TRANSFORMATION AND RESILIENCE OF URBAN COASTS

KOLKATA : Case Study

National Centre for Sustainable Coastal Management
Ministry of Environment & Forests
Anna University Campus
Chennai

25th August 2014
Coast and Vulnerability

- Acceleration of global sea level rise from an average of 1.7 mm/year during the last century to 3.1 mm/year (IPCC, 2007)

- Global Climate Change and Vulnerability Index 2011 ranked India as the second extreme risk country after Bangladesh

- 76 percent of Indian coast line of 7500 km is susceptible to cyclone hazards (GOI, 2010)

- The incidence of floods in the Himalayan region is likely to increase as a result of precipitation and glacial melt due to climate change (IPCC 2007)
Urbanization and Climate Change

• The level of urbanization in India is around 32 percent (377 million) and expected to increase to 45-50 percent during the next 20 years (Census 2011)

• Population exposed to natural hazards is 200 million (Planning Commission 2012)

• Planning Commission has estimated that 1 trillion USD would be required to build infrastructure
Institutions for the Management

- Institutions and strategic approach through Disaster Management Act 2005
- Creation of National and state disaster management authorities
- Shift from relief-driven response to prevention, mitigation and preparedness
- Absence of risk financing and risk insurance against natural hazards
- Average loss/uninsured disaster is $1.96 billion
- Disaster relief expenses $1.1 billion in 2009 to 1.4 billion in 2013
Kolkata: TRUC city

- Kolkata, the first capital of British India (until 1911), is also one of the first metropolitan cities of India.
- Kolkata, the oldest major port along the eastern side of the country serves a vast hinterland.
• Industrial development on the eastern side of river Hooghly has led to the growth of working population

• After the 1940s, 1970s during partition, liberation of Bangladesh; Kolkata witnessed steady rise in migrant influx

Steady growth in population from 1981 to 2011 from 9.9 million to 14.11 million
• Increasing pressure of urban growth and old infrastructure.
• Increasing vulnerability to natural hazards and the effects of climate change.
Geographical Location of the City

- The city lies in the mature delta region of Ganges-Brahmaputra Delta (tidally active, mature and moribund regions).
- Naturally overflowing river (vulnerable to flooding)
  - Shift from seismic zone III to zone IV (vulnerable to earthquakes)
- Heavily populated along the river Hooghly
- KMC population has increased from 9.1 million (1981) to 14.11 million (2011).
- Estimated net sea level rise in Diamond Harbour is 5.7 mm/year (MoEF, 2010)
# Records of Large Floods in West Bengal

<table>
<thead>
<tr>
<th>Period</th>
<th>Vulnerable Areas of Kolkata</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978: Sept 4-Sept 10</td>
<td>Monsoon rains caused unprecedented damage and made millions of people homeless in large parts of Northern India. Some areas of the state of West Bengal were 18 feet (5.5 meters) below water.</td>
</tr>
<tr>
<td>1986: Sept 24-Oct 10</td>
<td>Flooding from heavy rains in some areas of Kolkata, Hooghly, Howrah, Parganas and Midnapore</td>
</tr>
<tr>
<td>1999: Sept 24-Sept 29</td>
<td>Tropical cyclones caused destruction of an estimated number of 1500 villages. Floods due to brief torrential rains affected areas of Kolkata, Burdwan and Birbhum</td>
</tr>
<tr>
<td>2000: Sept 18-Oct 21</td>
<td>Late monsoon rains that triggered flash floods</td>
</tr>
<tr>
<td>2001: July 31–Sept 01</td>
<td>Monsoonal rains caused flooding in Kolkata</td>
</tr>
<tr>
<td>2004: June 20 Oct 07</td>
<td>Heavy monsoonal rains affected several districts</td>
</tr>
<tr>
<td>2006: Sept 18- Oct 05</td>
<td>Monsoonal rains and tropical cyclone-driven storms in the Bay of Bengal hit India and Bangladesh. West Bengal recorded 50 deaths, 300 were injured and 30,000 mud houses destroyed. Heavy rains left large parts of Kolkata city under water; subsequently 2,000 people were evacuated from the city</td>
</tr>
<tr>
<td>2007: July 03- Sept 22</td>
<td>The hazard affected Kolkata and several other districts. Eighty-three deaths were reported, and millions of people were marooned in 3000 villages in coastal areas of the state</td>
</tr>
</tbody>
</table>

