Proceedings of NCWRE 2018

1st National Conference on Water Resources Engineering

21-22 March 2018

Organized by
Department of Civil and Water Resources Engineering
Chittagong University of Engineering and Technology
Chittagong-4349, Bangladesh

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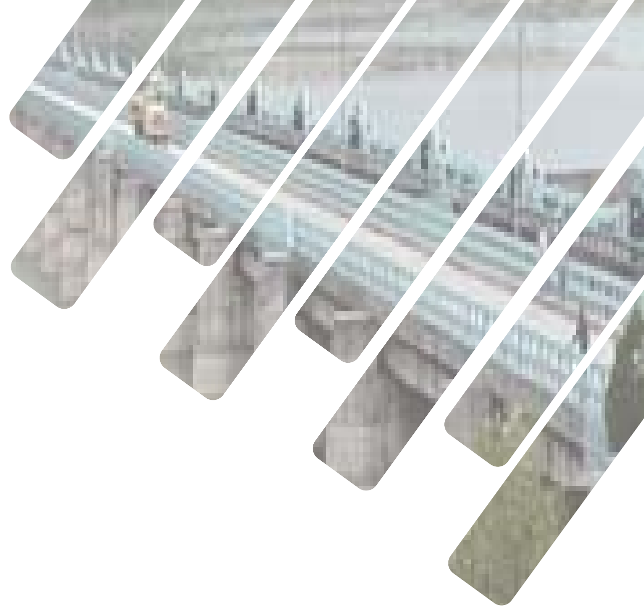

Proceedings of the
1st National Conference on Water Resources Engineering
21-22 March 2018, CUET, Chittagong, Bangladesh.

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Preface

It is our immense pleasure to present the proceedings of the 1st National Conference on Water Resources Engineering (NCWRE-2018) which is going to be organized by the Department of Civil and Water Resources Engineering, Chittagong University of Engineering and Technology (CUET), Chittagong, Bangladesh, on 21-22 March 2018. The NCWRE focuses on bringing together academicians, scientists, researchers, managers, administrators, engineers, architects and planners interested in water resources planning, engineering and management to exchange and share their experiences and researches regarding water resources issues.

Water Resource Engineering is a specific kind of civil engineering that involves the design of new systems and equipment that help manage human water resources. Some of the areas Water Resource Engineers work on are water treatment facilities, underground wells, and natural springs. Water Resource Engineers must create new equipment and systems to increase the effectiveness and efficiency of water treatment and aquatic resource management. A typical workday involves the analysis of data from relevant areas, then designing new or improved facilities to enhance the cleansing effects of the water treatment system. We strongly believe that, NCWRE-2018 will provide a real platform of exchanging and scientific and technical information of relevant fields from all the participants from throughout the nation.

As an event, the conference is considered to be highly successful. From 135 initially submitted abstracts, 69 papers finally have been accepted after a peer review process and then included in the processing. The papers have been grouped into six broad thematic areas namely, GIS and Remote Sensing in WRE; River Engineering; Sustainable Development; Urban Hydrology & Drainage; Water & Wastewater Treatment; and Water Supply, Sanitation & Health. The balanced contributions from the distinguished authors to the thematic areas show the importance of multi-disciplinary nature of water resources engineering. During the conference all those papers are planned to be presented in 6 technical sessions. In addition to these sessions, two keynote speeches and two invited speeches have been designed and scheduled.

Finally, we express our heartiest gratitude to our fellow members of different committees for their hard and sincere work in materializing the grand occasion. It goes without saying that the sincere hard work put in by the contributing authors deserves our praise and gratitude. At the same time, thanks and gratitude to the sponsor organizations for providing valuable and continuous support to NCWRE without which this this conference would not have been possible.

Editorial Board
NCWRE-2018

Message
From Chairman, UGC

It gives me immense pleasure to learn that the Department of Civil and Water Resources Engineering, Chittagong University of Engineering and Technology (CUET) is going to organize a two-day long National Conference on "Water Resources Engineering" (NCWRE-2018) to be held on 21- 22 March, 2018.

The extensive range of themes of this national conference emphasizes on sharing the knowledge of water resources with the young researchers, academicians, professionals. We know water is essential for sustaining life on our planet and its uneven distribution is a source of permanent conflict. The growth of human population combined with the irregularity in precipitation and water availability may restrict even further the access to water and Bangladesh is in this risk zone. This problem is made more severe by anthropogenic activities that affect its quality.

Bangladesh is a riverine country and the rivers worked like veins of Bangladesh. It pumps life throughout the nation. Bangladesh, face many water related problems including flooding in monsoon period, drought in summer, river bank erosion etc. To find out a sustainable solution regarding these issues we should work together. I urge upon our scientists, researchers and practitioners of this field to come forward and utilize the occasion with earnest zeal.

I believe that all the researchers, academicians and professionals in this great event will be encouraged towards more accomplishments in advanced research.

I wish the NCWRE-2018 event a total success.

(Professor Abdul Mannan)
Chairman
University Grant Commission, Bangladesh.

Message
From Vice-Chancellor

It is indeed a great pleasure to know that the Department of Civil and Water Resources Engineering, Chittagong University of Engineering & Technology (CUET) is going to organize a two days National Conference as "Water Resources Engineering" (NCWRE-2018) during 21-22 March 2018.

Water is one of the largest natural resources in Bangladesh. Water resources management is a very important issue from several angles such as development of water bodies for future, protection of available water bodies from pollution and over exploitation and to prevent disputes. A paramount issue is water-its availability, quality and management. Extensive hydrological information is necessary to develop water resources and protect them. Protecting the environment for the coming generations begins with more effective water management today.

I undoubtedly believe that NCWRE-2018 will be a strong base on sharing the state-of-the-art knowledge obtained from ongoing researches at various organizations in Bangladesh and it will help on building network among the professionals of their respective research area.

CUET is one of the prominent and prestigious universities in Bangladesh in the engineering education. The Department of Civil and Water Resources Engineering, CUET is praiseworthy regarding undergraduate program, it also bears a good reputation in multidisciplinary research activities despite being a new department. Their endeavor to arrange such conference deserves our praise.

I am optimistic in believing that the outcomes of this glorious event will eventually help enhancing the aim of the Civil and Water Resources Engineering Department and in general of the university.

I wish a very pleasant and successful completion of the conference.

(Prof. Dr. Mohammad Rafiqul Alam)
Vice-Chancellor
Chittagong University of Engineering & Technology
Chittagong-4349, Bangladesh.

Message
From Dean

I am very glad to acknowledge that the Department of Civil and Water Resources Engineering, Chittagong University of Engineering and Technology (CUET) is going to organize the "1st National Conference on Water Resources Engineering" (NCWRE-2018) on 21 and 22 March, 2018.

The need for safe water at everywhere demands specific professional on Water Resources Engineering to develop solutions that are environmentally sustainable, economically viable and socially acceptable. The Department of Civil and Water Resources Engineering (CWRE) has been established in CUET with the vision of producing the knowledgebase to deal with the challenges in a scientific and engineering way. Water Resource Engineering is a specific kind of civil engineering mostly involving the design of new systems and equipment to help manage human water resources. It involves the management of supply of surface and subsurface water to the people and risk associated with water disaster and maintains the health of ecological systems. Water Resource Engineers not only design these water management systems, but often oversee the construction and maintenance of these systems as well. An increasing population and continuous need for more water stimulates the fast-growing industrial sector.

Though Department of Civil and Water Resources Engineering comparatively is a very new department in CUET, it shows great valiance to organize such a glorious event. I am sure that this scholastic occasion will give opportunity to the scientists, researchers, professionals working at different organizations in Bangladesh for sharing the latest research findings, progresses and future prospects.

On behalf of the Faculty of Civil Engineering, I welcome all the participants to the conference. I wish them a happy and pleasant stay at the beautiful scenic campus of CUET.

I wish the NCWRE-2018 a grand success.

(Prof. Dr. Md. Abdur R. Bhuiyan)
Dean
Faculty of Civil Engineering
Chittagong University of Engineering and Technology
Chittagong-4349, Bangladesh.

Message
From Conference Chair

On behalf of the NCWRE-2018 organizing committee, I am honored and delighted to welcome you to the 1st National Conference on Water Resources Engineering to be held during 21 and 22 March, 2018 at Chittagong University of Engineering and Technology, Chittagong. The NCWRE-2018 promises to be an outstanding platform for participants to share their knowledge and expertise.

Bangladesh exists on the largest delta in the world. Water shapes the land and the destinies of its people. This has always been a dynamic and relentlessly changing ecosystem. Almost every year the people of Bangladesh face numerous water resources related problems includes monsoon flood, river bank erosion, drought, salinity intrusion etc. The researchers, academicians and different government bodies are working hard to find out the solutions of these issues. Over the years, dramatic improvements have been made in the field of water resources engineering. NCWRE-2018 focuses on sharing these innovative knowledge, idea and experience among the researchers, scientists and scholars. Students and young participants will have a unique chance to be acquainted with new and advanced Water Resources Engineering topics that will help them advance their careers, their respective organizations.

As conference chair of NCWRE-2018, I would like to express sincere thanks to the Chief Guest, Special Guests, Keynote Speakers, Invited Speakers and participants and the representatives of various organizations for their initiative, contribution and make this event lively and memorable one. Special thanks to all the students of Department of Civil and Water Resources Engineering for their day- night effort for the success of NCWRE-2018.

I hope and believe that you all will find the conference as a platform for networking, knowledge-sharing and enjoyable. I am looking forward to seeing you in the conference.

(Prof. Dr. Aysha Akter)
Conference Chair, NCWRE-2018 &
Head
Department of Civil and Water Resources Engineering
Chittagong University of Engineering and Technology
Chittagong-4349, Bangladesh

Message
From Conference Secretary

It is matter of pride and privilege for me to welcome you as the conference secretary of the 1st National Conference on Water Resources Engineering (NCWRE-2018) organized by the Department of Civil and Water Resources Engineering, Chittagong University of Engineering & Technology (CUET).

Bangladesh faces its challenging situation over decades relating water supply and sanitation, storm water drainage system, ground water pollution, river erosion, draught, flood, climate change, sea level rise, coastal erosion etc. managing water resource has become one of our biggest challenges. The NCWRE focuses on bringing together academicians, scientists, researchers, managers, administrators, engineers, architects and planners interested in water resources planning, engineering and management to exchange and share their experiences and researches regarding water resources issues. As a part of NCWRE-2018, water contests in four different categories i.e. water quiz, fluid mechanics challenge, poster presentation and photography competition has designed for the students interested in WRE. The winner students in two types of quizzes, poster presentation and related photography will be awarded. The conference is organized with interactive sessions, technical discussions on conference papers and information sharing sessions. Distinguish keynote and invited speakers from home will be presenting their significant research outcomes and will also attend technical discussions of this conference. I believe that participants will be able to harness valuable information to enhance both technical skill humanistic perception to better solve problems and hence to better contribute for sustainable infrastructure and socio-economic development of the country.

I would like to thanks all authors for their outstanding contributions and to our organizing teams and colleagues who spent much time and efforts to make this conference successful. Last but not least, thanks are also extended to our valuable sponsors (Diamond Cement Limited, BSRM, Chemito International Limited and BASF) for their immense support.

I hope and believe that you will find the conference both valuable and enjoyable. I am looking forward to seeing you in the conference.

(Md. Samiun Basir)
Conference Secretary, NCWRE-2018
&
Lecturer
Department of Civil and Water Resources Engineering
Chittagong University of Engineering and Technology
Chittagong-4349, Bangladesh

Message

From Joint Conference Secretary

It is my true delight and privilege to welcome all of you to the "1st National Conference on Water Resources Engineering (NCWRE-2018)" organized by Department of Civil and Water Resources Engineering, Chittagong University of Engineering and Technology (CUET) during March 21-22, 2018.

Water Resources Engineering focuses on the use and management of land and water resources in rural and urban watersheds. A growing population and the need for clean water demands Water Resources Engineers to develop solutions that are environmentally sustainable and economically viable. Water resources engineers deal with the control and utilization of water by society. In order to accelerate the research works, it is necessary to exchange the ideas and views with distinguished researchers of different fields of water resources engineering. I believe that the NCWRE-2018 will acts as an efficacious platform for sharing research experiences, state-of-the-art knowledge and ingenious ideas among the participants.

NCWRE-2018 is an early endeavor of Department of Civil and Water Resources Engineering, CUET. The mission of this department is to produce well-qualified graduates capable of mitigate the current problems and ever expanding needs of sustainable development and management of water and related resources of the country. I believe that this event will be a milestone for the progress of this department.

My sincere gratitude goes first to all my colleagues, fellows and the authority of CUET for their persistent supports all the way of this arrangement. Finally, I cordially acknowledge the financial assistance from our honorable sponsors who have kindly promoted their generous support for us.

I am optimistic that the objectives and goals of organizing the conference will be achieved in the best possible manner.

(Shovon Halder)
Joint Conference Secretary, NCWRE-2018 &
Lecturer
Department of Civil and Water Resources Engineering
Chittagong University of Engineering and Technology
Chittagong-4349, Bangladesh

Message

From Technical Secretary

On behalf of the technical & scientific committee, it's an honor for me to invite you to the First National Conference on Water Resources Engineering (NCWRE-2018) organized by the Department of Civil & Water Resources Engineering, CUET to be held at CUET campus during 21-22 March, 2018. The conference was scheduled on the eve of World Water Day (22 March) in order to emphasize on the responsibilities of the society towards sustainable management of the finite water resources. Engineering is no longer an isolated field but a combination and interconnection of multidisciplinary aspects of knowledge. The NCWRE-2018 focuses on bringing together specialists, professionals, planners and students from diverse academic backgrounds in order to identify the existing problems, prospects, and sustainable solutions for the emerging challenges in the water resources engineering sector.

In its first year, NCWRE has received overwhelming response from all over the country. A total of 135 abstracts were received from different organizations, among which, 69 full papers were finally selected for publication in the conference proceedings. The papers were categorized into 6 broad fields. The fields of GIS and Remote Sensing in WRE, River Engineering and Sustainable Development received 12 papers each whereas the fields of Urban Hydrology & Drainage, Water & Wastewater Treatment and Water Supply, Sanitation & Health received 11 papers each. Aside from these technical papers, two keynote and two invited lecture sessions are also arranged where experts of the water resources sector would share their views about the current status and prospects of water resources in Bangladesh including World Water Day-2018 theme, "Nature for Water", integrated water resources management, climate change impacts, present and future challenges to sustainable water resources management, etc.

To make the conference participatory and vivacious, several students' contests has also been arranged including Poster Presentation, Photography Competition, Water Quiz and Fluid Mechanics Challenge. Undergraduate students of various universities have shown great enthusiasm to participate in these students' contests. A grand and colorful World Water Day Rally will be held on 22nd March.

I would like to thank all the students, professionals, experts and other participants for their valuable contribution and spontaneous participation in NCWRE-2018. I would extend my gratitude towards CUET administration, members of the technical & scientific committee, organizing committee & the advisory committee for their valuable directions and contributions for organizing this conference. Also, I would like to acknowledge the contributions of our sponsors for their immense support.

(Rifat Talha Khan)
Technical Secretary, NCWRE-2018
&
Lecturer
Department of Civil and Water Resources Engineering
Chittagong University of Engineering and Technology
Chittagong-4349, Bangladesh

Message

From Treasurer

I feel honored to welcome you all to the 1st National Conference on Water Resources Engineering (NCWRE-2018) to be held on 21st and 22nd March 2018, organized by the Department of Civil and Water Resources Engineering, Chittagong University of Engineering and Technology (CUET).

Due to huge population load on limited amount of resources, the water resources is a highly stressed sector in Bangladesh. Environmental issues need to be addressed especially environmental pollution in terms of water, air and soil; waste management; health hazard etc. In Bangladesh, the environmental aspects of large scale civil engineering projects should be paid special attention to mitigate their adverse impacts on environment. On the other hand, the vast water resources of the country should be utilized and maintained carefully. I truly believe that this conference will provide a suitable platform to bring together our young researchers, professionals and experts to share their diverse opinions regarding the mitigation of current and upcoming challenges in the water resources engineering sector. It is an opportunity for the participants to exhilarate their research activities through proper communication.

This NCWRE-2018 is designed with distinguished keynotes and invited speeches and technical sessions with innovative and technically sound conference papers. Students' contests in four different categories have been organized for undergraduate university students

I would like to thank all the authors and participants. I am grateful to all of my colleagues, fellows, organizing committee and CUET authority. I specially thank UGC for their contributions. Finally, I gratefully acknowledge the financial support of our sponsors BSRM, Chemito, Diamond Cement & BASF.

Hope you will enjoy your time with us. I wish to have a flourishing completion of this conference. Thank you so much for your keen interest and participation.

(Pollen Chakma)
Treasurer, NCWRE-2018 &
Lecturer
Department of Civil and Water Resources Engineering
Chittagong University of Engineering and Technology
Chittagong-4349, Bangladesh

Keynote Speech-1

Sustainability of Integrated Water Resources Management: lessons of the bilateral Bangladesh-Netherlands cooperation (1976-2016)

Ir. Peter de Vries
Thematic Expert Water Management
Embassy of the Kingdom in the Netherlands
Dhaka, Bangladesh.

The approach of water management projects in Bangladesh and of the bilateral cooperation in this field shifted over time. From 1975 on a purely technical approach was followed focused on the construction of rehabilitation of water management infrastructure. Gradually, from the 1980s, a more integrated approach was followed in which the socio-economic development of the project participants was a main objective and a multi-sectoral approach was followed (i.e. water management, agriculture, fisheries, institutional development). From the 1990s onwards integrated water resources management became a dominant approach. Strong focus was given to the institutional and socio-economic aspects of water management, notably operation and maintenance and people's participation. This was to result in effective operation & maintenance of water management infrastructure and in long-term sustainability of water management systems (financial, institutional, environmental, technological and social). These more integrated approaches were in line with the policy and regulatory development of the 1990s (National Water Policy (1998), Guidelines for Participatory Water Management (2000), National Water Management Plan (2001). As a consequence, the bilateral water management projects of the Netherlands contained a number of elements:

- strong link to agricultural development (including aquaculture, livestock development)
- operation & maintenance of water management systems
- participatory water management: strengthening of Water Management Organizations
- empowerment of women for water management and economic development
- inclusive approach involving non-farmers (landless, fishing communities).

In 2017 the independent evaluation unit of the Netherlands cooperation ministry concluded that the bilateral cooperation program on water management in Bangladesh has produced substantial results in terms of improved water services for agriculture leading to enhanced yields and revenues in project areas and trickle down effects to landless and non-farming communities. However, the long-term effectiveness of these projects is weak and not sustained. Main reason for this is the fact that the appropriate institutional capacity at all levels of the water sector has not been created:

-at national level the needed massive transformation of the key water sector institutions into multidisciplinary water management institutions has not taken place
-the participatory water management organizations have not been backed by an appropriate permanent support structure. Such WMOs are only promoted in a limited number of foreign funded project. After closure of the project the WMOs are not yet strong enough to sustain their water management functions.
-resulting operation and maintenance of water management structures is weak and the build-neglect rehabilitate-neglect cycles continues.
A number of changes that are necessary in order to arrive at sustainable integrated water resources management will be discussed.

Keynote Speech-2

Water Resources Management in Bangladesh: Challenges and Way Towards Achieving Sustainable Water Environment

Prof. Dr. Md. Abdul Matin
Department of Water Resources Engineering
Bangladesh University of Engineering and Technology (BUET)
Dhaka-1000, Bangladesh.

Bangladesh is located on flood plain of Ganges, Brahmaputra and Meghna (GBM) rivers (GBM). As a tropical land, Bangladesh made on fertile soil and abundance of sun and water. Average rainfall received by Bangladesh is about 2300 mm annually. But the mighty river system of GBM brings in three times extra water from transboundary catchments. The basin is shared by Bangladesh (7%), Bhutan, China, India (80%), and Nepal. During monsoon (June to October) these catchment rushes water with fertile soil to the land through the mighty river system. In lean season (November to May) demands in-stream flow through these rivers becomes vital for marinating ecological balance, agriculture, fisheries and for navigation. Bangladesh has about 238 medium to large rivers spread like a network all over the country. Out of these rivers, 57 are transboundary i.e., sharing its basin with neighboring countries. These river systems are the main lifeline of water resources in Bangladesh. In addition, those rivers at the outfall of the Bay of Bengal produce a forest at Sundarban largest mangrove. Bangladesh has also a long coast line consists of enormous marine resources. In brief major water resources of Bangladesh are: River system for surface and ground water, coastal ecosystem and marine environment. Main category of water use in Bangladesh are instream requirement is about 56%, agricultural use 32%, Environment, fish and forest 9% and water supply is 3%. Under the present quandary of water resources availability and requirements is facing manifold challenges especially in dry season. In wet season, flood and bank erosion create enormous suffering to the people. Moreover, in 2016, UN provides a prescription for every country to achieve SDG goal in water management issue by 2030. To meet the challenges, water resources issues and related activities, and role of water professionals will be focused to some extent for the sustainable water management in Bangladesh. As way forward, implementation of climate change adaptation plans, river management, preservation and restoration of rivers and water bodies etc. are the vital investment plans and should be given priority in future development plans of the country. Role of skill water professionals is always required to combat the water related challenges. In speech attempt will be made to address all these issues in brief.

Invited Speech-1

Climate Change and Water Related Disasters in Bangladesh: Learning From the Past

Prof. Dr. Md. Shahjahan Ali
Head, Department of Civil Engineering
Khulna University of Engineering & Technology (KUET)
Khulna, Bangladesh.

Bangladesh is a disaster prone country, and the effect of climate change magnifies the governing factors of the disasters. In this paper, firstly the temporal changes of pattern of different disasters in Bangladesh are presented based on their occurrence rate, number of people killed, and exposure to human and economic loss. The paper concentrates on the temporal variation of floods in Bangladesh. The term 'Flood Intensity Index' is introduced to characterize the flood, which is considered as a function of inundation depth and duration. Previous data and various future predictions showed that both the parameters in Food Intensity Index in Bangladesh are in increasing trend due to climate change impact. The climate change induced increment in river discharge during monsoon will increase the inundation depth, and the increasing trend of Sea Level Rise will increase the duration of flood due to back water effect of sea. Flood Intensity Index is calculated for two mega floods of 1988 and 1998. It is observed that although the average depth of inundation among two mega floods does not differ too much, the Flood Intensity Index in 1998 was much higher (about double) than 1988 flood, and that is why the economic loss in 1998 flood was much higher (about 2.33 times) than that of 1988 flood. It is found that the Sea Level Rise due to elevated tides in the Bay of Bengal was the main cause for the prolonged flood in 1998. On an average, 0.19 m SLR was observed at that time (for about 2.5 months), which blocked the outflow of the swollen rivers into the Bay of Bengal. The severity of flood in 1998 due to the impact of temporary SLR of 0.19 m, gives a practical estimation how the SLR due to climate change will affect the flooding scenario of Bangladesh. If the impact of SLR due to climate change predicted by IPCC is superimposed with 1988 or 1998 extreme flooding, what will be the degree of disaster—is actually beyond the imagination. But the reality is, such future scenario is needed to be considered before the implementation of any adoption options or strategies to mitigate the climate change impacts.

The South-West coastal region of Bangladesh is likely to be adversely affected by Sea Level Rise. To investigate the impacts of sea level rise on polder enclosed beel communities, the Beel Dakatia (second largest beel in Bangladesh) region under polder no. 25 is studied. In the region, people's opinion regarding their resilience against different level of SLR induced permanent inundation was analyzed. To estimate the climate change vulnerability in coastal areas of Bangladesh, this paper also presents the Livelihood Vulnerability Index (LVI) for nine Upazillas in the south west coastal belt. The indicators (subcomponents) provided by research study are important for decision making toward managing sources of vulnerability and can be used to guide the development of adaptation policies. Peoples' perception regarding the unavailability of infrastructural supports during catastrophic disasters. This research relied on intensive field investigation of Dacope Upazila of Khulna district that was badly affected during cyclone Aila. Six available infrastructures were selected for this analysis. Uniformity of distribution (Ri), demand index (Di) and degree of demand (DDi) of the selected infrastructures were calculated. Results drawn from this research will be useful for local and national level planners, as well as international donors for future disaster mitigation planning in the studied area.

Invited Speech-2

Nature Smart for a Sustainable Water Future of Bangladesh

Prof. Dr. Rowshan Mamtaz
Department of Civil Engineering
Bangladesh University of Engineering and Technology (BUET)
Dhaka-1000, Bangladesh.

Water is a precious gift of nature and an essential resource for the survival and advancement of human society. In the present world, ever increasing demand for water, environmental pollution, damaged eco-system, and threat of climate change are creating a strain on the availability and quality of this precious resource. According to UN, 2.1 billion people live without safe drinking water which seriously affects their health and livelihoods. Bangladesh being a riverine country with its economy and population heavily dependent on availability of water is facing a tough challenge. The impacts of climate change and weather variability including rapid depletion of ground water table, salinity intrusion and pollution of water sources are threatening the future availability and quality of water.

Achieving sustainability in water sector means its efficient supply with safety and reliability, its accessibility to all in an equitable manner, reliable sanitation for all and waterways protected from pollution. To face the challenges of sustainability of water we need to act nature wise and become water wise. Nature always reinvents itself with novel solutions and there is a lot we can learn from it. Resilience, efficiency and quality are the three elements of a sustainable water future. Resilience and adaptive planning, innovations in science and technology, incorporation of environment with development projects, integrated water management system, application of water sensitive design are the key elements in achieving a sustainable water future.

Planning and planting trees, reconnecting rivers to flood plains, restoring and conserving wetlands and eco-systems and reducing pollution will rebalance the water cycle and improve human health and livelihoods. Green infrastructures can provide green spaces, reduce heat island effects and enhance bio-diversity and ecological resilience. Harvesting of rainwater for domestic and industrial use can be an alternative source of water. Reusing and transporting water in a cost-effective and safe manner can contribute considerably to the availability of water. Water use efficiency in agricultural sector may be increased by efficient irrigation systems. Further measures may include promoting development of draught/salt tolerant plants, appropriate water treatment and adopting practices that benefit both water quality and environment. In the urban sector, high efficiency water saving plumbing appliances, water efficient landscapes, leak detection and management processes should be encouraged. Depending upon the priorities and end use, grey water recycling may be promoted. Water sensitive urban design in storm water management promotes permeable areas as well as groundwater recharge. Development projects should not obstruct the natural waterways, instead they should facilitate drainage, remove water logging and increase crop yield. Reduced consumption of chemicals in the industries, chemical fertilizer and pesticides in agriculture means less pollution that improves the quality of water and harnesses the eco-system. There is only a limited amount of water, a precious natural resource, and we must find ways to use it responsibly and sustainably, so that there is enough for our future generations to come.

Contents

ESTIMATION OF RUNOFF OF DHARLA RIVER BASIN USING GSMAPSATELLITE ESTIMATED PRECIPITATION DATA

B.Sen[1*] & M. A. Islam[2]

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**Corresponding Author*

ABSTRACT
Hydrologic models have emerged as a basic tool for studying real processes in a watershed hydrologic system responding to various climatic forcing. Bangladesh has been formed as the greatest deltaic plain at the confluence of the Ganges, Brahmaputra and Meghna and is highly vulnerable to climate changes. For this reason, study on hydrologic model is very important for Bangladesh. To set up a hydrological model and to determine discharge of the outlet of Dharla river basin using Satellite Estimated precipitation data are the main objectives of this study. In this study, hydrologic model of Dharla river basin with drainage area of 6120 sq.km is developed using HEC-HMS. Flash flood, Monsoon flood and bank erosion are some common issues with this river basin. A lumped hydrological model is developed using HEC-HMS to simulate precipitation-runoff process. SRTM 90m resolution DEM is used for delineation of basin which is downloaded from CGIAR-CSI. River network is digitized by Google Earth. Arc map 10.1 is used for watershed delineation. In place of gauge rainfall, satellite estimated rainfall data is used. The Japan Aerospace Exploration Agency (JAXA) provide hourly data of precipitation in 0.1× 0.1-degree resolution observed by satellite. The simulation result is checked after real time data provided by BWDB at Kurigram station. The value of correlation coefficient (R^2) for calibration period (2009-2012) and validation period (2013-2014) are 0.71 and 0.81 respectively. From six-year model simulation, it is found that peak discharge occurred at 2 August, 2014. The value of peak flow is 4515.4 cumec. At the time of peak flow, volume passes through outlet is 38928 million m^3.From calibration and validation graph we can see that the model gives satisfactory result at dry period. At the time of high discharge, model result shows more deviation from observed data. So, GSMaP is more reliable at dry season.

Keywords: Hydrologic model; HEC-HMS; GSMaP; Satellite Estimated Precipitation; JAXA; SRTM DEM.

INTRODUCTION
Bangladesh is a riverine country. Due to its location in the low-lying deltaic floodplains at the convergence of three Himalayan Rivers, heavy monsoon rainfall concomitant with poor drainage often results in annual flooding. The river systems drain a catchment area of about 1.72 million sq. km. The floodplains of the rivers are home to a large population, most of which is rural and poor, whose life is linked to the flooding regime. It is very important to study on every river basin of Bangladesh. By this study, we can acquire knowledge about types, time and duration of flood around this region. Flood is a common phenomenon in this part of the world. It has effects on food security, ecology, biodiversity, river flows, water security, human and animal health etc.

Study Area
Dharala river basin is at north-west region of Bangladesh. It is a trans-boundary river, which originates from the Himalayas where it is known as the Jaldhaka River. Then it flows through the Jalpaiguri and Cooch Behar districts of West Bengal, India. The river enters Bangladesh through the Lalmonirhat District and flows as the Dharla River until it joins with the Brahmaputra River near the Kurigram District. The river basin has about 6000 sq.km area from which about 70% is at India. So, it is hard to get observed data from India. In this study, satellite generated precipitation data is used to avoid this difficulty.

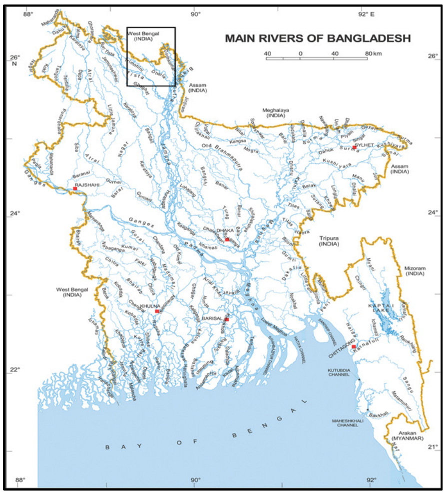

Figure 1 Location of study area at map of Bangladesh. (490km×645km)

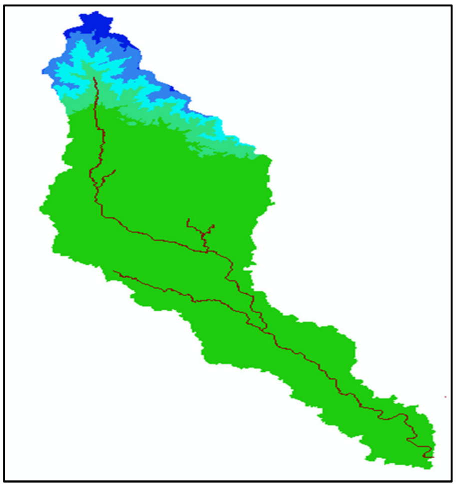

Figure 2 Clipped DEM with river network and sub-basin shape file.

DATA COLLECTION

Digital Elevation Model

To delineate watershed for Dharala river basin, digital elevation model (DEM) is downloaded from CGIAR-CSI GeoPortal (Source: http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp). The CGIAR-CSI GeoPortal is able to provide SRTM 90m Digital Elevation Data for the entire world. After downloading the SRTM digital elevation data, watershed delineation is done by ArcMap 10.1. After delineation shape file of stream network and sub-basin is found. Projection system of these shape file is Bangladesh Traverse Mercator. The clipped DEM and river network are shown in Figure 2.

GSMaP Rainfall

GSMaP stands for Global Satellite Mapping of Precipitation. The GSMaP project was promoted for the study "Production of a high-precision, high-resolution global precipitation map using satellite data", sponsored by Core Research for Evolutional Science and Technology (CREST) of the Japan Science and Technology Agency (JST) during 2002-2007. Since 2007, GSMaP project activities are promoted by the JAXA Precipitation Measuring Mission (PMM) Science Team.

Table 1: Description of GSMaP data

Variable	Rainfall rate (mm/hr)
Domain	Global (60N - 60S)
Grid resolution	0.1 degree latitude/longitude
Temporal resolution	1 hour

Evapotranspiration

Evapotranspiration data of Kurigram and Thakurgaon station been collected from IWM.

Water Level and Discharge

Water level and discharge data are collected from Bangladesh Water Development Board (BWDB). At the outlet of Dharala river basin, Kurigram station is situated which is numbered as station no.77.

GSmap Precipitation Data Analysis

GSMaP data is processed to obtain daily rainfall data. The downloaded data is compressed file in grid format. First, compressed zip file is expanded. Then, required data for specific catchment is picked from gridded file by using C++ program provided by JAXA. In the downloaded file, the precipitation data is in millimeter per hour unit. But, for use in the model data is converted into inch per day unit. Values of all grid point within a catchment are added to get gauge reading with unit gauge weight. From previous study, it can be seen that GSMaP rainfall are under simulated for every catchment of north-west region of Bangladesh (Sultana *et al,* 2009).

Model Run

Each run is composed of one basin model, one meteorological model and one control specification. After provision of all required parameters it is needed to manage and execute runs. By selecting compute in run manager menu option simulation run is created. The model is run for a year with output time interval of one day.

Calibration of Model

Before the application of any model, it is necessary to calibrate it with the observed data. Model Calibration is a process of comparing the model to actual system behavior until model accuracy is judged to be acceptable. Method used in this study are Simple Canopy, Simple Surface, Soil Moisture Accounting Loss, Clark Unit Transform and Linear Reservoir Base Flow. Each method in HEC-HMS has parameters. Some of the parameters may be estimated by observation and measurements of stream and basin characteristics, but some of them cannot be estimated. When the required parameters cannot be estimated accurately, the model parameters are calibrated by creating optimization trial. The model is calibrated using the observed discharge data of Kurigram station from January 2009 to January 2012. After optimizing the parameter, the value of Correlation Co-efficient (R^2) is 0.71.

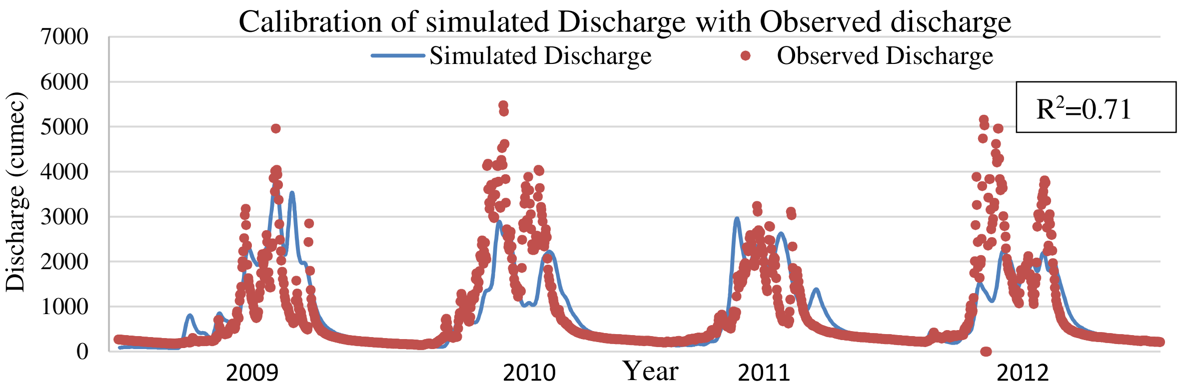

Fig. 3. Observed and Simulated discharge at the outlet of the Dharala basin

Validation of Model

Model validation demonstrates the capability of the model to produce accurate predictions for periods outside the calibration period. Model validation for this study was used to determine the effectiveness of the calibrated parameters in predicting the flow discharges at Kurigram station of Dharala River for the period 2013-2014.

From calibration and validation graph, it can be realized that validation graph shows more variation than calibration graph. With time, this variation increases. For example, in year 2013 peak flow occur at 23 July (2987 cumec) in simulated result where observed data shows that peak occurs at 11 July (4962 cumec). Again in year 2014, peak flow occurs at 8 August (4361 cumec) in simulation where observed data shows that peak flow occurs at 28 August (5920 cumec). It shows more variation in both time and discharge.

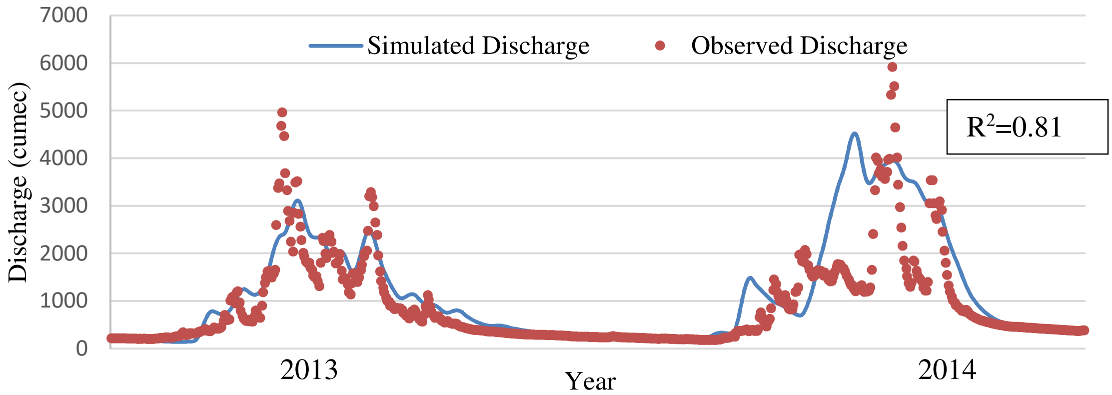

Fig. 4: Observed and Simulated discharge at the outlet of the Brahmaputra basin for validation period.

RESULTS:

- The value of correlation coefficient (R^2) for calibration period (2009-2012) and validation period (2013-2014) are 0.71 and 0.81 respectively.
- After simulation, it is seen that observed outflow is generally greater than simulated outflow. So, GSMaP gives underestimated precipitation value compered to observed value. This observation also proved in previous study relating GSMaP.
- From calibration and validation graph we can see that the model gives satisfactory result at dry period. At the time of high discharge, model result shows more deviation from observed data. So, GSMaP is more reliable at dry season.
- From six-year model simulation, it is found that peak discharge occurred at 2 August, 2014. The value of peak flow is 4515.4 cumec. At the time of peak flow, volume passes through outlet is 38928 million m^3.

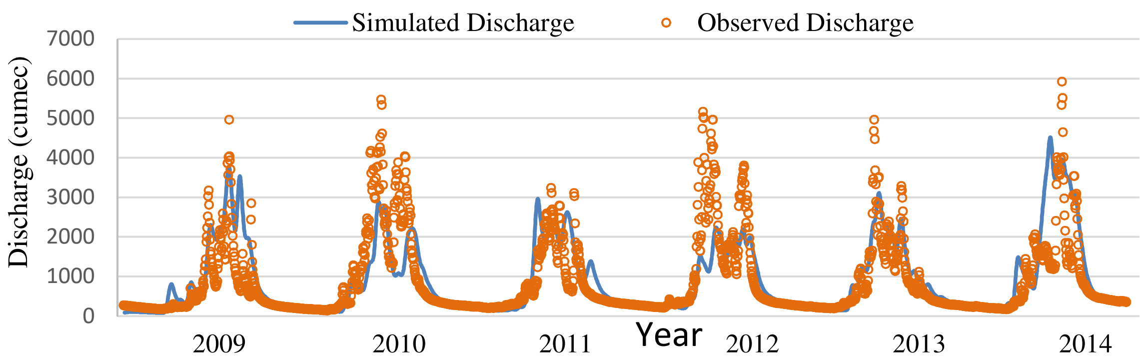

Fig. 5. Comparison of simulated discharge vs. observed discharge for year 2009-2014

RECOMMENDATIONS AND DISCUSSION

- Basin parameters are adjusted by several trials considering the effect of one component on others. Calibration can be more effective and give much better result if each parameters are adjusted corresponding to each sub basin. This process may be time-consuming and requires in depth knowledge of each parameters and their correlations in basin hydrology.
- Observed discharge data were very much insufficient for developing a rating curve of Kurigram Station. This was very crucial for calibration and validation of model. So a better rating curve equation shall obviously increase the performance of the model.
- River system designed in basin model of HEC-HMS is straight line. But rivers are not close to straight. It will be more realistic if river can be drawn with its natural bend.
- Working with satellite data is very complex and time consuming. On the other hand, real time data of transboundary river is very difficult to get and is not continuous. So, we should find more reliable way to relate satellite data with observed data.

- The model is simulated for six years. But longer time period may be used for further analysis on the availability of data.
- Several studies can be made using this model in future. These includes, but not limited to, effects of land use on flow, effects of any upstream development such as construction of dam, urbanization etc.

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METEOROLOGICAL DROUGHT MONITORING USING SATELLITE IMAGERY: ACASE STUDY ON RAJSHAHI, NAOGAON AND JAIPURHAT OF BANGLADESH

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ABSTRACT
Drought is considered as one of the major natural hazards that affect the environment and economy of a country. Different from other natural disasters, drought events appear slowly in time and their impacts generally span over a longer period of time. Weather data alone is not sufficient to monitor and evaluate the areas of drought, particularly when those data are rare and incomplete. Enhancement of weather data with satellite images to identify the location and severity of droughts are important for complete, up-to-date and comprehensive coverage of current drought conditions. The objective of this research is to monitor and understand meteorological drought using Standard Vegetation Index (SVI) and Vegetation Condition Index (VCI). Another objective is to measure the accuracy of two method's result by analyzing the changes in precipitation data. For this, SVI and VCI are derived from EVI and NDVI, which are obtained by analyzing MODIS (moderate-resolution imaging Spectroradiometer) data at 250m spatial resolution during July and August month of each year from 2000 to 2016 at 2 years interval. The study result shows the percentage of area affected by drought and its severity on the selected years. It also helps to understand how vegetation condition is being changed over time.

Keywords: Drought; MODIS; NDVI; VCI; SVI; EVI and Remote Sensing.

INTRODUCTION

Drought is one of the major threat to natural hazards which occurs at the time when the amount of precipitation is insufficient than the demands of natural habitats and the environment. The North-Western part of Bangladesh has been experiencing extremely hot weather and frequent drought conditions compare to the other parts of the country (Hassan & Mahmud-ul-islam, 2013).Especially, the districts under Barind Track suffer from frequent draught every year. The groundwater scarcity reveals that water level is declining gradually year-by-year, which creates the drought intensity higher (Shahid & Hazarika, 2006). Unfortunately, drought condition has received less attention and has less scientific research work compare to other calamities like flood or cyclone. The impact of drought can be much higher and can occur greater loss than flood, cyclone and storm surge (Alam et al., 2012; Paul, 1998; Shahid, 2008). For example, Drought incurred a huge loss of crop production in the country during the year of 1978-79, 1982 and 1997 (Paul, 1998; Ramsey et al., 2014). So, it is urgent to research more on drought and using scientifically method to get accurate scenario. Other than in-situ data, Remote sensing is a promising technology to monitor drought condition. In this paper it has aimed to reveal drought scenario through satellite imageries.

METHODOLOGY

Data Collection

To monitor the meteorological drought, two weeks maximum value composites (MVC) of NDVI from MODIS Imagery (for the year 2000, 2002, 2004, 2008, 2012, 2014 & 2016 in the month of July and August) along with land cover map have been used. The data is freely available to be downloaded from the Oak Ridge National Laboratory Distributed Active Archive Center (ORNLDAAC).For calculating SVI, we have used the Enhanced Vegetation Index (EVI) based on MODIS data at 250m spatial resolution as input. The only MODIS product providing EVI data is MOD13Q1 (on Terra satellite) and MYD13Q1 (on Aqua satellite). Here we have worked with the EVI band of MOD13Q1.The land cover map is made in ArcGIS software from Landsat 8 images. Unsupervised classification method was used to classify the region into to 3 land cover classes. Since, the main objective of the current study is to monitor meteorological drought impacts on natural vegetation (rain fed, rangeland& forest), these three classes were classified from the land cover map. Then, 3 land cover classes are reclassified into two classes: range land (value o) and non-Range land (value 1)**.** Also, precipitation data has been collected from "Bangladesh Water Development Board" to analysis objective two.

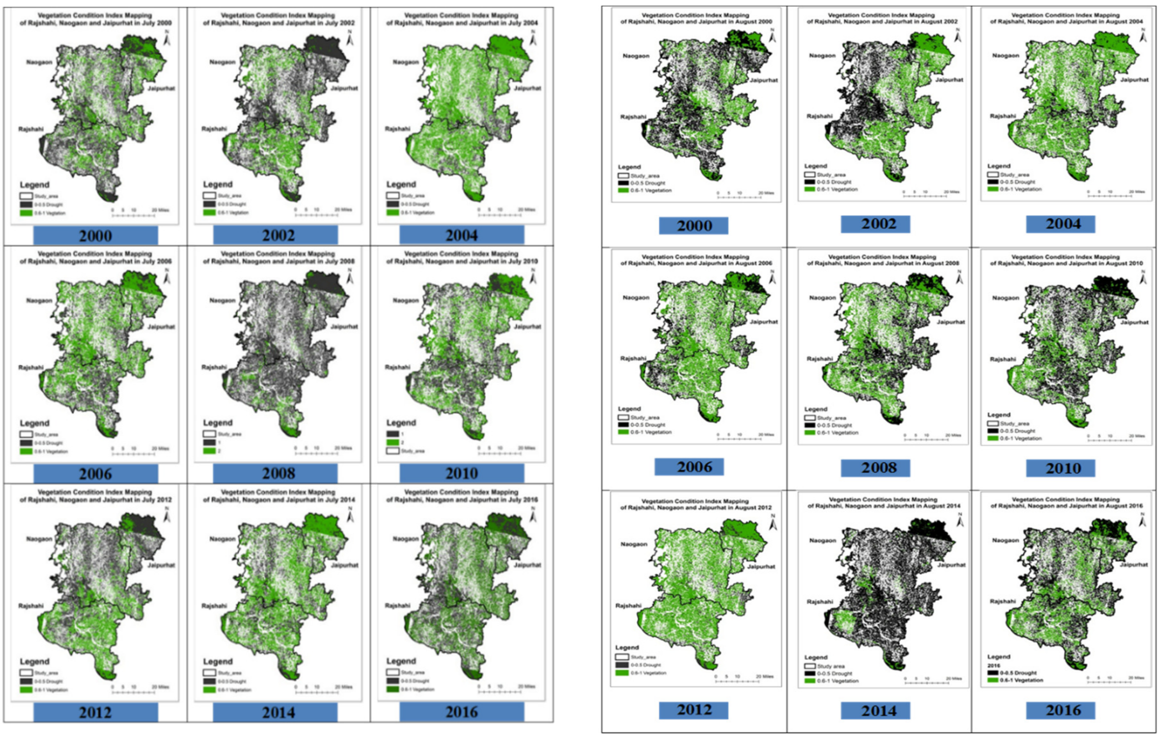
Data Preparation and Processing for Calculating VCI

The Data analysis for calculating VCI has been divided into three phases as follows:

- Data processing using ENVI software
  Step-1: Band math recalculation to value-1 to 1 and recalculating from MVC values to NDVI value range
  Step-2: Layer stacking (composition of nine maps to one map) and change map projection
  Step-3: Resizing the NDVI-MVC images to the study area
  Step-4: Masking out data with the study area
  Step-5: Masking out 'not vegetation' data via land cover data
- Calculating Vegetation Condition Index using the Eq. (1) given below;

$$\mathbf{VCI= (NDVI_{cur} - NDVI_{min}) /(NDVI_{max} - NDVI_{min})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

- Visualization and Analysis in ArcGIS software



July **August**

Fig.1: Vegetation Condition Index Mapping of Study Area (2000-2016)

Data Preparation and Processing for Calculating SVI

Following steps have been followed to calculate SVI

Step 1: MOD13Q1 EVI HDF (time series) data have been converted into GeoTIFF using the software named MRT (MODIS reprojection tools).

Step 2: In this step, data have been prepared for automatic map generation. It includes creating one folder where all converted data has been stored. Then each of day of the year (DOY) data has been renamed manualy or using total commander software. This will help to choose the relevant data for the region of interest.

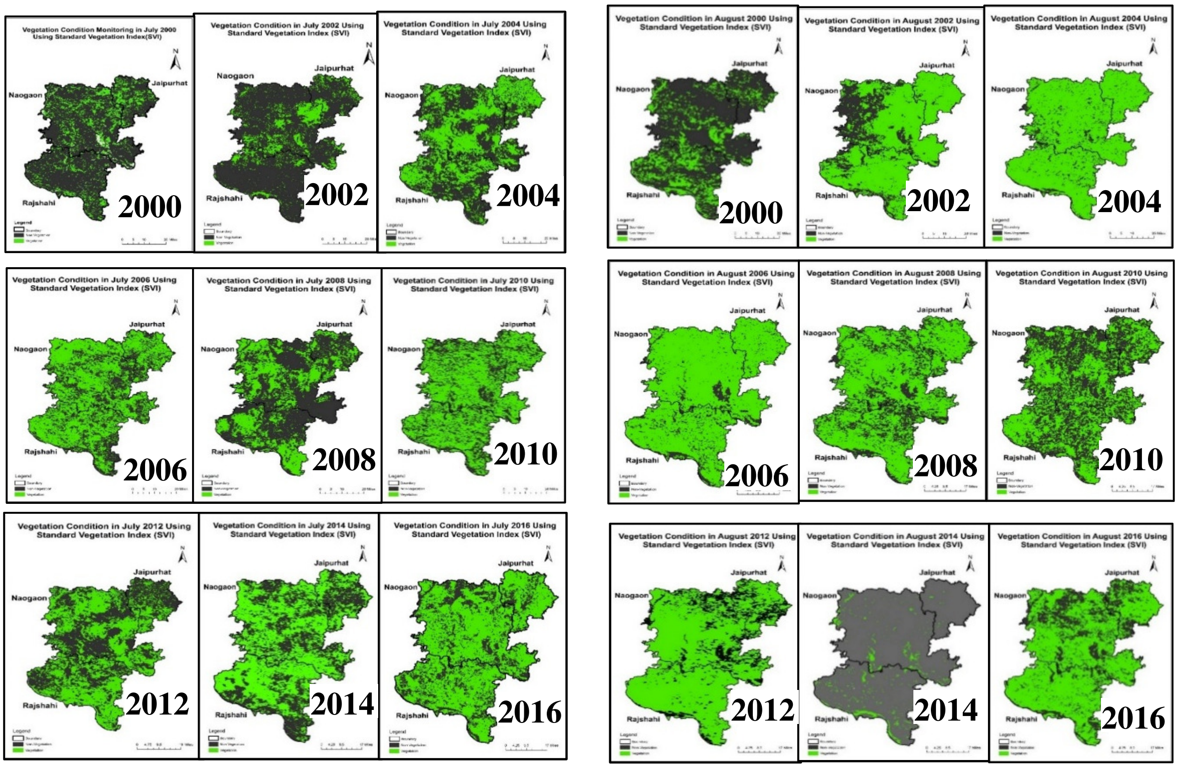
Step 3: Here layer stacking for each DOY, has been resized and masked with country shape file.

Step 4: It includes rescaling and set fill values and invalid data range to NA.

Step 5:After that, mean and standard deviation of Enhanced Vegetation Index (EVI) has been calculated. Then, standard vegetation index has been calculated using the following formula

$$SVI = (EVI-EVI_{mean}) / EVI$$

R-studio software has been used to complete step 5 and ArcGIS software has been used in order to visualize the obtained map



July **August**

Fig.2: Standard Vegetation Index Mapping of Study Area (2000-2016)

RESULT AND DISCUSSION

Data has been analyzed according to objective 1 and 2. These are discussed below:

Analysis of Objective- 01

Yearly drought scenario in terms vegetation growth (following VCI and SVI method) for the month of July and August have been presented in the Fig.1 and Fig.2. A comparison of vegetation area changes has been also presented in the Table 1.From the above of Table-1.it is seen that the vegetation growth is comparatively low in the year 2000, 2002 and 2008 from other years in July. It is also seen that the vegetation growth is comparatively low in the year 2000, 2010 and 2014 from the other years in August.

By this, it is very difficult to understand the severity of drought by finding out the lower vegetation growth in July and August. To solve this problem, the vegetation growth of two months by each method is ranked according to the lower vegetation to higher vegetation. That means the ranking is provided from 1 to 9 which actually denotes to lower vegetation to higher vegetation. Besides, lower vegetation indicates the higher severity of drought. So, the ranking 1 to 9 also means the higher severity of drought to lower severity of drought in that area.

Table1: Difference between VCI and SVI and their ranking

Year	**Vegetation Area (%) in the month of July**		**Vegetation Area (%) in the month of August**		**Two months Average Vegetation Area (%)**		**Vegetation Area Ranking**	
	VCI method	SVI method	VCI method	SVI method	VCI method	SVI method	VCI method	SVI method
2000	36.85	20.14	37.07	24.37	36.9556	22.25464	3	1
2002	32.33	16.77	50.29	75.08	41.30876	45.92453	4	3
2004	80.97	47.99	76.67	91.24	78.81895	69.61492	9	7
2006	57.99	64.27	70.30	88.67	64.14788	76.47132	7	9
2008	11.88	38.07	56.51	73.52	34.19813	55.79581	1	4
2010	48.72	68.20	38.36	52.63	43.5397	60.41485	5	5
2012	41.84	52.01	87.46	82.23	64.65103	67.11993	8	6
2014	63.82	59.56	9.31	4.73	36.56201	32.1464	2	2
2016	61.28	72.01	45.75	74.79	53.51723	73.39991	6	8

It is seen that the VCI and SVI are ranked from 1 to 9 separately. VCI and SVI rankings are respectively 3 and 1 in 2000, 4 and 3 in 2002, 1 and 4 in 2008 and 2 and 2 in 2014. Other VCI and SVI rankings are 5 or above 5 which denote higher vegetation. As the lower vegetation's were in 2000, 2002, 2008 and 2014 according to ranking, those years could be higher drought severity in the study area.

Analysis of Objective- 02

According to vegetation condition index method and standard vegetation index, the vegetation condition data is compared to the precipitation data. On the following Table-2, drought severity is ranked using the value from 1 to 9; where the value 1 means severe drought condition, on the contrary value 9 means less severity of drought that means vegetation condition is very good. In this case; percentage of vegetation condition obtained by standard vegetation index and vegetation condition index and amount of average rainfall during July and August month is used. The result showed that 2000 and 2014 are the two years when drought severity was the most compared to the other years in the studied area.

Table 2: Ranking of drought severity based on precipitation data, standard vegetation indexand vegetation condition index (Average value for the month of July and August has been considered)

Year	**Precipitation (mm)**	**Vegetation Area (%)**		**Drought Ranking**		
		VCI method	SVI method	VCI method	SVI method	Precipitation
2000	181.25	36.9556	22.25464	3	1	2
2002	280.7	41.30876	45.92453	4	3	7
2004	300.05	78.81895	69.61492	9	7	8
2006	209.05	64.14788	76.47132	7	9	4
2008	381.65	34.19813	55.79581	1	4	9
2010	164.7	43.5397	60.41485	5	5	1
2012	275.5	64.65103	67.11993	8	6	6
2014	201.3	36.56201	32.1464	2	2	3
2016	254.65	53.51723	73.39991	6	8	5

Following findings are obtained after analyzing the data;

- According to the analysis of objective one, the lower vegetations were in 2000, 2002, 2008 and 2014 where 2000 and 2014 were more drought severe years according to objective two.

- As 2000 and 2014 being common years according to the analysis of objective one and two, were the most drought-prone years with respect to the precipitation data of the studied area
- At that year's precipitation was comparatively low than the other years that means vegetation growth condition was low. As the precipitation rate was low during monsoon season in 2000 and 2014, it caused drought in the study area. Its effect might fall on the next year too.

For future meteorological drought monitoring and identifying its severity; following recommendation can be given;

- Conducting the prediction research on precipitation anomalies, soil moisture condition, evapotranspiration in future will help in monitoring drought through the understanding of vegetation.
- VCI and SVI can be two effective methods to measure the severity of drought in future.
- This type of research for investigating the drought severity should consider more factors, such as human activities, temperature, and so on for the more accurate result.

CONCLUTION

This research has explored the influence of precipitation anomalies on vegetation. By understanding the relationship between Standard Vegetation Index, Vegetation Condition Index, and precipitation anomalies, the potential impacts of drought on vegetation, especially in barind regions are estimated. The quantitative analyses presented in this study have illustrated the relationship between precipitation and vegetation. This paper highlights an overall approach to meteorological drought monitoring using satellite imagery and GIS techniques. Though there remains some limitation in our research, it is expected that these can be minimized by subsequent contribution and future development of science.

ACKNOWLEDGEMENT

We would like to express our profound gratitude to Bangladesh Water Development Board for providing precipitation data which helps us to analyze and compare the drought scenario derived from satellite images.

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A GIS BASED SPATIAL ACCESSIBILITY ASSESSMENT OF RURAL SANITATION FACILITIES

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ABSTRACT
Sanitation is very essential and vital part of our daily life. In Bangladesh the sanitation quality is low in the Northern region and it is going to face severe condition of sanitation which has a direct negative impact on our physical health as well as mental health. This study aims to analyse the accessibility to sanitation in rural areas. For the purpose of carrying out the study we used both primary and secondary data. Primary data was collected with the help of questionnaire survey through random sampling method and secondary data was collected from various authentic national sources. The collected data was analysed through various statistical, geographical computer application like SPSS, ArcGIS 10.2 etc. The study reveals severe conditions in terms of accessibility with least spatial variation. From this study we found that only 21% people have personal sanitary toilet and 44% people have no proper toilet facilities. This study analysed that more than 70% toilets are near to water sources which eventually contaminate the water. Pond water is used for other household activities even washing plate, bowl etc. The awareness of the mass people should be increased for safe and sustainable water and sanitation accessibility.

Keywords: Random Sampling; SPSS; ArcGIS; Gini Index.

INTRODUCTION
Sanitation is defined as 'the provision of facilities and services for the safe disposal of human urine and faeces' (Norstrom, 2007). Sanitation differs from hygiene in that it provides the means for people to be hygienic. Sanitation is important for all, helping to maintain health and increase life-spans. However, it is especially important for children. Around the world, over 800 children under age five die every day from preventable diarrhoea-related diseases caused by lack of access to water, sanitation and hygiene (WHO, 2013). Sanitation is a concept that is thought to define a single definition as a result of its complex nature (Allen et al., 2006). Though there are different definitions of sanitation, solid and liquid wastes are at the centre of all the definitions since they have been major problems confronting not only sprawling communities but towns of the world in general (Ayee and Crook, 2003). In the study area named Mundumala Paurashava, most of the people are suffering from the lack of the sanitation facility. Objectives of the study are to identify the present situation and seasonal characteristics of sanitation status to identify the major factors which affect the hygienic sanitation facilities. The study focuses on the finding accessibility sanitation facilities. This study has covered nine wards of the Mundumala Paurashava. The sanitation quality, water borne diseases also has been assessed in this study.

STUDY AREA
The study area has been selected on the basis of two parameters. The parameters are Reconnaissance Survey and Rationality analysis. First the researchers completed reconnaissance survey and then use Rationality analysis for completing this task.

Reconnaissance survey was carried out in three upazilla such as Nchole, Godagari, and Tanore upazilla. From the reconnaissance survey we found severe condition in Mundumala Pourosova which is situated inside the Tanore upazilla. They are to suffer from lack of drinking water. They haven't enough water source for available water. They have to collect water from long distance and use pond water for household activities. Second, rationality focuses on the identification of strong and weak points within an organization, community and the analysis of opportunities for, and threats to, further development. It identifies the basis behind the selection of the study area, fruitfulness of the study as well.

Sample Size Calculation

We determined the sample size based systematic random sampling method. We considered 95% confidence with 5% interval. From that we got total sample size about 357. In this case we collected 360 data for analysis. Once the cluster villages and mahall as were selected, we asked the residents to assist in determining centre points of each village/mahalla, and commenced with the eligible household nearest to the centre point. We skipped the nearest two households and determined the next nearest eligible household.

$$n = \frac{N \times X}{X + (N-1)} \quad (1)$$

$$X = \frac{z_{a/2}^2 \times p \times (1-p)}{E^2} \quad (2)$$

Where,

n = Sample Size

N= Household Number

$z_{a/2}$= Critical Value for Normal Distribution (for 95% confidence level, its value is 1.96).

P= the sample proportion (50%).

E= Margin of Error (5%).

RESULTS AND DISCUSSIONS

Spatial Accessibility of Sanitation facilities

It is the means of promoting hygiene through the prevention of human contact with hazards of wastes especially faeces, by proper treatment and disposal of the waste, often mixed into wastewater (WaSH, 2005). These hazards may be physical, microbiological, biological or chemical agents of disease. Wastes that can cause health problems include human and animal excreta, solid wastes, domestic wastewater (sewage), industrial wastes, and agricultural wastes (Awutu-Senya East Municipal Assembly, 2013).

Regional Disparity on the Distribution of Sanitation Facilities

This section identifies the ward wise regional disparities on the functional water source distribution. This analysis is undertaken by the Gini Index. The Gini Index represents the cumulative relationship among households and facilities. The table below shows the calculation & household-water source cumulative expressions.

The table shows that the cumulative percentage of sanitary and household is lowest at ward no.01. The cumulative percentage of sanitation at ward no.01 is about 7.12 and household is about .13. The lowest cumulative percentage represents the least amount of sanitation facilities serves the highest amount of household. That means only 1 sanitary facility serves about 8 households. The cumulative percentage of sanitation and household is largest at ward no. 03. The amount of sanitary facilities exists in ward no. 03 about 216 to serve about 718 people. That means 1 sanitary toilet serves about 3.5 households which indicates better situation the ward no.01 having the least cumulative percentage.

We developed a Lorenz curve based on the field data [Fig.1] and find the value of Gini Index is **0.14.** In the Lorenz curve the X-axis & Y-axis represents the cumulative percentage of households & cumulative percentage of sanitary facilities. The value of 0.14 is the least value of Gini Index which implies that, there is very little regional disparity and analysing the sanitary facilities data in relation to the household extent implies that there is severe condition of sanitary facility availability in the all wards of Mundumala Paurashava.

Table 1: Gini Co-efficient Calculation on Sanitation Facilities Distribution

Ward No.	Household	Sanitary	% of HH	% of Sanitation	C % of HH	C % of Sani	C % of HH in Unit	C % of Sani in Unit
Ward 01	637	80	13.05	7.13	13.05	7.13	0.13	0.07
Ward 09	514	70	10.53	6.21	23.58	13.35	0.24	0.13
Ward 02	308	56	6.31	4.98	29.89	18.33	0.30	0.18
Ward 07	436	99	8.93	8.80	38.82	27.13	0.39	0.27
Ward 06	391	92	8.01	8.17	46.83	35.30	0.47	0.35
Ward 05	809	209	16.57	18.55	63.40	53.85	0.63	0.54
Ward 04	578	157	11.84	13.98	75.24	67.83	0.75	0.68
Ward 08	491	146	10.06	12.96	85.29	80.79	0.85	0.81
Ward 03	718	216	14.71	19.21	100	100	1	1

By observing the above table we get that there are only 1125 sanitary toilet in the Paurashava under 9 wards. But the total numbers of households are about 4882. If we consider a flat distribution (i.e. no regional variation as the Gini Index is least) among the wards of Mundumala Paurashava, we can get: 4882/1125=4.5(Approx.) households are dependent on a single water source & this situation is almost same in the all wards of Mundumala Paurashava.

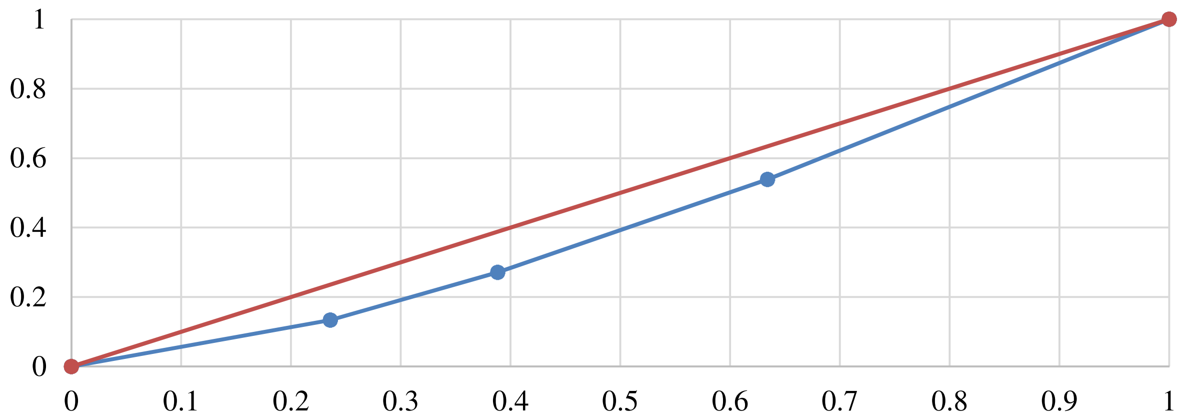

Fig 1: Lorenz Curve on Sanitation Facilities in Mundumala Paurashava

Toilet Quality

In the study area about 44% of total population use open toilet, as open toilet is very harmful to the environment. From the open latrines various germs are born and bound out many diseases. Only 21% of total population use personal toilet. About 35% of the total population use to share toilet to the other family as a result the toilet becomes dirtier. This can be represented by the figure 3. The 44% of the total population are using the open space like garden, bush etc. as latrines because of the lack of toilet facilities. Not only is the provision of human excreta facilities a priority, but more importantly the conditions of the facilities due to the health implications they have on users. According to MLGRD (2010), 'It is essential that human excreta disposal facilities are kept within minimum condition requirements for the avoidance of unwarranted eventualities through their use'. In spite of the innumerable positives effects of proper sanitation to mankind, residents of the area are bedevilled with one problem or another as a result of the difficulties in having access to toilet facilities.

Liquid Waste Disposal

Due to the sensitive nature of toilet facilities to mankind, discussions are that provision of human excreta disposal facility should be given prominence in any building endeavour geared towards accommodating people (MLGRD, 2010). In our study area the children don't use toilet (only 1%). About 55% of the family from total left the children's excreta in the open space. As a result some water borne disease brought out and the environment is getting pollution. About 27% of the total family use to throw the excreta in the garbage which is just outside space of a house. About 17% of the total population use to bury the children's excreta into ground. The figure 3 below represents the whole scenario of liquid waste disposal.

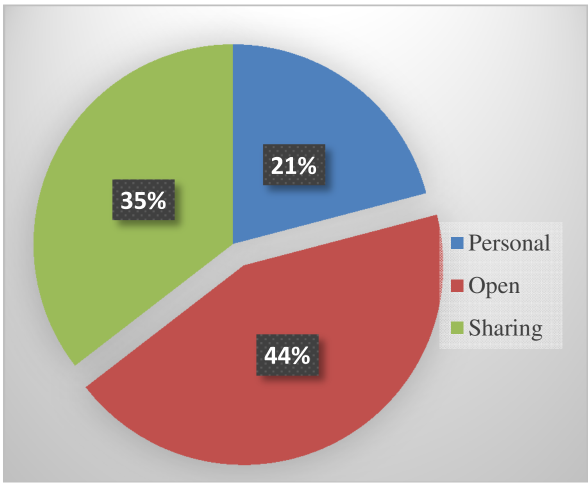

Fig. 2: Types of Toilet in Mundumala Paurashava

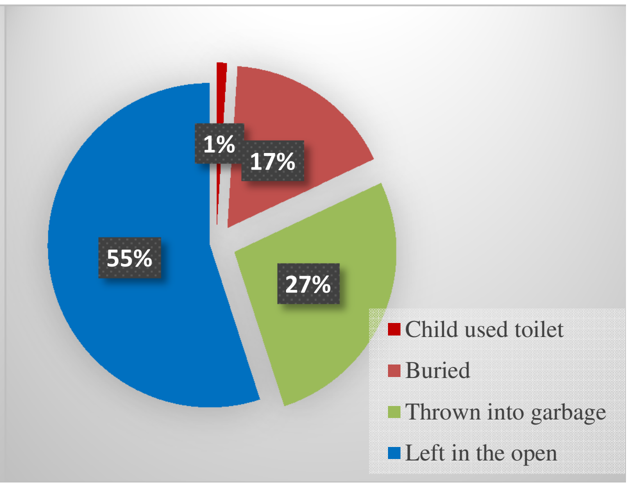

Fig. 3: Children's Excreta Management in Mundumala Paurashava

Solid Waste Disposal

Another major component of sanitation is the management of wastes. In the study area about 68% of the people through the solid wastes outside the house. As a result the wastes become decompose and make the environment polluted. About 24% of the population keep the household wastes in the garden which damage the fertility of the soil of garden. About 8% of the total population put the household waste on the street. As a result the accessibility of street is reduced.

Factors affecting the effective sanitation facilities:

It identifies the causes behind the non-sanitation facility & the hampers to cover the whole area. These are lack of public awareness, local environment, construction quality of the toilets and privatization of the sanitation facilities and water quality. These factors are identified based on the questionnaire survey between two types of peoples i.e. having water accessibility & do not have water accessibility. The researchers collected these data through field survey with direct questionnaire. The obtained data are then calculating the two-way contingency table tests for the independence of two variables. The two types of respondents are independence to answer the questions. Then the chi square test (Pearson,X^2) is calculated considering the significant at 5% and degree of freedom of 2. The chi-square (X^2) of these two respondents can be summarized throw the following table:

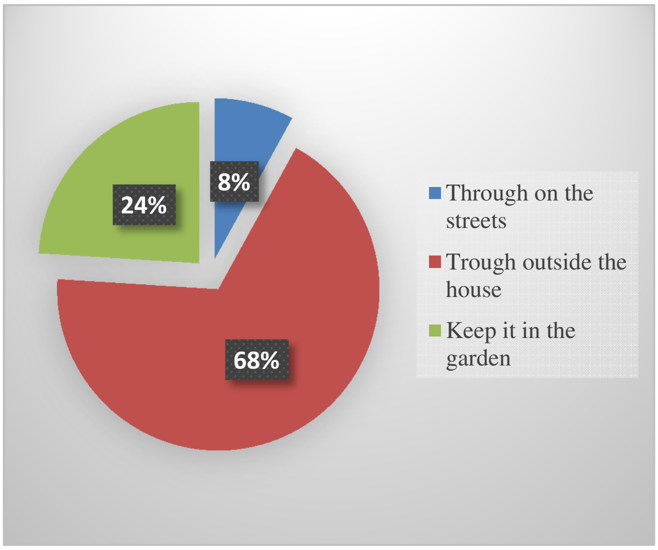

Fig. 4: Household Wastes Disposal System in Mundumala Paurashava

Table 2: Chi Square Calculation of Identifying Factors Influencing Scarcity

SL No	Factors	Respondents	Strongly Agree		Agree		Disagree		Total		χ^2
			No.	%	No.	%	No.	%	No.	%	
1	Local Environment	Have water access	108	60	58	32.2	14	7.8	180	100	2.16
		Do not have water access	121	67.2	46	25.6	13	7.2	180	100	
2	Lack of public awareness	Have water access	100	55.6	30	16.7	50	27.7	180	100	**3.51**
		Do not have water access	110	61.2	35	19.4	35	19.4	180	100	
3	Construction quality	Have water access	110	61.1	45	25	25	13.9	180	100	1.28
		Do not have water access	120	66.7	40	22.2	20	11.1	180	100	
4	Privatization of Sanitation Facilities	Have water access	90	50	80	44.5	10	5.5	180	100	1.19
		Do not have water access	100	55.6	70	38.9	10	5.5	180	100	
5	Water Quality	Have water access	120	66.7	45	25	15	8.3	180	100	1.41

ACKNOWLEDGEMENT

Firstly we would like to thank almighty Allah for giving us chance to finish this work. We also like to extend my sincere thanks to our teacher, parents and the people in the study area who helped at the time of field survey.

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INFLUENCE OF LAND COVER CHANGE ON LAND SURFACE TEMPERATURE USING RS AND GIS TECHNIQUES: A CASE STUDY OF GAZIPUR DISTRICT

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Abstract
Climate change has obtained more and more attention as the land surface temperature is getting high day by day. This being done as people are being attracted to live in urban area and this rate is increasing at an alarming rate. Gazipur which is situated beside Dhaka is one of the area which is experiencing rapid urbanization which is the main cause of urban heat island, decreasing of waterbody which will surely make a serious influence on regional climate, environment. This study represents integrated study of land cover changes between the periods and investigated their impacts on LST of Gazipur district by using Geographic Information System (GIS) and Remote Sensing (RS). In this study, remote sensing techniques were used to retrieve the land surface temperature (LST) and land cover change by using the Landsat Satellite imagery product. Landsat TM and ETM+ images from 1995 to 2015 are used as data source. The integration of remote sensing and GIS was further applied to examine the impact of land cover change on surface temperatures. Strong relationship is found between land surface temperatures over land cover classes. The result shows that waterbody is being decreased from 1206 Sq.km to 74 Sq.km. Result is same for vegetation land cover which also have decreased at an alarming rate. These areas are being converted into built-up an area which is increasing temperature. Over 10 years' temperature is changed from 26°C to 30°C.The results indicate that land surface temperature can be related to land cover classes in most cases. Vegetated and other natural areas enjoy lower surface temperature, than build up areas with little vegetation.

Keywords: Land surface temperature; land cover; change detection; urban heat island; climate change.

INTRODUCTION

Land is one of the most important resource from the first day human stepped on earth. With the passage of time land is being transformed from one type to another which is an extremely complex process, it is subject to the combined effect of a wide range of human activities, natural environment and economic environment and so on, all of that react on humans (Jianzhong et al., 2002; Station & Province, 2004). Urbanization is highly responsible to transform natural land surfaces into modern land which is consist of buildings, roads, and other impervious surfaces that affect the inhabitability of urban areas. This land use land cover changes leads to Urban Heat Island (UHI)(He et al. 2007) which causes temperature rise even 5-6°C surrounding the urban areas. UHI is defined as an environmental phenomenon where air and Land Surface Temperatures (LST) of urban areas are higher than those of its surrounding areas (Trenberth 2004). There are multiple factors which are responsible for the generation of UHI. Land cover change due to urbanization is the main driver for causing change in the LST because the quality, characteristics of each land type is different (Ahmed et al., 2013). However, this absorbed solar energy is re-radiated at night in the form of thermal infrared (Patz et al. 2005). Because of this, in a day, LST of a land cover type varies. In addition, this cross-sectional relationship between land cover types and LST also enabled researchers to investigate the impact of land cover changes on LST over time(Lo and Quattrochi 2003). This study has been intensified because of the variability of remotely sensed database and it focused on the past land cover change (Patz et al. 2005).

The aim of this study is to monitor and analyze the influence of land cover change on land surface temperature in Gazipur district using RS and GIS techniques for the years of 1995 to 2015

METHODOLOGY

The study area, Gazipur district of Bangladesh [Fig. 1] has been selected because migration of huge population is seen as because; it is very near to Dhaka capital city. It carries a good number of site for urban development center. As a result of population pressure and unplanned development, the local people are destroying forest, trees and valuable cultivable land for making various industries and brick fields etc. As a result, the forest area is gradually decreasing and the environment is changing significantly.

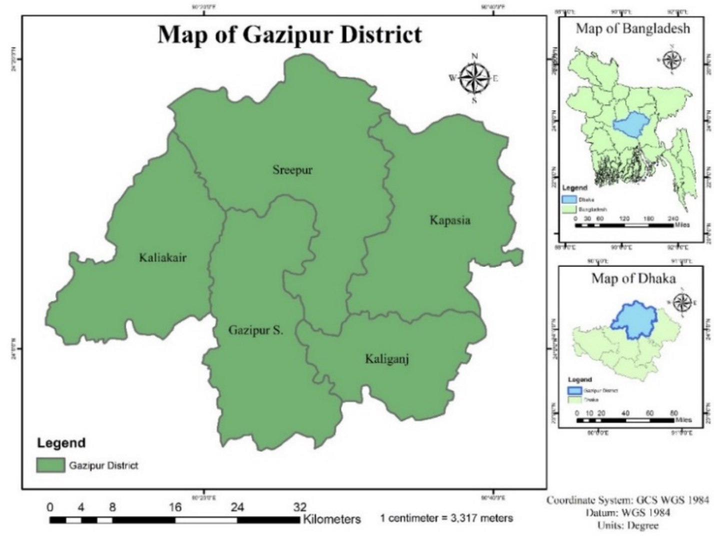

Fig. 1. Map of Study Area Location

For the study a consecutive methodology has been adopted. The estimation of impact of temperature on the land use has been done in several stages. For carrying the study TM and OLI TRS data of Landsat satellite imagery data is collected of three different years which is 1995, 2006 and 2015 and these data are taken of March-April month so that temperature of summer can be easily estimated. The cloud cover of all these data is less than 2%. After this the data is prepared for the analysis. The supervised classification used to determine the land use pattern of the study area. After supervised classification a conduction of accuracy assessment is done to assess the accuracy of the classification. Change detection is a process which has been done to estimate the change of land use in a time period such as a period of 5 years or 10 years. It actually determines what changes in land use the area undergo in a specific time period. After supervised classification this compared the resulting maps on a pixel-by-pixel basis using a change detection matrix to estimate the land use change of the study area in ten years 2000-2015.The one of the most important stage of the study to estimate the temperature from the prepared satellite image. This process is done into two steps.The first step is to convert the thermal band into radiance. Then the radiance is converted into temperature in Kelvin unit. Then temperature is again converted Kelvin to Degree Celsius. For Landsat TM image digital numbers DNs of thermal band (band 6) of were converted into radiance using the following Eq. (1)

$$T_{TM6} = \frac{V}{255}(R_{MAX} - R_{MIN}) + R_{MIN} \qquad (1)$$

Where V represents the DN of band 6 and

$$R_{Max} = 1.898(\mathrm{mW} * cm^{-2} * \mathrm{sr}^{-1}), \mathrm{R_{MIN}} = 0.1534(\mathrm{mW} * cm^{-2} * \mathrm{sr}^{-1})$$

And the second step, conversion of radiance into temperature in Kelvin T(K) was done by the following Eq. (2)

$$T = \frac{K_1}{\ln(\frac{K_2}{\frac{R_{TM6}}{b}} + 1)} \qquad (2)$$

Where, K_1=1260.56K and $K_2 = 607.66(\mathrm{mW} * \mathrm{cm}^{-2} * \mathrm{sr}^{-1} * \mu\mathrm{m}^{-1})$, b represents the effective spectral range and b=1.239(μm)

For Landsat OLI_TRS, at first, OLI and TRS band data can be converted to TOA using the following Eq. (3)

$$L_\lambda = M_L W Q_{cal} + A_L \qquad (3)$$

Where,
L= TOA spectral radiance($\mathrm{Watts/m^2 * srad * \mu m}$), M_L= Band specific multiplicative rescaling factor from the metadata, A_L= Band specific z rescaling factor from the metadata. Q_{cal}= Quantized and calibrated standard product pixel values (DN)
For converting spectral radiance to temperature following Eq. (3) is used

$$T = \frac{K_2}{\ln(\frac{K_1}{L_\lambda}+1)} \qquad (4)$$

Where
T= At satellite brightness temperature (K), L_λ= TOA spectral radiance($\mathrm{Watts/m^2 * srad * \mu m}$), K_1= Band-specific thermal conversion constant from the metadata (K_1_CONSTANT_BAND_x, where x is the band number, 10 or 11), K_2= Band-specific thermal conversion constant from the metadata (K_1_CONSTANT_BAND_x, where x is the band number, 10 or 11)
Temperature are derived in 'Kelvin (A)' which were converted into 'Degree Celsius (B)' using the following equation

B= A-273.15 (5)

The final stage of the study is the estimation of relationship between the land temperature impacts on the land use change.

RESULT AND DISCUSSION

From reclassified map of Gazipur for the year 1995 it can be said that the dominant land use of that time was vegetation. Almost more than half of the total area is covered by vegetation and water body. The other land use was open space and a very few portion of the area was build up area. From the land surface map of Gazipur for the same year, also this can be said that in the portion of the area which contains waterbody and vegetation has the lowest land surface temperature than other areas and the lowest land surface temperature at that time for Gazipur was between 22.08°C -23.82°C. The highest land temperature at that time was between 25.54°C-30.56°C which was the land used for buildup area and open space.

In 2006 reclassified land use map of Gazipur it is clearly evident that most the land of Gazipur at that time was vegetation which was most prominent land use at the year 2006. The other land use type which was dominating at that time was open space. The least land use of that year was waterbody and buildup area which was in a very insignificant portion of the whole area. The land surface map of Gazipur for the same year that means 2006 indicates that the dominant temperature of the most of the land of that time was moderate which was between 27.60°C -30.56°C and it was mainly temperature of those areas which has less dense vegetation and mostly open space. The lowest temperature was between 21.20°C -27.60°Cwhich is the temperature of area with dense vegetation and waterbody. The highest temperature contained land use at that time was some open space and buildup area which ranges 30.57°C -38.92°C.

From the land surface map of Gazipur for the year 2015 it can be said that in the portion of the area which contains waterbody and vegetation has the lowest land surface temperature than other areas and the dominant temperature of the of that year was low to moderate temperature which was between 17.65°C -23.98°C. The highest land temperature at that time was between 23.98°C -31.21°C which was the land used for buildup area and open space. Fig. 3 represented the percentage of land use and land cover change in different years in Gazipur. From the figure it can be said that there is an increase of vegetation in this period of time. Vegetation increased in 2015 in 14.9% than 1995. A huge decrease in the waterbody in this time period where in 1995 there is 42.45% waterbody which reduce to 3.59% in 2015. There is also reduction in open space though it increases in 2006. A very small increase of buildup area was found in this time period.

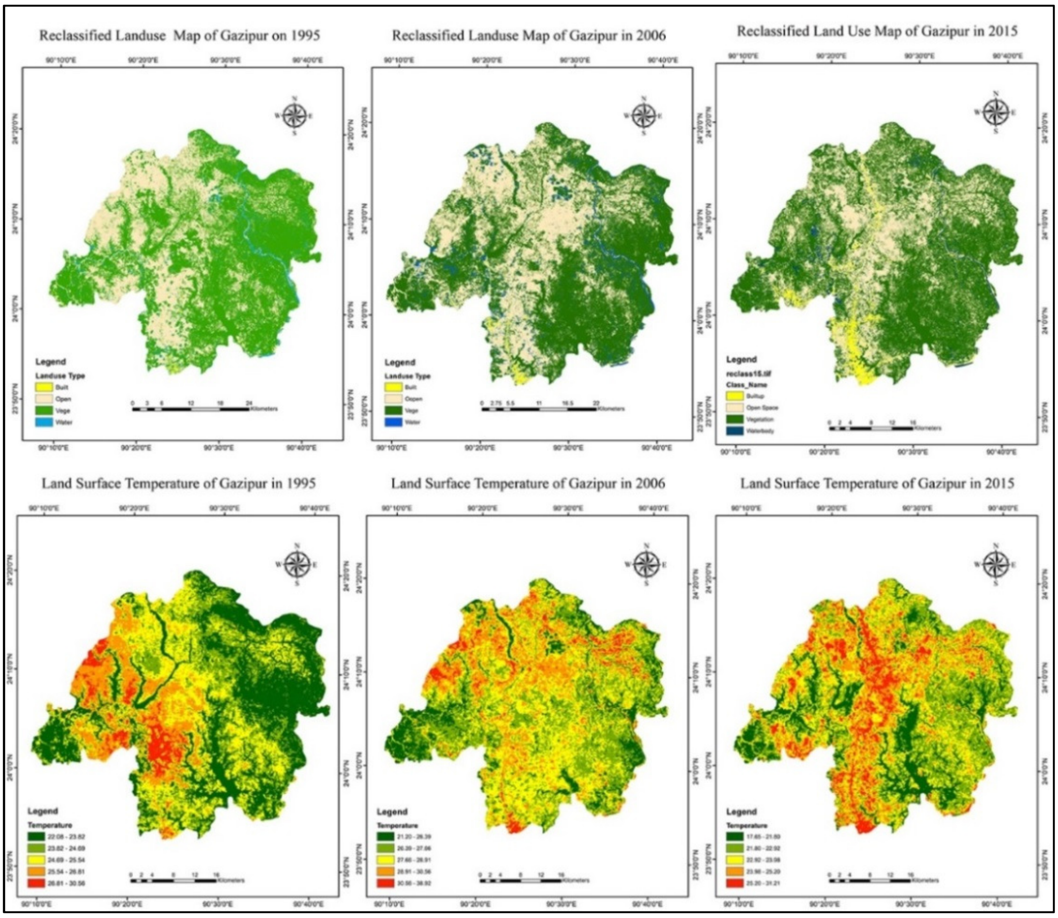

Fig. 2. Land use land cover and Land Surface temperature map of Gazipur from 1995 to 2015

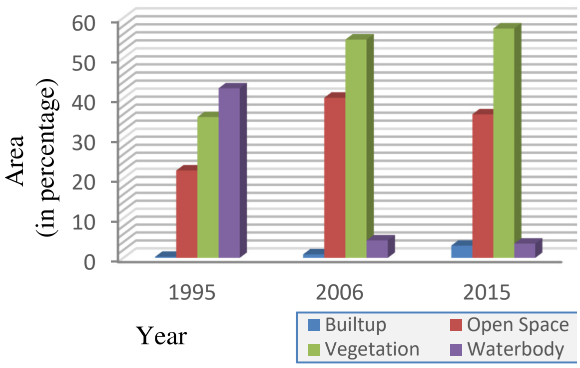

Fig. 3. Percentage of different LULC type

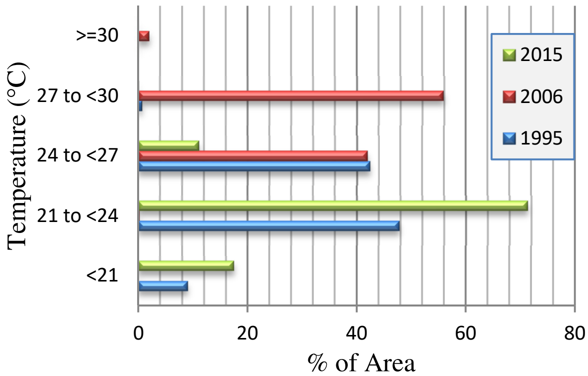

Fig. 4. Changing pattern of heat zone in Gazipur

Fig. 4 shows the changing of heat pattern zone in Gazipur. From the figure it can be assumed that in the year 1995 temperature of most of the area was remain between 21-27°C. In 2006 the land surface temperature of most of the area was between 24-30°C. In 2015 the land surface temperature of most of the area was between 21-24°C.

