

Bangladesh Climate Change Resilience Fund (BCCRF)
And
The Development Economics Research Group
Present



Urban Flooding of Greater Dhaka in a Changing Climate

Building Local Resilience to Disaster Risk

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Presenter:

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2016

Megacity Dhaka



- Location: Lower reaches of the Ganges Brahmaputra Delta
- Greater Dhaka Area: 1,548 sq. km
- Elevation: 0 – 10m MSL
- Average Rainfall: 2,000 mm per year
- Monsoon: June - September
- Population: 14 million (BBS 2012)
- Population Density: 34,000 per sq. km
- Dhaka will become the world's fifth largest city by 2025 (UN 2010)



Urban Flooding : A Recurring Problem in Dhaka



- Flooding batters the city, affecting communications, livelihoods and service facilities every monsoon.
- The fringe areas, slums and shanties suffer more.
- Recent Devastating Floods: 1974, 1987, 1988, 1998, 2004, 2007, 2009.

Dhaka Urban Flooding: Three Potential Threats



- **Natural Factors:** Flat topography and low relief of the area
- **Developmental Factors:** unplanned and unregulated urbanization, low capacity drainage and sewerage infrastructure that have not kept pace with the growth of the city or demand for services, siltation in available channels, obstructions, mainly through uncontrolled construction in the natural flow of the storm water, reclamation of and construction in natural drainage areas (marshlands), etc.
- **Climate Change Aspects:** More erratic rainfall and increase in the frequency and intensity of extreme rainfall events.

Research Motivation



- Gradual filling up of flood plains, rivers, canals and other water bodies with rapid urbanization will aggravate the water logging over time.
- More erratic rainfall and increase in the frequency and intensity of extreme rainfall events with climate change may further worsen Dhaka's flood vulnerability in the future.
- This study will provide local decision-makers an effective planning approach to minimize the damage from urban flooding.



Presentation Topics

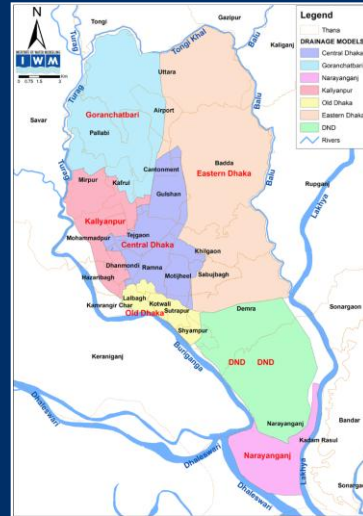


- Geographic coverage
- Study components and collaborators
- Future scenarios
- Hydrological Modeling
- Illustrative Example: Central Dhaka
- Flood vulnerability at ward level
- Current climate adaptation deficit
- Climate change effects
- Cost-Benefit comparison
- Message to policy makers
- Complementary flood mitigation measures
- Potential use of the study

Detailed Study Area



- Old Dhaka
- Central Dhaka
- Kallyanpur
- Goranchatbari
- Eastern Dhaka
- DND (Dhaka-Narayanganj-Demra)
- Narayanganj



Study Components



- **Assessment of Disaster Resilience:** Local preparedness for urban flooding emergencies of constituent wards was analyzed.
- **Hydrological modeling:** Location-specific depth and duration of flooding from an intense rainfall event was estimated.
- **Flood vulnerability:** The 10 most vulnerable wards of Greater Dhaka Area taking into account their exposure to flood as well as socioeconomic vulnerability and disaster resilience were identified.
- **Design of adaptation:** Recommended adaptation measures for each study area were developed and itemized adaptation costs were estimated.
- **Estimation of expected damage:** Expected economic damage from an intense rainfall event in 2050 and cumulative damage from similar rainfall between 2014 and 2050 with and without adaptation were estimated.
- **Complimentary flood mitigation measures** were recommended.

Study Components & Collaborators



- *Assessment of Disaster Resilience:* BUET.
- *Hydrological modeling:* IWM.
- *Flood vulnerability:* international consultants and BUET.
- *Design of adaptation:* DPG and IWM in consultation with local experts.
- *Estimation of expected damage:* international consultants in consultation with DPG and IWM.
- *Estimation of Adaptation Cost :* DPG and IWM in consultation with local experts.
- *Complementary Flood Mitigation Measures:* DPG in consultation with local experts.

