude of hazards in the milieu of climate change. In addition to these documents, a rich scholarly literature is available that was not taken in the purview of this paper. However, a brief reflection from the literature that exists beyond NCRs may provide an extended understanding of the issues mentioned in the paper. For instance, a study shows that due to saltwater intrusion, oil palm production in Malaysia will be seriously interrupted [34] under the increasing trend of storms, droughts and floods [35]. The increasing trend of storm intensity and sea level rise is projected for the Philippines [32], the vulnerability in low-lying coastal areas of Vietnam is increasing [37]. Studies show that the salinity level is becoming high in coastal regions of Bangladesh which is highly affecting the economy and livelihood in those areas including sectors such as health, water and sanitation [30], [31]. Apart from coral reef destruction, increased coastal flooding is expected in the Maldives [36]. Sri Lanka is expecting sea level rise that might cause increased coastal erosion [37]. In Thailand, increasing trends of droughts are reported in eastern parts of the country [38] and prolonged droughts, decreased agricultural and fishery yields, violent flooding, sea level rise and health related issues can be seen in the future throughout the country [39]. Both India and China might experience different types of hazards in their vast coastal areas from climate induced rainfall anomalies and increased temperature conditions [40, 41].

7. VULNERABILITIES OF BANGLADESH COAST IN THE CONTEXTS OF CLIMATE CHANGE INDUCED HAZARDS

It is widely reported that coastal regions of Bangladesh are one of the major vulnerable areas of the country [42], [43] that sufferers from a range of natural hazards such as cyclonic disturbance, storm surge, flooding, waterlogging, coastal erosion, salinity intrusion etc. [44], [45]. These situations are aggravating under the influence of climate change [16] and the people living in coastal areas are becoming more exposed to hazards. Even the efforts taken by the government, development partner agencies (like UNDP and other international agencies) and non-government agencies as part of the adaptation process (such as building infrastructure, providing livelihood support etc.) are also damaged repeatedly and thus the hard-earned gains towards building resilience become undermined. These challenges are currently being critically scrutinized by the researchers and also by the government agencies [46], [47] to devise appropriate pathways so that vulnerability-reducing actions and related gains could sustain. Improvements in the allocation of business of the government agencies (e.g. incorporating the 'climate change' in the name of the ministry of environment and forest and adoption of new responsibilities), developing climate sensitive budget codes by the Ministry of Finance [48], institutionalizing climate change interventions into regular development pathways of the government [47] are some of the evidences of taking different, novel and appropriate approach in tackling climate change threats in Bangladesh. In these contexts, it is imperative to know about the problem contexts happening in other countries facing similar kinds of challenges, may be happening in different forms. For example, Vietnam considers three approaches (adaptation, mitigation and withdrawal) to tackle climate change threats while Bangladesh is based on two (adaptation and mitigation). Bangladesh may learn from Vietnam whether 'withdrawal' is appropriate or not for Bangladesh for certain coastal regions. This cross fertilization of knowledge may help Bangladesh to develop policy and necessary instruments that are appropriate for the time and need to tackle climate change related challenges more effectively and sustainably.

8. CONCLUSION

The communities living in the coastal areas in Asian countries have been dealing with coastal hazards for hundreds of years. Some countries have enhanced their capacities to reduce the degree of impacts and to better adapt with the challenges, while some countries still suffer from disaster impacts due to weaker economic conditions and exposure of a large number of people to hazards. This review assessment, in this backdrop, suggests that climate change related hazards have appeared as a new dimension to the pre-existing set of uncertainties and exacerbating the situation that has already been fragile as a consequence of socio-economic-political systems of societies [14], [49]. The countries have been putting their efforts to develop policies and improve institutional capacities to deal with the challenges. But the inadequate and incomplete understanding of the hazards (in terms of intensity, magnitude and frequency of occurrence, spatial extent etc.), risk and vulnerability may create impediments in devising appropriate policy instruments to deal with the challenges.

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