RESEARCH SUMMARY

March 2021

National Resilience Programme

Study on Economic Impact of Waterlogging on Local Trade: The Case of Khatunganj, Chattogram

Introduction

Though Khatunganj is considered a local trade hub, in a broader sense, the place holds international importance as most of the imported grocery items are stocked in this area. The importance of Khatunganj can be traced back to the 4th century BC with the growth of Chattogram as a port city (Ministry of Information, Govt. of the People's Republic of Bangladesh, 1994). Chaktai khal became a part of the silk route's major trade route during the 11th and 12th centuries. This old glory of the land later got hindered with dependence on the motorized vehicle to transport and develop land ports. Khatunganj was grown organically with time to serve as a business hub as it is situated at the bank of Chaktai Khal (Chakoria Nallah), which was the gateway to inner land from Chattogram Port. The livability of Khatunganj is directly related to the survival of this water network. However, to date, very little has been done to conduct a scientific study on the economic impact of the current water scenario on Khatunganj, Chottagram. This study will provide the Chattogram Chamber of Commerce and Industry (CCC&I) and Khatunganj Trade and Industries Association with evidence and actionable information about root causes of water retention, policy gaps, and institutional capacity to raise awareness and policy advocacy for risk-informed business practices in the city.

Problem Scenario

Before elaborating on the problem scenario, it should be noted that Waterlogging is the saturation of soil with water, which is not the case in the study area. The study area's problem is an urban drainage problem, as there is no effective system in place for onsite water management from rainfall, upstream flow, and tidal flood. The city is a dynamic landscape characterized by natural (blue and green) and man-made (grey) elements (Galli A. et al. 2012). Over densification and unplanned urbanization leave little room for interaction among blue, green, and grey elements. As a result, the natural elements (e.g., water, green space) and natural characteristics (e.g., topography) are deprioritized in many cities. One manifestation of this is that water—a vital structuring element—can become a challenge for the urban environment during extreme weather events such as heavy rainfall. The compact urban fabric often does not possess porous surfaces for water permeability, causing historically unprecedented flooding events. In this study, water retention in the city area is the aggressor, which victimizes the economy, increasing operational costs and losses to the local traders.

Objectives of the Study

The aims of the study were -

1. Assessing the risk and vulnerability due to waterlogging at Khatunganj
2. Developing a vulnerability and risk profile of Khatunganj concerning waterlogging with climate change scenario with proper and reproducible methodology.
3. Determining strategic interventions for the best possible future scenario.
4. Estimating direct economic impacts of waterlogging in the form of damages to the building, physical infrastructure, etc., and collateral impacts like a disruption in transport, reduction in sales, net operating losses, and other related losses to suggest appropriate policy measures to strengthen the resilience of Khatunganj wholesale commodity market against the risks of waterlogging.

Review of the Related Literature

Waterlogging Vulnerability and Risk Assessment

In urban areas, the ground surface is gradually becoming rigid by several imperforated layers that hinder the natural water percolation process and generate more runoff. Drainage congestion is often observed in the urban areas that hinder stormwater movement and create waterlogging. Due to rapid urbanization to cope with population growth, cities are losing open space that earlier can act as stormwater retention zones. Unplanned city development often works in a synergistic way along this line. All these phenomena result in urban storm waterlogging. Vulnerability is the extent of harm expected under certain conditions of exposure, susceptibility, and resilience (Balica & Wright, 2009). Vulnerability is defined in terms of exposure, capacity, and potentiality. Risk can be defined as the combination of the probability of an event and its adverse consequences (UNISDR, 2009). Risk is described as the anticipated losses (of life, injured individuals, damaged assets, and interrupted financial activity) owing to a specific area and reference period hazard. Risk is the result of hazard and vulnerability based on mathematical calculations (WMO, 1999).

