

**IMPACT OF CLIMATE CHANGE ON COASTAL CITIES:
AN 'INTEGRATED ADAPTATION' APPROACH
PART I**

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29 November 2020*

Abstract

A country's coastline is the epicentre of its business, commerce, transportation, and industry. It provides a majority of the global ecosystem goods and services that are central to the country's socio-cultural and economic development. Hence, the threat posed to coastal cities by a rise in the sea level caused by climate change is both, high and multi-dimensional. The Indian coastline is one of the most vulnerable, risk-prone and densely populated regions in the world. Indian coastal cities have been altered profoundly in the last few decades due to their rapid growth in population and economic activities. The impact of climate change-induced sea-level rise is aggravated by unsustainable and unplanned development, and the growth of densely populated and unstructured settlements in coastal cities. Limited access to housing, public services and infrastructure for the poor, as also poverty itself, add to the vulnerability of coastal cities. Consequently, extreme climate-induced hazards weaken the resilience and coping-capacities of already poor and vulnerable communities, raising socio-economic costs.¹ The impact of climate change on coastal cities is a vital strategic, economic and political issue as well.

This article seeks to draw the attention of the Indian populace at large, but most particularly that of India's coastal communities and their governance structures, to the alarming and imminent challenge posed by climate-change-induced sea-level rise. In an attempt to present the arguments in smallish 'bite-sized' morsels, the article is being presented in two parts. Part I dwells on the impact of climate change and sea-level rise on coastal cities, while Part II focusses upon the manner in which urban expansion and encroachment have intensified vulnerability of coastal cities to climate-change-induced impacts. It also discusses how the most vulnerable and disadvantage section of the population is overlooked, and how the lack of fair equity in several dimensions of action and decision-making in terms of coastal adaptive measures ends-up reducing the adaptive capacity of coastal cities.

On the one hand, coastlines in general are highly productive and critical elements of any country as they provide a globally-connected ecosystem of goods and services, which is central to socio-cultural and economic development. On the other hand, they are areas that are highly risk-prone vis-à-vis climatic impact. Perhaps the most serious risk, and one that is growing much faster than predicted, involves the adverse impact of climate-change in its several manifestations. These include extreme climatic events such as flooding, drastic changes in the precipitation cycle,

¹ Aromar Revi, "Climate Change Risk: An Adaptation and Mitigation Agenda for Indian Cities", *Environment and Urbanization Journal*, 2008; Vol 20 (1), 207-229, doi: 10.1177/0956247808089157

a sharp and sustained rise in sea-surface temperature, and, tropical revolving storms (TRS) that are, of late, demonstrating a marked increase in frequency-of-occurrence and in ferocity/intensity, but an equally marked decrease in path-predictability. The occurrence of such extreme weather events is affecting both natural ecosystems and human systems severely and adversely, with socio-economic productivity being correspondingly impacted. Moreover, coastal cities already stand exposed to high and multi-dimensional risks induced by climate-change-related sea-level rise. Coastal cities are also highly vulnerable to anthropogenic climate change and have the least capacity to adapt. Yet, exposure to the impacts of climate hazards are expected to increase with growing population and economic relevance of coastal cities.²

Insofar as India is concerned, the country's coastline runs for some 7,516 kilometres (km) across nine states and four union territories (UTs) — two of the latter, namely, the Andaman and Nicobar island chain on the country's eastern seaboard, and the Lakshadweep chain on the western one, being archipelagos. This coastline is home to roughly 170 million people and, not only is it one of the most densely populated regions in the world, it is also extremely vulnerable to a multiplicity of sea-based threats and hazards, the more obvious of which have already been mentioned. The Indian coastline is studded by a number of human agglomerations, ranging from fishing hamlets and villages to megacities. Climate change and climate variability will produce an extremely complex web of interrelated and highly adverse impacts on all such human concentrations but will be most severely felt in large coastal cities. Amongst the most worrying of these effects concerns sea-level rise. Table 1 depicts how the warming of the globe will impact regional climatic variations such as temperature change, precipitation, and sea-level rise, in India.