Future Scenarios



- Baseline Rainfall (without climate change scenario): Historic September 2004 rainfall event (341 mm rainfall in 24 hours)
- Climate Change Rainfall Scenario: A 16 percent increase in 24-hour rainfall in Dhaka in 2050 as compared to the baseline.
- All planned and proposed drainage improvements discussed in the RAJUK's DAP, Sewerage Master Plan of DWASA, Narayanganj City Corporation's Concept Vision Plan, recommendations of JPZ et al., IWFM, IWM will be implemented.

Hydrological Modeling: Three Steps

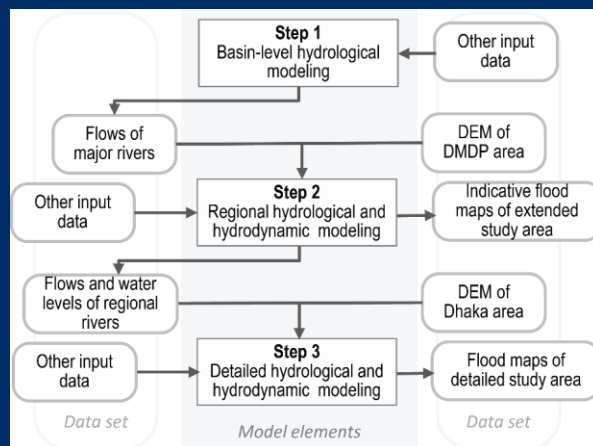


Dhaka is surrounded by 6 rivers and canals

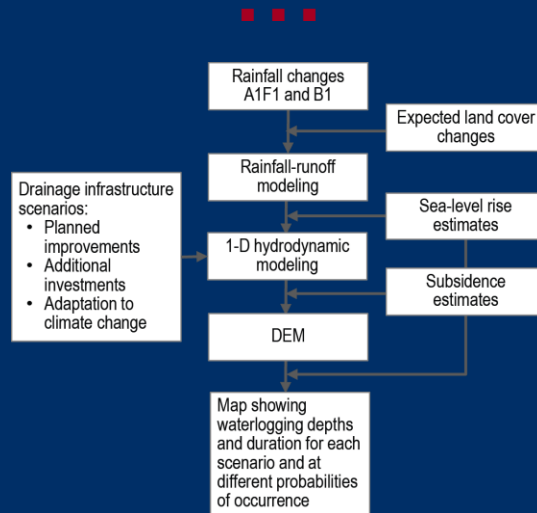
1. Basin-Level Modeling: Model developed by IWM for the GBM basin was used to estimate future flow changes of Brahmaputra (Jamuna) River due to climate change.
2. Region-Level Modeling: NCRHD was used to simulate monsoon seasonal flows and water levels of the river network in the extended study area.
3. Detailed Urban Area Modeling: MIKE11 and MIKE Urban were used for detailed level of hydrological and hydrodynamic modeling of the urban drainage system and relevant catchments.



Hydrological Modeling: Conceptual Framework



Hydrological Modeling: Detailed Area Modeling

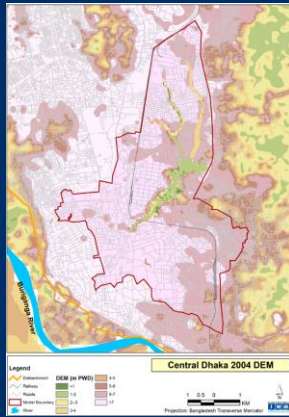


Detailed Area Modeling: Data

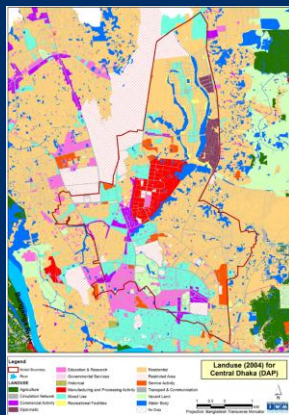
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Data	Source
Topography (DEM)	IWM, Survey of Bangladesh
Meteorological information	BMD and BWDB
Drainage infrastructure	Dhaka-WASA
Land cover	BUET and RAJUK
River stage	BWDB
River flow	BWDB
River sections, slopes and alignments	IWM
Population density	BBS