The land use change map and Table 1 showing the total area of change land use of Gazipur in between 2006-2015 that means land use change for a time period of 10 years. In this time period the most prominent land use change in this period is vegetation to open space which is about 780702 sq. km of the area**.** The dominating land use change is vegetation to buildup area which covered almost 261528 sq. km area and open space to vegetation which is about 202262 sq. km.

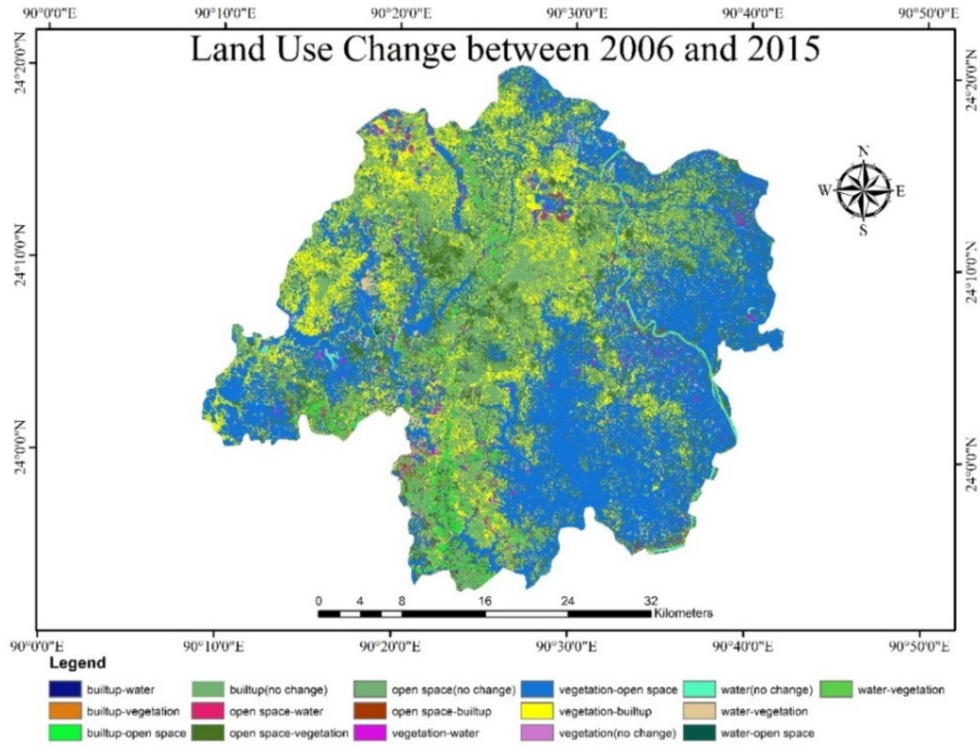

Figure 5: Land Use Change between 2006 and 2015

Table 1: Area of changed land use from 2006 to 2015

Land Use Change	Area (sq.km.)	Land Use Change	Area (sq.km.)	Land Use Change	Area (sq.km.)	Land Use Change	Area (sq.km.)
Built-up-Waterbody	3507	Open Space-Waterbody	15726	Vegetation-Water	29576	Waterbody (no change)	33405
Built-up-Vegetation	8423	**Open Space-Vegetation**	**205562**	**Vegetation-Open Space**	**780702**	Waterbody-Built-un	26055
Built-up-Open space	33102	**Open Space (no change)**	**447787**	**Vegetation-Built-up**	**261528**	Waterbody-Open Space	7319
Built-up(no change)	12698	Open Space-Built-up	3384	Vegetation(no change)	445	Waterbody-Vegetation	296

CONCLUSIONS

Gazipur is facing rapid land use change due to rapid urbanization. The main aims of this study is to reorganization of land use change in Gazipur city in the time period between 1995-2015 and also impact of land use change on the change of land surface temperature. From the study it is found that there is a change in land use pattern in this time period. Buildup area is increasing rapidly in Gazipur than earlier time. There is a decrease in the waterbody and vegetation in this time period. Waterbody is being decreased from 1206 sq.km to 74 sq.km. The situation is same for vegetation land cover which also have decreased at an alarming rate. Waterbody is greatly replaced by the buildup area. Also vegetated land is converted in the open space. As the land use of the area is changing rapidly it is affecting the land surface temperature of the area. Due to change of land use land surface temperature also increasing as the outcome of land use change. Over 10 years' temperature is changed from 26°C to 30°C.The land uses which were converted into buildup or open space are experiencing high temperature than earlier years. It indicates that there is relationship between land surface temperature and land cover changes. Vegetated and other natural areas enjoy lower surface temperature, than build up or open space areas with little vegetation.

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POND FILLING LOCATIONS IDENTIFICATION USING LANDSAT-8 IMAGES IN COMILLA DISTRICT, BANGLADESH

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ABSTRACT

Ponds are an important place for biodiversity. Collectively, they support more species and more scarce species, than any other freshwater habitat. According to Bangladesh Bureau of Statistics (BBS), the number of ponds in the year 2011 is 73,532 thousand in Comilla district. It's very much noticeable in recent few years that ponds are being filled up to meet up rapid urbanization in Comilla District. The study aimed at understanding the phenomenon of filling up ponds with the help of Landsat-8 images and also find out the causes for pond filling in Comilla district. Landsat 8 images contain 15m resolution and these satellite images have been used to identify the loss of ponds in every year starting from November, 2013 - November, 2017. Geographic Information System (GIS) and Erdas Imagine software have been used to perform a supervised classification and change detection technique to identify the locations of ponds fill up in every year. This study makes an attempt to find out the root causes of filling up the ponds and analyze the trends of pond fill during 2013-2017 years. The result shows us that in year 2017 the number of pond is 61,426 thousand which indicates almost more than 10,000 thousand ponds are being fillip in space of only 6 years. The pond filling will make the drainage system of Comilla district vulnerable which increases urban flooding, water logging and temperature rises to an unexpected extent. The conservation of ponds is crucial to keep a perfect ecological balance in Comilla District.

Keywords: Pond filling, Geographic Information System (GIS), Causes, Supervised classification, Landsat-8, Comilla District

INTRODUCTION

Ponds are very useful for maintaining the environment and balancing of the land use. Ponds are natural or manmade shallow water bodies which hold water permanently or temporarily (Céréghino et al., 2010). Ponds are small in sizes varies between 1 m² to 5 ha (Akhtar et al., 2017). Ponds are important to place for biodiversity. Collectively, they support more species, and more scarce species, than any other freshwater habitat. The protection of ponds is much essential because they are playing a very crucial part in conserving our biodiversity. The type of life in a pond is generally determined by a combination of factors including water level regime (particularly depth and duration of flooding) and nutrient levels (Meester et al, 2005). Other factors may also be important, including presence or absence of shading by trees, presence of streams, effects of grazing animals and salinity (Paul, 2010).
Bangladesh experienced a fast increase of urban population in the recent decades like other developing countries. In 2011 the total population lives in the urban area is about 29% and the annual rate of urbanization is 2.96% (CIA, 2015).Because of unplanned urbanization and haphazard situation present in earth-dumping, a total 4000 ponds have been filled in the last five decades. In Comilla, the urbanization is increasing significantly with the increase of population from in from 3.4 million to almost 5.4 million during 1981 to 2011(BBS, 2013). The increase in urbanization will hamper the present water body like ponds and ponds have been diminishing frequently to meet up the increasing urbanization. In the year 2011, the number of ponds in Comilla is 73,532 thousand (BBS, 2013) which significantly decrease to 61,426 thousand. It is noticed that the study area can be severely suffered from ecological degradation through rapid urbanization and harmful changes (Akhtar et al., 2017).

The present work implies upon the trend of pond fill in Comilla with the help of satellite images and identifies the causes behind it. High-resolution satellite imagery can be used for monitoring and advocacy of land use changes in any region. Remote sensing data from Landsat-8 satellite images to identify the ponds as well as locations of ponds filling in Comilla from the year 2013 to 2017.This study aimed to understand the causes of pond filling and explore the rate of pond filling in context Comilla district.

METHODOLOGY

Comilla City stands on the bank of the river Gumti .Comilla is bounded on the north by Brahmanbaria District, on the east by Tripura State of India, on the south by Feni and Noakhali and on the west by Narayanganj, Munshiganj and Chandpur [Fig. 1]. It lies between 23°02' and 23°48' north latitudes and between 90°38' and 91°22' east longitudes. The total area of the district is 3146.30 sq. km. (1214.79 sq. miles) with an estimated population of 5387288 people (Bangladesh Bureau of Statistics, 2013).

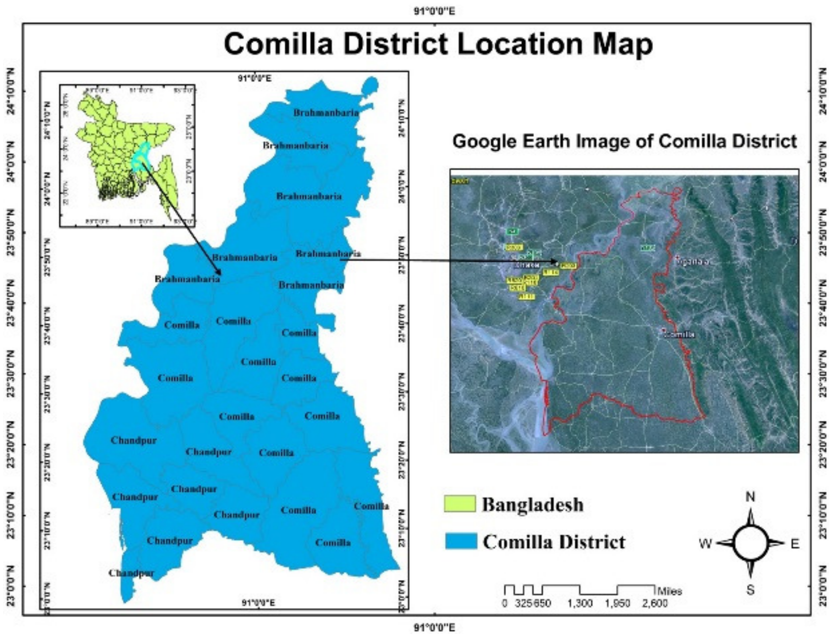


Fig.1: Location Map of Study area

The present work was conducted using both primary and secondary data. The primary data were collected from a structured questionnaire, and interviews and focus group observations in major ponds filling locations in different upazilas. The questionnaire survey was conducted based on random sampling which includes 250 respondents. The primary data were analyzed by IBM SPSS 20 software. The secondary data were collected from satellite images. Landsat-8 OLI images (in the form of both surface reflectance) at 15 m spatial resolution are freely available in United States Geological Survey (USGS) websites (Bartsch et al., 2016). For this study, these images covering the study area and within the time frame of 2013 to 2017 have been collected Landsat 8 operational land imager (OLI) images dated 13 October 2013, 25 November 2015 and 21 November 2017 were downloaded from the global visualization viewer of the United States Geological Survey (USGS). Images are collected from late autumn (October and November) since this season is cloud free and trees are not in leaf-off condition(Rahman et al., 2017). Images for three different years are collected within one month to avoid the season variation in this area. These images were acquired with a combination of path-row 136-44, 137-43 and 137-44 as this cover the study area. Upon acquiring all the required datasets, we performed the following set of pre-processing steps for Landsat-8 OLI. Those included: (i) re-projecting the images into Universal Traverse Mercator (UTM) Zone 46 N with World Geodetic System 1984 (WGS84) datum, (ii) clipping the images to represent the study area (iii) Supervised classification in three years 2013,2015 and 2017 to identify the water body iv) extract the water body which is less than 5 hectors from classified images. V) Matrix Union to identify the conversion of ponds in different land uses. Only visible and near-infrared bands of the Landsat scene are considered for the supervised classification to prepare decadal land cover maps of the Comilla. For easy understating of the study, four broad land cover categories are selected and mapped for the study area: waterbody, buildup area, vegetation which include agricultural land and bare soil (Kafy et al., 2017).Two change maps are prepared based on the post-classification land cover change between 2013 and 2015 as well as between 2015 and 2017. Since three types of changes such as ponds to buildup, ponds to vegetation and ponds to bare soil provide a favorable condition for how the ponds are converted in different land uses.

RESULTS AND DISCUSSIONS

Land use Change assessment

Fig. 1 shows the land cover map of three different years. Increase Urbanization might have observed from the map [Fig. 2]. Diminishing of water bodies for different land use activities have been significantly noticeable between years 2013 - 2017. In land cover changes, major changes are noticed in Built-up areas which were 556 km^2 in 2013 and increase almost double to 1006.89 km^2 in the year 2017. Fig. 1 indicates that Comilla District had 8% of its area as Buildup area which is significantly increased to 15 percent. Also, noticeable change in vegetation land which is 3520 km^2 and 2751.55 km^2 in 2013 and 2017 respectively. Between 2013 and 2017 there is very little change in bare soil condition. Waterbody change also noticeable which is 1127 km^2 (17%) in the year 2013 and significantly reduce to 887.949 km2 (13%) in the space of 5 years [Fig. 2].

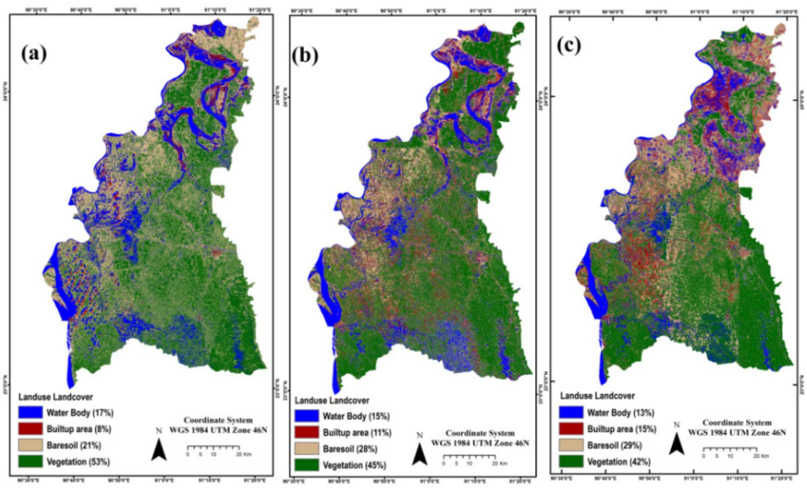


Fig.2: Land cover map of Comilla District in year 02013(a), 2015(b) and 2017(c)

Ponds Filling Change assessment

The number of ponds in Comilla district in year 2011 is 73,532 thousand (Bangladesh Bureau of Statistics, 2013) which is decrees significantly in every year interval. From fig. 3 the number of ponds in year 2013 is71523 thousand which achieve after processing the satellite images. With the increase in rapid urbanization the number of ponds are decreed in 61426 thousand in year 2017. Almost 12677.08km^2 ponds area have lost in the space of only six years which is very much alarming for Comilla district at present. Rapid loss of ponds (7426 thousands) happen between years 2013-2015 (Table 1).

Table 1. Diminishing of Ponds area in Comilla district, 2011-2017

Year	Number of Ponds	Area(km^2)
2011	73532	23876.07
2013	71523	21575.05
2015	64097	14727.15
2017	61426	11198.99

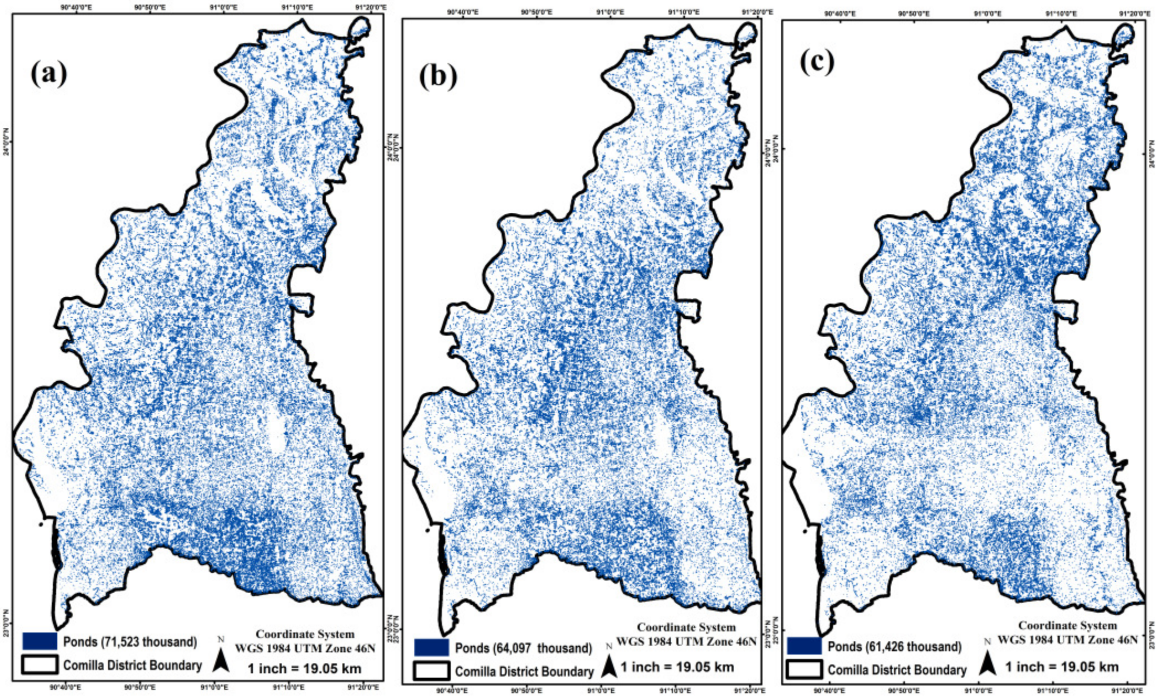
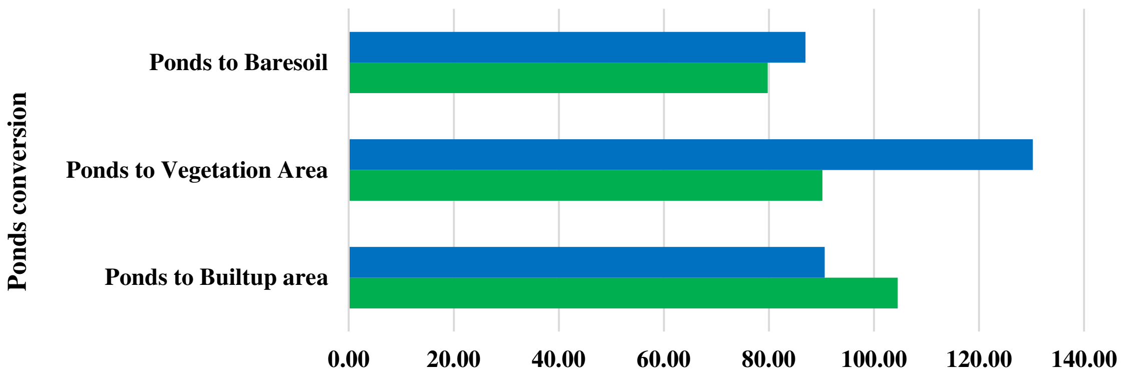


Fig.3: Ponds of Comilla District in year 2013(a), 2015(b) and 2017(c)

Conversion of ponds to different land uses

Major conversion of ponds to build up area happen between years 2013-2015. 104.55 km^2 and 9.65 km^2 area of ponds are fill up to build urban areas in year 2013-2015 and 2015-2017 respectively. Similarly the agricultural activities increase mostly in year 2015-2017 which diminish almost 130.27 km^{2}area of ponds. People fill up the agricultural lands and ponds to meet the rapid urbanization and for this reason the bare soil area is increase from 79.76 km^2 to 86.96 km^2 during 2015-2017 (Fig.4). The figures describe that ponds have been fill up across the Comilla district to meet the rapid urbanization as well as increase demand is vegetation and agricultural products.



	Ponds to Builtup area	Ponds to Vegetation Area	Ponds to Baresoil
2015-2017 (sq.km)	90.65	130.27	86.96
2013-2015 (sq.km)	104.55	90.18	79.76

Fig.4: Ponds Conversion to different land use in Comilla district, 2013-2017

Causes of Pond Fill

In last 7 years more ponds and wetland have been filled in Comilla district. Since then, extensive losses have occurred, with many of the original ponds were filled and many of them were converted to farmland. Activities resulting in pond fill loss and degradation include: urban (commercial and residential) area development, agriculture activities, land filling, encroachment and huge political and institutional support ignoring the rules and laws. The main causes of pond fill are shown in the Fig. 7 below.

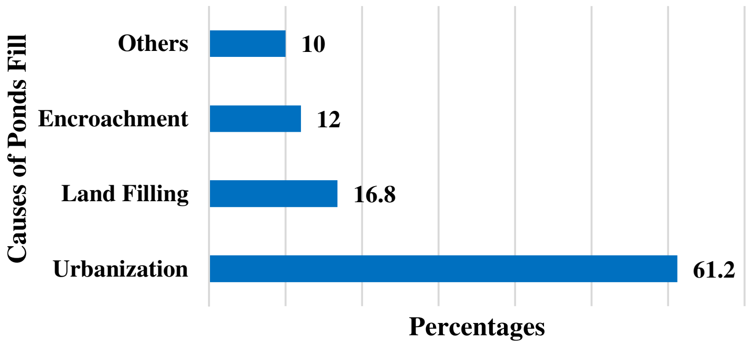


Fig.5: Reasons for ponds fill up in Comilla District

Urbanization is a major cause of impairment of ponds. Urbanization has resulted in direct loss of pond areas as well as degradation of ponds. Construction activities are a major source of suspended sediments that enter ponds through urban runoff. According to the survey in major ponds fill up locations in Comilla district, 61% of pond fill happened due to urbanization. Shopping Centre, Market, high rise building, restaurant are the main causes of pond fill in Comilla district. Land filling is the second most important causes of pond fill in Comilla district. About 17% respondent said that land filling is the one of the causes for pond fill in Comilla district. Most of the respondents said that encroachment mostly happens where pond owner has his house near the pond. From the survey data it can be said that 12% pond fill happens due to encroachment. The first step of encroachment is to build structures along the surroundings of ponds and further out on the ponds itself. To do this, rows and bamboo posts are positioned and fixed on the water body bed along the bank and extending into the main body of the pond. Then huts and shops are built on these stilts. The owners of these structures are then start reclaiming land by earth fills and dumping garbage. Pond filling has some other reason as well. Such as, political pressure in unlawful land grabbing, unplanned urbanization and district expansion, unplanned constructing of government building etc. [Fig.5].

CONCLUSIONS

In space of 7 years, 12677.08 km^2 area of ponds in Comilla district has been filled. There will be no pond in Comilla district area if the current trend continues for next 90 years. The study identifies the number of ponds in three different years using 15m resolution Landsat-8 images and also Observes he main causes for pond fill of Comilla district. The study finds that the main reasons are urbanization, encroachments, land filling etc. The critical effects of the pond fill are the loss of biodiversity, serious environmental degradation, Water logging, urban flooding, and loss of valuable water resources. To improve the beautification of Comilla district measure should be taken like conserve ponds and develop scenic view around the ponds to create more attraction to the district dwellers. The conservation of ponds is crucial for Comilla district to keep the ecological balance, especially to reduce the urban flooding. Necessary measures should be taken like social awareness, maintain of strict law and the Local government could play an important role in pond fill restriction.

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THE RAINFALL DISTRIBUTION CHARACTERIZATION AND FLOOD EXTENT MAPPING USING SAR SATELLITE IMAGE: A CASE STUDY IN NORTH WESTERN PART OF BANGLADESH

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ABSTRACT

Bangladesh is a flood-prone area among Asia for the geological location. Due to this natural disaster, infrastructure damages and human life losses occur every year in this country. Efficient monitoring and prediction of the flood in this county are very difficult without using satellite data. Flood mapping is a process which uses for damage assessment and risk management and helping rescuers during the flood. Somehow, Rainfall associated with flooding affects the study area with life loss and crop loss. The study area is the north western part (Rajshahi, Naogaon and Natore) of Bangladesh. The objective of this study is to define the extent of the flood in the study area during rainy season comparing two years of 2016 and 2017 and to identify the characterization of rainfall distribution during this period. The study also illustrates the links between evolving rainfall structure and spatial extent of flooding. The whole analysis is based on SAR (synthetic aperture radar) satellite images from Sentinel-1, have free access from ESA. The software is used for SAR imagery processing using threshold method to derive the flood extent and google earth is used to visualize the result of image processing. The results help operating estimation and detection of flooded area and determine the extent of flood causing damages in the study area. Finally, the study explores that due to the changing contribution of rainfall distribution, the extension of flooding is increased to a great extend or not in Rajshahi, Naogaon and Natore. It also helps to find that the rainfall distribution does really responsible for the flood in the study area or other reasons do responsible for it.

Keywords: Flood Extent; Rainfall distribution; SAR Image; Flood Mapping.

INTRODUCTION

Approximately one billion people live in extreme flood areas, which may be double by 2050 due to climate change and population increase (Long et al., 2014). A flood is described as an overflow or increase of the expanse of water which submerges urban or rural land. It results from the rising volume of water and the water flows its usual boundaries of village, city. Much of the districts are situated on low-lying and flood-prone areas, which made it particularly vulnerable to seasonal monsoon rains. In 2007, Bangladesh was seriously damaged by deadly monsoon flooding which led to over 1,000 deaths and in 2017 history is repeating (George, 2017). Prediction of precipitation and flooding has definite importance from a societal and economic perspective (Villarini et al., 2011).

Relevant study on the flood extent mapping has done to identify the intensity of the flood locations. The study areas are Rajshahi, Naogaon and Natore of Bangladesh. Earth Observation (EO) data which are collected from space is being used for effective monitoring of floods and precipitation data is collected for rainfall distribution characterization. Mainly the data required for the flood extent mapping is Sentinel-1 freely available from European Space Agency (ESA) which special resolution is 5m-40m. The product type is Level-1 Ground Range Detected (GRD) Sentinel-1 image, for SAR image analysis SNAP tool is used, DEM for ortho-rectification archived optical images, land cover with vector data. The time selection of the conducted image is to be considered due to the weather condition (Pustina, 2014). The methods and procedures in the relevant studies were followed to some extent to achieve the accurate flood extend map of the research area. Precipitation data helps to identify the characterization of rainfall distribution and it links to the inundation of flood (Villarini et al., 2011). The flood extent information is used for vulnerability and risk assessment.

Basically, the objective of the research practice is to determine the extent of flooded areas of the considered research area. The research explores the flood extend map which includes damage assessment of flooded mapping and severity of flood from the previous year. The application of SAR satellite image leads to a fast image processing system and provides flood extension area (Villarini et al., 2011). The study will help to risk assessment foreconomic activity and potential location at the risk of flooding. The study is based on the use of satellite remote sensing, geographic information system (GIS) and hydro-meteorological data to evaluate flood situation and assessing the impact of flood disaster with the aid of pre- and post-flood satellite images (Bhatt et al., 2016).

METHODOLOGY

A simple threshold method is applied which was successfully applied in Malwari, January 2015 and also used in Australia, Europe and Africa (Pustina, 2014). The materials for the research are Sentnel-1 images, SNAP 6.0, ArcGIS 10.2.2 and Google Earth. For data preparation, sentinel-1 images of 13th April 2016, 28th August 2016, 26th May 2017 and 27th August2017 are collected from *European Space Agency (*ESA). Advantages of SAR images are easy detection capability of smooth water and accuracy of detention almost 95%. The images are dereferenced, filtered with the adaptive Gamma filter and masked. To fulfill the second objective, rainfall data is collected from Bangladesh Meteorological Department (BMD).

The research conducts the following steps in SNAP software: Data preparation, pre-processing (Calibration, Speckle filtering), Binarization by band maths, Post-processing (Geometric correction). Then image processing for making maps and visualizes in Google Earth. Pre-processing includes calibration and spectacle filtering. Binarization is used to separate water from non- water region and it also analysis the filtered backscatter co-efficient where magnitude depends on the data. ArcGIS 10.2.2 is used to make flood extent map of the studied area (Rajshahi, Naogaon and Natore) and to visualization of the water band in Google earth is resulted to the flood extend map which classifies the water regions Africa (Pustina, 2014). To complete the other objective, rainfall data of the months of 2016 and 2017 analyses to know the relation between rainfall and flood. SPSS are used to correlate the rainfall amount and flood extent with the ANOVA and coefficient of the regression analysis.

RESULTS AND DISCUSSIONS

Two different sentinel-1 images are used for understanding the flood extent in Rajshahi, Naogaon and Natore districts. Table 1 and Fig. 1 represent a comparison of the extent of mapping of Rajshahi, Naogaon and Natore from August 2016 to August 2017 which was determined by sentinel image processing. The analysis has made a sense to understand the extent of the inundation of water of the present-past year. The extent of flooding evaluated is only illustrating the increase in flood extent from the previous year and not the entire extent.

Flood extent to the floodplain:

Four different sentinel-1 images are used for understanding the flood extent in Rajshahi, Naogaon and Natore districts.

Table 1: A list of water extent area in Rajshahi, Naogaon and Natore

Study Area	Total area (in sq. km.)	2016		2017	
		Water extent area in April (sq. km.)	Water extent area in August (sq. km.)	Water extent area in May (sq. km.)	Water extent area in August (sq. km.)
Rajshahi	2382.22	125.49	227.59	116.247	203.12
Naogaon	3449.22	38.24	246.164	21.502	514.67
Natore	1914.19	17.094	179.032	37.415	176.032

In the study, a comparison of the extent of mapping of Rajshahi, Naogaon and Natore from April 2016 to August 2017 which was determined by sentinel image processing is represented in Table 1, Fig. 1

and Fig. 2. The analysis has made a sense to understand the extent of the inundation of water of the present-past year.

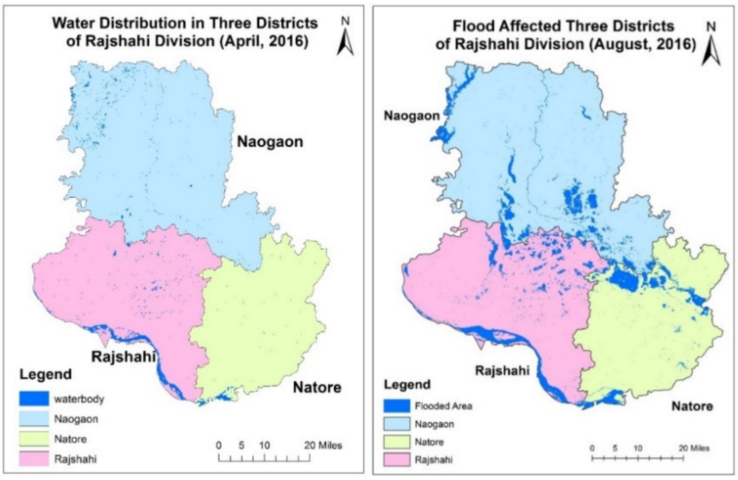

Fig. 1: Water Distribution in three Districts of Rajshahi Division in April 2016 (a) and Flood Affected three districts of Rajshahi Division in August 2016 (b)

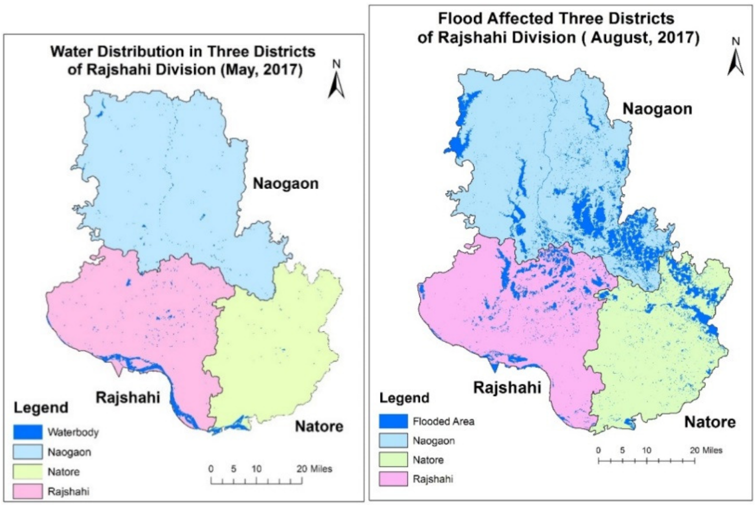

Fig. 2: Water Distribution in three Districts of Rajshahi Division in May 2017 (a) and Flood Affected three districts of Rajshahi Division in August 2017(b)

The water extent area is less in April than the month of August in 2016 over the study area [Fig. 1]. Similarly, water extent area is less in May 2017 than August 2017 in the study area [Fig. 2]. So, it assures that inundation of water in the august month in 2016 and 2017.

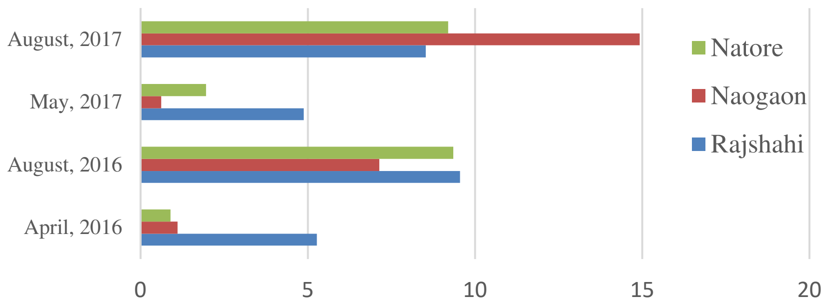

Fig. 3: Comparison of % of the extent of water in 2016- 2017 in Rajshahi, Naogaon and Natore

Flood extent of Rajshahi district is less in 2017 than 2016 [Fig. 3]. In 2016, the flooded area was 227.59 sq. km and in 2017 it was 203.12 sq. km since August. The flood extended area has decreased 1.03% from 2016 to 2017. Flood extent of Naogaon has increased in amount this year [Fig. 3].

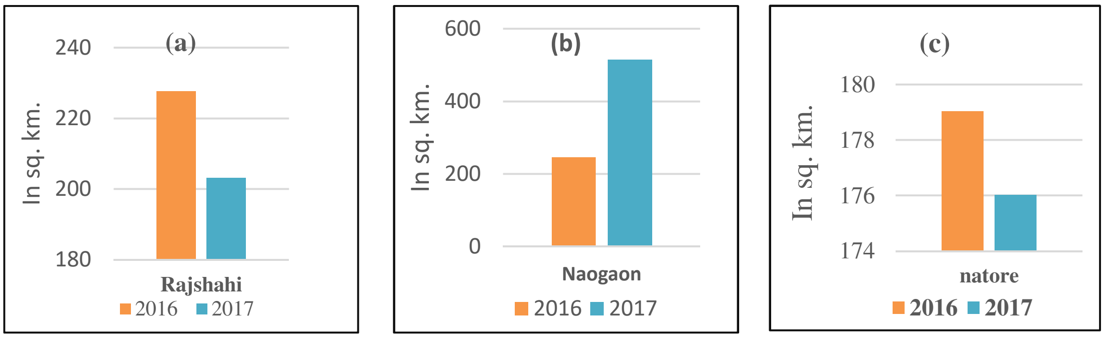

Fig. 4: Comparison of flood extent area in August between 2016 and 2017 in the three districts

In 2016, the flooded area was 246.164 sq. km. and in 2017, the area was 514.67 since August [Table 1]. The total area of Naogaon is 3449.22 sq. km. The flood exteded area has increased 7.79% from 2016 to 2017.Flood extent of Natore is less in amount in 2017. In 2016, the flooded area was 179.032 sq. km and in 2017, the area is 176.032 sq. km since August [Table 1]. The total area of Natore is 1914.195 sq. km. The flooded area was 9.35% and 9.19% respectively in 2016 and 2017 of thetotal area of Natore district. The flood extended area has decreased to 0.16% from 2016 to 2017.

Visualization of flood:

The extent of flooding between August 2016 and August 2017 is determined from the Sentinal-1 images. From the Google earth images, it helps to find out easily the flooded area among three districts. A comparison of flood extent of the present year and past year is shown in Fig. 5. From all the map, it is shown that the extension of inundation of water is more this year until august than the previous year in Naogaon. The time to maximum flood extent is very rapid in the Naogaon Floodplain, depending on the season.

Rainfall distribution to the floodplain:

Rainfall distribution is analyzed according to the meteorological data collected from Bangladesh Meteorological Department (BMD). Average rainfall is high in August 2016 and 2017 [Fig. 5]. In Naogaon and Rajshahi the average precipitation is higher than the Natore [Fig. 5]

(a) **(b)**

Fig.5: Visualization in google earth respectively year of 2016 (a) and 2017 (b)

Relationship between evolving rainfall structure and spatial extent of flooding:

The relationships are shown according to the Regression analysis. For regression analysis, water extent area is independent variable and rainfall distribution is the dependent variable. The mean water extend area is 6.12 sq. km and the Std. deviation is 4.45 sq. km which indicates that specific areas have huge extension of water in season. The mean rainfall length is 2.49 mm and Std. Deviation is 2.38 mm. The correlation value between rainfall distribution and flood extent area is 0.390 which indicates that they are moderately correlated. So according to the correlation, the extension of water level into the ground or flooding is not strongly depended on rainfall distribution. Other vital reason depends on the rainfall distribution [Table 3].

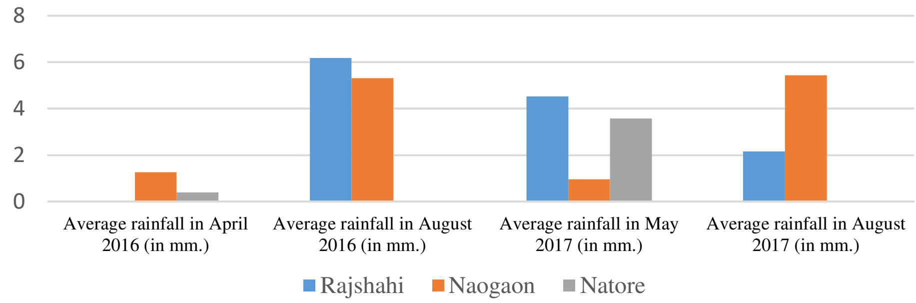

Fig.6: Comparison of the average rainfall distribution in 2016 and 2017

Table 2: Descriptive Statistics of the water extent area and rainfall

	Mean	Std. Deviation	N
Water Extent area	6.1179	4.45437	12
Rainfall	2.4856	2.38210	12

Table 3: Correlation between rainfall distribution and flood extent area

		Water Extent area	Rainfall
Pearson Correlation	Water Extent area	1.000	.390
	Rainfall	.390	1.000
Sig. (1-tailed)	Water Extent area	.	.105
	Rainfall	.105	.

Table 4: Model Summary of the regression analysis

Mode	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.390[a]	0.152	0.067	4.30254

[a]Predictors: (Constant), Rainfall

From Table 4, the Residual (R) value is 0.39 and the R-square value is 0.152 which indicates that from the predicting rainfall data, 15.2% data are accounted for water extension area. The increase in data collection would increase the data accountability. From Table 5, the F-value is 1.7 and Significance (Sig.-value) is .211. So the resultants of the variables are statistically significant.

Table 5: ANOVA[b] of the regression analysis

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	33.138	1	33.138	1.790	0.211[a]
	Residual	185.118	10	18.512		
	Total	218.256	11			

a) Predictors: (Constant), Rainfall b) Dependent Variable: Water extent area

Table 6: Coefficients of the regression analysis

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.307	1.837		2.344	0.041
	Rainfall	0.729	0.545	0.390	1.338	0.211

Here from unstandardized Coefficients of Table 6, it is indicating the increase in 1 mm rainfall would probably cause 0.729 sq. km water extent area. The increase in water extent area is increased according to the increase in the rainfall distribution in the study area. In highest length (in mm) rainfall distribution indicates the most extension of water level in the surface [Fig.7].

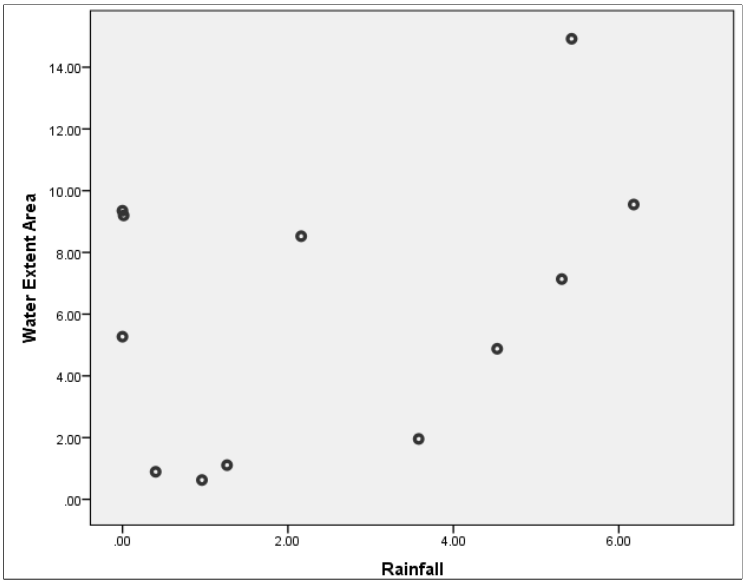

Fig.7: Scatter-plot of rainfall distribution and water extent area of the study area

CONCLUSIONS

In this research, it has explored the range of inundation of water in the study area. After a qualitative comparison of rainfall between the months of summer and monsoon in 2016 and 2017, it has shown that the rainfall was a moderate reason forflood in the study area. As all the three districts are situated on the bank of rivers, it might be the responsible for causing flood. At monsoon, over water is bypassed by the Farakka Barrage from India which may be the reason of inundation of water in the study area. In this case, international water law should need to be applied by the authority to distribute the river water carefully and reduce the casualties in flood time.

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PREDICTING THE MORPHOMETRIC CHANGE OF URBAN WATER BODIES IN CHITTAGONG METROPOLITAN AREA

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ABSTRACT
Urban Water body (UWB) refers to those lakes, ponds, reservoirs and wetlands in urban land cover. In the mood of rapid urbanization the number, shape, size and connectivity of UWB is changing along with the land use. Urban development including construction, burial, drainage and reshaping are responsible for the rapid morphological change of water body day by day. Chittagong is a major coastal seaport city and financial center in the southern part of Bangladesh. Due to the rapid development in metropolitan city, the total area of UWB is changing at an alarming rate due to increase of land use for construction. Morphometric change of urban water body during last 15 years in Chittagong metropolitan area will be determined and prediction of the change in the upcoming 10 years will be estimated in this study. For this research the past urban land use transitions in Chittagong was examined based on collected remote sensing data between 2000 and 2015. A Markov Cellular Automata approach is used for deriving the future urbanized condition based on the existing and planned strategies for Chittagong. This is done by a combination of multi-criteria evaluation processes originating transition probabilities that allow a better understanding of the region's urban future by 2025. While the transition probabilities are incorporated from the traditional Markov Chain process, the variables for suitability are measured through topography, road distance. The result offers a more integrative vision of policymaker's preference of future planning instruments, allowing for the creation of a better integration of propensity of future growth indicators.

Keywords: Urban water body; Metropolitan area; Morphometric change; Rapid urban development.

INTRODUCTION
Urbanization has become a ubiquitous reality throughout the world (Ali, 2008) .Along with the other major city of Bangladesh; Chittagong is undergoing rapid urbanization in recent decades. This development is also increasing rapid urban growth and land cover alteration. During this rapid urban growth the morphometric of urban water body is changing rapidly. UWB is an important element of eco-system (Januchta-Szostak, 2012). The size, shape, and connectivity of water bodies (lakes, ponds, and wetlands) can have important effects on ecological communities and ecosystem processes(Steele & Heffernan, 2014). So this problem has become one of the prime concerns of urban community. The aim of the paper is to predict the morphometric change of UWB in the upcoming 10 years of Chittagong metropolitan by analyzing the morphometric change of urban water body during last 15 years in Chittagong metropolitan area.

METHODOLOGY
Supervised classification method is used for land use classification of Landsat image. A total 200 signatures for each LULC class were extracted randomly covering the whole study area using the ERDAS Imagine software. Signatures were generated using the region growing technique of ERDAS Imagine that produces each region having similar spectral characteristic pixels. Based on these signatures a maximum likelihood supervised classification technique was used to classify the image into other desired classes such as vegetation, water body and built up (Sanjoy Roy, 2015).

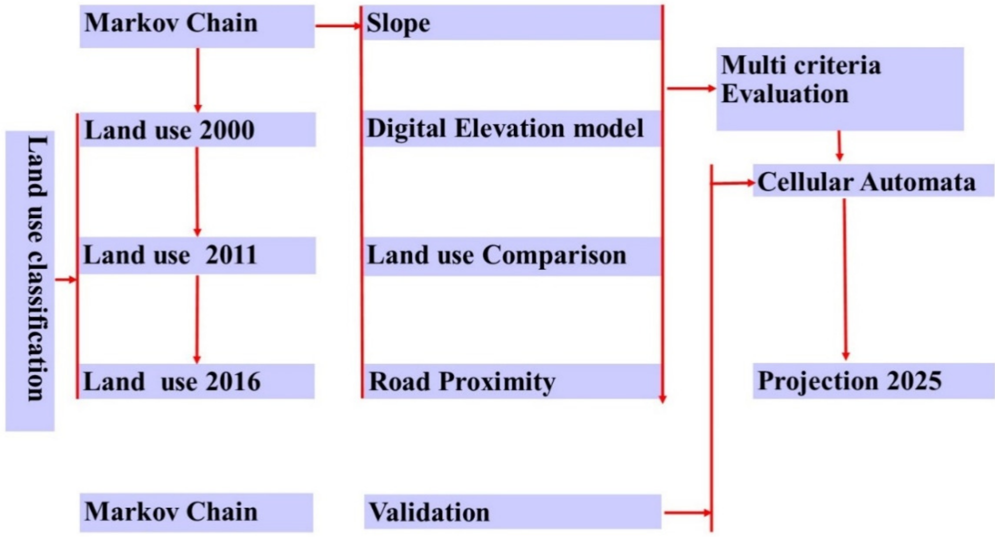

Fig. 1: Structure of the research work

Then accuracy assessment is done for evaluation of supervised image. Another estimator of accuracy is the Kappa statistics (Khat), which is a non-parametric discrete multivariate technique, developed by Cohen measures the overall agreement of a matrix (Sanjoy Roy, 2015).Markov chain (MC) analysis has been widely used for land use prediction model which is a stochastic process that takes into account the past state to predict the future changing of variables over time. Because of its immense ability to quantify the rates and states of conversion among and between categories respectively, it has been equally used in the LULC change modelling. In this research a combination of MC and some hybrid cellular automata (CA-Markov) technique was applied to predict land se classification for 2025 using the QGIS software. It requires two LULC data sets of different time frames based on which the probabilities of transition between periods are obtained (Ahmed, 2011).

Survey area- Chittagong City

Chittagong is the second largest metropolis in Bangladesh. Situated in the Bay of Bengal, Chittagong has historically been an important centre of commerce due to its geo-strategic location and is regarded as the commercial capital of the country.

The Chittagong Statistical Metropolitan Area (SMA) covers an area of 1,152 sq.km and consists of six metropolitan thanas. 68 wards and 236 mohallas (localities) with a population of 3.38 million. Chittagong City Corporation covers an area of 155 sq. km with a population of 4,009,423 in 2011, which had grown on average by 3.6% per annum between 1991 and 2001. The population growth is much higher compared with national growth of about 1.6 percent. Cities are being inundated with people looking for a job and a decent income. The Chittagong City is not an exception to it. Like many developing country cities, it is experiencing a rapid growth of population mainly because of rural-urban migration. (BBS, 1981, 1991, 2001)

Chittagong is unclassified, irregular and heterogeneous in character of its land use. It is very difficult to identify the zoning in a particular area. Unplanned urbanization creates chaotic development in this city. Due to this water body and many other resources of city are hampered. For constructing new buildings, they need more land as the population of the city is increasing at an alarming rate for these reason they destroy pond and other water reservoirs. Both Chaktai and Rajakhali Khals, two main drainage channels of Chittagong, terminate in the river Karnaphuli. Part of the area is densely populated. Remaining part of the area is expected to be developed in the immediate future as the area falls within Bakalia, earmarked as a thrust area for development in the Structure Plan for Chittagong, 1995. But now these two khals are in deteriorated condition. No matter, whether the road width is 6.096 m or 18.288 m, the drain width mysteriously remained constant at 0.6096 to 0.9144 m .People are very generous in building roads and highways but remained equally miser in building primary, secondary or tertiary drains of appropriate size. As a consequence, as expected, drainage became a menace for our cities (Ali, 2015).

Prediction analysis

Geographic Information System (GIS) and Remote Sensing (RS) have long been used and widely accepted as very powerful techniques in change analysis and simulation of LULC. Combined, they are capable of critical analysis and decision supports in earth's surface changes within shortest time with reasonable accuracy. RS is applied to retrieve information from analysis of earth observatory multi-temporal and multispectral satellite images of different spatial resolutions. These images offer tremendous opportunity in LULC monitoring (T. Loveland, 1999).

A spatial models are used to quantify predicted LULC in a particular region and associated driving forces (Kaufmann, 2003) whereas empirical-statistical models and rule based models included in the spatial category are mainly used in the analysis of LULC changing pattern and spatial location of existing and future potential changes. Among all spatial models the Markov chain model integrated with Cellular Automata has been widely used for spatiotemporal modelling of LULC in a reasonable way (Sanjoy Roy, 2015).

RESULTS AND DISCUSSIONS

Table1:The land use of Chittagong in three different years 2000, 2010 and 2016 respectively (sq.cm)

Land use	Year 2000	Year 2011	Year 2016	Change 00 to 11	Transition probability	Change 11 To 16	Transition probability
Vegetation	442044300	38101500	26361000	403942800	0.272156388	11740500	0.597009393
Build up	29418840	64559700	85758300	-35140860	-0.49140449	-21198600	-0.051936619
Others	208503000	58389300	48641400	150113700	0.225965952	9747900	0.221861335
Water Body	96712800	9299700	8847900	87413100	0.01047317	451800	0.129192652

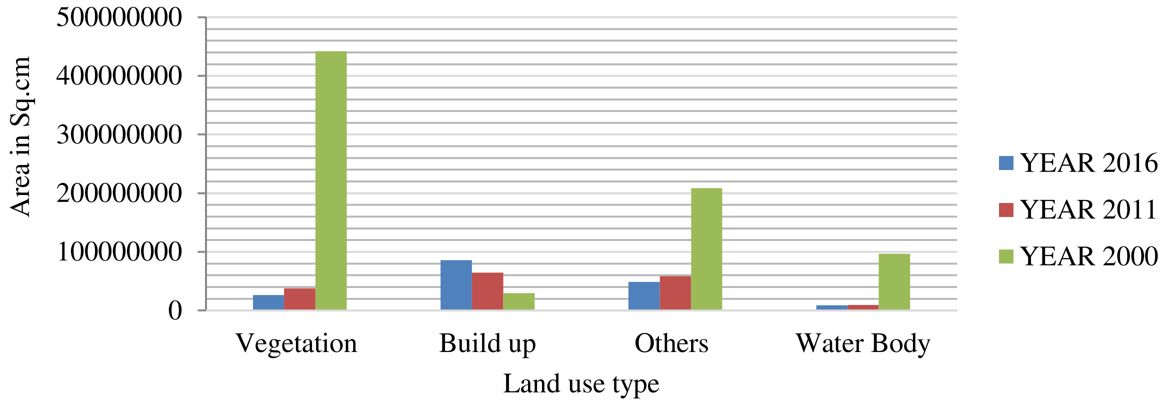

Fig. 2: The land use of Chittagong in three different years 2000, 2010 and 2016 respectively.

The above table and figures showing the land use of Chittagong in three different years 2000, 2010 and 2016 respectively. In the year 2000 the dominated land use was vegetation which decreased very rapidly in the year 2010 but in respect to 2010 the change of vegetation in 2016 is also very significant [Fig. 2]. From the transaction probability of vegetation, it can be sad that the change of vegetation to other land use increase to 0.59 which was 0.27 in 2010 [Fig. 2]. There is an increase in build-up area in 2010 and2016 in respect to 2000 and the proximity of change of build-up area to other land use is negative which refers that the build-up area will not change to other land use that much in the future. There is a very rapid decrease in the water body of Chittagong and there is a probability to change of land use of water body to others land use. Also apart from this there is huge change in other land use in 2010 and2016 with respect to 2000 and high probability to change of other land use.

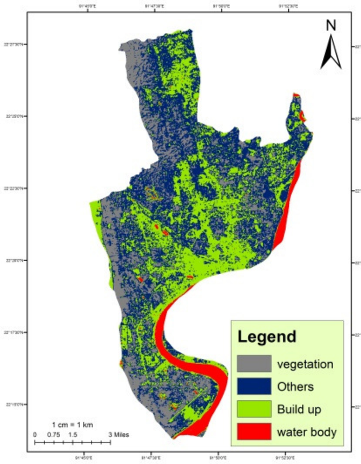

Fig.3: Land use map of 2000

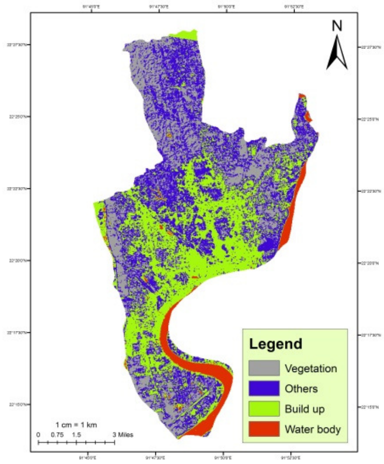

Fig.4: Land use map of 2011

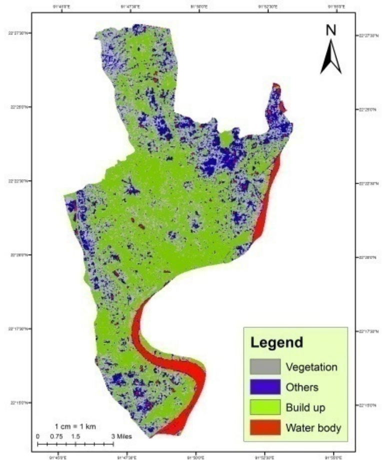

Fig.5: Land use map of 2016

The above figures represent the land use map of Chittagong city for three consecutive years 2000 [Fig.3], 2011 [Fig. 4] and 2016 [Fig. 5] respectively. From the map it can be said that most of the land use was vegetation but it reduces rapidly in 2011 [Fig 4] and 2016 [Fig. 5] on the contrary there is an increase in build-up area in 2011 [Fig. 4] and 2016 [Fig. 5] than 2000 [Fig. 3]. There is also reduction in water body and other land use in 2011 [Fig. 4] and 2016 [Fig. 5] than 2000 [Fig. 3].

Table 2: Transition probability matrix.

Land use	Vegetation	Build up	Others	Water Body
Vegetation	0.59700939	0.282093	0.080598	0.040299061
Build up	0.05193662	0.805854	0.094806	0.047403169
Others	0.22186134	0.622511	0.301991	0.558406996
Water Body	0.12919265	0.696646	0.242683	0.605853362

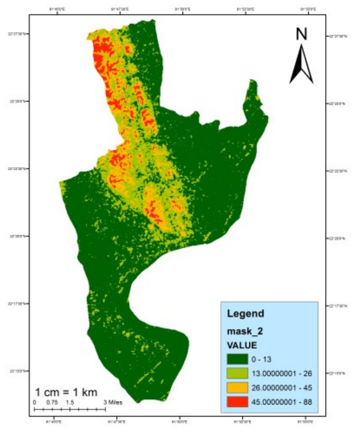

Fig.6: Digital elevation model of Chittagong.

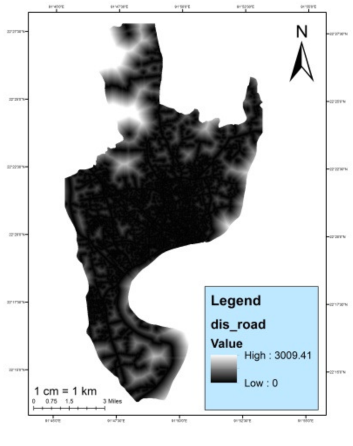

Fig.7: Road proximity map Of Chittagong

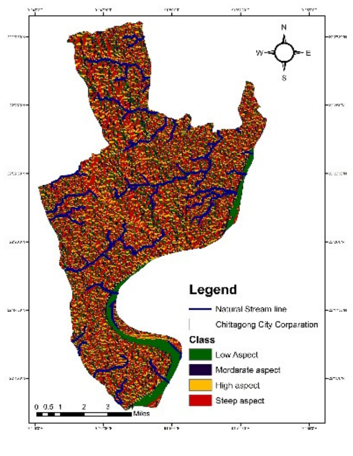

Fig.8: Aspect map of Chittagong

The table showing the transaction probability matrix of different land use. From the table it can be said that there is high probability of change of vegetation to build-up area than other land use. The probability of build-up area to be remain same is high than other land use. The proximity to change in other land use to build-up and water body is high. Water body change in to build-up areas proximity is also high. The below map showing the water body probability map of Chittagong city corporation area for the year 2025.The area of water body will reduce to 5352979 in 2025 to 8847900.

In Fig.7 the map showing the road proximity of Chittagong City Corporation. It indicates that land near the road have high proximity of development than land which are not near the road. The white portion indicates that the land is near the road and they have high proximity of development than black portion which are far away from the road. In Fig.8 the map showing the slope and stream line map of Chittagong City Corporation. The blue line indicates the natural stream line of the city area. The slope of the area is divided into four categories which are low aspect, moderately aspect, high aspect and Streep aspect.

Chittagong is the commercial capital of Bangladesh. There is a rapid change in the land use of this city due to rapid urbanization. The study is conducted to determine the land use change of the city for a definite time period and to predict the change of water body of this area in the year 2025.

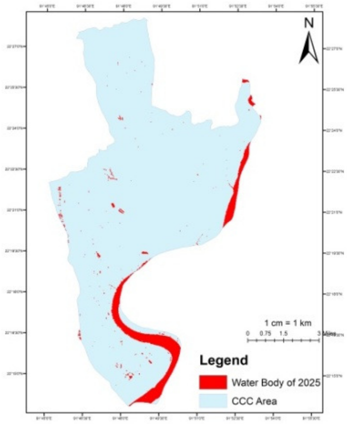

Fig.8: Water-body probability

From the findings of the analysis it can be concluded that in the year 2000 use of land in this city is mainly was vegetation and water body than build-up and other purpose. But the situation is completely different in the year 2010 and 2016. Now the use of land for build-up purpose is very high than vegetation and water body. There is a very rapid reduction or decrease of vegetation and water body and increase of the build-up area in this time period. It can be also said that the land use of water body and vegetation is change into the build-up use and there is high transaction proximity of change in these two land use into build up area near future. The study is predicted the approximate area of the water body will be remaining 2025 by Markova chain model. According to the findings the water body of Chittagong City Corporation will be 5352979 in 2025 to 8847900.

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MONITORING WATER SURFACE TEMPERATURE BY SATELLITE REMOTE SENSING: A CASE STUDY ON RIVER KARNAPHULI

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ABSTRACT

Passive microwave radiometry from satellites provides more precise atmospheric temperature information than that obtained from the relatively sparse distribution of thermometers over the earth's surface. Satellite remote sensing is the easiest way to monitor surface temperature of land cover and water bodies for several years. The aim of this research is to find out the temperature distribution over the water surface of the river Karnaphuli in the years 2000, 2007 and 2015 and to make necessary comparisons among them. LANDSAT satellite images have been used for remote sensing measurement of water surface temperature. The 2000 LANDSAT data used is ETM+, 2007 is TM and 2015 data is OLI_TIRS data. Surface temperature for three months (March, July, and November) has been calculated for each distinct year. The numeric value of temperature was observed at 15 different stations. It has seen that average temperature rose from 2000 to 2007 and then fell in 2015. For March the temperature rose almost 2°C from 2000 to 2007 and then fell around 1°C in 2015. In case of July the temperature first rose 5°C and then fell almost 6°C. But for November the temperature first rose 2°C and then remained nearly unchanged in 2015.

Keywords: Remote Sensing; LANDSAT; TM; ETM+; OLI_TIRS.

INTRODUCTION

Freshwater resources are becoming increasingly limited in many parts of the world and decision makers are demanding new tools for monitoring, (Anderson et al., 2011). Water quality is the key environmental concern because of its important provision of water for drinking and domestic purpose, irrigation and aquatic life including fish and fisheries, (Ahmed et al., 2013). In case of river, surface temperature is a major factor to be considered. According to United States Geological Survey temperature governs kind of organism that can live in rivers. Water temperature is a physical property expressing how hot or cold water is. As hot and cold are both arbitrary terms, temperature can both further be defined as a measurement of the average thermal energy of a substance, (Brown, 1999). Satellite image data sensed by the optical and thermal sensors on various remote sensing platforms has been widely used for water quality measurement studies, (Alparslan et al., 2007). The use of monitoring has evolved to help determine trends in the quality of aquatic environment and hoe the quality is affected by release of the contaminants, other anthropogenic activities or by waste treatment operations. The principal benefit of satellite remote sensing for inland water quality monitoring is the production of synoptic views without the need of costly in situ sampling, (Hadjimitsis et al., 2010). Karnaphuli is the largest river in Chittagong and Chittagong hill tracts which is 2188 ft. wide, originating from the Lushai hills in Mizoram, India, it flows 270 km, (Saleheen and Chowdhury, 2014).The objective of the study is to compare the temperature over the river at the target years both by distribution from map and numerical values obtained from 15 particular stations.

METHODOLOGY

Temperature for each data is calculated using the thermal band. LANDSAT TM and ETM+ data requires same method to find out brightness temperature and OLI_TIRS data requires a distinguished method for calculation of temperature. All procedures are obtained from LANDSAT data users' handbook. All coefficient and constant values are available in LANDSAT data users' handbook.

Temperature derivation from TM and ETM+

Calculating land surface temperature for TM & ETM+ is a tow step methodology. First the raw image is needed to convert into spectral radiance image following NASA (1999)

$$L_\lambda = ((LMAX_\lambda - LMIN_\lambda)/(QCALMAX - QCALMIN)) \times (QCAL - QCALMIN) + LMIN_\lambda \quad (1)$$

Here, L_λ= Cell value as radiance, Qcal= Digital Number, QCALMIN= the minimum quantized calibrated pixel value and $LMIN_\lambda$= the spectral radiance scaled to QCALMIN.

Then the reflectance images are converted into brightness temperature

$$T = \frac{K2}{Ln(\frac{k1}{L\lambda})+1} \quad (2)$$

Here, T= temperature in Kelvin, K_1= Calibrated constant 1 and K_2= Calibrated constant 2

Temperature derivation from OLI_TIRS

For OLI_TIRS the DN values are converted to surface reflectance

$$L_\lambda = M_L \times Qcal + A_L \quad (3)$$

Here, Q_{cal}= Pixel value as DN, A_L= Radiance additive scaling factor and M_L= Radiance multiplicative scaling factor.

From reflectance to brightness temperature conversion is done by using the Eq. (2). The temperature can be converted to degree Celsius from Kelvin using the following formula

$$C = Kelvin° - 273 \quad (4)$$

RESULTS AND DISCUSSION

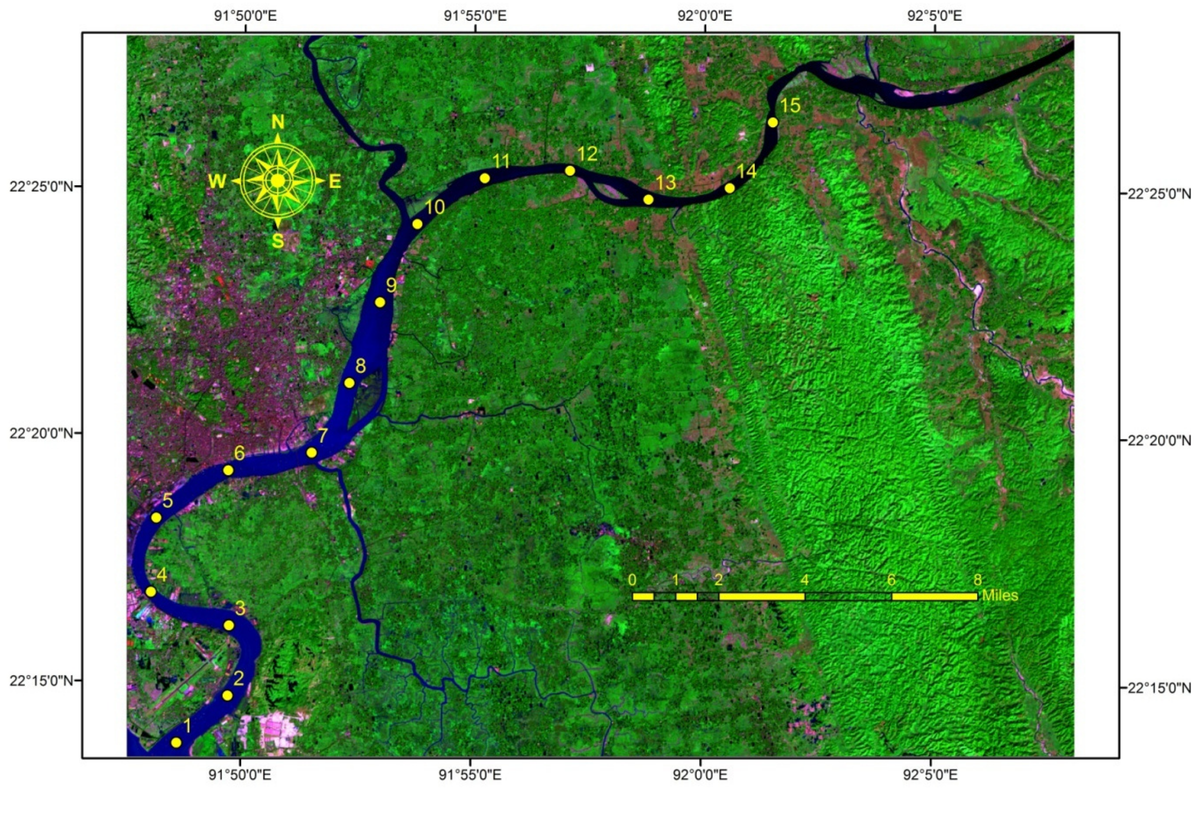

Fig.1: River Karnaphuli with observing stations in a LANDSAT image

The observed stations are visible in Fig.1 which are arranged serially keeping an approxiamte distance of 3000m between two points. For analysis and to facilitate comparison temperature has been classified into four categories which are Very high (24-28°C), High (21-24°C), Medium (19-21°C) and Low (<19°C). There are islands on the river which are omitted during analysis.

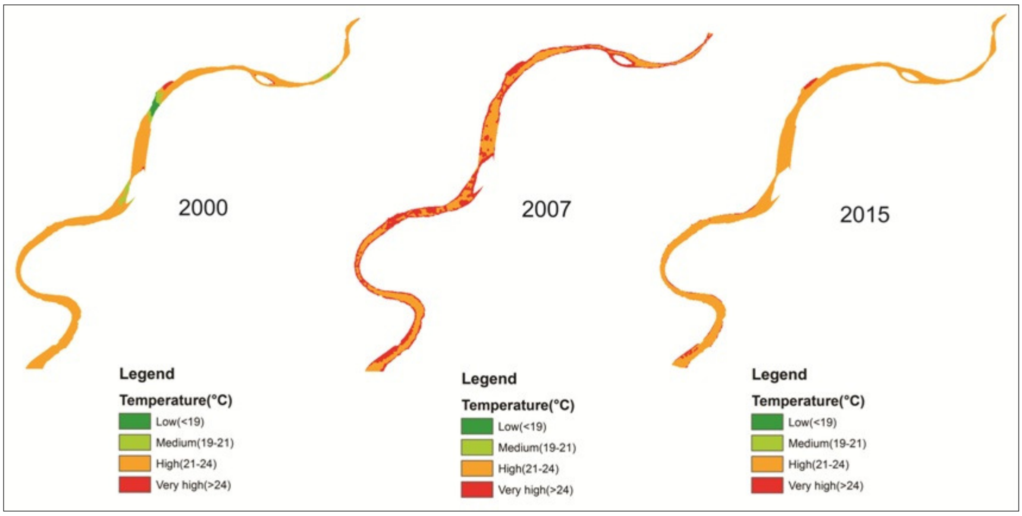

Fig.2: Temperature distribution at March

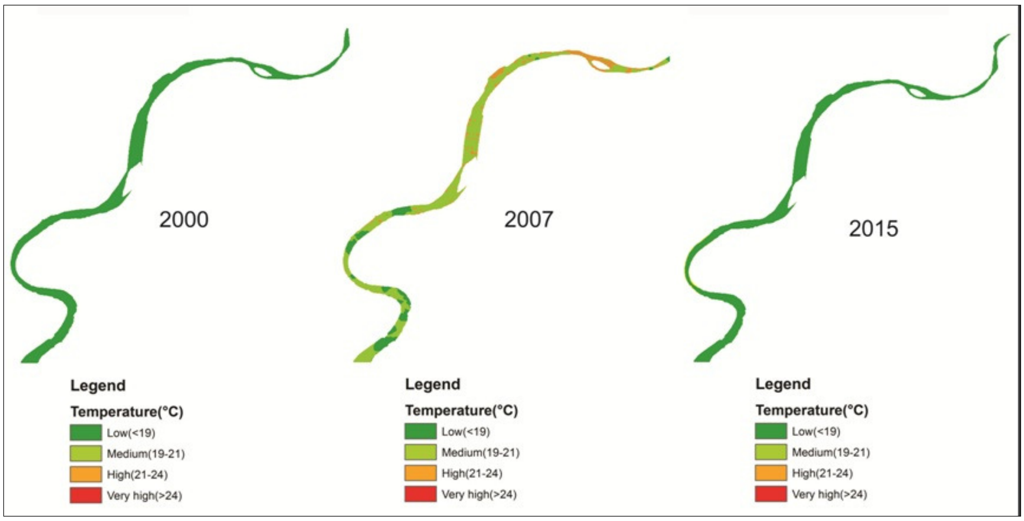

Fig.3: Temperature distribution at July

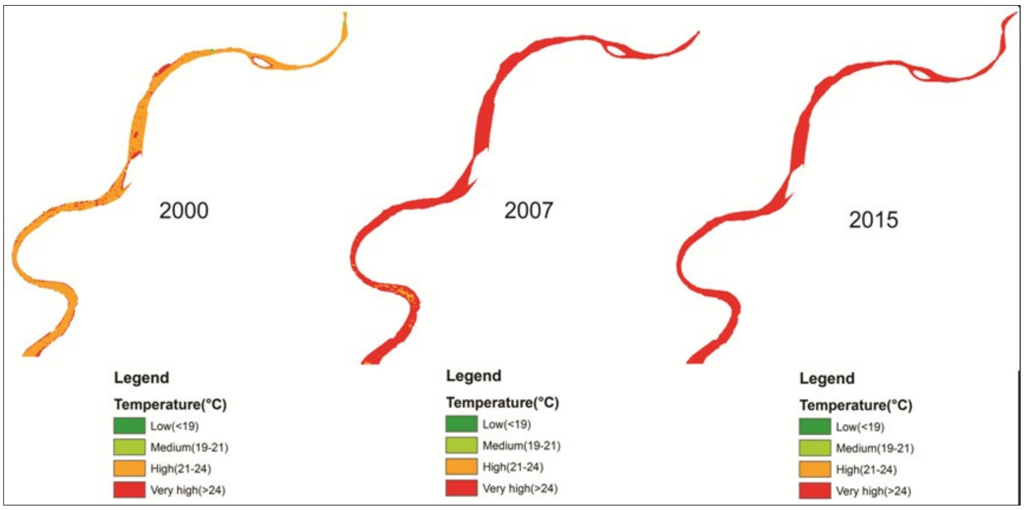

Fig.4: Temperature distribution at November

Temperature in the month of March

In Fig.2 for the derived temperature of March is seen. At the year 2000 the river is almost occupied by high range of temperature values though in some areas low and medium level of temperature exists. In 2007 the river is occupied by high to very high range of temperature and in case of 2015 it is high range of temperature values. From the observing stations the same scenerio has found. Temperature at all of the points are within 20°C to 25°C except for one. At station 14 the year 2000 has a temperature value of below 20°C. The years 2000 and 2015 almost overlapped at most of the stations.

Temperature in the month of July

At the month of July [Fig. 3] the river is found in low temperature in 2000. In 2007 most of the surface area of the river was occupied by medium class of temperature though some low level of temperature portions are seen in downstream and high range of temperature areas are visible in upstream. In case of the year 2015 the whole river is occupied by low range of temperature as like 2000. Observed temperature values [Fig: 2] show too many fluctuations and year wise variation in July. The year 2007 would lie above others in July on average.

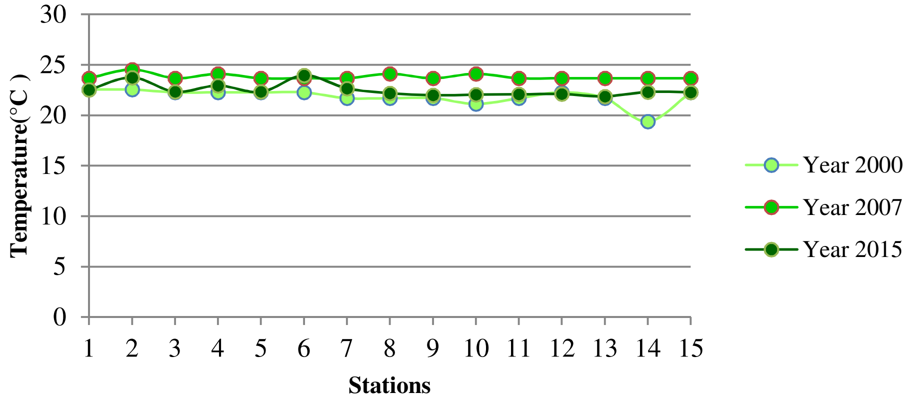

Fig.5: Observed temperature values at 15 stations of March

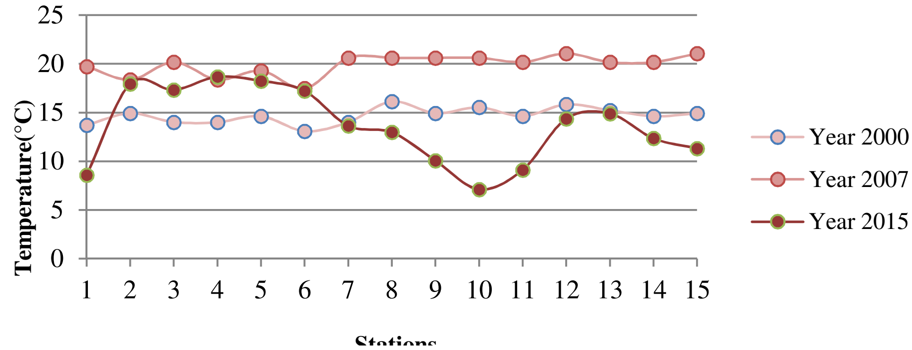

Fig.6: Observed values of temperature at July

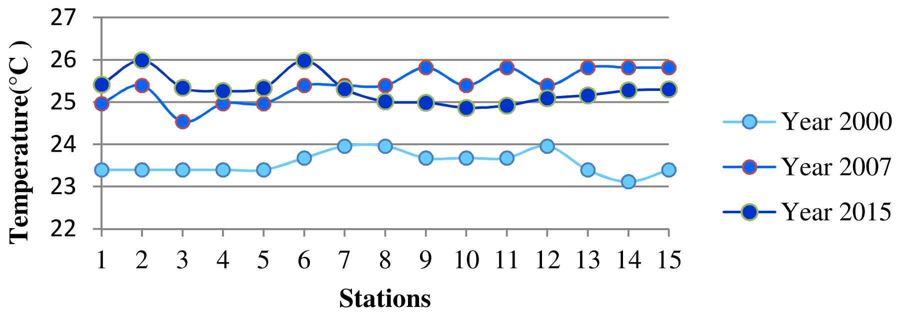

Fig.7: Observed temperature values at November

From the station 1 to 6 the line of 2015 lies above 2007 and also the maximum temperature found at the station 2 which is 25.98°C at the year 2015. In case of the stations 8 to 15 the year 2007 got higher temperature than 2015.

Temperature in the month of November

It is very clear from temperature distribution map [Fig. 4] for the month of November that in the year 2007 and 2015 the river was almost occupied by very high range of temperature values that is more than 24°C. In case of the year 2000 the river was occupied by high range of temperature values. From the extracted values at 15 stations [Fig. 3] a very significant and anticipated distribution is found. For 2000 all of the stations got temperature between 23°C to 24°C and also the year lies below the other two years. From the station 1 to 6 the line of 2015 lies above 2007 and also the maximum temperature found at the station 2 which is 25.98°C at the year 2015. In case of the stations 8 to 15 the year 2007 got higher temperature than 2015.

CONCLUSION

In Fig. 4 average fluctuation of temperature in 2000, 2007 and 2015 has depicted. In November average temperature in 2000was 23.56°C, in 2007 25.39°C and in 2015 it was 25.28°C. So, in November water surface temperature increased 2°C from 2000 to 2007 and remained almost same up to 2015.For the month of March too it represents 2°C increase as in 2000 it is 21.84°C and in 2007 it is 23.81°C, then in 2015 it fell 1°C upon 22.48°C. But in case of July it starts at 14.67°C in 2000 and rises to 19.89°C in 2007 and then fall to 13.58°C in 2015. As the month July is among the monsoon period it can be assumed the reason behaving different than other two months. The rainy season (June through October) accounts for 70 to 85% of the annual rainfall, which varies from 70% in the eastern part of the country to about 80% in the southeast and 85% in the northeast (Ahmed, 2015). However, for March and November it is found overall increase of temperature from 2000 to 2015.

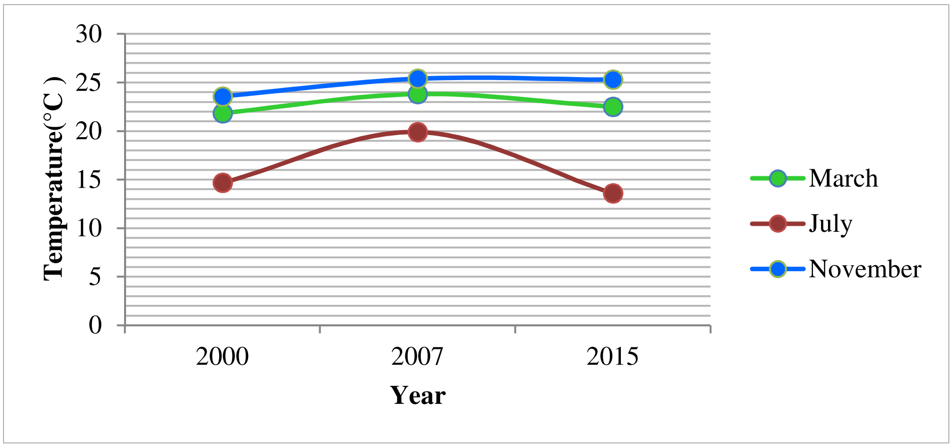

Fig.8: Average fluctuation of temperature.

Water temperature influences physical and chemical parameters of rivers and streams and is an important parameter of water quality (Fricke, 2013). Water temperature is deeply related with other parameters like chlorophyll-a, turbidity, pathogens etc. for large water reservoirs. So, to determine the water usability, temperature measurement and monitoring are essential. The inherent problem with remote sensing based research is high cloud coverage of satellite data. In the monsoon period the sky almost remains covered with dense cloud and satellite images taken at that time are quite unsuitable to work with. Also, high resolution image would facilitate better analysis on output then low resolution image. Used LANDSAT images are consists of 30 meter resolution. Even though, large scale water body monitoring and observing (to detect changes) for long period of time remote sensing based water quality assessment is an effective and user-friendly tool.

ACKNOWLEDGEMENT

This research was done as a part of undergraduate thesis for completion of Bachelor of Urban and Regional Planning. We had overall 4 objectives and one of them was temperature measurement and monitoring. We are grateful to our colleagues and batch mates for cooperation and inspiration to complete the work successfully.

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EROSION-DEPOSITION SCENARIO ALONG THE SOUTH-WESTERN COAST OF BANGLADESH

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ABSTRACT
Coastline is a dynamic morphological entity, which responds to the external forces exerted by wave, tide, near-shore current, storm, rainfall, human intervention etc. Coastal changes are more important since they have direct impact on economic development and land management. Both natural and anthropogenic processes control the erosion and deposition activities of a coastal zone. In this study, erosion-deposition scenario of the south-western part of the Bengal coast were analysed through satellite images of last ~30 years. LANDSAT images were collected for dry period of each year and used to identify the shoreline by manual digitizing as well as indexing (Modified Normalized Difference Water Index - MNDWI) method. Rate of shoreline changes due to erosion and deposition was also estimated. Both methods were then compared and discussed basing on the results obtained. The rate of erosion is found almost double than the rate of deposition along the south-western coast, which indicates loss of valuable land.

Keywords: LANDSAT images; Shoreline; Manual digitization; MNDWI; Bengal coast.

INTRODUCTION
Coastal zones are one of the most complicated ecosystems with a large number of living and non-living resources. These zones are exposed to a series of dynamic natural process i.e., erosion, accretion, sediment transport, environmental pollution, coastal development etc. which usually cause changes in the shoreline. A shoreline coincides with the physical interface of land and water and keeps changing its shape and position due to coastal erosion and deposition (Dolan et al., 1980). It is a time-dependent phenomenon that may exhibit substantial short-term variability (Morton, 1991). Generally, shoreline changes have different manifestations over small time-scale or large time-scale. Small time-scale influences are regular waves and currents, tides and winds, storm, rainfall etc. whereas large time-scale influences are glaciations or organic cycles that may change the sea level. Coastal erosion and deposition is relatively slow process and can take hundreds of years to notice the changes.

