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Kolkata and Climate Crisis

Shatabdi Das

2022

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Introduction

The United Nations (UN) outlines rising temperatures that fuel environmental degradation and climate change, along with the effects that trigger natural disasters, weather extremes, food and water insecurity, economic disruption and conflict, as a crisis in today's time[1]. According to the World Health Organisation (WHO) climate change impacts human lives in myriad ways causing disruptions of food systems, illness and death, and aggravates frequent extreme weather events, such as heat waves, storms and floods.[2] The threats, risks, and lack of adaptability to the vagaries of climate and sudden environmental changes that drive population amass, away from habitats, ecosystems and means of livelihood, may be considered as climate crisis. The *United Nations High Commissioner for Refugees (*UNHCR) states that climate change and the emergency demand for climate action is itself a crisis[3] at a time when disaster displacements are above million in number in India. The Internal Displacement Monitoring Centre (IDMC), points out that the Ganga delta region has the highest number of disaster displacement cases in West Bengal, among which flood and storm have the highest share.[4]

The Climate Action report of the United Nations in 2022, projects that pollution and carbon emission as by-products of urban landscape is linked with climate change.[5] The Gangetic plain remains a hotspot of migration and mobility due to the economic opportunities provided by fertile land. With intensification of global climate crisis and incidences of extreme climatic events like drought and other natural disasters people are forced to relocate to safer habitats in the absence of adequate rehabilitation schemes, sometimes struggling to make ends meet in reconstruction of houses. M. Bose in the article on sea-level rise and cyclones (2022)[6] recapitulates the warning sounded by the Intergovernmental Panel on Climate Change (IPCC) necessitating infrastructural interventions with growing number of storm surges, cyclones and rising sea surface temperatures that push coastal cities such as Mumbai, Chennai, Kolkata at heightened risk of flooding.

The reports of the IPCC (in 2014, 2019 and 2021) specify that research and assessments are on the rise, focusing on the changes of tropical cyclonic activities in areas along the coast of Bay of Bengal and its linkage with global warming. An analysis across three decades since 1970s to late 2000s suggests an intensification of cyclonic occurrences and spiralling damages on landfall.[7] Patterns of urban settlement, expansion of built-up space, livelihood and consumption trend together with fuel burning and emission rates affect the magnitude of pollution and environmental disaster.

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The location of Kolkata along the northern fringes of the Ganga delta - makes the capital city of the state of West Bengal in eastern India, vulnerable and prone to the shocks and stresses of climate change and natural disasters. The geographical setting of Kolkata in a flat terrain with inadequate natural drainage relief causing riverine flooding and the close proximity to the coast, makes it susceptible to sea level rise and storm surges. The riverine location on the one hand facilitates economic growth and urban agglomeration, while on the other handicaps the city when coastal storms lash out with incessant rain showers and thunderstorms.

Study Area

In the study of climate, it is difficult to look at Kolkata only as a city because of the topography and larger dynamics of the riverine delta and islands, an estuarine system and the coastline, all forging an ecological complex that controls and subsequently affects the attributes of demography and economy in the Kolkata Metropolitan Area (KMA). This planning area spreads out over a geographical area of 1876 sq. km., across six districts situated on both the eastern and western banks of the River Hugli namely Kolkata, Howrah, Hooghly, Nadia, North 24 Parganas and South 24 Parganas, including four Municipal Corporations, 37 Municipalities and 23 Panchayat Samities. KMA holds a population of 15 million and above (Census of India 2011), with a population density of 8500 persons per sq. km.[8] Though the major part of the study delves into the complex of temperature-rainfall interplay and the larger dynamics of extreme climate events and the consequent impacts in the Kolkata Municipal Corporation (KMC) area, overview of the surroundings of the metropolitan area are also included in the study.

Problems in the Study Area

Flat deltaic terrain, inadequate natural drainage, and tidal blockage of channels intensify flooding and waterlogging in the city, while runoff mixing with sewage raises the chances of health problems. The city is already at heightened risk of rapid sea level rise, periods of intense rainfall, cyclonic activity, and storm surges; thus, adequate funds, sustainable infrastructural systems and capacity building for disaster mitigation and management becomes imperative to make urban spaces resilient to climate change.

The shrinkage of waterbodies (including the East Kolkata Wetlands–a Ramsar site) and conversion into agricultural land or built-up space, loss of area under agriculture in peri-urban locales to construction, and damages inflicted by soil salinisation post-cyclones, have been significant landuse changes in the metropolitan area of Kolkata. Abnormal rise of sea level and sea-water inundation in low-lying areas due to cyclones lead to loss of life and property, also causing loss of livelihood and damage to infrastructure, destruction of vegetation and erosion of embankments; post-landfall there are high chances of spread of communicable diseases.

Research reveals that urban sprawl, increased urban density, and shrinking water surface areas are the most important phenomenon affecting the runoff and drainage of the city - these raise the potential extent of flooding in the city under climate-change scenarios. The addressal of the growing physical risks triggered by climate change is the need of the hour because the cities affected by changing climatic pattern are home to more than half of the world's population - a staggering figure of about hundreds of millions of people.[9] Climate events have been rising in number over the years and cities are not adequately planned to combat the consequences. Certain neighbourhoods in Kolkata are more prone to flooding depending on their location in relation to water-bodies, green

coverage, surface area of built-up space, drainage network and in the face of growing number of climate hazards require urban renewal in the forms of re-generation of infrastructure, control and prevention of transport emissions through the adoption of alternative, energy-saving technology, and transformation of built-up space to combat water-logging and the possibilities of vector-borne diseases.[10]

Objectives of the Study

The Fourth Assessment Report of IPCC (2007)[11] recognises several hotspots, categorising densely populated urban agglomerations in the low-lying delta regions as extremely vulnerable to the impacts of climate-related events. Corelating the major triggering factors for weather anomalies and their consequences in terms of heat wave and floods in any urban area is thus, essential for planning for protection, hazard mitigation, disaster prevention and management. This research attempts to present an overview of climate crisis in Kolkata, based on field observations and the analysis of secondary data in reports, books and articles. The study is broadly divided into three sections - the first section looks at the pattern of changes in land cover and landuse and the ensuing effects in terms of heat island and loss of waterbodies; the second section delves into the trend of climate hazards and their consequences over the last two decades; the concluding section attempts an overview of planning for climate hazard and disaster mitigation.