*Source: Dartmouth flood observatory global archive, World Bank, 2011*
Kolkata Metropolitan Corporation
Kolkata Metropolitan Corporation - Burough

Legend
Burough Numbers
I
II
III
IV
IX
V
VI
VII

VIII
X
XI
XII
XIII
XIV
XV

River Hooghly

0 1.25 2.5 5 7.5 10 Kilometers
Primary Tasks

Data Collection for Models

World Risk Index Model
- Exposure Data
- Susceptibility Data
- Coping Capacity Data
- Adaptation Data

SUEWS Model
- Meteorological Data
- Land Surface Data
- Flood Modelling Data

Stakeholder workshops

- Stakeholder Consultation – I
  - Kick-off meeting
- Stakeholder Consultation – II
  - Dissemination of results and incorporating feedback

- Civil Society Groups
- State Officials
- Industry/Developers
- Research /Academic Scholars

Documentation/Literature Review
### Data for the Exposure Index

<table>
<thead>
<tr>
<th>Variable</th>
<th>Source</th>
<th>Time period</th>
<th>Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood</td>
<td><a href="http://floodobservatory.colorado.edu/Archives/index">http://floodobservatory.colorado.edu/Archives/index</a></td>
<td>1985-2014</td>
<td>Data Collected</td>
</tr>
</tbody>
</table>

- Archived data from flood observatory Colorado provides the Magnitude for floods, exact cause of floods, area affected by floods.

- Time series data for flood events on the basis of excess-monsoon years obtained from IMD
## Data for the Susceptibility and Coping Capacity Indicators

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Progress</th>
<th>Issues/Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Susceptibility</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population with access to improved sanitation and water in %</td>
<td>Data Collected</td>
<td>Data available for 2001 and 2011</td>
</tr>
<tr>
<td>% of population undernourished</td>
<td>Not available</td>
<td></td>
</tr>
<tr>
<td>Population Dependency based on work participation ratio</td>
<td>Data Collected</td>
<td>Data available for 2001 and 2011</td>
</tr>
<tr>
<td>Poverty Level</td>
<td>Data Collected</td>
<td>Data available for 2001 and 2011</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>Data Collected</td>
<td>Data available from 2005 to 2010</td>
</tr>
<tr>
<td>GINI index</td>
<td>In Progress</td>
<td>Computable data</td>
</tr>
<tr>
<td><strong>Coping Capacity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corruption Perception Index</td>
<td>Data collected</td>
<td>Data available for India as a whole (2013)</td>
</tr>
<tr>
<td>Failed States Index</td>
<td>Data Collected</td>
<td>Data available for India as a whole (2013)</td>
</tr>
<tr>
<td>Number of Doctors per 10,000 People</td>
<td>Data Collected</td>
<td>Number of allopathic doctors at primary heath centres in West Bengal 2013</td>
</tr>
<tr>
<td>Number of Hospital Beds per 10,000 People</td>
<td>Data Collected</td>
<td>Data available for 2013</td>
</tr>
<tr>
<td>Insurance Coverage</td>
<td>Data Collected</td>
<td>Data available from 2006 - 2011</td>
</tr>
</tbody>
</table>
## Data for the Adaptation Indicators

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Progress</th>
<th>Issues/Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adaptation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adult Literacy Rate</td>
<td>Data collected</td>
<td>Available only for 1991, 2001 and 2011 census</td>
</tr>
<tr>
<td>Combined Gross Enrolment Ratio</td>
<td>Data collected</td>
<td>Available only for 1991, 2001 and 2011 census</td>
</tr>
<tr>
<td>Gender Parity in Education</td>
<td>Data collected</td>
<td>Available only for 1991, 2001 and 2011 census</td>
</tr>
<tr>
<td>Women In National Parliament</td>
<td>Data collected</td>
<td></td>
</tr>
<tr>
<td>Per Capita Government and Private Expenditure on Health</td>
<td>Data collected</td>
<td></td>
</tr>
<tr>
<td>Life Expectancy Rate</td>
<td>Data partially available</td>
<td>Data available for WB as a whole for the years 2006 and 2011; Kolkata data alone unavailable</td>
</tr>
</tbody>
</table>
# Meteorological Data for SUWES Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Source</th>
<th>Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Satellite/Gridded</td>
<td></td>
</tr>
<tr>
<td>Mean wind speed</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mean air temperature</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Station air pressure</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Rain</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mean relative humidity</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Incoming Solar Radiation</td>
<td>✓</td>
<td>No Data</td>
</tr>
</tbody>
</table>
Factors contributing to vulnerabilities in Kolkata