A large amount of land along the south-western coast was eroded and affected the habitat, tourism, aquaculture etc. The consequent changes in sediment and discharge processes of coastline and increase in salinity levels due to sea level rise has affected the phenology and morphology of the area. Sea level rise, increased frequency and intensity of storms, and amplified flooding episodes influence the rate of shoreline change and increase the vulnerability of individuals, households, communities, and cultures (Cutter and Emrich, 2006; Wu et al., 2002). Erosion and deposition processes that take place along the coastline of Sundarban create vast changes in the ecosystem of the forest. Destruction of this mangrove forest has left these coastal areas exposed to erosion and flooding, altered natural drainage patterns, and increased salt intrusion, also causing heavy loss of life and property, and jeopardizing the development activities (Ali, Anwar, 2003). Hence, a detailed study on erosion – deposition scenario of this area is required which has been done in the present study.

Study Area

The coastal zone of Bangladesh which is significant for its natural resources and ecosystems covers 19 districts out of the country's 64 districts and contains 28% of the country's population (Iftekhar and Saenger, 2008). The study area considers the Deltaic coastal plain of Bangladesh, which is situated in the west part along the Bay of Bengal as shown in Fig. 1. Bangladesh, the world largest deltaic region lies in the north-eastern part of South Asia between latitude 22°34'N and 26°34'N and longitude 88°1'E and 92°41'E (Hossain, 2001). Satkhira, Khulna, Bagerhat, Pirojpur, Barguna and Patuakhali districts are included in this Deltaic Coastal Plain. The coastal zone of Bangladesh covers an area of 47,201 sq km (WARPO 2006). The fluvial discharges come from the rivers connected to the shoreline are Harivanga, Jamuna, Maloncha, Arpongasia, Dhorla, Passur, Tista, Shilagang, Haringhata, Balesshawar, Bishkhali, Burisshawar, Andharmanik Rivers etc. These rivers provide fluvial discharge and cause deposition in the coastal area. The southwest coastal region of Bangladesh is the most disaster prone area. The Bangladesh Bureau of Statistics reports that the region is home over 10 million people (647 people per square km). The region is the part of an inactive delta of large Himalayan Rivers and is protected from tidal surge by the Sundarban mangrove forest. The delta areas are densely populated, with a predominance of agricultural activities due to the high fertility of the soils. The livelihood of most people depends on the environmental conditions of the delta, in terms of land cultivation, fishing, navigation, common property resources (e.g. from the Sundarban mangrove forest), and other economic activities.

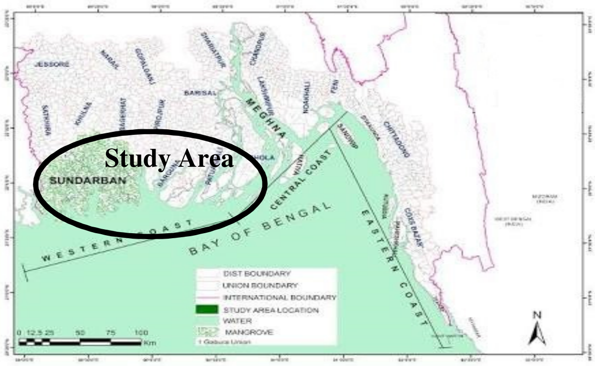

Fig. 1: Deltaic coastal plain of Bangladesh

Collection of Images

LANDSAT images were collected from the USGS Earth Explorer for 29 years (1989 - 2017). Images were downloaded for the month January particularly to get cloud free images. Delineation of the shoreline requires the images to be totally clear and cloud free which restricted the number of images. Downloaded images were sorted out into three categories: bad, moderate and good. Sample images of these three categories are displayed in Fig. 2.

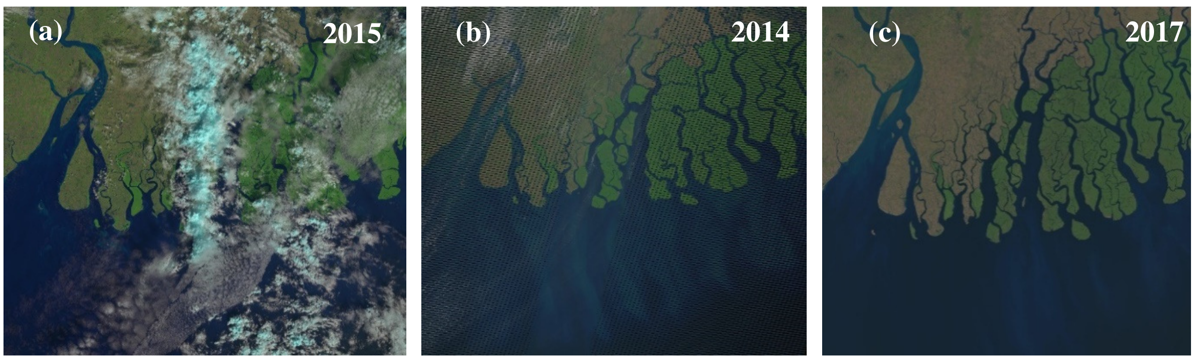

Fig. 2: Sample Landsat images with varying quality i.e. (a) bad quality with cloud waves, (b) moderate quality with minor noises and (c) relatively good quality images

Effect of Varying Water Level

Area coverage will change due to change of water level. It is better if similar images having same water level were used. But it is not always possible, because the satellite is moving in a certain time over the area. The Landsat images used for this study were collected from different Landsat sensors which capture images at different times. For Landsat 4 and 5, the satellite passing time is 4.00 am whereas for Landsat 7 and 8 satellites passing time is 4.30am. In this study, the water level is checked to get a uniform picture. Hourly tide data were collected from BIWTA (Bangladesh Inland Water Transport Authority) for the nearby tide station i.e. Pusser River. Table 1 shows that all the collected images were taken during low tide (according to NOAA, the range of tide level for low tide is up to 1.04 m) time except for year 2014. It may have bigger coverage and not representative. Tide levels during image acquisition times are also summarized in Table 1.

Table 1: Satellite image acquisition time and corresponding tide level

Acquisition Date and Time (AM)		Tide Level (m)	Tidal Condition	Acquisition Date and Time (AM)		Tide Level (m)	Tidal Condition
2/1/2015	4:30	0.835	Low Tide	1/7/2005	4:00	-0.006	Low Tide
2/4/2014	4:30	1.15	High Tide	1/13/2004	4:30	-0.07	Low Tide
1/5/2013	4:30	0.68	Low Tide	1/12/2001	4:00	0.726	Low Tide
1/28/2012	4:30	0.2	Low Tide	1/26/2000	4:00	-0.22	Low Tide
1/25/2011	4:30	0.179	Low Tide	1/1/1997	4:00	-0.48	Low Tide
1/22/2010	4:30	-0.275	Low Tide	1/28/1995	4:00	0.18	Low Tide
1/2/2009	4:00	-0.233	Low Tide	1/25/1994	4:00	0.32	Low Tide
1/16/2008	4:00	-0.827	Low Tide	1/22/1993	4:00	0.744	Low Tide
1/21/2007	4:30	-1.011	Low Tide	1/14/1990	4:00	0.459	Low Tide
1/26/2006	4:00	0.082	Low Tide	1/19/1989	4:00	0.261	Low Tide

DETECTION OF SHORELINE

The shoreline was detected using two methods. i) Manual digitization method (the land water boundary has been digitized manually and area was estimated). ii) Index method (the collected images were digitized and analysed through MNDWI method). Both methods are explained in the following sections:

Manual Digitization

Coastline can be extracted from a single band image only e.g. band-5 to extract shoreline manually (Alesheikh, et al., 2007). However, in this study, in manual method all the bands were used to get a perfect image of the area. When all the bands are collaborated and geo-referenced, the shoreline can be perfectly extracted from the images. In Landsat 4-5, there are seven bands. Eight bands are for Landsat 7, and for Landsat 8 there are eleven bands. The shoreline of the study area is very complex mainly because of the connection of many small rivers to the shoreline. Therefore, the digitization of this area is relatively difficult, so the area was divided into 7 segments as displayed in Fig.3.

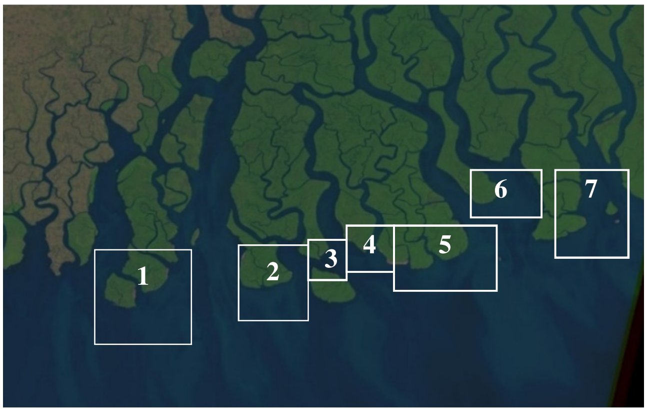

Fig. 3: Seven major segments of a Landsat image covering the study area

Edges of the shore were detected in the geo-referenced images manually to locate the shoreline position. Each segment was divided into six sub-segments except segment 3, 4, 6 and 7 which are divided into three sub-segments [Fig. 4] to identify the zone of erosion and deposition. The shoreline was converted into poly-lines using the editorial tool. Finally, the area of erosion and deposition were estimated.

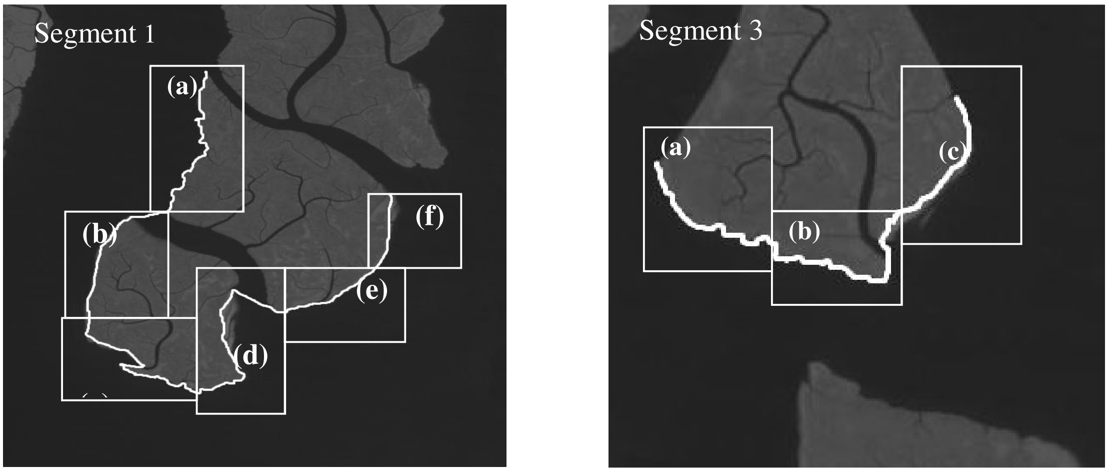

Fig. 4: Division of sub-segments of major segments.

MNDWI Method

Modified NDWI (Normalised Difference Water Index) is used for delineate open water features. In MNDWI (Modified Normalized Difference Water Index) method, Green and Middle Infrared Ray (MIR) are used instead of Near Infrared Ray (NIR) which is used in NDWI. MNDWI can be estimated using Eq.1.

$$\text{MNDWI} = \frac{\text{GREEN}-\text{MIR}}{\text{GREEN}+\text{MIR}} \quad (1)$$

According to the MNDWI, the build-up land has negative values while keeping the water values positive. Accordingly, the enhanced water features will no longer have build-up noise in a MNDWI image. This substitution has no impact on vegetation, as vegetation still has negative value when calculated using the equation. MNDWI is more suitable for enhancing and extracting water information for a water region with a background dominated by built-up land areas because of its advantage in reducing and even removing built-up land noise over the NDWI. In this method, two bands were used, Green and MIR. In Landsat 4, 5 and 7, band 2 is the green band and band 5 is the MIR band. But in Landsat 8, band 3 is green and band 6 is MIR band. Using QGIS, reflectance of the bands was calculated and Landsat images were converted to MNDWI images. This MNDWI images were then digitized using ArcGIS. The shoreline was then detected from the indexed images. From a series of shoreline, eroded and deposited areas were estimated.

RESULTS AND DISCUSSION

Net erosion and deposition rates were estimated for seven segments of the deltaic plain, which is having the same boundaries between the zones for 1989 to 2017 using both the methods (Manual and MNDWI). Table 2 summarizes the net rate of shoreline change, and the eroded and deposited land area in different years.

From manual method of shoreline extraction highest deposition observed in the year of 2014-2015and lowest value observed in the year of 2012-2013, area of which are 7.23 km^2 and 1.53 km^2 respectively. Maximum land area eroded is 9.19 km^2 in year 2005-2006, and the minimum erosion is 3.37 km^2 of year 2008-2009. The rate of deposition is 3.48 km^2/yrand the rate of erosion is 6.19 km^2/yr and the rate of net change is 2.7 km^2/yr. Therefore, the coastal area in manual method is observed to be erosion prone.

Table 2: Rate of shoreline changes for different periods using Manual and MNDWI methods

Year	Deposition (km^2/yr)		Erosion (km^2/yr)		Rate of Shoreline Change (km^2/yr)	
	Manual	MNDWI	Manual	MNDWI	Manual	MNDWI
1989-1990	2.7	0.87	4.59	4.88	-1.91	-4.01
1993-1994	8.7	0.15	8.18	1.13	0.51	-0.98
1995-1997	2.03	0.51	4.34	2.24	-1.40	-1.73
2000-2001	3.08	-	5.36	13.22	-2.28	-13.22
2005-2006	2.46	6.01	4.11	9.91	-1.65	-3.90
2008-2009	2.06	-	3.37	15.15	-1.31	-15.15
2010-2011	3.60	0.19	9.19	3.07	-5.59	-2.88
2012-2013	1.53	8.53	5.30	5.73	-3.76	2.8
2014-2015	7.23	6.24	8.15	8.79	-0.94	-2.55
2016-2017	1.45	4.98	9.48	9.53	-8.03	-4.56
Total	34.84	27.48	61.86	73.65	-27.02	-46.17
Rate	3.48	2.75	6.19	7.37	-2.7	-4.62

In MNDWI method, observed highest deposition is 8.53 km^2/yr of year 2012-2013 and the highest erosion is 15.15 km^2/yr of year 2008-2009. The change in shoreline is higher in 2008-2009. Results also show that no land masses deposited in the year of 2000-2001 and 2008-2009. The overall rate of deposition and erosion are 2.75 km^2/yr and 7.37 km^2/yr respectively. Shoreline changed at a rate of -4.62 km^2/yr in past 28 years. Fig. 5 displays the comparison of the Erosion and deposition rate of year 1995-1997 in manual and MNDWI methods. It is observed from Table 2, that MNDWI covers more area than manual method. White patterns developed by foams or breaking waves were covered by the index method as shown in Fig 6 and considered as land which differs the result. Indexing is faster than manual method though manual method is found to be more accurate.

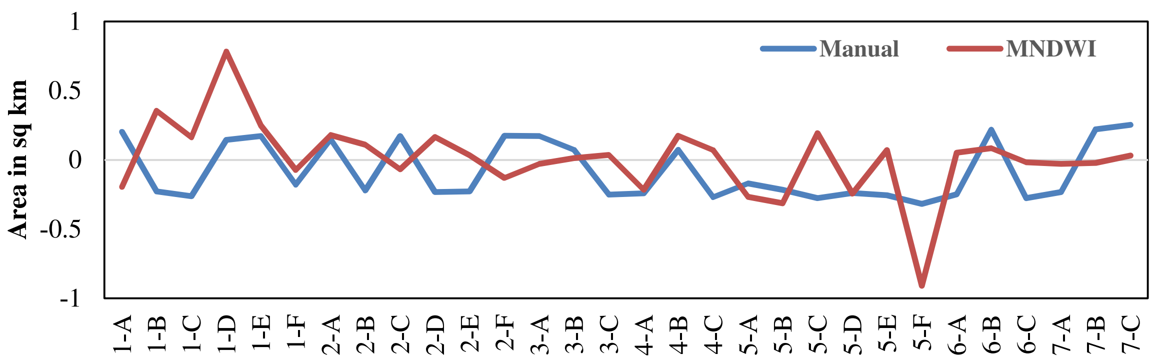

Fig. 5: Comparison of rate of erosion and deposition of year 1995-1997 in both methods

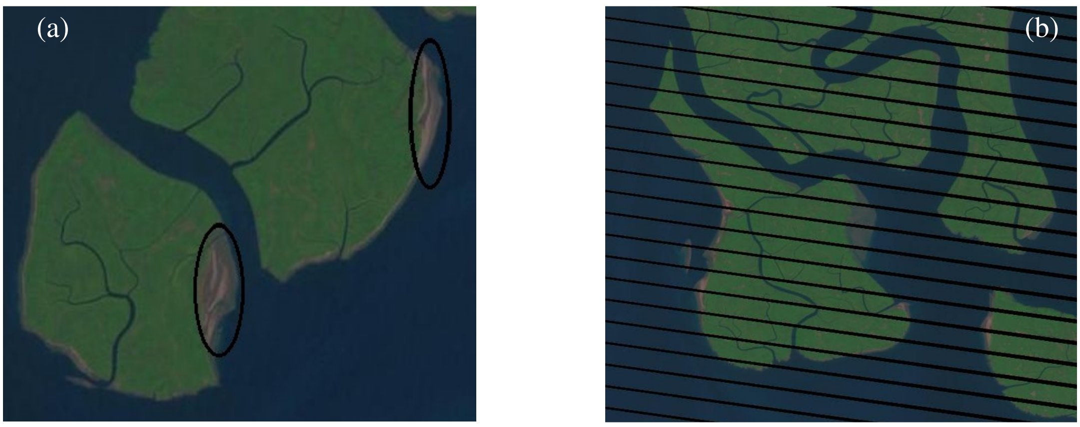

Fig. 6: Error in calculation due to (a) inundated portion and (b) noise problem

CONCLUSION

The aim of the study is to investigate the rate of coastal transformations along the western coast of Bangladesh. For this purpose, satellite remote sensing data were analysed to identify the rate of erosion and deposition along the western coastline of Bangladesh. This study was conducted by two methods - Manual and MNDWI (Modified Normalized Difference Water Index) method. Among the two methods, the rate of erosion and deposition is higher in index method but the results are more accurate in manual method. The result of shoreline change map will be more useful for coastal engineers and coastal zone management authorities to facilitate suitable management plans and regulation of coastal zones.

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A STUDY ON THE IMPACT OF HIGH END EMISSION ON THE CROP YIELDS AT THE COASTAL REGION OF BANGLADESH

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ABSTRACT

Bangladesh is an agrarian country and rice is its staple food. The ever increasing demand of rice due to population increase and decrease in cultivating land is making it difficult to deal with. Moreover, the abrupt changes in climate due to high end emission and global warming are making it even worse. Apart from the climate change, issues of salinity intrusion also play a role in coastal regions. Among the 64 districts, 6 districts from the coastal region of the country are selected for the study. Noakhali, Patuakhali, Bhola, Cox's Bazar, Bagerhat and Barguna are the selected districts. Impact of high end emission on production of Boro and Aman rice in study areas has been evaluated using the DSSAT 4.5 crop modelling system. It was calibrated using BR29 and BR11 variety for the years 2007-2010 and validated for 2011-2014 incorporating BBS data with statistical parameter nRMSE. Impact of future climate is analysed for the years 2020's (2021-2050), 2080's (2070-2099) with baseline years 1981-2010 using 7 bias corrected ensembles regional climate models (RCM's). The soil profile data was extracted from WISE 1.1 soil database. The results show that, the yield is negative everywhere, reaching over 20% decrease in some regions. The maximum temperature rise exceeds 1.5°C in 2020's and 4°C in 2090's whereas the minimum temperature rises up to 5°C in 2090's. This rise in daily temperature over the growing period of Boro and Aman rice indicates the adverse impact of temperature on crops. The decrease in yield has been more for Boro rice than Aman. This indicates that, the rain fed crop Aman has less vulnerability to climate change or emission than the irrigated crop Boro. Interestingly, lower loss to crop yield was observed for both verities of rice at elevated amount of carbon emission.

Keywords: Boro Rice; Aman Rice; RCM; Climate change; DSSAT 4.5.

INTRODUCTION

Like other agrarian countries, Bangladesh is hugely dependent on agriculture as it contributes to 35% of the GDP and 70% of the labour force in Bangladesh. Increasing demands for food, agricultural land and water warrant the studies on agriculture (Ahmed et al., 2000). About 40 million people of coastal region are directly or indirectly dependent on agriculture for their livelihood (BBS, 2011). The impacts of climate change on food production very important for Bangladesh. Boro and Aman rice is the leading rice producer varieties of Bangladesh (BRRI, 2006). Climate change is a threat for rice production. So evaluating the impact of climate change on Boro and Aman production is significant. Simulation studies have been carried out previously to assess impacts of climate change and variability on rice productivity in Bangladesh using the CERES-Rice model of DSSAT. (Mahmood et al., 2003; Mahmood, 1998; Karim et al., 1996). For instance, Basak (2010) has carried out simulations of 12 representative regions from various zones of the country using the regional climate model PRECIS. However, this study covers six coastal zones of the country using seven numbers of bias corrected ensembles of regional climate models which has taken high end emission into account while projecting the future climate data.

METHODOLOGY

Study area

This study was done on six coastal districts of Bangladesh (20°34″ North Latitude to 26°38″ North Latitude and from 88°01″East Longitude to 92°41″ East Longitude) which that encompass almost 0.018 million km^2 territory. Bangladesh is the largest delta of the world as 80% of the land is formed by the floodplains of the GBM basin (Ganges, Brahmaputra and Meghna) making it a fertile land for rice production. However, the coastal region is often intruded with salinity. The country experiences huge rainfall during Monsoon. However, some flash floods prior to the monsoon season also occur. This tropical country has annual average rainfall of 1600 mm and a temperature ranging from 8° to 38°during the growth season of Boro rice (Nov-April) over the last 30 years (1981-2010).

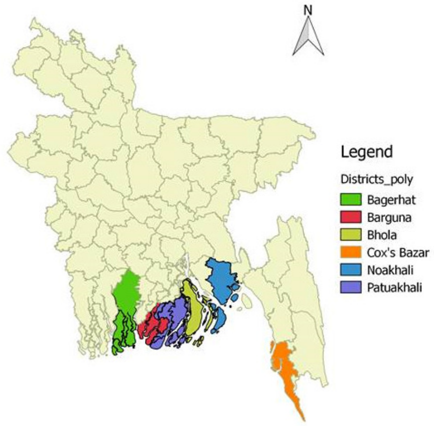

Fig. 1: Location of Selected Coastal Districts of Bangladesh

Selection of Crop Model

Among various crop modeling software like Crop-wat, DSSAT, PCSE etc. DSSAT 4.5 was chosen to calibrate and project the future crop yields. The CERES-Rice model of DSSAT is an advanced physiologically based rice crop growth simulation model and has been widely applied to understanding the relationship between rice and its environment. DSSAT estimates yield of both irrigated and non-irrigated rice, determine growth durations, dry matter production, effect of soil water and soil nitrogen contents on photosynthesis, carbon balance and water balance. Ritchie et al. (1987) and Hoogenboom et al. (2003) have provided a detailed description of the model.

Selection of Rice Variety

CERES-Rice model is variety-specific and it is able to predict rice yield and rice plant response to various environmental conditions. The model takes into effect of weather, crop management, genetics, and soil water, C and N. The model uses a detailed set of crop specific genetic coefficients, which allows the model to respond to diverse weather and management conditions. BR29 variety of Boro rice and BR11 variety of Aman rice has been selected as their genetic coefficients are available in the model.

Table 1: Some important information about BR29 and BR11 variety of Boro rice

Variety	BR29	BR11
Height	95 cm	115 cm
Duration of growth	160 days	145 days
Plantation	November	June
Harvest	April	November
Coarse Yield (Kg/hectares)	6500	5500
Developed on	1994	1980
Developed by	Bangladesh Rice Research Institute	Bangladesh Rice Research Institute

Integrating field data in DSSAT

WISE team has recently done experiments on 17 soil stations across Bangladesh. Once a region is selected from the global map, it enables the user to access the soil station data. This set of data is simply copied and pasted on the soil file. Thus the soil stations can easily be integrated in DSSAT.

Weather data

In this study, the historic weather data was taken from 35 stations of Bangladesh Meteorological Department (BMD). The weather data contains daily rainfall (mm), maximum and minimum temperature (°C) and daily solar hours. Rainfall and temperatures are used directly in DSSAT. However, the weather manager of DSSAT itself converts solar hours into solar radiation. As simulations were carried out over 6 districts, the data of the nearest station of the corresponding district was taken. Fig. 1 indicates the location of the meteorological stations of BMD. For calibrating the model, data of the years from 2007-2010 was taken and 2011-2014 was taken for validation.

Climatic Data

The future data was collected from 7 bias corrected ensembles with RCP 8.5 scenario of regional climate models RCM's under 4 GCM's. The baseline period was 30 years (1991-2010) and the projection was made for 2020's (2016-2035), 2050's (2046-2065) and 2090's (2080-2099). Table 2 describes the details of the ensembles.

Table 2: Details of the Ensembles

Institute	GCM	RCM	Driving Ensemble Member	Res.	RCP
SMHI	CNRM-CERFACS-CNRM-CM5	RCA4	r1i1p1	0.5°	8.5
SMHI	ICHEC-EC-EARTH	RCA4	r1i1p1	0.5°	8.5
MPI-CSC	MPI-M-MPI-ESM-LR	REMO2009	r1i1p1	0.5°	8.5
SMHI	MPI-M-MPI-ESM-LR	RCA4	r1i1p1	0.5°	8.5
SMHI	NOAA-GFDL-GFDL-ESM2M	RCA4	r1i1p1	0.5°	8.5
SMHI	IPSL-CM5A-MR	RCA4	r1i1p1	0.5°	8.5
SMHI	MIROC-MIROC5	RCA4	r1i1p1	0.5°	8.5

Crop Management

The crop management includes planting details, transplanted date, irrigation and fertilizer management, tillage, harvest and chemical applications. The date of transplant, the date of harvest, the amount of irrigation and fertilizer applications has been kept the same to a default set value according to the guidelines of BRRI.

Calibration and Validation

The model was calibrated to find the genetic coefficients for BR11 and BR29 variety of Aman and Boro rice respectively. Statistical parameter normalized root mean square error (RMSE) was used for the calibration. Value of nRMSE was found less than 15% for the selected regions. Trial and error method are used like previous studies (Saseendran et. al., 2013). Table 3 shows the default values of the genetic coefficients and the calibrated value of these parameters in selected coastal districts.

RESULTS AND DISCUSSIONS

It is observed that, most of the regions experience negative yield of BR29 and BR11 rice, reaching over 20% decrease in some regions [Fig. 3]. The maximum temperature rise exceeds 1.5°C in 2030's and 4°C in 2090's whereas the minimum temperature rises up to 5°C in 2090's. [Fig. 2] This rise in daily temperature over the growing period of Boro and Aman rice indicates the adverse impact of temperature on crops.

The rise of temperature for Aman rice is more for the regions of Barguna, Bagerhat and Bhola than the other three districts. It is observed that, for the growing season of Boro rice, the temperatures have not exceeded the specific warming level of 2°C in 2030's. But, for Aman rice some districts have crossed that warming level. In case of 2080's, it is observed that, both the growing periods have crossed the limit of specific warming level 4°C. It means, the temperature change would be severe in future than it is in present time.

Table 3: Values of the genetic coefficients in selected locations

Region	P1	P2R	P5	P20	G1	G2	G3	G4	nRMSE(%) (Calibration)	nRMSE(%) (Validation)
					For BR29 Boro Rice					
Default value	**650**	**90**	**400**	**13**	**67**	**.025**	**1**	**1**	**-**	**-**
Bagerhat	648	90	400	13	67	.026	1	1	6.4	3.7
Barguna	653	93	405	13.1	62	.026	1	1	13.9	9.0
Bhola	648	90	400	13	67	.025	1	1	5.5	3.8
Cox's Bazar	646	88	395	12.9	62	.025	1	1	9.4	6.2
Noakhali	650	90	400	13	67	.025	1	1	7.9	4.2
Patuakhali	653	93	405	13.1	67	.026	1	1	19.8	13.9
					For BR11 Aman Rice					
Default value	740	180	400	10	55	.025	1	0.9		
Bagerhat	740	180	400	10.5	55	.025	1	0.9	9.48	8.73
Barguna	740	181	404	10.4	55	.025	1	0.9	9.73	5.62
Bhola	740	180	400	10.5	55	.025	1	0.9	11.43	13.65
Cox's Bazar	735	177	405	10.1	55	.025	1	0.9	15.35	12.21
Noakhali	740	181	404	10.4	55	.025	1	0.9	10.73	4.62
Patuakhali	740	180	400	10.5	55	.025	1	0.9	13.44	12

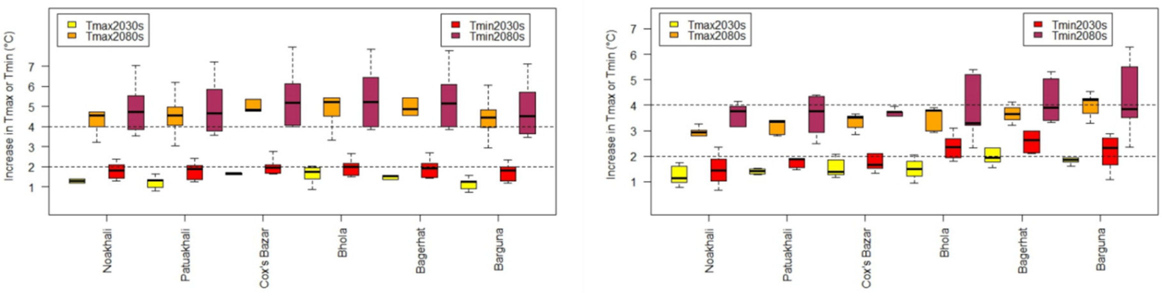

Fig. 2: a) Temperature increase for Boro Rice b) Temperature increase for Aman Rice

The results show a spatial distribution of the change of rice yield. As we see Fig. 3, for near future (2030's), the minimum reduction in yield of Boro rice has been 10%. On the contrary, there has been no loss greater than 10% in case of Aman rice. As for the far future or the 2080's, both the crops would suffer a loss more than 10%. However, according to some models, the situation would be worse for Boro rice than that of Aman rice as the loss would cross 20% for some coastal districts. Although the loss is less severe for Aman rice, the results point out how severe the impact of climate change is going to endanger the rice yield of the coastal regions in future.

The box plots at Fig. 3 also indicates the range of uncertainty of the yield changes of Boro and Aman rice in future predicted by seven different models. It is observed that, the range of uncertainty for far future (2070-2099) is more than the near future (2021-2050). These finding warns that, the change of climate would be so unpredictable in future that even the models are not certain of the severity of its extent in coming days.

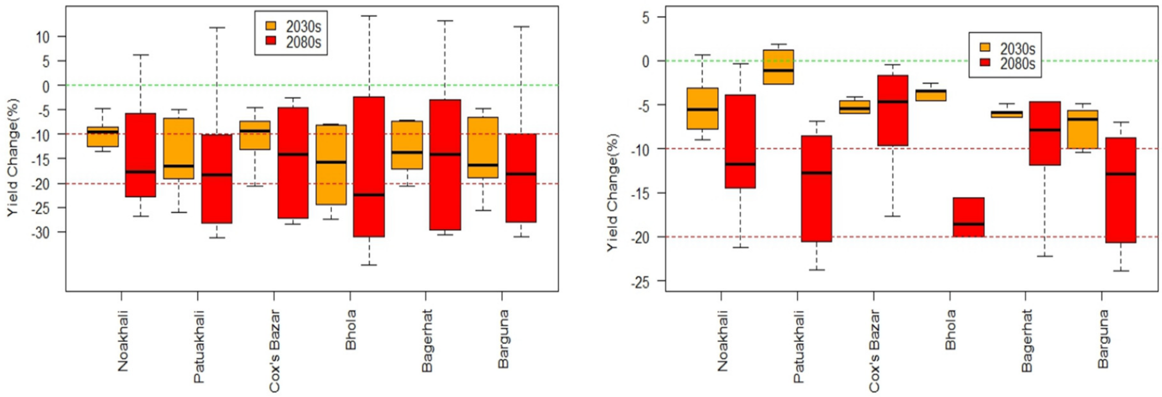

Fig. 3:(a) Yield Change for Boro Rice b) Yield Change for Aman Rice

CONCLUSIONS

Most of the regions encountered extreme change in maximum and minimum temperature over the emergence to end period of Boro and Aman crop. The yield trend is gradually decreasing at an alarming rate; crossing 10% decrease in 2020's to 20% decrease in 2090's for Boro rice. In case of Aman rice, the loss is somewhat less in extent comparatively. Temperature rise is assumed to be the major region for crop loss at coastal regions. Previous studies on coastal districts like Kibria et al., 2016 with the help of Aqua Crop model has projected that, if the global mean temperature would remain under tolerable limit, rice production would have increased instead of decreasing in that coastal regions. The growth and yield of crops are directly related to the rate of photosynthesis and their response to temperature, solar radiation and rainfall. Optimum temperatures for maximum photosynthesis range from 25ºC to 30ºC for rice under the climatic conditions of Bangladesh. Increased temperatures during the growing season cause grain sterility (Basak et al., 2010). Maximum temperatures cause the reduction in rice yield mainly. However CO_2 is also increasing which pose a positive impact on crop production. But, it is not dominant over the impact of temperature. The core finding in our predicted results suggest that, keeping the harvesting date same or shortening the emergence to harvest duration, we can actually get an increased yield in most of the regions. However, due to shortening the growth period, we are also shortening the irrigation water to a significant amount.

It is observed that, losses are more for Boro season than Aman season. Basically, Aman gets water naturally due to Monsoon while the growing period of Boro rice experiences no Monsoon at all. For this reason, the probable cause behind the reduction in yield of any zone is supposed to be lack of natural water supply. This finding calls for a more detailed works on SPI (standardized precipitation index) in future. DSSAT crop modeling could prove very effective for this potential study. Moreover, the high end emission as the IPCC could be simulated to assess how intense is the impact of increased emission on Boro and Aman rice.

Although DSSAT software has been working well to assess the climatic and soil parameters, the specific study and analysis of salinity is not possible with it. So, even DSSAT could easily explain the impacts of temperature rise and high carbon dioxide emission, it was not specifically certain to explain the salinity. Carrying similar studies with crop modeling software like Crop wat or Aqua crop could explain these soundly. Saha and Mondal, 2015 had done simulation studies with Aqua Crop and concluded that, this software can be used for assessing the impact of salinity on crop yield.

ACKNOWLEDGMENTS

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PLAN FORM ANALYSIS OF TEESTA RIVER

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ABSTRACT

Bangladesh, is house to myriad of rivers in its very compact space of only around 1, 47,570 sq. km. From the Himalayan Mountains flowing through India and entering Bangladesh through the Nilphamari district, the river Teesta is considered the very life giver for the people living in the Northern region of Bangladesh. Over the course of history this river has seen many changes in its flow path mainly due to flooding as well as tectonic plate shifting in the form of earthquake and geographical structural changes. Today the river is basically the accumulated flow of three rivers. At present this river however, is prone to changes in the form of constant erosion and deposition. The river bank sees more erosion than deposition in the present years; the river has experienced a high amount of erosion leading to the disruption of life of people along the river. In this paper, this erosion as well as deposition rate or in other words, the plan form analysis of the river has been shown. An analysis of 27 years has been presented in the study from 1990-2017. This analysis has been done with the help of images generated from USGS and later from these images after generating the necessary shape files with the help of ArcGIS software, the erosion and deposition along the river bank was quantified by using MS Excel software. From the analysis, it was seen that the rate of erosion is higher than the deposition. The river experiences high level of flow during the wet season leading to more erosion.

Keywords: Bangladesh; Teesta; Erosion; Deposition.

INTRODUCTION

The country Bangladesh is occupied with a network of about 405 rivers mostly alluvial in nature, spreading all over the country out of which 57 are transboundary (BWDB, 2011). Teesta River is a transboundary river shared by India and Bangladesh. Bangladesh being the lowermost riparian country, the water of the river is very vital for the sustenance of livelihood, planning of new water resources projects including evaluation of existing projects and optimum usage of natural resources. Riverbank erosion is one of the most unpredictable and critical disaster that takes into account the quantity of rainfall, soil structure, river morphology, topography of river and adjacent areas and effect of floods.

Rivers that are alluvial in nature has the problem associated with them of eroding banks as well as the constant threat of flooding and the humanitarian problems associated with constant flooding. Riverbank erosion has important implications for short and long term channel adjustment, development of meanders, sediment dynamics of the river catchment, riparian land loss and downstream sedimentation problems. Being alluvial in nature, floodplains of the rivers are predominantly formed of flood-borne sediments while their bank materials consist mostly of fine-grained cohesive sediments). In such alluvial rivers, through continuous erosion accretion processes, the channels frequently change its meandering pattern from reach to reach. On the other hand, development works such as, bank protection measures like embankment; dam and bridge may also cause local morphological changes of river affecting the ultimate sediment balance of the river. Thus fluvial channel form and its dynamics over the period of time have been a major interest of study in fluvial geomorphology (Nabi, 2016). Therefore, a better understanding on morphological changes of alluvial rivers, particularly bank shifting, channel migration due to erosion and accretion processes as well as techniques to detect resultant pattern would be useful for effective planning and management of the alluvial environments.

Temporal satellite remote sensing data of a river having unstable banks can be analysed in GIS for identification of river bank erosion as well as patches of embankment vulnerable to breaching, upholding the remote sensing approach in study of river morphology. Baki et al. (2012) studied on river bank migration and island dynamics of braided Jamuna River using LANDSAT images. Khan et al. (2014) studied on river bank erosion of Jamuna River by using GIS and Remote Sensing Technology. Hossain et al. (2012) assessed morphological changes of Ganges River. Sarker, analysed Rivers, chars and char dwellers of Bangladesh. Takagi et al. (2007) analysed the spatial and temporal changes in the channels of Brahmaputra. Sarker and Thorne (2006) examined the morphological response of major river systems of Bangladesh due to the Assam earthquake. In this study, the Teesta River, a river that has seen huge controversy erupting between two countries has been focused. The erosion and accretion rate of the Teesta River has been measured through the use of satellite imagery and finally the rate of erosion and accretion through the years has been compared. Mohammadi, (2008) analysed morphological changes of Dough river in north Iran using GIS.

Teesta River is an important river of the northern region of Bangladesh. According to Hindu mythology, it originated from the breast of Devi Parvati (Goddess Parvati). Actually it originates in Chitamu Lake in the Sikkim Himalayas at an altitude of about 7,200 m and comes down first to the Darjeeling plain and then to the plain of West Bengal (India). It flows through a magnificent gorge known as Sivok Gola in Darjeeling. It is a wild river in the Darjeeling Hills where its valley is clothed with dense forest. But its drainage area in the mountains is only 12,500 sq km. It enters Bangladesh at the Kharibari border of Nilphamari district.

Up to the close of the 18th century it flowed directly into the Ganges. The excessive rains of 1787 created a vast flood choked the original Atrai channel. This resulted in the Teesta bursting into theGhaghatwhich at that time was a very small river. After passing through Lalmonirhat, Rangpur, Kurigram and Gaibandha districts this deluge falls into the Jamuna, south of Chilmari river port. The total length of the river is about 315 km, of which nearly 115 km lies within Bangladesh. The land movement, earthquakes, floods and geological structural changes in the northern part of Bangladesh affected the original flows of the Karatoya, Atrai and Jamuneshwari rivers. The present Teesta is the result of these changes and the accumulated flows of the Karotoya, Atrai and Jamuneshwari rivers. Actually the Bangla name Teesta comes from Tri-Srota or three flows. Teesta has a mean monthly discharge of about 2,430 cumec. A number of old channels that were occupied by this river and the Karatoya through which it joined the Ganges are still known as the BuriTeesta or Old Teesta.
For the study area of this study a small portion of the TeestaRiver has been selected as it enters into the country through the Nilphamari district. A section of around a hundred kilometres was selected to understand the changes in terms of erosion and accretion that have taken place in the river through the span of 25 years.

METHODOLOGY

To conduct the analyses, Landsat satellite images are collected from USGS earth explorer website covering a portion of Teesta River in Bangladesh from the year 1990 to 2015. All the images collected were of the month of November or December as during dry season, vegetation cover and other ground conditions, particularly the water level, are relatively consistent from year to year which is essential for assessing the inter-year change of erosion and accretion of the River. In addition, during dry season the chances of getting a relatively cloud free atmosphere is a bit higher and the plan form generally shows the boundary and pattern of channels within the braid belt clearly. This is a method that is effective in quantifying the river change morphology and to properly identify the paleo-braided channels on terrace surface.
In the current study at first, the images were generated from USGS for the years 1990-2015 and afterwards, some cross sections on the study area was defined. These cross sections were put roughly 6 kmapart to ensure that when the images are digitized a good enough result will come. After that both the left bank and the right bank of each year were digitized with the help of GIS and later converted to

shape files within the software. Afterwards, points were placed for each year along the surfaces of both the right and left bank of the digitized images. Finally, all the generated points for each year were compared to each other using Microsoft Excel and finally results were generated in this way. In the case of this particular study after proper analysis of the different years the following results have been obtained. In the first case, the different years were processed in the excel file and the different years were quantified. The graphs are shown from [Fig.1 to Fig.5].

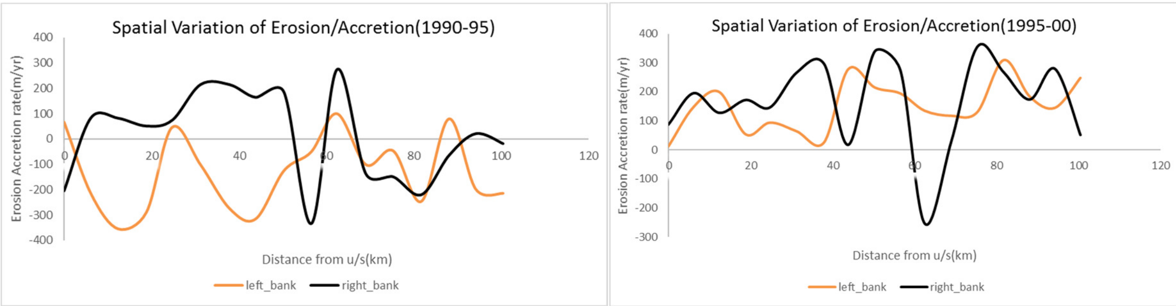

Fig1&2: Spatial variation of erosion and accretion inthe year 1990-1995 and 1995-2000

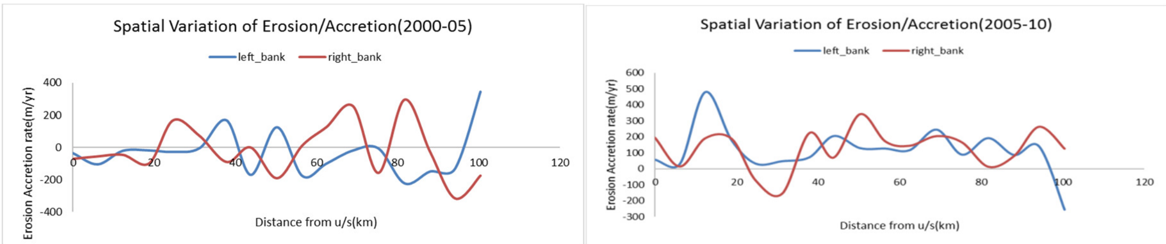

Fig 3&4: Spatial variation of erosion and accretion in the year 2000-2005 and 2005-2010

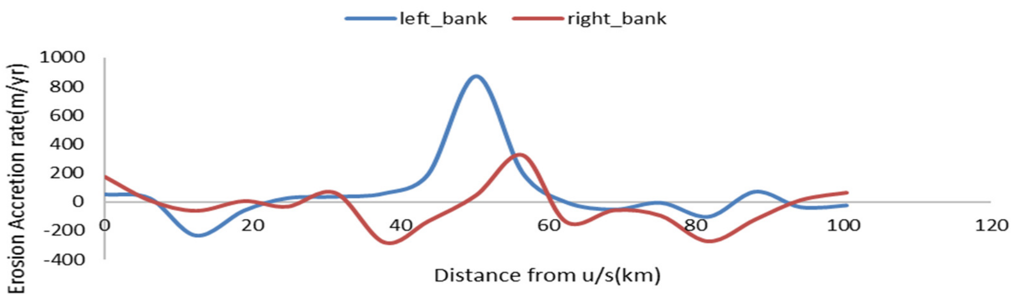

Fig 5: Spatial variation of erosion and accretion in the year 2010-2015

The average erosion accretion rate and the maximum erosion and accretion in both the left bank and the right bank can be shown through a chart that is given in the following Table 1.and Fig.6 to Fig.7 represent erosion and accretion from left bank and right bank.

Table 1: Maximum erosion and accretion both left bank and right bank

Year	Left bank Shifting				Right bank Shifting			
	Erosion		Accretion		Erosion		Accretion	
	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
1990-1995	385.52	425.256	72.15	99.02	160.68	333.81	239.65	325.23
1995-2000	0	0	225.13	247.52	252.92	252.12	192.6	289.53
2000-2005	137.95	285.26	296.52	385.24	189.34	285.24	175.32	190.23
2005-2010	256.23	365.25	139.3	174.53	115.01	156.12	188.77	254.32
2010-2015	97.83	125.24	168.14	256.23	153.98	198.23	88.46	175.21

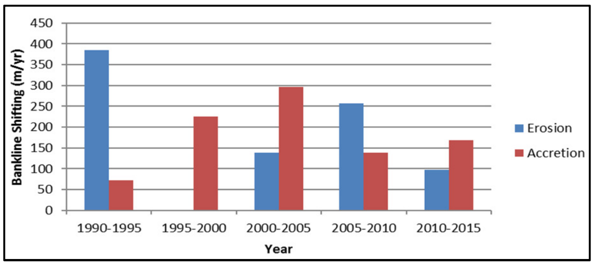

Fig 6: Erosion and accretion rate in left bank

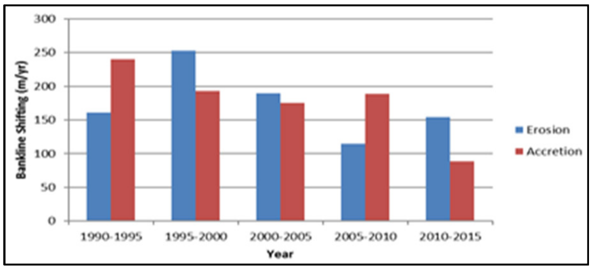

Fig 7: Erosion and accretion rate in right bank

RESULTS AND DISCUSSIONS

From Table:1, it can clearly be shown that the average rate of erosion in the left bank hovers around the 200-300 m/yr mark in all most of the years with some of the years like 2000-2005 and 2010-2015 showing a smaller rate of average erosion than normal. On the other hand, accretion shows a similar trend with smaller amount of accretion seen in the years when the erosion was less. For the right bank, the amount of erosion and accretion is also of the same trend hovering around the 200-300 m/yr mark in most of the years with 2005-2010 and 20010-2015 showing slightly lower amount of erosion trend. The same is seen for the accretion with accretion being low in recent years as well.

CONCLUSIONS

The present work using remote sensing and GIS based approach with multi-date satellite data has revealed sharp changes in fluvial land form in recent years resulting in considerable inhabited land loss. River adjustment processes that affected fluvial system of the river Teesta include forcing functions like channel degradation and aggradations, lateral river migration, widening or narrowing, avulsion, changes in the quantity and character of the sediment load at spatial and temporal scale, intensely powerful monsoon regime, recurring earthquakes and adverse impact of anthropogenic factors. However, the biggest problem that this river faces currently is the water crisis due to India not being willing to share water and this has culminated in the river becoming unstable and showing regular erosion and accretion along its banks.

This study has proved the utility and application of satellite remote sensing which allows a retrospective, synoptic viewing of large regions and so provides the opportunity for a spatially and temporally detailed assessment of changes in river channel erosion/deposition. This study has further demonstrated how the use of GIS has been expedient in organization of geo-spatial databases and facilitation of channel position mapping and measurement. The present study identified locations affected by of bank erosion accretion and the bank line shifting and indicated the urgent need to protect the river banks employing afforestation measures and other strategies. Therefore, it is necessary to incorporate geomorphic changes in formulating flood management programs.

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FLOOD HAZARD ZONING ASSESMENT OF CHITTAGONG CITY USING GIS AND MULTI CRITERIA DECISION ANALYSIS

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ABSTRACT
Recently, the port city of Bangladesh, Chittagong have been affected by several storm flood events, Heavy intensity rainfall, new housing developments covering previously permeable grounds, and old drainage systems are the main causes for this situation. This paper presents a simple approach of urban flood hazard assessment in a region where primary data are scarce. The objectives of this study are to develop a GIS-aided urban flood hazard zoning of the Chittagong city applying multi criteria decision analysis and to evaluate it by means of uncertainty and sensitivity analysis. The research methodology focused on the analysis of those variables that control the water routing when high peak flows exceed the drainage-system capacity. The model incorporates five parameters: distance to the drainage channels, topography (heights and slopes), and urban land use. A final hazard map for each category is obtained using an algorithm that combines factors in weighted linear combinations. This study will help to demarcate the flood hazard zone where built up area should have restricted. This study will help a planning instrument for land use zoning.

Keywords: Flood hazard assessment; Urban flood hazard zoning; Water routing; Drainage-system

INTRODUCTION
Chittagong is a district located in the south-eastern region of Bangladesh is a part of Chittagong division. It is a hilly city surrounded by Kornofuly River and Bay of Bengal The climate of Chittagong city is influenced by strong tropical monsoon characterized by high temperature and heavy rainfall in association with high humidity (Rashid 1991). Though Chittagong is called the commercial capital of Bangladesh faces a lot of socio-economic problem. Among them water logging is a most vital problem happens during in the rainy season is considered as an environmental threat for the human being (Papry and Ahmed 2015). This problem is getting worse and worse because of insufficient and unplanned drainage system. Unplanned urban infrastructure development and poor maintenance of the existing drainage facilities may also aggravate the congestion problem even in the previously well drained city like Sylhet (Ahmed 2009).

Water logging is mainly happened when the existing drainage system is blocked with the wastages and because of it the water cannot follow the natural drainage line. By making artificial drainage systems which will work as an alternative to natural water bodies and swamps which helps to reduce the flood risk. Because of the continuous changes in the land use with impervious surfaces in cities like Chittagong considerably affect flooding which is further exacerbated by increased runoff, which quickly blocks drains and channels with sediment, wastes and debris (Barua and Ast 2011). Around 1960-61 some master plans on drainage were made to reduce the water logging problem for Dhaka and Chittagong. Basically this plans were produced based on zoning maps with very little or no reference to drainage planning. But the matter of regret that the planning was taken over by drainage engineering without any conscious endeavour to integrate drainage planning with the land use planning process. There was a very little attention to the architect and planner's proposals about drainage system when they went ahead with their zoning proposals in housing and industries sector.

From the last three decades the total amount of rainfall is remained almost same where there is found a huge change in the development of physical feature in the Chittagong city. The open spaces are decreased, thus when rainfall occurs in the city, it cannot percolate through and increased the surface runoff. The increased runoff does not pass through the existing drainage channels creates drainage congestion in the city particularly in low lying area (Ahmed and Alam, 2010). There are some low lying areas, basically in the central part of Chittagong such as Chawkbazar, Muradpur, Bahaddarhat, Bakalia, 2 no. Gate, Agrabad, Badurtola and Shulokbohor are regularly waterlogged during rainy season (Papry and Ahmed, 2015). The sufferings of the residents of these areas knows no bounds when the schools, colleges, working places like office, business centres houses gone under the three or four feet of water in the rainy season. This is mainly happened because of the unplanned drainage system and poor maintenance of the drains. In these areas, land development through artificial landfill of depressions, back swamps and floodplains generally reduces the water storage capacity of the area and may increase the water levels, resulting in an increased hazard and risk (Papry and Ahmed, 2015).

For these, this study was aimed to find out the flood hazard risk zone of the Chittagong city by analysing the existing drainage condition of the study area.

METHODOLOGY

The study was conducted by aiming to find out the flood hazard risk zone of the Chittagong city corporation area based on the existing drainage condition of the study area. Before going through these work the first duty was to review the relevant literature of this topic. In our methodology at first, we reviewed some paper to find the methodology to find flood hazard risk zone assessment. Then according to that we fixed our goals and objective. Then we have collected DEM data (Digital Elevation Model), drainage carrying capacity data from CDA & Landsat data. From DEM data we tried find out the basin and streamline analysis also used for aspect analysis. From Landsat data we found built up area from build-up index. And from attribute input we analysis the drainage carrying capacity. Then those data are reclassified according to their weightage value. Then all the data are merge by zonal statistics. The intersection area is the desire output.

Analysis:

Aspect:

To find out the flood hazard risk zones it is necessary to define the various aspects of these areas.
Aspect identifies the downslope direction of the maximum rate of change in value from each cell to its neighbours. It can be thought of as the slope direction. The values of each cell in the output raster indicate the compass direction that the surface faces at that location. It is measured clockwise in degrees from 0 (due north) to 360. The value of each cell in an aspect dataset indicates the direction the cell's slope faces.

So, aspect defines the direction of water flow. So, the place where the aspect value is less the probability of water Accumulating will be more. We classified aspect value into four categories Low, moderate, high and steep. So, the place where the steep is high that place is upper stream and lower one is downstream. In southern part of Chittagong contains more downstream whereas north south part is upper stream. So, at middle its flat so probability of flood may occur form analysis is at middle part and the southern end.
Here the aspects which lies between the value of 1-74 degree is considered as low aspect zone. The value between 74-165.8 degree is considered as moderate risk zone and the value between 165.8-260.5 is considered as high aspect zone.

Sink:

Stream lines are the line through which natural water flow to the outlet. The place where from stream line can carry water are sink area. So, where sink area is more flood occurs probability is more there. Here a also we classified the area into four no sink, low sink, moderate sink, high sink. Maximum sink place is seen in area Agrabad, Chowmohoni, Boddarhat and 2 no gate area and slightly in the port region of Chittagong. From our analysis it is found that in Chittagong city the areas which lies between 13 to 26 cm^3 sink depth are considered as low sink area, 26 to 45 cm^3 are considered as moderate sink areas and 45 to 88 cm^3 areas are considered as high sink areas.

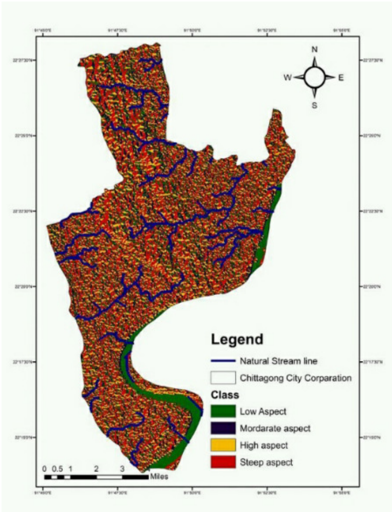

Fig. 1: Aspect analysis with stream line

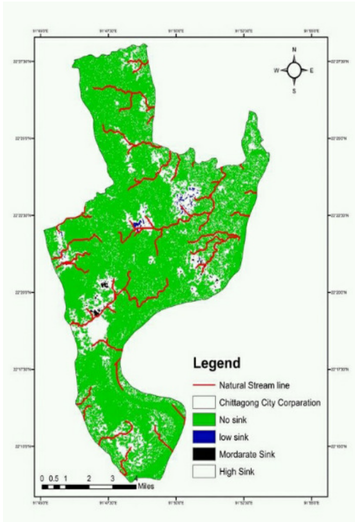

Fig. 2 : sink depth map

Built up area:
It has been seen from the following figure that maximum part of the Chittagong City Corporation area contains built up area. Its area is about 109.84 sq.km. which is almost 66% of the total area And for the reason water cannot be infiltrate into the soil.as result flood occurs. So the place where the built up area is more probability to occur flood is more.

Drainage capacity:
The reason of long lasting water logging situation in the city as well as in the study area is mainly due to inadequate drainage capacity. According to the experts, lack of enough drains and their reduced water holding capacity helps in creating drainage congestion due to heavy rainfall. Drain carrying capacity indicates that how much water can flow throughout the drain and up to which limit it will not over flow. So, where the drain water capacity slow in rainy season water can go out to the outlet. So, water will overflow and flood will occur. We classified the drain capacity into four, as follow high, medium, low, very low carrying capacity. It is seen from the following figure that maximum low carrying capacity drains are at the middle part of Chittagong and in western part of Chittagong. So according to drain capacity analysis maximum flood probability are in 2 no gate Agrabad.

From the analysis it is found that the high carrying capacity drains can hold the water from 45-27 cm^3 water where moderate capacity drains and low capacity drains hold the water from 27-16 and 16-9 cm^3 respectively.

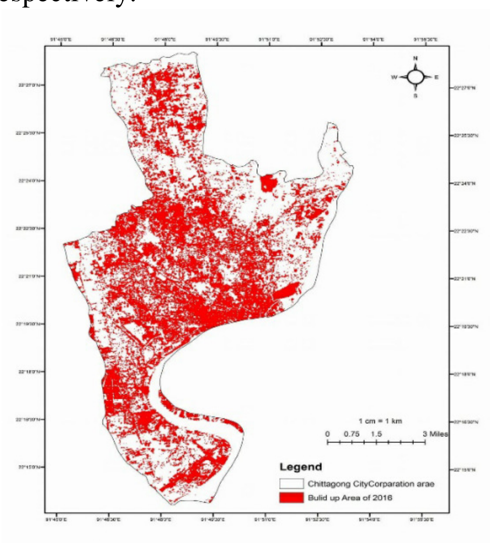

Fig. 3: Built up area map

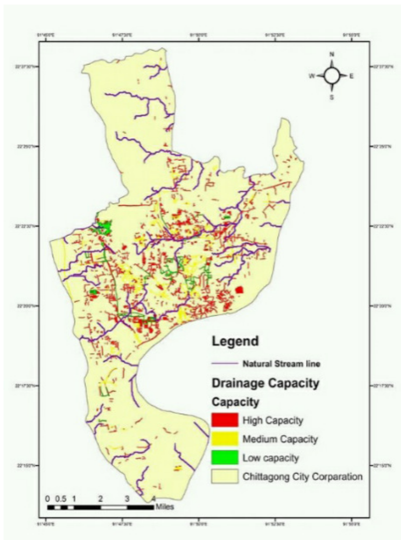

Fig. 4: Drainage capacity map

RESULTS AND DISCUSSIONS

From the above figure we can see the flood risk zone. But it is notable that high flood risk zone ward Sholokbahar, Pahartoli, West Sholosohor, middle halishor, Agrabad that is the middle of Chittagong. As the southern lower part of Chittagong their remains some floor risk but as their remains some outlet for water flow and as their Build up area is less. As major Build, up area and sink area are ward Shalakbar, west Shalokbahar, Halisohor, North Agrabad, Middle Halisohor. And water carrying capacity is very low in ward west Shalokbahar, South Middle Halishahar, North Middle Halishahar. When these data are merge The most flood hard risk zone comes Sholokbahar, Pahartoli, Agrabad, South and south Halishahar, West Sholashahar, Enayet Bazar.

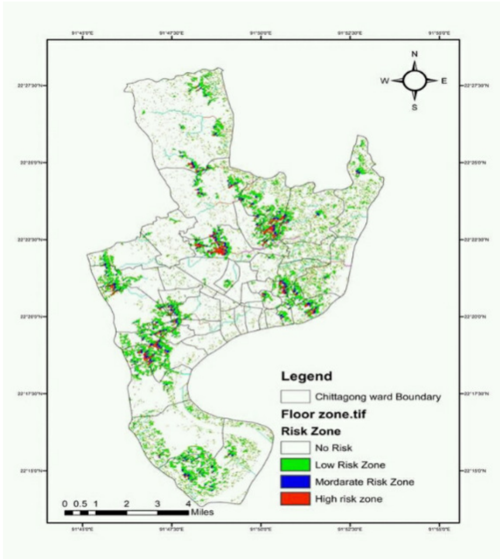

Fig. 5: Flood hazard zoning map of Chittagong

CONCLUSIONS

As Chittagong is the capital of commercialization of Bangladesh it is necessary to reduce the water logging problem of this area. The areas which are found in the flood hazard risk prone area are needed to take necessary steps to remove the problem.

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ESTIMATION OF RUNOFF OF DHARLA RIVER BASIN USING GSMAPSATELLITE ESTIMATED PRECIPITATION DATA

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ABSTRACT
Hydrologic models have emerged as a basic tool for studying real processes in a watershed hydrologic system responding to various climatic forcing. Bangladesh has been formed as the greatest deltaic plain at the confluence of the Ganges, Brahmaputra and Meghna and is highly vulnerable to climate changes. For this reason, study on hydrologic model is very important for Bangladesh. To set up a hydrological model and to determine discharge of the outlet of Dharla river basin using Satellite Estimated precipitation data are the main objectives of this study. In this study, hydrologic model of Dharla river basin with drainage area of 6120 sq.km is developed using HEC-HMS. Flash flood, Monsoon flood and bank erosion are some common issues with this river basin. A lumped hydrological model is developed using HEC-HMS to simulate precipitation-runoff process. SRTM 90m resolution DEM is used for delineation of basin which is downloaded from CGIAR-CSI. River network is digitized by Google Earth. Arc map 10.1 is used for watershed delineation. In place of gauge rainfall, satellite estimated rainfall data is used. The Japan Aerospace Exploration Agency (JAXA) provide hourly data of precipitation in 0.1× 0.1-degree resolution observed by satellite. The simulation result is checked after real time data provided by BWDB at Kurigram station. The value of correlation coefficient (R^2) for calibration period (2009-2012) and validation period (2013-2014) are 0.71 and 0.81 respectively. From six-year model simulation, it is found that peak discharge occurred at 2 August, 2014. The value of peak flow is 4515.4 cumec. At the time of peak flow, volume passes through outlet is 38928 million m^3.From calibration and validation graph we can see that the model gives satisfactory result at dry period. At the time of high discharge, model result shows more deviation from observed data. So, GSMaP is more reliable at dry season.

Keywords: Hydrologic model; HEC-HMS; GSMaP; Satellite Estimated Precipitation; JAXA; SRTM DEM.

INTRODUCTION
Bangladesh is a riverine country. Due to its location in the low-lying deltaic floodplains at the convergence of three Himalayan Rivers, heavy monsoon rainfall concomitant with poor drainage often results in annual flooding. The river systems drain a catchment area of about 1.72 million sq. km. The floodplains of the rivers are home to a large population, most of which is rural and poor, whose life is linked to the flooding regime. It is very important to study on every river basin of Bangladesh. By this study, we can acquire knowledge about types, time and duration of flood around this region. Flood is a common phenomenon in this part of the world. It has effects on food security, ecology, biodiversity, river flows, water security, human and animal health etc.

Study Area
Dharala river basin is at north-west region of Bangladesh. It is a trans-boundary river, which originates from the Himalayas where it is known as the Jaldhaka River. Then it flows through the Jalpaiguri and Cooch Behar districts of West Bengal, India. The river enters Bangladesh through the Lalmonirhat District and flows as the Dharla River until it joins with the Brahmaputra River near the Kurigram District. The river basin has about 6000 sq.km area from which about 70% is at India. So, it is hard to get observed data from India. In this study, satellite generated precipitation data is used to avoid this difficulty.

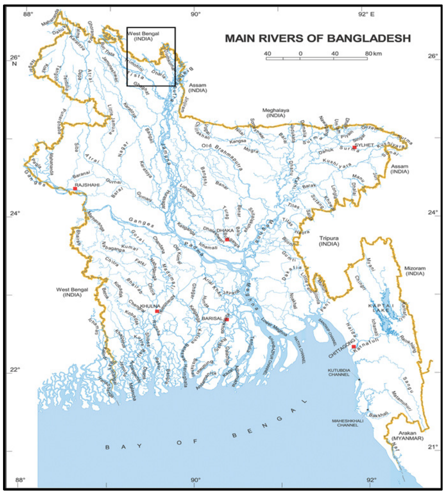

Figure 1 Location of study area at map of Bangladesh. (490km×645km)

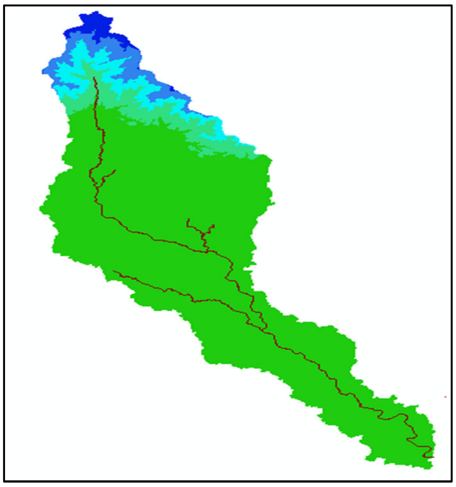

Figure 2 Clipped DEM with river network and sub-basin shape file.

DATA COLLECTION

Digital Elevation Model

To delineate watershed for Dharala river basin, digital elevation model (DEM) is downloaded from CGIAR-CSI GeoPortal (Source: http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp). The CGIAR-CSI GeoPortal is able to provide SRTM 90m Digital Elevation Data for the entire world. After downloading the SRTM digital elevation data, watershed delineation is done by ArcMap 10.1. After delineation shape file of stream network and sub-basin is found. Projection system of these shape file is Bangladesh Traverse Mercator. The clipped DEM and river network are shown in Figure 2.

GSMaP Rainfall

GSMaP stands for Global Satellite Mapping of Precipitation. The GSMaP project was promoted for the study "Production of a high-precision, high-resolution global precipitation map using satellite data", sponsored by Core Research for Evolutional Science and Technology (CREST) of the Japan Science and Technology Agency (JST) during 2002-2007. Since 2007, GSMaP project activities are promoted by the JAXA Precipitation Measuring Mission (PMM) Science Team.

Table 1: Description of GSMaP data

Variable	Rainfall rate (mm/hr)
Domain	Global (60N - 60S)
Grid resolution	0.1 degree latitude/longitude
Temporal resolution	1 hour

Evapotranspiration

Evapotranspiration data of Kurigram and Thakurgaon station been collected from IWM.

Water Level and Discharge

Water level and discharge data are collected from Bangladesh Water Development Board (BWDB). At the outlet of Dharala river basin, Kurigram station is situated which is numbered as station no.77.

GSmap Precipitation Data Analysis

GSMaP data is processed to obtain daily rainfall data. The downloaded data is compressed file in grid format. First, compressed zip file is expanded. Then, required data for specific catchment is picked from gridded file by using C++ program provided by JAXA. In the downloaded file, the precipitation data is in millimeter per hour unit. But, for use in the model data is converted into inch per day unit. Values of all grid point within a catchment are added to get gauge reading with unit gauge weight. From previous study, it can be seen that GSMaP rainfall are under simulated for every catchment of north-west region of Bangladesh (Sultana *et al,* 2009).

Model Run

Each run is composed of one basin model, one meteorological model and one control specification. After provision of all required parameters it is needed to manage and execute runs. By selecting compute in run manager menu option simulation run is created. The model is run for a year with output time interval of one day.

Calibration of Model

Before the application of any model, it is necessary to calibrate it with the observed data. Model Calibration is a process of comparing the model to actual system behavior until model accuracy is judged to be acceptable. Method used in this study are Simple Canopy, Simple Surface, Soil Moisture Accounting Loss, Clark Unit Transform and Linear Reservoir Base Flow. Each method in HEC-HMS has parameters. Some of the parameters may be estimated by observation and measurements of stream and basin characteristics, but some of them cannot be estimated. When the required parameters cannot be estimated accurately, the model parameters are calibrated by creating optimization trial. The model is calibrated using the observed discharge data of Kurigram station from January 2009 to January 2012. After optimizing the parameter, the value of Correlation Co-efficient (R^2) is 0.71.

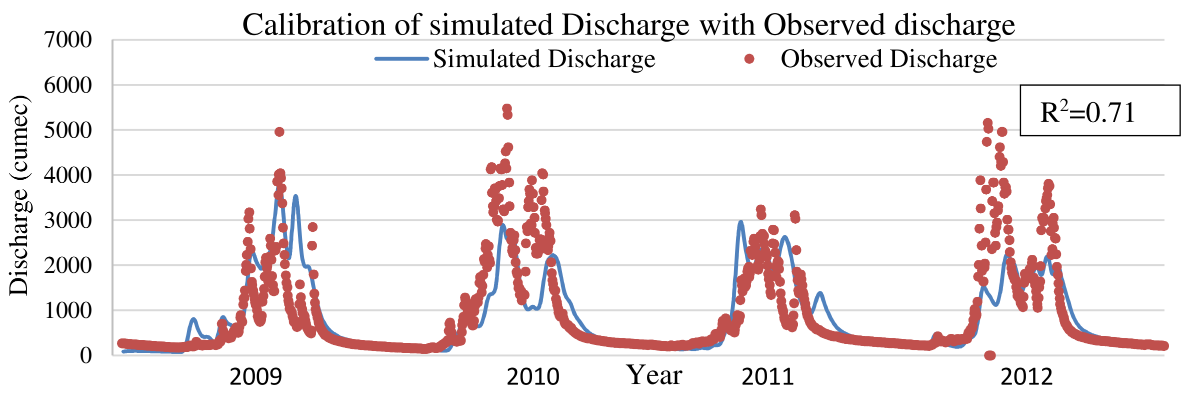

Fig. 3. Observed and Simulated discharge at the outlet of the Dharala basin

Validation of Model

Model validation demonstrates the capability of the model to produce accurate predictions for periods outside the calibration period. Model validation for this study was used to determine the effectiveness of the calibrated parameters in predicting the flow discharges at Kurigram station of Dharala River for the period 2013-2014.

From calibration and validation graph, it can be realized that validation graph shows more variation than calibration graph. With time, this variation increases. For example, in year 2013 peak flow occur at 23 July (2987 cumec) in simulated result where observed data shows that peak occurs at 11 July (4962 cumec). Again in year 2014, peak flow occurs at 8 August (4361 cumec) in simulation where observed data shows that peak flow occurs at 28 August (5920 cumec). It shows more variation in both time and discharge.

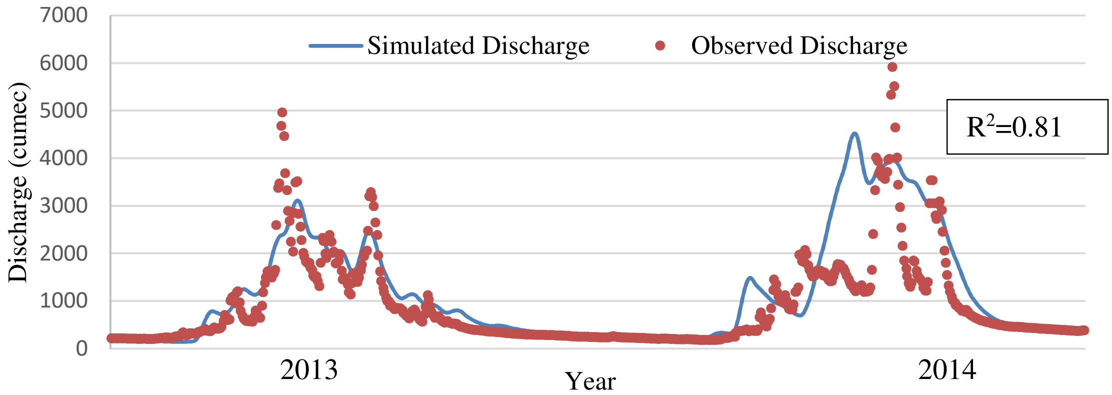

Fig. 4: Observed and Simulated discharge at the outlet of the Brahmaputra basin for validation period.

RESULTS:

- The value of correlation coefficient (R^2) for calibration period (2009-2012) and validation period (2013-2014) are 0.71 and 0.81 respectively.
- After simulation, it is seen that observed outflow is generally greater than simulated outflow. So, GSMaP gives underestimated precipitation value compered to observed value. This observation also proved in previous study relating GSMaP.
- From calibration and validation graph we can see that the model gives satisfactory result at dry period. At the time of high discharge, model result shows more deviation from observed data. So, GSMaP is more reliable at dry season.
- From six-year model simulation, it is found that peak discharge occurred at 2 August, 2014. The value of peak flow is 4515.4 cumec. At the time of peak flow, volume passes through outlet is 38928 million m^3.

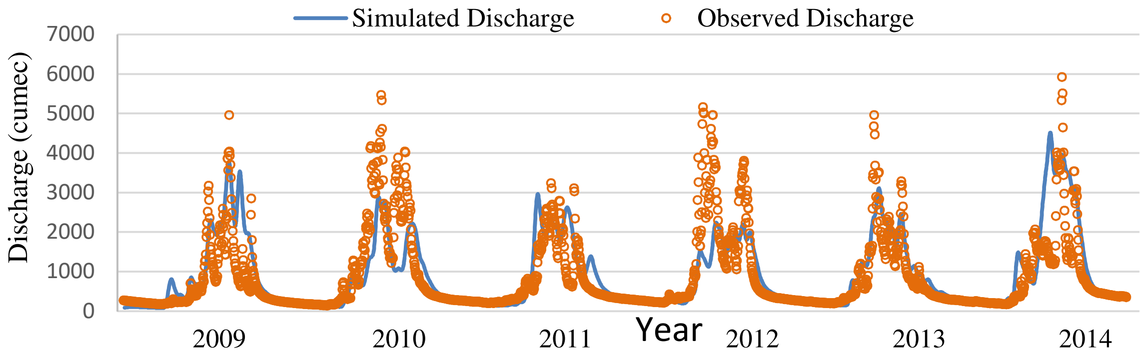

Fig. 5. Comparison of simulated discharge vs. observed discharge for year 2009-2014

RECOMMENDATIONS AND DISCUSSION

- Basin parameters are adjusted by several trials considering the effect of one component on others. Calibration can be more effective and give much better result if each parameters are adjusted corresponding to each sub basin. This process may be time-consuming and requires in depth knowledge of each parameters and their correlations in basin hydrology.
- Observed discharge data were very much insufficient for developing a rating curve of Kurigram Station. This was very crucial for calibration and validation of model. So a better rating curve equation shall obviously increase the performance of the model.
- River system designed in basin model of HEC-HMS is straight line. But rivers are not close to straight. It will be more realistic if river can be drawn with its natural bend.
- Working with satellite data is very complex and time consuming. On the other hand, real time data of transboundary river is very difficult to get and is not continuous. So, we should find more reliable way to relate satellite data with observed data.

- The model is simulated for six years. But longer time period may be used for further analysis on the availability of data.
- Several studies can be made using this model in future. These includes, but not limited to, effects of land use on flow, effects of any upstream development such as construction of dam, urbanization etc.

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METEOROLOGICAL DROUGHT MONITORING USING SATELLITE IMAGERY: ACASE STUDY ON RAJSHAHI, NAOGAON AND JAIPURHAT OF BANGLADESH

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ABSTRACT

Drought is considered as one of the major natural hazards that affect the environment and economy of a country. Different from other natural disasters, drought events appear slowly in time and their impacts generally span over a longer period of time. Weather data alone is not sufficient to monitor and evaluate the areas of drought, particularly when those data are rare and incomplete. Enhancement of weather data with satellite images to identify the location and severity of droughts are important for complete, up-to-date and comprehensive coverage of current drought conditions. The objective of this research is to monitor and understand meteorological drought using Standard Vegetation Index (SVI) and Vegetation Condition Index (VCI). Another objective is to measure the accuracy of two method's result by analyzing the changes in precipitation data. For this, SVI and VCI are derived from EVI and NDVI, which are obtained by analyzing MODIS (moderate-resolution imaging Spectroradiometer) data at 250m spatial resolution during July and August month of each year from 2000 to 2016 at 2 years interval. The study result shows the percentage of area affected by drought and its severity on the selected years. It also helps to understand how vegetation condition is being changed over time.

Keywords: Drought; MODIS; NDVI; VCI; SVI; EVI and Remote Sensing.

INTRODUCTION

Drought is one of the major threat to natural hazards which occurs at the time when the amount of precipitation is insufficient than the demands of natural habitats and the environment. The North-Western part of Bangladesh has been experiencing extremely hot weather and frequent drought conditions compare to the other parts of the country (Hassan & Mahmud-ul-islam, 2013).Especially, the districts under Barind Track suffer from frequent draught every year. The groundwater scarcity reveals that water level is declining gradually year-by-year, which creates the drought intensity higher (Shahid & Hazarika, 2006). Unfortunately, drought condition has received less attention and has less scientific research work compare to other calamities like flood or cyclone. The impact of drought can be much higher and can occur greater loss than flood, cyclone and storm surge (Alam et al., 2012; Paul, 1998; Shahid, 2008). For example, Drought incurred a huge loss of crop production in the country during the year of 1978-79, 1982 and 1997 (Paul, 1998; Ramsey et al., 2014). So, it is urgent to research more on drought and using scientifically method to get accurate scenario. Other than in-situ data, Remote sensing is a promising technology to monitor drought condition. In this paper it has aimed to reveal drought scenario through satellite imageries.

METHODOLOGY

Data Collection

To monitor the meteorological drought, two weeks maximum value composites (MVC) of NDVI from MODIS Imagery (for the year 2000, 2002, 2004, 2008, 2012, 2014 & 2016 in the month of July and August) along with land cover map have been used. The data is freely available to be downloaded from the Oak Ridge National Laboratory Distributed Active Archive Center (ORNLDAAC).For calculating SVI, we have used the Enhanced Vegetation Index (EVI) based on MODIS data at 250m spatial resolution as input. The only MODIS product providing EVI data is MOD13Q1 (on Terra satellite) and MYD13Q1 (on Aqua satellite). Here we have worked with the EVI band of MOD13Q1.The land cover map is made in ArcGIS software from Landsat 8 images. Unsupervised classification method was used to classify the region into to 3 land cover classes. Since, the main objective of the current study is to monitor meteorological drought impacts on natural vegetation (rain fed, rangeland& forest), these three classes were classified from the land cover map. Then, 3 land cover classes are reclassified into two classes: range land (value o) and non-Range land (value 1)**.** Also, precipitation data has been collected from "Bangladesh Water Development Board" to analysis objective two.

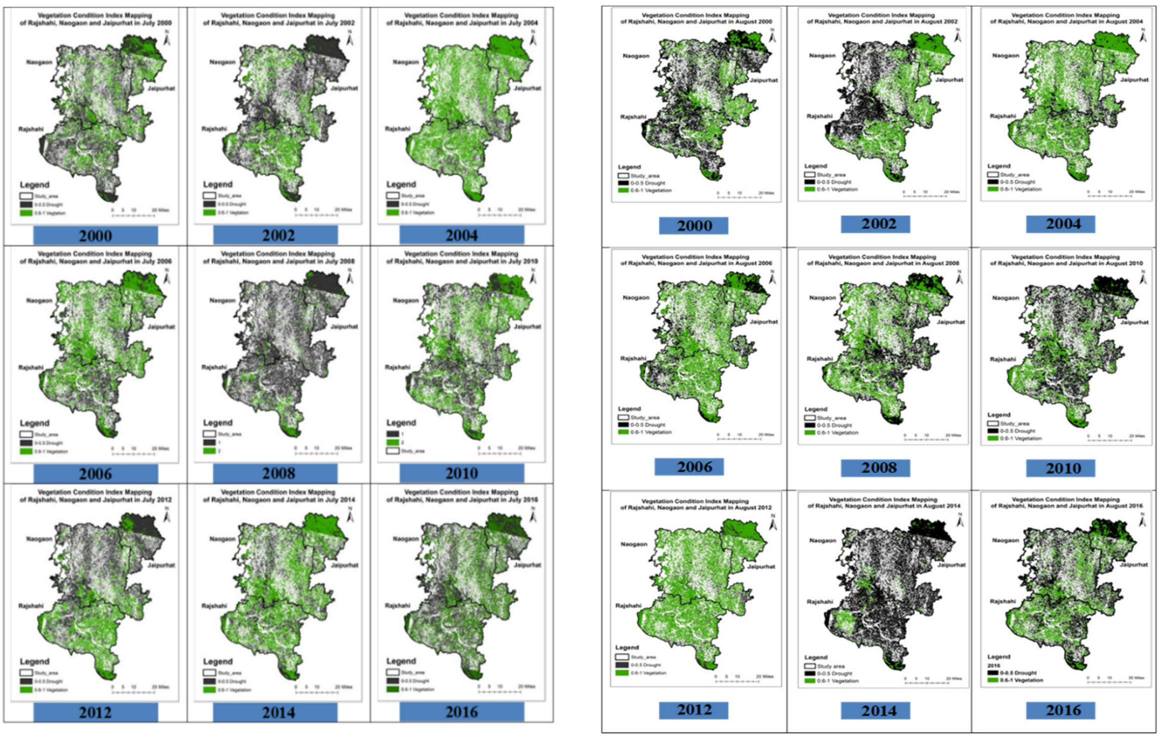
Data Preparation and Processing for Calculating VCI

The Data analysis for calculating VCI has been divided into three phases as follows:

- Data processing using ENVI software
  Step-1: Band math recalculation to value-1 to 1 and recalculating from MVC values to NDVI value range
  Step-2: Layer stacking (composition of nine maps to one map) and change map projection
  Step-3: Resizing the NDVI-MVC images to the study area
  Step-4: Masking out data with the study area
  Step-5: Masking out 'not vegetation' data via land cover data
- Calculating Vegetation Condition Index using the Eq. (1) given below;

$$\mathbf{VCI= (NDVI_{cur} - NDVI_{min}) /(NDVI_{max} - NDVI_{min})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

- Visualization and Analysis in ArcGIS software



July **August**

Fig.1: Vegetation Condition Index Mapping of Study Area (2000-2016)

Data Preparation and Processing for Calculating SVI

Following steps have been followed to calculate SVI

Step 1: MOD13Q1 EVI HDF (time series) data have been converted into GeoTIFF using the software named MRT (MODIS reprojection tools).

Step 2: In this step, data have been prepared for automatic map generation. It includes creating one folder where all converted data has been stored. Then each of day of the year (DOY) data has been renamed manualy or using total commander software. This will help to choose the relevant data for the region of interest.

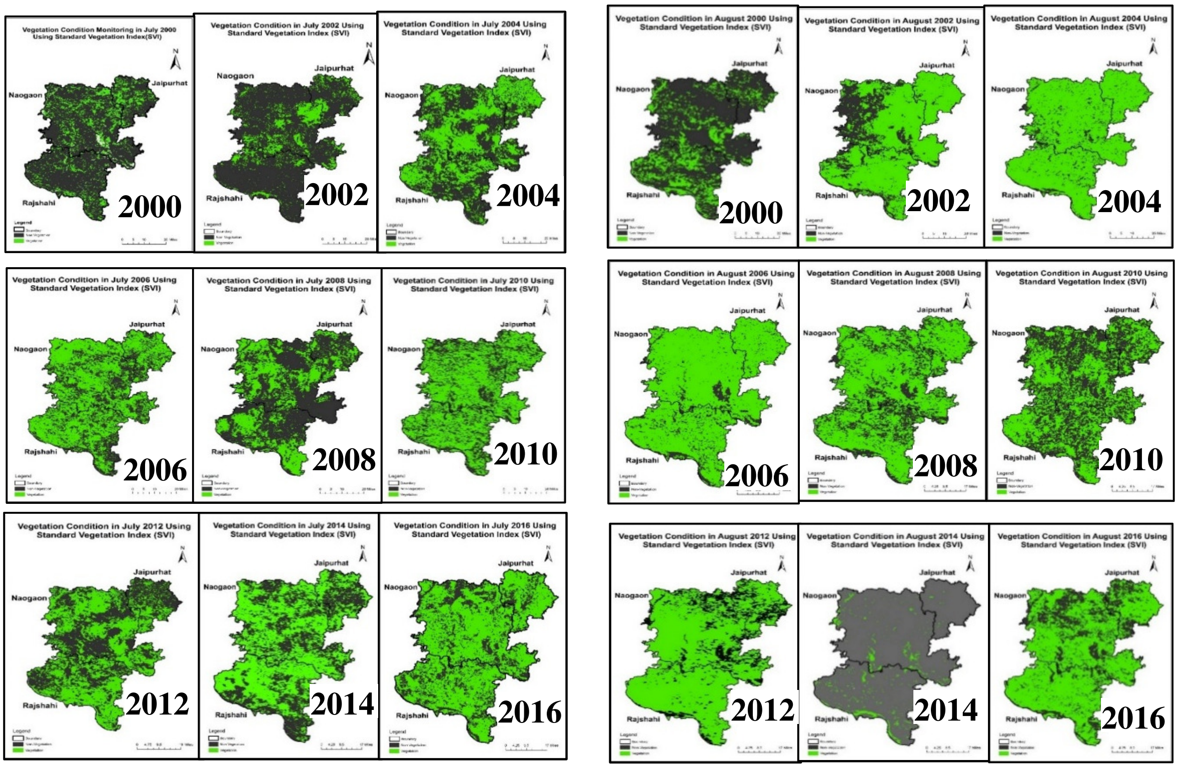
Step 3: Here layer stacking for each DOY, has been resized and masked with country shape file.