Economic Impacts of Urban Waterlogging

Waterlogging or floods can be a reason for the disruption of trade and commerce in any country. The losses from business interruption can sometimes be huge also. Such losses can be termed as the forgone value-added that is not created due to a flood (Vilier et al., 2014). The severity of impacts from urban waterlogging or flooding can intense on trade and commerce. Business interruptions take place, for example, if people are not able to carry out their work because their workplace is either destroyed or not accessible due to a hazard (Meyer et al., 2013). Addressing issues like urban waterlogging demands a well-coordinated and comprehensive plan. A real challenge for any developing country city like Chattogram is managing the required resources, including financial resources for carrying out necessary projects to develop required infrastructural facilities, excavating water channels for smooth flow of rainwater or city's wastewater, and developing regulatory frameworks. Considering resources have alternative uses and any development project where scare resource needs to be allocated demands a benefit-cost analysis.

Urban Multi-scale Environmental Predictor (UMEP)

"UMEP (Urban Multi-scale Environmental Predictor), a city-based climate service tool, combines models and tools essential for climate simulations. It includes tools to enable users to input atmospheric and surface data from multiple sources, characterize the urban environment, prepare meteorological data for use in cities, undertake simulations and consider scenarios, and compare and visualize different combinations of climate indicators." (Lindberg F. et al., 2018). The software is written as a plug-in to QGIS, a cross-platform, free, and open-source desktop geographic information system (GIS) application (QGIS Development Team, 2017).

Study site

Khatunganj is situated in the east part of the Chattogram city by the famous Chaktai canalside. This is the place where the Chaktai canal opens to the Karnaphuli River. The geographic location of Khatunganj is at 22.330N and 91.840E. Khatunganj is located at ward number 35 of Chattogram City Corporation. Figure 1 below shows the location of Khatunganj.

The place is vital for the economy of Chattogram city as well as for the entire country. This is the primary wholesale market for daily commodities. However, the business hub now a day are suffering extremely from inundation problem. Khatunganj traders reported their sufferings with excruciating costs due to waterlogging as their stocks are destroyed. A very short duration rainfall results in water logging in all the alleys of this crowded market. Figure 1 portrays the waterlogged situation of some shops at Khatunganj.

Figure 1: Waterlogged shops at Khatunganj

Methodology

The broad methodology for this study was divided into their parts economic, hydrology, and urban design and planning, as given in the following section.

Economic impact study

Considering Khatunganj does not maintain any systematic record of damages and no scientific study was found to address the issue of waterlogging from an economics point of view, the present research extensively used primary data collected from local traders and other key stakeholders. For this, a semi-structured questionnaire and a key informant interview (KII) schedule were designed to collect primary data. Secondary literature available in form of published reports, articles and unpublished data from relevant authorities were also collected for analysis. The economic analyses were mostly done by applying both qualitative and quantitative techniques.

Hydrological study

For hydrologic-hydraulic modeling purposes, a model was formulated on the SWMM model platform, which gave water levels at different points of the canal. The study is mostly based on secondary data collected from different government and non-government organizations. Primary data on structure type at both the sides of Khatunganj road was collected. Eight different scenarios on different rainfall events were simulated where an actual rainfall event was considered, and that is the rain event of 5th July 2017, and the remaining scenarios are based on design rainfall events. Due to data scarcity, the model was calibrated with a satellite image of inundation extent from the actual rainfall.

Urban planning study

For the urban planning part of the study GIS data from LGED, Chattogram City Corporation, and CDA (administrative boundaries, parcel boundaries, building footprints, building heights, number of stories per building) were collected. Meteorological Data (Air Temperature, Relative Humidity, Wind Speed, Wind Direction, Rainfall, and Solar radiation) from Ambagan, Chattogram; Patenga, Chattogram and Agargaon, Dhaka weather station of Bangladesh Meteorological Department (1990-2019) were obtained. Remote sensing data from Aerial Photogrammetric survey to prepare DEM and DSM Demographics and economic Data were obtained from BBS besides field survey. The spatial Morphology of the study area was analyzed using Space syntax. Then the analysis of the urban Water and Energy cycle for the site was conducted using **Urban Multi-scale Environmental Predictor** (UMEP) (a climate service tool, presented as a plug-in for QGIS). This tool was used for different purposes related to Urban Flooding and climate change adaptation etc. An overall methodology combining economy, hydrology, and planning is presented in the Figure 2 below.