Section 1

Land Cover and Landuse Changes

1.1 Decline in Vegetation Cover

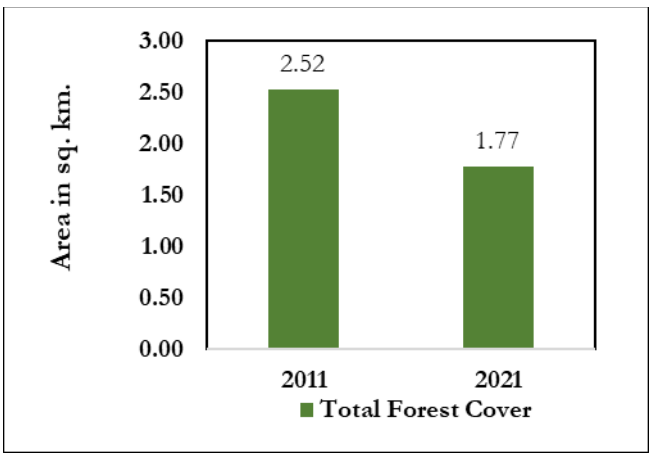
The analysis of landuse indicates that the change in percent of land under built-up space (residential and commercial area) is very high compared to other landuse categories within the administrative boundary of the Kolkata Municipal Corporation encompassing a total geographical area of 205 sq. km.[12] Research shows that built-up area has increased from close to 50 percent to around 76 percent (more than 25 percent increase) of the total area of the city within a period of 20 years from 1997 to 2017 respectively (Table 3); while the areas covered by waterbodies and plantation have diminished from 5.30 percent to 3.77 percent and 11.99 percent to 4.57 percent respectively (from 1997 to 2017).[13] Plantation (fall in coverage to 4.57 percent of total geographical area of Kolkata) shows a percent much lower than the national forest cover of 21.71 percent as per the India State of Forest Report (ISFR) 2021.[14] In West Bengal 18.93 percent of geographical area is under forest cover (slight reduction in percent coverage of geographical area from 19.04 percent in 2019),[15] with 'open forest' sharing the largest coverage (10.8 percent), followed by 'moderately dense forest' cover (4.7 percent) and 'very dense forest' cover (3.4 percent).[16] The Forest Survey of India defines Very Dense Forest (VDF) as "all land with tree canopy density of 70 percent and above;" Moderately Dense Forest (MDF) as "all land with tree canopy density of 40 percent or more but less than 70 percent;" and Open Forest (OF) as "all land with tree canopy density of 10 percent or more but less than 40 percent."[17] The Forest Survey of India Report (2021) states that among the seven major cities of India, namely, Ahmedabad, Bengaluru, Chennai, Delhi, Hyderabad, Kolkata and Mumbai, Kolkata recorded the lowest forest cover in 2021, with a further drop of 0.4 percent within a decade, from 1.35 percent of geographical area in 2011 to 0.95 percent in 2021.[18]

Table 1: Decline of Vegetation Cover in Kolkata

Forest Classification (in sq. km.)	Year		
	2011	**2019**	**2021**
Geographical Area (under analysis)	186.55	185.00	186.55
VDF	0.00	0.00	0.00
MDF	0.39	0.00	0.10
OF	2.13	1.00	1.67
Total Forest Cover	**2.52**	**1.00**	**1.77**
Percent	**1.35**	**0.54**	**0.95**

Data Source: Ministry of Environment, Forest and Climate Change, *India State of Forest Report 2021* (Dehradun: Forest Survey of India, 2021), 53, 55; Ministry of Environment, Forest and Climate Change, *India State of Forest Report 2019* (Dehradun: Forest Survey of India, 2019), 296.

Figure 1: Decline of Forest Cover in Kolkata, 2011-2021



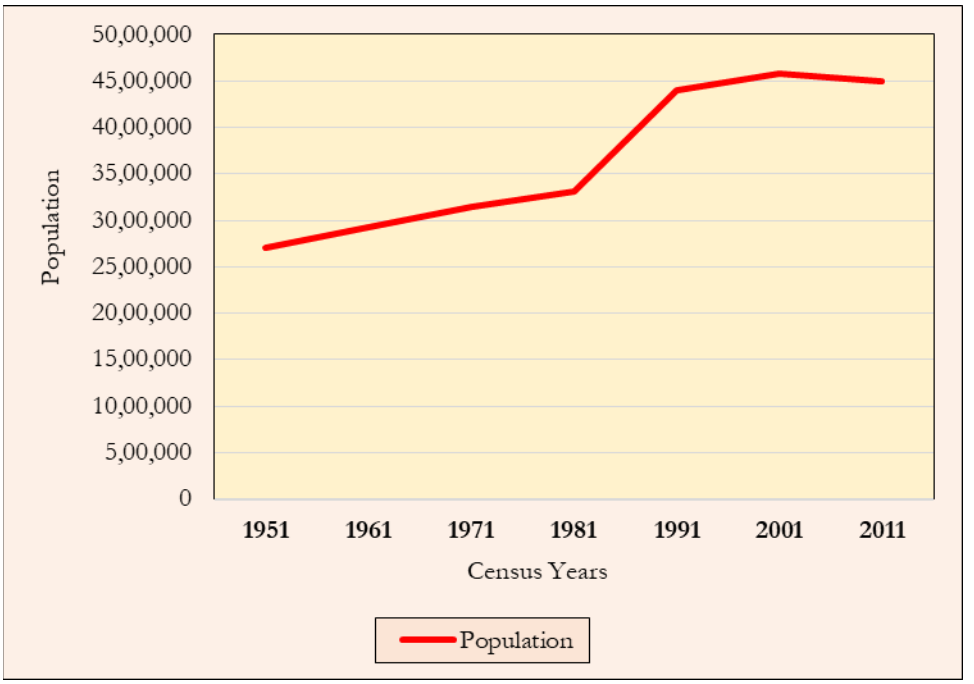
Data Source: Table 1.