Table 1: Climate Change Projections for India based on Four Global Environmental Multiscale (GEM) Model Outputs

Year	Temperature Change (°C)			Precipitation Change (%)			Sea Level Rise (cm)
	Annual	Winter	Monsoon	Annual	Winter	Monsoon	
2020s	1.36±0.19	1.61±0.16	1.13±0.43	2.9±3.7	2.7±17.7	2.9±3.7	4 to 8
2050s	2.69±0.41	3.25±0.36	2.19±0.88	6.7±8.9	-2.9±26.3	6.7±8.9	15 to 38
2080s	3.84±0.76	4.52±0.49	3.19±1.42	11.0±12.3	5.3±34.4	11.0±12.3	46 to 59

Source: Aromar Revi 2008³

Major factors that contribute to sea-level rise are ocean thermal expansion, the melting of glaciers and icecaps, glacier-melt from the Greenland and Antarctic ice-sheets, and, to a smaller extent, the melting of snow on land and permafrost. The sea-surface temperature (SST) of the tropical Indian Ocean rose by 1° C on average during 1951–2015, which was markedly higher than the global average SST warming of 0.7° C, over the same period. As a direct consequence, the sea-level rise experienced in the northern Indian Ocean, has accelerated to 3.3 mm per year

² RJ Nicholls, PP Wong, V Burkett, et al, "Climate Change and Coastal Vulnerability Assessment: Scenarios for Integrated Assessment", *Sustainability Science* Vol 3, (2008), 89–102, DOI 10.1007/s11625-008-0050-4

³ Revi, "Climate Change Risk...", p 212, *Supra* Note 1

between 1993-2017.⁴ This rate of sea-level rise will accelerate further with the rising mean temperature. Table 1 clearly depicts that increasing temperature is contributing to the sea-level rise and its impacts. For instance, the sea-level rise increased from 4-8 cm to 15-38 cm with a of temperature-rise of just 2° C. This sort of sea-level rise will inundate a very large number of low-lying areas. It is likely to aggravate flood situations, erode beaches and further impact coastal settlements in terms of population-displacement from presently densely-populated areas. As per studies undertaken by The Energy Institute (TERI), a one-metre rise in sea level would displace approximately 7.1 million people within the coastal population, and place about 5,764 sq km of land at risk of getting submerged. Several coastal areas — with their constituent population amounting to some 200 million people — are projected to be below the high-tide line by 2100.⁵

According to the Intergovernmental Panel on Climate Change (IPCC), climate models are consistent with the ocean temperature observations and indicate that thermal expansion will continue to contribute to sea-level rise over the next 100 years. Since deep-ocean temperatures change slowly, thermal expansion would continue for many centuries even if atmospheric concentrations of greenhouse gases were to be stabilized.⁶ Therefore, increasing temperatures and sea-level rise are likely to continue to be major risk factors for coastal cities in India, where one-third of the population [which is nearly 40 million people] is located. This regional temperature-rise, along with the changes being experienced in both, the global climate system and the Indian Ocean monsoon system, may lead to a mean increase in annual precipitation of 12.3 per cent by 2080, up from the 3.7 per cent change forecast for the 2020s. Even more worryingly, it is assessed that many regions in the semi-arid and drought-prone central part of India will also experience a simultaneous decline in precipitation of the order of 5-25 per cent. As if there were not challenge enough, a sharp decline in winter rainfall across northern India is also projected.⁷ This lethal combination of severe disruptions to the country's precipitation cycle will severely affect food security and agriculture production. According to a 2011 study conducted by the Indian Agricultural Research Institute and the CGIAR Research Program on Climate Change, Agriculture and Food Security, climate change could lead to a 15-50 per cent decrease in the yield of irrigated maize and a 10 per cent drop in yields of irrigated paddy in the majority of coastal districts by 2030.⁸

Chronic flooding, too, should be expected in the future. The Climate Central study on global vulnerability to sea-level rise and coastal flooding estimates that 36 million Indians are at risk of chronic flooding by 2050 and estimated that number will grow to 51 million Indians by 2100 [See Figure 1]. It also predicted that extreme precipitation similar to the Mumbai floods in 2005