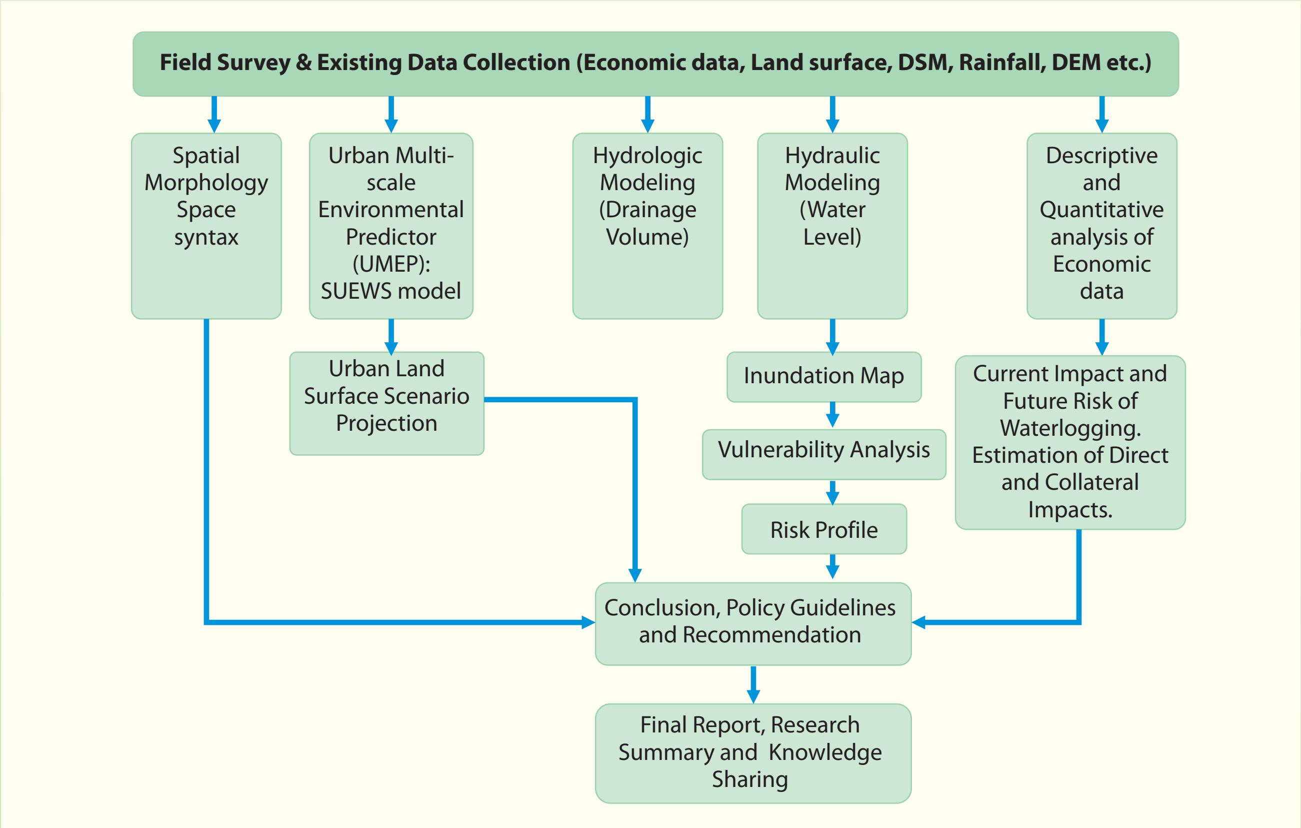

Figure 2: Methodological Framework for the study

Analysis and Results:

Direct economic impacts of waterlogging in Khatunganj

It is found that the business community in the area has been facing waterlogging problems for the last 15 years or so. The findings also suggest that although all business units are facing this problem, its extent can be found varied based on enterprises' floor heights and proximity to the canal and low-lying areas. Most of the respondents considered changes in tidal waves and rainfall patterns as the main reasons behind the problem of waterlogging in the Khatunganj market. Of the most important types of financial losses and impacts of waterlogging in the market, reduction of sales and damages to stocks is opined to be most severe by the respondent businessmen, while the cost of repairment and extra expense of transportation are also considered as major areas of economic impacts. In the case of the non-financial effects, anxiety by the affected businessmen, business reputational problems, and demotivation of doing business are identified as the major impacts of waterlogging on business people.