1.2 Urban Heat Island Effect

Urban land surface and ambient temperatures balance urban energy budget and are important factors affecting urban climate, regulating, controlling and impacting ecological processes. Intensive urbanisation results into constant increase of surface temperature, thus, affecting urban resource and energy flows. The structure and function of urban ecological systems change under the influence of temperature rise and in turn affect the health of city residents. Expansion of heat absorbing surfaces

and loss of vegetation, together with the construction of hard surfaces such as pavements with absence of plant lining take a heavy toll on the ambient air temperatures that induce high level of heat and elevate discomforts in weather conditions. Not only has urban sprawl and spread of built-up area affected the annual average temperature ranges in Kolkata but urban climate change risks have also spiralled due to increased incidences of extreme weather events and rise in the number of people living in zones sensitive to climate events. The population in Kolkata city documented a growth from 4,399,819 to 4,496,694 over two Census decades (from 1991 to 2011),[19] thus indicating the magnitude of risk, exposing millions of lives to the hazards of climatic change in and around the urban agglomeration.

Figure 2: Population in Kolkata, 1951-2011



Data Source: Census of India, *Census Handbook Kolkata 2011, West Bengal,* Series-20 Part XII-A District

(New Delhi: Directorate of Census Operations, 2014), 61. affecting urban residents' health

The India Meteorological Department (IMD) recorded the annual mean land surface temperature over India in 2022 at an average of +0.51°C above the long-term average for the period 1981-2010; with 2022 recorded as the fifth warmest year since 1901.[20] The global mean temperature in 2022 was estimated to be 1.15 ± 0.13 °C above the pre-industrial average for the decades between 1850 and 1900.[21] Kolkata has experienced close to 1°C rise in annual average temperature from 2010 to 2020.[22] The annual average temperature in Kolkata has been increasing by almost 0.157°C every year.[23] The total length of surfaced road has increased from 1650 km in 2006-2007 to 1670 km in 2010-2011 with an average increase of 5 km every year.[24] In 2007, 986,814 motor vehicles (inclusive of all categories) were registered in Kolkata, while the total number of registered motor vehicles grew to 3,916,252 in 2011.[25] Kolkata has witnessed an upsurge in sale of two-wheelers followed by four-

wheelers from 2019 to 2021 (adding 9,858 vehicles) due to the fear of use of public transport during the outbreak of pandemic and the months that followed;[26] between 2013 and 2021 the number of personal-use vehicles has spiked four times.[27] Higher usage of public transport helps to cut down vehicular emission rates due to their larger passenger carrying capacity. The switch to greater use of private vehicles adds to the pollution from vehicular exhaust. Increase in built-up space, the large rise in number of vehicles and a decreasing green cover, not only hinder the city's natural resilience to combat extreme wind systems and carbon sequestration, the disappearance of trees and urban forest cover intensifies the heat island effect in the city. Urban and infrastructural development (in the form of increase of concrete surface, construction and physical structures) control urban heat island effect and in turn raises the annual average temperature.

The World Meteorological Organisation (WMO) warns of the modification of environment by human activities in large urban settlements that result into variances of the attributes of meteorology and climatology that may intensify heat waves and result into urban heat island effect that may further raise temperatures by 5°C to 10°C.[28] Clustering of sky-scrappers, roads, concrete surfaces interspersed with green cover, open spaces and waterbodies affect the patterns of heat, air-quality, rain and wind in cities. Inhibited underground water percolation and heightened rate of surface rain water runoff, diminishes the recharge capacity of natural aquifers and sets off the risks of flood in an urban locale. Planning of the layout of buildings and emission of particulates from anthropogenic engagements, vehicular and industrial emission degrades ambient air quality. The research on "Adaptation Measures for Urban Heat Islands", brings out the significance of countermeasures (for mitigation) to reduce the urban heat island effect such as green roof, water-retentive materials, in addition to specific measures and technical sections.[29] The reflection that comes up here is how does Kolkata strengthen flood protection mechanism at a time when high precipitation concentration and local thunderstorms have grown in frequency in recent years. Planning real estate and designing urban forestry and tree canopy is required in sync with the growing demand for housing and sprawling infrastructure projects that increases built-up area.

Kolkata receives maximum rain from the South-West Monsoon. The city recorded excessive rainfall (above 100 mm rainfall within 24 hours) in the years 1971, 1978, 1984, 1986, 1990, 1993, 1999, with the highest amount of rainfall received in 1999 (260.5 cm, i.e., 152 percent of annual normal).[30] Records of rainfall show that both the total annual rainfall and monthly rainfall during monsoon months have increased. Analysis of rain in June illustrates escalation from 223.5 mm in 2014 to 419.4 mm in 2018 (around 87.6 percent rise within a period of five years).[31] Kolkata received exceptionally high amount of rainfall of 236 mm within a span of a day (24 hours) in 2020 when Cyclone Amphan had hit Bengal; whereas the stormwater pumping stations in the city can accommodate a maximum of 150 mm per day or 6 mm per hour.[32] Again, in 2021 pre-monsoon months (between March and May) Kolkata received 'largest excess rainfall (+60 percent or more)', 'excess rain' (+20 percent to +59 percent) in the monsoon months (June to September) and post-monsoon period (October to December).[33] The sudden onset of rain in June as monsoon sets in, together with the mounting amount of downpour worsens situation for flood combat due to the inhibited drainage capacity; the drainage channels fail to cope and carry the storm water runoff within a given time when there is excessive rain over short duration.