Central Dhaka - Land Elevation



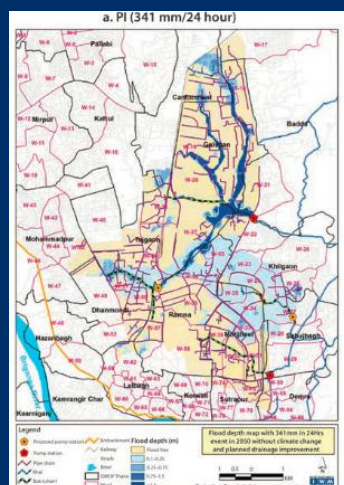
Central Dhaka - Land Use



Central Dhaka - Drainage



Central Dhaka – Flood Map without Climate Change



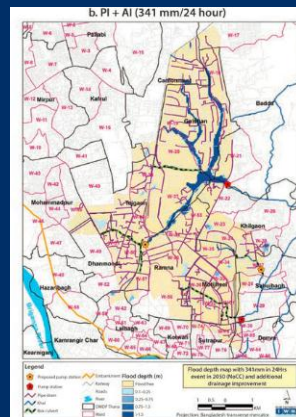
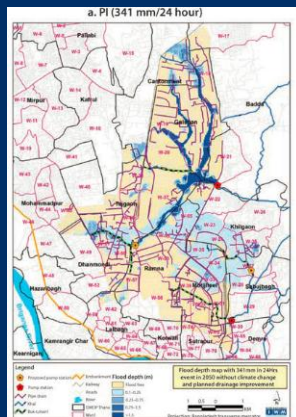
Central Dhaka – Adaptation Deficit



1. At Gulshan, Banani and Hatir Jheel Lakes – Reduce initial water levels from 5 m PWD to 4 m PWD
2. At outfall of Panthapath Box-Culvert- Install a new pump station with 12.5 m /s capacity and 80 % efficiency.
3. Near Bashabo Water Pump station of DWASA- Install new pump station and sluice gate; pump capacity is 15 m /s, with 80% efficiency, and gate size is 4 m x 3 m.

Extreme rainfall in 2050	Flood free	0.1m-0.25 m	0.25m-0.75m	0.75m-1.5m	> 1.5m	Average Duration above 0.1m (hours)
Maximum flooded area (sq. km)						
341mm/24 hour	26.4	8.8	1.9	0.3	1.8	10
Future without Adaptation deficit	36.4	0.7	0.3	0.1	1.7	1

Central Dhaka – Flood Maps with & without Adaptation Deficit



Central Dhaka – Additional Adaptation for Climate Change



1. Near Russel Square- Installation of a new sluice gate (3.4m x 3.4m) with automatic operation to divert excess water to Dhanmondi lake at the time of peak runoff and prevent backwater flow from Panthapath Box-Culvert.
2. Near Russel Square- Reactivate the existing sluice gate (2m x 2m) and automatic operation with the new gate to divert excess water to Dhanmondi lake at the time of peak runoff.

Central Dhaka – Extent and Duration of Flood with and without Climate Change



Extreme rainfall in 2050	Flood free	0.1m-0.25 m	0.25m-0.75m	0.75m-1.5m	> 1.5m	Average Duration above 0.1m (hours)
341 mm/ 24 hour	26.4	8.8	1.9	0.3	1.8	10
396 mm/ 24 hour	25.1	10.1	1.9	0.3	1.8	12
341 mm/24 hour without Adaptation deficit	36.4	0.7	0.3	0.1	1.7	1
396 mm/ 24 hour but without Adaptation deficit	35.7	1.1	0.5	0.2	1.8	2
396 mm/ 24 hour without Adaptation deficit and with adaptation for climate change	36.1	0.9	0.4	0.1	1.8	1

Central Dhaka-Adaptation Cost



	Tk. Million
<u>Addressing Current Climate Deficit:</u>	
Pump station, Bashabo *	849.5
Pump station, Panthapath	600.00
Total	1,449.5
<u>Addressing Climate Change Deficit:</u>	
Total estimated cost, sluice gates at Russel Square	91.1
Total Combined Cost	1,540.6

* Calculation based on price of pump, related mechanical, electrical and civil works, land acquisition and sluice gate.