Table 1: Estimated Direct Economic Losses[1] by Traders in the Khatunganj Wholesale Market in the last 10 Years (in crore taka)

Year	Direct Economic Losses from Waterlogging for Khatunganj Wholesale Market		Direct Economic Losses from Waterlogging for Khatunganj and Its Neighboring Markets including Asadganj, Chaktai, and Quarbaniganj	
	(N=1000)	(N=1200)	(N=4500)	(N=5000)
2011	34.96	41.95	157.33	174.81
2012	36.49	43.79	164.20	182.44
2013	36.67	44.00	165.00	183.33
2014	37.84	45.40	170.27	189.19
2015	41.55	49.86	186.98	207.76
2016	39.31	47.18	176.91	196.56
2017	80.46	96.55	362.06	402.29
2018	45.75	54.90	205.88	228.75
2019	47.46	56.95	213.55	237.28
2020	102.88	123.45	462.94	514.38

Estimating direct economic losses and impacts from the field survey supports the local business community's concerns. Findings suggest that the estimated losses in the year 2020 for the Khatunganj market reached over 100 crores. Asadganj, Chaktai and Qurbaniganj markets are considered the greater Khatunganj market[1] than the value is estimated to be over 460 crores. Data from 2011 to 2020 show that the losses are increasing with time, although some exceptions can also be seen. For example, the year 2017 saw a rapid jump in direct losses by the traders as the year saw some exceptional waterlogging incidences due to tidal waves and excessive rainfalls.

Analysis and results from hydrological study

Low rainfall (around 75 mm/day) generates a water level of 2.5 m, whereas average rainfall generates a water level of 3-3.2m. Such a water level results in the inundation of the Khatunganj main road. The level of the Khatunganj Main road is about 2.9 to 3.1 m. An average rainfall (125 mm/day) creates water inundation about 6 inches to 1 foot over the main road. A heavy rainfall (>200 mm/day) with a climate change scenario gives around 4.1 m water level, meaning around 1 m depth of water inundation on the road. The cases are considered at high tide occurrence time. Four criteria are chosen to determine the vulnerability of the Khatunganj due to the flooding caused by different rainfall scenarios. The four criteria are namely, plinth level of the structure, proximity to Chaktai khal, structure type (kacha, pacca, or semi pacca), and land use pattern.

Structure-based risk profiling has been carried out. The total number of structures found on both sides of Khatunganj main road was 224. The number of structures falling in different vulnerability classes for the three different rainfall scenarios is documented and presented in Table 2. With three rainfall cases (low, average, and high), the risk profile for the structures has been estimated. The majority of the structure at both the sides of Kahtunganj main road falls in the medium vulnerable class for all three rainfall cases. In case of high rainfall, all structures are, to some extent of vulnerable.

1 Traders often consider the neighbourhood markets including Asadganj, Chaktai and Qurbanignaj as Khatunganj market. Similarly, these areas too face the problem of waterlogging like Khatunganj wholesale market. Thus, the study considers estimation of both the values to understand the gravity of the problem.

Table 2: Number of structures falling in different vulnerability classes for three different rainfall scenarios

	Low rainfall	Average Rainfall	Heavy Rainfall
Not Vulnerable	122	37	0
Less Vulnerable	33	83	68
Medium Vulnerable	42	74	85
Very Vulnerable	27	30	71
Total	224	224	224

Analyzing Spatial Morphology

Axial map analysis on 1.5Km surrounding road network and waterway network catering Khatunganj is used in this study. From the analysis, integration and intangibility values have been considered to understand the relation of existing land use with road and water network. For referring to the water network, the terminology "blue network" has been used. For developing the blue network, all canals were considered actively connected both at a higher altitude of the city and with the Karnaphuli river. UCL Depth Map 10 has been used to analyze integration values of the road network and blue network. Integration values are presented in a chromatic scale ranging from blue to red. The blue color indicates the least integrated or least used ones, and the red color indicates the most integrated or the most used ones.