Step 4: It includes rescaling and set fill values and invalid data range to NA.

Step 5:After that, mean and standard deviation of Enhanced Vegetation Index (EVI) has been calculated. Then, standard vegetation index has been calculated using the following formula

$$SVI = (EVI-EVI_{mean}) / EVI$$

R-studio software has been used to complete step 5 and ArcGIS software has been used in order to visualize the obtained map



July **August**

Fig.2: Standard Vegetation Index Mapping of Study Area (2000-2016)

RESULT AND DISCUSSION

Data has been analyzed according to objective 1 and 2. These are discussed below:

Analysis of Objective- 01

Yearly drought scenario in terms vegetation growth (following VCI and SVI method) for the month of July and August have been presented in the Fig.1 and Fig.2. A comparison of vegetation area changes has been also presented in the Table 1.From the above of Table-1.it is seen that the vegetation growth is comparatively low in the year 2000, 2002 and 2008 from other years in July. It is also seen that the vegetation growth is comparatively low in the year 2000, 2010 and 2014 from the other years in August.

By this, it is very difficult to understand the severity of drought by finding out the lower vegetation growth in July and August. To solve this problem, the vegetation growth of two months by each method is ranked according to the lower vegetation to higher vegetation. That means the ranking is provided from 1 to 9 which actually denotes to lower vegetation to higher vegetation. Besides, lower vegetation indicates the higher severity of drought. So, the ranking 1 to 9 also means the higher severity of drought to lower severity of drought in that area.

Table1: Difference between VCI and SVI and their ranking

Year	Vegetation Area (%) in the month of July		Vegetation Area (%) in the month of August		Two months Average Vegetation Area (%)		Vegetation Area Ranking	
	VCI method	SVI method	VCI method	SVI method	VCI method	SVI method	VCI method	SVI method
2000	36.85	20.14	37.07	24.37	36.9556	22.25464	3	1
2002	32.33	16.77	50.29	75.08	41.30876	45.92453	4	3
2004	80.97	47.99	76.67	91.24	78.81895	69.61492	9	7
2006	57.99	64.27	70.30	88.67	64.14788	76.47132	7	9
2008	11.88	38.07	56.51	73.52	34.19813	55.79581	1	4
2010	48.72	68.20	38.36	52.63	43.5397	60.41485	5	5
2012	41.84	52.01	87.46	82.23	64.65103	67.11993	8	6
2014	63.82	59.56	9.31	4.73	36.56201	32.1464	2	2
2016	61.28	72.01	45.75	74.79	53.51723	73.39991	6	8

It is seen that the VCI and SVI are ranked from 1 to 9 separately. VCI and SVI rankings are respectively 3 and 1 in 2000, 4 and 3 in 2002, 1 and 4 in 2008 and 2 and 2 in 2014. Other VCI and SVI rankings are 5 or above 5 which denote higher vegetation. As the lower vegetation's were in 2000, 2002, 2008 and 2014 according to ranking, those years could be higher drought severity in the study area.

Analysis of Objective- 02

According to vegetation condition index method and standard vegetation index, the vegetation condition data is compared to the precipitation data. On the following Table-2, drought severity is ranked using the value from 1 to 9; where the value 1 means severe drought condition, on the contrary value 9 means less severity of drought that means vegetation condition is very good. In this case; percentage of vegetation condition obtained by standard vegetation index and vegetation condition index and amount of average rainfall during July and August month is used. The result showed that 2000 and 2014 are the two years when drought severity was the most compared to the other years in the studied area.

Table 2: Ranking of drought severity based on precipitation data, standard vegetation indexand vegetation condition index (Average value for the month of July and August has been considered)

Year	Precipitation (mm)	Vegetation Area (%)		Drought Ranking		
		VCI method	SVI method	VCI method	SVI method	Precipitation
2000	181.25	36.9556	22.25464	3	1	2
2002	280.7	41.30876	45.92453	4	3	7
2004	300.05	78.81895	69.61492	9	7	8
2006	209.05	64.14788	76.47132	7	9	4
2008	381.65	34.19813	55.79581	1	4	9
2010	164.7	43.5397	60.41485	5	5	1
2012	275.5	64.65103	67.11993	8	6	6
2014	201.3	36.56201	32.1464	2	2	3
2016	254.65	53.51723	73.39991	6	8	5

Following findings are obtained after analyzing the data;

- According to the analysis of objective one, the lower vegetations were in 2000, 2002, 2008 and 2014 where 2000 and 2014 were more drought severe years according to objective two.

- As 2000 and 2014 being common years according to the analysis of objective one and two, were the most drought-prone years with respect to the precipitation data of the studied area
- At that year's precipitation was comparatively low than the other years that means vegetation growth condition was low. As the precipitation rate was low during monsoon season in 2000 and 2014, it caused drought in the study area. Its effect might fall on the next year too.

For future meteorological drought monitoring and identifying its severity; following recommendation can be given;

- Conducting the prediction research on precipitation anomalies, soil moisture condition, evapotranspiration in future will help in monitoring drought through the understanding of vegetation.
- VCI and SVI can be two effective methods to measure the severity of drought in future.
- This type of research for investigating the drought severity should consider more factors, such as human activities, temperature, and so on for the more accurate result.

CONCLUTION

This research has explored the influence of precipitation anomalies on vegetation. By understanding the relationship between Standard Vegetation Index, Vegetation Condition Index, and precipitation anomalies, the potential impacts of drought on vegetation, especially in barind regions are estimated. The quantitative analyses presented in this study have illustrated the relationship between precipitation and vegetation. This paper highlights an overall approach to meteorological drought monitoring using satellite imagery and GIS techniques. Though there remains some limitation in our research, it is expected that these can be minimized by subsequent contribution and future development of science.

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A GIS BASED SPATIAL ACCESSIBILITY ASSESSMENT OF RURAL SANITATION FACILITIES

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ABSTRACT
Sanitation is very essential and vital part of our daily life. In Bangladesh the sanitation quality is low in the Northern region and it is going to face severe condition of sanitation which has a direct negative impact on our physical health as well as mental health. This study aims to analyse the accessibility to sanitation in rural areas. For the purpose of carrying out the study we used both primary and secondary data. Primary data was collected with the help of questionnaire survey through random sampling method and secondary data was collected from various authentic national sources. The collected data was analysed through various statistical, geographical computer application like SPSS, ArcGIS 10.2 etc. The study reveals severe conditions in terms of accessibility with least spatial variation. From this study we found that only 21% people have personal sanitary toilet and 44% people have no proper toilet facilities. This study analysed that more than 70% toilets are near to water sources which eventually contaminate the water. Pond water is used for other household activities even washing plate, bowl etc. The awareness of the mass people should be increased for safe and sustainable water and sanitation accessibility.

Keywords: Random Sampling; SPSS; ArcGIS; Gini Index.

INTRODUCTION
Sanitation is defined as 'the provision of facilities and services for the safe disposal of human urine and faeces' (Norstrom, 2007). Sanitation differs from hygiene in that it provides the means for people to be hygienic. Sanitation is important for all, helping to maintain health and increase life-spans. However, it is especially important for children. Around the world, over 800 children under age five die every day from preventable diarrhoea-related diseases caused by lack of access to water, sanitation and hygiene (WHO, 2013). Sanitation is a concept that is thought to define a single definition as a result of its complex nature (Allen et al., 2006). Though there are different definitions of sanitation, solid and liquid wastes are at the centre of all the definitions since they have been major problems confronting not only sprawling communities but towns of the world in general (Ayee and Crook, 2003). In the study area named Mundumala Paurashava, most of the people are suffering from the lack of the sanitation facility. Objectives of the study are to identify the present situation and seasonal characteristics of sanitation status to identify the major factors which affect the hygienic sanitation facilities. The study focuses on the finding accessibility sanitation facilities. This study has covered nine wards of the Mundumala Paurashava. The sanitation quality, water borne diseases also has been assessed in this study.

STUDY AREA
The study area has been selected on the basis of two parameters. The parameters are Reconnaissance Survey and Rationality analysis. First the researchers completed reconnaissance survey and then use Rationality analysis for completing this task.

Reconnaissance survey was carried out in three upazilla such as Nchole, Godagari, and Tanore upazilla. From the reconnaissance survey we found severe condition in Mundumala Pourosova which is situated inside the Tanore upazilla. They are to suffer from lack of drinking water. They haven't enough water source for available water. They have to collect water from long distance and use pond water for household activities. Second, rationality focuses on the identification of strong and weak points within an organization, community and the analysis of opportunities for, and threats to, further development. It identifies the basis behind the selection of the study area, fruitfulness of the study as well.

Sample Size Calculation

We determined the sample size based systematic random sampling method. We considered 95% confidence with 5% interval. From that we got total sample size about 357. In this case we collected 360 data for analysis. Once the cluster villages and mahall as were selected, we asked the residents to assist in determining centre points of each village/mahalla, and commenced with the eligible household nearest to the centre point. We skipped the nearest two households and determined the next nearest eligible household.

$$n = \frac{N \times X}{X + (N-1)} \quad (1)$$

$$X = \frac{z_{a/2}^2 \times p \times (1-p)}{E^2} \quad (2)$$

Where,

n = Sample Size

N= Household Number

$z_{a/2}$= Critical Value for Normal Distribution (for 95% confidence level, its value is 1.96).

P= the sample proportion (50%).

E= Margin of Error (5%).

RESULTS AND DISCUSSIONS

Spatial Accessibility of Sanitation facilities

It is the means of promoting hygiene through the prevention of human contact with hazards of wastes especially faeces, by proper treatment and disposal of the waste, often mixed into wastewater (WaSH, 2005). These hazards may be physical, microbiological, biological or chemical agents of disease. Wastes that can cause health problems include human and animal excreta, solid wastes, domestic wastewater (sewage), industrial wastes, and agricultural wastes (Awutu-Senya East Municipal Assembly, 2013).

Regional Disparity on the Distribution of Sanitation Facilities

This section identifies the ward wise regional disparities on the functional water source distribution. This analysis is undertaken by the Gini Index. The Gini Index represents the cumulative relationship among households and facilities. The table below shows the calculation & household-water source cumulative expressions.

The table shows that the cumulative percentage of sanitary and household is lowest at ward no.01. The cumulative percentage of sanitation at ward no.01 is about 7.12 and household is about .13. The lowest cumulative percentage represents the least amount of sanitation facilities serves the highest amount of household. That means only 1 sanitary facility serves about 8 households. The cumulative percentage of sanitation and household is largest at ward no. 03. The amount of sanitary facilities exists in ward no. 03 about 216 to serve about 718 people. That means 1 sanitary toilet serves about 3.5 households which indicates better situation the ward no.01 having the least cumulative percentage.

We developed a Lorenz curve based on the field data [Fig.1] and find the value of Gini Index is **0.14.** In the Lorenz curve the X-axis & Y-axis represents the cumulative percentage of households & cumulative percentage of sanitary facilities. The value of 0.14 is the least value of Gini Index which implies that, there is very little regional disparity and analysing the sanitary facilities data in relation to the household extent implies that there is severe condition of sanitary facility availability in the all wards of Mundumala Paurashava.

Table 1: Gini Co-efficient Calculation on Sanitation Facilities Distribution

Ward No.	Household	Sanitary	% of HH	% of Sanitation	C % of HH	C % of Sani	C % of HH in Unit	C % of Sani in Unit
Ward 01	637	80	13.05	7.13	13.05	7.13	0.13	0.07
Ward 09	514	70	10.53	6.21	23.58	13.35	0.24	0.13
Ward 02	308	56	6.31	4.98	29.89	18.33	0.30	0.18
Ward 07	436	99	8.93	8.80	38.82	27.13	0.39	0.27
Ward 06	391	92	8.01	8.17	46.83	35.30	0.47	0.35
Ward 05	809	209	16.57	18.55	63.40	53.85	0.63	0.54
Ward 04	578	157	11.84	13.98	75.24	67.83	0.75	0.68
Ward 08	491	146	10.06	12.96	85.29	80.79	0.85	0.81
Ward 03	718	216	14.71	19.21	100	100	1	1

By observing the above table we get that there are only 1125 sanitary toilet in the Paurashava under 9 wards. But the total numbers of households are about 4882. If we consider a flat distribution (i.e. no regional variation as the Gini Index is least) among the wards of Mundumala Paurashava, we can get: 4882/1125=4.5(Approx.) households are dependent on a single water source & this situation is almost same in the all wards of Mundumala Paurashava.

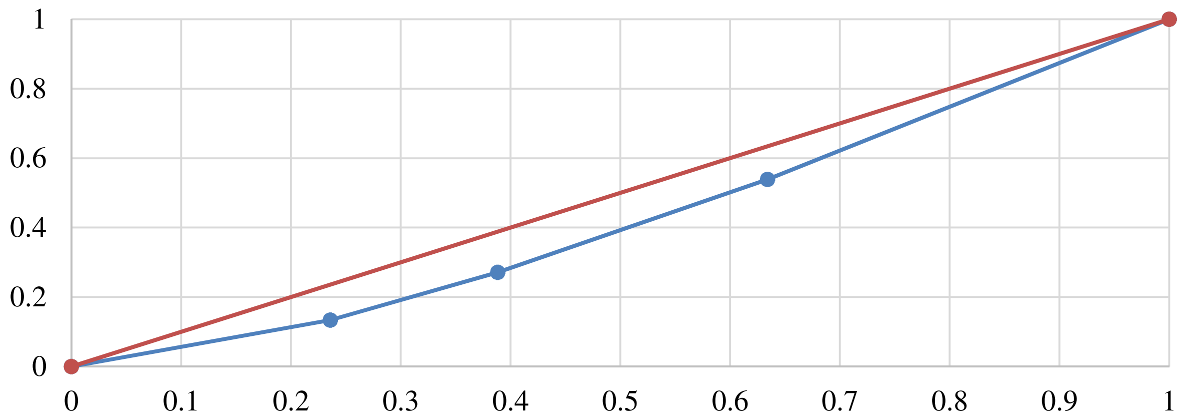

Fig 1: Lorenz Curve on Sanitation Facilities in Mundumala Paurashava

Toilet Quality

In the study area about 44% of total population use open toilet, as open toilet is very harmful to the environment. From the open latrines various germs are born and bound out many diseases. Only 21% of total population use personal toilet. About 35% of the total population use to share toilet to the other family as a result the toilet becomes dirtier. This can be represented by the figure 3. The 44% of the total population are using the open space like garden, bush etc. as latrines because of the lack of toilet facilities. Not only is the provision of human excreta facilities a priority, but more importantly the conditions of the facilities due to the health implications they have on users. According to MLGRD (2010), 'It is essential that human excreta disposal facilities are kept within minimum condition requirements for the avoidance of unwarranted eventualities through their use'. In spite of the innumerable positives effects of proper sanitation to mankind, residents of the area are bedevilled with one problem or another as a result of the difficulties in having access to toilet facilities.

Liquid Waste Disposal

Due to the sensitive nature of toilet facilities to mankind, discussions are that provision of human excreta disposal facility should be given prominence in any building endeavour geared towards accommodating people (MLGRD, 2010). In our study area the children don't use toilet (only 1%). About 55% of the family from total left the children's excreta in the open space. As a result some water borne disease brought out and the environment is getting pollution. About 27% of the total family use to throw the excreta in the garbage which is just outside space of a house. About 17% of the total population use to bury the children's excreta into ground. The figure 3 below represents the whole scenario of liquid waste disposal.

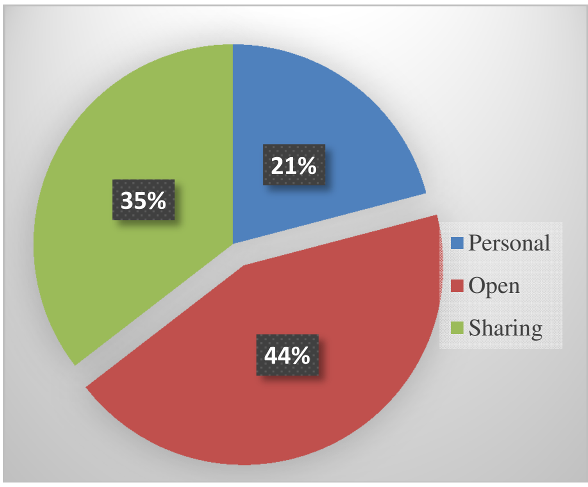

Fig. 2: Types of Toilet in Mundumala Paurashava

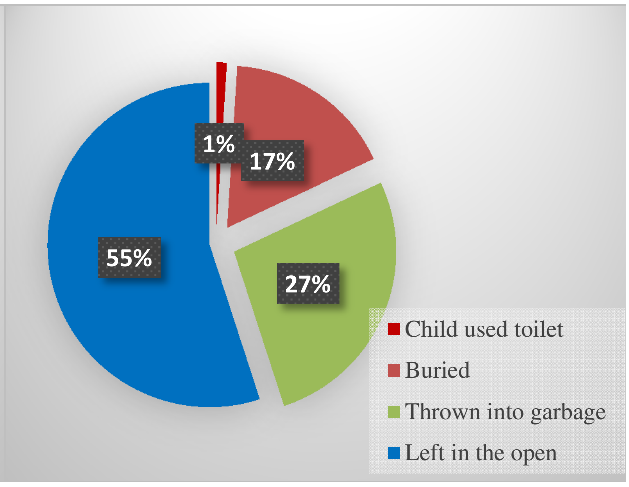

Fig. 3: Children's Excreta Management in Mundumala Paurashava

Solid Waste Disposal

Another major component of sanitation is the management of wastes. In the study area about 68% of the people through the solid wastes outside the house. As a result the wastes become decompose and make the environment polluted. About 24% of the population keep the household wastes in the garden which damage the fertility of the soil of garden. About 8% of the total population put the household waste on the street. As a result the accessibility of street is reduced.

Factors affecting the effective sanitation facilities:

It identifies the causes behind the non-sanitation facility & the hampers to cover the whole area. These are lack of public awareness, local environment, construction quality of the toilets and privatization of the sanitation facilities and water quality. These factors are identified based on the questionnaire survey between two types of peoples i.e. having water accessibility & do not have water accessibility. The researchers collected these data through field survey with direct questionnaire. The obtained data are then calculating the two-way contingency table tests for the independence of two variables. The two types of respondents are independence to answer the questions. Then the chi square test (Pearson,X^2) is calculated considering the significant at 5% and degree of freedom of 2. The chi-square (X^2) of these two respondents can be summarized throw the following table:

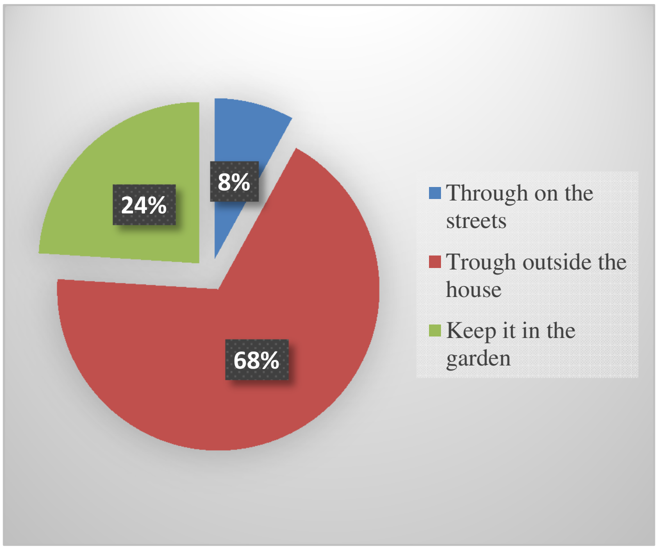

Fig. 4: Household Wastes Disposal System in Mundumala Paurashava

Table 2: Chi Square Calculation of Identifying Factors Influencing Scarcity

SL No	Factors	Respondents	Strongly Agree		Agree		Disagree		Total		χ^2
			No.	%	No.	%	No.	%	No.	%	
1	Local Environment	Have water access	108	60	58	32.2	14	7.8	180	100	2.16
		Do not have water access	121	67.2	46	25.6	13	7.2	180	100	
2	Lack of public awareness	Have water access	100	55.6	30	16.7	50	27.7	180	100	**3.51**
		Do not have water access	110	61.2	35	19.4	35	19.4	180	100	
3	Construction quality	Have water access	110	61.1	45	25	25	13.9	180	100	1.28
		Do not have water access	120	66.7	40	22.2	20	11.1	180	100	
4	Privatization of Sanitation Facilities	Have water access	90	50	80	44.5	10	5.5	180	100	1.19
		Do not have water access	100	55.6	70	38.9	10	5.5	180	100	
5	Water Quality	Have water access	120	66.7	45	25	15	8.3	180	100	1.41

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Firstly we would like to thank almighty Allah for giving us chance to finish this work. We also like to extend my sincere thanks to our teacher, parents and the people in the study area who helped at the time of field survey.

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INFLUENCE OF LAND COVER CHANGE ON LAND SURFACE TEMPERATURE USING RS AND GIS TECHNIQUES: A CASE STUDY OF GAZIPUR DISTRICT

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Abstract
Climate change has obtained more and more attention as the land surface temperature is getting high day by day. This being done as people are being attracted to live in urban area and this rate is increasing at an alarming rate. Gazipur which is situated beside Dhaka is one of the area which is experiencing rapid urbanization which is the main cause of urban heat island, decreasing of waterbody which will surely make a serious influence on regional climate, environment. This study represents integrated study of land cover changes between the periods and investigated their impacts on LST of Gazipur district by using Geographic Information System (GIS) and Remote Sensing (RS). In this study, remote sensing techniques were used to retrieve the land surface temperature (LST) and land cover change by using the Landsat Satellite imagery product. Landsat TM and ETM+ images from 1995 to 2015 are used as data source. The integration of remote sensing and GIS was further applied to examine the impact of land cover change on surface temperatures. Strong relationship is found between land surface temperatures over land cover classes. The result shows that waterbody is being decreased from 1206 Sq.km to 74 Sq.km. Result is same for vegetation land cover which also have decreased at an alarming rate. These areas are being converted into built-up an area which is increasing temperature. Over 10 years' temperature is changed from 26°C to 30°C.The results indicate that land surface temperature can be related to land cover classes in most cases. Vegetated and other natural areas enjoy lower surface temperature, than build up areas with little vegetation.

Keywords: Land surface temperature; land cover; change detection; urban heat island; climate change.

INTRODUCTION

Land is one of the most important resource from the first day human stepped on earth. With the passage of time land is being transformed from one type to another which is an extremely complex process, it is subject to the combined effect of a wide range of human activities, natural environment and economic environment and so on, all of that react on humans (Jianzhong et al., 2002; Station & Province, 2004). Urbanization is highly responsible to transform natural land surfaces into modern land which is consist of buildings, roads, and other impervious surfaces that affect the inhabitability of urban areas. This land use land cover changes leads to Urban Heat Island (UHI)(He et al. 2007) which causes temperature rise even 5-6°C surrounding the urban areas. UHI is defined as an environmental phenomenon where air and Land Surface Temperatures (LST) of urban areas are higher than those of its surrounding areas (Trenberth 2004). There are multiple factors which are responsible for the generation of UHI. Land cover change due to urbanization is the main driver for causing change in the LST because the quality, characteristics of each land type is different (Ahmed et al., 2013). However, this absorbed solar energy is re-radiated at night in the form of thermal infrared (Patz et al. 2005). Because of this, in a day, LST of a land cover type varies. In addition, this cross-sectional relationship between land cover types and LST also enabled researchers to investigate the impact of land cover changes on LST over time(Lo and Quattrochi 2003). This study has been intensified because of the variability of remotely sensed database and it focused on the past land cover change (Patz et al. 2005).

The aim of this study is to monitor and analyze the influence of land cover change on land surface temperature in Gazipur district using RS and GIS techniques for the years of 1995 to 2015

METHODOLOGY

The study area, Gazipur district of Bangladesh [Fig. 1] has been selected because migration of huge population is seen as because; it is very near to Dhaka capital city. It carries a good number of site for urban development center. As a result of population pressure and unplanned development, the local people are destroying forest, trees and valuable cultivable land for making various industries and brick fields etc. As a result, the forest area is gradually decreasing and the environment is changing significantly.

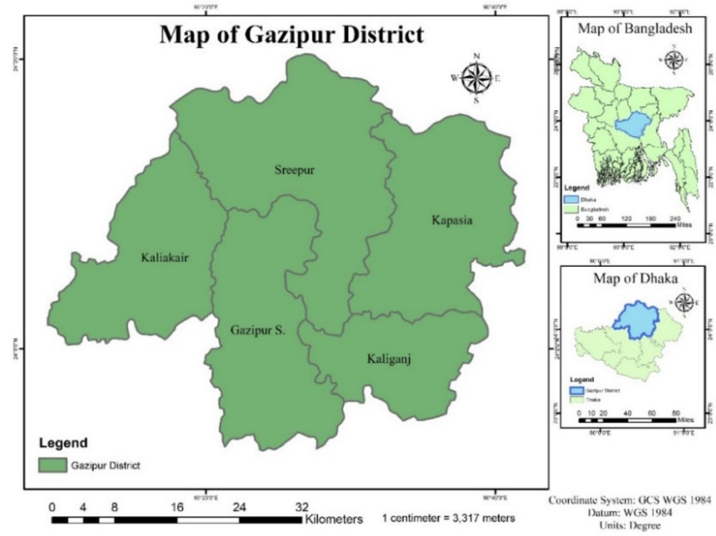

Fig. 1. Map of Study Area Location

For the study a consecutive methodology has been adopted. The estimation of impact of temperature on the land use has been done in several stages. For carrying the study TM and OLI TRS data of Landsat satellite imagery data is collected of three different years which is 1995, 2006 and 2015 and these data are taken of March-April month so that temperature of summer can be easily estimated. The cloud cover of all these data is less than 2%. After this the data is prepared for the analysis. The supervised classification used to determine the land use pattern of the study area. After supervised classification a conduction of accuracy assessment is done to assess the accuracy of the classification. Change detection is a process which has been done to estimate the change of land use in a time period such as a period of 5 years or 10 years. It actually determines what changes in land use the area undergo in a specific time period. After supervised classification this compared the resulting maps on a pixel-by-pixel basis using a change detection matrix to estimate the land use change of the study area in ten years 2000-2015.The one of the most important stage of the study to estimate the temperature from the prepared satellite image. This process is done into two steps.The first step is to convert the thermal band into radiance. Then the radiance is converted into temperature in Kelvin unit. Then temperature is again converted Kelvin to Degree Celsius. For Landsat TM image digital numbers DNs of thermal band (band 6) of were converted into radiance using the following Eq. (1)

$$T_{TM6} = \frac{V}{255}(R_{MAX} - R_{MIN}) + R_{MIN} \quad (1)$$

Where V represents the DN of band 6 and

$$R_{Max} = 1.898(\text{mW} * cm^{-2} * \text{sr}^{-1}), \text{R}_{\text{MIN}} = 0.1534(\text{mW} * cm^{-2} * \text{sr}^{-1})$$

And the second step, conversion of radiance into temperature in Kelvin T(K) was done by the following Eq. (2)

$$T = \frac{K_1}{\ln(\frac{K_2}{\frac{R_{TM6}}{b}} + 1)} \quad (2)$$

Where, K_1=1260.56K and $K_2 = 607.66(\text{mW} * \text{cm}^{-2} * \text{sr}^{-1} * \mu\text{m}^{-1})$, b represents the effective spectral range and b=1.239(μm)

For Landsat OLI_TRS, at first, OLI and TRS band data can be converted to TOA using the following Eq. (3)

$$L_\lambda = M_L W Q_{cal} + A_L \qquad (3)$$

Where,
L= TOA spectral radiance($\text{Watts/m}^2 * \text{srad} * \mu\text{m}$), M_L= Band specific multiplicative rescaling factor from the metadata, A_L= Band specific z rescaling factor from the metadata. Q_{cal}= Quantized and calibrated standard product pixel values (DN)
For converting spectral radiance to temperature following Eq. (3) is used

$$T = \frac{K_2}{\ln(\frac{K_1}{L_\lambda}+1)} \qquad (4)$$

Where
T= At satellite brightness temperature (K), L_λ= TOA spectral radiance($\text{Watts/m}^2 * \text{srad} * \mu\text{m}$), K_1= Band-specific thermal conversion constant from the metadata (K_1_CONSTANT_BAND_x, where x is the band number, 10 or 11), K_2= Band-specific thermal conversion constant from the metadata (K_1_CONSTANT_BAND_x, where x is the band number, 10 or 11)
Temperature are derived in 'Kelvin (A)' which were converted into 'Degree Celsius (B)' using the following equation

$$B= A-273.15 \qquad (5)$$

The final stage of the study is the estimation of relationship between the land temperature impacts on the land use change.

RESULT AND DISCUSSION

From reclassified map of Gazipur for the year 1995 it can be said that the dominant land use of that time was vegetation. Almost more than half of the total area is covered by vegetation and water body. The other land use was open space and a very few portion of the area was build up area. From the land surface map of Gazipur for the same year, also this can be said that in the portion of the area which contains waterbody and vegetation has the lowest land surface temperature than other areas and the lowest land surface temperature at that time for Gazipur was between 22.08°C -23.82°C. The highest land temperature at that time was between 25.54°C-30.56°C which was the land used for buildup area and open space.

In 2006 reclassified land use map of Gazipur it is clearly evident that most the land of Gazipur at that time was vegetation which was most prominent land use at the year 2006. The other land use type which was dominating at that time was open space. The least land use of that year was waterbody and buildup area which was in a very insignificant portion of the whole area. The land surface map of Gazipur for the same year that means 2006 indicates that the dominant temperature of the most of the land of that time was moderate which was between 27.60°C -30.56°C and it was mainly temperature of those areas which has less dense vegetation and mostly open space. The lowest temperature was between 21.20°C -27.60°Cwhich is the temperature of area with dense vegetation and waterbody. The highest temperature contained land use at that time was some open space and buildup area which ranges 30.57°C -38.92°C.

From the land surface map of Gazipur for the year 2015 it can be said that in the portion of the area which contains waterbody and vegetation has the lowest land surface temperature than other areas and the dominant temperature of the of that year was low to moderate temperature which was between 17.65°C -23.98°C. The highest land temperature at that time was between 23.98°C -31.21°C which was the land used for buildup area and open space. Fig. 3 represented the percentage of land use and land cover change in different years in Gazipur. From the figure it can be said that there is an increase of vegetation in this period of time. Vegetation increased in 2015 in 14.9% than 1995. A huge decrease in the waterbody in this time period where in 1995 there is 42.45% waterbody which reduce to 3.59% in 2015. There is also reduction in open space though it increases in 2006. A very small increase of buildup area was found in this time period.

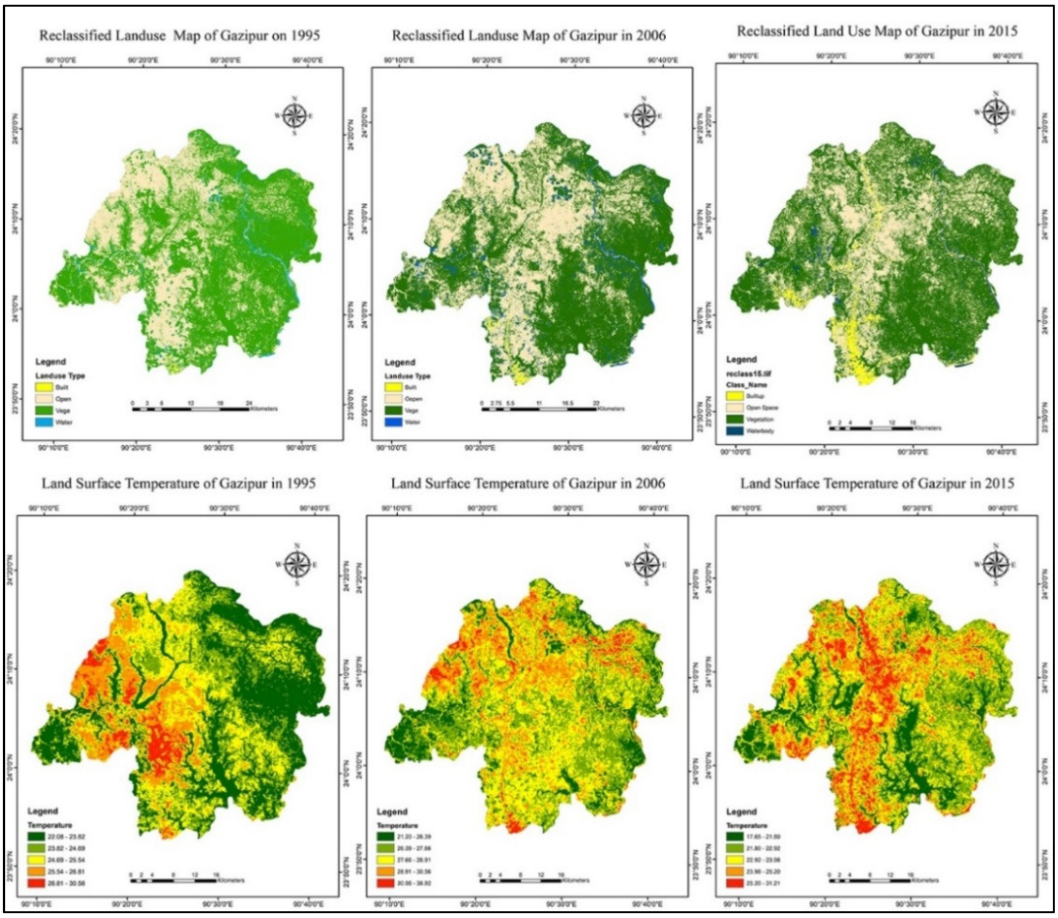

Fig. 2. Land use land cover and Land Surface temperature map of Gazipur from 1995 to 2015

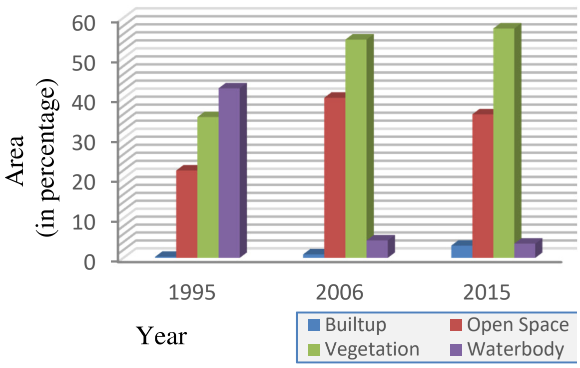

Fig. 3. Percentage of different LULC type

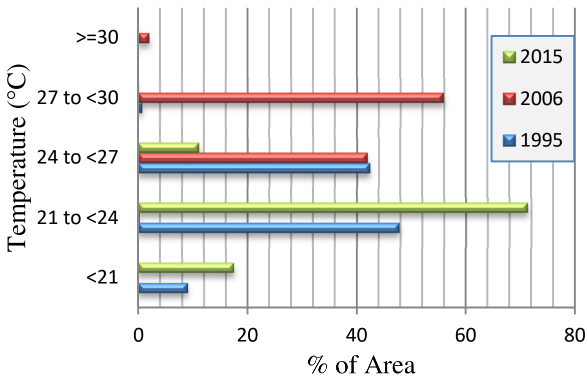

Fig. 4. Changing pattern of heat zone in Gazipur

Fig. 4 shows the changing of heat pattern zone in Gazipur. From the figure it can be assumed that in the year 1995 temperature of most of the area was remain between 21-27°C. In 2006 the land surface temperature of most of the area was between 24-30°C. In 2015 the land surface temperature of most of the area was between 21-24°C.

The land use change map and Table 1 showing the total area of change land use of Gazipur in between 2006-2015 that means land use change for a time period of 10 years. In this time period the most prominent land use change in this period is vegetation to open space which is about 780702 sq. km of the area**.** The dominating land use change is vegetation to buildup area which covered almost 261528 sq. km area and open space to vegetation which is about 202262 sq. km.

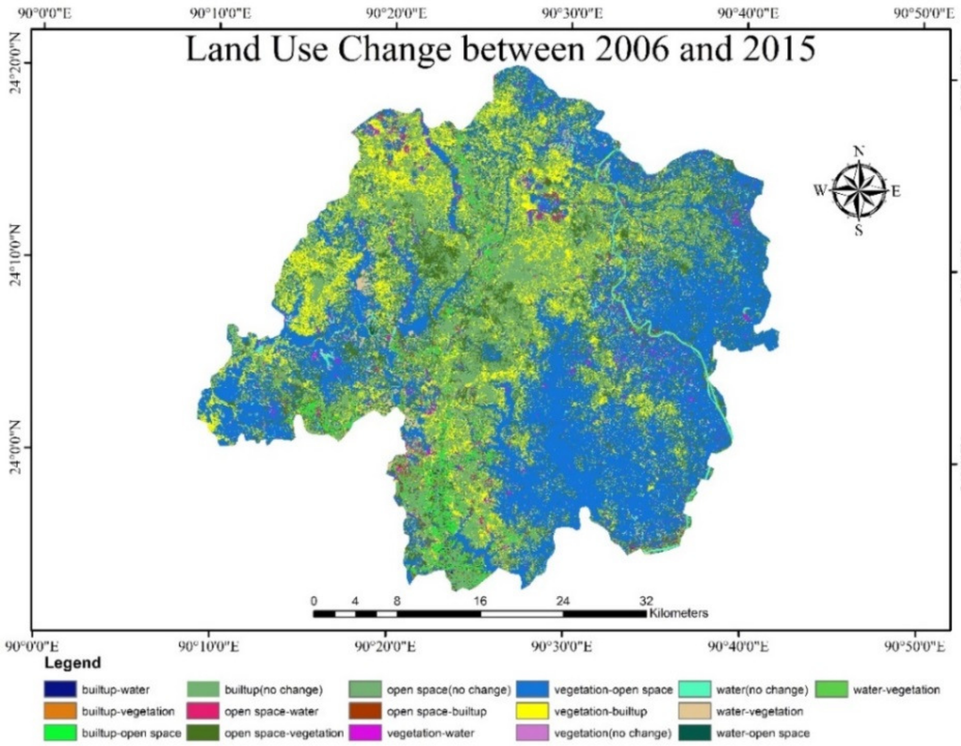

Figure 5: Land Use Change between 2006 and 2015

Table 1: Area of changed land use from 2006 to 2015

Land Use Change	Area (sq.km.)	Land Use Change	Area (sq.km.)	Land Use Change	Area (sq.km.)	Land Use Change	Area (sq.km.)
Built-up-Waterbody	3507	Open Space-Waterbody	15726	Vegetation-Water	29576	Waterbody (no change)	33405
Built-up-Vegetation	8423	**Open Space-Vegetation**	**205562**	**Vegetation-Open Space**	**780702**	Waterbody-Built-un	26055
Built-up-Open space	33102	**Open Space (no change)**	**447787**	**Vegetation-Built-up**	**261528**	Waterbody-Open Space	7319
Built-up(no change)	12698	Open Space-Built-up	3384	Vegetation(no change)	445	Waterbody-Vegetation	296

CONCLUSIONS

Gazipur is facing rapid land use change due to rapid urbanization. The main aims of this study is to reorganization of land use change in Gazipur city in the time period between 1995-2015 and also impact of land use change on the change of land surface temperature. From the study it is found that there is a change in land use pattern in this time period. Buildup area is increasing rapidly in Gazipur than earlier time. There is a decrease in the waterbody and vegetation in this time period. Waterbody is being decreased from 1206 sq.km to 74 sq.km. The situation is same for vegetation land cover which also have decreased at an alarming rate. Waterbody is greatly replaced by the buildup area. Also vegetated land is converted in the open space. As the land use of the area is changing rapidly it is affecting the land surface temperature of the area. Due to change of land use land surface temperature also increasing as the outcome of land use change. Over 10 years' temperature is changed from 26°C to 30°C.The land uses which were converted into buildup or open space are experiencing high temperature than earlier years. It indicates that there is relationship between land surface temperature and land cover changes. Vegetated and other natural areas enjoy lower surface temperature, than build up or open space areas with little vegetation.

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POND FILLING LOCATIONS IDENTIFICATION USING LANDSAT-8 IMAGES IN COMILLA DISTRICT, BANGLADESH

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ABSTRACT

Ponds are an important place for biodiversity. Collectively, they support more species and more scarce species, than any other freshwater habitat. According to Bangladesh Bureau of Statistics (BBS), the number of ponds in the year 2011 is 73,532 thousand in Comilla district. It's very much noticeable in recent few years that ponds are being filled up to meet up rapid urbanization in Comilla District. The study aimed at understanding the phenomenon of filling up ponds with the help of Landsat-8 images and also find out the causes for pond filling in Comilla district. Landsat 8 images contain 15m resolution and these satellite images have been used to identify the loss of ponds in every year starting from November, 2013 - November, 2017. Geographic Information System (GIS) and Erdas Imagine software have been used to perform a supervised classification and change detection technique to identify the locations of ponds fill up in every year. This study makes an attempt to find out the root causes of filling up the ponds and analyze the trends of pond fill during 2013-2017 years. The result shows us that in year 2017 the number of pond is 61,426 thousand which indicates almost more than 10,000 thousand ponds are being fillip in space of only 6 years. The pond filling will make the drainage system of Comilla district vulnerable which increases urban flooding, water logging and temperature rises to an unexpected extent. The conservation of ponds is crucial to keep a perfect ecological balance in Comilla District.

Keywords: Pond filling, Geographic Information System (GIS), Causes, Supervised classification, Landsat-8, Comilla District

INTRODUCTION

Ponds are very useful for maintaining the environment and balancing of the land use. Ponds are natural or manmade shallow water bodies which hold water permanently or temporarily (Céréghino et al., 2010). Ponds are small in sizes varies between 1 m² to 5 ha (Akhtar et al., 2017). Ponds are important to place for biodiversity. Collectively, they support more species, and more scarce species, than any other freshwater habitat. The protection of ponds is much essential because they are playing a very crucial part in conserving our biodiversity. The type of life in a pond is generally determined by a combination of factors including water level regime (particularly depth and duration of flooding) and nutrient levels (Meester et al, 2005). Other factors may also be important, including presence or absence of shading by trees, presence of streams, effects of grazing animals and salinity (Paul, 2010).

Bangladesh experienced a fast increase of urban population in the recent decades like other developing countries. In 2011 the total population lives in the urban area is about 29% and the annual rate of urbanization is 2.96% (CIA, 2015).Because of unplanned urbanization and haphazard situation present in earth-dumping, a total 4000 ponds have been filled in the last five decades. In Comilla, the urbanization is increasing significantly with the increase of population from in from 3.4 million to almost 5.4 million during 1981 to 2011(BBS, 2013). The increase in urbanization will hamper the present water body like ponds and ponds have been diminishing frequently to meet up the increasing urbanization. In the year 2011, the number of ponds in Comilla is 73,532 thousand (BBS, 2013) which significantly decrease to 61,426 thousand. It is noticed that the study area can be severely suffered from ecological degradation through rapid urbanization and harmful changes (Akhtar et al., 2017).

The present work implies upon the trend of pond fill in Comilla with the help of satellite images and identifies the causes behind it. High-resolution satellite imagery can be used for monitoring and advocacy of land use changes in any region. Remote sensing data from Landsat-8 satellite images to identify the ponds as well as locations of ponds filling in Comilla from the year 2013 to 2017.This study aimed to understand the causes of pond filling and explore the rate of pond filling in context Comilla district.

METHODOLOGY

Comilla City stands on the bank of the river Gumti .Comilla is bounded on the north by Brahmanbaria District, on the east by Tripura State of India, on the south by Feni and Noakhali and on the west by Narayanganj, Munshiganj and Chandpur [Fig. 1]. It lies between 23°02' and 23°48' north latitudes and between 90°38' and 91°22' east longitudes. The total area of the district is 3146.30 sq. km. (1214.79 sq. miles) with an estimated population of 5387288 people (Bangladesh Bureau of Statistics, 2013).

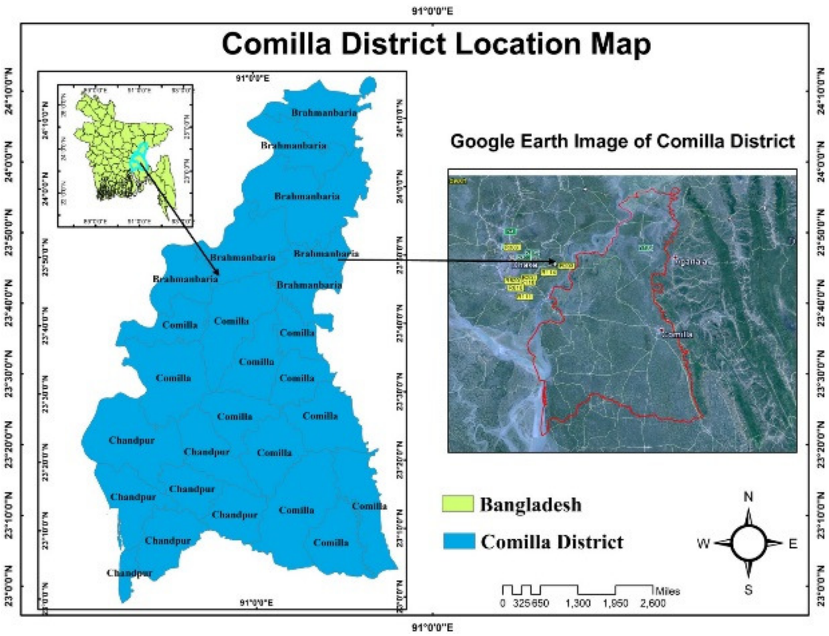


Fig.1: Location Map of Study area

The present work was conducted using both primary and secondary data. The primary data were collected from a structured questionnaire, and interviews and focus group observations in major ponds filling locations in different upazilas. The questionnaire survey was conducted based on random sampling which includes 250 respondents. The primary data were analyzed by IBM SPSS 20 software. The secondary data were collected from satellite images. Landsat-8 OLI images (in the form of both surface reflectance) at 15 m spatial resolution are freely available in United States Geological Survey (USGS) websites (Bartsch et al., 2016). For this study, these images covering the study area and within the time frame of 2013 to 2017 have been collected Landsat 8 operational land imager (OLI) images dated 13 October 2013, 25 November 2015 and 21 November 2017 were downloaded from the global visualization viewer of the United States Geological Survey (USGS). Images are collected from late autumn (October and November) since this season is cloud free and trees are not in leaf-off condition(Rahman et al., 2017). Images for three different years are collected within one month to avoid the season variation in this area. These images were acquired with a combination of path-row 136-44, 137-43 and 137-44 as this cover the study area. Upon acquiring all the required datasets, we performed the following set of pre-processing steps for Landsat-8 OLI. Those included: (i) re-projecting the images into Universal Traverse Mercator (UTM) Zone 46 N with World Geodetic System 1984 (WGS84) datum, (ii) clipping the images to represent the study area (iii) Supervised classification in three years 2013,2015 and 2017 to identify the water body iv) extract the water body which is less than 5 hectors from classified images. V) Matrix Union to identify the conversion of ponds in different land uses. Only visible and near-infrared bands of the Landsat scene are considered for the supervised classification to prepare decadal land cover maps of the Comilla. For easy understating of the study, four broad land cover categories are selected and mapped for the study area: waterbody, buildup area, vegetation which include agricultural land and bare soil (Kafy et al., 2017).Two change maps are prepared based on the post-classification land cover change between 2013 and 2015 as well as between 2015 and 2017. Since three types of changes such as ponds to buildup, ponds to vegetation and ponds to bare soil provide a favorable condition for how the ponds are converted in different land uses.

RESULTS AND DISCUSSIONS

Land use Change assessment

Fig. 1 shows the land cover map of three different years. Increase Urbanization might have observed from the map [Fig. 2]. Diminishing of water bodies for different land use activities have been significantly noticeable between years 2013 - 2017. In land cover changes, major changes are noticed in Built-up areas which were 556 km^2 in 2013 and increase almost double to 1006.89 km^2 in the year 2017. Fig. 1 indicates that Comilla District had 8% of its area as Buildup area which is significantly increased to 15 percent. Also, noticeable change in vegetation land which is 3520 km^2 and 2751.55 km^2 in 2013 and 2017 respectively. Between 2013 and 2017 there is very little change in bare soil condition. Waterbody change also noticeable which is 1127 km^2 (17%) in the year 2013 and significantly reduce to 887.949 km2 (13%) in the space of 5 years [Fig. 2].

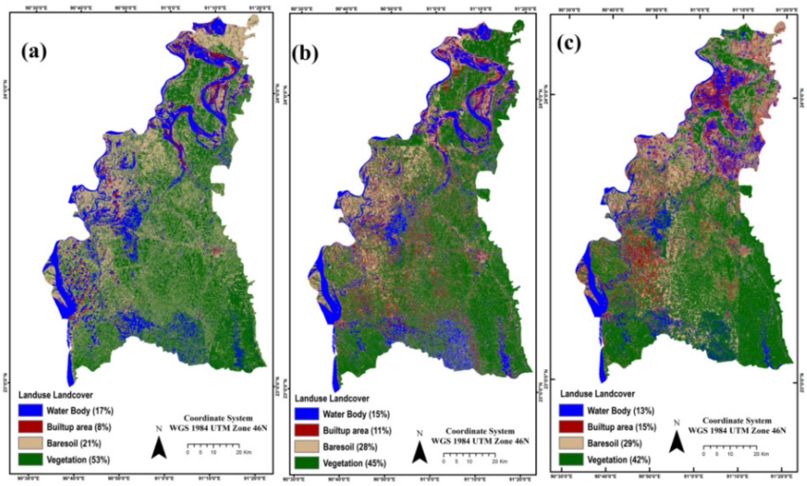


Fig.2: Land cover map of Comilla District in year 02013(a), 2015(b) and 2017(c)

Ponds Filling Change assessment

The number of ponds in Comilla district in year 2011 is 73,532 thousand (Bangladesh Bureau of Statistics, 2013) which is decrees significantly in every year interval. From fig. 3 the number of ponds in year 2013 is71523 thousand which achieve after processing the satellite images. With the increase in rapid urbanization the number of ponds are decreed in 61426 thousand in year 2017. Almost 12677.08km^2 ponds area have lost in the space of only six years which is very much alarming for Comilla district at present. Rapid loss of ponds (7426 thousands) happen between years 2013-2015 (Table 1).

Table 1. Diminishing of Ponds area in Comilla district, 2011-2017

Year	Number of Ponds	Area(km^2)
2011	73532	23876.07
2013	71523	21575.05
2015	64097	14727.15
2017	61426	11198.99

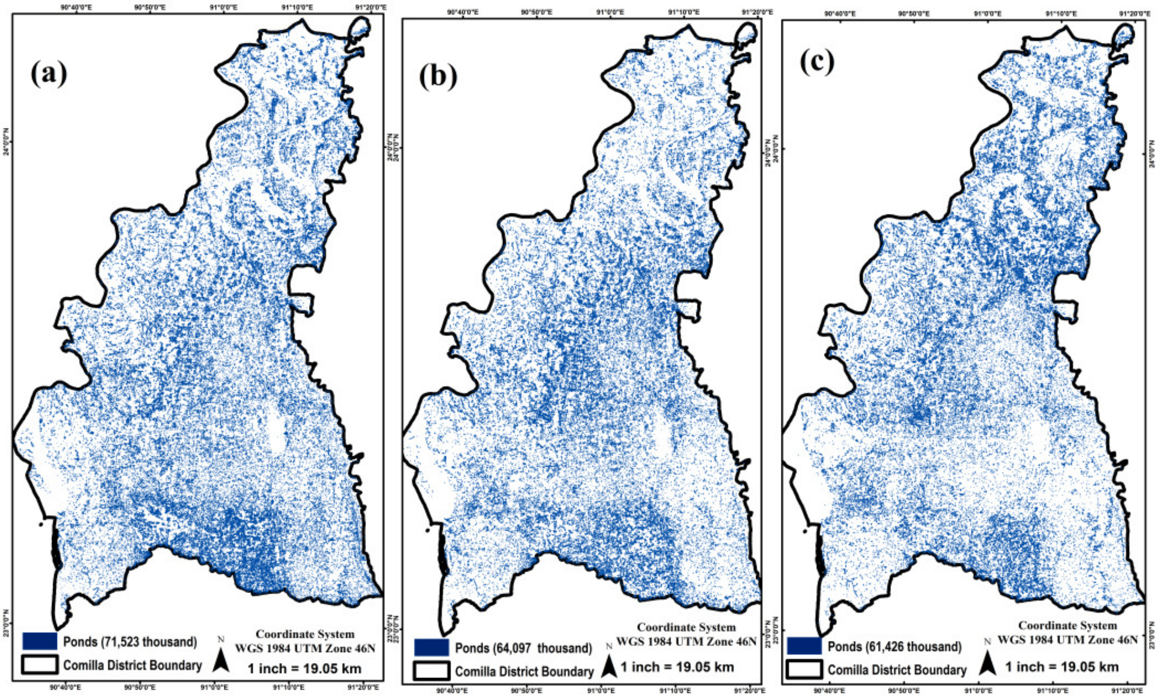
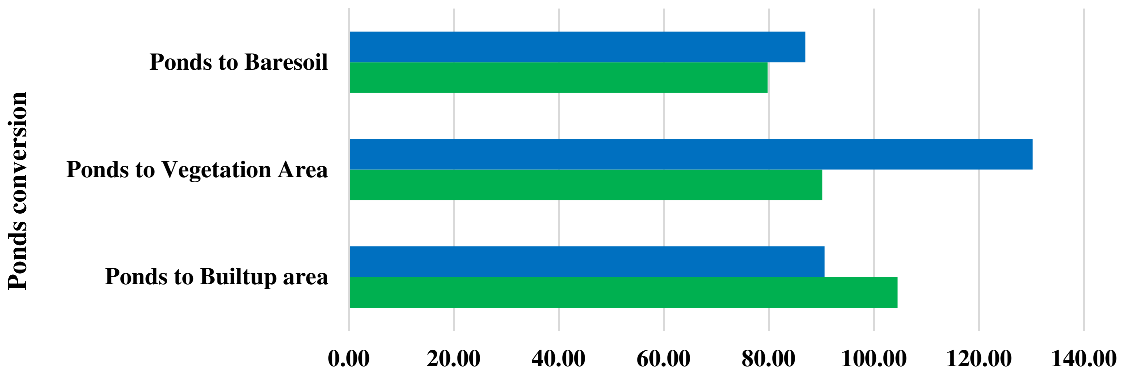


Fig.3: Ponds of Comilla District in year 2013(a), 2015(b) and 2017(c)

Conversion of ponds to different land uses

Major conversion of ponds to build up area happen between years 2013-2015. 104.55 km^2 and 9.65 km^2 area of ponds are fill up to build urban areas in year 2013-2015 and 2015-2017 respectively. Similarly the agricultural activities increase mostly in year 2015-2017 which diminish almost 130.27 km^{2}area of ponds. People fill up the agricultural lands and ponds to meet the rapid urbanization and for this reason the bare soil area is increase from 79.76 km^2 to 86.96 km^2 during 2015-2017 (Fig.4). The figures describe that ponds have been fill up across the Comilla district to meet the rapid urbanization as well as increase demand is vegetation and agricultural products.



	Ponds to Builtup area	Ponds to Vegetation Area	Ponds to Baresoil
2015-2017 (sq.km)	90.65	130.27	86.96
2013-2015 (sq.km)	104.55	90.18	79.76

Fig.4: Ponds Conversion to different land use in Comilla district, 2013-2017

Causes of Pond Fill

In last 7 years more ponds and wetland have been filled in Comilla district. Since then, extensive losses have occurred, with many of the original ponds were filled and many of them were converted to farmland. Activities resulting in pond fill loss and degradation include: urban (commercial and residential) area development, agriculture activities, land filling, encroachment and huge political and institutional support ignoring the rules and laws. The main causes of pond fill are shown in the Fig. 7 below.

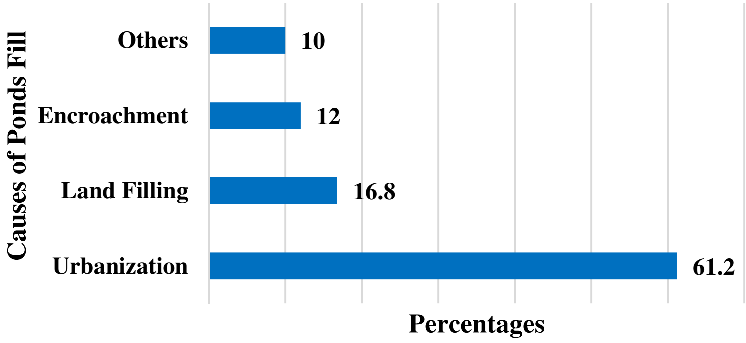


Fig.5: Reasons for ponds fill up in Comilla District

Urbanization is a major cause of impairment of ponds. Urbanization has resulted in direct loss of pond areas as well as degradation of ponds. Construction activities are a major source of suspended sediments that enter ponds through urban runoff. According to the survey in major ponds fill up locations in Comilla district, 61% of pond fill happened due to urbanization. Shopping Centre, Market, high rise building, restaurant are the main causes of pond fill in Comilla district. Land filling is the second most important causes of pond fill in Comilla district. About 17% respondent said that land filling is the one of the causes for pond fill in Comilla district. Most of the respondents said that encroachment mostly happens where pond owner has his house near the pond. From the survey data it can be said that 12% pond fill happens due to encroachment. The first step of encroachment is to build structures along the surroundings of ponds and further out on the ponds itself. To do this, rows and bamboo posts are positioned and fixed on the water body bed along the bank and extending into the main body of the pond. Then huts and shops are built on these stilts. The owners of these structures are then start reclaiming land by earth fills and dumping garbage. Pond filling has some other reason as well. Such as, political pressure in unlawful land grabbing, unplanned urbanization and district expansion, unplanned constructing of government building etc. [Fig.5].

CONCLUSIONS

In space of 7 years, 12677.08 km^2 area of ponds in Comilla district has been filled. There will be no pond in Comilla district area if the current trend continues for next 90 years. The study identifies the number of ponds in three different years using 15m resolution Landsat-8 images and also Observes he main causes for pond fill of Comilla district. The study finds that the main reasons are urbanization, encroachments, land filling etc. The critical effects of the pond fill are the loss of biodiversity, serious environmental degradation, Water logging, urban flooding, and loss of valuable water resources. To improve the beautification of Comilla district measure should be taken like conserve ponds and develop scenic view around the ponds to create more attraction to the district dwellers. The conservation of ponds is crucial for Comilla district to keep the ecological balance, especially to reduce the urban flooding. Necessary measures should be taken like social awareness, maintain of strict law and the Local government could play an important role in pond fill restriction.

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THE RAINFALL DISTRIBUTION CHARACTERIZATION AND FLOOD EXTENT MAPPING USING SAR SATELLITE IMAGE: A CASE STUDY IN NORTH WESTERN PART OF BANGLADESH

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ABSTRACT
Bangladesh is a flood-prone area among Asia for the geological location. Due to this natural disaster, infrastructure damages and human life losses occur every year in this country. Efficient monitoring and prediction of the flood in this county are very difficult without using satellite data. Flood mapping is a process which uses for damage assessment and risk management and helping rescuers during the flood. Somehow, Rainfall associated with flooding affects the study area with life loss and crop loss. The study area is the north western part (Rajshahi, Naogaon and Natore) of Bangladesh. The objective of this study is to define the extent of the flood in the study area during rainy season comparing two years of 2016 and 2017 and to identify the characterization of rainfall distribution during this period. The study also illustrates the links between evolving rainfall structure and spatial extent of flooding. The whole analysis is based on SAR (synthetic aperture radar) satellite images from Sentinel-1, have free access from ESA. The software is used for SAR imagery processing using threshold method to derive the flood extent and google earth is used to visualize the result of image processing. The results help operating estimation and detection of flooded area and determine the extent of flood causing damages in the study area. Finally, the study explores that due to the changing contribution of rainfall distribution, the extension of flooding is increased to a great extend or not in Rajshahi, Naogaon and Natore. It also helps to find that the rainfall distribution does really responsible for the flood in the study area or other reasons do responsible for it.

Keywords: Flood Extent; Rainfall distribution; SAR Image; Flood Mapping.

INTRODUCTION
Approximately one billion people live in extreme flood areas, which may be double by 2050 due to climate change and population increase (Long et al., 2014). A flood is described as an overflow or increase of the expanse of water which submerges urban or rural land. It results from the rising volume of water and the water flows its usual boundaries of village, city. Much of the districts are situated on low-lying and flood-prone areas, which made it particularly vulnerable to seasonal monsoon rains. In 2007, Bangladesh was seriously damaged by deadly monsoon flooding which led to over 1,000 deaths and in 2017 history is repeating (George, 2017). Prediction of precipitation and flooding has definite importance from a societal and economic perspective (Villarini et al., 2011).
Relevant study on the flood extent mapping has done to identify the intensity of the flood locations. The study areas are Rajshahi, Naogaon and Natore of Bangladesh. Earth Observation (EO) data which are collected from space is being used for effective monitoring of floods and precipitation data is collected for rainfall distribution characterization. Mainly the data required for the flood extent mapping is Sentinel-1 freely available from European Space Agency (ESA) which special resolution is 5m-40m. The product type is Level-1 Ground Range Detected (GRD) Sentinel-1 image, for SAR image analysis SNAP tool is used, DEM for ortho-rectification archived optical images, land cover with vector data. The time selection of the conducted image is to be considered due to the weather condition (Pustina, 2014). The methods and procedures in the relevant studies were followed to some extent to achieve the accurate flood extend map of the research area. Precipitation data helps to

identify the characterization of rainfall distribution and it links to the inundation of flood (Villarini et al., 2011). The flood extent information is used for vulnerability and risk assessment.

Basically, the objective of the research practice is to determine the extent of flooded areas of the considered research area. The research explores the flood extend map which includes damage assessment of flooded mapping and severity of flood from the previous year. The application of SAR satellite image leads to a fast image processing system and provides flood extension area (Villarini et al., 2011). The study will help to risk assessment foreconomic activity and potential location at the risk of flooding. The study is based on the use of satellite remote sensing, geographic information system (GIS) and hydro-meteorological data to evaluate flood situation and assessing the impact of flood disaster with the aid of pre- and post-flood satellite images (Bhatt et al., 2016).

METHODOLOGY

A simple threshold method is applied which was successfully applied in Malwari, January 2015 and also used in Australia, Europe and Africa (Pustina, 2014). The materials for the research are Sentnel-1 images, SNAP 6.0, ArcGIS 10.2.2 and Google Earth. For data preparation, sentinel-1 images of 13th April 2016, 28th August 2016, 26th May 2017 and 27th August2017 are collected from *European Space Agency (*ESA). Advantages of SAR images are easy detection capability of smooth water and accuracy of detention almost 95%. The images are dereferenced, filtered with the adaptive Gamma filter and masked. To fulfill the second objective, rainfall data is collected from Bangladesh Meteorological Department (BMD).

The research conducts the following steps in SNAP software: Data preparation, pre-processing (Calibration, Speckle filtering), Binarization by band maths, Post-processing (Geometric correction). Then image processing for making maps and visualizes in Google Earth. Pre-processing includes calibration and spectacle filtering. Binarization is used to separate water from non- water region and it also analysis the filtered backscatter co-efficient where magnitude depends on the data. ArcGIS 10.2.2 is used to make flood extent map of the studied area (Rajshahi, Naogaon and Natore) and to visualization of the water band in Google earth is resulted to the flood extend map which classifies the water regions Africa (Pustina, 2014). To complete the other objective, rainfall data of the months of 2016 and 2017 analyses to know the relation between rainfall and flood. SPSS are used to correlate the rainfall amount and flood extent with the ANOVA and coefficient of the regression analysis.

RESULTS AND DISCUSSIONS

Two different sentinel-1 images are used for understanding the flood extent in Rajshahi, Naogaon and Natore districts. Table 1 and Fig. 1 represent a comparison of the extent of mapping of Rajshahi, Naogaon and Natore from August 2016 to August 2017 which was determined by sentinel image processing. The analysis has made a sense to understand the extent of the inundation of water of the present-past year. The extent of flooding evaluated is only illustrating the increase in flood extent from the previous year and not the entire extent.

Flood extent to the floodplain:

Four different sentinel-1 images are used for understanding the flood extent in Rajshahi, Naogaon and Natore districts.

Table 1: A list of water extent area in Rajshahi, Naogaon and Natore

Study Area	Total area (in sq. km.)	2016		2017	
		Water extent area in April (sq. km.)	Water extent area in August (sq. km.)	Water extent area in May (sq. km.)	Water extent area in August (sq. km.)
Rajshahi	2382.22	125.49	227.59	116.247	203.12
Naogaon	3449.22	38.24	246.164	21.502	514.67
Natore	1914.19	17.094	179.032	37.415	176.032

In the study, a comparison of the extent of mapping of Rajshahi, Naogaon and Natore from April 2016 to August 2017 which was determined by sentinel image processing is represented in Table 1, Fig. 1

and Fig. 2. The analysis has made a sense to understand the extent of the inundation of water of the present-past year.

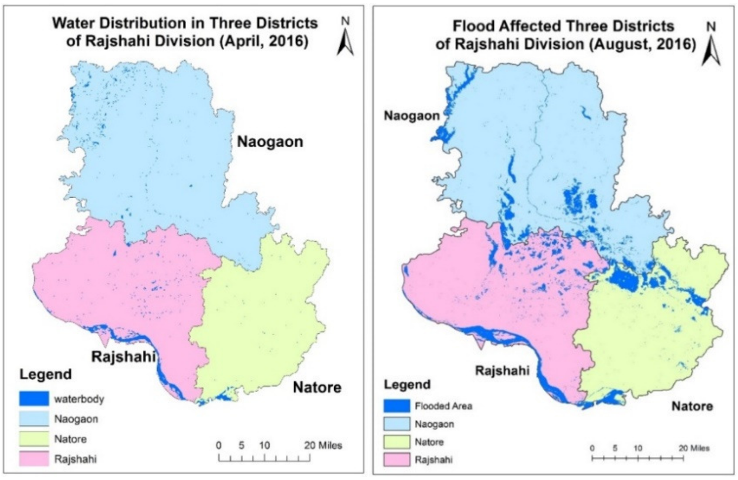

Fig. 1: Water Distribution in three Districts of Rajshahi Division in April 2016 (a) and Flood Affected three districts of Rajshahi Division in August 2016 (b)

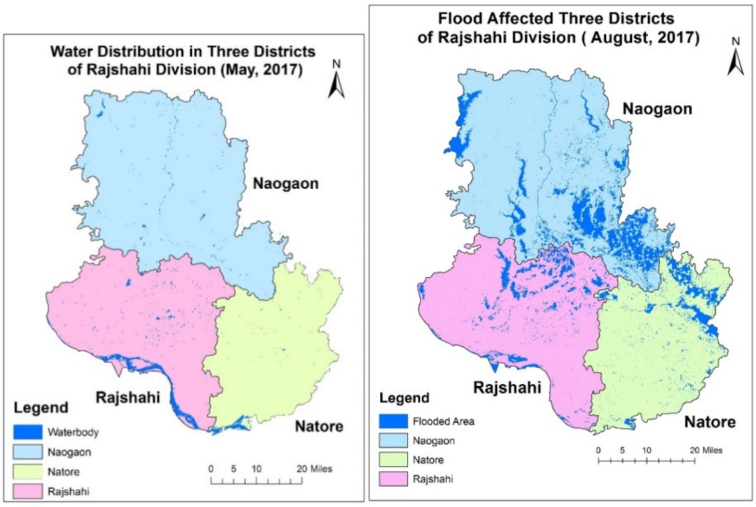

Fig. 2: Water Distribution in three Districts of Rajshahi Division in May 2017 (a) and Flood Affected three districts of Rajshahi Division in August 2017(b)

The water extent area is less in April than the month of August in 2016 over the study area [Fig. 1]. Similarly, water extent area is less in May 2017 than August 2017 in the study area [Fig. 2]. So, it assures that inundation of water in the august month in 2016 and 2017.

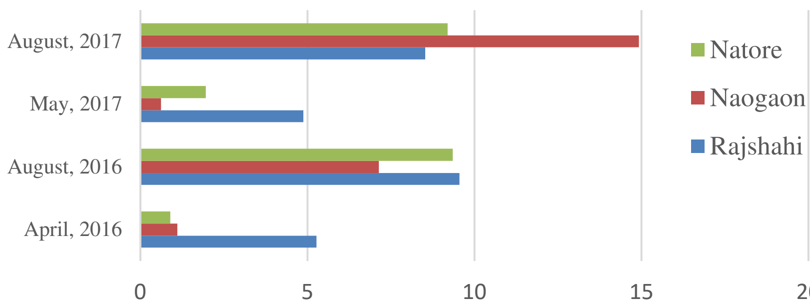

Fig. 3: Comparison of % of the extent of water in 2016- 2017 in Rajshahi, Naogaon and Natore

Flood extent of Rajshahi district is less in 2017 than 2016 [Fig. 3]. In 2016, the flooded area was 227.59 sq. km and in 2017 it was 203.12 sq. km since August. The flood extended area has decreased 1.03% from 2016 to 2017. Flood extent of Naogaon has increased in amount this year [Fig. 3].

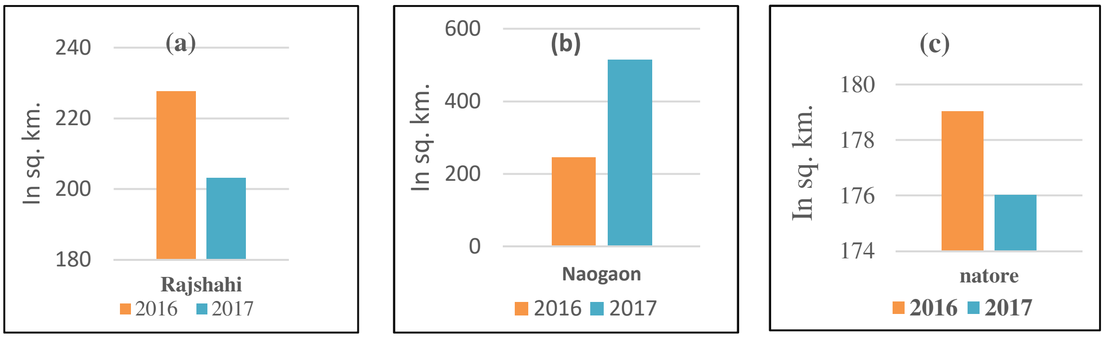

Fig. 4: Comparison of flood extent area in August between 2016 and 2017 in the three districts

In 2016, the flooded area was 246.164 sq. km. and in 2017, the area was 514.67 since August [Table 1]. The total area of Naogaon is 3449.22 sq. km. The flood exteded area has increased 7.79% from 2016 to 2017.Flood extent of Natore is less in amount in 2017. In 2016, the flooded area was 179.032 sq. km and in 2017, the area is 176.032 sq. km since August [Table 1]. The total area of Natore is 1914.195 sq. km. The flooded area was 9.35% and 9.19% respectively in 2016 and 2017 of thetotal area of Natore district. The flood extended area has decreased to 0.16% from 2016 to 2017.

Visualization of flood:

The extent of flooding between August 2016 and August 2017 is determined from the Sentinal-1 images. From the Google earth images, it helps to find out easily the flooded area among three districts. A comparison of flood extent of the present year and past year is shown in Fig. 5. From all the map, it is shown that the extension of inundation of water is more this year until august than the previous year in Naogaon. The time to maximum flood extent is very rapid in the Naogaon Floodplain, depending on the season.

Rainfall distribution to the floodplain:

Rainfall distribution is analyzed according to the meteorological data collected from Bangladesh Meteorological Department (BMD). Average rainfall is high in August 2016 and 2017 [Fig. 5]. In Naogaon and Rajshahi the average precipitation is higher than the Natore [Fig. 5]

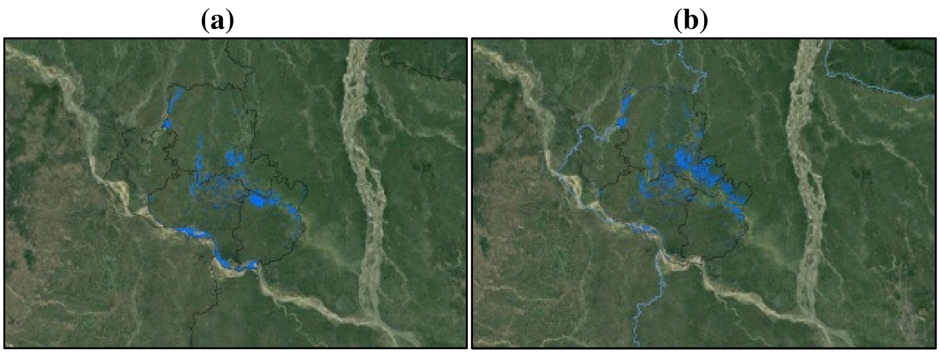

Fig.5: Visualization in google earth respectively year of 2016 (a) and 2017 (b)

Relationship between evolving rainfall structure and spatial extent of flooding:

The relationships are shown according to the Regression analysis. For regression analysis, water extent area is independent variable and rainfall distribution is the dependent variable. The mean water extend area is 6.12 sq. km and the Std. deviation is 4.45 sq. km which indicates that specific areas have huge extension of water in season. The mean rainfall length is 2.49 mm and Std. Deviation is 2.38 mm. The correlation value between rainfall distribution and flood extent area is 0.390 which indicates that they are moderately correlated. So according to the correlation, the extension of water level into the ground or flooding is not strongly depended on rainfall distribution. Other vital reason depends on the rainfall distribution [Table 3].

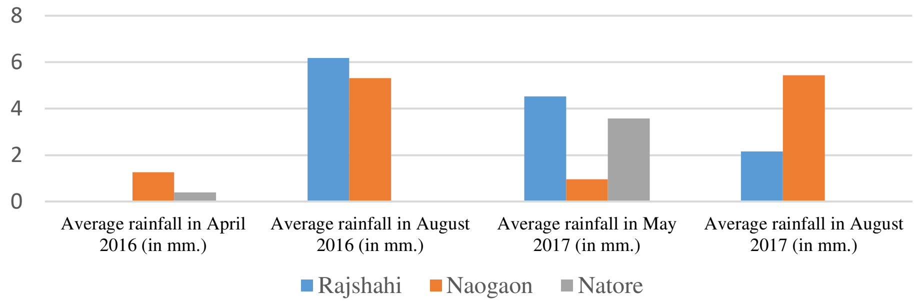

Fig.6: Comparison of the average rainfall distribution in 2016 and 2017

Table 2: Descriptive Statistics of the water extent area and rainfall

	Mean	Std. Deviation	N
Water Extent area	6.1179	4.45437	12
Rainfall	2.4856	2.38210	12

Table 3: Correlation between rainfall distribution and flood extent area

		Water Extent area	Rainfall
Pearson Correlation	Water Extent area	1.000	.390
	Rainfall	.390	1.000
Sig. (1-tailed)	Water Extent area	.	.105
	Rainfall	.105	.

Table 4: Model Summary of the regression analysis

Mode	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.390[a]	0.152	0.067	4.30254

[a]Predictors: (Constant), Rainfall

From Table 4, the Residual (R) value is 0.39 and the R-square value is 0.152 which indicates that from the predicting rainfall data, 15.2% data are accounted for water extension area. The increase in data collection would increase the data accountability. From Table 5, the F-value is 1.7 and Significance (Sig.-value) is .211. So the resultants of the variables are statistically significant.

Table 5: ANOVA[b] of the regression analysis

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	33.138	1	33.138	1.790	0.211[a]
	Residual	185.118	10	18.512		
	Total	218.256	11			

a) Predictors: (Constant), Rainfall b) Dependent Variable: Water extent area

Table 6: Coefficients of the regression analysis

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.307	1.837		2.344	0.041
	Rainfall	0.729	0.545	0.390	1.338	0.211

Here from unstandardized Coefficients of Table 6, it is indicating the increase in 1 mm rainfall would probably cause 0.729 sq. km water extent area. The increase in water extent area is increased according to the increase in the rainfall distribution in the study area. In highest length (in mm) rainfall distribution indicates the most extension of water level in the surface [Fig.7].

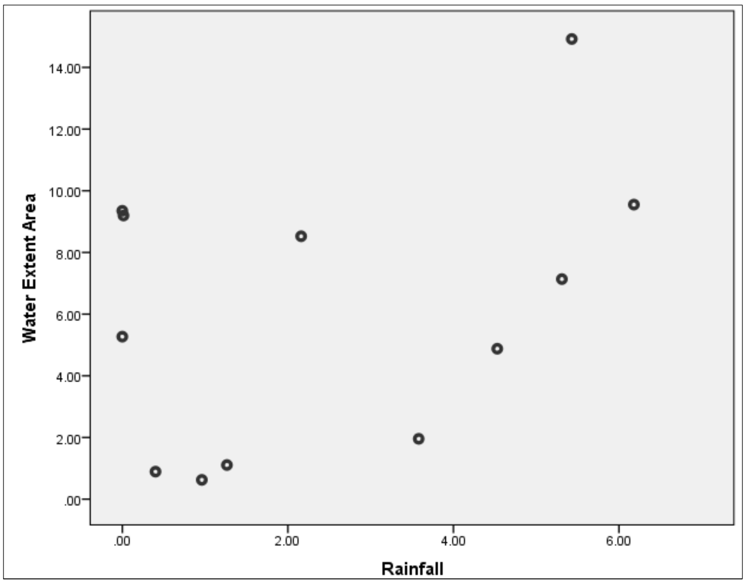

Fig.7: Scatter-plot of rainfall distribution and water extent area of the study area

CONCLUSIONS

In this research, it has explored the range of inundation of water in the study area. After a qualitative comparison of rainfall between the months of summer and monsoon in 2016 and 2017, it has shown that the rainfall was a moderate reason forflood in the study area. As all the three districts are situated on the bank of rivers, it might be the responsible for causing flood. At monsoon, over water is bypassed by the Farakka Barrage from India which may be the reason of inundation of water in the study area. In this case, international water law should need to be applied by the authority to distribute the river water carefully and reduce the casualties in flood time.

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PREDICTING THE MORPHOMETRIC CHANGE OF URBAN WATER BODIES IN CHITTAGONG METROPOLITAN AREA

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ABSTRACT
Urban Water body (UWB) refers to those lakes, ponds, reservoirs and wetlands in urban land cover. In the mood of rapid urbanization the number, shape, size and connectivity of UWB is changing along with the land use. Urban development including construction, burial, drainage and reshaping are responsible for the rapid morphological change of water body day by day. Chittagong is a major coastal seaport city and financial center in the southern part of Bangladesh. Due to the rapid development in metropolitan city, the total area of UWB is changing at an alarming rate due to increase of land use for construction. Morphometric change of urban water body during last 15 years in Chittagong metropolitan area will be determined and prediction of the change in the upcoming 10 years will be estimated in this study. For this research the past urban land use transitions in Chittagong was examined based on collected remote sensing data between 2000 and 2015. A Markov Cellular Automata approach is used for deriving the future urbanized condition based on the existing and planned strategies for Chittagong. This is done by a combination of multi-criteria evaluation processes originating transition probabilities that allow a better understanding of the region's urban future by 2025. While the transition probabilities are incorporated from the traditional Markov Chain process, the variables for suitability are measured through topography, road distance. The result offers a more integrative vision of policymaker's preference of future planning instruments, allowing for the creation of a better integration of propensity of future growth indicators.

Keywords: Urban water body; Metropolitan area; Morphometric change; Rapid urban development.

INTRODUCTION
Urbanization has become a ubiquitous reality throughout the world (Ali, 2008) .Along with the other major city of Bangladesh; Chittagong is undergoing rapid urbanization in recent decades. This development is also increasing rapid urban growth and land cover alteration. During this rapid urban growth the morphometric of urban water body is changing rapidly. UWB is an important element of eco-system (Januchta-Szostak, 2012). The size, shape, and connectivity of water bodies (lakes, ponds, and wetlands) can have important effects on ecological communities and ecosystem processes(Steele & Heffernan, 2014). So this problem has become one of the prime concerns of urban community. The aim of the paper is to predict the morphometric change of UWB in the upcoming 10 years of Chittagong metropolitan by analyzing the morphometric change of urban water body during last 15 years in Chittagong metropolitan area.

METHODOLOGY
Supervised classification method is used for land use classification of Landsat image. A total 200 signatures for each LULC class were extracted randomly covering the whole study area using the ERDAS Imagine software. Signatures were generated using the region growing technique of ERDAS Imagine that produces each region having similar spectral characteristic pixels. Based on these signatures a maximum likelihood supervised classification technique was used to classify the image into other desired classes such as vegetation, water body and built up (Sanjoy Roy, 2015).

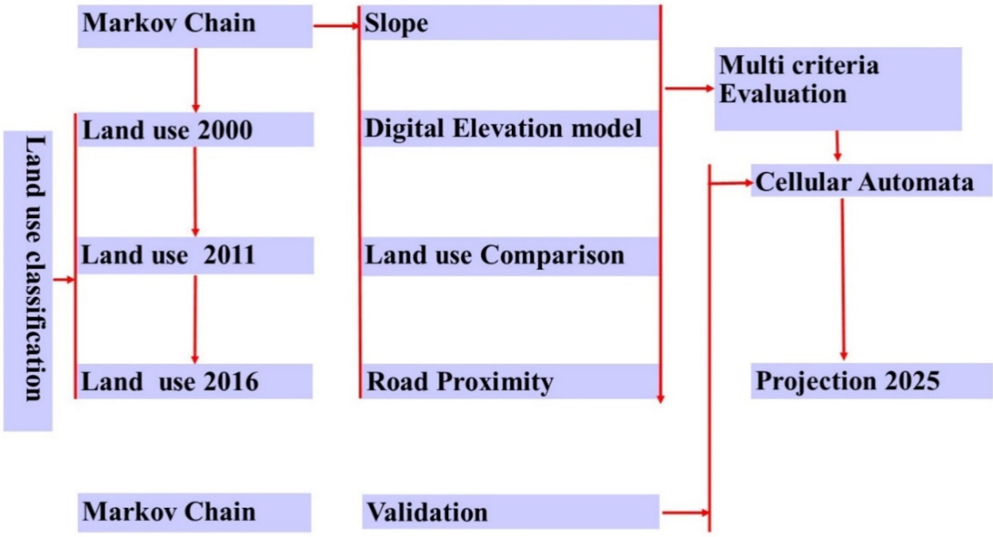


Fig. 1: Structure of the research work

Then accuracy assessment is done for evaluation of supervised image. Another estimator of accuracy is the Kappa statistics (Khat), which is a non-parametric discrete multivariate technique, developed by Cohen measures the overall agreement of a matrix (Sanjoy Roy, 2015).Markov chain (MC) analysis has been widely used for land use prediction model which is a stochastic process that takes into account the past state to predict the future changing of variables over time. Because of its immense ability to quantify the rates and states of conversion among and between categories respectively, it has been equally used in the LULC change modelling. In this research a combination of MC and some hybrid cellular automata (CA-Markov) technique was applied to predict land se classification for 2025 using the QGIS software. It requires two LULC data sets of different time frames based on which the probabilities of transition between periods are obtained (Ahmed, 2011).

Survey area- Chittagong City

Chittagong is the second largest metropolis in Bangladesh. Situated in the Bay of Bengal, Chittagong has historically been an important centre of commerce due to its geo-strategic location and is regarded as the commercial capital of the country.

The Chittagong Statistical Metropolitan Area (SMA) covers an area of 1,152 sq.km and consists of six metropolitan thanas. 68 wards and 236 mohallas (localities) with a population of 3.38 million. Chittagong City Corporation covers an area of 155 sq. km with a population of 4,009,423 in 2011, which had grown on average by 3.6% per annum between 1991 and 2001. The population growth is much higher compared with national growth of about 1.6 percent. Cities are being inundated with people looking for a job and a decent income. The Chittagong City is not an exception to it. Like many developing country cities, it is experiencing a rapid growth of population mainly because of rural-urban migration. (BBS, 1981, 1991, 2001)

Chittagong is unclassified, irregular and heterogeneous in character of its land use. It is very difficult to identify the zoning in a particular area. Unplanned urbanization creates chaotic development in this city. Due to this water body and many other resources of city are hampered. For constructing new buildings, they need more land as the population of the city is increasing at an alarming rate for these reason they destroy pond and other water reservoirs. Both Chaktai and Rajakhali Khals, two main drainage channels of Chittagong, terminate in the river Karnaphuli. Part of the area is densely populated. Remaining part of the area is expected to be developed in the immediate future as the area falls within Bakalia, earmarked as a thrust area for development in the Structure Plan for Chittagong, 1995. But now these two khals are in deteriorated condition. No matter, whether the road width is 6.096 m or 18.288 m, the drain width mysteriously remained constant at 0.6096 to 0.9144 m .People are very generous in building roads and highways but remained equally miser in building primary, secondary or tertiary drains of appropriate size. As a consequence, as expected, drainage became a menace for our cities (Ali, 2015).