Central Dhaka – Cumulative Damage from Extreme Rainfall Events during 2014-2050



- Cumulative damage between 2014 and 2050 from an intense rainfall event based on random assignment of 1 % probability of occurrence during each year:
 - If there is no climate change and no action is undertaken: Tk. 56,315 million
 - If current climate adaptation deficit is met: Tk. 11,460 million
 - If there is climate change (no change in frequency-only more intense rainfall) and no action is undertaken: Tk. 65,754 million
 - If current climate adaptation deficit is met and climate change adaptation is undertaken: Tk. 12,367 million
- Cumulative damage between 2014 and 2050 from an intense rainfall event based on random assignment of 5 % probability of occurrence during each year:
 - If rainfall intensity remains the same and no action is undertaken: Tk. 65,322 million
 - If current climate adaptation deficit is met: Tk. 13,119 million
 - If there is climate change and no action is undertaken: Tk. 76,205 million
 - If current climate adaptation deficit is met and climate change adaptation is undertaken: Tk. 14,159 million

Damage Assessment



- Water Levels & Expected Impact:
 - (0 - 0.1 m): No impact
 - (0.1 m – 0.25 m): slight impact
 - (0.25 – 0.75 m) low impact
 - (0.75 – 1.50 m) moderate impact
 - (> 1.50 m) extensive impact

It has been found that a depth level below 0.25 m produces little damage in most affected areas as people in Dhaka have learned to adapt to such level of flooding as a common occurrence every year.

- Duration of Flooding & Expected Impact:
 - duration of flooding above 0.25 m level is analyzed up to 10 days in order to examine the severity of flood damage as it was found that water starts receding rapidly from most areas in Dhaka city by that period.

Damage Assessment: Methodology



- The damage is estimated separately for the following main sectors of the economy: residential, commerce and industry, health, roads, railways and other surface transport.
- In each sector, efforts have been made to estimate the damage to physical capital and the damage to earnings to get an estimate of total damage.

➢ *Damage to Physical Capital = Value of Physical Capital* Percentage of Physical capital Exposed to Flooding*Damage Factor*

Damage factor is estimated based on the depth and duration of flooding.

➢ *Damage to Earning = Daily Value of Income/Output*Average Number of Days of Loss.*

Residential Damage & Income Loss



Residential Building Repair Cost



- Dhaka's categorization of building structures: *Jhupri*, *kutcha*, *semi-pucca* and *pucca* were considered.
- *Pucca* structures were further divided into economically weaker section (EWS), middle-income groups (MIG) and high-income groups (HIG).
- Building upgrades would reduce the number of *jhupris* and *kutcha* structures and a percentage of *semi-pucca* buildings will be transformed to *pucca* over time.
- *Jhupri*, *Kutcha*, *semi-pucca* structures are one-storied buildings, average *pucca* structure consists of two (EWS), three (MIG) or four (HIG) stories.
- Flood damage will be restricted only to the first floor.
- Building construction costs of different types of buildings were estimated from the ACC Help Home Building Calculator.
- Repair costs of *Jhupri*, *kutcha*, *semi-pucca* and *pucca* are 50%, 25%, 12% and 6% of the building construction cost respectively.
- Any inundation of depth > 0.25 meter for more than a day is expected to cause a minimum threshold proportional damage requiring repair that varies with the type of the building.
- Any building submerged for 10 days or longer at an inundation depth greater than 1.5 m would always require repair.
- The proportion of buildings needing repair decreases linearly for fewer days of inundation.
- Proportion of damage differs across inundation depth ranges.