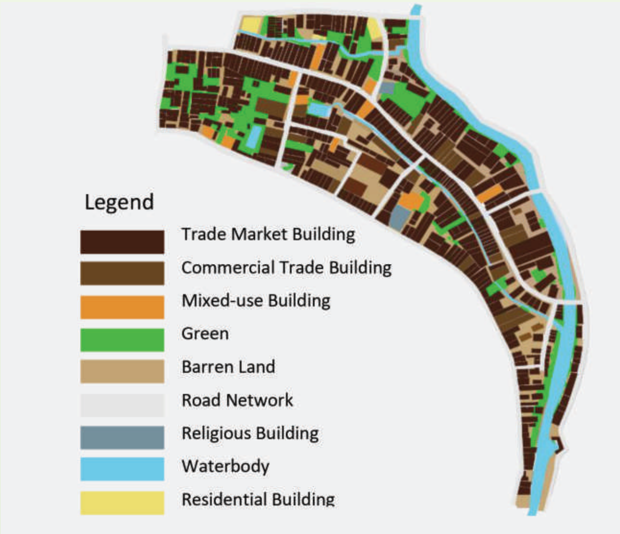

Figure 3: Existing Land use of Khatunganj Wholesale Market Area

Though a larger area has been analyzed, this study will only focus on the area of the Khatunganj wholesale market. Figure 3 shows the existing land use of the Khatunganj Wholesale market area, and figure:7 (a) shows the global integration map of road network without an active Blue network, which represents the existing scenario. The base map for the space syntax analysis has been prepared from the existing GIS file of Chattogram city.

UMEP (Urban Multi-scale Environmental Predictor) Modelling

This modeling work consisted of three elements: First: pre-processing (for inputs of meteorological and surface information); Second: processing the data (Urban Land Surface Models, ULSM); and Third: post-processing using tools to analyze the outputs. The following variables are usually required as a minimum for meteorological data: air temperature, relative humidity, barometric pressure, wind speed, incoming shortwave radiation, and rainfall; if available, other variables could be supplied as well. In the case of Khatunganj, air temperature, relative humidity, wind speed, wind direction, and rainfall data were collected from the Patenga weather station. Other data were taken from the EnergyPlus weather data belonging to the US Department of Energy's (DOE). The three site-specific building morphology parameters needed were derived from the following Digital Surface Models DSMs and other survey data. DSM and DEM mentioned in the above data were processed through a Morphometric calculator to generate three site-specific building morphology parameters in the form of an isotropic file in text format. This data then imported into SUEWS for modeling. Existing Landcover fractions had been derived from the existing GIS file and field survey data. They are as follows (Table 3):

Table 3: Existing land cover fraction

Sl no.	Land cover	fraction
1	Building	0.5590
2	Paved/Impervious	0.2021
3	Evergreen trees	0.0200
4	Grass	0.1405
5	Water	0.0784

Population density

The population density in people/ha (hectare) around the interest area was considered 170 based on the survey and existing Bangladesh Bureau of Statistics data.

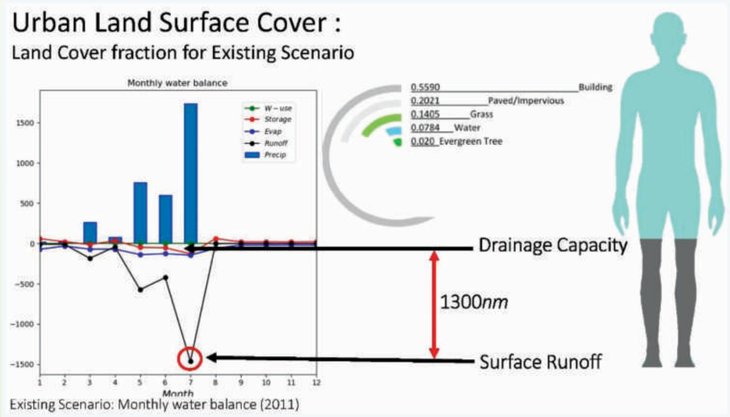

Figure 4: Existing condition: Monthly partition of the surface energy balance and monthly water balance.