⁴ R Krishnan, J Sanjay, et al, eds., "Assessment of Climate Change over the Indian Region", A Report of the Ministry of Earth Sciences (MoES), Government of India, 2020, <https://doi.org/10.1007/978-981-15-4327-2>

⁵ Seetharaman, G. "Coastal Concerns: Rising Sea Levels Will Inundate Coastal Areas Sooner than Projected", *Economic Times*, 10 Nov 2019, <https://economictimes.indiatimes.com/news/politics-and-nation/coastal-concerns-rising-sea-levels-will-inundate-coastal-areas-sooner-than-projected-/articleshow/71985765.cms?from=mdr>

⁶ IPCC, *Climate Change 2007: The Physical Science Basis*, Summary for Policymakers, 2007

⁷ Revi, "Climate Change Risk...", p 212, *Supra* Note 1

⁸ Seetharaman, G. "Coastal Concerns: Rising Sea Levels will Inundate Coastal Areas Sooner than Projected", *Economic Times*, 10 Nov 2019, <https://economictimes.indiatimes.com/news/politics-and-nation/coastal-concerns-rising-sea-levels-will-inundate-coastal-areas-sooner-than-projected-/articleshow/71985765.cms?from=mdr>

and Gujarat floods in 2006 could occur over other parts of the west coast in the absence of effective measures.⁹

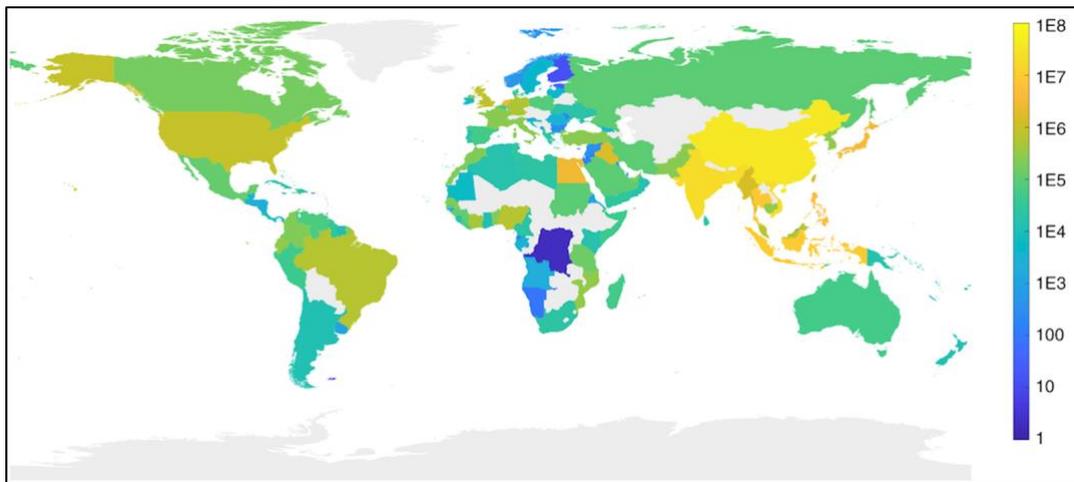


Fig 1: Number of People on Land Exposed to Sea-level Rise and Coastal Flooding by 2050

Source: Scott A. Kulp and Benjamin H. Strauss, “New Elevation Data Triple Estimates of Global Vulnerability to Sea-Level Rise and Coastal Flooding”, *Nature Communication*, 10, No 4844 (2019).

Cyclones and storm surges are very likely to be devastating for coastal mega-cities such as Mumbai, Chennai, Visakhapatnam, Surat, Bharuch, Bhavnagar and Jamnagar, apart from causing critical bottlenecks in important ports such as Kandla.¹⁰ It needs to be remembered that a storm surge, accompanied by coastal flooding and cyclonic winds, is the second most destructive, rapid onset hazard in Gujarat. It accounts for 12 per cent of the risk to the state and a potential loss of over 11,000 lives for a probabilistic 100-year event.¹¹ Increased migration to the coast, drawn by huge investments in coastal infrastructure, settlements and enterprise would be disastrous as there are future risks involved, which have not been considered.