Prediction analysis

Geographic Information System (GIS) and Remote Sensing (RS) have long been used and widely accepted as very powerful techniques in change analysis and simulation of LULC. Combined, they are capable of critical analysis and decision supports in earth's surface changes within shortest time with reasonable accuracy. RS is applied to retrieve information from analysis of earth observatory multi-temporal and multispectral satellite images of different spatial resolutions. These images offer tremendous opportunity in LULC monitoring (T. Loveland, 1999).

A spatial models are used to quantify predicted LULC in a particular region and associated driving forces (Kaufmann, 2003) whereas empirical-statistical models and rule based models included in the spatial category are mainly used in the analysis of LULC changing pattern and spatial location of existing and future potential changes. Among all spatial models the Markov chain model integrated with Cellular Automata has been widely used for spatiotemporal modelling of LULC in a reasonable way (Sanjoy Roy, 2015).

RESULTS AND DISCUSSIONS

Table1:The land use of Chittagong in three different years 2000, 2010 and 2016 respectively (sq.cm)

Land use	Year 2000	Year 2011	Year 2016	Change 00 to 11	Transition probability	Change 11 To 16	Transition probability
Vegetation	442044300	38101500	26361000	403942800	0.272156388	11740500	0.597009393
Build up	29418840	64559700	85758300	-35140860	-0.49140449	-21198600	-0.051936619
Others	208503000	58389300	48641400	150113700	0.225965952	9747900	0.221861335
Water Body	96712800	9299700	8847900	87413100	0.01047317	451800	0.129192652

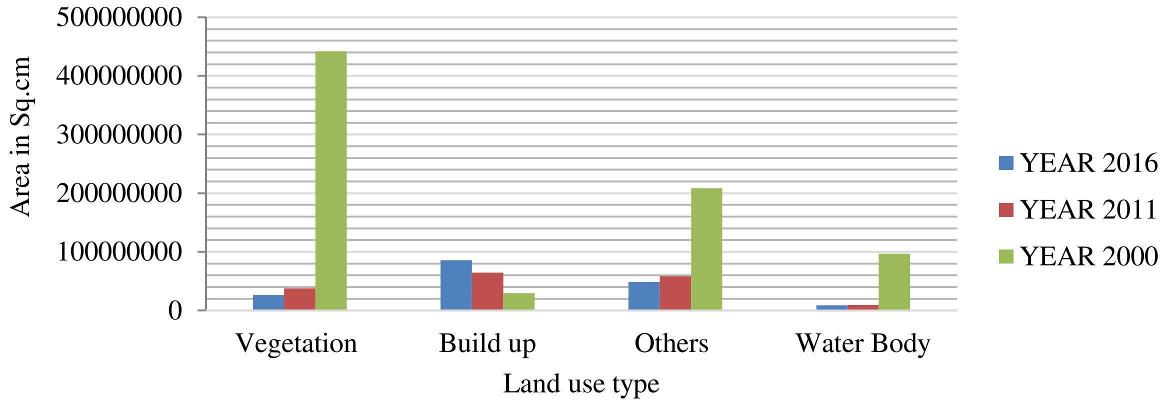
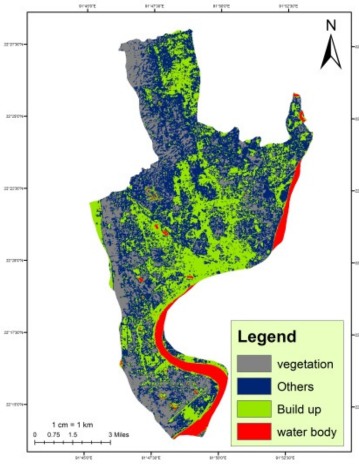
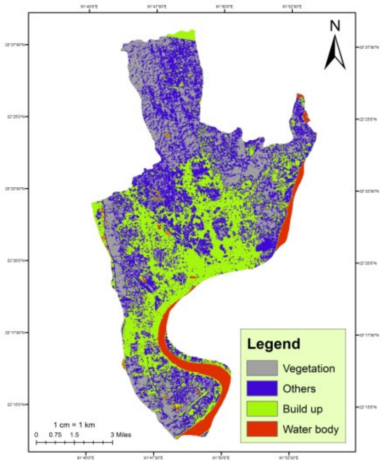


Fig. 2: The land use of Chittagong in three different years 2000, 2010 and 2016 respectively.

The above table and figures showing the land use of Chittagong in three different years 2000, 2010 and 2016 respectively. In the year 2000 the dominated land use was vegetation which decreased very rapidly in the year 2010 but in respect to 2010 the change of vegetation in 2016 is also very significant [Fig. 2]. From the transaction probability of vegetation, it can be sad that the change of vegetation to other land use increase to 0.59 which was 0.27 in 2010 [Fig. 2]. There is an increase in build-up area in 2010 and2016 in respect to 2000 and the proximity of change of build-up area to other land use is negative which refers that the build-up area will not change to other land use that much in the future. There is a very rapid decrease in the water body of Chittagong and there is a probability to change of land use of water body to others land use. Also apart from this there is huge change in other land use in 2010 and2016 with respect to 2000 and high probability to change of other land use.





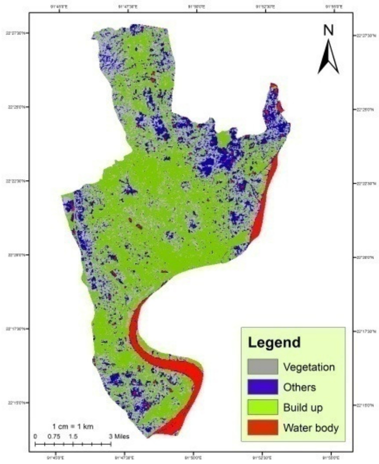
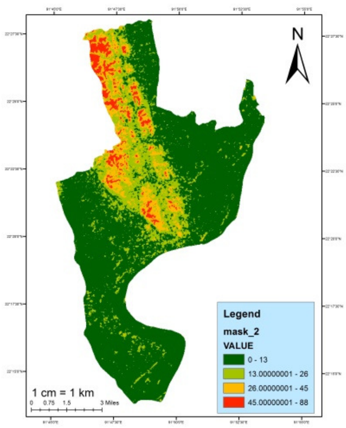


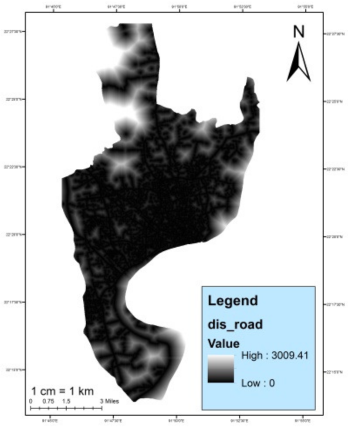
Fig.3: Land use map of 2000 Fig.4: Land use map of 2011 Fig.5: Land use map of 2016

The above figures represent the land use map of Chittagong city for three consecutive years 2000 [Fig.3], 2011 [Fig. 4] and 2016 [Fig. 5] respectively. From the map it can be said that most of the land use was vegetation but it reduces rapidly in 2011 [Fig 4] and 2016 [Fig. 5] on the contrary there is an increase in build-up area in 2011 [Fig. 4] and 2016 [Fig. 5] than 2000 [Fig. 3]. There is also reduction in water body and other land use in 2011 [Fig. 4] and 2016 [Fig. 5] than 2000 [Fig. 3].

Table 2: Transition probability matrix.

Land use	Vegetation	Build up	Others	Water Body
Vegetation	0.59700939	0.282093	0.080598	0.040299061
Build up	0.05193662	0.805854	0.094806	0.047403169
Others	0.22186134	0.622511	0.301991	0.558406996
Water Body	0.12919265	0.696646	0.242683	0.605853362





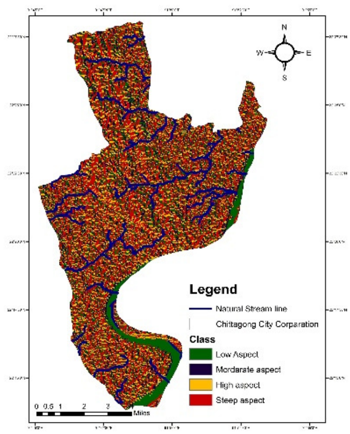


Fig.6: Digital elevation model of Chittagong.

Fig.7: Road proximity map Of Chittagong

Fig.8: Aspect map of Chittagong

The table showing the transaction probability matrix of different land use. From the table it can be said that there is high probability of change of vegetation to build-up area than other land use. The probability of build-up area to be remain same is high than other land use. The proximity to change in other land use to build-up and water body is high. Water body change in to build-up areas proximity is also high. The below map showing the water body probability map of Chittagong city corporation area for the year 2025.The area of water body will reduce to 5352979 in 2025 to 8847900.

In Fig.7 the map showing the road proximity of Chittagong City Corporation. It indicates that land near the road have high proximity of development than land which are not near the road. The white portion indicates that the land is near the road and they have high proximity of development than black portion which are far away from the road. In Fig.8 the map showing the slope and stream line map of Chittagong City Corporation. The blue line indicates the natural stream line of the city area. The slope of the area is divided into four categories which are low aspect, moderately aspect, high aspect and Streep aspect.

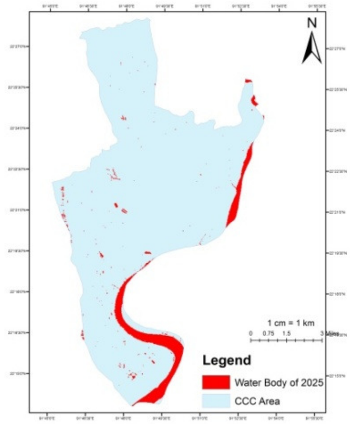


Fig.8: Water-body probability

Chittagong is the commercial capital of Bangladesh. There is a rapid change in the land use of this city due to rapid urbanization. The study is conducted to determine the land use change of the city for a definite time period and to predict the change of water body of this area in the year 2025.
From the findings of the analysis it can be concluded that in the year 2000 use of land in this city is mainly was vegetation and water body than build-up and other purpose. But the situation is completely different in the year 2010 and 2016. Now the use of land for build-up purpose is very high than vegetation and water body. There is a very rapid reduction or decrease of vegetation and water body and increase of the build-up area in this time period. It can be also said that the land use of water body and vegetation is change into the build-up use and there is high transaction proximity of change in these two land use into build up area near future. The study is predicted the approximate area of the water body will be remaining 2025 by Markova chain model. According to the findings the water body of Chittagong City Corporation will be 5352979 in 2025 to 8847900.

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MONITORING WATER SURFACE TEMPERATURE BY SATELLITE REMOTE SENSING: A CASE STUDY ON RIVER KARNAPHULI

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ABSTRACT
Passive microwave radiometry from satellites provides more precise atmospheric temperature information than that obtained from the relatively sparse distribution of thermometers over the earth's surface. Satellite remote sensing is the easiest way to monitor surface temperature of land cover and water bodies for several years. The aim of this research is to find out the temperature distribution over the water surface of the river Karnaphuli in the years 2000, 2007 and 2015 and to make necessary comparisons among them. LANDSAT satellite images have been used for remote sensing measurement of water surface temperature. The 2000 LANDSAT data used is ETM+, 2007 is TM and 2015 data is OLI_TIRS data. Surface temperature for three months (March, July, and November) has been calculated for each distinct year. The numeric value of temperature was observed at 15 different stations. It has seen that average temperature rose from 2000 to 2007 and then fell in 2015. For March the temperature rose almost 2°C from 2000 to 2007 and then fell around 1°C in 2015. In case of July the temperature first rose 5°C and then fell almost 6°C. But for November the temperature first rose 2°C and then remained nearly unchanged in 2015.

Keywords: Remote Sensing; LANDSAT; TM; ETM+; OLI_TIRS.

INTRODUCTION
Freshwater resources are becoming increasingly limited in many parts of the world and decision makers are demanding new tools for monitoring, (Anderson et al., 2011). Water quality is the key environmental concern because of its important provision of water for drinking and domestic purpose, irrigation and aquatic life including fish and fisheries, (Ahmed et al., 2013). In case of river, surface temperature is a major factor to be considered. According to United States Geological Survey temperature governs kind of organism that can live in rivers. Water temperature is a physical property expressing how hot or cold water is. As hot and cold are both arbitrary terms, temperature can both further be defined as a measurement of the average thermal energy of a substance, (Brown, 1999). Satellite image data sensed by the optical and thermal sensors on various remote sensing platforms has been widely used for water quality measurement studies, (Alparslan et al., 2007). The use of monitoring has evolved to help determine trends in the quality of aquatic environment and hoe the quality is affected by release of the contaminants, other anthropogenic activities or by waste treatment operations. The principal benefit of satellite remote sensing for inland water quality monitoring is the production of synoptic views without the need of costly in situ sampling, (Hadjimitsis et al., 2010). Karnaphuli is the largest river in Chittagong and Chittagong hill tracts which is 2188 ft. wide, originating from the Lushai hills in Mizoram, India, it flows 270 km, (Saleheen and Chowdhury, 2014).The objective of the study is to compare the temperature over the river at the target years both by distribution from map and numerical values obtained from 15 particular stations.

METHODOLOGY
Temperature for each data is calculated using the thermal band. LANDSAT TM and ETM+ data requires same method to find out brightness temperature and OLI_TIRS data requires a distinguished method for calculation of temperature. All procedures are obtained from LANDSAT data users' handbook. All coefficient and constant values are available in LANDSAT data users' handbook.

Temperature derivation from TM and ETM+

Calculating land surface temperature for TM & ETM+ is a tow step methodology. First the raw image is needed to convert into spectral radiance image following NASA (1999)

$$L_\lambda = ((LMAX_\lambda - LMIN_\lambda)/(QCALMAX - QCALMIN)) \times (QCAL - QCALMIN) + LMIN_\lambda \quad (1)$$

Here, L_λ= Cell value as radiance, Qcal= Digital Number, QCALMIN= the minimum quantized calibrated pixel value and $LMIN_\lambda$= the spectral radiance scaled to QCALMIN.

Then the reflectance images are converted into brightness temperature

$$T = \frac{K2}{Ln(\frac{k1}{L\lambda})+1} \quad (2)$$

Here, T= temperature in Kelvin, K_1= Calibrated constant 1 and K_2= Calibrated constant 2

Temperature derivation from OLI_TIRS

For OLI_TIRS the DN values are converted to surface reflectance

$$L_\lambda = M_L \times Qcal + A_L \quad (3)$$

Here, Q_{cal}= Pixel value as DN, A_L= Radiance additive scaling factor and M_L= Radiance multiplicative scaling factor.

From reflectance to brightness temperature conversion is done by using the Eq. (2). The temperature can be converted to degree Celsius from Kelvin using the following formula

$$C = Kelvin° - 273 \quad (4)$$

RESULTS AND DISCUSSION

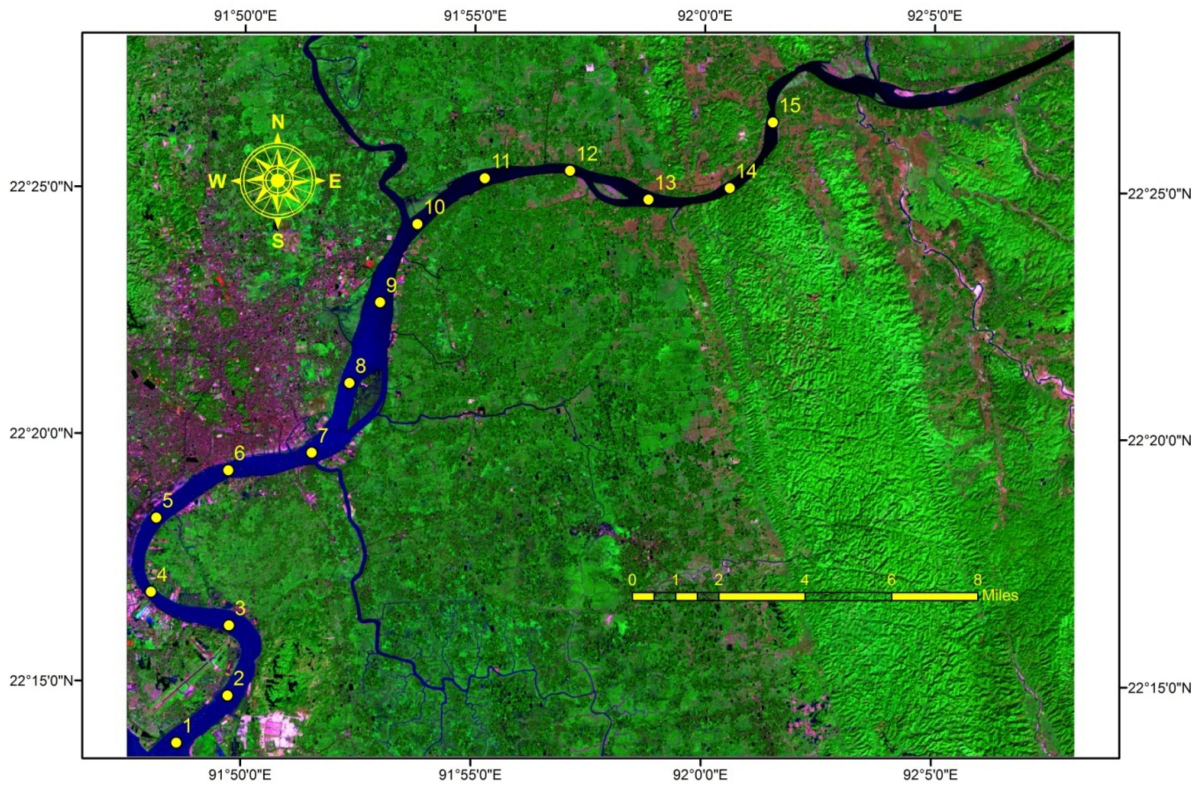

Fig.1: River Karnaphuli with observing stations in a LANDSAT image

The observed stations are visible in Fig.1 which are arranged serially keeping an approxiamte distance of 3000m between two points. For analysis and to facilitate comparison temperature has been classified into four categories which are Very high (24-28°C), High (21-24°C), Medium (19-21°C) and Low (<19°C). There are islands on the river which are omitted during analysis.

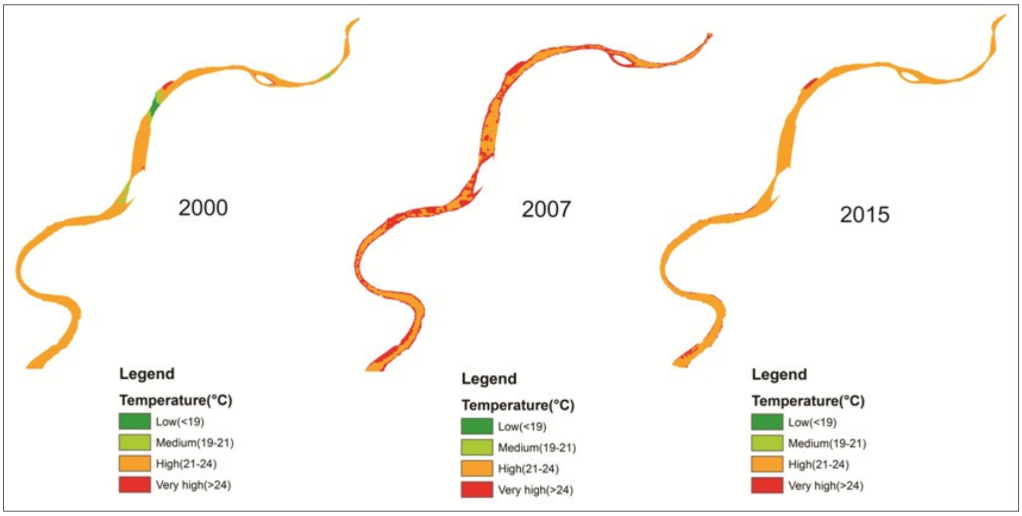

Fig.2: Temperature distribution at March

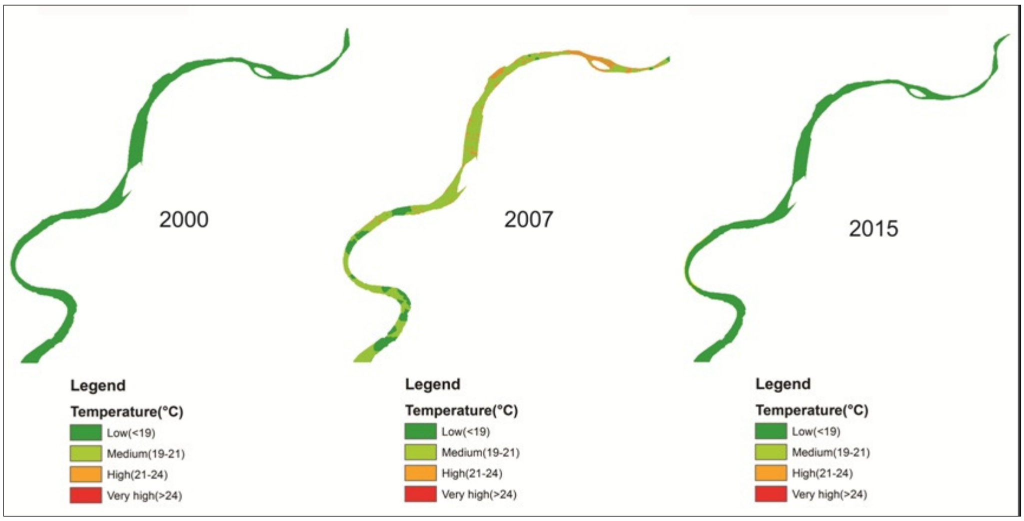

Fig.3: Temperature distribution at July

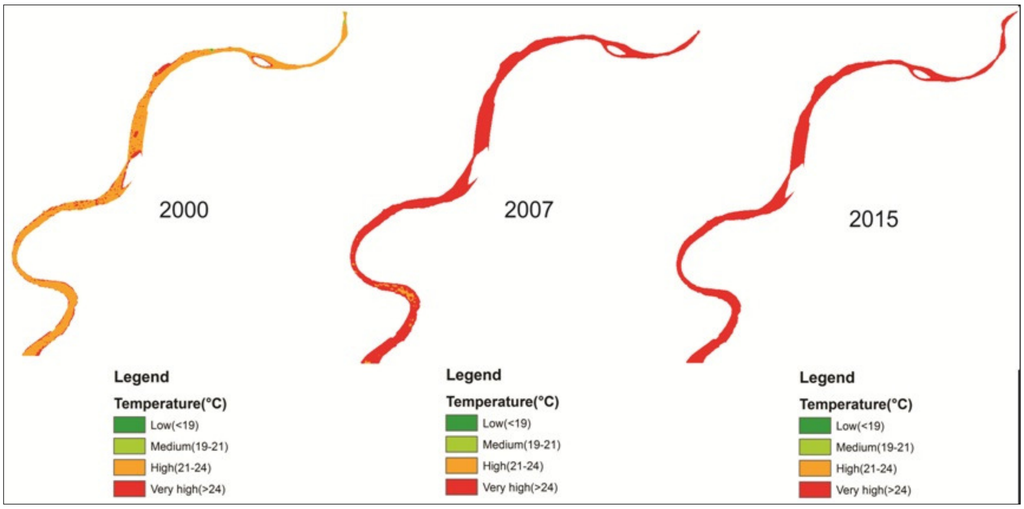

Fig.4: Temperature distribution at November

Temperature in the month of March

In Fig.2 for the derived temperature of March is seen. At the year 2000 the river is almost occupied by high range of temperature values though in some areas low and medium level of temperature exists. In 2007 the river is occupied by high to very high range of temperature and in case of 2015 it is high range of temperature values. From the observing stations the same scenerio has found. Temperature at all of the points are within 20°C to 25°C except for one. At station 14 the year 2000 has a temperature value of below 20°C. The years 2000 and 2015 almost overlapped at most of the stations.

Temperature in the month of July

At the month of July [Fig. 3] the river is found in low temperature in 2000. In 2007 most of the surface area of the river was occupied by medium class of temperature though some low level of temperature portions are seen in downstream and high range of temperature areas are visible in upstream. In case of the year 2015 the whole river is occupied by low range of temperature as like 2000. Observed temperature values [Fig: 2] show too many fluctuations and year wise variation in July. The year 2007 would lie above others in July on average.

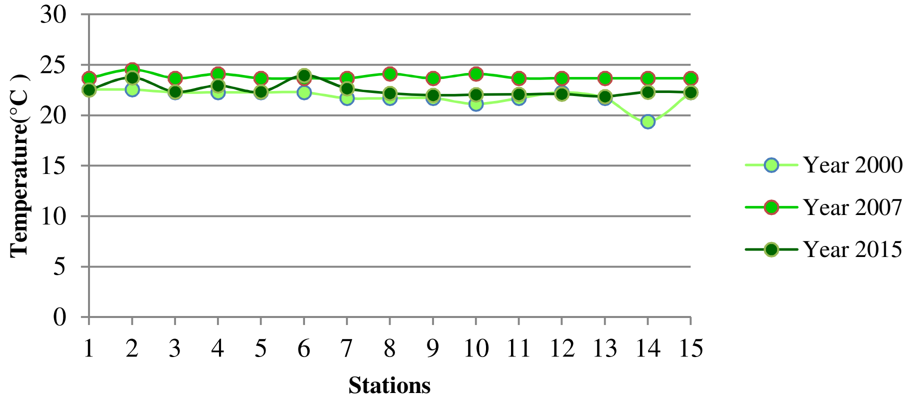

Fig.5: Observed temperature values at 15 stations of March

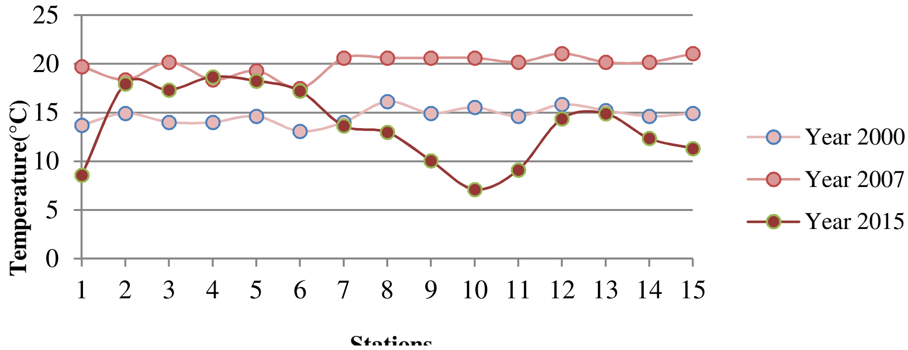

Fig.6: Observed values of temperature at July

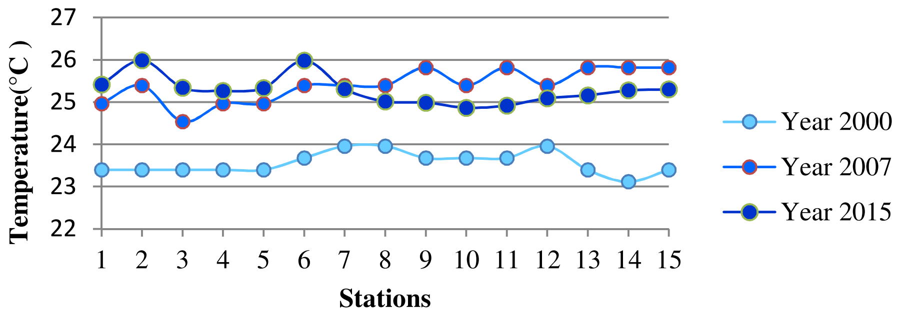

Fig.7: Observed temperature values at November

From the station 1 to 6 the line of 2015 lies above 2007 and also the maximum temperature found at the station 2 which is 25.98°C at the year 2015. In case of the stations 8 to 15 the year 2007 got higher temperature than 2015.

Temperature in the month of November

It is very clear from temperature distribution map [Fig. 4] for the month of November that in the year 2007 and 2015 the river was almost occupied by very high range of temperature values that is more than 24°C. In case of the year 2000 the river was occupied by high range of temperature values. From the extracted values at 15 stations [Fig. 3] a very significant and anticipated distribution is found. For 2000 all of the stations got temperature between 23°C to 24°C and also the year lies below the other two years. From the station 1 to 6 the line of 2015 lies above 2007 and also the maximum temperature found at the station 2 which is 25.98°C at the year 2015. In case of the stations 8 to 15 the year 2007 got higher temperature than 2015.

CONCLUSION

In Fig. 4 average fluctuation of temperature in 2000, 2007 and 2015 has depicted. In November average temperature in 2000was 23.56°C, in 2007 25.39°C and in 2015 it was 25.28°C. So, in November water surface temperature increased 2°C from 2000 to 2007 and remained almost same up to 2015.For the month of March too it represents 2°C increase as in 2000 it is 21.84°C and in 2007 it is 23.81°C, then in 2015 it fell 1°C upon 22.48°C. But in case of July it starts at 14.67°C in 2000 and rises to 19.89°C in 2007 and then fall to 13.58°C in 2015. As the month July is among the monsoon period it can be assumed the reason behaving different than other two months. The rainy season (June through October) accounts for 70 to 85% of the annual rainfall, which varies from 70% in the eastern part of the country to about 80% in the southeast and 85% in the northeast (Ahmed, 2015). However, for March and November it is found overall increase of temperature from 2000 to 2015.

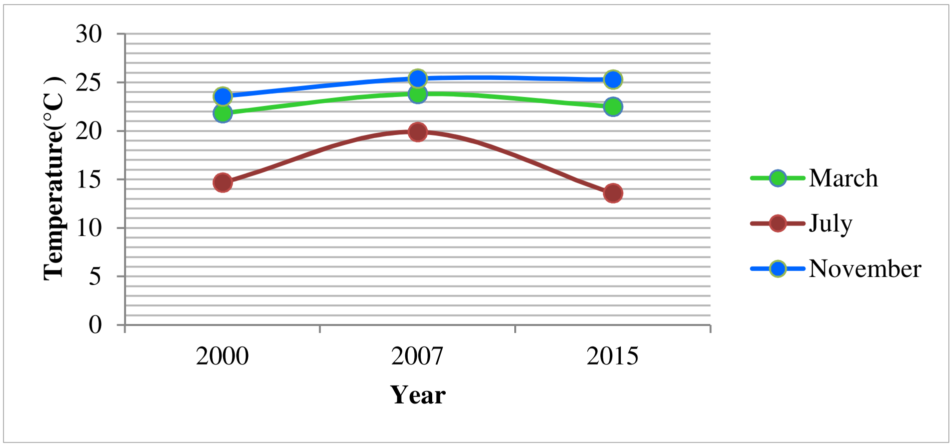

Fig.8: Average fluctuation of temperature.

Water temperature influences physical and chemical parameters of rivers and streams and is an important parameter of water quality (Fricke, 2013). Water temperature is deeply related with other parameters like chlorophyll-a, turbidity, pathogens etc. for large water reservoirs. So, to determine the water usability, temperature measurement and monitoring are essential. The inherent problem with remote sensing based research is high cloud coverage of satellite data. In the monsoon period the sky almost remains covered with dense cloud and satellite images taken at that time are quite unsuitable to work with. Also, high resolution image would facilitate better analysis on output then low resolution image. Used LANDSAT images are consists of 30 meter resolution. Even though, large scale water body monitoring and observing (to detect changes) for long period of time remote sensing based water quality assessment is an effective and user-friendly tool.

ACKNOWLEDGEMENT
This research was done as a part of undergraduate thesis for completion of Bachelor of Urban and Regional Planning. We had overall 4 objectives and one of them was temperature measurement and monitoring. We are grateful to our colleagues and batch mates for cooperation and inspiration to complete the work successfully.

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EROSION-DEPOSITION SCENARIO ALONG THE SOUTH-WESTERN COAST OF BANGLADESH

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ABSTRACT
Coastline is a dynamic morphological entity, which responds to the external forces exerted by wave, tide, near-shore current, storm, rainfall, human intervention etc. Coastal changes are more important since they have direct impact on economic development and land management. Both natural and anthropogenic processes control the erosion and deposition activities of a coastal zone. In this study, erosion-deposition scenario of the south-western part of the Bengal coast were analysed through satellite images of last ~30 years. LANDSAT images were collected for dry period of each year and used to identify the shoreline by manual digitizing as well as indexing (Modified Normalized Difference Water Index - MNDWI) method. Rate of shoreline changes due to erosion and deposition was also estimated. Both methods were then compared and discussed basing on the results obtained. The rate of erosion is found almost double than the rate of deposition along the south-western coast, which indicates loss of valuable land.

Keywords: LANDSAT images; Shoreline; Manual digitization; MNDWI; Bengal coast.

INTRODUCTION
Coastal zones are one of the most complicated ecosystems with a large number of living and non-living resources. These zones are exposed to a series of dynamic natural process i.e., erosion, accretion, sediment transport, environmental pollution, coastal development etc. which usually cause changes in the shoreline. A shoreline coincides with the physical interface of land and water and keeps changing its shape and position due to coastal erosion and deposition (Dolan et al., 1980). It is a time-dependent phenomenon that may exhibit substantial short-term variability (Morton, 1991). Generally, shoreline changes have different manifestations over small time-scale or large time-scale. Small time-scale influences are regular waves and currents, tides and winds, storm, rainfall etc. whereas large time-scale influences are glaciations or organic cycles that may change the sea level. Coastal erosion and deposition is relatively slow process and can take hundreds of years to notice the changes.

A large amount of land along the south-western coast was eroded and affected the habitat, tourism, aquaculture etc. The consequent changes in sediment and discharge processes of coastline and increase in salinity levels due to sea level rise has affected the phenology and morphology of the area. Sea level rise, increased frequency and intensity of storms, and amplified flooding episodes influence the rate of shoreline change and increase the vulnerability of individuals, households, communities, and cultures (Cutter and Emrich, 2006; Wu et al., 2002). Erosion and deposition processes that take place along the coastline of Sundarban create vast changes in the ecosystem of the forest. Destruction of this mangrove forest has left these coastal areas exposed to erosion and flooding, altered natural drainage patterns, and increased salt intrusion, also causing heavy loss of life and property, and jeopardizing the development activities (Ali, Anwar, 2003). Hence, a detailed study on erosion – deposition scenario of this area is required which has been done in the present study.

Study Area

The coastal zone of Bangladesh which is significant for its natural resources and ecosystems covers 19 districts out of the country's 64 districts and contains 28% of the country's population (Iftekhar and Saenger, 2008). The study area considers the Deltaic coastal plain of Bangladesh, which is situated in the west part along the Bay of Bengal as shown in Fig. 1. Bangladesh, the world largest deltaic region lies in the north-eastern part of South Asia between latitude 22°34'N and 26°34'N and longitude 88°1'E and 92°41'E (Hossain, 2001). Satkhira, Khulna, Bagerhat, Pirojpur, Barguna and Patuakhali districts are included in this Deltaic Coastal Plain. The coastal zone of Bangladesh covers an area of 47,201 sq km (WARPO 2006). The fluvial discharges come from the rivers connected to the shoreline are Harivanga, Jamuna, Maloncha, Arpongasia, Dhorla, Passur, Tista, Shilagang, Haringhata, Balesshawar, Bishkhali, Burisshawar, Andharmanik Rivers etc. These rivers provide fluvial discharge and cause deposition in the coastal area. The southwest coastal region of Bangladesh is the most disaster prone area. The Bangladesh Bureau of Statistics reports that the region is home over 10 million people (647 people per square km). The region is the part of an inactive delta of large Himalayan Rivers and is protected from tidal surge by the Sundarban mangrove forest. The delta areas are densely populated, with a predominance of agricultural activities due to the high fertility of the soils. The livelihood of most people depends on the environmental conditions of the delta, in terms of land cultivation, fishing, navigation, common property resources (e.g. from the Sundarban mangrove forest), and other economic activities.

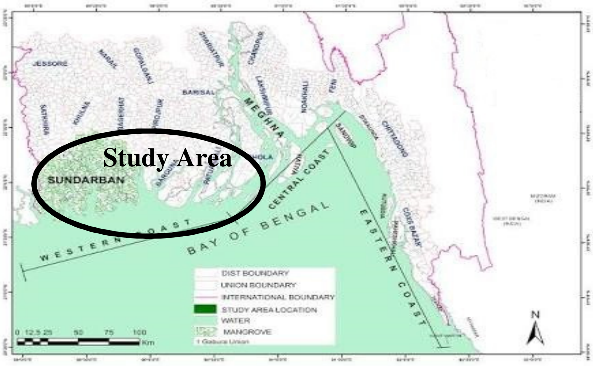

Fig. 1: Deltaic coastal plain of Bangladesh

Collection of Images

LANDSAT images were collected from the USGS Earth Explorer for 29 years (1989 - 2017). Images were downloaded for the month January particularly to get cloud free images. Delineation of the shoreline requires the images to be totally clear and cloud free which restricted the number of images. Downloaded images were sorted out into three categories: bad, moderate and good. Sample images of these three categories are displayed in Fig. 2.

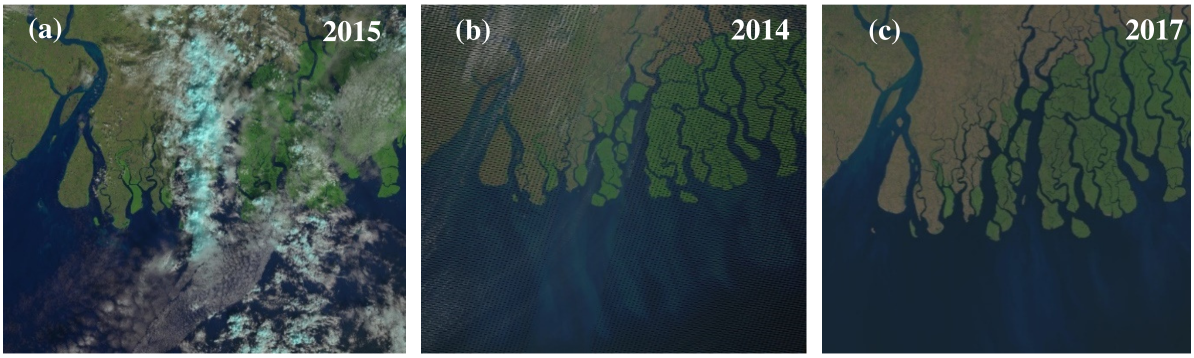

Fig. 2: Sample Landsat images with varying quality i.e. (a) bad quality with cloud waves, (b) moderate quality with minor noises and (c) relatively good quality images

Effect of Varying Water Level

Area coverage will change due to change of water level. It is better if similar images having same water level were used. But it is not always possible, because the satellite is moving in a certain time over the area. The Landsat images used for this study were collected from different Landsat sensors which capture images at different times. For Landsat 4 and 5, the satellite passing time is 4.00 am whereas for Landsat 7 and 8 satellites passing time is 4.30am. In this study, the water level is checked to get a uniform picture. Hourly tide data were collected from BIWTA (Bangladesh Inland Water Transport Authority) for the nearby tide station i.e. Pusser River. Table 1 shows that all the collected images were taken during low tide (according to NOAA, the range of tide level for low tide is up to 1.04 m) time except for year 2014. It may have bigger coverage and not representative. Tide levels during image acquisition times are also summarized in Table 1.

Table 1: Satellite image acquisition time and corresponding tide level

Acquisition Date and Time (AM)		Tide Level (m)	Tidal Condition	Acquisition Date and Time (AM)		Tide Level (m)	Tidal Condition
2/1/2015	4:30	0.835	Low Tide	1/7/2005	4:00	-0.006	Low Tide
2/4/2014	4:30	1.15	High Tide	1/13/2004	4:30	-0.07	Low Tide
1/5/2013	4:30	0.68	Low Tide	1/12/2001	4:00	0.726	Low Tide
1/28/2012	4:30	0.2	Low Tide	1/26/2000	4:00	-0.22	Low Tide
1/25/2011	4:30	0.179	Low Tide	1/1/1997	4:00	-0.48	Low Tide
1/22/2010	4:30	-0.275	Low Tide	1/28/1995	4:00	0.18	Low Tide
1/2/2009	4:00	-0.233	Low Tide	1/25/1994	4:00	0.32	Low Tide
1/16/2008	4:00	-0.827	Low Tide	1/22/1993	4:00	0.744	Low Tide
1/21/2007	4:30	-1.011	Low Tide	1/14/1990	4:00	0.459	Low Tide
1/26/2006	4:00	0.082	Low Tide	1/19/1989	4:00	0.261	Low Tide

DETECTION OF SHORELINE

The shoreline was detected using two methods. i) Manual digitization method (the land water boundary has been digitized manually and area was estimated). ii) Index method (the collected images were digitized and analysed through MNDWI method). Both methods are explained in the following sections:

Manual Digitization

Coastline can be extracted from a single band image only e.g. band-5 to extract shoreline manually (Alesheikh, et al., 2007). However, in this study, in manual method all the bands were used to get a perfect image of the area. When all the bands are collaborated and geo-referenced, the shoreline can be perfectly extracted from the images. In Landsat 4-5, there are seven bands. Eight bands are for Landsat 7, and for Landsat 8 there are eleven bands. The shoreline of the study area is very complex mainly because of the connection of many small rivers to the shoreline. Therefore, the digitization of this area is relatively difficult, so the area was divided into 7 segments as displayed in Fig.3.

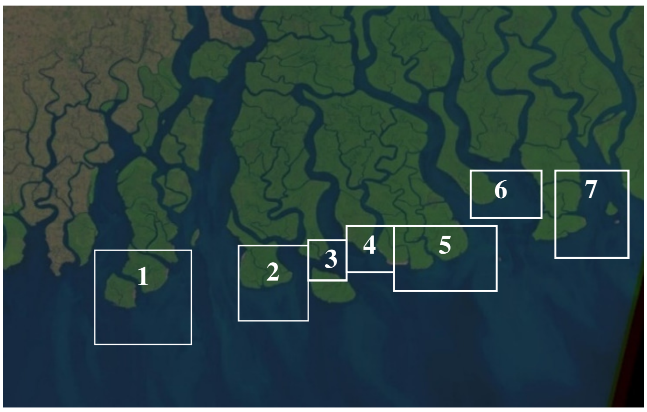

Fig. 3: Seven major segments of a Landsat image covering the study area

Edges of the shore were detected in the geo-referenced images manually to locate the shoreline position. Each segment was divided into six sub-segments except segment 3, 4, 6 and 7 which are divided into three sub-segments [Fig. 4] to identify the zone of erosion and deposition. The shoreline was converted into poly-lines using the editorial tool. Finally, the area of erosion and deposition were estimated.

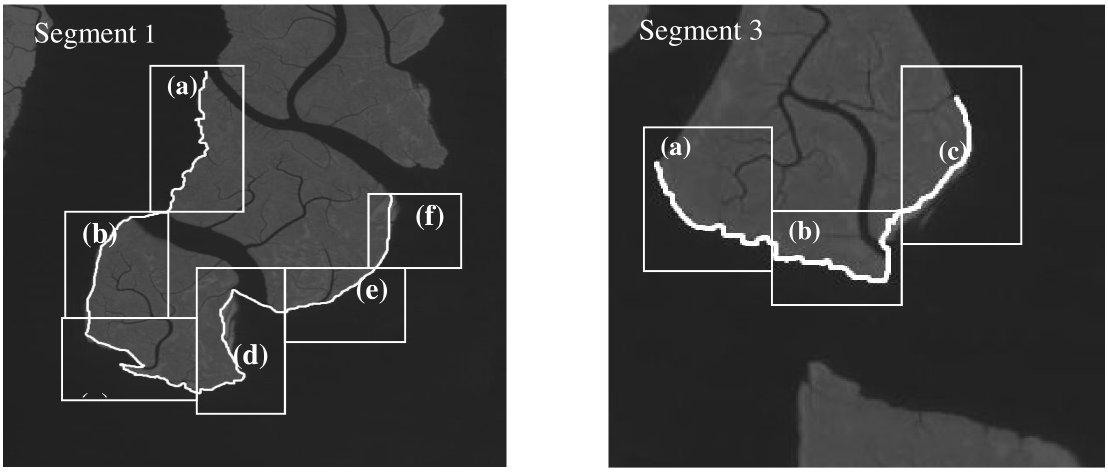

Fig. 4: Division of sub-segments of major segments.

MNDWI Method

Modified NDWI (Normalised Difference Water Index) is used for delineate open water features. In MNDWI (Modified Normalized Difference Water Index) method, Green and Middle Infrared Ray (MIR) are used instead of Near Infrared Ray (NIR) which is used in NDWI. MNDWI can be estimated using Eq.1.

$$\text{MNDWI} = \frac{\text{GREEN}-\text{MIR}}{\text{GREEN}+\text{MIR}} \quad (1)$$

According to the MNDWI, the build-up land has negative values while keeping the water values positive. Accordingly, the enhanced water features will no longer have build-up noise in a MNDWI image. This substitution has no impact on vegetation, as vegetation still has negative value when calculated using the equation. MNDWI is more suitable for enhancing and extracting water information for a water region with a background dominated by built-up land areas because of its advantage in reducing and even removing built-up land noise over the NDWI. In this method, two bands were used, Green and MIR. In Landsat 4, 5 and 7, band 2 is the green band and band 5 is the MIR band. But in Landsat 8, band 3 is green and band 6 is MIR band. Using QGIS, reflectance of the bands was calculated and Landsat images were converted to MNDWI images. This MNDWI images were then digitized using ArcGIS. The shoreline was then detected from the indexed images. From a series of shoreline, eroded and deposited areas were estimated.

RESULTS AND DISCUSSION

Net erosion and deposition rates were estimated for seven segments of the deltaic plain, which is having the same boundaries between the zones for 1989 to 2017 using both the methods (Manual and MNDWI). Table 2 summarizes the net rate of shoreline change, and the eroded and deposited land area in different years.

From manual method of shoreline extraction highest deposition observed in the year of 2014-2015and lowest value observed in the year of 2012-2013, area of which are 7.23 km^2 and 1.53 km^2 respectively. Maximum land area eroded is 9.19 km^2 in year 2005-2006, and the minimum erosion is 3.37 km^2 of year 2008-2009. The rate of deposition is 3.48 km^2/yrand the rate of erosion is 6.19 km^2/yr and the rate of net change is 2.7 km^2/yr. Therefore, the coastal area in manual method is observed to be erosion prone.

Table 2: Rate of shoreline changes for different periods using Manual and MNDWI methods

Year	Deposition (km^2/yr)		Erosion (km^2/yr)		Rate of Shoreline Change (km^2/yr)	
	Manual	MNDWI	Manual	MNDWI	Manual	MNDWI
1989-1990	2.7	0.87	4.59	4.88	-1.91	-4.01
1993-1994	8.7	0.15	8.18	1.13	0.51	-0.98
1995-1997	2.03	0.51	4.34	2.24	-1.40	-1.73
2000-2001	3.08	-	5.36	13.22	-2.28	-13.22
2005-2006	2.46	6.01	4.11	9.91	-1.65	-3.90
2008-2009	2.06	-	3.37	15.15	-1.31	-15.15
2010-2011	3.60	0.19	9.19	3.07	-5.59	-2.88
2012-2013	1.53	8.53	5.30	5.73	-3.76	2.8
2014-2015	7.23	6.24	8.15	8.79	-0.94	-2.55
2016-2017	1.45	4.98	9.48	9.53	-8.03	-4.56
Total	34.84	27.48	61.86	73.65	-27.02	-46.17
Rate	3.48	2.75	6.19	7.37	-2.7	-4.62

In MNDWI method, observed highest deposition is 8.53 km^2/yr of year 2012-2013 and the highest erosion is 15.15 km^2/yr of year 2008-2009. The change in shoreline is higher in 2008-2009. Results also show that no land masses deposited in the year of 2000-2001 and 2008-2009. The overall rate of deposition and erosion are 2.75 km^2/yr and 7.37 km^2/yr respectively. Shoreline changed at a rate of -4.62 km^2/yr in past 28 years. Fig. 5 displays the comparison of the Erosion and deposition rate of year 1995-1997 in manual and MNDWI methods. It is observed from Table 2, that MNDWI covers more area than manual method. White patterns developed by foams or breaking waves were covered by the index method as shown in Fig 6 and considered as land which differs the result. Indexing is faster than manual method though manual method is found to be more accurate.

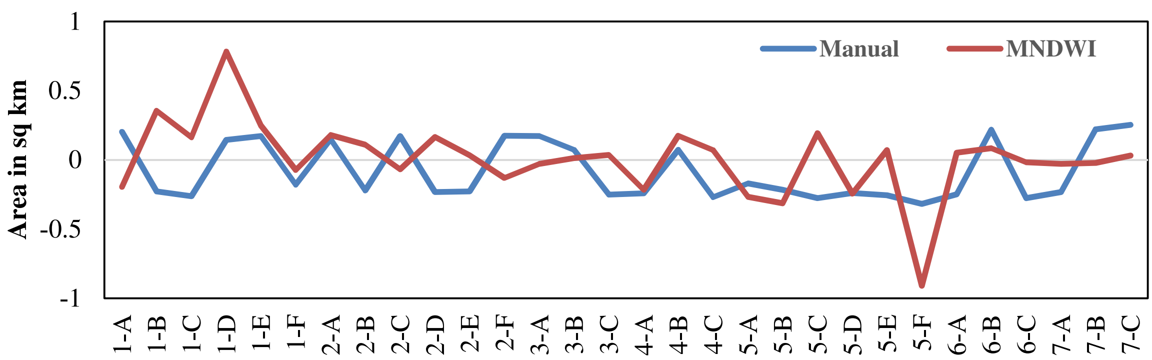

Fig. 5: Comparison of rate of erosion and deposition of year 1995-1997 in both methods

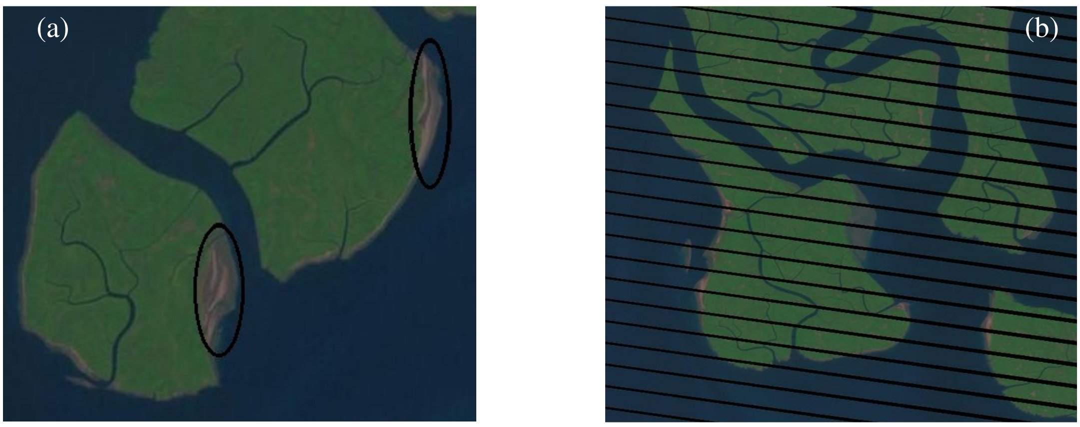

Fig. 6: Error in calculation due to (a) inundated portion and (b) noise problem

CONCLUSION

The aim of the study is to investigate the rate of coastal transformations along the western coast of Bangladesh. For this purpose, satellite remote sensing data were analysed to identify the rate of erosion and deposition along the western coastline of Bangladesh. This study was conducted by two methods - Manual and MNDWI (Modified Normalized Difference Water Index) method. Among the two methods, the rate of erosion and deposition is higher in index method but the results are more accurate in manual method. The result of shoreline change map will be more useful for coastal engineers and coastal zone management authorities to facilitate suitable management plans and regulation of coastal zones.

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A STUDY ON THE IMPACT OF HIGH END EMISSION ON THE CROP YIELDS AT THE COASTAL REGION OF BANGLADESH

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ABSTRACT

Bangladesh is an agrarian country and rice is its staple food. The ever increasing demand of rice due to population increase and decrease in cultivating land is making it difficult to deal with. Moreover, the abrupt changes in climate due to high end emission and global warming are making it even worse. Apart from the climate change, issues of salinity intrusion also play a role in coastal regions. Among the 64 districts, 6 districts from the coastal region of the country are selected for the study. Noakhali, Patuakhali, Bhola, Cox's Bazar, Bagerhat and Barguna are the selected districts. Impact of high end emission on production of Boro and Aman rice in study areas has been evaluated using the DSSAT 4.5 crop modelling system. It was calibrated using BR29 and BR11 variety for the years 2007-2010 and validated for 2011-2014 incorporating BBS data with statistical parameter nRMSE. Impact of future climate is analysed for the years 2020's (2021-2050), 2080's (2070-2099) with baseline years 1981-2010 using 7 bias corrected ensembles regional climate models (RCM's). The soil profile data was extracted from WISE 1.1 soil database. The results show that, the yield is negative everywhere, reaching over 20% decrease in some regions. The maximum temperature rise exceeds 1.5°C in 2020's and 4°C in 2090's whereas the minimum temperature rises up to 5°C in 2090's. This rise in daily temperature over the growing period of Boro and Aman rice indicates the adverse impact of temperature on crops. The decrease in yield has been more for Boro rice than Aman. This indicates that, the rain fed crop Aman has less vulnerability to climate change or emission than the irrigated crop Boro. Interestingly, lower loss to crop yield was observed for both verities of rice at elevated amount of carbon emission.

Keywords: Boro Rice; Aman Rice; RCM; Climate change; DSSAT 4.5.

INTRODUCTION

Like other agrarian countries, Bangladesh is hugely dependent on agriculture as it contributes to 35% of the GDP and 70% of the labour force in Bangladesh. Increasing demands for food, agricultural land and water warrant the studies on agriculture (Ahmed et al., 2000). About 40 million people of coastal region are directly or indirectly dependent on agriculture for their livelihood (BBS, 2011). The impacts of climate change on food production very important for Bangladesh. Boro and Aman rice is the leading rice producer varieties of Bangladesh (BRRI, 2006). Climate change is a threat for rice production. So evaluating the impact of climate change on Boro and Aman production is significant. Simulation studies have been carried out previously to assess impacts of climate change and variability on rice productivity in Bangladesh using the CERES-Rice model of DSSAT. (Mahmood et al., 2003; Mahmood, 1998; Karim et al., 1996). For instance, Basak (2010) has carried out simulations of 12 representative regions from various zones of the country using the regional climate model PRECIS. However, this study covers six coastal zones of the country using seven numbers of bias corrected ensembles of regional climate models which has taken high end emission into account while projecting the future climate data.

METHODOLOGY

Study area

This study was done on six coastal districts of Bangladesh (20°34˝ North Latitude to 26°38˝ North Latitude and from 88°01˝East Longitude to 92°41˝East Longitude) which that encompass almost 0.018 million km^2 territory. Bangladesh is the largest delta of the world as 80% of the land is formed by the floodplains of the GBM basin (Ganges, Brahmaputra and Meghna) making it a fertile land for rice production. However, the coastal region is often intruded with salinity. The country experiences huge rainfall during Monsoon. However, some flash floods prior to the monsoon season also occur. This tropical country has annual average rainfall of 1600 mm and a temperature ranging from 8° to 38°during the growth season of Boro rice (Nov-April) over the last 30 years (1981-2010).

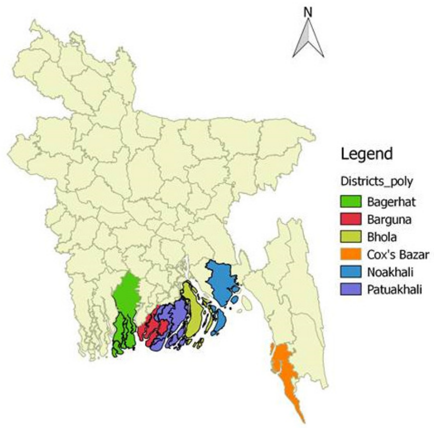

Fig. 1: Location of Selected Coastal Districts of Bangladesh

Selection of Crop Model

Among various crop modeling software like Crop-wat, DSSAT, PCSE etc. DSSAT 4.5 was chosen to calibrate and project the future crop yields. The CERES-Rice model of DSSAT is an advanced physiologically based rice crop growth simulation model and has been widely applied to understanding the relationship between rice and its environment. DSSAT estimates yield of both irrigated and non-irrigated rice, determine growth durations, dry matter production, effect of soil water and soil nitrogen contents on photosynthesis, carbon balance and water balance. Ritchie et al. (1987) and Hoogenboom et al. (2003) have provided a detailed description of the model.

Selection of Rice Variety

CERES-Rice model is variety-specific and it is able to predict rice yield and rice plant response to various environmental conditions. The model takes into effect of weather, crop management, genetics, and soil water, C and N. The model uses a detailed set of crop specific genetic coefficients, which allows the model to respond to diverse weather and management conditions. BR29 variety of Boro rice and BR11 variety of Aman rice has been selected as their genetic coefficients are available in the model.

Table 1: Some important information about BR29 and BR11 variety of Boro rice

Variety	BR29	BR11
Height	95 cm	115 cm
Duration of growth	160 days	145 days
Plantation	November	June
Harvest	April	November
Coarse Yield (Kg/hectares)	6500	5500
Developed on	1994	1980
Developed by	Bangladesh Rice Research Institute	Bangladesh Rice Research Institute

Integrating field data in DSSAT

WISE team has recently done experiments on 17 soil stations across Bangladesh. Once a region is selected from the global map, it enables the user to access the soil station data. This set of data is simply copied and pasted on the soil file. Thus the soil stations can easily be integrated in DSSAT.

Weather data

In this study, the historic weather data was taken from 35 stations of Bangladesh Meteorological Department (BMD). The weather data contains daily rainfall (mm), maximum and minimum temperature (°C) and daily solar hours. Rainfall and temperatures are used directly in DSSAT. However, the weather manager of DSSAT itself converts solar hours into solar radiation. As simulations were carried out over 6 districts, the data of the nearest station of the corresponding district was taken. Fig. 1 indicates the location of the meteorological stations of BMD. For calibrating the model, data of the years from 2007-2010 was taken and 2011-2014 was taken for validation.

Climatic Data

The future data was collected from 7 bias corrected ensembles with RCP 8.5 scenario of regional climate models RCM's under 4 GCM's. The baseline period was 30 years (1991-2010) and the projection was made for 2020's (2016-2035), 2050's (2046-2065) and 2090's (2080-2099). Table 2 describes the details of the ensembles.

Table 2: Details of the Ensembles

Institute	GCM	RCM	Driving Ensemble Member	Res.	RCP
SMHI	CNRM-CERFACS-CNRM-CM5	RCA4	r1i1p1	0.5°	8.5
SMHI	ICHEC-EC-EARTH	RCA4	r1i1p1	0.5°	8.5
MPI-CSC	MPI-M-MPI-ESM-LR	REMO2009	r1i1p1	0.5°	8.5
SMHI	MPI-M-MPI-ESM-LR	RCA4	r1i1p1	0.5°	8.5
SMHI	NOAA-GFDL-GFDL-ESM2M	RCA4	r1i1p1	0.5°	8.5
SMHI	IPSL-CM5A-MR	RCA4	r1i1p1	0.5°	8.5
SMHI	MIROC-MIROC5	RCA4	r1i1p1	0.5°	8.5

Crop Management

The crop management includes planting details, transplanted date, irrigation and fertilizer management, tillage, harvest and chemical applications. The date of transplant, the date of harvest, the amount of irrigation and fertilizer applications has been kept the same to a default set value according to the guidelines of BRRI.

Calibration and Validation

The model was calibrated to find the genetic coefficients for BR11 and BR29 variety of Aman and Boro rice respectively. Statistical parameter normalized root mean square error (RMSE) was used for the calibration. Value of nRMSE was found less than 15% for the selected regions. Trial and error method are used like previous studies (Saseendran et. al., 2013). Table 3 shows the default values of the genetic coefficients and the calibrated value of these parameters in selected coastal districts.

RESULTS AND DISCUSSIONS

It is observed that, most of the regions experience negative yield of BR29 and BR11 rice, reaching over 20% decrease in some regions [Fig. 3]. The maximum temperature rise exceeds 1.5°C in 2030's and 4°C in 2090's whereas the minimum temperature rises up to 5°C in 2090's. [Fig. 2] This rise in daily temperature over the growing period of Boro and Aman rice indicates the adverse impact of temperature on crops.

The rise of temperature for Aman rice is more for the regions of Barguna, Bagerhat and Bhola than the other three districts. It is observed that, for the growing season of Boro rice, the temperatures have not exceeded the specific warming level of 2°C in 2030's. But, for Aman rice some districts have crossed that warming level. In case of 2080's, it is observed that, both the growing periods have crossed the limit of specific warming level 4°C. It means, the temperature change would be severe in future than it is in present time.

Table 3: Values of the genetic coefficients in selected locations

Region	P1	P2R	P5	P20	G1	G2	G3	G4	nRMSE(%) (Calibration)	nRMSE(%) (Validation)
				For BR29 Boro Rice						
Default value	**650**	**90**	**400**	**13**	**67**	**.025**	**1**	**1**	**-**	**-**
Bagerhat	648	90	400	13	67	.026	1	1	6.4	3.7
Barguna	653	93	405	13.1	62	.026	1	1	13.9	9.0
Bhola	648	90	400	13	67	.025	1	1	5.5	3.8
Cox's Bazar	646	88	395	12.9	62	.025	1	1	9.4	6.2
Noakhali	650	90	400	13	67	.025	1	1	7.9	4.2
Patuakhali	653	93	405	13.1	67	.026	1	1	19.8	13.9
				For BR11 Aman Rice						
Default value	740	180	400	10	55	.025	1	0.9		
Bagerhat	740	180	400	10.5	55	.025	1	0.9	9.48	8.73
Barguna	740	181	404	10.4	55	.025	1	0.9	9.73	5.62
Bhola	740	180	400	10.5	55	.025	1	0.9	11.43	13.65
Cox's Bazar	735	177	405	10.1	55	.025	1	0.9	15.35	12.21
Noakhali	740	181	404	10.4	55	.025	1	0.9	10.73	4.62
Patuakhali	740	180	400	10.5	55	.025	1	0.9	13.44	12

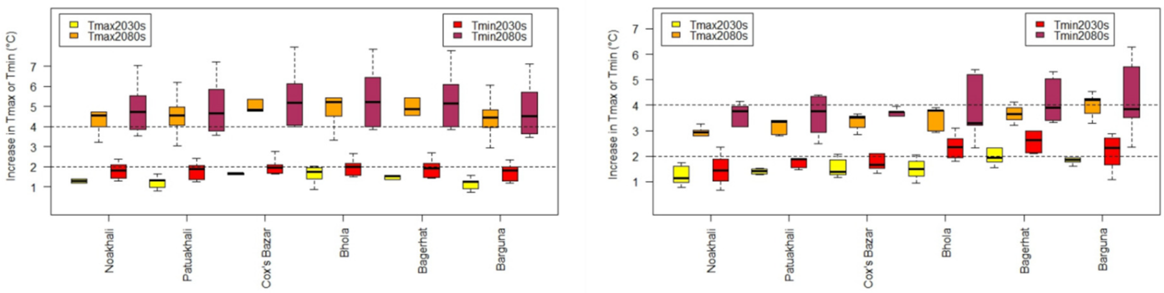

Fig. 2: a) Temperature increase for Boro Rice b) Temperature increase for Aman Rice

The results show a spatial distribution of the change of rice yield. As we see Fig. 3, for near future (2030's), the minimum reduction in yield of Boro rice has been 10%. On the contrary, there has been no loss greater than 10% in case of Aman rice. As for the far future or the 2080's, both the crops would suffer a loss more than 10%. However, according to some models, the situation would be worse for Boro rice than that of Aman rice as the loss would cross 20% for some coastal districts. Although the loss is less severe for Aman rice, the results point out how severe the impact of climate change is going to endanger the rice yield of the coastal regions in future.

The box plots at Fig. 3 also indicates the range of uncertainty of the yield changes of Boro and Aman rice in future predicted by seven different models. It is observed that, the range of uncertainty for far future (2070-2099) is more than the near future (2021-2050). These finding warns that, the change of climate would be so unpredictable in future that even the models are not certain of the severity of its extent in coming days.

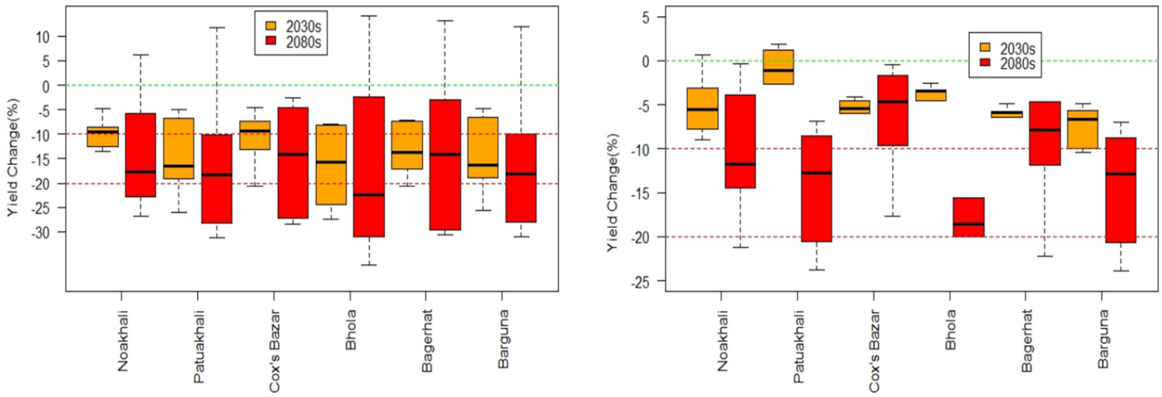

Fig. 3:(a) Yield Change for Boro Rice b) Yield Change for Aman Rice

CONCLUSIONS

Most of the regions encountered extreme change in maximum and minimum temperature over the emergence to end period of Boro and Aman crop. The yield trend is gradually decreasing at an alarming rate; crossing 10% decrease in 2020's to 20% decrease in 2090's for Boro rice. In case of Aman rice, the loss is somewhat less in extent comparatively. Temperature rise is assumed to be the major region for crop loss at coastal regions. Previous studies on coastal districts like Kibria et al., 2016 with the help of Aqua Crop model has projected that, if the global mean temperature would remain under tolerable limit, rice production would have increased instead of decreasing in that coastal regions. The growth and yield of crops are directly related to the rate of photosynthesis and their response to temperature, solar radiation and rainfall. Optimum temperatures for maximum photosynthesis range from 25ºC to 30ºC for rice under the climatic conditions of Bangladesh. Increased temperatures during the growing season cause grain sterility (Basak et al., 2010). Maximum temperatures cause the reduction in rice yield mainly. However CO_2 is also increasing which pose a positive impact on crop production. But, it is not dominant over the impact of temperature. The core finding in our predicted results suggest that, keeping the harvesting date same or shortening the emergence to harvest duration, we can actually get an increased yield in most of the regions. However, due to shortening the growth period, we are also shortening the irrigation water to a significant amount.

It is observed that, losses are more for Boro season than Aman season. Basically, Aman gets water naturally due to Monsoon while the growing period of Boro rice experiences no Monsoon at all. For this reason, the probable cause behind the reduction in yield of any zone is supposed to be lack of natural water supply. This finding calls for a more detailed works on SPI (standardized precipitation index) in future. DSSAT crop modeling could prove very effective for this potential study. Moreover, the high end emission as the IPCC could be simulated to assess how intense is the impact of increased emission on Boro and Aman rice.

Although DSSAT software has been working well to assess the climatic and soil parameters, the specific study and analysis of salinity is not possible with it. So, even DSSAT could easily explain the impacts of temperature rise and high carbon dioxide emission, it was not specifically certain to explain the salinity. Carrying similar studies with crop modeling software like Crop wat or Aqua crop could explain these soundly. Saha and Mondal, 2015 had done simulation studies with Aqua Crop and concluded that, this software can be used for assessing the impact of salinity on crop yield.

ACKNOWLEDGMENTS

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PLAN FORM ANALYSIS OF TEESTA RIVER

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ABSTRACT

Bangladesh, is house to myriad of rivers in its very compact space of only around 1, 47,570 sq. km. From the Himalayan Mountains flowing through India and entering Bangladesh through the Nilphamari district, the river Teesta is considered the very life giver for the people living in the Northern region of Bangladesh. Over the course of history this river has seen many changes in its flow path mainly due to flooding as well as tectonic plate shifting in the form of earthquake and geographical structural changes. Today the river is basically the accumulated flow of three rivers. At present this river however, is prone to changes in the form of constant erosion and deposition. The river bank sees more erosion than deposition in the present years; the river has experienced a high amount of erosion leading to the disruption of life of people along the river. In this paper, this erosion as well as deposition rate or in other words, the plan form analysis of the river has been shown. An analysis of 27 years has been presented in the study from 1990-2017. This analysis has been done with the help of images generated from USGS and later from these images after generating the necessary shape files with the help of ArcGIS software, the erosion and deposition along the river bank was quantified by using MS Excel software. From the analysis, it was seen that the rate of erosion is higher than the deposition. The river experiences high level of flow during the wet season leading to more erosion.

Keywords: Bangladesh; Teesta; Erosion; Deposition.

INTRODUCTION

The country Bangladesh is occupied with a network of about 405 rivers mostly alluvial in nature, spreading all over the country out of which 57 are transboundary (BWDB, 2011). Teesta River is a transboundary river shared by India and Bangladesh. Bangladesh being the lowermost riparian country, the water of the river is very vital for the sustenance of livelihood, planning of new water resources projects including evaluation of existing projects and optimum usage of natural resources. Riverbank erosion is one of the most unpredictable and critical disaster that takes into account the quantity of rainfall, soil structure, river morphology, topography of river and adjacent areas and effect of floods.
Rivers that are alluvial in nature has the problem associated with them of eroding banks as well as the constant threat of flooding and the humanitarian problems associated with constant flooding. Riverbank erosion has important implications for short and long term channel adjustment, development of meanders, sediment dynamics of the river catchment, riparian land loss and downstream sedimentation problems. Being alluvial in nature, floodplains of the rivers are predominantly formed of flood-borne sediments while their bank materials consist mostly of fine-grained cohesive sediments). In such alluvial rivers, through continuous erosion accretion processes, the channels frequently change its meandering pattern from reach to reach. On the other hand, development works such as, bank protection measures like embankment; dam and bridge may also cause local morphological changes of river affecting the ultimate sediment balance of the river. Thus fluvial channel form and its dynamics over the period of time have been a major interest of study in fluvial geomorphology (Nabi, 2016). Therefore, a better understanding on morphological changes of alluvial rivers, particularly bank shifting, channel migration due to erosion and accretion processes as

well as techniques to detect resultant pattern would be useful for effective planning and management of the alluvial environments.

Temporal satellite remote sensing data of a river having unstable banks can be analysed in GIS for identification of river bank erosion as well as patches of embankment vulnerable to breaching, upholding the remote sensing approach in study of river morphology. Baki et al. (2012) studied on river bank migration and island dynamics of braided Jamuna River using LANDSAT images. Khan et al. (2014) studied on river bank erosion of Jamuna River by using GIS and Remote Sensing Technology. Hossain et al. (2012) assessed morphological changes of Ganges River. Sarker, analysed Rivers, chars and char dwellers of Bangladesh. Takagi et al. (2007) analysed the spatial and temporal changes in the channels of Brahmaputra. Sarker and Thorne (2006) examined the morphological response of major river systems of Bangladesh due to the Assam earthquake. In this study, the Teesta River, a river that has seen huge controversy erupting between two countries has been focused. The erosion and accretion rate of the Teesta River has been measured through the use of satellite imagery and finally the rate of erosion and accretion through the years has been compared. Mohammadi, (2008) analysed morphological changes of Dough river in north Iran using GIS.

Teesta River is an important river of the northern region of Bangladesh. According to Hindu mythology, it originated from the breast of Devi Parvati (Goddess Parvati). Actually it originates in Chitamu Lake in the Sikkim Himalayas at an altitude of about 7,200 m and comes down first to the Darjeeling plain and then to the plain of West Bengal (India). It flows through a magnificent gorge known as Sivok Gola in Darjeeling. It is a wild river in the Darjeeling Hills where its valley is clothed with dense forest. But its drainage area in the mountains is only 12,500 sq km. It enters Bangladesh at the Kharibari border of Nilphamari district.

Up to the close of the 18th century it flowed directly into the Ganges. The excessive rains of 1787 created a vast flood choked the original Atrai channel. This resulted in the Teesta bursting into theGhaghatwhich at that time was a very small river. After passing through Lalmonirhat, Rangpur, Kurigram and Gaibandha districts this deluge falls into the Jamuna, south of Chilmari river port. The total length of the river is about 315 km, of which nearly 115 km lies within Bangladesh. The land movement, earthquakes, floods and geological structural changes in the northern part of Bangladesh affected the original flows of the Karatoya, Atrai and Jamuneshwari rivers. The present Teesta is the result of these changes and the accumulated flows of the Karotoya, Atrai and Jamuneshwari rivers. Actually the Bangla name Teesta comes from Tri-Srota or three flows. Teesta has a mean monthly discharge of about 2,430 cumec. A number of old channels that were occupied by this river and the Karatoya through which it joined the Ganges are still known as the BuriTeesta or Old Teesta.
For the study area of this study a small portion of the TeestaRiver has been selected as it enters into the country through the Nilphamari district. A section of around a hundred kilometres was selected to understand the changes in terms of erosion and accretion that have taken place in the river through the span of 25 years.

METHODOLOGY

To conduct the analyses, Landsat satellite images are collected from USGS earth explorer website covering a portion of Teesta River in Bangladesh from the year 1990 to 2015. All the images collected were of the month of November or December as during dry season, vegetation cover and other ground conditions, particularly the water level, are relatively consistent from year to year which is essential for assessing the inter-year change of erosion and accretion of the River. In addition, during dry season the chances of getting a relatively cloud free atmosphere is a bit higher and the plan form generally shows the boundary and pattern of channels within the braid belt clearly. This is a method that is effective in quantifying the river change morphology and to properly identify the paleo-braided channels on terrace surface.
In the current study at first, the images were generated from USGS for the years 1990-2015 and afterwards, some cross sections on the study area was defined. These cross sections were put roughly 6 kmapart to ensure that when the images are digitized a good enough result will come. After that both the left bank and the right bank of each year were digitized with the help of GIS and later converted to

shape files within the software. Afterwards, points were placed for each year along the surfaces of both the right and left bank of the digitized images. Finally, all the generated points for each year were compared to each other using Microsoft Excel and finally results were generated in this way. In the case of this particular study after proper analysis of the different years the following results have been obtained. In the first case, the different years were processed in the excel file and the different years were quantified. The graphs are shown from [Fig.1 to Fig.5].

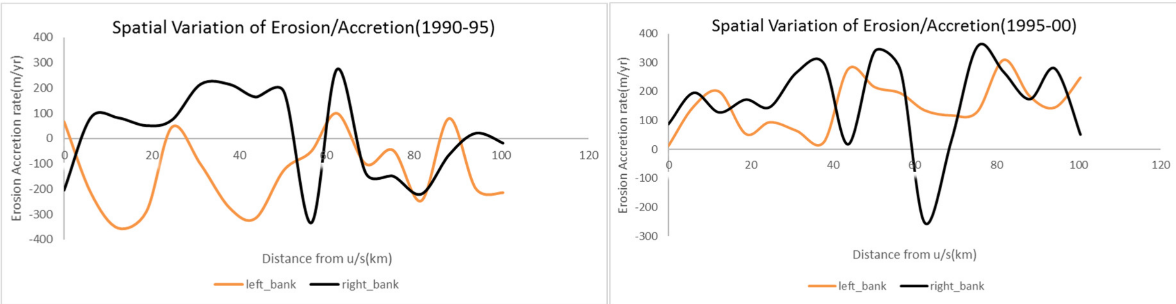

Fig1&2: Spatial variation of erosion and accretion inthe year 1990-1995 and 1995-2000

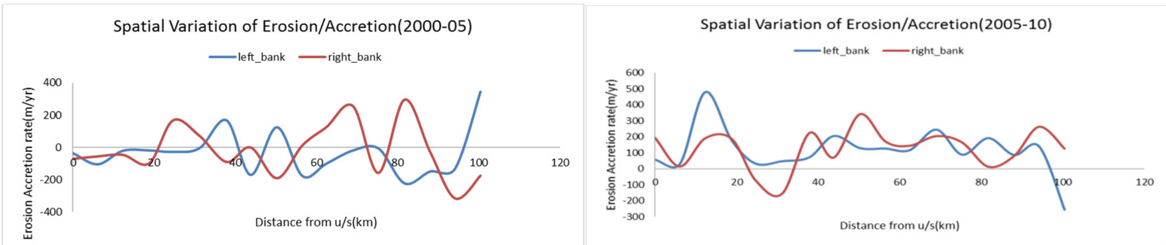

Fig 3&4: Spatial variation of erosion and accretion in the year 2000-2005 and 2005-2010

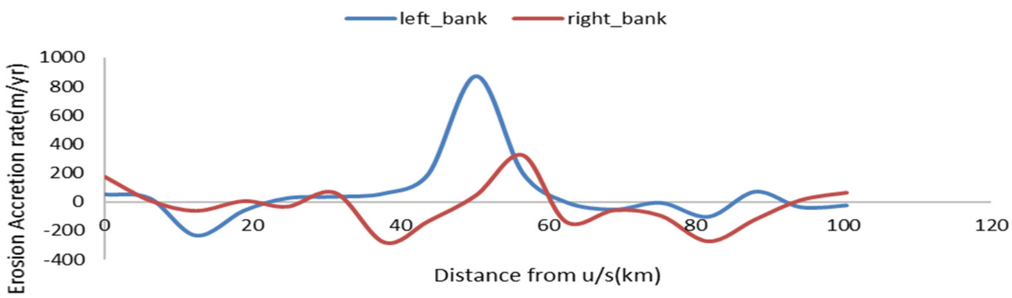

Fig 5: Spatial variation of erosion and accretion in the year 2010-2015

The average erosion accretion rate and the maximum erosion and accretion in both the left bank and the right bank can be shown through a chart that is given in the following Table 1.and Fig.6 to Fig.7 represent erosion and accretion from left bank and right bank.

Table 1: Maximum erosion and accretion both left bank and right bank

Year	Left bank Shifting				Right bank Shifting			
	Erosion		Accretion		Erosion		Accretion	
	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
1990-1995	385.52	425.256	72.15	99.02	160.68	333.81	239.65	325.23
1995-2000	0	0	225.13	247.52	252.92	252.12	192.6	289.53
2000-2005	137.95	285.26	296.52	385.24	189.34	285.24	175.32	190.23
2005-2010	256.23	365.25	139.3	174.53	115.01	156.12	188.77	254.32
2010-2015	97.83	125.24	168.14	256.23	153.98	198.23	88.46	175.21

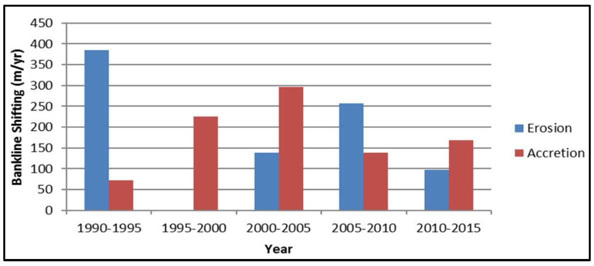

Fig 6: Erosion and accretion rate in left bank

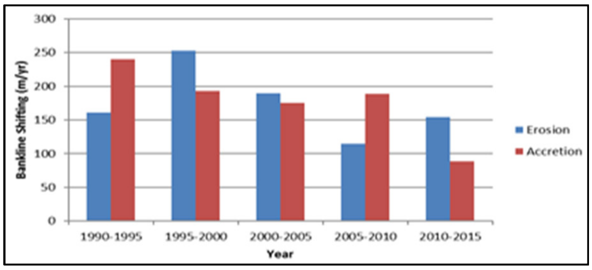

Fig 7: Erosion and accretion rate in right bank

RESULTS AND DISCUSSIONS

From Table:1, it can clearly be shown that the average rate of erosion in the left bank hovers around the 200-300 m/yr mark in all most of the years with some of the years like 2000-2005 and 2010-2015 showing a smaller rate of average erosion than normal. On the other hand, accretion shows a similar trend with smaller amount of accretion seen in the years when the erosion was less. For the right bank, the amount of erosion and accretion is also of the same trend hovering around the 200-300 m/yr mark in most of the years with 2005-2010 and 20010-2015 showing slightly lower amount of erosion trend. The same is seen for the accretion with accretion being low in recent years as well.

CONCLUSIONS

The present work using remote sensing and GIS based approach with multi-date satellite data has revealed sharp changes in fluvial land form in recent years resulting in considerable inhabited land loss. River adjustment processes that affected fluvial system of the river Teesta include forcing functions like channel degradation and aggradations, lateral river migration, widening or narrowing, avulsion, changes in the quantity and character of the sediment load at spatial and temporal scale, intensely powerful monsoon regime, recurring earthquakes and adverse impact of anthropogenic factors. However, the biggest problem that this river faces currently is the water crisis due to India not being willing to share water and this has culminated in the river becoming unstable and showing regular erosion and accretion along its banks.

This study has proved the utility and application of satellite remote sensing which allows a retrospective, synoptic viewing of large regions and so provides the opportunity for a spatially and temporally detailed assessment of changes in river channel erosion/deposition. This study has further demonstrated how the use of GIS has been expedient in organization of geo-spatial databases and facilitation of channel position mapping and measurement. The present study identified locations affected by of bank erosion accretion and the bank line shifting and indicated the urgent need to protect the river banks employing afforestation measures and other strategies. Therefore, it is necessary to incorporate geomorphic changes in formulating flood management programs.

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FLOOD HAZARD ZONING ASSESMENT OF CHITTAGONG CITY USING GIS AND MULTI CRITERIA DECISION ANALYSIS

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ABSTRACT
Recently, the port city of Bangladesh, Chittagong have been affected by several storm flood events, Heavy intensity rainfall, new housing developments covering previously permeable grounds, and old drainage systems are the main causes for this situation. This paper presents a simple approach of urban flood hazard assessment in a region where primary data are scarce. The objectives of this study are to develop a GIS-aided urban flood hazard zoning of the Chittagong city applying multi criteria decision analysis and to evaluate it by means of uncertainty and sensitivity analysis. The research methodology focused on the analysis of those variables that control the water routing when high peak flows exceed the drainage-system capacity. The model incorporates five parameters: distance to the drainage channels, topography (heights and slopes), and urban land use. A final hazard map for each category is obtained using an algorithm that combines factors in weighted linear combinations. This study will help to demarcate the flood hazard zone where built up area should have restricted. This study will help a planning instrument for land use zoning.

Keywords: Flood hazard assessment; Urban flood hazard zoning; Water routing; Drainage-system

INTRODUCTION
Chittagong is a district located in the south-eastern region of Bangladesh is a part of Chittagong division. It is a hilly city surrounded by Kornofuly River and Bay of Bengal The climate of Chittagong city is influenced by strong tropical monsoon characterized by high temperature and heavy rainfall in association with high humidity (Rashid 1991). Though Chittagong is called the commercial capital of Bangladesh faces a lot of socio-economic problem. Among them water logging is a most vital problem happens during in the rainy season is considered as an environmental threat for the human being (Papry and Ahmed 2015). This problem is getting worse and worse because of insufficient and unplanned drainage system. Unplanned urban infrastructure development and poor maintenance of the existing drainage facilities may also aggravate the congestion problem even in the previously well drained city like Sylhet (Ahmed 2009).