- Climate Change
- Water Extraction
- Wetland Degradation
- Water and Air Pollution
- Unsustainable Urban Growth
- Waste Management
Climate Change

Meteorological conditions for Kolkata 1980 - 2013

Rainfall (mm)

- Total Monthly Rainfall
- Mean Max Temperature
- Mean Minimum Temperature

Months:
- Jan
- Feb
- Mar
- Apr
- May
- Jun
- Jul
- Aug
- Sep
- Oct
- Nov
- Dec

Jan to Dec:
- Jan: 25
- Feb: 50
- Mar: 75
- Apr: 100
- May: 150
- Jun: 250
- Jul: 350
- Aug: 400
- Sep: 350
- Oct: 300
- Nov: 250
- Dec: 200
Temperature Variability

<table>
<thead>
<tr>
<th>Period</th>
<th>Mean Maximum (°C)</th>
<th>Mean Minimum (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>µ</td>
<td>S.D</td>
</tr>
<tr>
<td>1980 -1995</td>
<td>35.28</td>
<td>0.92</td>
</tr>
<tr>
<td>1996 -2013</td>
<td>36.11</td>
<td>0.71</td>
</tr>
</tbody>
</table>
Rainfall Variability

Annual rainfall anomalies in the last 33 years
Water Resources and Sanitation

- Severe stress in terms of per capita water availability.
- Theoretical subsidence value in Kolkata due to over withdrawal ranges between 7mm/yr to 14mm/yr.

### Sources of Water 2001-2011

<table>
<thead>
<tr>
<th>Source of Water</th>
<th>2001</th>
<th>2011</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tap Water</td>
<td>1699052</td>
<td>1416366</td>
<td>-17%</td>
</tr>
<tr>
<td>Covered/Uncovered Well</td>
<td>8528</td>
<td>14290</td>
<td>68%</td>
</tr>
<tr>
<td>Hand Pump/Tube Well / Bore-well</td>
<td>191156</td>
<td>397538</td>
<td>108%</td>
</tr>
<tr>
<td>Others</td>
<td>29630</td>
<td>11172</td>
<td>-62%</td>
</tr>
</tbody>
</table>

### Sanitation

<table>
<thead>
<tr>
<th>Sanitation</th>
<th>2001</th>
<th>2011</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available</td>
<td>1830638</td>
<td>1759974</td>
<td>-4%</td>
</tr>
<tr>
<td>Not Available</td>
<td>97728</td>
<td>79392</td>
<td>-19%</td>
</tr>
</tbody>
</table>
Wetland Degradation

• Expanding townships closer to east Kolkata wetlands, with 7500 hectares which is notified under Ramsar in 2002

• The estimated value of livelihood support and sewage water treatment services was USD 40 million/year

• Negative impacts on the profitability of the fisheries and agriculture

• Increasing dependence on groundwater extraction
Air Quality

• Need for phasing out of old automobiles

• Deterioration of air quality and rise in numerous health problems including lung cancer

• Howrah is considered as one of the critically polluted regions
Planning of Urbanization

- Incentives to follow KMC Building Rules, 2009

- Maintaining urban -carbon sink (need for restoration of green coverage and water bodies)

- Increasing carbon footprint estimated as 93 lakh tons/year

- 14% total population live in slums in 20 wards out of 141 along Ganges

- Increasing probability storm surges and sea level rise.