Clean-up Cost of Residential Building: Methodology



- It is assumed that all inundated buildings not requiring repair will incur clean-up costs.
- Clean-up costs mainly involve disinfecting building premises and minor repairs including cleaning of the floor, whitewashing walls etc.
- Based on field surveys, Clean-up costs are assessed to be around Tk. 500 for *jhupri*, *kutch*a and *semi-pucca* structures, and Tk. 1000, Tk. 2,000 and Tk. 4,000 respectively for EWS, MIG, and HIG buildings.
- The building clean-up costs are then extrapolated to 2050 costs.

Damage of Residential Property: Methodology



Extensive residential property damage is caused by sudden & prolonged flooding, especially if household property cannot be moved to upper floors.

Building Blocks:

- The damage to residential property is estimated based on the total property exposed to inundation in the first floor times a *property damage factor*.
- The estimate of residential property is based on the household income in Dhaka. In particular, it is assumed that the value of the property owned depends on the savings accumulated in each income category over a 5 year period. Savings rate differs across income groups.
- The *property damage factor* is based on the depth and duration of flooding. Based on observation, it is assumed that a maximum of 33% of household property will be damaged if buildings are submerged for 10 or more days with inundation depth > 1.5 m with proportional decrease for fewer days of inundation. The corresponding maximum damage for depths 0.75 m – 1.5 m and 0.25 m – 0.75 m are assumed to be 25% and 20%.

Location-specific Vulnerability Assessment



- Hydrological modeling provided location-specific estimates of the depth, duration and extent of flooding.
- The impact of inundation of even the same depth and duration on population and infrastructure differ significantly depending on an affected area's disaster resilience.
- The climate disaster resilience of Dhaka City at ward and thana level were quantified with 125 variables (25 components along five dimensions physical, social, economic, institutional and natural).
- Survey data was collected and experts were consulted to quantify location-specific disaster resilience.

Top 10 Flood-Vulnerable Wards



Kallyanpur	09
DND	87
Old Dhaka	82
DND	86
Central Dhaka	25*
Kallyanpur	10
Kallyanpur	58
DND	88
DND	90
Eastern Dhaka	Khilgaon outside DNCC

- * Flood extent, Flood duration, high Population density, high population of informal settlers, high number of children and elderly, low literacy rate, low access to internet, lower number of public awareness programs/ disaster drills, Education and awareness, low level of community participation, low ability to reach consensus, inadequate interaction between social class,

Current Climate Adaptation Deficit



- Beyond improvements in drainage infrastructure already planned and proposed, additional structural measures (pumps, sluice gates, storm-water pipes) will be necessary to mitigate waterlogging even without climate change.
 - From the hydrological modeling simulations, the study recommended a list of investment options for each study area to reduce inundation depth to 4-8 inches within 12 hours.
 - The cost of mitigating Dhaka's waterlogging even without climate change would cost Tk. 2.7 billion.
- * **NOTE:** Tk 2.7 billion is equivalent to only 0.35% of the govt's development budget in 2014-2015.

Climate Change Impacts



- Rainfall in Ganga-Brahmaputra-Meghna basin is expected to be more erratic with climate change.
- More intense rainfall is expected in the coming decades.
- Intense rainfall events are expected to be more frequent.
- Climate Change Rainfall is approximated by 16 percent increase in 24-hour rainfall in Dhaka in 2050 as compared to the baseline.
- Adaptation to climate change would require an additional investment of Tk 1.3 billion.

Cost-Benefit Comparison



- Potential cumulative damage from intense rainfall events between 2014 and 2050 even without climate change is Tk 110 billion.
- Potential cumulative damage from intense rainfall events between 2014 and 2050 with climate change is Tk 139 billion.
- With recommended Tk 2.7 billion investment made to mitigate the historic September 2004 waterlogging in current climate:
 - Potential cumulative damage will reduce to Tk 37 billion without climate change.
 - Potential cumulative damage will reduce to Tk 49 billion with climate change.
 - This estimate of potential savings in damage is conservative.