Water logging is mainly happened when the existing drainage system is blocked with the wastages and because of it the water cannot follow the natural drainage line. By making artificial drainage systems which will work as an alternative to natural water bodies and swamps which helps to reduce the flood risk. Because of the continuous changes in the land use with impervious surfaces in cities like Chittagong considerably affect flooding which is further exacerbated by increased runoff, which quickly blocks drains and channels with sediment, wastes and debris (Barua and Ast 2011). Around 1960-61 some master plans on drainage were made to reduce the water logging problem for Dhaka and Chittagong. Basically this plans were produced based on zoning maps with very little or no reference to drainage planning. But the matter of regret that the planning was taken over by drainage engineering without any conscious endeavour to integrate drainage planning with the land use planning process. There was a very little attention to the architect and planner's proposals about drainage system when they went ahead with their zoning proposals in housing and industries sector.

From the last three decades the total amount of rainfall is remained almost same where there is found a huge change in the development of physical feature in the Chittagong city. The open spaces are decreased, thus when rainfall occurs in the city, it cannot percolate through and increased the surface runoff. The increased runoff does not pass through the existing drainage channels creates drainage congestion in the city particularly in low lying area (Ahmed and Alam, 2010). There are some low lying areas, basically in the central part of Chittagong such as Chawkbazar, Muradpur, Bahaddarhat, Bakalia, 2 no. Gate, Agrabad, Badurtola and Shulokbohor are regularly waterlogged during rainy season (Papry and Ahmed, 2015). The sufferings of the residents of these areas knows no bounds when the schools, colleges, working places like office, business centres houses gone under the three or four feet of water in the rainy season. This is mainly happened because of the unplanned drainage system and poor maintenance of the drains. In these areas, land development through artificial landfill of depressions, back swamps and floodplains generally reduces the water storage capacity of the area and may increase the water levels, resulting in an increased hazard and risk (Papry and Ahmed, 2015).

For these, this study was aimed to find out the flood hazard risk zone of the Chittagong city by analysing the existing drainage condition of the study area.

METHODOLOGY

The study was conducted by aiming to find out the flood hazard risk zone of the Chittagong city corporation area based on the existing drainage condition of the study area. Before going through these work the first duty was to review the relevant literature of this topic. In our methodology at first, we reviewed some paper to find the methodology to find flood hazard risk zone assessment. Then according to that we fixed our goals and objective. Then we have collected DEM data (Digital Elevation Model), drainage carrying capacity data from CDA & Landsat data. From DEM data we tried find out the basin and streamline analysis also used for aspect analysis. From Landsat data we found built up area from build-up index. And from attribute input we analysis the drainage carrying capacity. Then those data are reclassified according to their weightage value. Then all the data are merge by zonal statistics. The intersection area is the desire output.

Analysis:

Aspect:

To find out the flood hazard risk zones it is necessary to define the various aspects of these areas.
Aspect identifies the downslope direction of the maximum rate of change in value from each cell to its neighbours. It can be thought of as the slope direction. The values of each cell in the output raster indicate the compass direction that the surface faces at that location. It is measured clockwise in degrees from 0 (due north) to 360. The value of each cell in an aspect dataset indicates the direction the cell's slope faces.

So, aspect defines the direction of water flow. So, the place where the aspect value is less the probability of water Accumulating will be more. We classified aspect value into four categories Low, moderate, high and steep. So, the place where the steep is high that place is upper stream and lower one is downstream. In southern part of Chittagong contains more downstream whereas north south part is upper stream. So, at middle its flat so probability of flood may occur form analysis is at middle part and the southern end.
Here the aspects which lies between the value of 1-74 degree is considered as low aspect zone. The value between 74-165.8 degree is considered as moderate risk zone and the value between 165.8-260.5 is considered as high aspect zone.

Sink:

Stream lines are the line through which natural water flow to the outlet. The place where from stream line can carry water are sink area. So, where sink area is more flood occurs probability is more there. Here a also we classified the area into four no sink, low sink, moderate sink, high sink. Maximum sink place is seen in area Agrabad, Chowmohoni, Boddarhat and 2 no gate area and slightly in the port region of Chittagong. From our analysis it is found that in Chittagong city the areas which lies between 13 to 26 cm^3 sink depth are considered as low sink area, 26 to 45 cm^3 are considered as moderate sink areas and 45 to 88 cm^3 areas are considered as high sink areas.

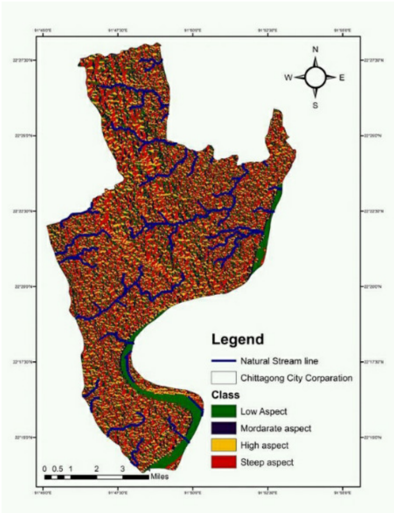

Fig. 1: Aspect analysis with stream line

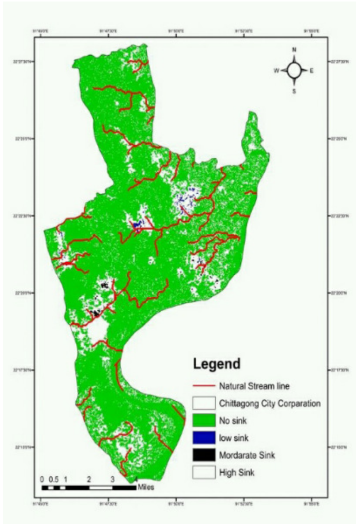

Fig. 2 : sink depth map

Built up area:

It has been seen from the following figure that maximum part of the Chittagong City Corporation area contains built up area. Its area is about 109.84 sq.km. which is almost 66% of the total area And for the reason water cannot be infiltrate into the soil.as result flood occurs. So the place where the built up area is more probability to occur flood is more.

Drainage capacity:

The reason of long lasting water logging situation in the city as well as in the study area is mainly due to inadequate drainage capacity. According to the experts, lack of enough drains and their reduced water holding capacity helps in creating drainage congestion due to heavy rainfall. Drain carrying capacity indicates that how much water can flow throughout the drain and up to which limit it will not over flow. So, where the drain water capacity slow in rainy season water can go out to the outlet. So, water will overflow and flood will occur. We classified the drain capacity into four, as follow high, medium, low, very low carrying capacity. It is seen from the following figure that maximum low carrying capacity drains are at the middle part of Chittagong and in western part of Chittagong. So according to drain capacity analysis maximum flood probability are in 2 no gate Agrabad.

From the analysis it is found that the high carrying capacity drains can hold the water from 45-27 cm^3 water where moderate capacity drains and low capacity drains hold the water from 27-16 and 16-9 cm^3 respectively.

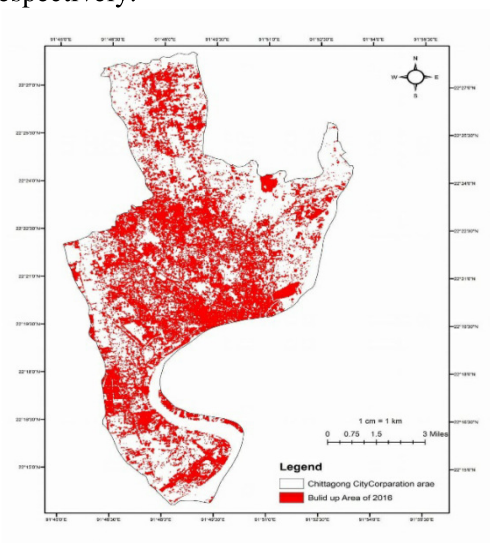

Fig. 3: Built up area map

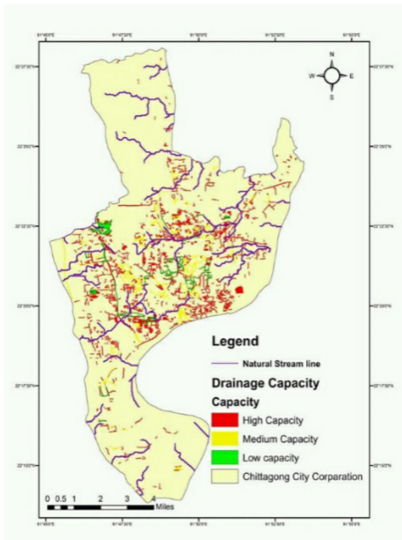

Fig. 4: Drainage capacity map

RESULTS AND DISCUSSIONS

From the above figure we can see the flood risk zone. But it is notable that high flood risk zone ward Sholokbahar, Pahartoli, West Sholosohor, middle halishor, Agrabad that is the middle of Chittagong. As the southern lower part of Chittagong their remains some floor risk but as their remains some outlet for water flow and as their Build up area is less. As major Build, up area and sink area are ward Shalakbar, west Shalokbahar, Halisohor, North Agrabad, Middle Halisohor. And water carrying capacity is very low in ward west Shalokbahar, South Middle Halishahar, North Middle Halishahar. When these data are merge The most flood hard risk zone comes Sholokbahar, Pahartoli, Agrabad, South and south Halishahar, West Sholashahar, Enayet Bazar.

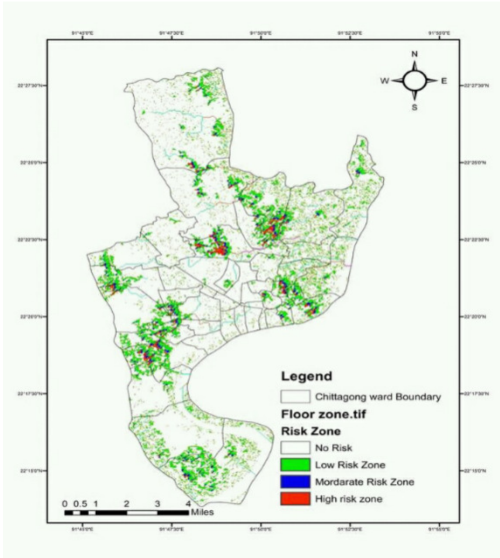

Fig. 5: Flood hazard zoning map of Chittagong

CONCLUSIONS

As Chittagong is the capital of commercialization of Bangladesh it is necessary to reduce the water logging problem of this area. The areas which are found in the flood hazard risk prone area are needed to take necessary steps to remove the problem.

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HYDROLOGIC STUDY OF THE SANGU RIVER BASIN

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ABSTRACT
The Sangu River is a transboundary river between Myanmar and Bangladesh. The Sangu River drains off the waters of Patiya, Satkania, and Banshkhali Upazilas. This paper deals with the hydrological modeling of the Sangu river basin. HEC-HMS model and NRCS triangular unit hydrograph method are applied for this purpose. Two rainfall events such as 2-h 5 year and 2-h 10 year return period have been used for hydrograph generation. Sub-catchments were delineated for using in the model and shapefiles and landuse were prepared. Curve number values obtained from GIS shapefiles of existing landuse maps. For example, in case of the sub-catchment 1, the direct runoff volume for each of these cases was obtained by summing the area under each of these hydrographs by the trapezoidal method. From the HEC-HMS model, the runoff volume was found to be 18892 m^3/s and from the NRCS triangular unit hydrograph method the runoff volumes were found 18600 m^3/s. The variation in values of peak discharge and slight difference in time to peak can be attributed to the different formulae adopted to obtain the hydrographs. The difference in peak discharges varied by 202 m^3/s or by 6.2% with respect to the result obtained from the calculation without model. On an average, the difference in peak discharges varied by 6.2~6.5 % with respect to the result obtained from the calculation without model from the other sub-catchments.

Keywords: Sangu River; Sub-catchments; IDF Curve; Runoff Hydrograph.

INTRODUCTION
Sangu is one of the main perennial rivers of the south-east region of Bangladesh. Life and livelihood of local people and environmental setting of the area is largely dependent on the hydrological characteristics of Sangu River. Existence of the river in a form conducive to the environment is pre-requisite for overall economic development and environmental sustainability of the area. The Sangu gas field is located about 50 km southwest of Chittagong and reaches a depth of 10 m at its mouth [Fig. 1]. Previously various studies were conducted at different time to assess the hydrologic behaviour of the urban catchments (e.g. Das et al. 2010, Khan, 2016).HEC-HMS software is used in this study for analysing the hydrologic behaviour of the Sangu River basin. The specific objectives of the study are set as to estimate the peak discharge for different return period and to compare between the results obtained from HEC-HMS model and NRCS triangular unit hydrograph method.

It has a connection with the Karnafuli River through the Chand Khali River. The Sangu is a shallow river, but it becomes violent during rains and develops rapid currents. It is navigable up to 48.27 km from the estuary.

METHODOLOGY
The design rainfall data was generated from IDF curves of Chittagong hilly area for the interval 1984-2016. Required maps of the study area were collected from Google Earth. The required shapefile were collected from my thesis supervisor. Delineating the watershed and determining its size is a first step in modeling studies. Time of concentration and lag are parameters that reflect characteristics influencing how quickly precipitation flows off of the watershed. The first step is to delineate the boundaries of the watersheds. The drainage area is delineated by observing the contour maps, storm sewer network, constructed drainage facilities, as well as topography. Some areas were also found within the watersheds which do not contribute runoff at the outlet.

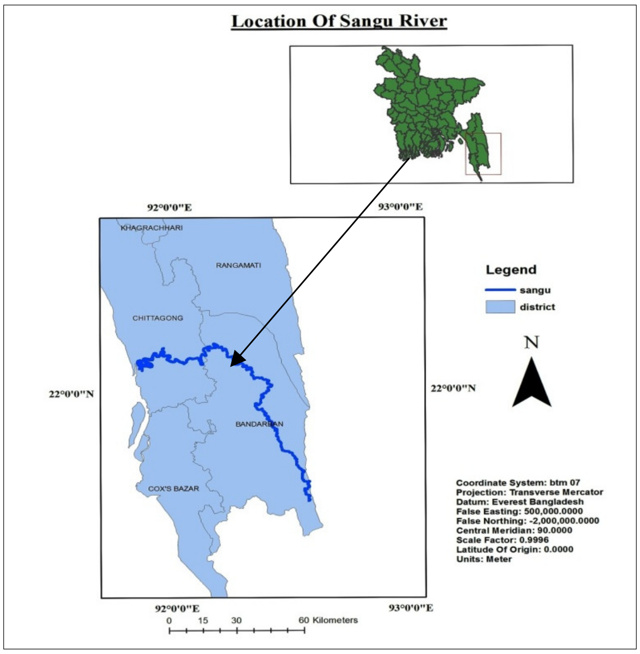


Fig. 1: Location map of the Sangu River

Those closed subareas were found to drain to lakes or low terrain not hydraulically connected to the watershed outlet. The total watershed delineation process was completed with the help of **ArcGIS** [Fig. 2]. The command used were downloading the DEM, filling the DEM, flow-direction command, flow-accumulation command, converting the data from raster to vector, converting the stream to feature, defining the outlet, snapping pour point. Lag t_L is sometimes viewed as the time between the center of mass of rainfall and center of mass of the runoff hydrograph. However, more typically, $t_L$is defined as the time between the center of mass of rainfall and peak of the hydrograph.The NRCS developed the following relationship based on empirical analysis of numerous gaged watersheds (Subramanya, 2016).

$$t_L = 0.6 * t_c \tag{1}$$

Where t_c= Time of concentration, the time needed for water to flow from the most remote point in a watershed to the watershed outlet. It is a function of the topography, geology, and land use within the watershed.

NRCS developed the following equation for watersheds with areas of less than about 8 km^2 and CN between 50 and 95. Equations 2 and 3 are English (l in ft) and metric (l in m) versions of the NRCS lag formula (Chow, 1988).

$$t_L = \frac{l^{0.8}(1000-9CN)^{0.7}}{1900CN^{0.7}Y^{0.5}} \tag{2}$$

$$t_L = \frac{l^{0.8}(2540-22.86CN)^{0.7}}{1410CN^{0.7}Y^{0.5}} \tag{3}$$

CN is a dimensionless parameter between zero and hundred, CN = 0 represents an infinitely abstracting catchment with maximum potential retention, S= ∞, and a CN value of 100 represents a condition of zero potential retention (i.e. impervious catchment). Y is the average land slope of the watershed in percent. The hydraulic length, L is obtained from ArcGIS 10.2.2, by taking the lengths of the flow paths in the different sub-catchments. The curve number chart is used to obtain the Weighted Curve Numbers for the sub-catchment areas. The average basin slope, Y (%), was determined from the following equation:

$$Y=100*CI/A \qquad (4)$$

Where, Y= average land slope, % C= summation of the length of the contour lines that pass through the watershed drainage area on the quad sheet, ft. I= contour interval used, ft. A= drainage area, ft^2.

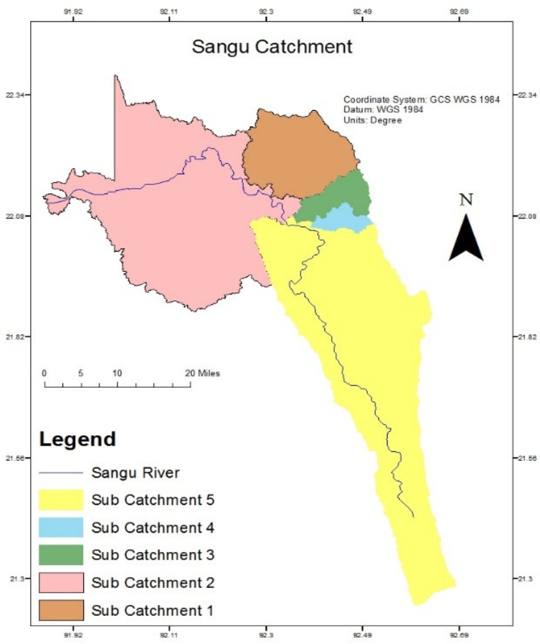


Fig. 2: Sub-catchments of the Sangu River

Table 1: Calculations of lag time for the sub catchments (NRCS method)

Sub catchment(title)	Summation of Length of Contour lines C (ft)	Area(ft^2)	Contour Interval I (ft)	Avg Land Slope Y(%)	CN	Hydraulic Length, L (ft)	lag time, tL (hour)	lag time, tL (min)
Sub catchment1	4339971.00	3874918342.30	30.00	3.3600	74.77	7848.34	1.05	63.20
Sub catchment2	5959576.00	14657813930.10	30.00	1.2197	77.65	9343.56	1.85	110.83
Sub catchment3	1524382.00	1136607712.04	30.00	4.0235	75.32	4756.34	0.63	38.08
Sub catchment4	1015578.00	527044779.32	30.00	5.7808	75.78	3745.364	0.43	25.90
Sub catchment5	7573681.00	16348322403.90	30.00	1.3898	68.72	9849.38	2.32	139.25

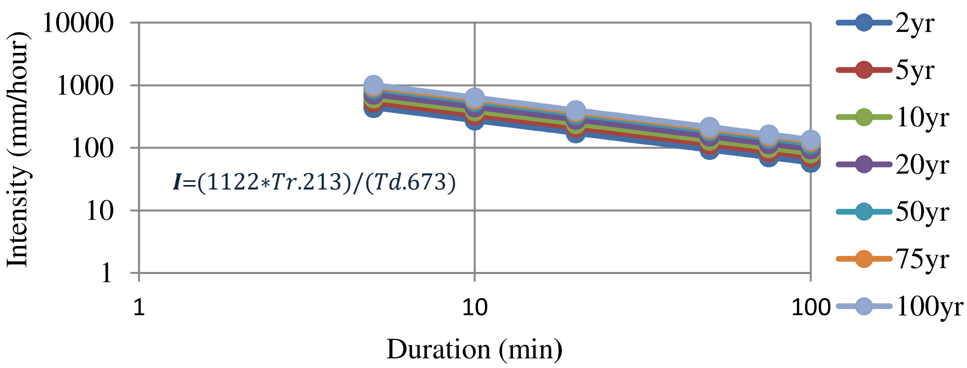


Fig. 3: IDF curves for Chittagong hilly area for 1984-2016

The equation of IDF curves of Chittagong hilly area for the interval 1984-2016 was obtained as:

$$I = \frac{1122 * Tr^{.213}}{Td^{.673}} \quad (5)$$

Here, I= intensity in mm/hr, T_r = Return Period, in Years, T_d= Duration, in minutes.
Usually for design of drainage structures, short duration rainfall is used as design rainfall. For present study, the model was simulated with the following rainfall events 2h 5-Year Return Period, 2h 10-Year Return Period as shown in [Fig. 4] and [Fig. 5] respectively.

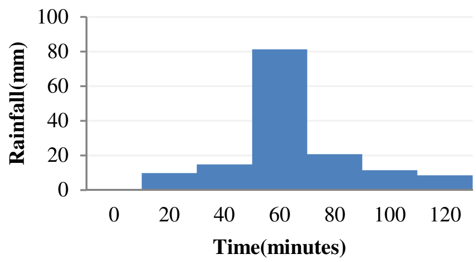


Fig 4: Design Rainfall Hyetograph for 5-Year 2 hour Return Period

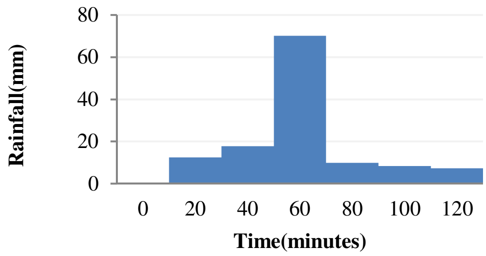


Fig 5: Design Rainfall Hyetograph for 10-Year 2 hour Return Period

The terms runoff and rainfall excess are used synonymously to refer to that portion of the precipitation that reaches the watershed outlet. Precipitation P is the input to the watershed. Rainfall excess or runoff is the water remaining after accounting for losses due to hydrologic abstractions.
(Runoff = precipitation – abstractions)
The basic sets of equation for determining abstractions are

$$V_R = \frac{(P-.2S)^2}{P+.8S} \quad (6)$$

$$V_R = 0 \quad for\ P \leq Ia = .2*s \quad (7)$$

$$S = \frac{2540}{CN} - 25.4 \quad for V_R, P, S\ in\ cm \quad (8)$$

$$S = \frac{1000}{CN} - 10 \quad for V_R,\ P,\ S\ in\ inch \quad (9)$$

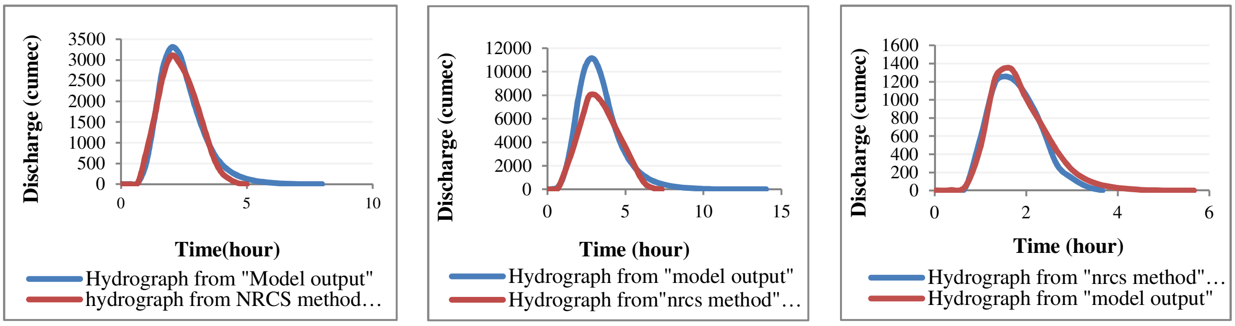
$V_R$is the runoff volume (rainfall excess) to result from precipitation P. It is the maximum potential abstraction after runoff begins. I_a is the initial abstraction before runoff begins. V_R, P, S, and I_a have units of cm or inches. CN is a dimensionless number between 0 and 100. The values of V_R are computed for P values obtained from design rainfall hyetographs. In this study, the triangular unit hydrograph approach was used to develop hydrographs without model simulation. The unit hydrographs developed for the 5 sub-catchments (1, 2, 3, 4, 5) for existing land use patterns for 2hour durations are formed. The ordinates of these hydrographs are multiplied by excess rainfall depths at that instant to obtain the resulting runoff volume.

RESULTS AND DISCUSSIONS

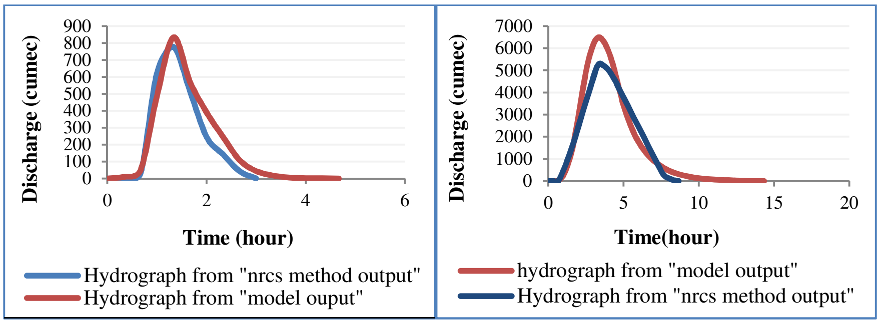
The comparison Hydrographs from HEC-HMS model output and by NRCS triangular unit hydrograph method for sub-catchments (for design rainfall depth of 2-h 5 year return period) are showed in Fig. 6. The direct runoff volume for each of these cases was obtained by summing the area under each of these hydrographs by the trapezoidal method.

It was observed that the time base of the resulting hydrograph from calculation was slightly less than that obtained from HEC-HMS model. On an average, the difference in peak discharges varied by 6.2~6.5 % with respect to the result obtained from the calculation without model from the sub-catchments [Fig. 7].

The peak design discharge was obtained from arbitrarily chosen 2-h 5 year and 2-h 10 year return period of rainfall [Fig. 8]. The resulting hydrographs for each sub-catchment for different return period of rainfall are showed below:



(a) Sub-catchment 1 *(b) Sub-catchment 2* *(c) Sub-catchment 3*



(d) Sub-catchment 4 *(e) Sub-catchment 5*

Fig. 6: Comparison between model output and NRCS triangular unit hydrograph

CONCLUSIONS

HEC-HMS model has been applied for the Sangu River basin. The time of concentration was determined based on empirical equations. It was observed that the time base of the resulting hydrograph from NRCS triangular method calculation was slightly less than that obtained from HEC-HMS model. On an average, the difference in peak discharges from HEC-HMS output varied by 6.2~6.5 % with respect to the result obtained from the NRCS method. It is expected that the results obtained from present hydrologic simulation can be useful for application of hydrodynamic boundary condition of the Sangu River. The model can be further updated with measured data if available.

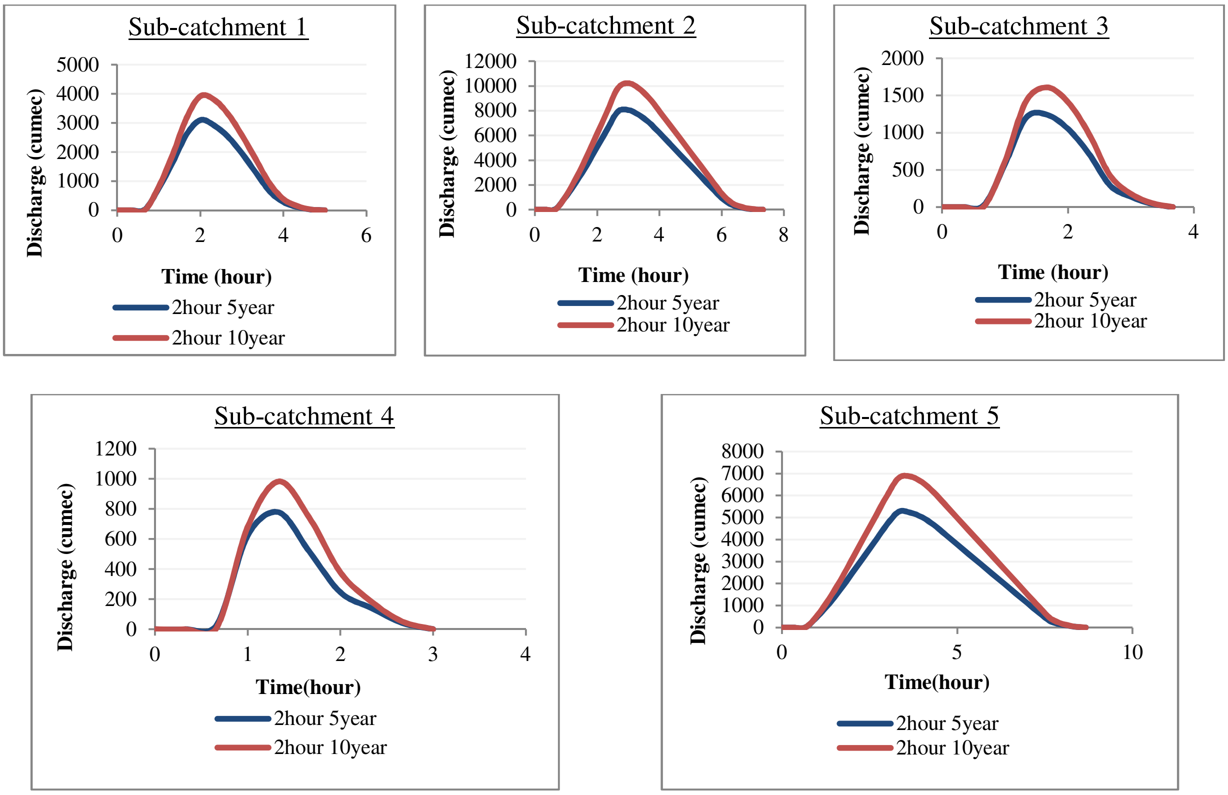


Fig 7: Inflow Hydrographs for sub-catchments for different design rainfall conditions

ACKNOWLEDGMENTS

Authors are gratefully acknowledging the cooperation rendered by Hydrology division of Bangladesh Water Development Board (BWDB) for providing the necessary data for this study.

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FLOOD INUNDATION MAPPING OF TEESTA RIVER AND CLIMATE CHANGE IMPACT ON IT USING HEC-RAS 1D/2D COUPLED MODEL

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ABSTRACT

Bangladesh lies at the confluence of worlds three major rivers, namely the Ganges, the Brahmaputra and the Meghna. The country is very much prone to flooding owing to its lower elevation. Flood causes tremendous losses in terms of property and life, particularly in the low land areas. At least 20% areas are flooded every year and in case of severe flood, about three fourth part of the country is inundated. Therefore, the study is carried out to understand the characteristics of the flood in Teesta River. As part of this study inundation maps were generated by HEC RAS 1D/2D coupled model and also using GIS. The model is calibrated and validated. The model simulated the flood of 2016 in the Teesta River. It was then compared with the flood inundation map generated by FFWC of BWDB. The comparison showed that the model accurately predicts inundated area. From the hydrological data analysis it was found that the discharge at Dalia point corresponding to flood with 100 year return period was 6909.028 cumec. The water level corresponding to 100 year return period flood was found to be 53.48707 mPWD. The maximum observed flood discharge was 5294.21 cumec on 2003. The peak flood generally occurs during Late June to Late August. From the model simulation, the maximum inundated area in 2016 was found to be on August 10, 2016. The maximum inundated area was 295.22 square kilometers. The maximum percent inundation was found in the Hatibandha Upazila of Lalmonirhat District. It had an inundation percentage of about 76.2%. It was also found that the areas on the left bank of Teesta were badly affected because a vast length of the left bank was not embanked. On the other hand areas on the right bank were less affected because the right bank was embanked significantly. Moreover, the impact of increased flood on the inundation of the Teesta river flood plain due to climate change has been simulated using the model. The outcomes of the research may help the concerned authorities in managing the flood of Teesta flood plain.

Keywords: Teesta River, Flood mapping, HEC-RAS, Climate Change.

INTRODUCTION

Floods are common phenomenon in a lower riparian country like Bangladesh. During Monsoon, the combine basin of three major rivers namely Ganges, Brahmaputra and Meghna discharges water from a catchment area of about 1.75 million sq km. This huge discharge travels through the siltation prone channels; causing flood in the countryside mostly. Flood causes major losses to the country's economy. During the 2004 flood alone, overall loss to economy was estimated to be US $1,660,000,000 (Islam, 2010). Teesta floodplain has become one of the worst hit areas by flood during recent years. Teesta River is getting silted up due to flow diversion in the upstream and hence its channel capacity is declining. Moreover, the probability of extreme flood occurrence is on the rise due to climate change induced effects. Therefore, for proper flood management policy it is very essential to know the water level at different location and the corresponding flood extent. It helps in preparing risk maps and also assists the policymakers to formulate an effective flood management plan. Many hydrodynamic models are currently on use to simulate flood inundation which are classified as 1D, 2D or coupled 1D/2D model. The 1D model has a limitation that it cannot properly simulate the propagation of flood wave in the floodplains.

It is because the propagation of flood wave in the flood plain is two dimensional. On the other hand 2D model can effectively capture the real scenario in a much better way. A coupled 1D-2D model is actually even better than the both 1D and 2D model (Werner, 2015). 1D-2D coupled model had been applied for developing inundation maps of Jamuna River in Bangladesh (Ali, 2016). The changing climate is affecting the nature and devastation of flood greatly. So this study is carried out on Teesta river to evaluate the climate change impact on the Teesta River flooding. Since HEC RAS is a open source software it was used. The main objective of this study is to develop a model; to simulate flooding in Teesta River. And hence, quantifying and evaluating the probable impact of climate change in Teesta river flooding in the year 2050.

STUDY AREA AND DATA COLLECTION

Being originated from the Himalayas in the Sikim State of India; Teesta River flows approximately 180 km before entering Bangladesh. It travels further downstream to meet Jamuna at Chilmari [Fig.1].

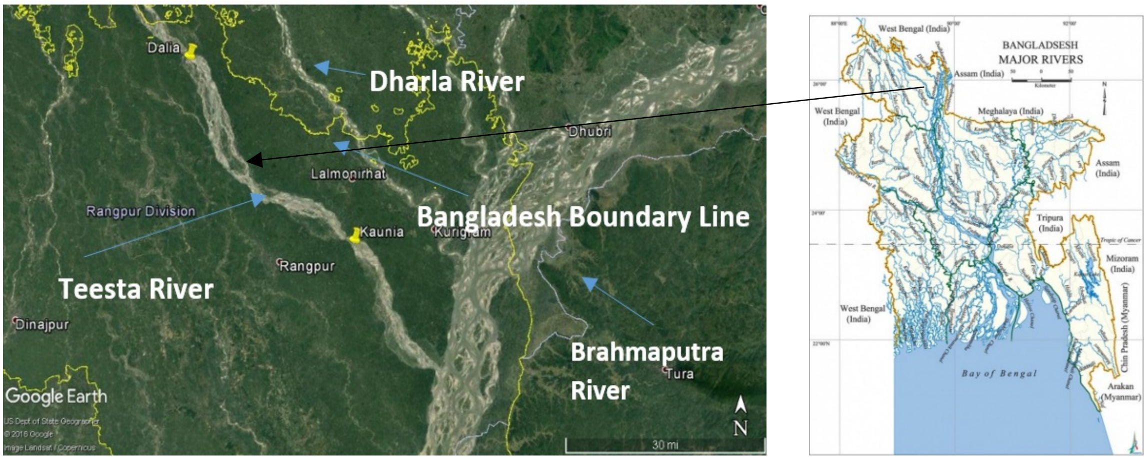

Figure 1: Study Area – Teesta River

The Chilmari point is almost 121 km downstream from the point Teesta enters Bangladesh. The necessary data are collected from various sources. These data include: DEM, river cross-sections, water level and discharge. Digital Elevation Model (DEM) is required to represent the topography of the floodplain in the model. It was obtained from SRTM datasets of USGS website. The resolution of the DEM is 30m. River cross-sections of Teesta River are collected for the year 2014 from Bangladesh Water Development Board (BWDB). These cross-sections depict the shape and morphology of a river. Historical water level data of the Teesta River from 1998 to 2016 at two stations Dalia, Kaunia and Haripur were collected from BWDB. Discharge data at Dalia have also been collected from BWDB for the same time period. The embankment alignment data along the Teesta River have been collected from GIS unit of LGED.

METHODOLOGY

To perform the flood inundation simulation two main tasks are performed. At first, hydrodynamic model was setup, calibrated and validated using observed stage data. In the second step, the simulated flood was compared with observed flood in 2016.

Model Setup

The terrain of the area was formed using 30m resolution DEM. Then the bathymetry data of 20 cross sections obtained from BWDB were inputted to the software. Then 2D flow areas were drawn on both sides and meshes were created [Fig. 2]. Each mesh had a cell size of 75m. Then levees were created. The levee height was kept the same as the height of the bank station. The datum of the DEM was MSL. But the datum for the water level data was PWD. So the datum of DEM was transferred from MSL to PWD by adding 0.45m. Discharge Hydrograph at Dalia was provided as upstream boundary condition and Stage Hydrograph at Haripur was given as Downstream Boundary condition.

Model Calibration and Validation

The calibration parameter of our model is Manning's n. Different values of Manning's n were adopted and finally the model was calibrated for the year 2016 at Kaunia station for manning's n of 0.025. Values of manning's n for natural channel is 0.025 and for flood plain is about 0.04. The model was validated for the year of 2015 at Kaunia station [Fig. 3]. The observed stage hydrograph and model simulated hydrographs were in agreement; furthermore, the peak stage were properly captured in the simulation.

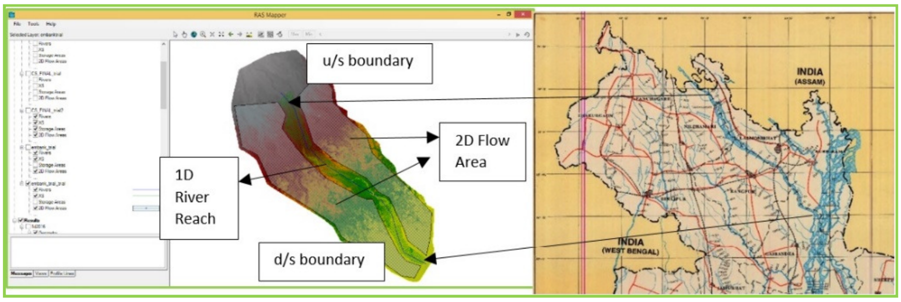

Fig. 2: Model Setup

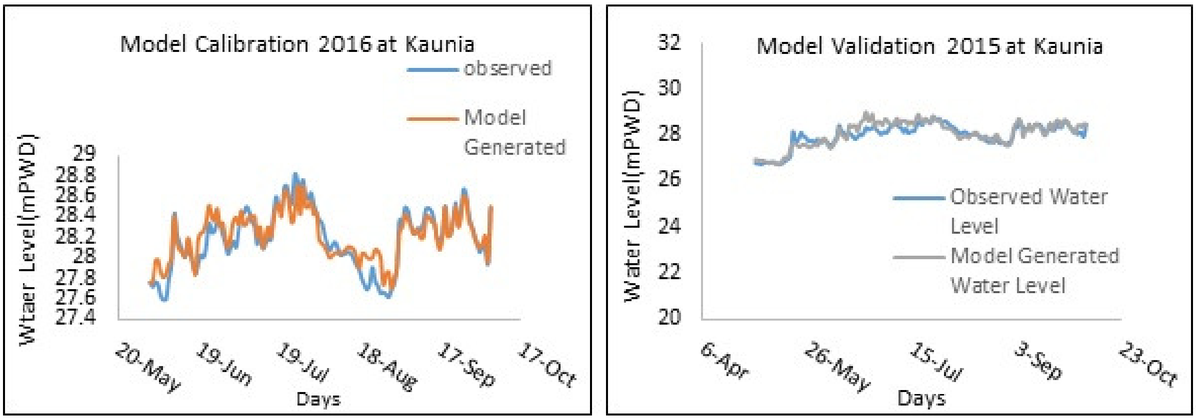

Fig. 3: Model Calibration and Validation

Hydrologic data analysis

Hydrological analysis was done using different Gumbel's method using the data spanning 19 years (1998-2016). Flood corresponding to different return period was found. It has been estimated that a moderate climate (temperature increased by 4°C, precipitation increase by about 20%), expected in the mid-21st (year 2050) century, will potentially increase the mean annual stream flow by about 22% in the Brahmaputra river basin (Alam, 2016). To determine the floodplain corresponding to 50 year return period the discharge value was adjusted accordingly to incorporate climate change effect.

RESULTS AND DISCUSSION

The simulated vs observed water level is shown in Fig. 4. The value of coefficient of determination, R^2 is 0.8339 for calibration and 0.8171 for the case of validation. This means an excellent correlation is established between simulated and observed value for the same value of Manning's n. From the hydrological analysis, it is found that the discharge corresponding to 50 and 100 year return period are 6195 m^3/s and 6909 m^3/s consecutively. At the same time, the water level corresponding to 50 and 100 year return period are 53.33 mPWD and 53.49 mPWD consecutively [Fig. 5]. From the Fig. 6 it is seen that the peak during 2003 flood came in early July. Whereas the peak flood during 2001 came in late June. The 2001 flood had two peaks. One came in late June and the other came in Late August. The peak of the flood of year 1998 and 1999 came in late August to early September. Historical data shows that the maximum observed discharge at Teesta was observed on the year 2003. The maximum observed discharge was

5294.21 m^3/s. The discharge has decreased since then. The flood map for August 10, 2016 from the model simulation and its comparison with the flood map provided by FFWC (Fig. 7); shows that the areas in the right bank of Teesta were more or less flood free during the 2016 flood; it may have occurred due to the fact that major portion of left bank is not embanked. But areas in the upper left bank of Teesta were greatly affected by flood. The slight under flooding is noted due to the fact that the flooding caused by Dharla River is not incorporated in the model simulation.

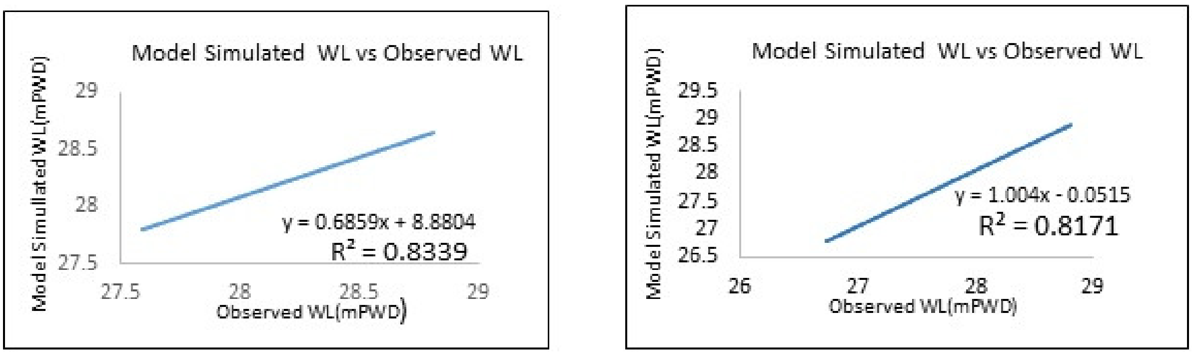

Fig. 4: Model performance evaluation for calibration (on left) and validation (on right)

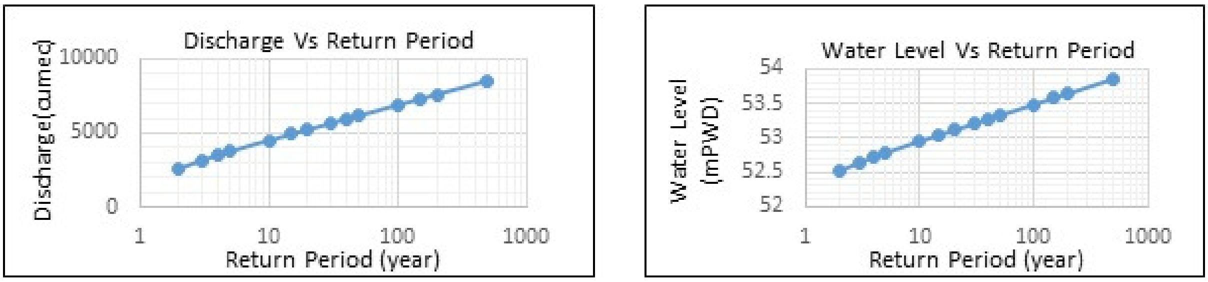

Figure 5: Flood frequency graph of water level and discharge at Dalia

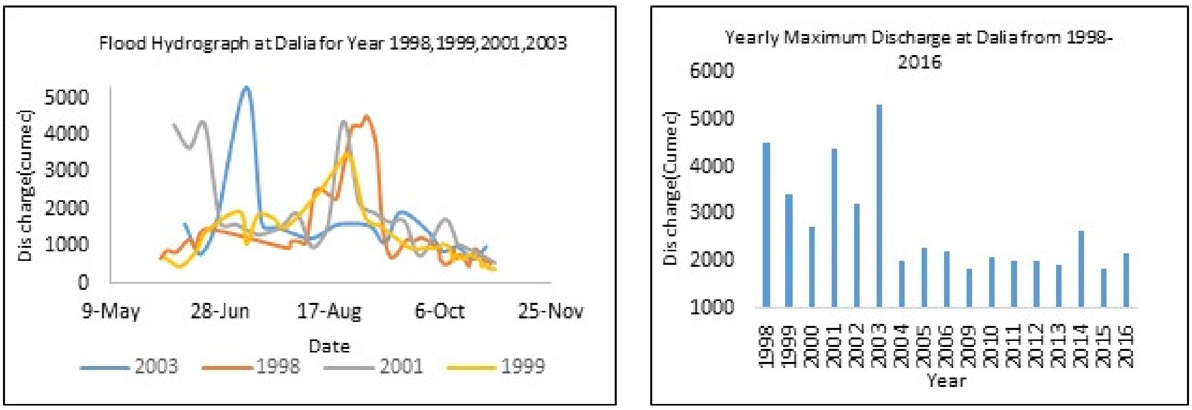

Fig. 6: Flood Hydrograph at Dalia (left) and Yearly peak discharges (right)

From the output of the model it is seen that during Early June the Char lands around Teesta Rivers were flooded especially in the Dimla and Jaldhaka Upazila. Later the month the riverbanks overtopped due to the high discharges at Dalia point. From the model, upazila wise inundated areas are estimated [Fig. 8]. It can be seen that, the worst affected district due to Inundation of the Teesta River in 2016 was Lalmonirhat and the worst affected upazila was Hatibandaha Upazila of Lalmonirhat District with an inundation percentage of 76.2. The effect of climate change from the model can be seen in Fig. 9. This shows great increase in the extent of floodplain. It is seen that both the areas in the right and left banks will be greatly impacted by flooding. It is also found that upazilas like Gangachara and Kaunia will be the worst hit. As it is found that almost 82.7 and 95.6 percent of the areas will be inundated in the case of a flood with 50 year return period in the year 2050.

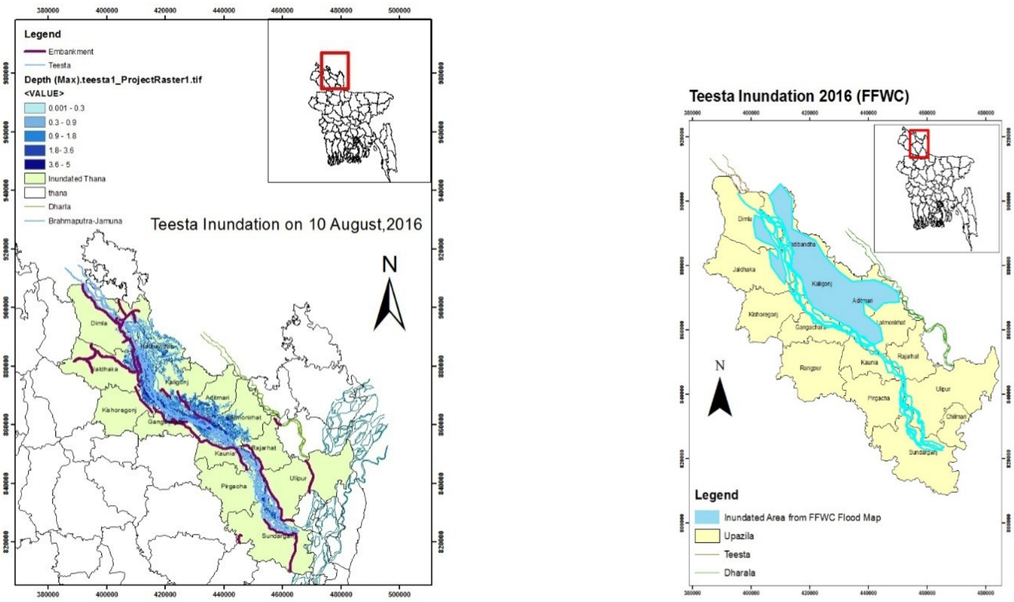

Fig. 7: Comparison between model simulated (left) and flood map prepared by FFWC (Right)

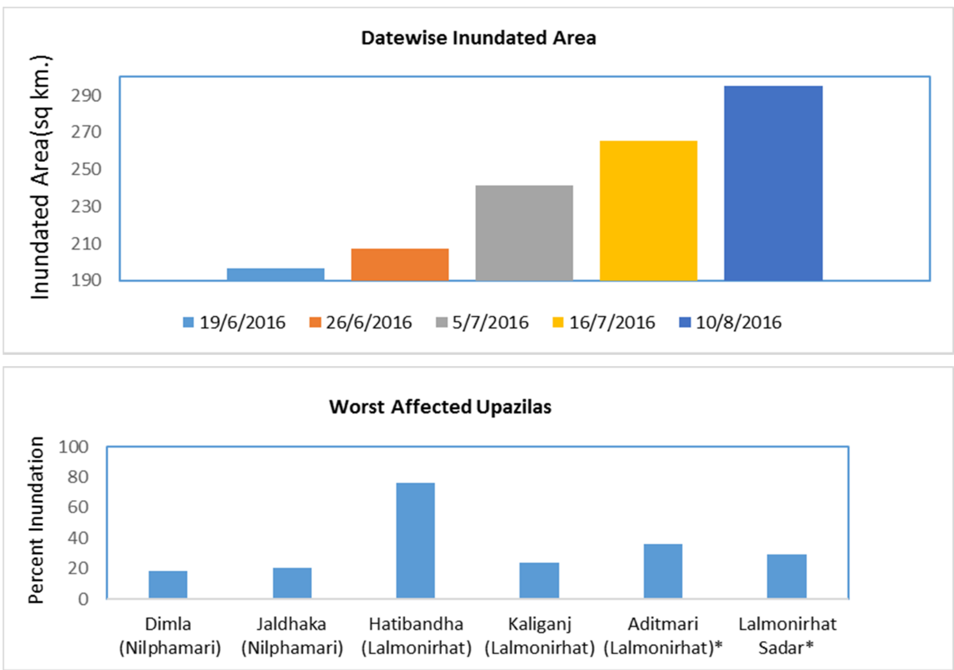

Fig.8: Inundated area (Top) and worst affected Upazilas (bottom) by inundation percentage

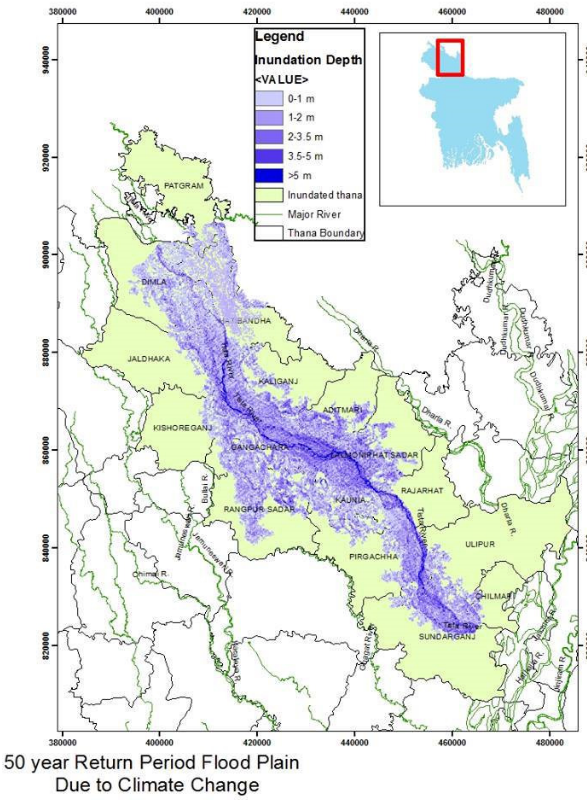

Figure 9: 50 year return period floodplain in the year 2050

CONCLUSION

The main objective of this study is to develop a model that can simulate the climate change impact on long term flooding in the Teesta River. The hydrodynamic model showed good performance with coefficient of determination (R^2) equal to 0.8339 (calibration) and 0.8171 (validation). The qualitative comparison between flood map of 10th August, 2016 simulated by the model and actual flood condition showed good similarity. The maximum inundated area from model simulation was found to be 295.22 square kilometers and Hatibandha upazila was the worst hit by 2016 flood with an inundation percentage of 76.2. The model also simulated the floodplain corresponding to 50 year flood in changing climate condition. It showed that, with current levee height; the river would not be able to content the flooding in the year 2050. The result from this study will help in the planning of development activities in the Teesta floodplain in near future. This will also assist the decision makers to adopt a proper flood management policy for the region. Future studies can be carried out to find out the optimum levee height to limit the extent of flooding to cope with extreme flooding caused due to climate change.

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AN OVERVIEW OF CAPITAL (PILOT) DREDGING OF RIVER SYSTEM IN BANGLADESH

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ABSTRACT

Bangladesh is a riverine landmass formed by the alluvial deposits of the Ganges, the Brahmaputra and the Meghna (GBM) river systems. The discharges carry a sediment load of about 1.15 billion tons annually. Due to deposition of uncontrolled silt rivers conveyance capacities are decreased and frequency of severe flood, erosion, reduction of navigability is increasing. For Sustainable river management in Bangladesh dredging and river training works has become an important issue which is also stressed in The National Water Policy of Bangladesh. In view of this situation, the Capital (Pilot) Dredging of River System in Bangladesh (CDRSB) Project has been formulated by Bangladesh water Development Board (BWDB). Under the CDRSB project "Feasibility Study of Capital Dredging and Sustainable River Management in Bangladesh" total 24 major and important rivers such as Ganges, Brahmaputra-Jamuna, Meghna etc are studied for sustainable river management. The study was composed of capital dredging, sustainable maintenance dredging module, spoil management, channelization of the main rivers, land development etc. The physical components involved: (1) 2 km Pilot Dredging of Jamuna Right Bank at Nalin Bazar, (2) 14 km Capital (Pilot) Dredging from Upstream of Sirajganj Hard Point (SHP) to Upstream of Bangabandhu Bridge; and (3) 6 km Capital (Pilot) Dredging from Downstream of Bangabandhu Bridge to Dhaleswari off-take which was implemented by BWDB during the year 2010-2014. After dredging of Jamuna River, the flow has channelized and SHP, its upstream and downstream areas and west guide bund of Bangabandhu Bridge are less vulnerable to attack by erosion and deep scour. By dredged material four cross bars (Groyne) has constructed at upstream and downstream of SHP for land reclamation. As a result about 16.0 sq. Km land has been reclaimed between four cross bar from Jamuna river at Sirajganj. This reclaimed area will be used as an economic zone.

Keywords: Capital Dredging; Sediment load; Jamuna River; cross bar; land reclamation.

INTRODUCTION

The catchment area of the Ganges, Brahmaputra and Meghna rivers totals 17,21,000 km^2 at the Bay of Bengal. Of this area 93%, or 16,01,000 km^2, lies upstream of Bangladesh. The outflow of water from this catchment into the Bay amounts on average to 1352 km^3/year, or 42,000 m^3/s. Of this 87%, or 1177 km^3/year, is generated upstream of Bangladesh while only 13%, 175 km^3/year, is generated within the country. Most of the country is low-lying land comprising mainly the delta of the Ganges and Brahmaputra rivers. Floodplains occupy 80% of the country. Bangladesh is a very densely populated country (World Bank, 2002). Higher population density increases vulnerability to climate change because more people are exposed to risk and opportunities for migration within a country are limited.

The annual sediment load carried by the waters is estimated at about 1 – 2 billion tons. All of the sediment loads carried by the rivers do not travel up to the bay, but a considerable portion is deposited inland causing aggradations of river beds leading to wandering and braiding of major rivers through a complex morphological process. Increase in bed level of the river systems of Bangladesh has introduced problems of reduction of the capacity of river to accommodate the flow; flooding propensity; frequent riverbank erosion due to prolonged intensive flooding; reduction of navigability; closure of off-takes of the distributaries due to insufficient flow; increased width of the river leading to hindrance in development activities, disasters to peoples' lives and properties.

For sustainable river management, The National Water Policy stressed the dredging and river training works for sustainable river management in Bangladesh. In 2009, a decision was taken to prepare a package programme for dredging of all the major rivers and land reclamation programmes. This lead to the formulation of the 'Capital (Pilot) Dredging of River System in Bangladesh (CDRSB) Project' by Bangladesh water Development Board (BWDB). CDRSB consists of 4 study components and 3 physical components.

(A): The study components are:

Component – 1: Feasibility Study of Capital Dredging and Sustainable River Management in Bangladesh (FSCD&SRMB).

Component – 2: Mathematical Morphological Modelling and Investigation in connection with the Sustainable River Management Plan of Main Rivers, Distributaries and Tributaries in Bangladesh.

Component – 3: Geo-morphological and Planform Studies with Environmental and Social Impact Assessment in connection with the Study of Capital Dredging and Sustainable River Management in Bangladesh.

Component – 4: Quality Control, Monitoring and Impact Assessment of Pilot Dredging of Jamuna River at 2 Locations from Sirajganj Hard Point to Dhaleswari Off-take (20 km) and near Nolin Bazar (2 km).

(B): The physical components are:

Component – 1: 2 km Pilot Dredging of Jamuna Right Bank at Nolin Bazar under Gopalpur Upazila of Tangail District.

Component – 2: 14 km Capital (Pilot) Dredging from Upstream of Sirajganj Hard Point to Upstream of Bangabandhu Bridge.

Component – 3: 6 km Capital (Pilot) Dredging from Downstream of Bangabandhu Bridge to Dhaleswari off-take.

The broad objectives of the dredging were:

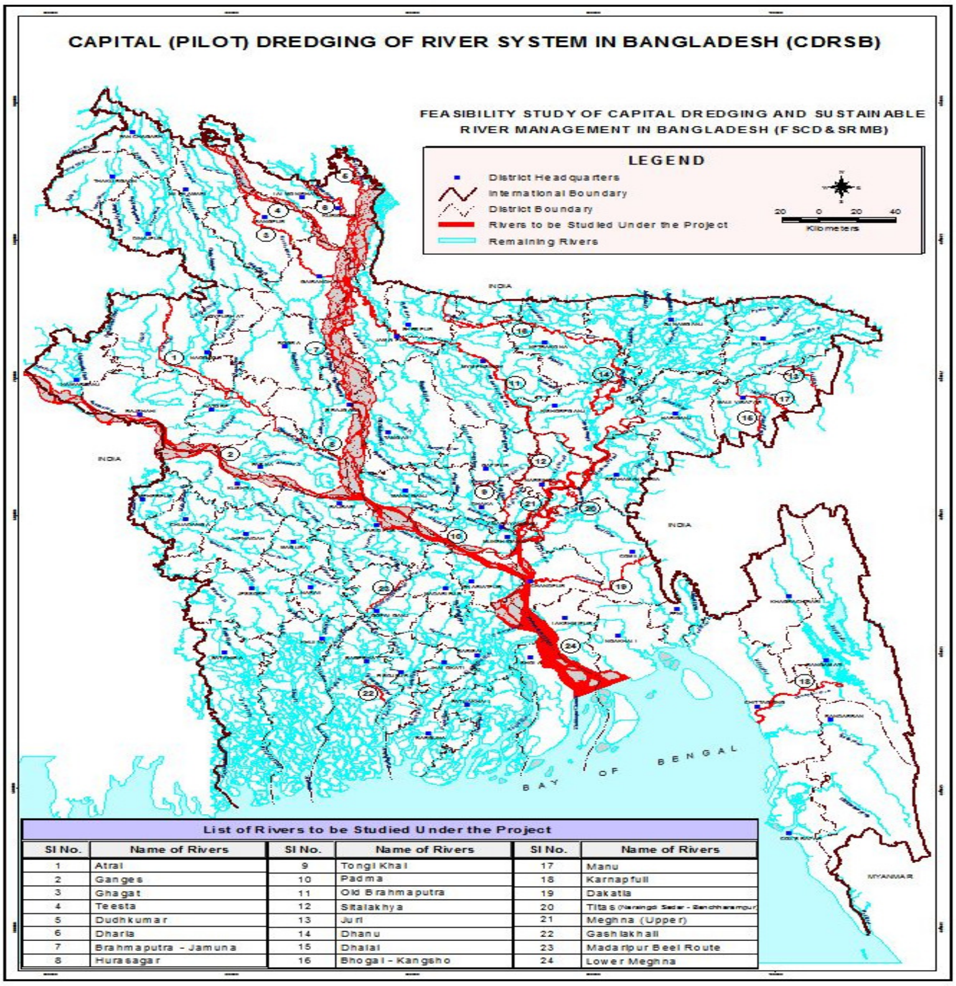
- To establish a channel by dredging around Sirajganj and concentrate the maximum flow along that channel.
- Ensure that Sirajganj hard point, its upstream and downstream area and west guide bund of Jamuna Bridge are less vulnerable to attack by erosion and deep scour.
- To divert the flow from the existing left anabranch of the Jamuna River for reducing erosion near Nalin Bazar and save existing Tarakandi-Bhuapur road cum flood control embankment.
- Ensure the future productive use of land reclaimed by the capital dredging works.

METHODOLOGY

Selection of Rivers for the Feasibility Study

During Feasibility Study of Capital Dredging and Sustainable River Management in Bangladesh (FSCD&SRMB) total 24 major and important rivers were studied to devise river management plan of major rivers, tributaries and distributaries for mitigation of flood and erosion management, to improve navigability and to augment dry season flow in the distributaries considering capital dredging and river training works (RTWs) and other interventions.

Thus 24 rivers to be studied were: (1) Atrai, (2) Ganges, (3) Ghagot, (4) Teesta, (5) Dudhkumar, (6) Dharla, (7) Brahmaputra-Jamuna, (8) Hurasagar, (9) Tongi Khal, (10) Padma, (11) Old Brahmaputra, (12) Sitalakhya, (13) Juri, (14) Dhanu, (15) Dhalai, (16) Bhogai-Kangsho, (17) Manu, (18) Karnafuli, (19) Dakatia, (20) Titas (Narsingdhi Sadar– Bancharampur), (21) Meghna (Upper), (22) Ghasiakhali, (23) Madaripur Beel Route, and (24) Lower Meghna.



List of Rivers to be Studied Under the Project					
Sl No.	Name of Rivers	Sl No.	Name of Rivers	Sl No.	Name of Rivers
1	Atrai	9	Tongi Khal	17	Manu
2	Ganges	10	Padma	18	Karnapfuli
3	Ghagat	11	Old Brahmaputra	19	Dakatia
4	Teesta	12	Sitalakhya	20	Titas (Narsingdi Sadar - Banchharampur)
5	Dudhkumar	13	Juri	21	Meghna (Upper)
6	Dharla	14	Dhanu	22	Gashiakhali
7	Brahmaputra - Jamuna	15	Dhalai	23	Madaripur Beel Route
8	Hurasagar	16	Bhogai - Kangsho	24	Lower Meghna

Fig 1: Locations of 24 rivers of FSCD & SRMB

Morphological Modeling

A two-dimensional morphological model was applied for the morphological analysis of the Jamuna River. It provided means of exploring the governing morpho-dynamic process in more detail form and it makes predictions of the effects of various options by varying different design sections and alignments. The model developed in the study "Mathematical Modeling and Morphological Forecast for Protection of Soilabari and adjacent areas of Sirajganj Town from Erosion of Jamuna River" was used as a base model of the study. This model was calibrated and validated with 2008 and 2009 monsoon data.

MIKE21C model was utilized by IWM to resolve the flow dynamics by solving the vertically integrated equations of continuity and conservation of momentum. The model was calibrated with 2010 monsoon (June-October) data and was validated at the end of 2011. The model was further validated with subsequent data collected from the project. The validated 2D morphological model was used to accomplish the expected prediction. The model simulation results were carried out considering "without dredging" and "with dredging" conditions for one monsoon ahead. In this connection, a moderate flood event (1 in 10 years) was analyzed. The hydrological year of 1995 was found as a moderate flood event from frequency analysis of observed Jamuna flow at Bahadurabad (1956-2010).

Fixation of Dredging Alignment

A series of options have been tested by the 2D model and finally, a suitable alignment had been selected on char in front of SHP [Fig. 2]. But due to land acquisition problem the present alternative alignment has been decided to review in 2D model. In new perspective, the alternate dredging alignment proposal was thoroughly discussed among resource persons of both IWM and BWDB. After discussion, simulation was made using the proposed alternate dredging alignment.

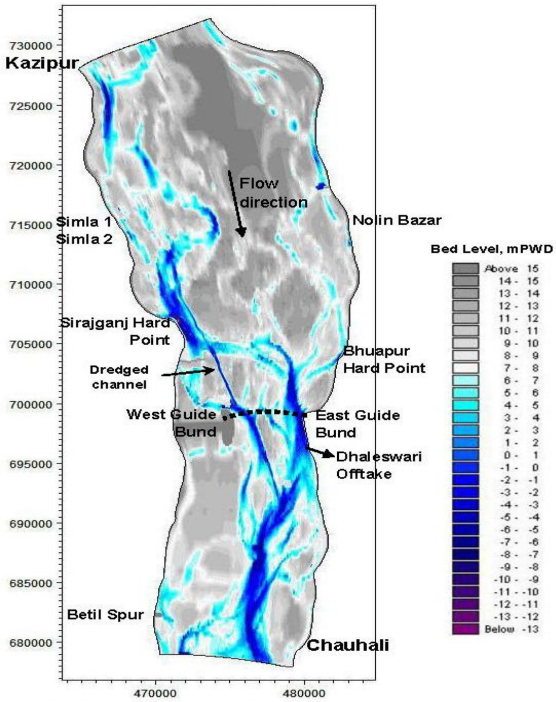


Fig 2: Study area showing model bathymetry based on survey in January 2011

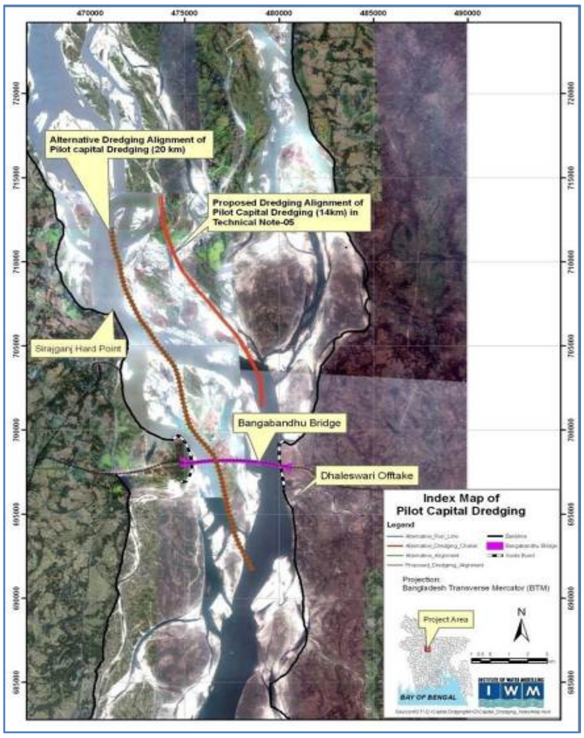


Fig 3: Fixation of dredging alignment

It was decided that dredging of 2 (two) km existing channel (inter connecting two branch) will be dredged to construct a closure to stop flow in the left anabranch, threatening the left bank near Nalin Bazar. The design features of the closure were 60m crest width and 1:4 side slopes with a crest level of 16.5mPWD.

Capital (Pilot) Dredging During 2011 and 2012

The capital dredging at Sirajganj Hard point (SHP) to Dhaleswari Offtake commenced in December, 2011 and continued up to June, 2012. The Capital (Pilot) dredging at Nalin Bazar was started in April, 2011. The dredging discontinued at the end of June, 2011 and work resumed again in December, 2011. The 2nd year dredging continued up to June 2012. 2 (two) km length of existing channel inter connecting two branches were dredged to build up a closure to stop flow in left channel near Nalin Bazar which was causing threat to Bhuapur road. The design features of dredged channel at Nalin Bazar were 120m bed width and 1:3 side slopes on both sides. The channel upstream bed level at the beginning and end was 1.70 and 0.50 mPWD respectively. The site at SHP was located from the hard point to Dhaleswari off take through Bangabandhu Bridge. The total length was 20km.The bottom width of design section was 120m, side slope 1:3 in both sides and longitudinal slope was 7cm/km. The channel upstream bed level at km 0.00 was 3mPWD and down stream bed level at km 14 was -2.40mPWD. The bed level at km 16 was 0.00mPWD and km 22 was -0.42mPWD.

Construction of Four Cross Bars

The closure was planned to be constructed with the dredged spoil. Model simulation was done incorporating 4km dredging at downstream and 3km dredging at upstream with 2 cross bars at Sailabari and 2 cross bar at downstream (Fig. 4).

The first year maintenance dredging and crossbar construction and protection were recommended for reducing erosion of Simla and Sailabari area in the upstream and ensuring long time safety of Sirajganj hard point as predicted in model output by IWM. In addition, a major consideration was the improvement of 16sq km of already reclaimed land after capital dredging of last year. Thus these cross bars needed proper protection to ensure long time safety. Thesecross bar properly designed as an earthen groyne fully protected with the combination of geobag and hard rock.

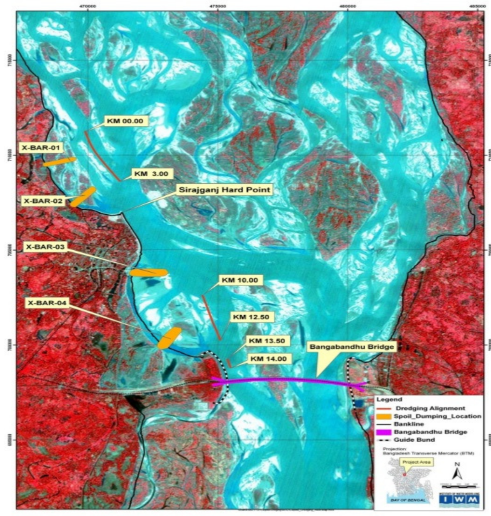


Fig. 4 : Locations of four cross bars

Observation on Capital Pilot Dredging in Jamuna

In the process of capital dredging at Sirajganj and Nalin Bazar it is seen that the flow diversion was effective through the new dredged channel as the channel was dredged but that the new channel cannot be sustained by dredging unless maintenance dredging is continued every year. To guide the flow in a defined channel and keeping the deep channel away from Sirajganj hard point four cross bars were constructed as per recommendation of the morphological model study.

Closure of left channel for diverting flow to stop erosion at Nalin Bazar

A 2 km dredging work was taken up at Nalin Bazaar in for closing a channel along the left bank of Jamuna River and diverting the flow away from an eroding bank nearing Bhuapur – Tarakanda highway. The length of the closure was about 1.5km. The closure dam width was designed with top width of 100m and was later revised to 30m but contractor could make it as only 20m. As a consequence the closure was washed away in June, 2012 by the flowing water. It showed that only dredging cannot make closures sustainable. Proper design section, proper slope and end protection work is to be completed well before rising of water level.

Fig. 5: Reclaimed land and location

Land reclamation among four cross bar (Groyne):

By using dredged material four cross bar are constructed along the left bank of Jamuna River. Due to these cross bar almost 16 sq. Km land has been reclaimed. For sustainability of this land, cross bars are protected using hard rock and geobag. Recently Bangladesh Economic Zone Authority (BEZA) has declared that they will use this reclaimed land as an economic zone.

CONCLUSIONS AND RECOMMENDATIONS

Success in sustainable management of rivers of Bangladesh will go a long way in ensuring security of life and better living conditions for its people. It is an inevitable fact that, future lean season in-flow of the rivers are going to be drastically reduced due to exogenous and endogenous interventions. Dry season flow reduction will jeopardize agriculture, fisheries, flora and fauna; navigation etc. River bed aggradations and consequent conveyance sections reduction will increase propensity of monsoon flooding and river bank erosion. These will have drastic negative impacts on natural environment and socio-economy of the country. Increase of run-of-the-river storage area to increase river's monsoon-season carrying or lean-season holding capacity will be required as part of any/all mitigatory measures. This is going to need decades of dredging.Sediment load of Jamuna River has predominant role in development of its bed and bank formation. The river regime frequently reshapes its section due to sand bar movement and it accelerates with the magnitude of flood. Dredging of a channel alone would not be sustainable unless and until the section of the river is duly optimized and trained by regular maintenance. The dredged channel shall have to be followed by maintenance dredging to facilitate the river flow in desired alignment. Partial dredging of a channel, without supportive measures will not be sustainable.
Capital (Pilot) Dredging was planned as a pilot case for enhancing knowledge and experience during dredging. Pilot Dredging was limited only for length of 20km having bed width 120m which is very partial (small) in respect of length and width of existing river. After the completion of pilot dredging of Jamuna River it can be conclude as follows:

- The river carries huge sediment load and channel shifts from one location to another. The siltation pattern of the river in different year shows dissimilarity. Siltation rate reveals that dredging without management of the river as a whole is not a sustainable solution for the river like Jamuna.
- Flowing anabranches in Jamuna can be closed in a planned way and diversion of flow is possible by the construction of strong cross bars. It was seen that due to closure of the right channel, the river has been adjusting gradually both upstream and downstream areas. Planned construction of cross-bars, bank protection work and dredging can divert the flow and automatically make the channel size as required by eroding chars and river bed.
- Partial dredging of channel is not sustainable
- The existing alignment of thalweg is preferable for dredging alignment as it disturbs the nature to the minimum and may be expected to be more sustainable;
- The velocity to be developed in dredged channel shall be such that it is within limits of non-scouring and non-silting range as far as possible.
- Dredging of channel alone would not be sustainable unless and until the section of the river is duly optimized and trained by regular maintenance. The dredged channel shall have to be followed by maintenance dredging to facilitate the river flow along the desired alignment;
- The dredged material management is a very important part of dredging. The dredged material disposal areas have to be protected from flowing back into the channel due to river current, rain water flow etc. Disposal of dredged material in specified locations and their protection will yeild good result. Dredged material should be dumped with an aim to reclaim the land to a height suitable for cultivation, homestead and industry.

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SIMULATION ON FLOW PATTERN FOR 90° CONVERGENT CHANNEL WITHOUT SECONDARY CURRENT

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ABSTRACT

In nature, convergent type open-channel confluences are common as well as in hydraulic structures and have a significant role in fluvial channel processes. Any natural open-channel confluence can be both convergent and divergent in nature during flow, if the confluence zone is under tidal influence. Flow pattern at these vicinities are greatly influenced by three-dimensional effects, such as secondary flows induced by channel streamline curvature. These types of three dimensional effects are very complex in nature but describe the flow uncertainty very well in an open-channel confluence. To develop a 3D model of these types of complexity, both physically and numerically, is very time consuming and expensive enough. So, developing depth-averaged 2D model can be a well solution of avoiding such time consuming and expensive complexity. But this type of depth-averaged 2D model may be more meaningful and effective if different complex variables are considered during modeling. In this study, such a variable like secondary flow is not considered, to observe the deviation from accuracy of modeling, by comparing the simulated result with experimental and developed other models considering secondary flow. The simulation process is performed by River 2Dsolver provided by iRIC software application. After analysis, it is found that present study agrees with experimental result, as well as, developed other two models considering secondary flow, at middle of the channel section. But over-estimates at the channel boundary, where secondary flow is the main reason of energy loss of fluid flow.

Keywords: Convergent; depth-averaged 2D model; open-channel flow; secondary current; hydraulic structures.

INTRODUCTION

Fluid flow in an open channel confluence is very complex in nature. Flow features in these regions are complicated and are characterized with one separation zone or recirculation zone immediately downstream of the confluence in the inner bank side and one contracted flow region in the outer bank side (Thanh et al., 2010). According to Weber et al. (2001) the distinctive characteristics of a sharp-edged, open-channel junction flow are a zone of separation immediately downstream of the junction branch channel, a contracted flow region in the main channel due to the separation zone, a stagnation point immediately upstream of the junction, a shear plane developed between the two combining flows, and an increase in depth from the downstream channel to the upstream contributing channels. Taylor (1944) first thought about the topic of open-channel junction flow by focusing on the depth ratio between the upstream branches and the downstream channel. Hsu et al. 1998, described a combined energy momentum approach to solve for the depth ratio, which was dependent upon a number of junction variables. Gurram et al. (1997), provided a momentum analysis, which produced an equation for the prediction of depth increases across the junction. Ramamurthy et al. (1988) and Hager (1989) reported extensive studies and methods for the prediction of the depth increase in a transitional flow junction. Kumar (1993) described a refinement and simplification of the predictive equation by Hager.

Weber et al., 2001, Huang et al., 2002, Qing-Yuan et al., 2009, show that flow in a junction are three-dimensional with predominant secondary currents of the first kind induced by curvature of the streamlines in comparison with the ones driven by turbulence. Generally 2D models do not consider this type of 3D flow variables, which brings result slightly erroneous. Thanh et al., 2010, shows that 2D models developed by considering 3D effect like secondary flow, brings more accurate result. Here in present study, such a 3D variable as secondary current does not consider during modeling, to observe the level of error, compared with experimental result by Weber et al., 2001 and simulated result by Thanh et al., 2010, who considers secondary current for modelling.

METHODOLOGY

In this experiment by Weber et al. (2001), the channel consists of a main channel of 21.946m in length and a branch channel of 3.658 m in length located 5.486m downstream of the entrance of the main channel. Both these channels have the same width (W) of 0.914m. The total combined flow discharge (Q_t) is 0.170m^3/s and the downstream water depth is held constant at 0.296m. With these conditions, the averaged downstream velocity (U_0) is 0.628 m/s corresponding to a Froude number of 0.37. A total of two runs of the experiments were conducted for two various values of q* defined as the ratio of the upstream main channel flow (Q_m) to the total flow (Q_t). In this study, two cases, q* = 0.25, that is, Q_m (main channel discharge) = 0.043 m^3/s and Q_b (branch discharge) = 0.127 m^3/s and q* = 0.75 (Q_m = 0.127 m^3/s and Q_b = 0.043 m^3/s), are selected for computations. During comparison every dimension is normalized by dividing channel width (W) 0.914m and velocity is normalized by dividing averaged downstream velocity (U_0) 0.628 m/s. During simulation all this flow criteria is adopted.

Depth averaged 2D is developed by River2d solver provided by iRIC software application. Computer used for simulation purpose is arranged by 8 gigabyte RAM and 2 gigabyte graphics-card with 1 terabyte hard-disk drive, which takes more or less 45 minutes for each simulation. In the present study, concept of geometric similarity is applied for better result. During simulation by River2D, very shallow depth of flow as compared with Weber et al., 2001 and Thanh et al., 2010, brings erroneous result. The condition of geometric similarity is expressed in Table 1 with prototype (p) (Weber et al., 2001), where L, A, V stands for length, area and volume respectively.

Table 1: Conditions of geometric similarity of present model (m)

Length scale ratio (L_m/L_p)	4
Area scale ratio (A_m/A_p)	16
Volume scale ratio (V_m/V_p)	64

Table 2: Calculation condition for numerical solution (present study)

Start Time	0 second
Final Time	1000 second
Initial Time Increment	0.01 second
Maximum Time Increment	10 second
Goal Solution Change	0.1
Plot Increment	1
Solver Type	Direct (Active Zone)
Jacobian Type	Numerical
Upwind Coefficient	0.5
Maximum Depth to Groundwater Flow	0.01
Groundwater Transmissivity	0.1
Groundwater Storativity	1
Eddy Viscosity Coefficient – epsilon 1	0
Eddy Viscosity Coefficient – epsilon 3	0.1
Upstream Water Surface Elevation	1.187 meter
Downstream Water Surface Elevation	1.184 meter
Channel Roughness	0.01

In this numerical solution, Bousinessq type eddy viscosity is used for the transverse shear modeling. The Finite Element Method used in River2D's hydrodynamic model, based on the Streamline Upwind Petrov-Galerkin weighted residual formulation. Calculation condition is represented in for Table 2.During discretization TIN type of grid is created as represented in following Fig. 1, where number of grids are 6765.

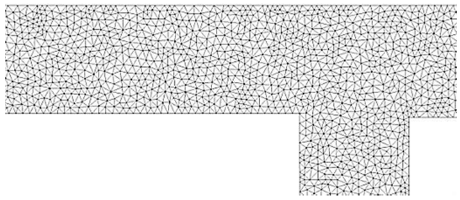

Fig. 1: Grid shape for numerical simulation in present study

Equation for conservation of mass:

$$\frac{\partial H}{\partial t}+\frac{\partial q_x}{\partial x}+\frac{\partial q_y}{\partial y}=0 \tag{1}$$

Conservation of x-direction momentum:

$$\frac{\partial q_x}{\partial t}+\frac{\partial}{\partial x}(Uq_x)+\frac{\partial}{\partial y}(Vq_x)+\frac{g}{2}\frac{\partial}{\partial x}H^2=gH(S_{0x}-S_{fx})+\frac{1}{\rho}\left(\frac{\partial}{\partial x}(H\tau_{xx})\right)+\frac{1}{\rho}\left(\frac{\partial}{\partial y}(H\tau_{xy})\right) \tag{2}$$

Conservation of y-direction momentum:

$$\frac{\partial q_y}{\partial t}+\frac{\partial}{\partial x}(Uq_y)+\frac{\partial}{\partial y}(Vq_y)+\frac{g}{2}\frac{\partial}{\partial y}H^2=gH(S_{0y}-S_{fy})+\frac{1}{\rho}\left(\frac{\partial}{\partial x}(H\tau_{yx})\right)+\frac{1}{\rho}\left(\frac{\partial}{\partial y}(H\tau_{yy})\right) \tag{3}$$

The friction slope is termed as

$$S_{fx}=\frac{\tau_{bx}}{\rho gH}=\frac{\sqrt{U^2+V^2}}{gHC_s^2}U \tag{4}$$

Nondimensional Chezy coefficient

$$C_s=5.75\log\left(12\frac{H}{k_s}\right) \tag{5}$$

Depth-averaged transverse turbulent shear stresses are modeled with a Boussinesq type eddy viscosity formulation. For example:

$$\tau_{xy}=\nu_t\left(\frac{\partial U}{\partial y}+\frac{\partial V}{\partial x}\right) \tag{6}$$

For wet/dry area treatment, specifically, the water mass conservation equation is replaced by:

$$\frac{\partial H}{\partial t}=\frac{T}{S}\left(\frac{\partial^2}{\partial x^2}(H+z_b)+\frac{\partial^2}{\partial y^2}(H+z_b)\right) \tag{7}$$

Where, H is the depth of flow, U and V are the depth averaged velocities in the x and y coordinate directions respectively. q_x and q_y are the respective discharge intensities, g is the acceleration due to gravity and ρ is the density of water. S_{0x} and S_{0y} are the bed slopes in the x and y directions; S_{fx} and S_{fy} are the corresponding friction slopes. $\tau_{xx}, \tau_{xy}, \tau_{yx}$, and τ_{yy} are the components of the horizontal turbulent stress tensor, τ_{bx} is the bed shear stress in the x direction, ν_t is the eddy viscosity coefficient, T is the transmissivity, S is the storativity of the artificial aquifer and z_b is the ground surface elevation.

RESULTS AND DISCUSSION

In Fig. 2 velocity distribution contour for flow condition q*= 0.25 and q* = 0.75 is expressed. Fig. 3 shows the streamwise velocity component profiles at some cross-sections along the post-confluence main channel for q* = 0.25, while Fig. 4 depicts those at the same places for q* = 0.75. All velocity values are averaged over the depth.