- Management plan for climate change impacts in the City Development Plan(2015-25)
Urbanization

<table>
<thead>
<tr>
<th>Number of HH</th>
<th>Number of Wards 2001</th>
<th>Number of Wards 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000-4999</td>
<td>38</td>
<td>41</td>
</tr>
<tr>
<td>5000-8999</td>
<td>83</td>
<td>63</td>
</tr>
<tr>
<td>9000-12999</td>
<td>17</td>
<td>29</td>
</tr>
<tr>
<td>13000-16999</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>17000-21000</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Growth of Housing

EKW: East Kolkata Wetland
Population

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2011</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>2500040</td>
<td>2356766</td>
<td>-6%</td>
</tr>
<tr>
<td>Female</td>
<td>2072836</td>
<td>2139928</td>
<td>3%</td>
</tr>
</tbody>
</table>

Legend:
- Very low (< 20000)
- Low (20000 - 40000)
- Medium (40000 - 60000)
- High (60000 - 80000)
- Very High (> 80000)
Population of River-Bank Wards

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2011</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>358752</td>
<td>325531</td>
<td>-9%</td>
</tr>
<tr>
<td>Female</td>
<td>265969</td>
<td>262555</td>
<td>-1%</td>
</tr>
</tbody>
</table>
### Population of Wards with High Slum Concentration

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2011</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>647380</td>
<td>619210</td>
<td>-4%</td>
</tr>
<tr>
<td>Female</td>
<td>547904</td>
<td>572111</td>
<td>4%</td>
</tr>
</tbody>
</table>
Employment

KMC Total

<table>
<thead>
<tr>
<th>Category</th>
<th>2001</th>
<th>2011</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivators</td>
<td>6376</td>
<td>16039</td>
<td>152%</td>
</tr>
<tr>
<td>Agricultural Labour</td>
<td>4378</td>
<td>12388</td>
<td>183%</td>
</tr>
<tr>
<td>Household Labour</td>
<td>52543</td>
<td>68438</td>
<td>30%</td>
</tr>
<tr>
<td>Other Workers</td>
<td>1654437</td>
<td>1698875</td>
<td>3%</td>
</tr>
</tbody>
</table>

Legend:
- Very Low (< 10000)
- Low (10000 - 15000)
- Medium (15000 - 20000)
- High (20000 - 25000)
- Very High (> 25000)
High -Slum Concentration Wards

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2011</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivators</td>
<td>1779</td>
<td>4367</td>
<td>145%</td>
</tr>
<tr>
<td>Agricultural Labour</td>
<td>1907</td>
<td>4470</td>
<td>134%</td>
</tr>
<tr>
<td>Household Labour</td>
<td>27184</td>
<td>31664</td>
<td>16%</td>
</tr>
<tr>
<td>Other Workers</td>
<td>387040</td>
<td>412161</td>
<td>6%</td>
</tr>
</tbody>
</table>

Wards along River Hooghly

<table>
<thead>
<tr>
<th></th>
<th>2001</th>
<th>2011</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivators</td>
<td>997</td>
<td>1998</td>
<td>100%</td>
</tr>
<tr>
<td>Agricultural Labour</td>
<td>490</td>
<td>1647</td>
<td>236%</td>
</tr>
<tr>
<td>Household Labour</td>
<td>16079</td>
<td>18839</td>
<td>17%</td>
</tr>
<tr>
<td>Other Workers</td>
<td>214124</td>
<td>210789</td>
<td>-2%</td>
</tr>
</tbody>
</table>
Ward Classification - State of Development

**Literacy Rate**

- **2001**: 70
- **2011**: 85

**Employment Rate**

- **2001**: 35
- **2011**: 40

**Dependency Ratio**

- **2001**: 160
- **2011**: 150
Waste Management

- Wastes generated by 169 hazardous units is one of the highest

- Difficulty to implement Extended Producer Responsibility

- Production of 26,000 metric tons of e-waste/year and likely to increase to 1,44,823 metric tons by 2020

- Absence of organized recycling units

- The impact of climate change on the state’s energy systems

- The energy consumed by Kolkata metropolitan area are from coal, petroleum and biomass

- The contribution of energy from renewable sources is marginal
Changing pattern towards acceptance for special landscape with high risers

City expanded to maximum limit. Lack of space.