Table 2: Worst Floods in Kolkata

Year	Description of Flood
1986	Flooding due to heavy rains in some areas of Kolkata.
1999	Tropical cyclones and floods due to brief torrential rains.
2006	Heavy rains left large parts of Kolkata city under water; subsequently 2000 people were evacuated from the city.

Data Source: West Bengal Disaster Management and Civil Defence Department, "Natural Disaster: Flood," last updated January 3, 2020, http://wbdmd.gov.in/pages/flood2.aspx.

The anomalies and unexpected rise in precipitation due to deviation of weather pattern from normal, largely affected by the constantly changing microclimate within the city, are induced by changes in land surface and ambient air temperatures and moisture; the major control factors such as heat absorbent surfaces, gaseous emissions, loss of tree cover, air and water pollution, are impediments for the city's mechanism for disaster protection. Sudden onset of high precipitation, thereby, often leaves the flooded city battling for safety.

1.2 Role of the East Kolkata Wetlands

Kolkata has seen the disappearance of lakes and ponds in the eastern and southern parts of the city; some of the canals and tidal channels have shrunk into dry, narrow channels due to the recent phases of metro railway extension project. It is important to note that the waterbodies and tidal channels in the southern and eastern part of Kolkata play a very important role in sustaining drainage and balancing ecological homeostasis and are part of the larger network of the East Kolkata Wetlands (EKW) situated in the eastern fringe of the city. The EKW was included in the Ramsar list of 'Wetlands of International Importance', on August 19, 2002.[34] The EKW is designated as a Ramsar Site because it meets the criteria of a site that is a representative, rare or unique wetland type and is important for the conservation of biological diversity.[35] The EKW located adjacent to the Dhapa waste disposal ground in the eastern fringe of Kolkata, is not only a productive ecosystem home to biodiversity but also supports a wide range of ecosystem services such as erosion control, water storage, water purification, aquifer recharge, flood mitigation, microclimate regulation, aesthetic enhancement of landscape, in addition to the reinforcement of social, cultural, and recreational activities. These wetlands interweave a number of facilities for urban ecological services in the form of landuse pattern, treatment for the city's waste water, utilisation of treated water for agriculture and pisciculture, sustainable ecological protection and management practices with the involvement of local communities.[36] The spatio-temporal analysis of contaminated surface water at the EKW divulge that there is reduction of as high as 63 percent Total Organic Carbon (TOC) and 71 percent Total Inorganic Carbon between source point and final discharge site.[37] However, urban pollution and encroachment into the wetland fringes affects this multifunctional niche, making it essential for environmental education institutes, departments of urban local bodies as well as residents and stakeholders in the city to plan initiatives and awareness programmes for dissemination of information on the significance of the wetlands and why it becomes absolutely necessary to keep the waterbodies intact, protected and conserved.

Expansion of concrete cover induces urban heat island effect, and with the absence of green belts in the most densely populated parts and congested transport arteries of the city, the role of carbon sequestration by vegetal cover as well as waterbodies and the East Kolkata Wetlands is massively inhibited. The stacking of air pollutants, dust from construction sites and vehicular emission in turn disturbs the microclimate; among the consequences of the convectional currents heating up the ambient air are untimely thundershowers and intermittent torrential rain followed by flash floods in the city. It is critical that urban forestry and waterway rejuvenation with the inclusion of local stakeholders dependent on waterbodies for their economic practices be taken up together with planning of investments and environmental and social impact assessments for infrastructure, real-estate and commercial projects.

Table 3: Landuse Changes in KMC Area, 1987-2017

Landuse (In percent)	Years			
	1987	**1997**	**2007**	**2017**
Built-up Area	49.20	49.42	65.13	75.91
Waterbodies	6.26	5.30	4.58	3.77
Plantations	21.97	11.99	13.65	4.57
Scrubs	18.33	28.15	13.32	12.39
Barren Land	4.24	5.13	3.31	3.36

Data Source: John Bernadette, Subhasish Das and Rajib Das, "Effect of changing land use scenario in Kolkata Metropolitan on the variation in volume of runoff using multi-temporal satellite images," *Journal of Indian Chemical Society,* 97 (April 2020), 559.

Section 2

Climate Hazards and the Consequences

2.1 Incidences of Cyclones and Floods

The World Wide Fund for Nature (WWF) India, reports the increase in frequency of severe cyclonic storms over the years. High tide levels, raised incidences of storm surges, disappearances of islands have been indicative of climate change.[38] Studies conducted by universities across the state of Bengal point out that the annual mean land surface temperature in Kolkata has increased by 4.72 °C in the last three decades. The loss of vegetation cover and increase of built-up space enhances the heat island effect in the city.[39] High rainfall within a short period of time results into loss of water in runoff rather than underground recharge, and this high volume of runoff causes flood. It is inherent

to the nature of monsoon to be erratic, intermittent with broken spells but the India Meteorological Department (Kolkata) resounds that extreme weather events and variations in inter-annual rainfall have increased[40]; sudden spells of heavy rain over a short period of time triggered by local thunderclouds have become more common due to the growing intensity of urban heat island effect.