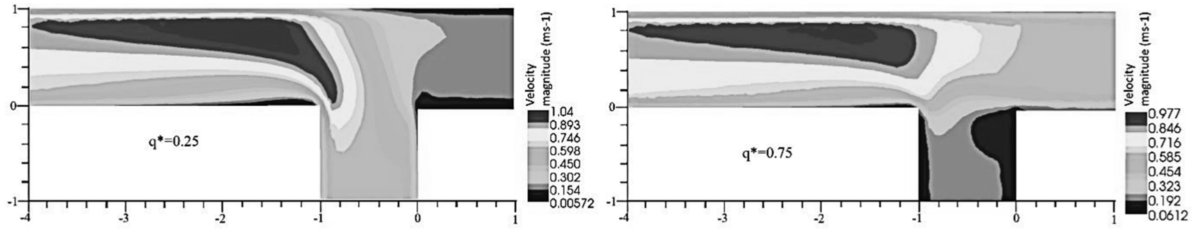

Fig. 2: Velocity distribution contour for flow condition q*= 0.25 and q* = 0.75. Distance along x-axis and y-axis is normalized in present study

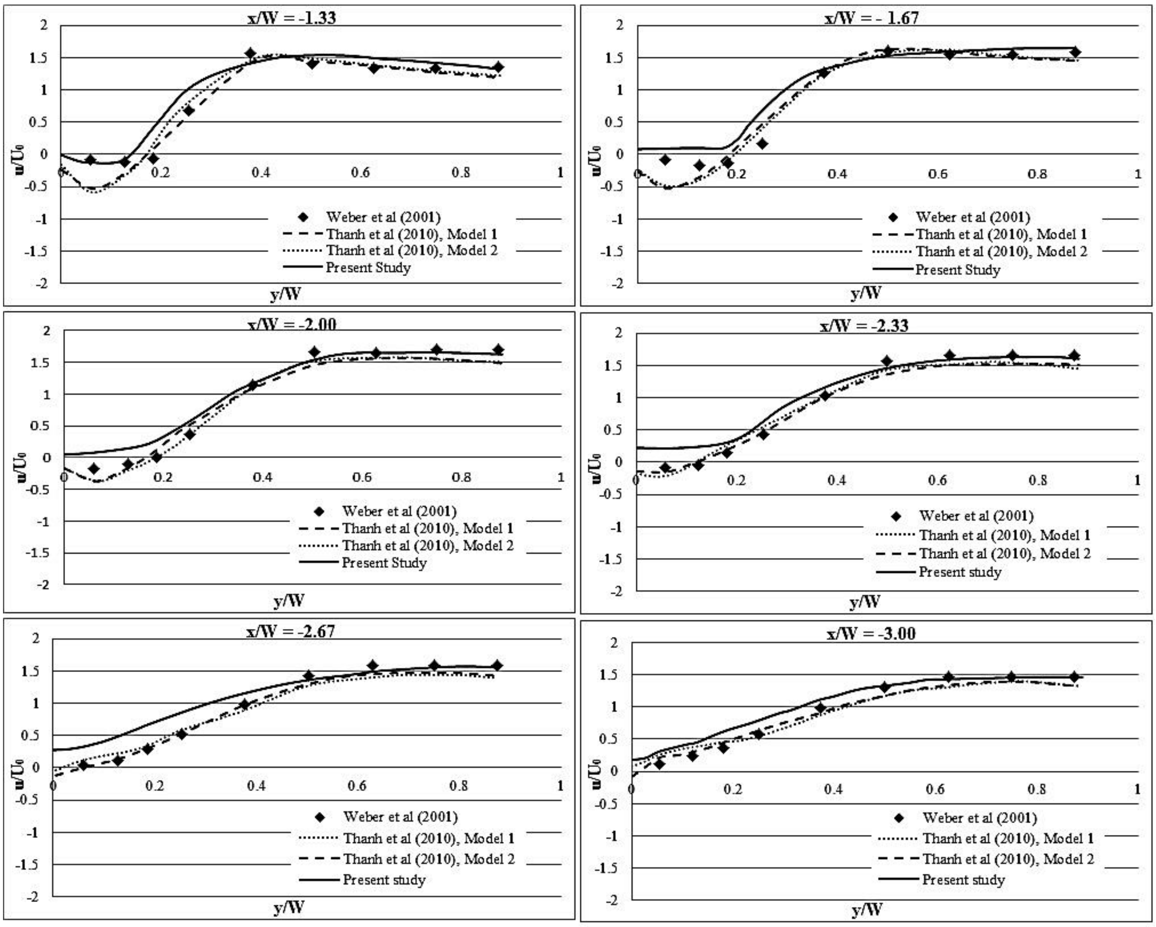

Fig. 3: Comparison of longitudinal velocity component at some locations for q* = 0.25

Positive values in Fig. 3 and Fig. 4 indicate downstream motion, while negative ones show upstream motion. It is observed in Fig. 3 that the results obtained from Thanh et al (2010) performed Model 1 and Model 2 agree well with the experimental ones, except in the beginning reach of the separation zone (In this reach, all models by Thanh et al, 2010 over-predict velocity). However, the similar agreement is not obtained with present study, because in preset study, length of the separation zone is under-predicted. The separation zone generated in present study seems to drop somewhere after the section of x/W = -1.33, while it, in reality, extends to a place around the section of x/W=-1.67. This can be realized, because velocity direction in the region near the inner bank of the main channel changes between the section of x/W=-1.33 and the section of x/W= -1.67 and the velocity profile in this region has a tendency to be flattened in the next sections as seen in Fig. 3. The reason for this shortcoming of present study, as explained above, is due to not considering effects of secondary current. Unlike the case of q* = 0.25, Fig. 4 shows that there is no significant difference in velocity profiles as well as in location where the separation zone drops between the results with present study and those two models by Thanh et al (2010) for q* = 0.75. It indicates that, if q* is large, secondary current is weak. Moreover in present study secondary current is not considered but has no significant change on flow pattern as compared with Thanh et al. (2010).

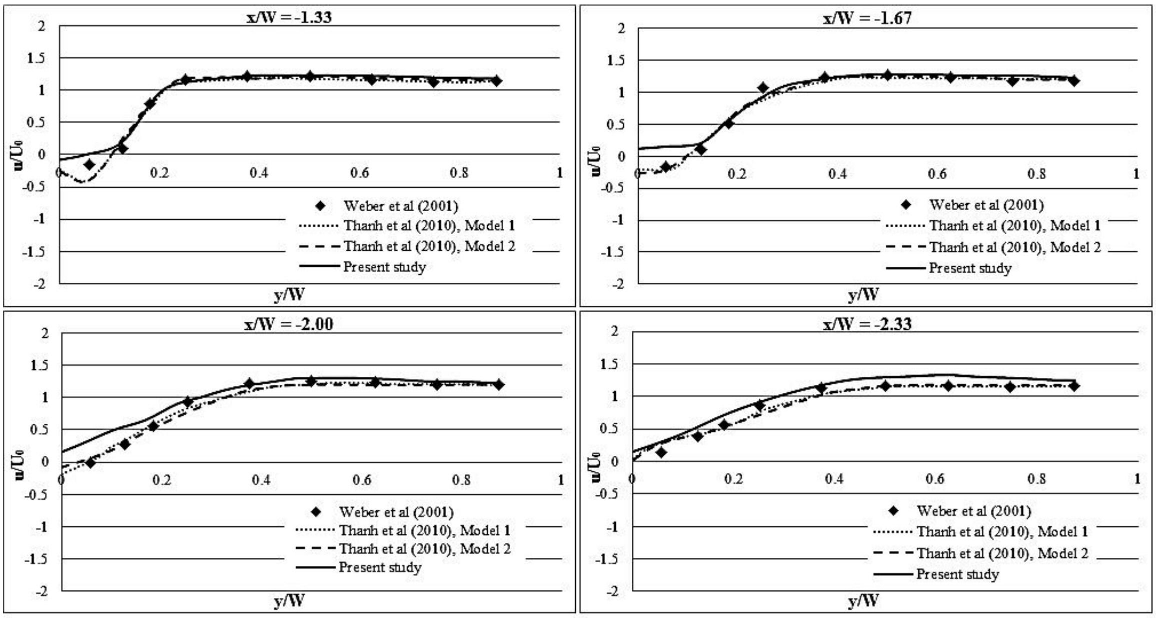

Fig. 4: Comparison of longitudinal velocity component at some locations for q* = 0.75

From present study, it is fairly clear that, energy of flow reduces along the boundary of the channel due to secondary current. Also secondary current effects the length of separation zone, not its position. Because models developed by Thanh et al. (2010) and present study show that separation zone starts at the same position, only it shows an elongated shape when secondary current is considered. So considering secondary current is a good means of having correct simulated result of experimental one. But results are over predicted by models considering secondary current at the starting point of separation zone, while present study shows more accurate result without considering secondary current. Secondary current is an important phenomenon that should be considered during flow model, as it is responsible for energy loss along the boundary of the channel. It is very effective for modeling flow pattern near the channel boundary. Because it is clear that models developed by Thanh et al. (2010) considering secondary current and present study without considering secondary current shows almost same result at the middle channel, where secondary current is not effective enough. But over activeness of secondary current model at the starting point of separation zone should be minimized, so that result may be more accurate.

CONCLUSIONS

From all above study, it is obtained that, during 2D modeling, variables which creates 3D effects, must be considered. This type of variable like secondary current, acts as a catalyst to change the flow pattern and responsible for loosing flow energy near the channel boundary. Also this effect elongated the mixing length. If this type of variable is not considered during 2D modeling, then accuracy level of the solution decreases. But during modeling over prediction of the expected result also brings inaccuracy when secondary current is being considered. So modeling of flow in a convergent type open channel confluence, especially flow in separation zone and near channel boundary should be more sophisticated.

ACKNOWLEDGMENTS
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TIDAL MEETING ZONES AND THEIR IMPLICATION IN LAND RECLAMATION IN THE MEGHNA ESTUARY - A NUMERICAL APPROACH

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ABSTRACT

The Meghna Estuary of Bangladesh experiences dynamic morphological changes due to heavy sediment discharge from the Ganges, Brahmaputra and upper Meghna Rivers with annual rate of nearly a billion tons. Various physical factors such as: river discharges and tidal circulations also affect the estuary mouth. On the other hand, tidal current itself is affected by the dynamic morphological changes. Thus, it is essential to understand distinct features of tides and flow discharges along the morphologically active chars and channels. The present paper focuses on the hydrodynamic characteristics along the tidal meeting zones in Sandwip-Urirchar-Jahaijjer char area with an implementation of cross-dams. Cross-dam is a physical intervention to restrict the natural flow of a stream or river. For Bangladesh, it would require the establishment of structures like cross dam to speed up the silt deposition pace in accreted or nearly accreted areas. To understand the effects of cross-dams and to explore the hydrodynamic parameters, a two-dimensional hydrodynamic model has been developed using Delft3D. Model results show that flow as well as velocity has been affected immensely as a result of construction of cross-dams which may help in reclaiming new land in the Meghna Estuary.

Keywords: Tide; Tidal meeting zone; Cross-dam; Numerical model; Delft3D; Meghna Estuary

INTRODUCTION

The mega delta of the Ganges-Brahmaputra-Meghna (GBM) river system is remarked as third in terms of discharge (40,000 m^3/sec) and first in terms of sediment discharge (about 1 billion tons) respectively (Milliman and Meade, 1983). The combined flow generated from the GBM basins is drained into the Bay of Bengal through the lower Meghna River and estuarine system of the delta, along with multifarious cross connecting channels of the south-west region of Bangladesh (Islam et al., 1999). During pre- and post-monsoon period, lower Meghna estuary can be divided into 3 sub-units i.e. Tetulia channel, west Shahbazpur channel and west Hatiya channels in the sense that river outflow dominates over the tidal inflow. The east Shahbajpur and the west Hatiya channels can be termed as 'fluvio-tidal', and the east Hatiya, the Shahbazpur and Sandwip channels can be termed as 'tidal' according to the interactions between the river discharge and tidal volume moving through the channels. The 'fluvial' and the 'fluvio-tidal' sub-units act as a tidal river with very high discharges in the monsoon whereas the 'tidal' unit behaves as a tidal estuary without significant fresh water discharge from the Feni River. Moreover, morphologically this zone is immensely active due to continuous and gradual natural process of land accretion and erosion (MoWR, 1997). To accommodate rapid growing population and to boost up agricultural production more land is needed. In these circumstances it is seen that physical intervention is needed in order to accelerate the rate and area.Sediment distribution of both coarse and fine fractions in the Meghna estuary is largely influenced by residual current which is primarily dictated by the tidal currents. Also, the other important factor which can influence sediment distribution especially in the Meghna estuary is salinity because a major fraction of the sediments in the estuary are fine graded. The salinity distribution again is largely affected by the interaction between highly varying fresh water inflow from the rivers and the flow distribution between different channels along the lower Meghna River. So, the investigation of tidal characteristics which is essentially influenced by the morphologic changes of the Meghna estuary is important. The tidal characteristics of the Meghna estuary in relation to its morphological changes were represented by (Hussain et al., 2013).

In Bangladesh, land reclamation by closure or cross-dam construction in order to promote accretion process started in 1956-57. Noakhali Cross-dam-1 having 13 km was the first such dam built over a dying branch of the Meghna River. The second cross dam having 30 km length was constructed in 1964 connecting Char Jabbar Island to the Noakhali mainland. About 1,000 sq km land were reclaimed due to the construction of these two cross-dams. To assess the potential of land reclamation in the Meghna estuary, Land Reclamation Project (LRP) and Meghna Estuary Study (MES) were carried out. Based on the LRP and the MES findings, Bangladesh Water Development Board made a priority list of 19 potential cross-dam sites for accelerating the natural processes of land accretion. In this study, three cross-dams have been considered at the middle of three channels to inspect the effects on hydrodynamic characteristics along the channels through a numerical model. The present study uses Delft3D modelling suit to model hydrodynamics and to find out the possible zones of land reclamation within the study area.

STUDY AREA

As the flow of the drainage channels from Noakhali region (Feni, Little Feni, Bamni rivers and Noakhali Khal) plays an insignificant role on the hydrodynamics, the Jahaijjer char and Urir char area are mostly tide dominated. This area is also influenced by monsoon flow through Lower Meghna River. Progressing at an angle to the Chittagong coast this tide creates a funnelling effect along the coast with progressively higher tidal ranges through Sandwip channel. Also in the estuary and around the east and west coasts of the Sandwip Island and Hatiya channels show that some reflection of the tidal waves, contributing to the increase of tidal range around the northeast and northwest of Sandwip Island. Following the hydrodynamic modelling this study shows a possible application of implementation of cross-dam for predicting the variation between the tidal meeting zones along Jahaijjer char-Urir char-Sandwip channel. Fig. 1 is displaying the Meghna estuary and surrounding channels which are considered as the area for the model study.

HYDRODYNAMIC MODELING

Model Setup

A two-dimensional, depth averaged hydrodynamic model of Bay of Bengal (BoB) using open source software Delft3D has been applied in this study. For the development of the tidal hydrodynamic model, the selected domain has been divided into approximately 27400 grid cells.

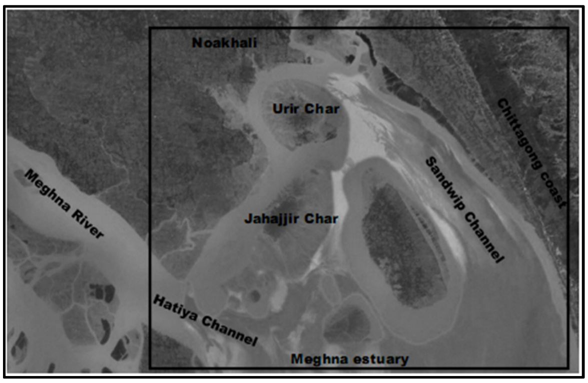

Fig. 1. The location of tidal meeting zones along the Meghna estuary.

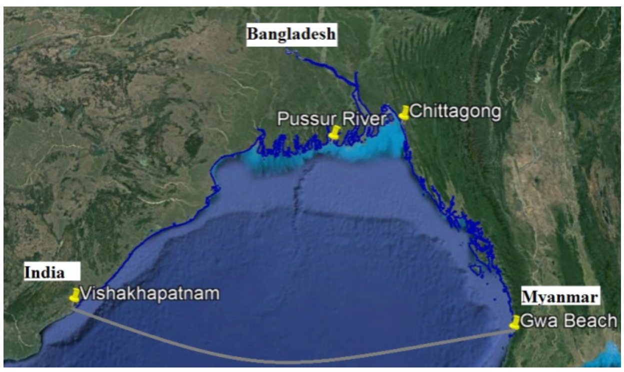

Fig. 2. An overview of the model domain of Bay of Bengal

A higher resolution is provided near the sharp coastlines of Bangladesh in order to obtain detailed information of the hydrodynamics in that area. Sizes of the grids are 100 m ~ 200 m near the Bengal coast, which is approximately around 10 km ~ 15 km near open boundaries. The bathymetry was collected from the Open Access General Bathymetric Chart of the Oceans (GEBCO) and inland data collected from Bangladesh Water Development Board. The geographical extent of the model is shown in Fig 2. The model defines three open boundaries: one in Padma River at Baruria and another one in upper Meghna River at Bhairab- both are located in the north and the other boundary is in the South that extends from Vishakhapatnam, India to Gwa beach, Myanmar [Fig. 3].The northern boundaries (i.e. Bruria and upper Meghna River) were defined by fresh water discharges collected from the BWDB. Whereas in the southern boundary the model was forced at the open boundaries with the sea-surface heights collected from TPXO 7.2 global inverse tide Model.

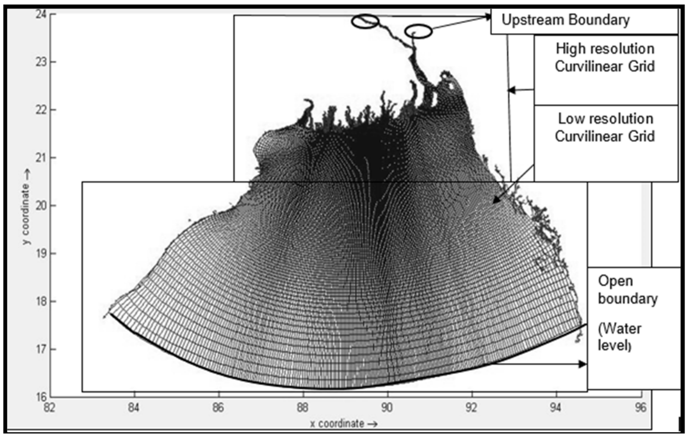

Fig.3. Computational mesh of the Bay of Bengal model domain representing upstream and downstream boundaries

Model Validation

The developed two-dimensional hydrodynamic model was validated against measured water level at different locations for the year 2015 considering February-March as dry period and August-October as monsoon period. Water level data of Vishakhapatnam, Kalinga Patnam, Pussur River, Chittagong and Akyub station were collected from Delft Dashboard, which are stored from the International Hydrographic Organization (IHO). Water level data of several other stations i.e. Khepupara, Charchanga, Sandwip, Kutubdia, Cox's bazar and Saint Martin were collected from Bangladesh Inland Water Transport Authority (BIWTA). Sample validation plot of Pussur River and Vishakhapatnam are displayed in Fig. 4.

RESULT AND DISCUSSION

Tide, Current speed and discharge influence the hydrodynamic condition along the coastal zones of Bangladesh. Various morphological changes along the coastal zones eventuate due to the interactions of various hydrodynamic forces active in the estuary. During dry season tidal action becomes stronger and dominates water flow due to the upland freshwater inflow through the Meghna River into the Bay of Bengal. The lowest velocities of about 0.25-0.50 m/s are found in the upper part of the lower Meghna River. The flow from the drainage channels from Noakhali region (Little Feni River) plays an insignificant role on the hydrodynamics of the area around Urir char-Jahaijjer char-Sandwip channel. During the monsoon season, this area is also influenced by the flow through lower Meghna River. On the other hand, during dry seasons this area is mostly tide dominated.

Impact analysis of the potential Cross-dams

From the depth-average velocity plot as displayed in Fig. 6, it is observed that maximum velocity found around the Sandwip channel during both dry and monsoon period than around Urir char channel. There are three tidal meeting zones are found in the Sandwip-Jahaijjer char-Urir Char area where velocities are remarkably lower, which results in sedimentation on channel bed. Fig. 6 represents the tidal meeting zones and possible cross-dam locations within the area.

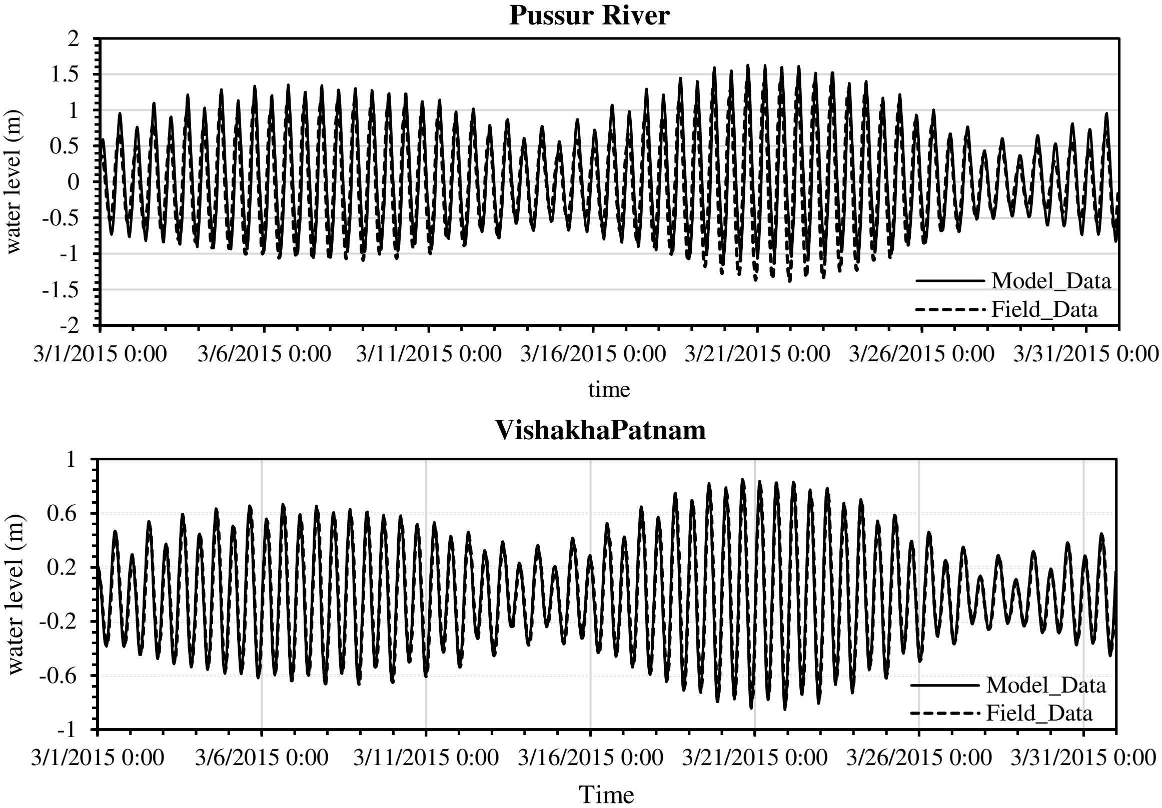

Fig. 4. Comparison of water level between model result and field data at Pussur River (upper panel) and Vishakhapatnam (lower panel) during dry season (March, 2015).

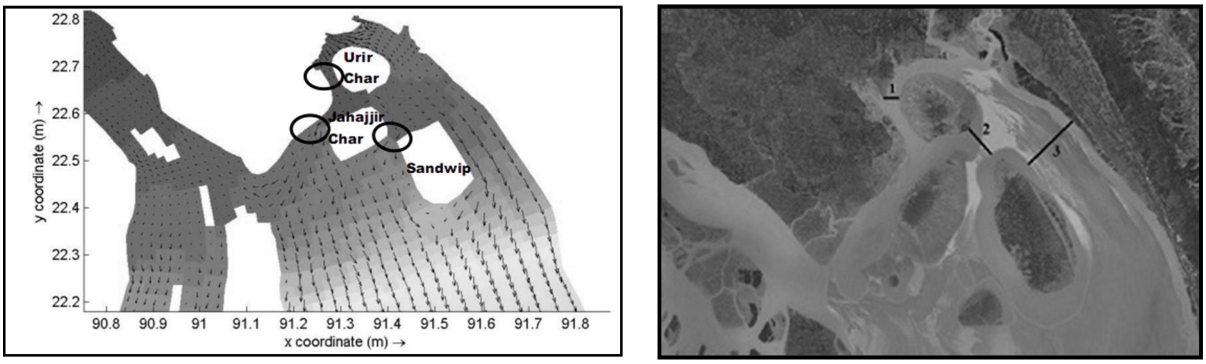

Fig. 5. Left panel: The location of tidal meeting zones without Cross-dam. Right panel: The location of tidal meeting zones with Cross-dam options such as option-1, option-2 and option-3

For the reduction of erosion of the char by decreasing the velocity and facilitate the connectivity of the char with the main land, these tidal meeting zones are the potential locations for cross-dam. Cross-dam can accelerate natural accretion, which will result in reducing erosion of the char. Current speed variation along the tidal meeting zone during dry season considering without and with cross-dam (options 1, 2 and 3) are displayed in Figure 6 during dry season. Without cross dam implementation, depth averaged velocity in Sandwip channel ranges 0.5-0.9 m/s during dry season and 0.8-1.4 m/s during monsoon period which is shown in Table 1. These values remarkably decreased by cross-dam 3 for both Sandwip channel and Urir char. As the flood current is stronger for every situation, this region can be said as flood dominant. Flood velocity exceeds ebb velocity which would induce suspended and bed load residual transport of coarse sediments towards land. During monsoon period it ranges between 0.5-0.75 m/s for Sandwip and 0.1-0.20

m/s for Urir char. Thus, it can be a better option for land reclamation in between Urir char and Jahaijjer char area. At the same time, these values increased by cross-dam 2 option. The velocity values are found low after the implementation of cross-dam 1.

Without cross-dam impact the total discharge is highest in both dry and monsoon period along the Sandwip channel than Urir char, which ranges between 32000-42000 m^3/s as shown in Table 2. Implementation of cross-dam 3 can reduce this range into 7000-21000, which can occur due to sedimentation. Meanwhile, it ranges between 4500-1000 m^3/s in Urir char area during dry and monsoon season without cross-dam impact. Cross-dam 1 increases the discharge rate remarkably in Urir char area, which ranges between 9000-15000 m^3/s. Cross-dam 2 keeps stability in between Urir Char and Sandwip channel.

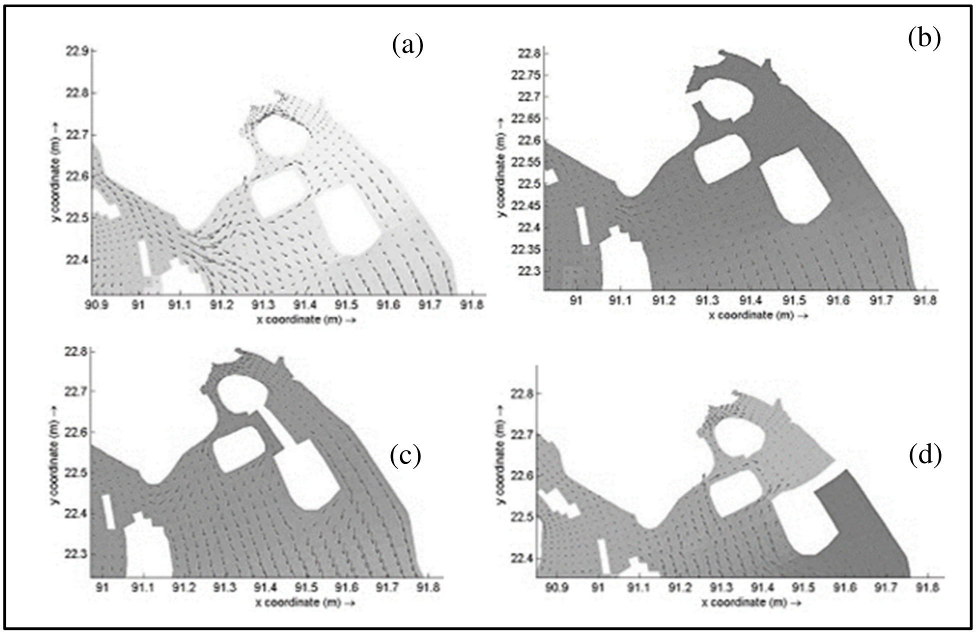

Fig. 6. Qualitative diagram of velocity vectors during dry season around Sandwip-Jahaijjer char-Urir char area with (b, c, d) and without (a) cross-dam.

Table 1: Depth averaged velocity variation for both dry and monsoon period

Design Parameter	Season	Tidal Period	Without Cross-Dam		Cross Dam Option	Season	Tidal Period	Sandwip Channel	Urir Char
			Sandwip Channel	Urir char					
Max. Depth avg. velocity (m/s)	Dry	Flood	0.9	0.2	Cross Dam-1	Dry	Flood	1.0	0.20
							Ebb	0.6	0.04
						Monsoon	Flood	1.4	0.6
		Ebb	0.5	0.04			Ebb	0.9	0.05
					Cross Dam-2	Dry	Flood	0.9	0.70
							Ebb	0.6	0.05
	Monsoon	Flood	1.4	0.6		Monsoon	Flood	1.45	0.80
							Ebb	0.85	0.10
					Cross Dam-3	Dry	Flood	0.50	0.185
		Ebb	0.8	0.05			Ebb	0.20	0.05
						Monsoon	Flood	0.75	0.20
							Ebb	0.50	0.10

Table 2: Discharge variation for the Sandwip channel and Urir char

<table>
<tr><th rowspan="2">Design Parameter</th><th rowspan="2">Season</th><th rowspan="2">Tidal Period</th><th colspan="2">Without Cross-Dam</th><th rowspan="2">Cross Dam Option</th><th rowspan="2">Season</th><th rowspan="2">Tidal Period</th><th rowspan="2">Sandwip Channel</th><th rowspan="2">Urir Char</th></tr>
<tr><th>Sandwip channel</th><th>Urir char</th></tr>
<tr><td rowspan="12">Max. Discharge (m^3/s)</td><td rowspan="6">Dry</td><td rowspan="3">Flood</td><td rowspan="3">38000</td><td rowspan="3">8000</td><td rowspan="4">Cross-Dam-1</td><td rowspan="2">Dry</td><td>Flood</td><td>38000</td><td>10000</td></tr>
<tr><td>Ebb</td><td>20000</td><td>11000</td></tr>
<tr><td rowspan="2">Monsoon</td><td>Flood</td><td>45000</td><td>15000</td></tr>
<tr><td rowspan="3">Ebb</td><td rowspan="3">32000</td><td rowspan="3">4500</td><td>Ebb</td><td>22000</td><td>9000</td></tr>
<tr><td rowspan="4">Cross Dam-2</td><td rowspan="2">Dry</td><td>Flood</td><td>35000</td><td>8000</td></tr>
<tr><td>Ebb</td><td>18000</td><td>12000</td></tr>
<tr><td rowspan="6">Monsoon</td><td rowspan="3">Flood</td><td rowspan="3">42000</td><td rowspan="3">10000</td><td rowspan="2">Monsoon</td><td>Flood</td><td>45000</td><td>9000</td></tr>
<tr><td>Ebb</td><td>22000</td><td>11000</td></tr>
<tr><td rowspan="4">Cross Dam-3</td><td rowspan="2">Dry</td><td>Flood</td><td>17000</td><td>2200</td></tr>
<tr><td rowspan="3">Ebb</td><td rowspan="3">38000</td><td rowspan="3">5000</td><td>Ebb</td><td>7000</td><td>800</td></tr>
<tr><td rowspan="2">Monsoon</td><td>Flood</td><td>21000</td><td>2500</td></tr>
<tr><td>Ebb</td><td>12000</td><td>1000</td></tr>
</table>

CONCLUSION

A two dimensional depth-average hydrodynamic model based on non-linear shallow water wave equations was applied to investigate the tidal meeting zone and their characteristics after validation with observed water level data. The accuracy of model was estimated using statistical analysis by Skill and RMSE. Skill values for undertaken stations were exceeded 80% and RMSE values were less than 1, which remarks the good performance of the developed model. To explore the characteristics of tidal meeting zones before and after consideration of three cross-dams, observed total flow and depth average velocity data were collected from around Urir Char, Jahijjer char and Sandwip channel at the north-eastern part of the Meghna Estuary. It has been found that a tidal meeting zone exists between these three channels and along the northern channel of Urir Char Island flood velocity exceeds ebb velocity which would induce residual transport of coarse sediments towards land. Cross dam-2 has been accelerating total flow and depth average velocity between Urir char and Sandwip channel.

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A STUDY ON THE FLOOD DAMAGE AND MITIGATION MEASURES OF FLOODS OCCURRING IN BANGLADESH AT THE LAST DECADE

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ABSTRACT
Bangladesh is a riverine country with more than 400 rivers. Most of the rivers of this country are in the Ganges-Brahmaputra-Meghna basin. Flood is a common phenomenon for this country. Although monsoon flood is the most severe in terms of frequency and damage, the impact of other types of flood like flash flood is not negligible. For the study, the flood data was collected for last 10 years (2006-2015). The secondary hydrologic data (discharge, highest and lowest water level) was collected from the Bangladesh Water Development Board (BWDB) and Bangladesh Meteorological Department (BMD) while data regarding disasters of flood was collected from Department of Disaster Management (DDM). From the analysis of flood data, it was found that the country experienced a maximum rainfall of 2176mm in 2007. Due to the effects of massive and frequent rainfall coupled with sedimentation and erosion, flood damage is a recurring occurrence in Bangladesh. Many people became homeless, lost their agricultural products and livestock due to flood. In 2007, 2851559 families with 1335382 acres of crop and 1459 livestock, 563 institutions got damaged. Flood brought a massive infrastructural damage at some places. The death and health damage to flood affected people is indescribable. In order to mitigate the devastating effects of flood, two mitigation approaches can be made- one is the non-structural ways like: afforestation to protect river bank. The other approach is the structural measures like dams, regulators, embankments, flood ways to divert flow etc. The higher income group of the country along with the NGO's can come forward to take necessary non-structural measures while the Local administration should take necessary steps for construction of flood fighting structures. Mass awareness among people can be an effective measure to fight flood along with mitigation measures.

Keywords: Flood, Monsoon, Flash flood, Disaster, Mitigation, Flood fighting, awareness.

INTRODUCTION

Flood is one of the oldest disasters that have been threatening humanities throughout the history of civilizations (Ferreira, 2011). Ever increasing population and change of land use pattern has intensified the occurrence of flood in present world. Direct impacts like death or other human vulnerability and indirect impacts like loss of agricultural products and infrastructures are the results of flood (Doocy et al., 2013; IPCC, 2007). Water pollution, water-borne diseases and other epidemics are the results of flood. Loss of human life and livestock, escalation of prices, social insecurity and costs of rebuilding infrastructure are additional layers of constraints that affected regions have to bear after the floods along with resource diversion for immediate response, rescue, relief and early recovery activities (Ghatak et al., 2012). Scientific projections affirm that risks of flooding will increase considerably in the main river basins of Bangladesh. A rapid shift in frequency and depth of flooding will occur with a global mean temperature rise of 2.6°C above pre-industrial levels. Glacier melts of the Himalayas are likely to adversely impact the hydrological regime of the region (Isaacs et al., 1998; Regmi et al., 2008).

Flood is natural and recurring phenomenon for Bangladesh due to its unique geographic location. The country is located at a floodplain delta of three major river basins: the Ganges, the Brahmaputra and the Meghna (GBM). Every year, one fourth to one third of the country is inundated during monsoon season by overflowing rivers. These normal flooding brings many benefits such as increase of soil fertility, recharge of aquifer, improve of ecosystem and increase of fish production, etc. This regular and natural flood is acceptable for the nation because of its immense benefits on agriculture and food production, fisheries and livelihood. However, the degree of this inundation sometimes become severe and causes damage to infrastructures, crops, communication system, and human being. Flood in 2007 was one such severe flood in recent years in terms of magnitude and duration. Bangladesh is very much sensitive to flood. Every year about 26,000 km^2 area is flooded. About 5000 people died. More than 7 million homes destroyed and many people become homeless. During severe floods the affected area may exceed 75% of the country. Which was found in 1998 and the volume of water was about 95% of the total annual in flow. The floods have caused devastation in Bangladesh throughout history, especially during the years 1966, 1970,1987,1988,1998. The 2007 South Asian floods also affected a large portion of Bangladesh. This study would assess available information and documental evidence to highlight the vulnerabilities and effects of floods on the socio-economic conditions of Bangladesh. This study would try to understand the nature of vulnerability to floods and help to establish sustainable national and regional flood management policies accordingly. The study would reflect on causes of floods, their impacts, coping strategies and national policies. It aims to identify gaps in knowledge for future work and places special attention to indigenous practices adopted to cope with floods.

METHODOLOGY

This study was done on six coastal districts of Bangladesh (20°34″ North Latitude to 26°38″ North Latitude and from 88°01″East Longitude to 92°41″ East Longitude) which that encompass almost 0.15 million Km^2 territory. About 80% of the land in Bangladesh is located on the world's largest delta comprising three of the world's most unstable rivers, the Ganges, the Brahmaputra and the Meghna, which annually flood during the monsoon period. It is known as the land of six seasons and the rainy season lasts from May to September. The country experiences huge rainfall during Monsoon. However, some flash floods prior to the monsoon season also occur. This tropical country has annual average rainfall of 1600 mm. The rivers flowing into Bangladesh drain some of the wettest catchment areas on earth with average rainfalls as high as 1100 cm. The major rivers and their tributaries have their origins outside Bangladesh and only about 7.5% of their total catchment area of about 1.5 million km^2 lie within Bangladesh. Ninety percent of their annual flows originate outside the country. The country can be divided in four different categories depending on the types of flood it encounters. Fig. 1 shows the map of Bangladesh depending on the types of flood that various locations encounter.

Flood affected area, caused by the floods of different year have been visited to gather the knowledge about disasters and damage. Field visits were also done to collect the information and the data on flood.

Flood related data such as water level (HWL & LWL) Rainfall etc. were collected from the concerned departments like BWDB. Data information and photographs on flood protection work were also collected for how to mitigate flood. For the study of flood period considered for the months of June, July, August, September and October as floods are obtained regular and frequent during these periods of every year. The rainfall and water level are collected from Bangladesh Water Development Board (BWDB). The damage due to flood has also been collected from Department of Disaster Management (DDM).

Data analysis

Different data collected has been synchronized and arranged as per requirement of the analysis. Detailed analyses related to the hydraulic characteristics of the flood were performed. Previous study performed on the flood in Bangladesh have been collected and studied. Different Journal studied, internet searching was also under literature review. Literature review mainly based on the necessary available literatures including journals, books, bulletins, manuals, reports etc. published in Bangladesh on floods. The information gathered was used to examine and document the societal impacts and vulnerability of Bangladesh and Nepal to floods specially reflecting on coping strategies.

RESULTS AND DISCUSSIONS

Highest and Lowest Water Levels

The major floods in last ten years occurred in 2007, 2011, 2012 and 2015. The data of Highest Water Level (HWL) and Lowest Water Level (LWL) was taken for last ten years at three important points of major rivers of Bangladesh. Readings were taken for Ganges - Padma at Harding Bridge, for Surma – Meghna at Chandpur and for Brhmaputra - Jamuna at Bahadurabad. These results are shown in Fig. 2 reveals that, in the year 2007, the value of highest or lowest water levels has been near the peak of last ten years at a particular station. Similarly, during the years 2011, 2012 and 2015 we can also observe that all the three stations have a value of HWL and LWL near the peak of water levels. These signs indicate that, the flow has not shown any decreasing trend over the last decade. So, the possibility of flood to occur in future years is also evident.

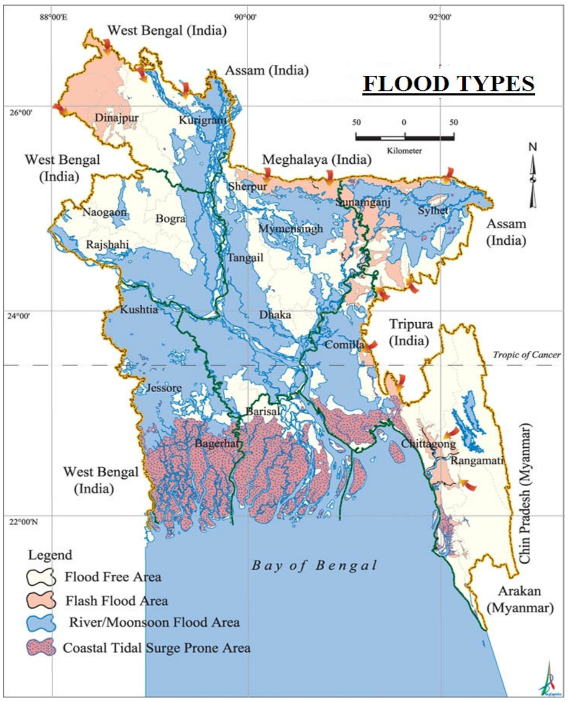

Fig.1: Spatial mapping of various types of flood occurring in Bangladesh (Source: en.banglapedia.org)

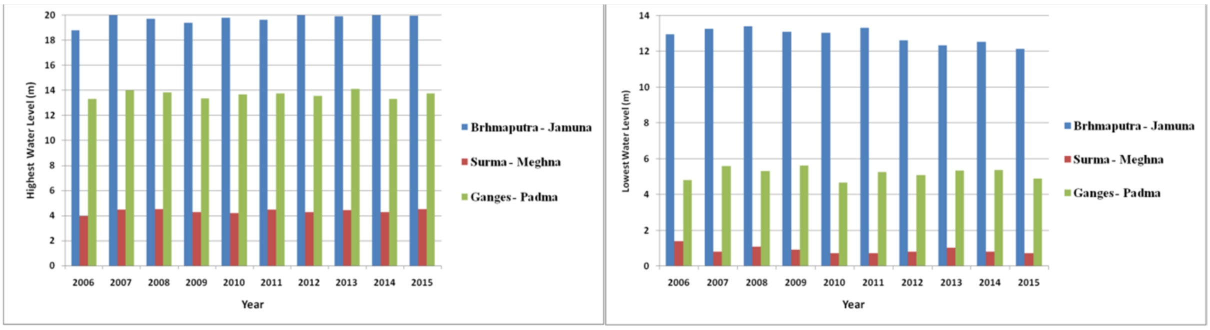

Fig. 2: Highest and Lowest Water Levels at three important locations of major rivers (2006-2015)

Annual rainfall during flood years

As most of the flood occurred in Monsoon season, the rainfall pattern during the months of June-October is vital to analyse. The rainfall pattern of capital city Dhaka for the years of flood: 2007, 2011, 2012 and 2015 are shown in Fig. 3. From the figure, we see that, the number of peaks in these years has been more than the other times. The more is the peaks, the more is the accumulation of rainwater at a small amount of time in a catchment, and the more is the chance of getting flooded.

Hazards and Damages Due to Flood

Over the last two decades, there have been eight noticeable floods in the country. Among these, the flood of 1998 was the most widespread as 52 of 64 districts with 366 upazillas got affected by it. However, the flood of 2004 was more devastating in terms of number of family and people affected. Moreover, flood of 2004 also had the highest loss of agricultural products as well as the partial damage of houses and institutions. However, the flood of 1998 had the most losses in livestock. Number of fully damaged house and partially damaged crops had also been the most for the flood of this year. Apart from infrastructural loss, the length of damaged road has been the most in this year; both partially and fully damaged roads. The flood of 2002 has been vital in case of damages in embankment, bridge and culverts.

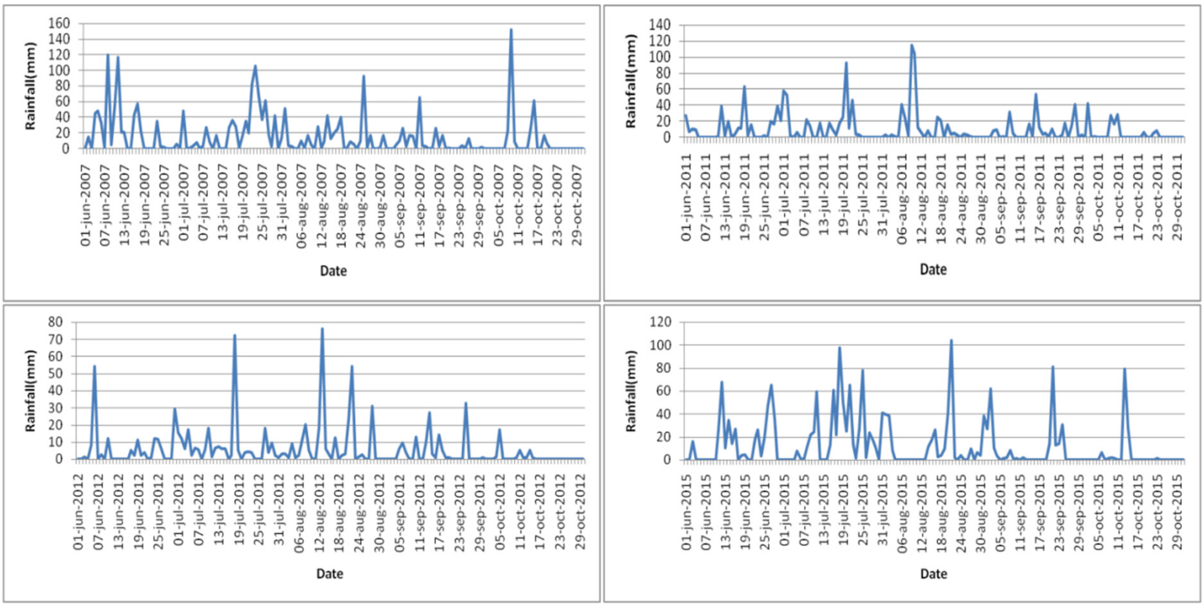

Fig. 3: Annual Rainfall at Capital Dhaka during the flood occurring years (Monsoon season)

One very important finding is the number of losses in human life, livestock and infrastructures are not as vital in last 3 flood years (2011, 2012 and 2015) as the previous ones. However, the frequency of flood over the last 5 years is more than previous years. Although the loss in these years have not been a financial burden like previous occasions to mitigate with, the number of dead people and affected family is still a burden. So, considering both recurring frequency and loss of lives, the adaptation and mitigation measures as well as awareness projects should be taken immediately. Table 1 includes the summary of the list of hazards and damages during the previous floods in Bangladesh.

Mitigation Measures of Flood

There are two types of mitigation measures of flood in Bangladesh: Structural and Non-structural measures. The Non-structural measure is mainly increasing the vegetation layer in order to save the land from erosions. The structural measures include dams, embankments etc. Our country has three big dams like Kaptai, Tista and Karnaphuli. Redirecting water by holding them for crop lands have been done by making diversion canals. Embankments and coastal defences are also the structural measures of flood fighting. Apart from this, some river training works are also done for guiding rivers.

CONCLUSIONS

From the study, it is evident that, the number of lives lost and the infrastructural and agricultural loss occurred by a flood poses a sudden impact on the affected mass. Although, the losses are decreasing compared to the past, the numbers are still threatening. Moreover, its frequency is increasing day by day. Flood, being a natural disaster is not possible to stop, but the after effects of flood can be minimized by appropriate mitigation measures. It is not possible to stop flood but can reduce its intensity and educate the people about the flood. In order to maintain the normal flow in the river systems and to minimize the extend of floods in Bangladesh caused due to overtopping of the canals and river banks, the cross sections including the depth of the channels are suggested to be increased by proper dredging. The reduction of floods, flood damages, and rehabilitation activities for the flood affected people are suggested to be done properly in due time to establish the stable national economy and enhance the socio-economy of the people of this poor disaster prone country, Bangladesh. Awareness of the people affected by the flood should be increased about the needfulness during and after floods, safe drinking water, sanitation, hygiene health, environment, socio-economy, rehabilitation activities etc. After the flood, many people lost their jobs and become jobless, homeless and helpless. Only the Government cannot mitigate the flood damaged of rehabilitate the flood affected people. The higher income group of people should come forward to rehabilitate these flood-affected people. The NGOs and other voluntary society/group should come forward during and after the flood for the help of flood affected people.

Table 1: Hazards and Damages of major floods occurring in Bangladesh in last 20 years

Year→ / Damage↓		1998	2000	2002	2004	2007	2011	2012	2015
No. of victims	District	**52**	9	36	39	46	11	17	48
	Upazilla	**366**	40	209	265	263	64	58	222
	Family	5711962	81144	1949940	**7468128**	2851559	348621	888336	165054
	People	30916351	3244576	7606837	**36337944**	13343802	923465	1386060	816988
Crops Damaged (Acre)	Fully	1423320	14262	321355	**1605958**	890898	77486	37987	40445
	Partially	**1808401**	438016	521742	1038176	1335382	245968	125089	60531
No. of House Damage	Fully	**980571**	437050	115511	894954	81817	243191	14101	218275
	Partially	2446395	309775	564527	**3389101**	961420	370587	58418	598818
No. of Dead People		918	37	26	747	**970**	190	41	76
No. of Dead Livestock, Cattles & Goats		**26564**	1643	25237	15143	1459	1501	8716	4946
No. of Damage Institution	Fully	**1718**	41	302	1295	563	445	239	292
	Partially	23272	1777	4050	**24276**	8031	4588	387	2968
Road Damage (Km.)	Fully	**15927**	409	3720	14271	3705	2233	171	1635
	Partially	**45896**	8874	15690	45528	27125	6621	1210	10922
No. Damages Bridge & Culvert		6890	1234	**9406**	5478	360	157	123	1573
Embankment Damages (Km.)		4528	118	**4734**	3158	88	1743	125	448

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MORPHOLOGICAL CHANGES OF RIVER TEESTA DURING THE LAST DECADE

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ABSTRACT

River Teesta, a major transboundary river and the only significant river in the northern region of Bangladesh, is playing a vital role in boosting agriculture production in this region and enhancing self-reliance in food stock of Bangladesh. However, in recent years, Teesta is facing challenges of very low flow (8 cubic meter) during dry season and abnormal erosion-deposition phenomena in certain places along its course. After the construction of 'Gajoldoba' barrage, India is withdrawing substantial water for irrigation during dry season and releasing excess water to downstream Bangladesh during monsoon flooding. The difference of highest and lowest flow makes the river susceptible to meet demand of irrigation, agriculture and pose a great threat to river management. This study is undertaken to get an enhanced perceptive of the morphological response of river Teesta by observing shifting of bank line and estimating erosion deposition volumes over a period of years. Extensive morphological survey data from 2001 to 2014 at 20 sections along its length has been collected from the database of Bangladesh Water Development Board. Erosion and deposition volumes are estimated by calculating average area (erosion/ deposition) generated between 2 superimposed sections of year 2001 and 2014, multiplied by the distance between the 2 sections. Sedimentation/deposition phenomenon has been observed to be predominant in river Teesta. The highest deposition area is found at cross section number RMT16 (4005.84m^2). The highest net deposition volume has been found to be 16144821.55 m^3 between sections RMT 15 and16 near Kaliganj, Hatibandha and Jaldhaka upazila. Erosion has also been found to dominate in five cross sections. The highest net erosion area (1942.42m^2) has been found at the outfall near Chilamri and Sundarganj upazila. This study will assist in improved understanding of the morphological changes of the river and help in formulating river management planning.

Keywords: Teesta; Deposition; Erosion; Morphological response.

INTRODUCTION

Bangladesh, the second largest deltaic flood plain of the world, is mostly formed with huge sediment deposition by numerous tributaries and distributaries of the three great river systems- Ganges-Padma, the Brahmaputra-Jamuna and Meghna. There is a complex network of 405 rivers in the country including 57 transboundary rivers (BWDB, 2011). Most of the water resources of Bangladesh are received from upstream countries through these transboundary rivers. Annually 1000 billion cubic meter of flow drain to Bay of Bengal through Lower Meghna and about 1.10 billion tons of sediment enters into Bangladesh (BWDB, 2013). However, we have little influence over these transboundary rivers. River Teesta, one of the major transboundary rivers is the biggest fresh water resource in the northern region flowing through the 5 districts- Rangpur, Lalmonirhat, Nilphamari, Kurigram and Gaibandha. To meet water demand for agriculture during dry season and facilitate supplementary irrigation during monsoon season, Bangladesh Water Development Board (BWDB) constructed Teesta Barrage in 1988. Since then, this river is playing a virtual role for boosting agriculture production in northern region and enhancing self-reliance in food stock of Bangladesh. In recent years, Teesta is facing challenges of very low flow (8cumec) during dry season and abnormal erosion-deposition phenomena in certain places of its course. To meet agricultural water demand and provide supplementary irrigation during dry season, India also constructed a barrage in 'Gagoldoba' just few kilometers upstream of Bangladesh border. In absence of water sharing treaty with India for river Teesta, India is withdrawing excess water for irrigation during dry season without keeping minimum water for downstream channel sustainability and releasing excess water to downstream Bangladesh during monsoon flooding which causes enormous sufferings of public and properties living alone the banks of river Teesta. This difference of highest and lowest flow makes the river susceptible to meet demand of irrigation, aquaculture and pose a great threat to river management.

Several studies have accounted for the morphological responses of rivers of Bangladesh. A slope stability analyses have showed that banks of river Surma are eroding mainly due to slope failure in the wet condition (Islam and Hoque, 2014). A study has been done by Bangladesh Water Development Board (BWDB) to get a better understanding of the morphological responses of major rivers (Ganges, Padma, Brahmaputra-Jamuna) by estimating yearly erosion and deposition volumes, observing existing trend, shifting characteristics and finding ways to cope with these morphological changes. The study shows that during 1992 to 2011, net total of 523Mm^3 of silt has been deposited. While during 2000 to 2010, 111Mm^3 of net erosion has been observed in Upper Meghna River (BWDB, 2013). Islam et al., 1999 have shown that of the total suspended sediment load (1037 million tons) transported by rivers Ganges and Brahmaputra, only 525 million tons (51% of the total load) are delivered to the coastal area of Bangladesh and the remaining 512 million tons are deposited within the lower basin, offsetting the subsidence. Of the deposited load, after deposition on the floodplains of these rivers, the remaining 223 million tons (about 21% of the total load) are deposited within the river channels, resulting in aggradations of the channel bed at an average rate of about 3·9 cm yr−1.Remotely sensed imageries from 1989 and 2015 were used to detect changes of present land use, river erosion and bar deposition in Chowhali Upazila, Sirajganj district of Bangladesh in a study (Hassan and Islam, 2015). Their study reveals that about 1340 hectare of study area has been eroded, while 630 hectares are deposited as channel bar in the study area over the last 26 years.

This study is undertaken to get an enhanced perceptive of the morphological response of river Teesta during the last decade by observing shifting of bank line and estimating erosion deposition volumes over a period of years. This study will assist in improved understanding of the morphological changes of the river and help in formulating river management planning.

METHODOLOGY

River Teesta, a much controversial transboundary river, has originated from the Himalayas Range of Sikimin India and enters through Dimlaupazila under Nilphamari district and falls into river Brahmaputra-Jamuna in Sundarganjupazila under Gaibandha district. Physical descriptions of the river are listed in Table 1.

Table 1: Physical descriptions of river Teesta as per Rivers of Bangladesh (BWDB, 2011).

Length	129 km (in Bangladesh)
Width	0.7km (minimum), 5.5km (maximum), 3km (average)
Bank Level (upstream to downstream)	Left : 57.10m to 18.37m
	Right : 56.18m to 19.00m
Bed Level (upstream to downstream)	54.00m to 16.74m

Teesta is a braided, perennial and non-tidal river with low flow during February to April (8cumec) and higher flow during July to September (4494cumec). From Table 1, it is observed that the elevation of bed level have been reduced about 37.26m from near off take with a travel length of 129km to outfall. Due to this higher gradient, this river is flashy in nature.

River Morphology and Research Circle (RMRC) of BWDB is mandated for monitoring river morphology and investigation of bathymetric survey of 170 rivers including Teesta. River Morphology Processing Branch (RMPB) under Processing and Flood Forecasting Circle (PFFC) of BWDB is responsible for collection, storage, processing and analysis of morphological data collected from field divisions of RMRC. River Teesta is divided into 20 sections along its length for morphological investigations and is surveyed once in every 2 years at an interval of around 6km.The flow path and bathymetric survey station locations of river Teesta are illustrated in Table 2 and Fig. 1. Fig. 2 illustrates that annual maximum discharge and water levels of river Teesta raises from 1985 to 2003 and there is a significant decrease in the annual maximum discharge and water levels of river Teesta from 2003 to 2004. This low discharge and water level continues till 2016.

Table 2: Locations of bathymetric survey stations of river Teesta as per BWDB, 2011.

CS station number	Left Bank (Upazila, District)	Right Bank (Upazila, District)
RMT1	Chilamri, Kurigram	Sundarganj, Gaibandha
RMT2 to 5	Ulipur, Kurigram	Sundarganj, Gaibandha
RMT6	Rajarhat, Kurigram	Pirgacha, Rangpur
RMT7	Rajarhat, Kurigram	Kaunia, Rangpur
RMT8 to 10	Lalmonirhat, Lalmonirhat	Kaunia, Rangpur
RMT11to 12	Aaditmari, Lalmonirhat	Gangachara, Rangpur
RMT13 to 14	Kaliganj, Lalmonirhat	Gangachara, Rangpur
RMT15	Kaliganj, Lalmonirhat	Jaldhaka, Nilphamari
RMT16	Hatibandha, Lalmonirhat	Jaldhaka, Nilphamari
RMT17 to 20	Hatibandha, Lalmonirhat	Dimla, Nilphamari

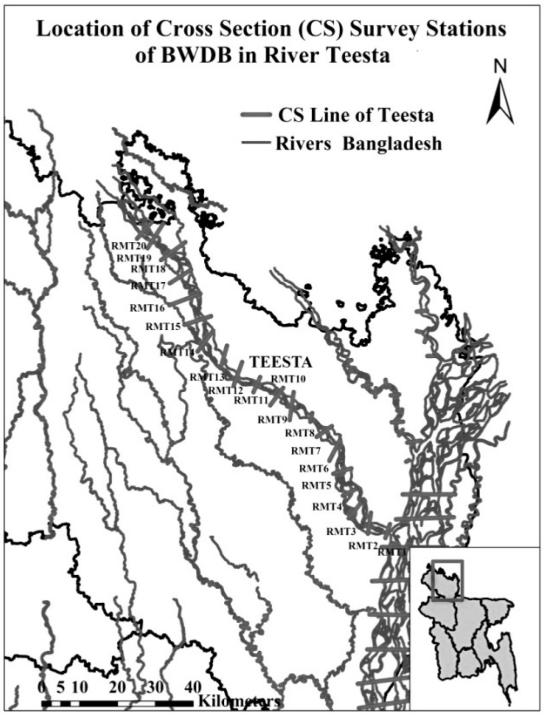


Fig. 1: Flow path and bathymetric survey station locations of river Teesta

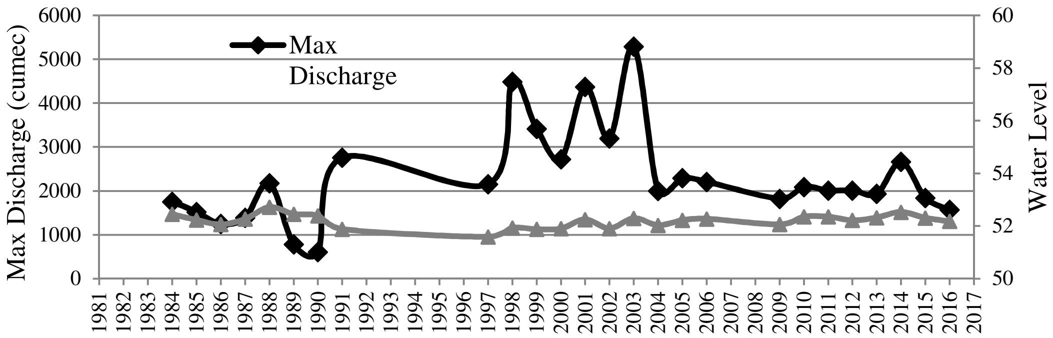


Fig. 2: Annual maximum discharge and water levels of river Teesta

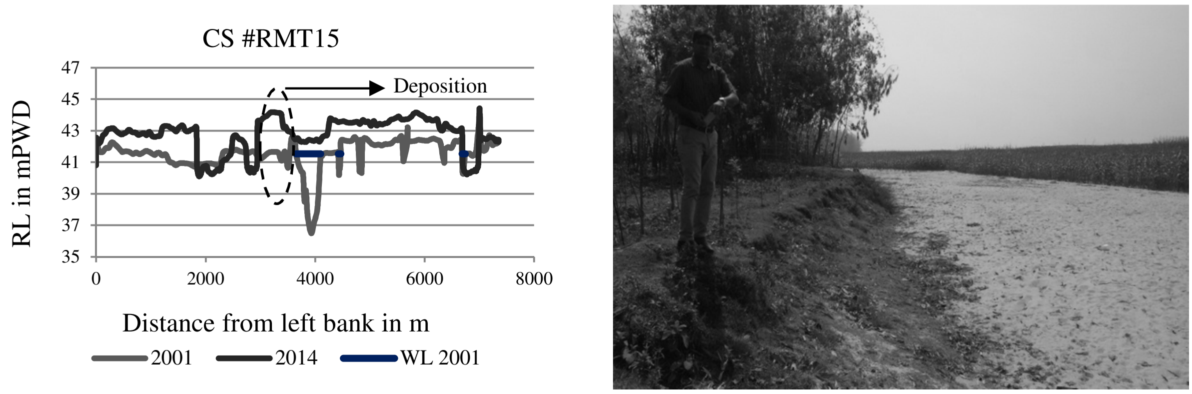


Fig. 3: (left) Superimposed cross section at RMT 15 and (right) site condition at left bank of the section (Daoabari union, Hatibandhaupazila) of river Teesta.

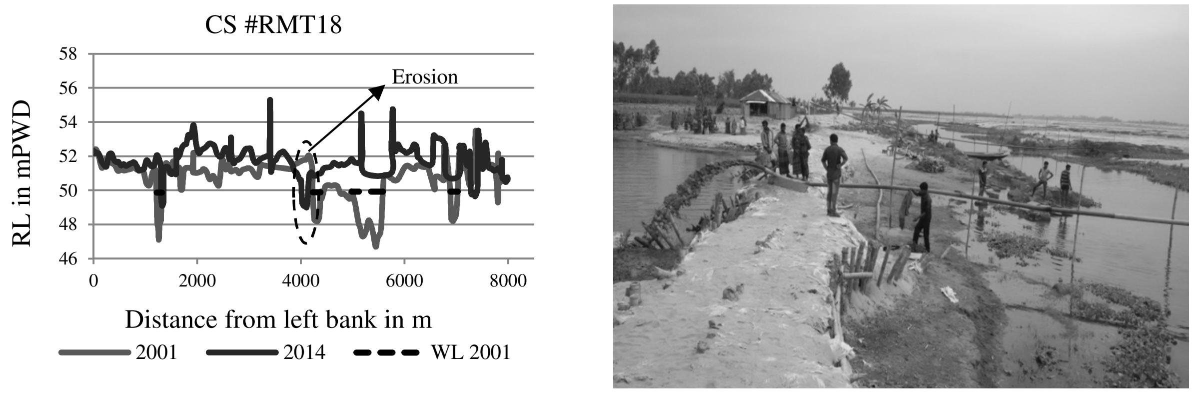


Fig. 4: (left) Superimposed cross section at RMT 18 and (right) site condition at left bank of the section (Guddimari union, Hatibandhaupazila) of river Teesta.

Cross sectional data of river Teesta during period of 2001 and 2014 were taken into consideration for morphological analysis and superimposed. From superimposed cross-sections of the 2 different years, erosion or deposition phenomena of the river are easily understandable. Erosion and deposition volumes are estimated by calculating average area (erosion/ deposition) generated between 2 superimposed sections of year 2001 and 2014, multiplied by the distance between the 2 sections (Table 3). Fig. 3 shows deposition at left bank of RMT 15 and Fig. 4 shows bank erosion at left bank of RMT 18. Both conditions agree with field scenario as seen in the photographs taken respective sights.

RESULTS AND DISCUSSIONS

The estimated net erosion/deposition areas and volumes during the time period of 2001 to 2014 for all twenty cross sections of river Teesta are represented in Fig. 5. It has been found that river Teesta has eroded significantly during 2001 to 2014 at several locations near its off take (cross section number RMT1, RMT13, RMT14, RMT17, RMT19 and RMT20) [Fig. 5, left]. Fig. 5(right) illustrates that erosion dominates between cross section number RMT 13and14 (2499810.63m^3).

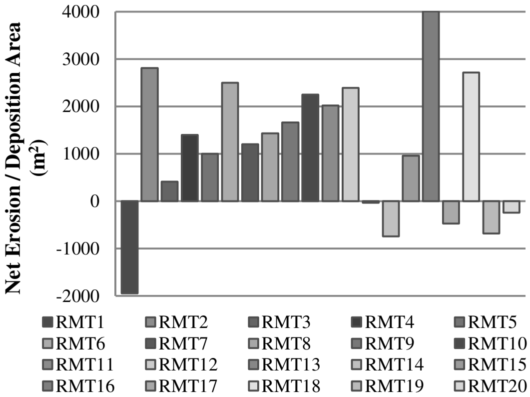
Erosion near sections RMT 19and20 (near Hatibandha and Dimla upazila has also been found to be 1387616.40m^3). The highest net erosion area (1942.42m^2) has been found at the outfall the river (RMT1 near Chilamri and Sundarganj upazila). On the other hand, deposition is found in most of the upstream sections with very low flow. The highest deposition area is fond at cross section number RMT16 (4005.84m^2). The highest net deposition volume has been found to be 16144821.55m^3 between sections RMT 15 and16 near Kaliganj, Hatibandha and Jaldhaka upazila.

Table 3: Estimated erosion and deposition volume of river Teesta

CS Station	Location (Km.)	Erosion Area (m^2)	Deposition Area (m^2)	Remarks	Average Erosion/ Deposition Area between two Sections (m^2)	Total Erosion/ Deposition Volume between two Sections(m^3)
RMT1	3	2209.84	267.42	Erosion dominated (1942.42)	-	-
RMT2	9.5	120.81	2927.27	Deposition dominated (2806.46)	432.02	2808117.65
RMT3	16	1319.51	1732.79	Deposition dominated (413.29)	1609.87	10464174.83
RMT4	22.5	868.55	2264.73	Deposition dominated (1396.19)	904.74	5880800.58
RMT5	29	1864.40	2865.34	Deposition dominated (1000.94)	1198.56	7790666.65
RMT6	35.5	553.84	3052.10	Deposition dominated (2498.25)	1749.60	11372375.30
RMT7	42	1089.91	2295.28	Deposition dominated (1205.37)	1851.81	12036766.30
RMT8	48.5	401.12	1833.33	Deposition dominated (1432.22)	1318.79	8572152.88
RMT9	55	169.27	1833.15	Deposition dominated (1663.88)	1548.05	10062304.85
RMT10	61.5	763.91	3014.52	Deposition dominated (2250.61)	1957.24	12722066.18
RMT11	68	180.06	2198.35	Deposition dominated (2018.30)	2134.45	13873930.20
RMT12	74.5	554.26	2945.14	Deposition dominated (2390.88)	2204.59	14329827.20
RMT13	81	1101.43	1072.16	Erosion dominated (29.27)	1180.81	7675246.80
RMT14	87.5	3632.10	2892.19	Erosion dominated (739.91)	-384.59	2499810.63
RMT15	94	817.81	1779.62	Deposition dominated(961.80)	110.95	721159.40
RMT16	100.5	294.96	4300.79	Deposition dominated (4005.84)	2483.82	16144821.55
RMT17	107	1338.82	868.77	Erosion dominated (470.05)	1767.89	11491312.95
RMT18	114	518.76	3235.41	Deposition dominated (2716.66)	1123.30	7863122.75
RMT19	121	1337.95	654.44	Erosion dominated (683.51)	1016.57	7116018.70
RMT20	124	1960.53	1718.96	Erosion dominated (241.57)	-462.54	1387616.40

CONCLUSIONS

This study has tried to clearly indicate the location of significant erosion/ deposition alone the entire length of river Teesta. However, this study only considers net erosion/deposition volumes at all channels of a particular section and does not consider the effect of erosion/deposition at a specific channel of the section. In this study, erosion has been mainly observed near off take (Hatibandha of Lalmonirhat and Dimla of Nilphamari) and near outfall (Chilmari of Kurigram and Sundargonj of Gaibandha) portion. On other places along the river, sedimentation/deposition phenomena were predominant with highest deposition observed in Kaligonj of Lalmonirhat and Jaldhaka of Nilphamari. River management through river improvement is one of the prior agenda of Bangladesh government. River improvement through capital dredging program is an ongoing mega project of government implemented by BWDB, BIWTA. This study will help to find appropriate locations of river dredging works for Teesta. In addition, very low flow in dry season and high flow during monsoon season are also responsible for change in river morphology. Joint River Commission (JRC) of Bangladesh can continue their negotiation with India to establish a water sharing treaty so that channels can be operative with minimum standard flow all the year and meet agriculture and aquatic demand in the northern region.



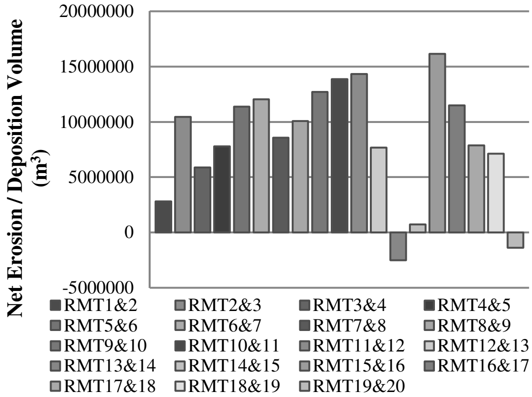


Fig. 5: (left) Summary of cross-section wise erosion and deposition area of river Teesta and (right) Summary of erosion and deposition volume between the cross-sections of river Teesta.

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EFFECT OF RIVER MORPHOLOGICAL CHANGES ON THE FLOOD INTENSITY ALONG THE FLOOD PLAIN AREAS OF BRAHMAPUTRA-JAMUNA RIVER SYSTEM

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ABSTRACT
Brahmaputra-Jamuna, one of the major transboundary rivers in Bangladesh is the largest fresh water resource of Bangladesh that meets our agriculture and domestic water demand to a great extent. This river contributes around 60% of flood water as well as huge amount of sediment during monsoon (June-August). It has been observed that flood intensity and its associated damages are increasing adjacent to the floodplain areas of Jamuna River in recent years with lower flow discharges than previous years. In addition, morphology of this river has also been changed by generating a network of interlacing channels with numerous sandbars enclosed between them. This study has been undertaken to reveal the influence of morphological changes of Brahmaputra-Jamuna on the flow characteristics. Historical (last 30 years) hydrological, morphological and sediment data from Bangladesh Water Development Board (BWDB) were collected for analysis in this study at a representative section in Brahmaputra-Jamuna River. Complex behaviour in the changing pattern of the morphology of river Jamuna significantly affects flow characteristics. Change of channel bed due to sedimentation/deposition is not the dominant factor influencing flow; but other factors like shifting of channel, narrowing or widening of channel and creation of new channel etc also significantly influence flow behaviour as well as flooding phenomena. This study will give a clear insight how the changing morphology of river Jamuna is imposing a great influence on increasing the intensity of recent years' flooding and suggests taking remedial measures in river management where necessary.

Keywords: River Morphology; Discharge; Flood.

INTRODUCTION
Hydrological characteristics of a river are greatly influenced by morphological changes alone the river courses. Although these changes are insignificant for straight-reach small or medium sized rivers, in case of big rivers, morphological changes directly affect hydrological characteristics such as flow, velocity, water level etc. Bangladesh is a delta formed by the alluvial deposits of the three major rivers: the Ganges, the Brahmaputra, the Meghna and their numerous distributaries and tributaries. There are 405 rivers in Bangladesh of which 53 rivers come from India and other 4 rivers (BWDB, 2008) come from Myanmar. Being criss-crossed by these river systems, Bangladesh is experienced annual flood every year. Flood, having inundated 25% of the country area, refers to normal flood which has positive impact by supplying alluvial soil in flood plain and thus boosting agricultural production. Areal inundation more than 25% indicates severe flood and susceptible to damages of homesteads and agricultural productions. Flood intensity is found increasing in recent years and posing a threat to livelihood. The major rivers of Bangladesh carry huge sediment load from the large catchments a resulting to about 1.0 to 1.1 billion tons annually (BWDB, 2008). A significant portion of these huge sediment are deposited in the river bed resulting channel bed aggregation which is also one the major causes of increasing flood intensity. While investigating the causes of increasing flood intensity, it is found that not only the hydrological factors (monsoon rainfall, sediment flow etc) are responsible for this; the effect of morphological changes of the river has also a great impact. The Brahmaputra- Jamuna is one of the largest braided rivers in the world.

The changing plan form of banks and sandbar of the river not only cause suffering to the people living along its course but also cause national losses damaging cultivated land, settlements, commercial centres and infrastructures. Therefore, the better understanding of the behaviour of the river would be useful to mitigate losses by river erosion. In a study of CEGIS, they made an attempt to predict the morphological changes of the main rivers of Bangladesh using dry season satellite images and they found that time-series satellite images could be intelligently used to monitor and predict the planform changes of the dynamic rivers with a reasonable accuracy. For a scientific and rational approach to different river problems and proper planning and design of water resources projects as well as understanding of the morphology and behaviour of the river is a pre-requisite. Morphology of river is a field of science which deals with the change of river plan form and cross-sections due to sedimentation and erosion. In this field, dynamics of flow and sediment transport are the principal elements. The morphological studies play an important role in planning, designing and maintaining river engineering structures. Due to carrying huge sediment loads with low gradient, riverbed aggradations is most pronounced for the major rivers of Bangladesh. The morphology of the major rivers is very dynamic in nature and frequent human interventions caused the rapid declining the behaviour of river morphology. These metamorphoses have been changing the flood regimes, agricultural practices, floodplain ecosystem and navigation. Human intervention, without considering the river morphology often caused the aggradations and reduced navigability as well as the water carrying capacity of rivers.

Bangladesh is the lower riparian of Brahmaputra-Jamuna River system. The river basin of Brahmaputra-Jamuna includes parts of China, Bhutan, India and Bangladesh. Total catchment area is 560,000 sq.km out of which 42,000 sq.km is lying in Bangladesh. The river basin represents a higher rainfall area with an annual average rainfall of around 1900 mm. The river is approximately 2,900 km long, out of which 240 km from Noonkhawa to Aricha is lying in Bangladesh. In response to the rainfall distribution, the river stage varies by about 6m. The river has an average surface water slope of around 7 cm/km. The width of Brahmaputra- Jarnuna River varies from 9 km to 16 km with an average of 12 km. Consequently, the Brahmaputra- Jamuna River carries a heavy sediment load, estimated to be over 500 million tons annually (Klassen et. al., 1988). Most of this is in the silt size class (suspended load) but around 15 to 25 percent is sand (bed load). This sand is deposited along the course of the river and the clay fraction is transported to the delta region. The composition of the bank materials is remarkably uniform and consists of fine sand (Coleman, 1969). The erosion and shifting of river courses, loss of land, especially along the Brahmaputra-Jamuna river have long been recognized as a natural problem that affects a sizeable population in Bangladesh. The overall width of the river exhibits an increasing trend, especially at the upstream part of the Brahmaputra- Jamuna River. This study intends to identify the influence of morphological changes of Brahmaputra-Jamuna on the flow characteristics specially effect the intensity of flooding.

This paper will try to assess that flooding in this mighty river not only depends due to high inflow from upstream during monsoon but also continuous changing pattern of river channel and river bed that affecting the conveyance capacity of the channel.

DATA & METHODOLOGY

The characteristic feature of the hydrograph of the Brahmaputra- Jamuna is the existence of the broad peak between July-September. The discharge varies from minimum of 3430 cumec at dry period to maximum of about 102,535 cumec at wet period (BWDB, 2011). Recently it has been observed that flood intensity has increased with lower discharge value. So the historical hydrological value of Brahmaputra- Jamuna River at Bahadurabad station has been collected from Bangladesh Water Development Board to analysis this phenomenon. Fig. 1 shows the hydrograph of this station for last three decades. It can be seen that recorded water level in 2017 is the highest over the time of last thirty years but observed discharge was not the highest. In this study, a morphological evaluation of this river has been conducted at a section near Bahadurabad station (300 m upstream) and the amount of average sediment disposal at Bahadurabad station has also been observed.

Table 1: Location of the stations from where hydrological values have been collected

		Co-ordinate	Upazila	District
Discharge		25°07'50.3"N, 89°44'15.7"E	Islampur	Jamalpur
Sediment		25°07'50.3"N,89°44'15.7"E	Islampur	Jamalpur
Cross section	Left Bank	25°11'15"N, 89°44'10.6"E	Dewanganj	Jamalpur
	Right Bank	25°09'58"N, 89°34'42.9"E	Fulchori	Gaibandha

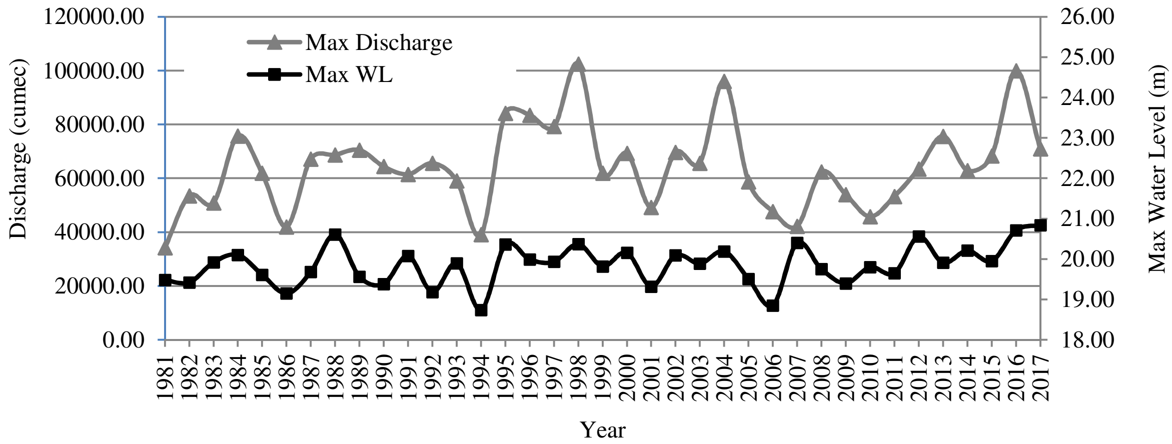


Fig. 1: Hydrograph of Brahmaputra-Jamuna River at Bahadurabad station for last 30 years

Cross sectional data of river Brahmaputra-Jamuna during period of 1979 and 2016 are taken into consideration for morphological analysis and they were superimposed on the cross sectional data of 1979 for comparison. Fig. 2 shows two superimposed cross-sections. From superimposed cross-sections of the 2 different years, erosion or deposition of the section has been calculated. Erosion and deposition volumes have been estimated by area (erosion/ deposition) at the section of year 1979 and the year in concern, multiplied by a distance of 6 km (Table 2).

It has been found from Fig. 2 that for section of 1979, there are 4 major channels visible. But in course of time, we found 2 major channels in section 2006 and 2016. These 2 major channels have to carry most of the discharges during monsoon.

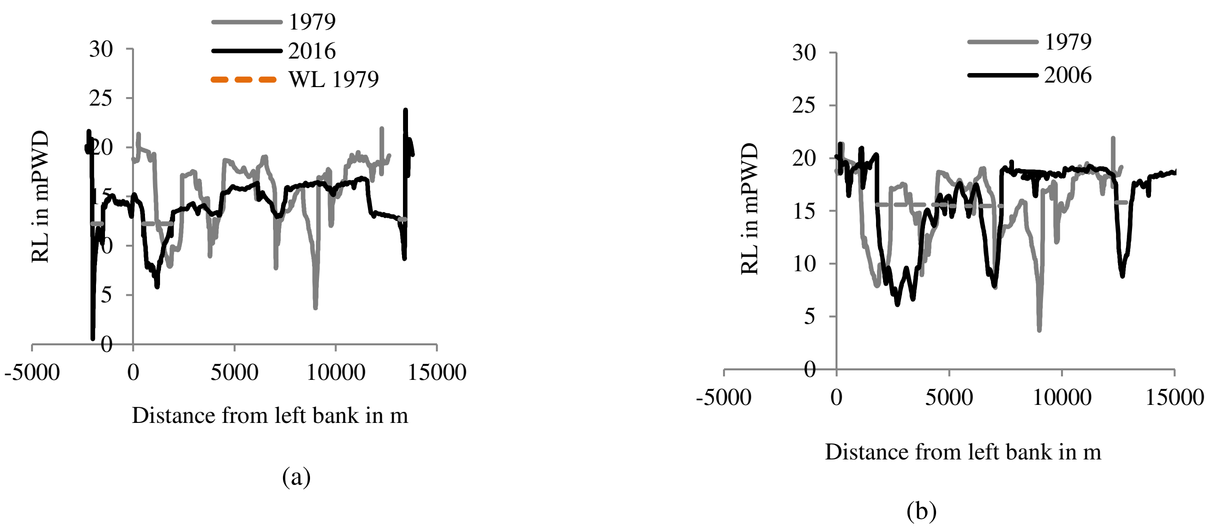


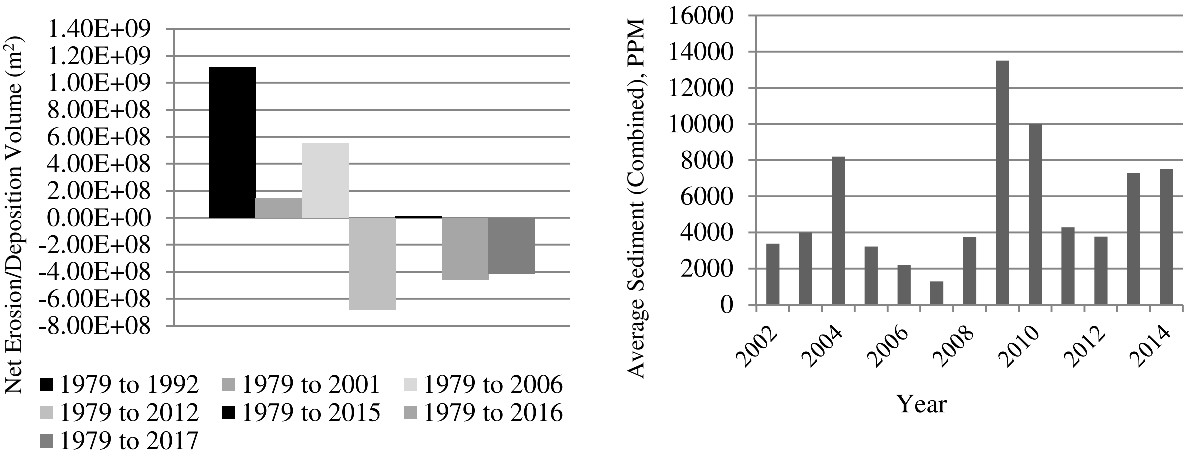
Fig. 2: Superimposed cross-section (a) between 1979 and 2016; (b) between 1979 and 2006

Table 2: Estimated erosion and deposition volume of river Brahmaputra-Jamuna at Bahadurabad station

Comparing Years	Erosion Area (m^2)	Deposition Area (m^2)	Remarks Net Erosion/ Deposition Area (m^2)	Total Erosion/ Deposition Volume (m^3)
1979 to 1992	7878.5905	26481.5522	Deposition dominated (18602.96)	1116177702
1979 to 2001	12805.9349	15271.0122	Deposition dominated (2465.08)	147904638
1979 to 2006	12992.3965	22203.5357	Deposition dominated (9211.14)	552668352
1979 to 2012	35699.821	3388.2772	Erosion dominated (-32311.54)	-1938692628
1979 to 2015	27206.6431	27364.9767	Deposition dominated (158.33)	9500016
1979 to 2016	18375.2814	10707.9262	Erosion dominated (-7667.36)	-460041312
1979 to 2017	29164.4574	22297.6468	Erosion dominated (-6866.81)	-412008636

RESULTS AND DISCUSSIONS

The estimated net erosion/deposition areas and volumes during the time period of 1979 to 2017 for cross sections of river Brahmaputra-Jamuna at Bahadurabad section are represented in table 2. It has been found that river Brahmaputra-Jamuna has deposited significantly during 1979 to 2006. Fig. 3(a) illustrates that erosion-deposition at the cross-section. On the other hand, erosion is found in most of the sections of recent years. The highest deposition area is found at cross section between 1979 and 1992 (18602.96 m^2). The highest net deposition volume has been found to be 1116177702 m^3.



(a) (b)

Fig. 3: (a) Summary of erosion and deposition volume at Bahadurabad station of river Brahmaputra-Jamuna. (b) Average sediment concentration of different year

CONCLUSIONS

The characteristics of river Jamuna is very peculiar in response to the hydrological and morphological phenomena. Flooding in this mighty river has a devastating effect on the community and agricultural land. The results of this study showed that the morphological characteristics have been changed significantly over the last 3 decades. Flow carrying channels at Bahadurabad had been reduced to one or two single channels.