Safer; Sustainable; Smart
DISCUSSION WITH STAKEHOLDERS

### STATE GOVERNMENT INSTITUTIONS

<table>
<thead>
<tr>
<th></th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Urban Development Department</td>
</tr>
<tr>
<td>2</td>
<td>Public Works Department</td>
</tr>
<tr>
<td>3</td>
<td>Department of Panchayat and Rural Development</td>
</tr>
<tr>
<td>4</td>
<td>Department of Municipal Affairs</td>
</tr>
<tr>
<td>5</td>
<td>Municipal Engineering Directorate</td>
</tr>
<tr>
<td>6</td>
<td>State Urban Development Agency</td>
</tr>
<tr>
<td>7</td>
<td>Change Management Unit (CMU) - KUSP</td>
</tr>
<tr>
<td>8</td>
<td>Land and Land Reforms Department</td>
</tr>
<tr>
<td>9</td>
<td>Housing Department, Government of WB</td>
</tr>
<tr>
<td>10</td>
<td>Department of Health and Family Welfare, Government of WB</td>
</tr>
<tr>
<td>11</td>
<td>West Bengal Fire and Emergency Services</td>
</tr>
<tr>
<td>12</td>
<td>The Planning Department, Government of WB</td>
</tr>
<tr>
<td>13</td>
<td>West Bengal Pollution Control Board</td>
</tr>
<tr>
<td>14</td>
<td>Public Health Engineering Department</td>
</tr>
<tr>
<td>15</td>
<td>Micro and Small Scale Enterprises</td>
</tr>
<tr>
<td>16</td>
<td>Department of Agriculture</td>
</tr>
<tr>
<td>17</td>
<td>Department of Disaster Management</td>
</tr>
<tr>
<td>18</td>
<td>Institute of Environmental Studies and Wetland Management</td>
</tr>
<tr>
<td>19</td>
<td>Statistics and Programme Implementation</td>
</tr>
<tr>
<td>20</td>
<td>Department of Municipal Affairs</td>
</tr>
<tr>
<td>21</td>
<td>West Bengal Industrial Development Corporation</td>
</tr>
<tr>
<td>22</td>
<td>West Bengal Forest Development Corporation Limited</td>
</tr>
<tr>
<td>23</td>
<td>Calcutta Port &amp; Shore Mazdoor Union</td>
</tr>
<tr>
<td>24</td>
<td>Department of Water Resources Investigation &amp; Development</td>
</tr>
<tr>
<td>25</td>
<td>Regional Meteorological Centre</td>
</tr>
<tr>
<td>26</td>
<td>Commissioner of Police</td>
</tr>
<tr>
<td>27</td>
<td>Environment Department</td>
</tr>
</tbody>
</table>

### RESEARCH / ACADEMIC INSTITUTIONS

<table>
<thead>
<tr>
<th></th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Indian Institute of Engineering, Science and Technology</td>
</tr>
<tr>
<td>2</td>
<td>University of Burdwan</td>
</tr>
<tr>
<td>3</td>
<td>Centre for Urban Economic Studies</td>
</tr>
<tr>
<td>4</td>
<td>Jadavpur University</td>
</tr>
</tbody>
</table>

### Civil Society Groups

<table>
<thead>
<tr>
<th></th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Development Research Communication &amp; Services Centre</td>
</tr>
<tr>
<td>2</td>
<td>International Foundation for Sustainable Development</td>
</tr>
<tr>
<td>3</td>
<td>South Asian Forum for Environment (SAFE)</td>
</tr>
<tr>
<td>4</td>
<td>Society for Socio Economic and Ecological Development (SEED)</td>
</tr>
<tr>
<td>5</td>
<td>Nature Environment and Wildlife Society</td>
</tr>
<tr>
<td>6</td>
<td>Riddhi Foundation</td>
</tr>
<tr>
<td>7</td>
<td>Action Aid</td>
</tr>
<tr>
<td>8</td>
<td>Endev- A Society for Environment and Development</td>
</tr>
<tr>
<td>9</td>
<td>PUBLIC</td>
</tr>
</tbody>
</table>

### Issues

Migration; Poverty; Social Security; Gender Equality; Environmental Awareness; Disaster Risk Management; Industrial Growth; Health; Education; Etc?
Response on Vulnerabilities

**Government**
- Need for integrated climate policy
- Absence hazard proof infrastructure
- High risk of submergence
- Inclusion of R&R in disaster management
- Saline intrusion in potable water
- Improper Solid waste management

**NGOs**
- Linkage between education and industry
- High river-siltation
- Environmental awareness through media
- Lack of youth’s involvement in social issues
- No sewage treatment plant
- Highly polluting tanneries
- Urbanization of river coasts
- Capabilities of women ignored

**Academicians**
- Forced Migration
- Unsatisfactory disaster preparedness and awareness
- Unsustainable urban planning
- Sewage flowing in wrong direction
- Arsenic prone zone