The addition of heat raises the temperature of ambient air over land and causes the winds to accelerate and carry the heat to the sea, and this variability of temperature and anomalies of heat between land and sea then intensifies energy for cyclone formation over the Bay of Bengal. Recently, the changing trend of sea surface temperatures, have given rise to pre-monsoon cyclones.[41] The Office of Climate Research and Services of the India Meteorological Department, Pune, demarcates Gangetic Bengal as an area with cyclonic storm return period of four to six years.[42]

The West Bengal Disaster Management Authority has documented the history, classification and damages of devastating cyclones over the last few centuries[43] - the frequency of destructive cyclones has increased. Earlier severe cyclones were not frequent. Cyclone Bhola in 1970 had caused the death of 3 to 5 lakh people; but there has been an increase in the number of cyclones traversing West Bengal in the last 20 years namely cyclones BOB 03 (2002), Aila (2009), Bulbul (2019), Amphan (2020), Yaas (2021), have caused intensive damage. The advancement of forecasting systems and monitoring in recent times helps to reduce the number of deaths through evacuation, warning and storm shelters, relief and disaster management authorities operating at ground level, but property damage and interruption of basic services ravages people's lives. The recurrence of cyclones every year burdens resources, and delays recovery and rehabilitation. Cyclone Bulbul in 2019 had destroyed crops in 198,000 hectares of land, Amphan in 2020 took lives and destroyed property, with 44.5 lakh people affected in both rural and urban areas of Bengal;[44] consequently, agricultural fields in low-lying areas inundated by storm water have left farmers devastated and a number of people without work amidst ruins of homes. Vulnerability to tropical cyclones is a serious concern due to the rising population density in this riverine-deltaic metropolitan area.

The Annual Flood Report of 2010 records 43 percent of geographical area of West Bengal as flood prone with the state being one of the main flood prone states in the country[45]. Intensity and duration of rainfall, sedimentation in river bed, natural or man-made obstruction are factors controlling the occurrence of flood. Study of the factors and evaluation of flood hazards is indispensable to flood management measures. The West Bengal Disaster Management Authority[46] has recorded increasing number of floods since 2000, with heavy monsoon rain, cyclones and inundation being the dominant causes and Kolkata and adjacent districts being frequently affected.

When rainfall excess induces the rivers to swell, water coming from adjacent high lands lead to the overflow of water into adjacent banks of areas lying in sub-montane, alluvial plains in the foot hill stretches and the lower courses. Rains in the period of onset of monsoon mostly replenish underground water reservoirs, thus, after the period of replenishment of soil moisture and recharge of aquifers, surface runoff reaches rivers, lakes, ponds, and other channels.[47] Thus, other than control of river discharge by construction of multipurpose river valley projects, dams and barrages, river valley and flood basin planning along with watershed management require thrust and priority-based management. Deposition of silt and debris raises the riverbed thus hindering river's water carrying capacity; dredging of river, drainage channels, and sewage canals at intervals, becomes crucial for the prevention of spill-over. Kolkata located near the river mouth and bound by distributaries of river Ganga requires investment and monitoring of its vulnerability to flood because the natural drainage system in most parts of the metropolitan area has reduced to an effluent channel network, further encroached by squatters, slums, and transport development projects. The city needs to look for new ways of combating the shocks of climate hazard through the protection, rejuvenation and

conservation of natural pathway – the network of lakes and distributary channels draining parts of the East Kolkata Wetlands and surrounding the urban agglomeration that plays a vital role in the conservation of environment in Kolkata.

2.2 Areas Vulnerable to Flooding in the City

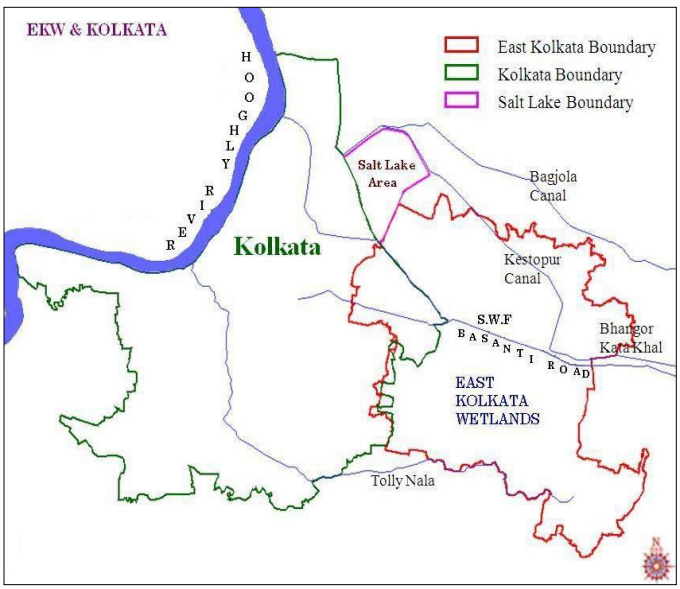
The close location of Kolkata (with a population of 4.5 million as per the Census of India 2011)[48] to the coastline, and the sprawl of urban built-up space contiguous to the Ganga delta, exposes the city to the dangers of floods. Certain neighbourhoods in Kolkata are more prone to flooding depending on their physical setting in relation to low-lying areas, tidal channels, peripheries of wetlands and water-bodies, green coverage, surface area of built-up space, and drainage network.