Landcover scenario

Besides the existing landcover scenario, three more landcover scenarios were considered in relation to the area's waterlogging problem. The primary purpose of the scenario run was to investigate between the water storage and the surface water runoff of the site. Land cover fraction for Scenario 3, the fraction of Building, Evergreen trees, and Water were respectively 0.46, 0.02, and 0.52 with all other landcover fraction considered zero.

Results of the UMEP scenario run

The results from the modeling of existing land cover fraction, and the hypothetical scenario three (3) are given in figure 4:

Existing Landcover scenario

It is clear from the existing situation present water storage in terms of the water body is too low to manage the surface water runoff generated from the site. Hence it is clear that we need to increase the storage capacity of stormwater of the site if we want to manage it on site. However, it is also possible to have a sound drainage system to drain out the water.

Scenario 3

In the scenario, three water bodies' fractions were further increased by reducing the existing building appropriately. The results can be seen in figure 5. From scenario three, the effect of the increase of water body and decreasing the fraction of

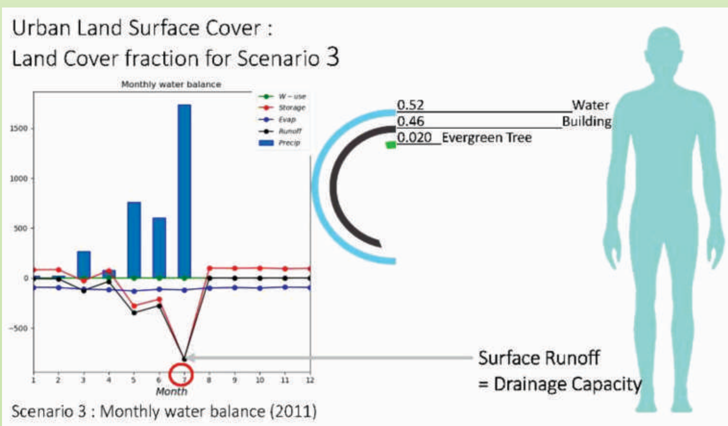

Figure 5: Scenario 3: Monthly partition of the surface energy balance and monthly water balance.

building an appropriate amount from the existing conditions balance both water runoff and storage. Hence these combinations could be an ideal combination as a starting point for future urban planning and design intervention.

Action Matrix

Based on the above findings, the following actions, in particular, are suggested to be made by involving the relevant stakeholders:

Table : Action Matrix

Issue/ Action/ Recommendation	Policy/ Plan/ Regulation	Relevant Agency/ Ministry
Revitalizing Chaktai Canal by demolishing all RCC works from the bottom of Chaktai canal. Widening the canal to allow adequate flow of water to revive bio-diversity.	Long term policy to protect water ecology.	Chattogram Development Authority (CDA.),Chattogram Municipal Corporation (CCC)
Revitalization and reconnection of water-based transportation in the supply-chain by reactivating the Chaktai canal as a water transport path by demolishing present bridges over the Chaktai canal and construct a new bridge suitable for navigation under the bridge.	Plan for integrating Chaktai canal with other modes of transport.	Chattogram Development Authority (CDA.) Chattogram Municipal Corporation (CCC) B.I.W.T.A.
Vision planning of Khatunganj through Urban blue-green infrastructure (BGI). BGI for Khatunganj needs to include **Greenelements like:** trees, shrubs, grass, etc. Blue elements such as rainfall and flood, water-body **Man-made interventions**, such as permeable pavements, bioswales, retention basins, and constructed wetlands as an integrated whole.	Creating separate urban design policy and act following the principle of "**Smart resilient city**" using "**Big Data/ Artificial Intelligence (AI)**" to implement urban blue-green infrastructure (BGI) at the different urban scale	Chattogram Development Authority (CDA.) Chattogram Municipal Corporation (CCC) Research organization, ie. universities/ individual researchers on the field of urban blue-green infrastructure (BGI.)
Multimodal Transport Hubs (MTHs) at Khatunganj to integrate road connection with the waterway	Plan for Multimodal transport hubs (MTHs).	Chattogram Development Authority (CDA.) Chattogram Municipal Corporation (CCC) BIWTA BRTA
Integrating and generating urban tourism economy by introducing water-based "**Heritage Tourism**" at Khatunganj	National Heritage Tourism Planning Policy	Bangladesh Parjatan Corporation CDA CCCI
'**Uploading**' the trade and the inventory on to the **eCommerce network** at Khatunganj		Ministry of Commerce CCCI
Responsible waste management practices in terms of source separation, onsite treatment of waste, and recycling centers.	A local waste management plan	Traders and sellers of Khatunganj wholesale market
"**Waste to Energy**" plant to manage solid waste at city/local scale.	Long term waste management plan	Chattogram Development Authority (CDA.) Chattogram Municipal Corporation (CCC)
Proper planning on land use to maintain water retention area in the Chaktai Khal Catchment	Waterbody Conservation Law (জলাধার সংরক্ষণ আইন)	CDA.
To increase the water retention capacity of the Chaktai Khal by dredging of the canal and by widening/deepening the roadside drains.	Plan for lowering water inundation at Khatunganj	CCC