**Students**
- Students less interested in climate change education
- NGO activities driven by sponsors
- Huge slum-non slum differential

**Disaster management**
- Disastrous management is relief based not preventative based

**Huge slum-non slum differential**
Government

MNREGA to mitigate rural to urban migration
Plans to retrofit old structures
NULM – migration focused employment
Food secure & self-sufficient
Environmental footprint comparatively better than other metros
Kolkata Environment Improvement Project
Calcutta Slum Improvement Project

NGOs

Some pockets plastic-free
JNNURM – infrastructure development
Improved medical facilities
High disposable incomes
Mandatory rainwater harvesting
Afforestation encouraged
SMEs doing good & supporting economic growth

Historical resilience – working class adapts
EKW still a waste disposable sink for the city
Improved drainage and sewage systems
Afforestation encouraged

Academiacs

Media’s role in environmental awareness is top-down
NGOs effective in rural areas
Positive attitude of slum dwellers towards environmental education

Govt. pro-NGO

SMEs doing good & supporting economic growth
High disposable incomes
Mandatory rainwater harvesting
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Highlights

Positive Aspects
• Perennial supply of fresh water
• Declining dependency ratio
• Increase in literacy rate
• Zero investment on sewage treatment
• Improved access to sanitation
• Declining population growth
• Increase in vertical infrastructure

Negative Aspects
• Climate change variables (rainfall, cyclones, river flood)
• Degradation & shrinking of wetlands
• Loss of livelihood and migration
• Increasing dependency on ground water
• No organized waste disposal system (solid/sewage)
Prediction of Future Scenarios using SUES Model: A case study for Kolkata
Meteorological Parameters over Kolkata

Average Wind Speed (kmph)

Trend line significant:
- Declining: - 3.62 kmph
- Declining rate per year: − 0.10 kmph
Mean Wind Speed (kmph)

\[ y = -0.0058x + 6.6321 \]

Trend line significant:
- Declining: - 3.83 kmph
- Declining rate per year: – 0.11 kmph
Wind Speed and Direction over Kolkata

35 yrs wind data
Most of the time high wind speed in the southward

High frequency wind speed is varying between 2.5 - 7.5 kmph.
**Trend line significant:**

- Increasing: +0.6042 hPa
- Increasing rate per year: +0.0173 hPa
Air Temperature (° C)

Trend line significant:
- Increasing: +1.208 ° C
- Increasing rate per year: +0.0345 ° C
Relative Humidity (%)

Trend line significant:
- Increasing: +4.8%
- Increasing rate per year: +0.1371%
Mean Vapour Pressure (hPa)

Trend line significant:
- Increasing: +3.8326 hPa
- Increasing rate per year: +0.1095 hPa
Total Rainfall (mm/h)

Trend line significant:
- Increasing: +13.091mm/h
- Increasing rate per year: +0.3740 mm/h
Features of meteorological parameters over Kolkata region

<table>
<thead>
<tr>
<th>parameter</th>
<th>Trend line variation (1980-2014)</th>
<th>Variation per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average wind speed (kmph)</td>
<td>↓3.62</td>
<td>↓0.10</td>
</tr>
<tr>
<td>Mean wind speed (kmph)</td>
<td>↓3.83</td>
<td>↓0.11</td>
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<tr>
<td>Sea Level Pressure (hPa)</td>
<td>↑0.60</td>
<td>↑0.01</td>
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<tr>
<td>Air Temperature (° C)</td>
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<td>↑0.03</td>
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<tr>
<td>Relative humidity (%)</td>
<td>↑4.80</td>
<td>↑0.13</td>
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<tr>
<td>Mean Vapour Pressure (hPa)</td>
<td>↑3.83</td>
<td>↑0.10</td>
</tr>
<tr>
<td>Total rainfall (mm/h)</td>
<td>↑13.09</td>
<td>↑0.37</td>
</tr>
</tbody>
</table>
Ongoing Work

- Meso-scale models (WRF or CWRF) are to be configured over Kolkata region for the hind and forecast of meteorological conditions.

- The simulated meteorological parameters - hourly, daily, monthly and yearly.

- Hourly meteorological parameters are inputs to the SUEWS model to calculate the radiation fluxes and water balance exchange.

- Model performance and its validation to be carried out with available IMD tower data.
Thank you