The wetlands constituting the natural drainage system of Kolkata, the slums along the western stretch of the Eastern Metropolitan Bypass (road) as well as the sprawling urban built-up space in the eastern fringes of the city almost encroaching upon the threatened East Kolkata Wetlands are susceptible to the aftermath of cyclones, storms and unexpected spells of incessant rain occurring more frequently in the last few decades. Along with the high-rise residential complexes at risk of waterlogging in newer residential areas, due to the lack of maintenance of drainage network and overflowing canals (locally known as *khals*), the wards in the municipal corporation with larger number of slums are the most vulnerable to city flooding. The slums of Kolkata may be divided into three groups – the older ones around 150 years old - located centrally in the city that may be linked with the earliest urbanisation process. The history of the second group can be traced back to the 1940s and 1950s, emerging as an outcome of industrialisation and urbanisation due to rural-urban migration, with the affinity of location near industrial and transport corridors. The third group settled down in vacant urban lands and areas along roads, canals and in the peripheral parts of the city after independence.[49] As a result, around 1.4 million slum dwellers are at risk, and may face the impacts of flood in the city.[50]

The steps that the city administration takes up to combat the ill-effects of storm, fall short during intense spells of rain and thundershower. There are reports of old buildings collapsing under conditions of prolonged waterlogging after thundershower, especially in the old residential areas of north Kolkata[51] that have higher density of population and dense clusters of residential neighbourhoods. Floods in large parts of South Kolkata and localities adjacent to the Eastern Metropolitan Bypass (road) that flanks the eastern fringe of the Kolkata Municipal Corporation may be connected to outfall canals that flush out rainwater from the city.[52] Lack of dredging of canals before monsoon looms large with threat of flash floods in the city during incessant rains. The intercepting canals in the fringes of the East Kolkata Wetlands remain clogged, especially with the metro rail track extension and construction work in progress, blockage of canal discharge and encroachment of drainage channels remain a common problem. The blocked paths of drainage channels ensue heightened risks of flash floods in the city. Studies reveal that different localities within the municipal boundary of Kolkata are vulnerable to hazards. Low lying areas in the city situated along the bank of river Ganges closer to open water such as Garden Reach, Khidderpore, Tollygunge are prone to tidal surges; exposed areas near the riverfront in Central, West, and South-West Kolkata and the southern suburbs are more vulnerable to the lashes of cyclones. Neighbourhoods of North and North-Central Kolkata with dense residential and commercial landuse are paralysed by more frequent incidences of urban storm or heavy rain related flash floods and waterlogging.[53] The KMC action plan for mitigation of flood, cyclone and waterlogging (2021) enlists the major waterlogging pockets in Kolkata in sixteen boroughs of the municipal corporation.

Out of the 144 municipal wards in the city, 101 wards have waterlogging pockets.[54] The north and central part of the city surrounding the Amherst Street, College Row, M.G. Road, Chandni Chowk, Ganesh Chandra Avenue, C.R. Avenue, B.B.D. Bag-Lalbazar area and south and south-west Kolkata stretching across Bosepukur, Dhakuria Station Road, Selimpur, Jodhpur Park, Lake Gardens, P.G.M Saha Road, Uday Sankar Sarani, P.G.H. Shah Road, Bikramgarh, Bijoygarh Jadavpur East Road, Behala, Barisha, Diamond Park, stretches of Diamond Harbour Road, are interspersed with the highest number of wards that have waterlogging pockets.[55] Temporary portable pumps are deployed during monsoon to help pump out excess rain water. There are 74 drainage pumping stations located in north, east, central, south and western parts of Kolkata; with five sewerage treatment plants (STPs) namely, South Subaman East (Keorapukur) STP, Garden Reach STP (has the maximum capacity among the five, i.e., 57 MLD), Baghajatin STP, Hatisure STP, Bangur STP.[56] Several on-going and upcoming projects focus on the reduction of the retention time of waterlogging within the pockets in the city, for the prevention of floods.[57]

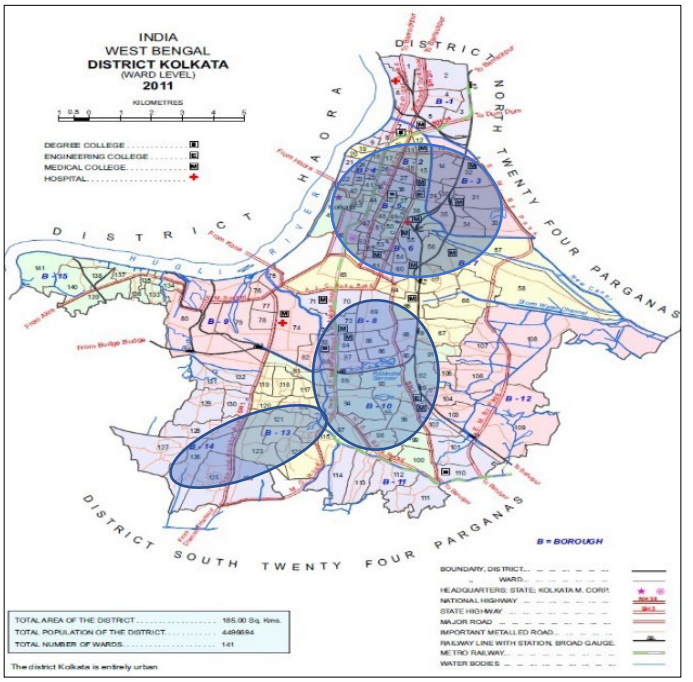
Map 1: East Kolkata Wetlands



Map Source: East Kolkata Wetlands Management Authority, "Maps: EKW and Kolkata," n.d., https://ekwma.in/ek/maps-2/, accessed November 4, 2022.

Areas close to the river bank not only have higher density of buildings and clustering of built-up space but also serve as the Central Business District (CBD) and are affected by waterlogging, and prone to flash flood. The localities near the East Kolkata Wetlands in the eastern part of the city have on-going road and metro railway construction projects together with real estate development and have recorded disappearance of waterbodies. This makes the eastern stretch of Kolkata vulnerable to flash floods during periods of excessive rainfall.