Another major big loss of climate change-induced changes on the coastal region is infrastructure, predominantly ports because India has 12 major and 205 notified minor and intermediate ports. Indian port operator handles significantly large number cargo movement and 95 per cent of the country’s trade by volume and 70 per cent by value is done through the ports. “*Sea level rise, storm surges and waves are likely to induce major impact on coastal transport hubs and networks, including transient or permanent flooding of seaports and connecting coastal roads and rail lines,*” says a report by the United Nations Conference on Trade and Development.

The ongoing-and-accelerating rise in sea level poses a clear, direct and imminent threat to the populations of each such coastal city, and adversely impacts their livelihoods, the city’s economy, its tourism, coastal infrastructure, and marine ecosystems. For instance, the degradation of coastal ecosystems, especially wetlands and coral reefs, has serious implications for the wellbeing

⁹ P Rupa Kumar, et al, “High-Resolution Climate Change Scenarios for India for the 21st Century”, Indian Institute of Tropical Meteorology, Pune, *Current Science*, Vol. 90, 3, 10 February 2006

¹⁰ “Cyclone Preparedness and Response Plan”, Gujarat State Disaster Management Authority, 2014, <http://www.gsdma.org/uploads/Assets/other/cyclonepreparednessresponseplan06072017051948575.pdf>

¹¹ *Ibid*

of coastal communities that are largely dependent on the coastal ecosystem for goods and services. It is fairly obvious that coastal flooding caused or accompanied-by sea-level rise will cause serious degradation of drinking-water sources and supply-systems, fishery resources, and, lead to the inundation of low-lying areas, impacting millions of people, with unpredictable consequential political fallouts as well.

A cause of considerable disquiet if not actual alarm is that even if Greenhouse Gas (GHG) emissions are stabilised in the near future, sea levels would continue to rise for many decades.¹² The adverse impact of greenhouse gas emissions and the associated global warming would be irreversible and devastating to the coastal cities, whose millions of economically-disadvantaged inhabitants, many of whom dwell in low-lying areas, are extremely vulnerable to the impact of anthropogenic climate induced hazards and also have least coping capacities. In many cases, these slums and informal settlements are built in low-lying areas that are flood-prone and geologically unstable. Hence, sea-level rise due to climate change is likely to pose not just a serious socio-economic, environmental and security threat to these segments of the population, but rather, an existential one.

Conclusion

Clearly, sea-level rise and anthropogenic drivers of climate change constitute a serious challenge to India's coastal cities. These challenges are aggravated by unsustainable development and rapid population growth, high-density but unplanned settlements, and, urban poverty with associated high-differentials in access to housing, public services and infrastructure. The impact of extreme climate-induced hazards further reduces the resilience and coping capacities of poor and vulnerable communities within these cities. At the same time, these hazards increase socio-economic costs very significantly.¹³ The impact of climate-change on coastal cities has strong strategic, economic and political repercussions, as well. Clearly, there is an urgent need to integrate climate change, developmental projects and population growth in climate adaptation and mitigation policy.

Part II of this article will address urbanisation and the enhanced vulnerability of India's already densely populated coastal cities to the impact of climate change. It will discuss how it is important to provide environmental justice and bottom-up solutions on the community level to tackle inequality and eliminate poverty.

About the Author

Chime Youdon is an Associate Fellow and a 'Vice Admiral KK Nayyar' Fellow at the National Maritime Foundation. She is deeply engaged in a set of major studies relating to resilience-assessments of urban agglomerates in the face of climate change and is concentrating upon the city of Mumbai. She may be contacted at climatechange1.nmf@gmail.com

¹² S Dasgupta, et al, "The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis", World Bank Policy Research Working Paper 4136, February 2007, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=962790

¹³ Revi, "Climate Change Risk...", p 207, *Supra* Note 1