Issue/ Action/ Recommendation	Policy/ Plan/ Regulation	Relevant Agency/ Ministry
Maintaining the linkage of drainage networks for proper disposal of domestic wastewater and stormwater	Drainage regulation of city corporation	CCC
Regular maintenance of the Chaktai canal and surrounding drains to keep the canal free from blockage	Drainage regulation of city corporation	CCC
Dredging of Karnaphuli River to reduce the effect of sea level rise due to climate change	Navigation policy of the government	BIWTA/CPA
Construction of tidal gate at the confluence of Chaktai khal and Karnaphuli River	Plan for lowering water inundation problem at Khatunganj	CCC/CDA
Countrywide LIDAR based land cover data for disaster management and climate change adaption.	National data collection policy	Bangladesh Space Research and Remote Sensing Organization (SPARRSO.)
Time-series data on loss of life and wealth related to hydro-meteorological disasters like floods, storm surges, etc. should be collected by all government, semi-government and private authorities to project future scenarios of the urban areas due to disaster.	National/local data collection policy	All the relevant government authorities, i.e., LGED, Department of Disaster Management (DDM), semi-government and private agencies (e.g. NGOs)
Digitize all collected data on the disaster, displacement, transport, etc., and submit to Central Database, which should be readily available for researchers and relevant persons/organizations.	National data collection, storage, and distribution policy	Planning Commission

Conclusion

The research findings suggest that there are extensive financial losses in the form of direct impacts from waterlogging in the Khatunganj wholesale market. It is also clear from the results that the estimated impacts are on increasing trends with time. With changes in climatic conditions, such impacts are expected to be even higher with time if no effective solution to the problem of waterlogging is undertaken. Solutions to the existing waterlogging problem suggest having a regular dredging facility for the Karnaphuli River and Chaktai canal and ensuring responsible waste management practices by the traders. This study also set up the hydrologic and hydraulic models and did an extensive analysis of the water logging problem in the Khatunganj commercial area and observed that a small rainfall results in inundation in the area. The consequences are huge economic losses in the commercial areas of Khatunganj and neighboring areas. Water retention options increase in canal capacity and the canal's regular maintenance is extremely important for managing such a crisis. The study further identified the appropriate proportion of urban land cover for a given climatic scenario, which could be a guideline for all the relevant agencies for designing and implementing Blue-Green Infrastructure (BGI) to revitalize the area by addressing the problem of urban flooding. The study particularly emphasized the increase of "Urban Blue" as a solution to the waterlogging of the Khatunganj wholesale market.

The study conducted by NRP consultants - **Dr. Abu Taib Mohammed Shahjahan**, Team Leader & Urban Planner, **Dr. Reaz Akter Mullick**, Climate Change and Hydrology Expert and **Dr. A K M Nazrul Islam**, Environmental Economist

Published by : National Resilience Programme (NRP), Programming Division, Planning Commission