Map 2: Municipal Wards with Waterlogging Pockets



Map Source: Census of India, *Census Handbook Kolkata 2011, West Bengal,* Series-20 Part XII-A District (New Delhi: Directorate of Census Operations, 2014).
Data Source: Kolkata Municipal Corporation, "Action Plan to Mitigate Flood, Cyclone and Water Logging," 2021, 11-21, https://www.kmcgov.in/KMCPortal/downloads/Monsoon_Book_2021_07_06_2021.pdf.

In September 2021, the cyclonic storm 'Gulab' left Kolkata and southern districts of the state of West Bengal, waterlogged for days.[58] Devastation and property damage by recent cyclones such as Amphan in May 2020 expose the inadequacy of urban infrastructure during and in post-disaster phase.[59] Efforts towards combating climate change need to commence at ground level with the awareness and education of preparedness to reduce the potential damages caused in the post climatic hazard phase, monitoring and coordination between civic bodies, government departments and educational institutes. Assessment of climatic patterns together with reflections, monitoring and the involvement of local communities, and understanding the role of ecological stakeholders who may work in coordination with civic bodies in the phases of preparation and mitigation to reduce risks, losses and the burdens of relief and rehabilitation, are essential for protection against disasters. Lack of drainage channels and clogging of sewage pipe openings due to littering are common scenes in many localities across the city. Unless sweeping drives at the onset of monsoon stir clear of the waste fragments obstructing pathways meant for rainwater passage, submergence, spread of water borne diseases, and damage to property will remain impending threats.

The spiralling impacts of frequent storms and cyclones induce a domino-effect. Ravaged by cyclones, people with no means of livelihood, migrate to the neighbouring metropolitan region due

to accessibility and hopes of finding opportunities of income generation; however, they struggle to find affordable housing facilities and end up in slums or dwelling in shanties, pavements, or are often tagged as encroachers of public or open spaces. Although it is difficult to identify climate migrants among slum dwellers - the slums still remain the most prone areas to city floods.

2.3 Vulnerability in the Sundarbans

Inhabitants of Sundarbans have lived with the threats of cyclones since colonial times, but people living in transitional zones between land adjoining the mainland and areas closer to the core zones of the sea facing forests remain most vulnerable to environmental hazards. According to 2011 Census, more than 1.3 million people reside in the tidal islands of the Indian Sundarbans Delta,[60] with a mere 2 percent having access to storm shelters.[61] The pummelling of cyclones leave behind ravaged islands in Sundarbans while people struggle to rebuild homes from the wreckages. There is pollution of water due to mixing of salt water (left behind by storm surges within the enclosures of embankments) with fresh water sources; and ailments are caused by this lack of accessibility to drinking water.

Both slow and sudden onset of climate stress causes socio-economic vulnerability, and push people to migrate from one island to another. Some of the islands have reduced in size due to erosion like Ghoramara Island, resulting into displacement of thousands to the nearby Sagar Island; and islands such as Lohachara, Suparibhanga, Bedford have been submerged in the sea. Compaction of soil and deltaic subsidence add to the vulnerability due to a rise in sea level of about 3 mm to 8 mm every year;[62] this ecologically fragile zone has been transformed into a hotspot of displacement, owing to its natural environment.

In Sundarban, the storm water breaks through embankments built around islands during cyclones and fill paddy fields with sea water; land turns saline and affects subsistence agriculture. It was estimated by the agricultural department of the government that 10,800 farmers had incurred heavy losses across 17,800 hectares of crop field. After Cyclone Aila struck in 2009, land was left uncultivable for three to four years and inhabitants were forced to migrate out of Sundarban[63] in search of work, leaving families behind with lean sources of remittances; but in case of Amphan in 2020, at a time when people were already struggling to survive through the medical crisis of pandemic, Sundarban witnessed an influx of return migrants.[64] News dailies[65] reported the aids and reliefs of the central and state governments but the complexity in this situation lies in the fact that short-term relief barely helps to reverse the long-term changes in environment and difficulties of adaptation that cyclones create in the fragile ecosystem of the delta (due to its geomorphological characteristics and socio-economic attributes). In the wake of the COVID-19 pandemic more than 300,000 migrants were reported to have returned back to the Sundarbans (in 2020), resulting in loss of remittances in migrant households, increased pressure on natural resources and an overwhelmed local labour market.[66]

Surveys reveal that the pattern of migration in the delta region is of three broad types: long-term migration in search of work to distant cities in Kerala, Karnataka, Tamil Nadu, Gujarat, Maharashtra; seasonal migration to neighbouring districts as agricultural labour during paddy-sowing and harvesting seasons; and short-term migration to Kolkata for informal employment in public works, sanitation services, masonry, etc. In such cases the individuals cannot be called environmental migrants but indirectly they are victims of environmental changes because climate hazards leave behind little work opportunities and in the absence of livelihood alternatives the inhabitants are left with no choice but to migrate. Therefore, here again, a vicious cycle operates with poverty arising

from hazards caused by climate change and the poverty again exposes migrants to environmental hazards due to the lack of protection.

Section 3

Planning for Climate Hazards and Disaster Management

3.1 Planning for Climate Hazards

Identifying and defining hazards and understanding the risks they pose to communities, in addition to the analysis of costs, feasibility and impacts of risk reduction are important in the study of hazard management. River catchment and estuarine zone management and sustainable solutions for urban drainage become relevant in case of Kolkata. The struggles with economic growth, decarbonisation, environmental protection and health infrastructure bring in more complicated challenges. Slums and squatters in the city are more vulnerable to the effects of climate disasters because they have dearth of adequate infrastructure required for reduction of the magnitude of damage posed by climate hazards. Crowded residential areas raise vulnerability for a larger population size of the city because of the higher density of population. Community-based knowledge and understanding of the urban issues faced by local stakeholders is of foremost importance in capacity-building.