Message to Policy Makers



- Invest to address historic waterlogging in the current climate - the city is already facing the risk even without climate change.
- Benefits of these recommended investments to mitigate waterlogging in current climate exist even in the absence of climate change, making such investments an attractive low-regret option.
- Develop additional measures to mitigate climate risks sequentially after addressing the current climate risks.
- Climate and disaster resilience is not uniform in all parts of megacity Dhaka. There is room to improve local disaster resilience. Facilitate area-specific action planning for strengthening the local climate disaster resilience.

Complementary Flood-mitigation Measures



- Routine Cleaning of Drains: Sludge Removal
 - Hydraulic Jetting and Vacuum Suction Machines for DWASA and DCC (8 sets for Tk 120 million each)
 - Remote-Controlled Excavators for DWASA (3 machines for Tk 40 million each)
- Shaving Peak Flow
 - Green Roofs
 - Management of Impervious Surfaces
- Use of Water Bodies as Detention Ponds
- Last Resort: Truck-Mounted Water Pumps

Book Launch

World Bank, Dhaka

23 November 2015



DIRECTIONS IN DEVELOPMENT
Environment and Sustainable Development

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Can be downloaded from:

<https://openknowledge.worldbank.org/handle/10986/22768>

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Potential Use of the Book



- This analytical work will assist to mitigate current waterlogging and to further climate-proof drainage infrastructure in Greater Dhaka Area.
- Recommended list of investment options will help decision-makers to formulate more effective flood-control strategies, prioritize interventions, and sequence activities as resources permit.
- Identified priority zones and priority sectors to improve disaster resilience.
- Facilitate area-specific action planning for strengthening the local climate disaster resilience.
- Major reference resource for researchers, practitioners and students.

Bangladesh Development Series Report:

Climate Disaster Resilience of Greater Dhaka Area

A Micro Level Analysis



- Climate and disaster resilience is not uniform in all parts of megacity Dhaka.
- Variations result from spatial differences in the strengths and weaknesses of the economic, social, physical, institutional or natural aspects.
- The climate disaster resilience of Dhaka City in its seven drainage zones - at ward and thana level was quantified with the planning tool CDRI developed by the Kyoto University.
- To compute Dhaka's CDRI with 125 variables (25 components along five dimensions physical, social, economic, institutional and natural), survey data was collected and experts were consulted.

Findings



- Overall, Dhaka city has moderate level of disaster resilience.
- There is room to improve disaster resilience by
 - Improving governance
 - Mainstreaming Disaster Risk Reduction and Climate Change Adaptation
 - Management and Dissemination of knowledge
 - Effectiveness of the Crisis Management Framework
- Central Dhaka has the highest CDRI.
- DND area has the lowest CDRI.

Potential Use



- Identify priority zones and priority sectors to improve disaster resilience.
- Identify specific potentials of different localities that other areas can learn from.
- Identify specific weaknesses of different localities to improve upon.
- Facilitate area-specific action planning for strengthening the local climate disaster resilience.
- Facilitate integration of Climate Change Adaptation with the Disaster Management Plans and Urban Development Plans of the Greater Dhaka Area.

Timeline



- April 2012: Review and Approval of Concept Note
- June 2012: Consultative Workshop #1 (Presentation of methodology)
- April 2013: Consultative Workshop # 2 (Hydrological Modeling Results on Climate Change Impacts)
- May 2013: Focus Group Discussion #1 (Recommendation of Location-specific Adaptation Measures)
- June 2014: Technical Review of the Report by Local Experts
- August 2014: Consultative Workshop # 3 (Presentation of the Study Results)
- August 2014: Focus Group Discussion #2 (Discussion of Flood Mitigation Policy)
- March 2015: Review of the Book by International and Bangladeshi Reviewers
- November 2015: Launch of the Book and the BDS Report

Special Acknowledgement



- BCCRF Funding
- Mr. Mahbub Rahman, Director, Water Resources Planning Division, IWM
- Mr. Kazi Habibullah, Executive Engineer, D-WASA
- Mr. Liakath Ali, Climate Change and Environmental Advisor, DFID – Bangladesh
- Ms. Norma Adams, Book Editor
- Ms. Polly Adams, Graphics Editor, World Bank
- Ms. Angie Harney, Program Assistant, World Bank

Report Launch ■ ■ ■
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