The Sixth Assessment Report of IPCC (2022) lays emphasis on reduction of greenhouse gases (GHGs) as one of the major keys to combating climate change.[67] Hence, analysis of the status of greenhouse gas emission (control and reduction), fossil fuel driven vehicles (lowering of consumption and hence emission levels), budget for green technology – call for micro studies keeping in mind the rising temperatures that trigger abrupt, unanticipated weather events. Kolkata, similar to many other megacities of India, has a long way to go in the adoption of alternative sources of energy and strengthening green energy use. It becomes important to analyse the cost incurrences and impacts of basic services in cities such as housing, transport, infrastructure on the urban life, planning for green space management and vegetation conservation within the city and the demands of investments and blue prints.[68]

Engineering or structural measures for reduction and prevention of spilling, and structures for improving drainage, channelising runoff, de-silting, dredging, play crucial role in flood management measures.[69] Investments in mitigation are more cost-effective than spending on relief and rehabilitation in the post-disaster phases. The reports of Rashtriya Barh Aayogh (RBA) or the National Flood Commission, Central Water Commission, Ganga Flood Control Commission, document the flood prone areas with recommendations for planning flood management systems to lower the compounding risks of floods; nonetheless realising the plans on the ground and monitoring their effectiveness and the successful execution of the management projects become challenging.

3.2 Disaster Mitigation

Disaster management policies in India are mostly focused on provision of relief for extreme weather events, but migration due to environmental stress is often not taken into account. In some cases, it is difficult to assert 'environmental change' as the cause of migration because many a times the drivers of displacement in an ecosystem work in combination or influence one another; therefore, identification of the causes of migration in the post-disaster phases should be emphasised for the

effective implementation of policies. Environmental migration appears to be a multi-causal phenomenon in Sundarban, where poverty, inaccessibility to amenities, malnutrition, environmental fragility, and lack of social security, force people to move.

The Kolkata Municipal Corporation (KMC) in its action plan for the mitigation of flood, cyclone and waterlogging (2021) outlines the necessary implementation measures, like prevention, mitigation or risk reduction, capacity building, preparedness to deal with disasters, prompt response, assessment of severity or magnitude of effects of disaster, evacuation, rescue, relief, rehabilitation and reconstruction.[70] *Prevention, Response, Relief and Recovery* are key to disaster management. Municipal wards in Kolkata vulnerable to different forms of disasters are identified, and prevention and mitigation measures are adopted by different departments of KMC and Boroughs within KMC. Capacity-building and preparedness measures are drawn-up by the departments of KMC and government agencies. The action plans in the different stages pre-waterlogging and post-waterlogging are important.[71] The Kolkata Environmental Improvement Investment Programme (KEIIP) with the financial assistance of the Asian Development Bank (ADB) together with the Government of India and Government of West Bengal took up renovation, upgradation and construction of new drainage and sewerage pumping station in the core area of the city, underway,[72] with the objective of reduction of waterlogging and improvement of environmental condition. Effective disaster mitigation information system in Kolkata functions in conjunction with quick-response teams at waterlogging areas, temporary pumping systems along with pumping stations, in addition to communication between various departments of the Municipal Corporation, West Bengal Disaster Management and Civil Defence Department and the regional IMD office.

Research by environmental forums and climate specialists, and government monitoring and assessment reports warn about sea-level rise, storm surges, cyclones, and sea temperature rise and their impacts on the city. The aftermath of cyclones, and unpredictable rainfall, raise questions on the resilience of megacities to combat climate hazards. Awareness, monitoring, forecasts, precautions, preparedness, and strengthening of mitigation measures through the adaptation of sustainable practices, adoption of green technology and conservation of energy for emission reductions, are fundamental to environmental protection for communities and minimising losses in case of disaster.

Conclusion

Migration in the delta region often occurs as part of adaptation response to environmental threats like climate change. Habitat loss and inundation due to sea-level rise and inconsistent climatic experiences in the Sundarban islands may result into loss of livelihoods; under such circumstances people will be forced to migrate to the neighbouring megacity of Kolkata due to the ease of connectivity, for finding alternative work opportunities. Dissemination of research to vulnerable sections of population about climate change, and awareness on mitigation of disasters plays a pivotal role in landuse planning and zonation for flood risk management in urban areas.

The role of education and awareness generation is requisite in climate change adaptation and disaster risk management, including practices in risk management, preparedness, and emergency responses. Community participation and involvement of stakeholders at the grass-root level in landuse planning for urban, and peri-urban areas, especially squatters, become essential because such settlements remain most vulnerable to climate disasters. In such setup, emergency responses and dissemination of information on flood forecasting and early warning systems for cyclones and storms play crucial role. The damaging consequences of heavy rainfall that paralyse the city for hours,

demands endeavours on the part of the urban local bodies to work with local population in initiating environmental protection drives towards the making of a 'disaster resilient city'.

The question that could be raised here, is - given the records of bouts of unusual spells of monsoon and occurrence of floods since late nineteenth to early twentieth century when undivided North Bengal had been hit by 22 floods of slight, medium, severe and catastrophic magnitudes within a span of 50 years as was recorded in the report of the North Bengal Flood Committee (1927), the crisis of climate may not be a recent phenomenon after all but comes out more as a failure of cities to protect environment and conserve resources and the lack of alternatives for combating and managing sudden physical changes when hit by climate hazards.

Though the trajectory of storms and the point of landfall are important determinants of the level of damage that will be caused, the status of cities in terms of protection, reduction of losses and quick recovery in the post-hazard phase is important, at a time when planning bodies and management authorities in the country are still confronting the difficulties of setting-up sustainable coping mechanisms. The state government in West Bengal is working on reformatory measures for stakeholders in the delta but it is necessary to keep looking back at why several of the measurements whether physical (structural), economic or social, that are planned for providing protection and minimising risks of hazards fail to provide adequate results at times of utmost necessity, manifesting crisis.

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