The existing channel bed was also experienced aggregation due to deposition of excessive sediment. Both of these events lowered the capacity of channel, so water crossed the recorded highest level in lower discharges during 2017 peak flood. River training works through river dredging is a priority work of Bangladesh government. This study will give the engineers and planners a insight to select the appropriate location of dredging area. Improvement of channel conveyance capacity through river dredging will reduce the possibility of river flooding in nearby areas at lower discharges.

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A REVIEW ON NUMERICAL AND EXPERIMENTAL METHODS OF RIVER MEANDER PREDICTION

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ABSTRACT
Meandering channels is an immense research field, traversing a wide assortment of time and space scales, ecological areas, and applied and methodological approaches. However, river meander prediction is an unpredictable and dynamic procedure of the parallel development of a stream because of disintegration on one bank and statement on the contrary bank. As a result, the diversion moves in a parallel bearing, which may be a noteworthy worry for the bridges security of extensions amid their life expectancy. A series of analysis was performed in a significant flume to decide the impact of slope and sediment load on channel designs. This paper will briefly explore the process of meander formation and aims to conduct a thorough literature review about the analyses of meander prediction. It looks at the historical approaches used and concludes that there are three tools of meander prediction namely, Experimental, Numerical, and Descriptive Methods. The objective of this study is about to know the different numerical and experimental methods. The elements of meander development and planimetric design arrangement is driven by a few straight and nonlinear procedures which, alongside outside constraining (e.g., soil properties, stream flow fluctuations, and riparian vegetation). These analyses propose that landforms may not generally react dynamically to modified conditions. Rather, demonstrative morphologic changes can happen suddenly when critical erosional and (or) depositional threshold esteems are surpassed. These exploration headings to accentuate the basic significance of the coupling of close bank geomorphic and stream forms, the portrayal of co-advancement of meandering rivers and their floodplains, and the need to enhance linkages between meandering streams research and waterway administration and reclamation.

Keywords: Meander; River; Numerical; Experimental; Morphological; Landform.

INTRODUCTION
Waterways can be arranged into three classifications: Braided stream, Meandering river and Straight River. A meandering river is a twist in a sinuous water course; it is shaped while moving water in a stream dissolves the external banks and extends its valley. The measure of vitality and sediment testimony is substantially less in the inward part interestingly with the external part. As the volume of stream approaches it dissolves dregs from the outside of a twist and stores within, this outcomes in a winding example cruising forward and backward from tough to downhill. So as time goes by the wind gets cut off from the standard framing an oxbow lake, and as the meanders begin in the downstream; challenges begin ascending for Civil Engineers. This wonder causes issues for neighbourhood regions who oversee the upkeep of stable streets and scaffolds. Stream winding channel so jeopardize transportation foundations by sidelong development and down-valley interpretation of meander twist. Sinuosity is one of the channel composes that a stream expects over all or part of its course. All streams are twisted eventually in their geologic history over some piece of their length. This sinuosity when approaches at a basic state at which the contradicting powers which makes and cuts off meanders cooperate such that sinuosity varies around a steady mean, paying little heed to the first conditions. Analysis of Meandering Prediction and Pattern of River is fundamental because of numerous reasons, probably the most important are the progression of meander advancement and planimetric design development is driven by a few direct and nonlinear procedures which, alongside outer compelling (e.g., soil properties, stream changes, and riparian vegetation). This is a key procedure in numerous designing issues.

For instance, the assessment of stream bank disintegration and the resulting silt transport are essential information for fluvial administration, route, waterway rebuilding, and oil examine, and so forth. Channel relocation is a noteworthy thought in outlining span intersections and other transportation offices. It is an incremental procedure and the issue at an extension site may end up plainly evident a few decades after the scaffold has been built. And to manage vulnerabilities like this we must get ready re-enactments. There are a few distinct models accessible for the expectation of meander relocation, which incorporates exact conditions, time-grouping maps and extrapolations, and numerical models. River Meander and subsequent example or angle and type of the stream decide to arrive utilize design, plan of dike or disintegration control offices, removal of individuals living the region of the waterway and so on.

METHODOLOGY

Numerical Methods for Meander Prediction:

Rapid advances in technology has made it possible to analyze meander formation and subsequent erosion and flow pattern etc. One-, two- and three-dimensional, computational fluid dynamic models simulate the morpho-dynamic processes of natural rivers. Meandering models employ the quasi two-dimensional analytical solutions of Navier–Stokes equation while flow patterns and velocity profiles have been examined with depth-integrated models. Some recent models focused on the diffusion and dispersion characteristics in meander bends using transient tracer tests. Several models can also simulate bank erosion and lateral migration of alluvial channels. However, the knowledge regarding the fundamental physical processes that govern meandering evolution is not completely clear and accurate. The complete simulation of the various modes of deformation of meandering channels such as downstream and upstream migration, lateral extension and rotation of meander bends are not thoroughly studied or reported in literature. The mechanisms governing meander formation is not fully understood: there are numerous factors at play and need to be considered. e.g. flow, sediment, bank erosion, etc. List of numerical methods are given below: Keady and Priest (1977) collected meander migration data from published reports on the Mississippi River in Tennessee, on the Red River in 1063 Arkansas, on the Pearl River in Louisiana, on the Tombigbee River in Mississippi, on the Buffalo River in Louisiana, etc. This gave them eight data points from which they obtained their eq. M_r = 0.315 $(ga)^{0.5}$ f(s). Where, $M_r$is the meander migration rate (m/yr.), g is the acceleration due to gravity (m/s^2), a is the meander amplitude (m). f(s) is a function of s, the free surface slope of the river. The assumptions for the method are as follows:

- The rate of downstream meander migration is related to the shear stress on the boundary.
- The shear stress is related to the free surface slope of the channel, geometric shape of the channel, and acceleration due to gravity.

Hooke (1980) collected meander migration data using field measurements and historical maps for 11 streams in Devon, England. Hooke isolated the catchment area, A, as the main influencing parameter. He expected a reasonable correlation between migration rate and site conditions, which includes catchment area, fine-grained soil content of bank material, presence of gravel layer, width to depth ratio, radius of curvature, slope, and bank height. Hooke proposed the eq. M_r = 2.45A $(km^2)^{0.45}$. Where M= Migration rate in m/year, A= Catchment Area in sq. km It clearly indicates that Brice's empirical equation seriously under-estimates the erosion rates in other rivers. This implies that his model is too simple to be applied to the other cases because he correlated migration rate with only one parameter, channel width. Brice (1982) collected meander migration data for 43 meanders in four different river types (equiwidth, wide bend, braided-point bar, and braided). An equiwidth river is one where the width of the river is approximately constant. A wide bend river is one where the river width is larger at the meanders. A braided point bar river is one where the inside of the meanders fills with sand bars and the main channel does not fill the entire width at lower flows. Brice selected the channel width, b, as the main influencing parameter and obtained his equation from regression against the 43 data points. Brice gave an equation. In their eq. M_r = 0.01b, M_r= is the meander migration rate (m/yr.), and b is the width of the river channel (m). Nanson and Hickin (1983) collected meander migration data for 18 river channels in Western Canada. They selected the radius of curvature normalized with respect to the channel width, r_c/b, as the main influencing parameter. Then they plotted their data and observed that when the ratio r_c/b was between 2 and 3, the migration rate tended to be maximum. They drew two envelopes on their data. In their eq. $\frac{Mr}{b}$= 0.1 (($\frac{r_c}{b}$) - 1), when $\frac{r_c}{b}$is smaller than 2.3 &$\frac{Mr}{b}$= 0.35 (($\frac{r_c}{b}$) -1), when $\frac{r_c}{b}$is larger than 2.3, $M_r$is the meander migration rate (m/yr.), b is the channel width (m), and $r_c$is the radius of curvature of the meander (m). The normalized migration rate (M_r/w) is highest when the ratio of radius of curvature to channel width (r_c/w) is about 3. At large r_c/b ratios, the radius $r_c$is large compared to the channel width b and, for a given flow velocity, the centrifugal force which is inversely proportional to the radius of curvature is small; this leads to a small erosion rate. Geometry is only one factor affecting meander migration. Blondeaux and Seminara (1985), a 2D model of flow and bed topography in sinuous channels with erodible boundaries is developed and applied to investigate the mechanism of meander initiation. 'Resonance' phenomenon is detected which occurs when the values of the relevant parameters fall within a neighborhood of certain critical values. This controls the bend growth, and it is shown that it is connected in some sense with bar instability. In fact, by performing a linear stability analysis of flow in straight erodible channels, resonant flow in sinuous channels is shown to occur when curvature 'forces' a 'natural' solution represented by approximately steady perturbations of the alternate bar type. The assumptions of the method are: (i) Flow in a sinuous channel with constant normal width 2B*, small curvature and erodible boundary to develop a "bar" and "bend" approach, (ii) Longitudinal channel axis at the level of the undisturbed bed has constant slope S and describes a curve in space, & (iii) A convenient orthogonal coordinate system is (s*, n*, y*), where n* is the radial distance from the longitudinal axis and y* is a vertical coordinate positive in the direction opposite to gravity. Odgaard (1987) adopted the bend theory (Ikeda et al. 1981), in which the rate of bank erosion is proportional to the difference between the near-bank depth-averaged mean velocity and the reach-averaged mean velocity at bank full discharge. The subsequent condition shows that the disintegration rate corresponds with channel qualities, for example, width, depth, curvature, twist point of channel focus line, channel slope, friction variable, and level of vegetation on the banks. The predictions using this equation agreed well with data measured using historical records (air photos, maps, and stream flow records), field measurements, and soil analysis in the East Nishnabotna River and Des Moines River in Iowa. They proposed an eq.

$$\frac{\bar{v}}{u}=2\mathbf{E}\times\frac{b}{r_c}\left(1+\frac{b}{r_c}\right)^{-1}\mathbf{F}\ ;$$

$$\text{where, } \mathbf{E}=\frac{e}{8}\left(\frac{3\alpha}{2}\frac{\sqrt{\theta}}{k}\frac{m+1}{m+2}F_{DC}-1\right),\ \mathbf{F}=1-\exp\left(-\mathbf{B}\frac{r_c\phi}{b}\left(1-\frac{\beta}{\emptyset}\right)\right)\&\mathbf{B}=\frac{2k^2}{(m+1)^2}\frac{b}{d_c}.$$

Here, $\bar{v}$= the average rate of the erosion, (m/yr.), u = reach-average mean velocity, (m/s), e = erosion constant, α = 1.27, θ = Shields' parameter (= 0.06), m = friction parameter, k = Karman's constant (= 0.40), F_{DC} = particle froude number, b = bank-full width of channel (m), r_c= radius of curvature (m), φ = bend angle, β = angle from crossover to first outer bank erosion occurrence, $_{DC}$ = center line flow depth. If the right erosion constant is picked, the predicted migration rate is close to the measured one. Although soil erodibility is a fundamental property of soil, it is treated as an empirical coefficient here. An e value can be chosen based on existing records, but there is no guarantee that the value will work for a true prediction case. Soil erodibility can be obtained using the erosion function apparatus (EFA) to test the erosion function of the soil (Briaud et al., 2001a). It would be worthwhile to study how to replace the erosion constant e here with the EFA function. Biedenharn et al. (1989) investigated the behavior of meandering bends on the Red River, particularly the reaches between Shreveport, LA, and Index, AR. Total 27 annual erosion rate were correlated with the ratio of radius of curvature of a bend (r) to channel width (W) as Nanson & Hicken (1984) did for their empirical approach [M = f (ω, W, D50, h, r)]. For correlation, data were collected from historical maps, hydrographic surveys and aerial photographs for the years 1930, 1938, 1959, 1969, 1980 and 1984. There is no empirical equation for this theory. Hudson and Kesel (2000) investigated channel migration and morphology of meandering bends for the lower Mississippi River for the period from 1877 to 1924, prior to channel cutoffs, revetments, and change in sediment regime. The average migration rate was 45.2 m/yr. in the upper alluvial valley and increased to 59.1 m/yr. in the lower alluvial valley. They tried to correlate the migration rate with the ratio of radius of curvature of a bend (r) to channel width (W). The highest migration rate occurred when the ratio of radius of curvature to channel width was between 1.0 and 2.0. They did not propose a prediction method. Darby et al. (2002) developed a comprehensive numerical model to simulate bank erosion and channel migration in meandering rivers. Their model consists of three sub models for flow, sediment transport, and bank erosion. One of unique features in this model is that the model can simulate the deposition of collapsed bank material and its removal from the toe of the bank by the flow. The model was evaluated by using two sets of flume tests data and one set of actual river data. The results are promising, but they generally underestimate the bank migration rates, which is undesirable. Abad and Garcia (2006) developed the RVR MEANDER program as a handy toolbox to assist the prediction of meander migration. This program is based on their model for the evolution of meandering rivers. There are two sub-modules in this model. One sub-module (statistical module) estimates primary parameters of the meandering channel such as sinuosity, migration rate, fattening, and skewness automatically by comparing input geometries at three different times. Another sub-module (migration module) simulates a plan form evolution (migration) based on the bend theory (Ikeda et al. 1981) where the bank erosion rate is proportional to the difference between the near-bank depth-averaged mean velocity and the reach-averaged mean velocity. RVR Meander was developed using object-oriented programming (OOP) style.

Experimental methods for meander prediction:

Experiment of meandering river commonly requires a significant amount of effort to prepare the physical model in a flume, as well as an extremely high cost. A few valuable previous works based on the experimental study related to meander migration are reviewed and summarized in the following sections. List of Experimental Methods are given below: Friedkin (1945), the most remarkable set of flume tests on behaviour of self-formed meandering rivers in a large-scale flume, 36 m long and 11.4 m wide, was conducted by the U.S. Army Corps of Engineers (Friedkin 1945). They conducted these flume tests in different conditions to investigate the effect of discharge, angle of attack, bed slope, initial cross-section, material types, and not feeding sand at the entrance. The studies were not based on a quantitative approach but rather on a qualitative approach. Schumm & Khan (1972) suggest that landforms may not always respond progressively to altered conditions. Rather, dramatic morphologic changes can occur abruptly when critical erosional and (or) depositional threshold values are exceeded. Schumm and Khan examined the behaviour of the model channel in a flume with respect to slopes and sediment loads. Nakagawa (1983) investigated the effect of the different boundary conditions at the wetted perimeter on the channel meandering by conducting a series of flume tests. He proposed that the shear stress distribution in the transverse direction is one of the primary parameters affecting channel meandering. Based on the experimental results, it was found that there is a prerequisite criterion in terms of a ratio of two shear forces at the channel bottom and bank to initiate river meandering. When the ratio of the total shear force along the channel bottom to that at the bank is lower than 0.2, the channel will meander. Smith (1998) used a small-scale flume with a mixture of light, fine grained sediment to simulate meandering streams. Total of three experiments were conducted with different combinations of rock flour, diatomaceous earth, kaolinite, corn-starch, calcined white China clay. Nagata et al. (2000), in this method, to predict the movement of the bank-line associated with erosion, a sediment transport model was developed based on the theory of non-equilibrium sediment transport reported by Nakagawa. No specific relationship of meander migration from the experiments was proposed in this study. Briaud et al. (2003) developed the SRICOS-EFA method to predict the scour depth in clay as a function of time in a probabilistic way. This analysis provides a statistical framework that can be used in a cost-benefit study of bridge foundation design. Lagasse et al. (2003, 2004a, 2004b), the drawbacks of this method are that it cannot incorporate either a change in soil condition or a future hydrograph different from the past hydrograph. It was conducted under National Cooperative Highway Research Program (NCHRP). The advantages are its simplicity and its field-scale soil specifications.

RESULTS AND DISCUSSIONS

The analysis developed in the previous sections and the comparison with experimental data seems to support the idea that alternate-bar formation and bend amplification are controlled by two distinct mechanisms: instability in the former case, resonance in the latter. While laboratory observations have been used to substantiate theoretical findings, a comparison between theoretical predictions and field data was not attempted. This is because such a comparison would suffer from several difficulties associated with various features of the natural phenomenon that are not accommodated in the model. The main difficulty arises when one is forced to choose a 'representative' discharge of the river to feed in the calculations. By this procedure it is implicitly assumed that the effect of the variable regime of a river can be satisfactorily modelled in terms of a 'formative' discharge. There is not enough experimental or theoretical evidence to justify the above approach, which is then followed on empirical grounds, and this leads to different choices of the formative discharge by various authors, either based on geometrical criteria (bank full discharge) or on statistical considerations (mean annual discharge). The available data do not always correspond to the same choice, which complicates any attempt at comparison even further. Moreover, the theory concerns the incipient formation of meanders, whereas field data often refer to fully developed meanders. It has been observed that meander wavelength does not change much as its amplitude grows, but the same statement does not apply to the variations of slope, depth and width ratio. Data found in the literature should often be modified to reproduce the initial conditions of the process of meander formation. However, information is not always sufficient to allow such corrections.

SRH MEANDER: Simulation for Meander Prediction

SRH-Meander (Sedimentation and River Hydraulics - Meandering) is a computer model that simulates the bed topography, flow field, and bank erosion rate in a curved channel with an erodible bed. SRH-Meander is part of the SRH series, developed in the Sedimentation and River Hydraulic Group, Technical Service Centre, Bureau of Reclamation. Besides SRH-Meander, SRH series also includes SRH-1D (Sedimentation and River Hydraulics – One Dimension) and SRH-W (Sedimentation and River Hydraulics – Watershed).

SRH-Meander Capabilities:

SRH-Meander is a numerical model developed to simulate channel migration in meandering rivers. Some of the model's capabilities are: 1. Computation of water surface profiles in a single channel with standard step method or normal depth method. 2. Calculation of bank erosion rate with Randle's minimization method or Johannesson and Parker's linearization method. 3. Sixteen different non-cohesive sediment transport equations that are applicable to a wide range of hydraulic and sediment conditions. 4. Channel cut off simulation. 5. Computation of channel alignment. 6. Computation of river topography. 7. GIS input of channel alignment & channel erosion rate parameters. 8. GIS raster file input of river and floodplain elevations. 9. GIS raster file input of river and floodplain elevations.

CONCLUSIONS

For the empirical methods, most of the methods simplify the prediction and usually are concerned with one hydraulic parameter. However, for greater accuracy meander prediction models must consider soil, channel geometry and water. The comparisons indicate that the Keady and Priest method is reasonably conservative, that the Hooke method is overly conservative, that the Brice method is seriously under predicting the measurements, and that the Nanson and Hickin method splits the measured data with significant scatter. Based on this data alone, the Keady and Priest method appears to be a reasonably safe method to use keeping in mind that the scatter is significant. The input data for the MEANDER program consists of three parts; erodibility of the soil from the EFA test, digitized river coordinates, and hydrograph at a river. Among three input data, digitizing the geometries of the rivers and obtaining the hydrographs at the rivers are time consuming tasks, especially the digitization work. Therefore, it will be very helpful for the bridge engineers to run the MEANDER program if there are pre-developed databases of digitized coordinates and hydrographs for the rivers which have a relatively high potential for large migration. The current version of the MEANDER program was developed in the mixed language programming such as Visual C++ and MATLAB. Therefore, standardization is essential for greater accuracy in results.

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CHARACTERIZATION OF TROPICAL CYCLONES TRACK IN THE NORTHERN INDIAN OCEAN

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ABSTRACT
The Northern Indian Ocean (NIO) is a tropical cyclone prone region with annually average cyclone frequency of five to six. To identify the tropical cyclones characteristics this study was performed with 207 cyclones track during 1977-2016 over the NIO that consists of Bay of Bengal and Arabian Sea. From the Joint Typhoon Warning Center best track achieve record it was observed that the Bay of Bengal experienced 135 tropical cyclones during the study period but this amount was reduced to 50% (72) in case of the Arabian Sea. In the NIO an unequal cyclone distribution was observed as statistical records shows that the Bay of Bengal had experienced 1.88 times cyclones than Arabian Sea, although the Arabian Sea has an area 1.77 times of Bay of Bengal. The peak cyclone activity occurred during post monsoon season (Oct-Dec) and its secondary maxima are pre-monsoon phase (Apr-June).Therefore bimodal seasonal distribution of cyclone activity is prominent in the NIO. Most of the cyclones (73%) in the NIO were either depression or tropical storm. Rest of the observed cyclones (56 cyclones) was categorized in scale 1-5 in Saffir-Simpson scale. 5 tropical cyclones were categorized in scale 5.Among those catastrophic cyclone events cyclone 1991 and Sidr (2017) that hits Bangladesh had sinuosity respectively 1.28 and 1.18. Again in 2010 cyclone Giri that hit the Myanmar coasts had the sinuosity of track 1.05. Therefore the spatial pattern of track is also important as the track curvature related to the cyclone intensity. It was concluded from the study that the atmospheric parameters i.e. wind velocity and pressure were not sufficient to characterize the cyclones track rather spatial pattern of cyclones movement can make more rational categorization.

Keywords: ArcGIS, Cyclone category, Wind velocity, Sea level pressure.

INTRODUCTION
Tropical cyclones (TCs) are commonly associated with devastation resulting in enormous loss of life and property depending on storm surge height, landfall intensity and location, and wind velocity etc. TCs are intense atmospheric vortices develop over the warm oceans with some consecutive atmospheric events i.e. wind circulates in cyclonic convection form, surface air begins to flow inward cyclone's center, inward trek air maintains exactly same temperature as sea surface but collect tremendous water vapor from ocean (Wahiduzzaman et al., 2017; Zhao et al., 2018). Analyzing historical cyclone track can aid to costal vulnerability assessment by providing precise information on cyclone movement pattern(Levinson et al., 2010). With climate change the frequency and intensity of tropical cyclone got increased from previous century that could cause frequent coastal flood. Northern Indian Ocean (NIO) that consists of Bay of Bengal (BoB) and Arabian Sea, notably experiences 7%. of global tropical cyclone activity(Jensen, 2007; Sahoo and Bhaskaran, 2016). Bay of Bengal has tropical cyclone frequency of five times higher than Arabian Sea. The cyclone activity in NIO is predominant in two periods, i.e. April-June and October-December, although lesser frequency of tropical cyclones was observed in other months of year. Due to most populated coastal zone on earth this region attracted attention in recent decades. Previous archival

information identified 2.08 human death tolls due to cyclone activity between1484-2009 (Alam and Dominey-Howes, 2015). To characterize the cyclones track this study was carried out using ArcGIS geospatial analysis over the 40 years (1977-2016) with 207 tropical cyclones track in the NOI. Wind velocity and atmospheric pressure at cyclone eye was considered to categorize the cyclone track based on available best track information of Joint Typhoon Warning Center (JTWC).

METHODOLOGY

To analyze the tropical cyclone track the related information i.e. wind speed, atmospheric pressure, six hour position, beginning and end time was acquired from JTWC (www.usno.navy.mil/JTWC/). The pressure at cyclone eye was available from 2001 after the development of satellite based cyclones observation. Further the information was stored as geodatabase for geospatial analysis in ArcGISv10.1for each cyclone track. The geodatabase composed of cyclones track as polyline and cyclone position as point shapefile. To get an accumulated cyclones achieve further the polyline was merged together. Then the cyclones track was reclassified based on the ocean basins i.e. Arabian Sea and BoB to get details information of cyclone activity over those oceans. Considering the cyclone frequency the month October was used as a boundary of two cyclone period i.e. pre monsoon (Feb-Sep) and post monsoon (Oct-Jan). Based on the Best track dataset for all individual cyclone track following parameters were attributed: a) start time (origin) and end (decay), b) duration, c) pressure d) wind velocity. The cyclones track was reclassified in ArcGIS using query string while selecting in attribute based on the cyclone periods and the ocean. To categorize the cyclones track Saffir-Simpson scale was applied (Table 1). To categorize the cyclones track the attributes were exported in Excel and classified using if-else statement. After categorizing the cyclones the attributes were imported as new field using Join Field tool. This methods was adopted over 207 cyclones track with 4306 cyclones position to symbolize the tracks accordingly the cyclone periods [Fig. 4] wind velocity]Fig. 5], cyclone pressure]Fig. 6] and the category [Fig. 7].

Table 1: Categorization of cyclones track

Scale	Wind Speed		Pressure (mb)
	kmph	knots	
Depression	<63	< 34	-
Tropical Sorm	64-118	34-63	-
Category1	119-153	64-82	> 980
Category 2	154-177	83-95	965-980
Category 3	178-209	96-112	945-965
Category 4	210-249	113-135	920-945
Category 5	≥250	>135	<920

RESULTS AND DISCUSSIONS

Frequency and spatial variations in cyclogenesis

From the observed 207 cyclones event 62.8% was occurred between October-December that is after the summer monsoon or post monsoon. The cyclones event has less pre monsoon (April-June) occurrence of 25.12%. Therefore the bimodal seasonal distribution is prominent in NIO. The peak cyclone activity occurred during post monsoon seasons and its secondary maxima are pre-monsoon phase. There were no cyclone activity in the month February and March (Fig. 1).In the NIO basin an unequal cyclone distribution was observed between Arabian Sea and BoB which can be appeared from the BoB was experienced 1.88 times than Arabian Sea. Most of the cyclones (73%) in the NIO were either depression or tropical storm. Among the observed cyclones 56 cyclones can be categorized in scale1-5 [Fig. 7]. Peak cyclone activity was observed during the year 1991, 2007 and 2009 with annual frequency more than 6. Increasing sea surface temperature (SST) changes the ocean more favorable for cyclogenesis. In northern hemisphere tropical cyclone activity was reduced by El Niño-Southern Oscillation (ENSO) phenomenon (Kuleshov et al., 2010). Subsequently the spatial and temporal distributions are also changing throughout the globe. Therefore in upcoming decades the ENSO effects and increasing SST should consider while observing TC activity.

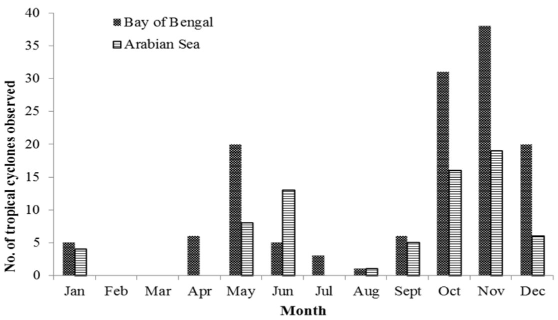

Fig. 1: Monthly distribution of cyclones over 1977-2016

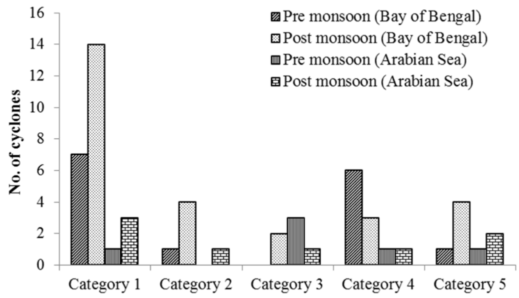

Fig. 2: Bimodal seasonal distribution of cyclone category

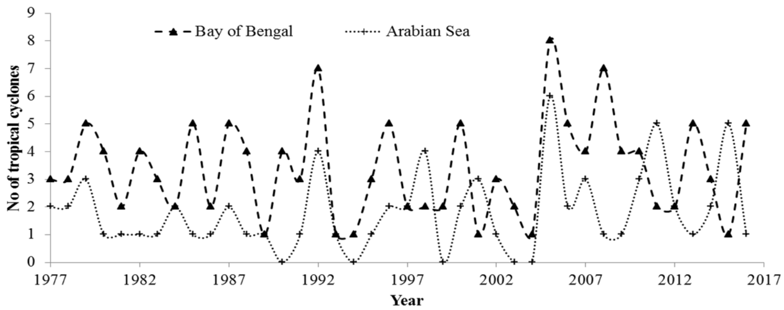

Fig.3: Frequencies of tropical cyclone during 1977-2016

Spatial pattern of cyclones track

From geographical perspective cyclone research necessarily requires spatial analysis cyclogenesis locations, movement pattern, initial origins and formations. In this study the cyclones track is their path of migration from its origin. To analyze the spatial pattern in the NIO the cyclones track was classified according to pre and post monsoon period [Fig. 4].

In the Bay of Bengal the majority of cyclones were originated from the central and southern parts of Bay of Bengal. During the pre-monsoon period of Bay of Bengal the most vulnerable part for cyclone was south east region of Bangladesh as cyclone track density was highest.

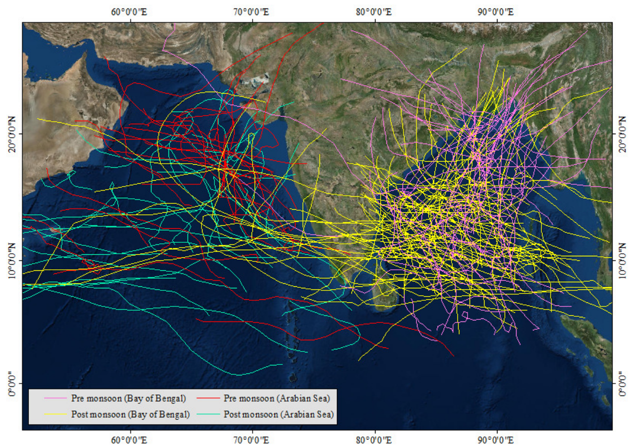

Fig. 4 Pre-monsoon and post monsoon cyclones track in the Northern Indian Ocean from 1977-2016

For post monsoon period in the same ocean the scenario got altered and Tamil Nadu, located in south India found vulnerable in terms of cyclones track density. In the Arabian Sea the cyclones track originating from central parts of Indian Ocean turns towards either north or south direction while hitting the coastal regions. Maximum cyclone track density was found in Yemen or Somalia during post monsoon periods that changed to Oman during pre-monsoon periods. The cyclones track shape is also important as track curvature related to the cyclone intensity. The sinuosity (indicates the ratio between the travelled distance and the shortest distance between origin and end) can be related to the cyclone intensity (Terry et al., 2013). Previous catastrophic cyclone events like cyclone 1991 and Sidr (2017) that hits Bangladesh had sinuosity respectively 1.28 and 1.18. Again in 2010 cyclone Giri hits the Myanmar coasts had the sinuosity of track 1.05. Sinuosity near 1 indicates straight cyclone track that can be identified as more vulnerable for coastal zones. 5 tropical cyclones (Table 2) were categorized in scale 5 that brought catastrophe at the coastal zone.

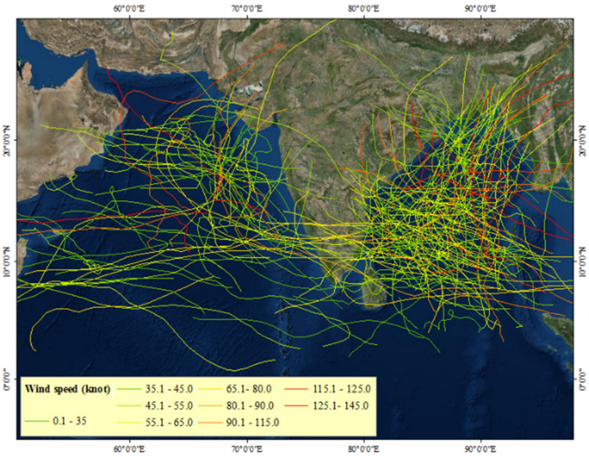

Fig. 5: Wind velocity map of the cyclones

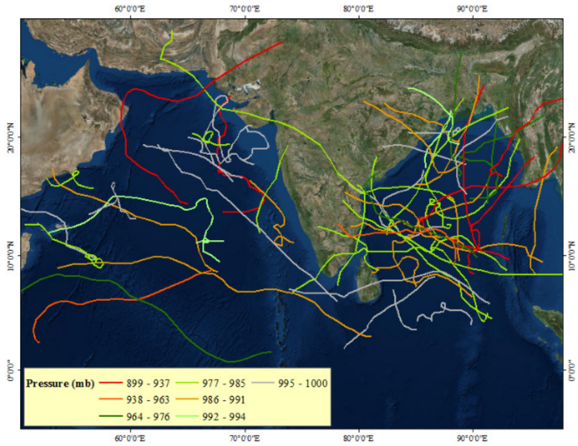

Fig. 6: Cyclone pressure map during 2001-2016

Table 2: List of Category 5 cyclones in the Northern Indian Ocean

Cyclone name	Landfall location	Duration	Maximum Wind speed (knot)	Prssure (mb)
Sidr	Bangladesh	10Nov 2007- 16 Nov2007	145	934
Kavali	India	31Oct1989-10 Nov 1989	140	--
Phailin	India	07 Oct 2013-14 Oct 2013	140	940
Cyclone 1991	Bangladesh	22 Apr 1991- 30 Apr 1991	140	918
Gonu	Oman	31May 2007-08 June 2007	145	920

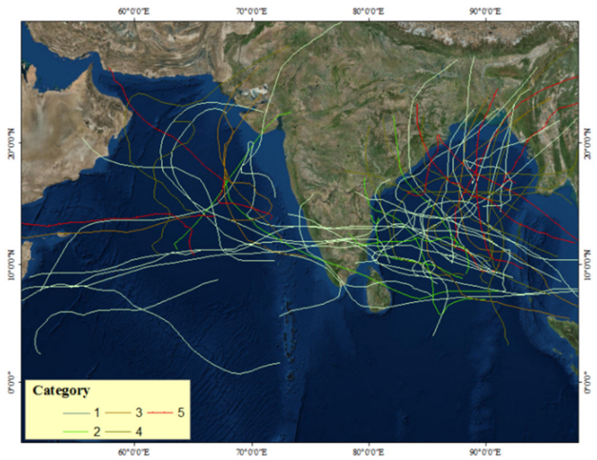

Fig. 7 Categorization of tropical cyclones track in Saffir-Simpson scale

CONCLUSIONS

This study was conducted with 207 cyclones track in the northern Indian Ocean occurred between 1977-2016, based on JTWC best track achieve. ArcGIS was employed to analyze the spatial pattern of the cyclones movement. The atmospheric parameters i.e. wind speed, pressure were used to categorize the cyclones in Saffir-Simpson scale. Bimodal seasonal distribution was observed with principle maxima during post monsoon seasons. The catastrophic cyclones event had occurrence probability during post monsoon phase. During the study period 5 tropical cyclones i.e. cyclone Sidr, Kavali, Gonu, Phailin and cyclone 1991 were categorized in scale 5. To comprehend the cyclogenesis process several parameters i.e. sinuosity, ENSO, climate change, sea surface temperature can be recommended for improved characterization. The southern Bay of Bengal and central parts of Bay of Bengal was detected as the origin of cyclogenesis. Therefore this region could be further studied to obtain the meteorological parameters that promote cyclogenesis. For improved classification of cyclones K-means clustering and climatology highlighting lower and upper troposphere can be embedded with atmospheric parameters (Horvath et al., 2008). Therefore, this study recommended further cyclone characterization with physical parameters like sea level pressure, wind velocity, relative humidity with climate change.

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CALIBRATION OF MANNING'S ROUGHNESS COEFFICIENT FOR KUSHIYARA RIVER USING HEC-RAS 1D MODEL

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ABSTRACT
Channel roughness is the most sensitive parameter in development of hydraulic model for flood forecasting and flood plain mapping. Hence, it is essential to calibrate the channel roughness coefficient (Manning's "n" value) for various river reaches through simulation of floods. The appropriate value of Manning's roughness coefficient (n) is chosen through the process of calibration i.e., the value which reproduces observed data to an acceptable accuracy. In this study, the HEC-RAS unsteady flow model is applied to Kushiyara River, Bangladesh to predict the value of Manning's roughness coefficient through the calibration procedure. The data are taken for the period from 01 January 2009 to 31 December 2010 and divided equally into two sets. The first set (year of 2009) is for calibration purpose i.e., estimation of (n) and the rest (year of 2010) for validation which is the process of testing the model with actual data to establish its predictive accuracy. It is found from the simulation of flood for year of 2009 that the value of Manning's roughness coefficient (n) for Kushiyara River is 0.029. Analysis of results shows that the roughness value of (n=0.029) reasonably produces hydrographs closer to the observed ones and this indicates that the model is acceptable. In this study, a Statistical test (Root Mean Square Error) has been used for comparison of simulated hydrographs with the observed hydrographs. It is concluded from this study that the manning's roughness coefficient for the Kushiyara River is 0.029, since it gives reasonable agreement between computed and observed hydrographs.

Keywords: Manning's Roughness Coefficient; Calibration; Kushiyara River; HEC-RAS Model.

INTRODUCTION
A well calibrated hydraulic model provides reliable information on different aspects of the real situation. The numerical model is used to simulate the actual behaviour of the river, but it is also an important tool to produce a forecast on possible flooding, peak discharges, low water levels etc. For that, a representative model, with determination of the topography of the river and river banks and registration of the discharges and water levels, is necessary. A parameter of main importance is the roughness of the river channel and the banks (Doncker et al., 2009). For flood warning, the discharge and river stage were chosen as the variables, which along with other hydraulic properties are interrelated to each other (Bao et Al., 2009). Among various hydraulic parameters, the channel roughness plays very important role in the study of open channel flow particularly in hydraulic modelling. Channel roughness is highly variable which depends upon number of factors like surface roughness, vegetation cover, channel irregularities, channel alignment etc. (Ramesh et al., 1997). It also depends on such factors as: bed material, vegetation, channel irregularity and alignment, scour and deposition, obstructions, channel size and shape, stage and discharge, seasonal changes, suspended material and bed load (HEC-RAS user manual). Several researchers including (Patro et al., 2009), (Usul and Turan 2006), (Vijay et al., 2007) and (Wasantha Lal 1995) have calibrated channel roughness for different rivers for the development of hydraulic model for flood forecasting and flood plain mapping. (Hammed et al., 2013) estimated manning's roughness coefficient for Hilla River through calibration using HEC-RAS model. (Doncker et al., 2009) determines the manning roughness coefficient influenced by vegetation in the river Aa and Biebrza river.

(Kumar 2013) calibrated and validated Mannnig's "n" value using HEC-RAS for Mahanadi River in Odisha (India). In the above context, there is a need to calibrate the channel roughness coefficient (Mannnig's "n" value) for the Kushiyara River, Bangladesh through simulation of floods, using HEC-RAS. Since Kushiyara River experiences severe floods frequently causing huge loss to life and property. Hence the present study attempts to estimate the channel roughness coefficient (Manning's "n") of Kushiyara River. The main objective of this study is to calibrate and validate HEC-RAS model for Kushiyara River to estimate the Manning's roughness coefficient.

METHODOLOGY

Study Area and Data Collection

This study concentrates to the Kushiyara River [Fig. 1] which originates from Barak River in India and passes through Sylhet, Moulvibazar and Habiganj district in the North-East region of Bangladesh. Model input data (bathymetry, water level and discharge) have been collected from Bangladesh Water Development Board (BWDB). Water level and discharge data have been collected for the year of 2009 and 2010. Calibration has been done for the year of 2009 and second set of data (2010) has been used for validation purpose.

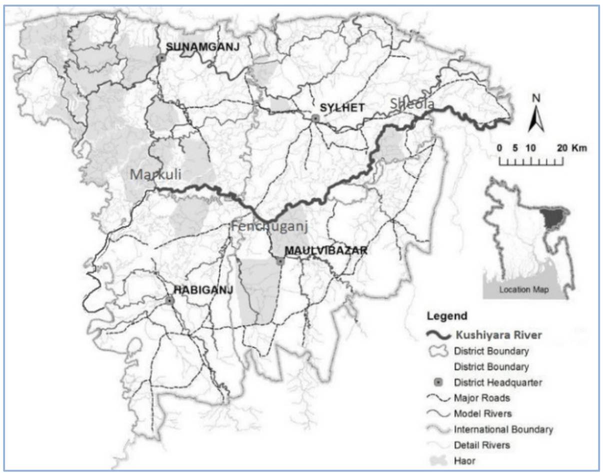

Fig. 1: Study area

Model Description

In the present study, HEC-RAS 1D Model has been applied for assessing flow of the Kushiyara River of Bangladesh. HEC-RAS, which is dependent on finite difference solutions of the Saint-Venant equations has been used to simulate the flood

$$\frac{\partial \boldsymbol{A}}{\partial \boldsymbol{t}} + \frac{\partial \boldsymbol{Q}}{\partial \boldsymbol{x}} = \boldsymbol{0} \qquad (1)$$

$$\frac{\partial Q}{\partial t} + \frac{\partial \left(Q^2 / A \right)}{\partial x} + gA\frac{\partial H}{\partial x} + gA(S_0 - S_f) = 0 \qquad (2)$$

Here, A = cross-sectional area normal to the flow; Q = discharge; g = acceleration due to gravity; H = elevation of the water surface above a specified datum, also called stage; S_0 = bed slope; S_f= energy slope; t = temporal coordinate and x = longitudinal coordinate. Both equations are solved using the well-known four-point implicit box finite difference scheme.

Kushiyara River unsteady flow HEC-RAS model

For the calibration of channel roughness coefficient (Manning's "n") HEC-RAS 1D unsteady flow model has been developed for the Kushiyara River, Bangladesh. At the upstream of the Kushiyara River flow hydrograph and at the downstream stage hydrograph has been used as upstream and downstream boundary conditions respectively. There are some lateral channels exist with the Kushiyara River which affect the flow of the main River. SonaiBorda and Juri Rivers meet with Kushiyara River near Fenchuganj. For this purpose a lateral flow hydrograph has been used for the development of the model.

RESULTS AND DISCUSSIONS

Calibration of HEC-RAS Model for Manning's Roughness Coefficient

The data pertaining to the floods for year 2009 (1st January 2009 to 31st December 2009) have been used for calibration of Manning's roughness coefficient "*n*". In the present study, effort has been made to calibrate Manning's roughness coefficient for single value using aforesaid data and subsequently, different values of "*n*" (from 0.035 to 0.026) have been used to justify their adequacy for simulation of flood in the study reach along the channel. Root Mean Square Error (RMSE) test has been used for comparison of simulated stage hydrograph (computed using different Manning's roughness coefficient "*n*") with the observed stage hydrograph at Sheola and Fenchuganj gauging station where gauge stage data is available. Table 1 shows the simulation duration, name of gauging station and various single values of "n" (from 0.035 to 0.026) used for model calibration. Among them the comparison of observed and simulated stage hydrograph (calibration) at Sheola and Fenchuganj gauging station for Manning's "*n*" value of 0.029 and 0.035 is shown in [Fig. 2] and [Fig. 3] respectively.

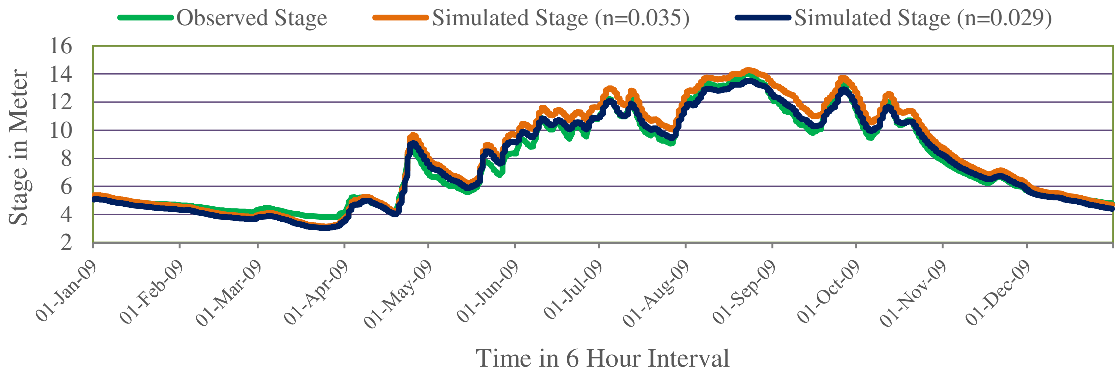

Fig. 2: Simulated and observed stage hydrographs at Sheola station for different Manning's (n)

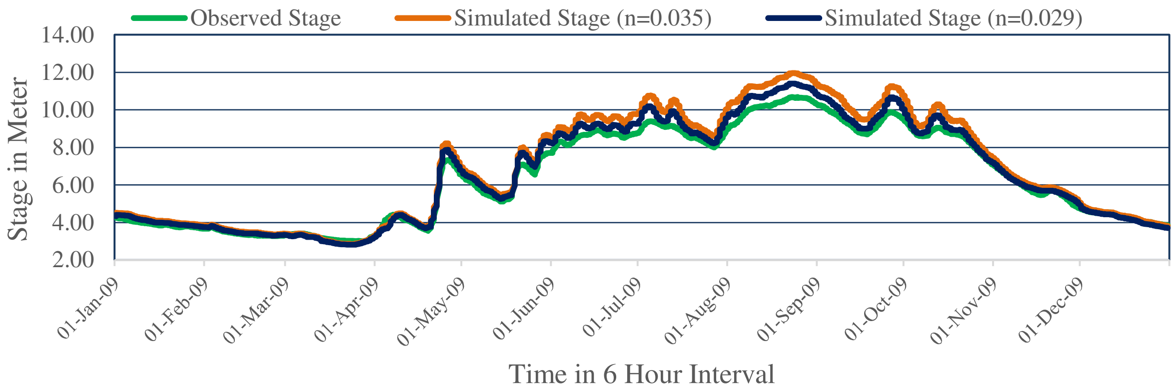

Fig. 3: Simulated and observed stage hydrographs at Fenchuganj station for different Manning's (n)

The observed and simulated hydrograph for Manning's n=0.029 is close enough. But in the high flow period (June to October) simulated stage is higher than the observed stage whereas in the low flow period (January to March) observed stage is higher than the simulated stage. The correlation between observed and simulated stage hydrograph gives R^2 value at Sheola and Fenchuganj station is 0.9851 and 0.997 respectively which is shown in [Fig. 4] and [Fig. 5]. From Table 1 it is clearly visible that for the flood of the year 2009 Manning's "n" value of 0.029 yields minimum RMSE of 0.412 at Sheola station and RMSE of 0.337 at Fenchuganj station.

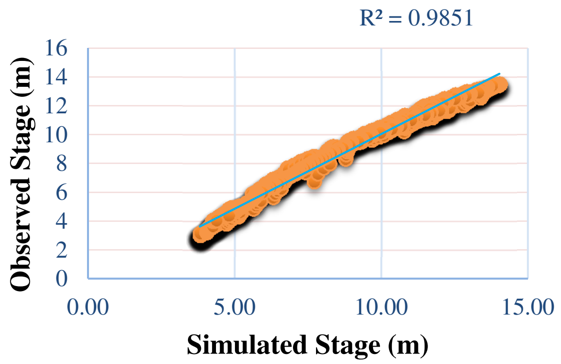

Fig. 4: Correlation between observed and simulated stage at Sheola station for the value of Manning's n=0.029

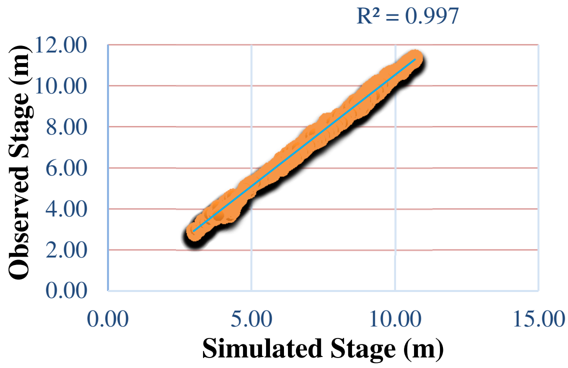

Fig. 5: Correlation between observed and simulated stage at Fenchuganj station for the value of Manning's n=0.029

Table 1: Simulation duration, Manning's "n" and gauge stations used for calibration

Simulation duration	Gauge stations used for calibration	Roughness coefficient Manning's "n"	Root Mean Square Error (RMSE)
1st January 2009 to 31st December 2009	Sheola	0.035	0.713
		0.033	0.574
		0.031	0.464
		0.030	0.423
		0.029	0.412
		0.028	0.418
		0.026	0.492
1st January 2009 to 31st December 2009	Fenchuganj	0.035	0.676
		0.033	0.564
		0.031	0.454
		0.030	0.401
		0.029	0.337
		0.028	0.331
		0.026	0.356

Performance of Calibrated Model in Simulation of Flood for Year 2010

Model verification, which is an essential test for any simulation model, is achieved by applying it to the second set of data from the period (1st January 2010 to 31st December 2010) using the roughness parameter (n=0.029) derived from the calibration runs. The verification process of the unsteady flow model has been achieved by making a comparison between the observed and computed stage hydrographs at the Sheola and Fenchuganj gauge station. Results of the verification process show that the (n) value of (0.029) reasonably produces hydrographs closer to the observed ones as shown in [Fig. 6] and [Fig. 7].

From the correlation between observed and simulated stage (1st January 2010 to 31st December 2010) it is shows that R^2 value is 0.9929 and 0.995 at Sheola and Fenchuganj station respectively which is shown in [Fig. 8] and [Fig. 9]. Table 2 shows the simulated flood hydrograph at Sheola and Fenchuganj gauging station for Manning's "n" value of 0.029.

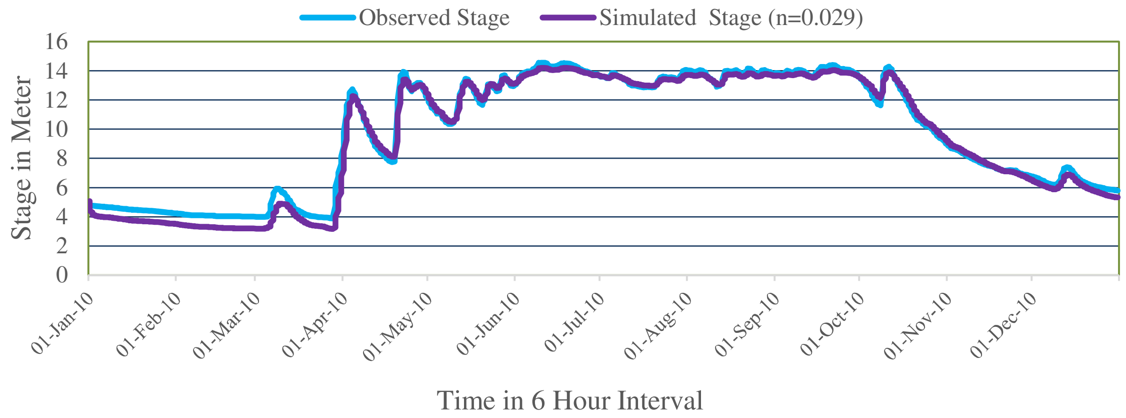

Fig. 6: Simulated and observed stage hydrographs at Sheola station for the value of Manning's n=0.029

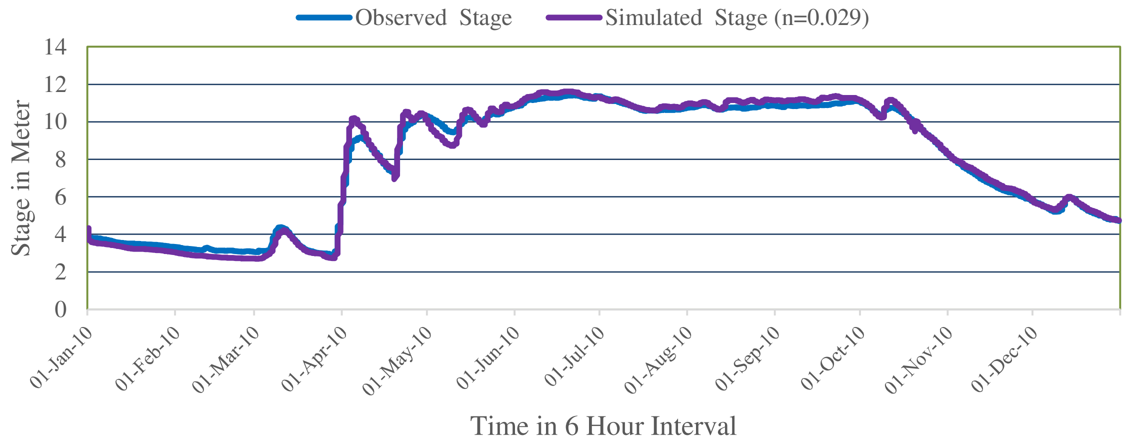

Fig. 7: Simulated and observed stage hydrographs at Fenchuganj station for the value of Manning's n=0.029

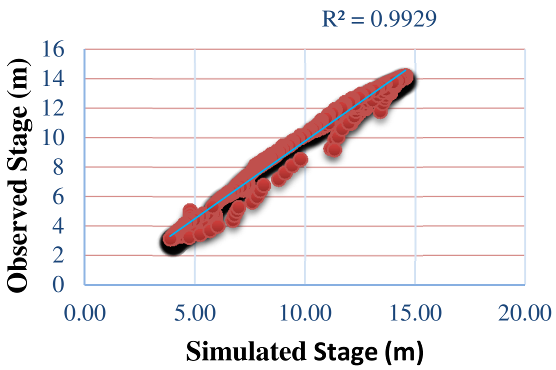

Fig. 8: Correlation between observed and simulated stage at Sheola station for the value of Manning's n=0.029

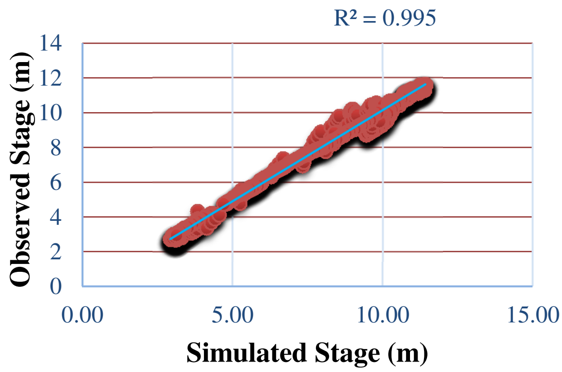

Fig. 9: Correlation between observed and simulated stage at Fenchuganj station for the value of Manning's n=0.029

Table 2: Simulation duration, Manning's "n" and gauge stations used for validation

Simulation duration	Gauge stations used for validation	Roughness coefficient Manning's "n"	Root Mean Square Error (RMSE)
1st January 2010 to 31st December 2010	Sheola	0.029	0.485
1st January 2010 to 31st December 2010	Fenchuganj	0.029	0.312

CONCLUSIONS

Unsteady flow HEC-RAS model is developed for the Kushiyara River to predict the value of Manning's (n) through calibration process. The most effective single Manning's roughness coefficient calibrated (on flood data of the year 2009) and validated (on flood data of the year 2010) for the Kushiyara River comes out to be 0.029, since it gives reasonable agreement between computed and observed hydrographs. RMSE value is minimum for the calibrated Manning's roughness coefficient (n=0.029). Since the roughness coefficient seem to be strongly dependent of river discharge and show a cyclic variation over the year. For this reason if calibration has to be develop with the low flow and high flow period separately it may provide better result than calibration for the whole year. The roughness coefficient is higher when the discharge is low due to the development of bed forms in river at low discharges. The roughness coefficient is lower when the discharge is high. At high discharges bed forms almost disappear.

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A REVIEW ON SEDIMENT TRANSPORT MODELS OF TIDAL RIVERS

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ABSTRACT
Sediment transport in tidal rivers largely depends on settling velocity and river flow. However, heavy sediment deposition poses threat to the aquatic lives as well as increases the floodplain of the rivers. On the other hand, lower deposition reduces vegetative growth leading to the river bank erosion and land loss. Although Karnafuli and Halda River play important economic role in Bangladesh, there are very few field studies as well as numerical modelling covered the detail sediment transport in these rivers. Thus, there is a knowledge gap for the decision makers to implement any integrated water resources project in these rivers. Therefore, along with a periodic field survey an intensive numerical model study could provide information on sediment transport. In this connection, an intensive review was conducted on available sediment transport modelling literatures since 1977. Review outcomes showed 1D numerical models performed better in predicting basic parameters of the channels with unsteady flow. Then, since 1990s 2D models showed better performance over 1D by providing spatially varied information about water depth and bed elevation within rivers. Coupled 1D2D model may perform better in simulating sediment flow in one year period or higher but 3D model should be used to simulate the flow around an obstacle for getting better output of the model. In this regard, Delft3D appeared more convenient and reliable in generating reasonable output on sediment transport of tidal rivers.

Keywords: Tidal rivers; Sediment; Modelling; Karnafuli; Delft3D.

INTRODUCTION
The processes of water flow and sediment transport take place simultaneously in rivers, floodplains, and coastal areas. In natural rivers the water flow generally influences sediment transport and thus morphological evolution occurs (Qian et al., 2015, Simpson and Castelltort, 2006; Li and Duffy, 2011). Tidal channels are highly dynamic morphological features of many estuaries. At the earlier stage, most studies were based on in situ measurements or historical data (Ahnert, 1960) In recent years, with the development of computer capacity, long-term morphodynamic models have been developed (Vriend, 2003) and increasingly employed for tidal channel research (Hibma et al., 2003; Guo et al., 2015). They provide good insight to understand the tidal channel morphological evolution. The calculation of flow and sediment transport is one of the most important tasks in river engineering. It is not easy because of the many complex and interacting physical phenomena. 3D models were developed and tested over the years those allowed both suspended and bed-load sediment transport and the associated bed deformation for natural rivers (Papanicolaou et al., 2008). Rapid developments in numerical methods for fluid mechanics, computational modeling has supported studying sediment transport and associated morphological changes in different environments such as rivers, lakes, and coastal areas (Papanicolaou et al., 2008). This study provides a better understanding about trends and applications with respect to sediment transport models. Finally, this article is mainly focused on multidimensional computational 3D models. However, a brief overview of the 1D and 2D models is also included for providing a rational comparison with the main features of the 3D models.

APPROACHES

A wide range of models exists for use in simulating sediment transport. An intensive review were carried out on the model types based on the published works during 1968 to 2017. These models differ in terms of complexity, processes considered, and the data required for model calibration and model application. The most appropriate model will depend on the intended use and the characteristics of the catchment being considered. Data requirements of the model including the spatial and temporal variation of model inputs and outputs are also important factors (Merritt et al., 2003). In general, models fall into four categories. These are: empirical, conceptual, physics based and computational.

Empirical models

These are the simplest model, usually based on the analysis of observations and seek to characterize response from input data. Empirical models are frequently used as they can be implemented with limited data and parameter inputs, and are particularly useful as a first step in identifying sources of sediment and nutrient generation (Merritt et al., 2003). In last 50 years, 19 numbers of empirical models used for simulating sediment transport [Fig. 1].

Conceptual models

These tend to include a general description of catchment processes, without including the specific details of process interactions. This model does not require large amounts of spatially and temporally distributed input data. Parameter values for conceptual models have typically been obtained through calibration against observed data, for instance stream discharge and concentration measurements (Abbott et al., 1986). The lack of uniqueness in parameter values for conceptual models means that the parameters in such models have limited physical interpretability. Moreover, conceptual models are prone to error of aggregation. Compare to other models these are relatively low in numbers [Fig. 1].

Physics-based models

These are based on the solution of fundamental physical equations describing stream flow, sediment and associated nutrient generation in a catchment. Standard equations used in such models are the equations of momentum for flow and conservation of mass for both flow and sediment (Bennett, 1974). Where parameters cannot be measured in the catchment they must be determined through calibration against observed data. Each parameter has its own inaccuracy which may arise from measurement errors (Beck, 1987). Remarkable number of physics based models were developed since 1980 [Fig.1]. However, physics-based models are error prone due to their large parameter requirements.

Computational Models

With the rapid growth in computer technology, numerical models have become popular tools for the study of mobile bed hydraulics. Sediment transport computer models differ greatly in their characteristics based on their basic concepts (Merritt et al., 2003).

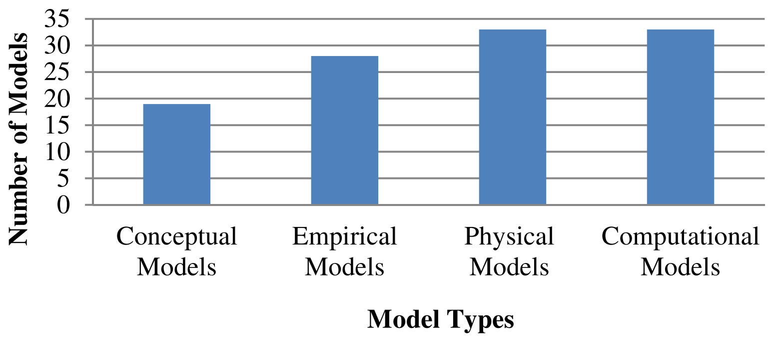

Fig. 1: Number of different types of models during 1968 to 2012

The computational models are divided into many different categories based on their dimension, width and many other factors that have been considered. Nowadays these are the most used and preferred model for simulation and modelling [Fig.1]. Conceptual models are prone to error of aggregation.

One-dimensional models

1D flow model solves only the cross-sectional averaged velocity, flow rate or discharge at each model cross-section. These models are simple to develop as well as use. Though model simplicity is gained by spatial averaging without details. Moreover, model cannot efficiently represent small scale flow and sediment processes. Therefore, 1D model is rather less responsive in predicting sediment transport and channel form (Table 1).

Table 1: 1D model description

Model Name	Application
IALLUVIAL	Simulation of flow and sediment processes in the Missouri River (Karim and Kennedy 1982)
FLUVIAL-11	Simulation of sediment-routing and associated river channel changes in the San Dieguito River (Chang, 1984).
Environmental Fluid Dynamics Code – 1D (EFDC1D)	Modelling the sediment transport in river with necessary data (hydrologic, hydraulic, and sediment data (Hayter et al., 2001)
NETSTARS	Simulation of bed load and suspended load separately under unsteady flow (Lee and Hsieh, 2003)
Mobile BED (MOBED)	Comparison of MOBED results with HEC-6 results for the flow and sediment transport along with the bed-level change for the Saskatchewan River below Gardiner Dam, Canada (Papanicolaou et al., 2008)

Two-dimensional models

For representing large-scale flow and sediment-transport processes 1D models are suitable. However, to address the position and amplitude of bars within the channel reach generally a 2D model is necessary, as a 1D model cannot predict the local flow and bar evolution. A 2D model should be applied to predict the details of local sediment transport or changes in bed morphology (Table 2).

Table 2: Description and application of 2D models

Model Name	Application
SEdiment and RAdionuclide TRAnsport (SERATRA)	Investigation of the effects of sediment on the transport of radionuclides in Cattaraugus and Buttermilk Creeks, New York (Walters et al. 1982)
SUTRENCH-2D	A mathematical model for predicting sedimentation (Van rijn et al., 1985)
TABS-2	Simulation of the flow and sediment transport processes in the Black Lake, Alaska (Papanicolaou et al. 2006)
Unsteady Sediment Transport models for Alluvial Rivers Simulations (USTARS)	Simulation of sand transport processes and associated bed-level changes of a reach in the Keelung River, Taiwan (Lee et al. 1997)
FLUVIAL 12	Simulation of flow and sediment processes of the San Dieguito River, Southern California (Chang et al., 1996)
MIKE 21	Quantitative analysis of hydrodynamic characteristics and suspended sediment transport in southern Yellow Sea (Xing et al., 2012)
Delft 2D	Simulation of the morphological processes responsible for the formation and evolution of the tidal channel system in the Hangzhou Bay (Xie et al., 2009)

Three-dimensional models

3D models for flow, sediment transport and bed evolution have become relatively common over the last decade. In many hydraulic engineering applications, one has to employ 3D models when 2D models are not suitable for describing certain sediment transport processes (Merritt et al., 2003, Papanicolaou et al., 2008). 2D models do not adequately represent the physics of flows which is possible in 3D models. With the latest developments in computing resources such as computational speed, parallel computing, and data storage classification 3D sediment transport models have become much more attractive to use (Table 3 and Table 4).

Model selection criteria

The competency of a model usually based on how the model will be used? Required details i.e. the count and type of inputs and outputs of the model and their spatial and temporal variability, and model validity. Generally model selection should be carefully carried out:

(a) Model assumptions should be carefully reviewed, especially of the empirical practices.
(b) The circumstances in which the model is presented, i.e., the topography, geography and geomorphological. For example, if a model was prepared for a monsoon weather condition, the

caution should be applicable for dry weather condition. Similarly the basin or watershed sizes also need to be considered during model selection.

(c) Awareness needs for model input data requirements while dealing with limited data bank.

Moreover, the model must be selected based on the evaluation, feasibility, cost, and time.

Table 3: Summary of selected 3D models

Model and references	Last Update	Flow	Equation Used	Cohesive Sediment	Source code	Language
TELEMAC	v7p1r0 January 2016	Unsteady	Navier-Stokes	Yes	Public	Fortran90
FLOW-3D	v11.2, Nov 2016	Unsteady	Meyer-Peter Muller	No	Proprietary	Fortran90
MIKE 3	2017	Unsteady	Navier-Stokes	Yes	Proprietary	Fortran90
Delft3D-FLOW	V4 2016	Unsteady	Navier-Stokes	Yes	Public	Fortran90
SSIIM 2	v.186, May 2016	Steady	Navier-Stokes and convection-diffusion	No	Public	C++
Computational Hydraulics 3D-SEDiment (CH3DSED3D)	-	Unsteady	Advection-diffusion	Yes	copyrighted	Fortan90
SHETRAN	V4 2016	Unsteady	Physics-based partial differential equations	Yes	Proprietary	Fortran77
Environmental Fluid Dynamics code (EFDC3D)	Version 1.01, 2007	Unsteady	Advective-diffusion	Yes	Public	Fortran77

Table 4: Application of 3D models

Model Name	Application
MIKE 3	Simulation of the flow, sediment transport processes, and water quality of Upper Klamath Lake, Oregon (Jacobsen and Rasmussen, 1997)
CH3D-SED	Simulation of hydrodynamics and sediment transport at several reaches of the Mississippi River (Gessler et al., 1999)
SHETRAN	Establishing relation between sediment yield and basin area (Birkinshaw and Bathurst, 2006)
Delft3D-FLOW	Simulated the morphological changes in Yangtze Estuary, China. (Logan et al., 2010)
TELEMAC	Simulation of sediment transport and bed morphology around Gangjeong Weir on Nakdong River in Korea. (Nguyen et al., 2014)
EFDC3D	Simulation of suspended sediment transport at Yuan-Yang lake in Taiwan. (Liu et al., 2016)

Studies in Bangladesh

Several hydrodynamic and morphological assessments have been carried out on some major rivers in Bangladesh viz. Padma, Karnafuli and Jamuna (Table 5). The main determinant of an appropriate model for exploring aspects of sediment movement through river basins is what the model user is attempting to address. This will identify the required explicit representation in the model as well as the spatial and temporal resolution at which a model needs to be applied. Determining the appropriate model for an application requires consideration of the suitability of the model to local catchment conditions, data requirements, model complexity, the accuracy, validity, assumptions, components and the objectives of the model user.

CONCLUSIONS

All numerical model considered predicting the similar hydrodynamic conditions. To understand the morphological behavior and sediment transport of rivers in Bangladesh several models have been used.

Among the discussed models so far the Delft3D is the most convenient and powerful tool for understanding and predicting sediment flow in rivers and coastal areas with reasonable output. However, for model section should be made as per the general criteria described earlier.

Table 5: Morphological studies in Bangladesh using different models

Source	Study area	Model used	Approach	Findings
Laz (2012)	Jamuna River	Delft 3D	Observation of water level data from 2010-2011, cross sectional variation from 2010-2012.	Simulation of sediment transport rate and variation of bed level was carried out.
Alam (2013)	Karnafuli River	Delft3D 2D model- flow module	Water level data for November (post monsoon) and June (monsoon) were collected.Velocity measured for January and August.	Assessed the erosion and deposition pattern due to dredging activities.
Chisty et al. (2014)	Karnafuli River	Remote sensing and GIS	Twelve years interval data of Landsat TM and ETM+ Satellite image of 1989, 2001 and 2013.	Prediction of shifting pattern of Karnafuli river.
Chowdhury and Navera (2015)	Karnafuli River	HEC-RAS 4.1.0	Time series discharge and water level data, bathymetry data were collected.	Analysis of sedimentation rate in the river.
Roy and Saha (2016)	Padma river	Delft3D	Bathymetry data for 2010, upstream discharge and water level data for 2010-2011, and Updated sediment data were collected.	Hydrodynamic and morphological behavior of the Padma River.

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EL NINO SOUTHERN OSCILLATION: LINKS AND POTENTIAL FOR LONG RANGE FLOOD FORECASTING IN THE JAMUNA AND THE GANGES RIVERS

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ABSTRACT
The forecasting of river flow has been an important goal for scientists and engineers for centuries. This research attempts to explore the nature and strength of possible teleconnections between the river flows of Jamuna and Ganges and El Nino Southern Oscillation (ENSO) variability over the equatorial Pacific Ocean and to develop a model which can capture the natural variability of flow and provide a large forecasting lead-time. El Nino was associated with decreased annual stream flow and La Nina with increased annual flows. The objective is to develop new methodologies for long-range forecasting of river flow, using El Nino forecasts, which can improve significantly the options for water resources management in the tropics. This research demonstrates a noteworthy relationship between natural variability of average flood flows of the month July-August-September (JAS) of the Jamuna River with ENSO index of the corresponding months. Sea surface temperature has been used as ENSO index. The correlation analysis between Sea Surface Temperature (SST) and river flows of Jamuna for different time period shows a notable improvement in relationship from the beginning of 1986s. From discriminant analysis it has been found that high flood events are mostly associated with La Nina and low floods are linked with El Nino. For Jamuna, possibility of high flow in a cold event is 100%.These links prompted the development of a statistical model which will allow a forecast lead time up to one year. The appreciable performances of the models in the calibration period assure the potentiality of the proposed approach for long-term planning of water resource management, agricultural practices and disaster relief preparation.

Keywords: El Nino; La Nina; Teleconnection; Correlation; ENSO Index; Flood Forecast Model.

INTRODUCTION

The country of Bangladesh frequently experiences severe catchment-scale flooding from the combined discharges of the Ganges and Brahmaputra rivers. Flooding normally occurs during the monsoon season from June to September. The aim of this research is to find out an effective and long-lead flood forecasting method which will be invaluable to the management of flood and water resources in Bangladesh using EI Nino-Southern Oscillation (ENSO) index .This long lead Forecast and warning information, hence, are vital for reducing potential human and economic losses due to floods. Especially our agricultural sector will be highly benefited from this model through proper planning of crops and its calendar. Floods during the summer monsoon are a recurring event in Bangladesh due to excessive rainfall and discharge, mainly from the Ganges and the Brahmaputra, into the Bangladesh delta, as well as retardation of outflow into the Bay of Bengal from high sea levels. A long lead forecast model can be defined as a model with lead time longer than hydrologic response time, usually up to several months (Maidment, 1992). Long range forecasts (monthly, seasonal) can help in Planning cropping strategy, national budget for relief, rehabilitation and reconstruction and Planning flood and drought response activities.

It has become increasingly apparent that skilful and long lead forecasts of monsoon inter seasonal variability may provide optimal information for regional agriculture. For example, in ADPC (2002), which deals with the impact of climate forecasts on agriculture in Bangladesh, it is noted that a long lead forecast is needed which will allow the farming community to respond and take meaningful remedial actions against either flood or drought. The objectives of the study are-

- To identify the nature and strength of possible teleconnections between the river flow (Jamuna and Ganges) and the ENSO index (sea surface temperature, SST) of different regions of Equatorial Pacific Ocean known as Nino regions.
- To assess the potentiality for flood flow forecast in wet months with a lead time of few months to one year using discriminant prediction approach and to evaluate the forecast skill.
- To develop statistical models for wet season flow in the selected rivers.

METHODOLOGY

Using ENSO as predictor a long lead flood forecast model has been developed in this research. The steps of the methodology of this research may be stated as follows:

1) Identification of Possible Teleconnection

i) To identify the teleconnection of ENSO with river flow, cumulative frequency distribution analyses have been done for normal, EI Nino and La Nina years.

ii) Then to assess the strength of correlation between river flow and ENSO, correlation analyses between ENSO indices (SST of different NINO regions in different season) of any year and river flow of that year have been done.

2) Assessment of Flow Forecasting Possibilities Using Discriminant Prediction Approach

i) The discriminant prediction approach has been used here for the assessment of long range flood forecasting possibilities using the best correlation obtained from step 1 (ii), between ENSO and river flow. This approach has previously been used in many studies for flood forecasting. Eltahir (1999) used this method to forecast Nile flood.

ii) In order to easily judge the forecast skill and to compare different forecasts, a synoptic parameter, "the Forecasting Index (FI)", previously used by Wang and Eltahir (1999) has been used. FP(j), the forecasting probability of the flood category which describes the observed flood condition for that year, can be computed as: $\mathrm{FP(j)}=\sum_{i=1}^{3}\mathrm{Pp}\ (\mathrm{i,j})\mathrm{Pr}\ (\mathrm{i,j})$ (1)

Forecasting index, FI is the average of these probabilities over a certain period is determined by

$\mathrm{FI(j)}=\frac{1}{n}\sum_{j=1}^{n}FP(j)$ (2)

3) Development of Forecast Model

Discriminant approach can forecast only the event type not the size of flow, but certainly provides valuable information for flood forecasting. Then attempt has been made to develop a forecast model which will forecast more efficiently and capture the size of flow. One of the traditional popular models used in annual streamflow modeling is the autoregressive model (Maass et al., 1962). The autoregressive model is expressed as $Q_{i+1}=\bar{Q}+\alpha(Q_i-\bar{Q})+\epsilon_{i+1}$ (3)

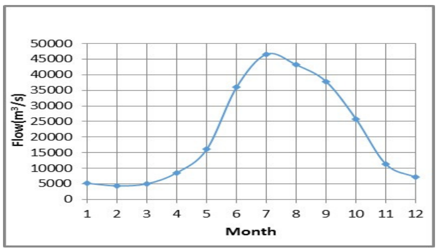

Fig. 1: Monthly average flow of Jamuna

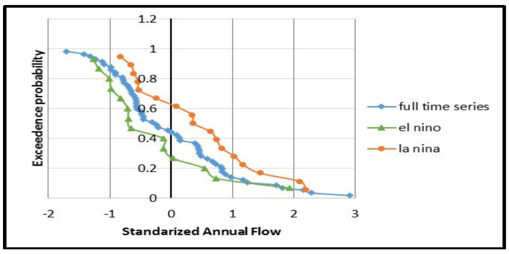

Fig. 2: Cumulative frequency distributions of the standardized annual flow during 1956-2012

Q = the mean observed flow, Qi = the flow in period i,α= the autocorrelation coefficient $\in_{i+1}$ = the simulation error due to unexplained variance with mean zero,where Q_{i+1} = the generated streamflow in period i + 1(day, month, year)

4) Assessment of Forecast Skill of the Model

Then the model results i.e. the predicted flows have been compared with the actual flows for the calibration and verification period to judge the forecast.

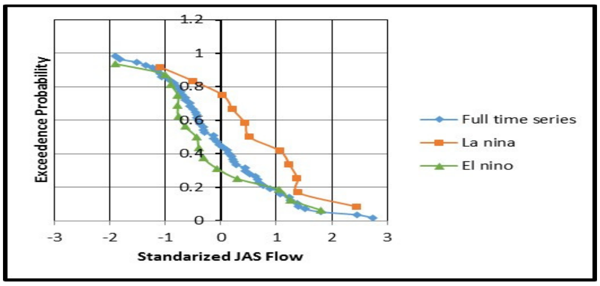

Fig. 3: Cumulative frequency distributions of the standardized JAS flow in Jamuna during 1956-2012

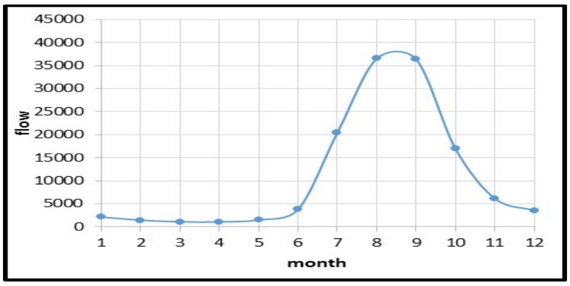

Fig. 4: Monthly average flow of Ganges

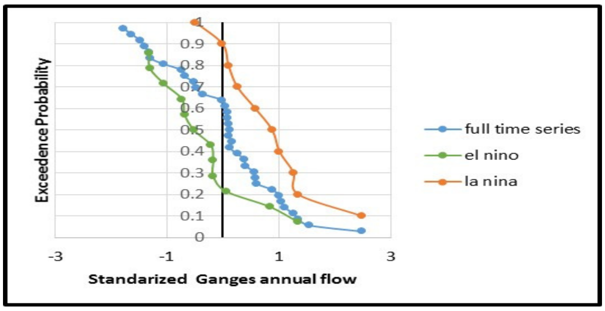

Fig. 5: Cumulative frequency distributions of the standardized annual flow in the Ganges

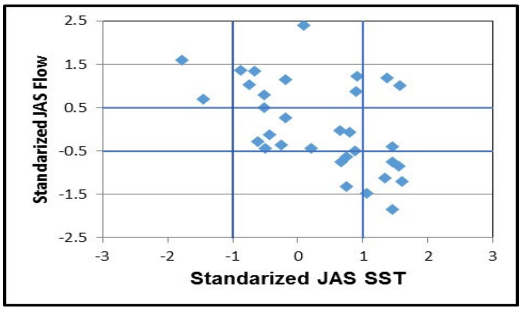

Fig. 6: Categories of JAS flow of Jamuna and the JAS SST (1980-2012)

Table 1: Correlation between average JAS flow of Jamuna and different monthly SST (Nino4)

Dependent variable	Time period	Independent variable	Coefficient of correlation R	Coefficient of Determination R^2	F-statistic	p-value
JAS Flow	1956-2012	July SST	-0.13106	0.017178	0.92633	0.3312
		Aug SST	-0.15398	0.023711	1.287201	0.2528
		Sep SST	-0.19027	0.036204	1.990862	0.1563
	1986-2012	July SST	-0.47166	0.222463	7.438924	0.0130
		Aug SST	-0.50459	0.254612	8.881162	0.0073
		Sep SST	-0.5461	0.298221	11.04872	0.0032
	1997-2012	July SST	-0.56214	0.316005	6.005974	0.0234
		Aug SST	-0.57179	0.326939	6.314732	0.0207
		Sep SST	-0.62458	0.390104	8.315093	0.0097

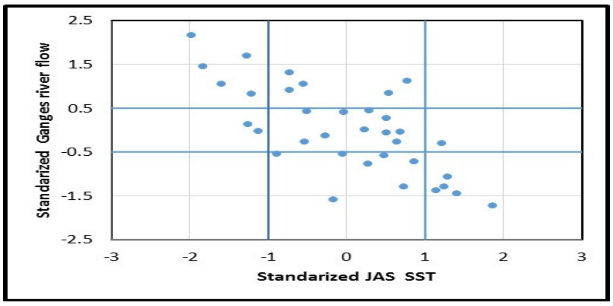

Fig.7: Categories of JAS flow of Ganges and the JAS SST (1976-2006)

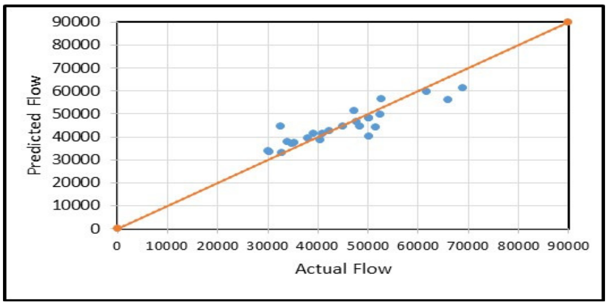

Fig. 8: Calibration of JAS flow forecast for Jamuna based on the statistical model and using the actual SST

Table 2: Correlation between average JAS flow of Jamuna and JAS SST (Nino 4) of the same year

Dependent Variable	Independent Variable	Time Period	Coefficient of correlation R	Coefficient of Determination R^2	F-statistic	p-value
JAS Flow	JAS SST	1956-2012	-0.16897	0.028552	1.557757	0.2089
	JAS SST	1986-2012	-0.5294	0.280268	10.12457	0.0045
	JAS SST	1997-2012	-0.61021	0.372352	7.712233	0.0121

Table 3: Conditional probability of the JAS flow of Jamuna, given the JAS SST and based on observations of 1980-2012

JAS ENSO condition	JAS Flow(1980-2012)		
	Low	Average	High
Cold	0	0	1
Normal	0.14	0.48	0.38
Warm	0.67	0.11	0.22

RESULTS AND DISCUSSIONS

The statistical flow forecast model aims at a long term flow forecast with a lead time three months to one year. The forecast accuracy usually decreases with the increase of lead time. Forecast accuracy for different lead time will be verified using forecasted SST data as well as using actual SST data. To examine different aspects of the quality of forecasts, several measures have been used. The most frequently used verification measures are bias, mean absolute error, Root mean squared error, variance explained or reduction of variance, skill and correlation.R^2 is the square of correlation coefficient between the observed and forecasted values. Forecast of JAS flow has been made for the time period 1986-2011 as an assessment of the forecast skill. Here the flows have been forecasted using the following equation, developed for JAS flow forecast in any year

$$Q_{i+1} = \bar{Q} + \alpha(Qi - \bar{Q}) - 7891x - 8027.8y + 228504 \quad (4)$$

Here is an important thing to mention that the time period 1986- 2011 has been used as calibration period. In Table 4 forecasts have been made using the actual SST to determine the possible errors if SST could be forecasted perfectly. Among the twenty five events, the model forecasts seven events quite satisfactorily (error is less than 10%). The maximum error has occurred in the event 1994. Next, the performance of the model, at 3 month lead is evaluated using the forecasted SST of 3 month lead. The performance of the forecast model with six month lead has also been evaluated using JAS SST with six month lead. For this forecast three month lead MAM SST has been used. This forecast may be highly useful for agricultural planning. The forecasts of the model with a lead time of twelve month have been computed. The overall analysis of the forecast efficiency of the model with different lead times reflects the possibility of long range flood forecasting in the Jamuna River with considerable accuracy. Although the skill of these forecasts decrease substantially with the increase of lead time, but still considerable enough to capture JAS flow and provide necessary information in water resources management.

Table 4: JAS flow forecast for Jamuna based on the statistical model and using the actual SST

year	JAS Flow(m^3/s)	JAS SST °C	JAS-MAM (m^3/s)	Forecasted JAS flow (m^3/s)	Error in percent
1986	34005	28.98	0.56	36959.02	8.68
1987	40169	29.42	0.38	37600.62	-6.39
1988	52576	28.13	-0.32	56494.15	7.45
1989	52443	28.24	0.39	49866.75	-4.91
1990	51594	29.03	0.26	44097.82	-14.53
1991	45345	29.15	1.003	45036.3	-.68
1992	42616	29.07	-0.07	52052.25	-9.319
1993	49164	29.03	-.98	43973.00	-10.55
1994	30280	29.43	-.51	35390.35	16.27
1995	47251	28.73	-0.45	51539.74	9.1
1996	47742	28.59	0.28	46772.19	-2.03
1997	40385	29.42	0.27	38537.09	-4.57
1998	61619	28.20	-0.50	59623.92	-3.23
1999	46018	28.01	0.26	51136.87	11.12
2000	48556	28.35	0.82	44549.57	-7.77
2002	34779	29.50	0.35	37118.64	6.72
2003	40119	29.13	0.11	40919.71	1.99
2004	45040	29.43	0.59	44423.21	-1.37
2005	37901	28.94	-0.16	39341.19	3.79
2006	35358	29.29	0.87	37530.83	6.14
2007	68873	28.64	-0.27	61389.68	-10.86
2008	50292	28.2	0.48	48162.10	-4.23
2009	40952	29.36	0.84	41512.72	1.36
2010	42260	27.90	-1.31	42444.37	0.43
2011	40103	28.33	0.05	40908.80	2.00

Table 5: Forecast skill of the statistical model for Jamuna using actual SST

Root mean squared error(RMSE)	Coefficient of Determination,R^2	Coefficient of Correlation, R	F-Statistic	P-Value
5197.2	0.7207	.848	21.3	0.0001

CONCLUSIONS

The strong link with ENSO, manifested as an increased propensity of low flow during El Nino and high flow during La Nina, has been established for Jamuna and Ganges rivers. The correlation analyses between JAS flow and SSTs (seasonal and monthly) show that JAS flow is highly correlated with JAS SST of Nino 4 region for both of the rivers. Discriminant analysis based on the observation of 1980-2012 depicts that the possibility of high flow is 100% in a cold year and 25% percent in a warm year for the Jamuna. In a La Nina year probability of occurring high flow is 86% percent and in an El Nino year probability of high flow is 0%. A 3-months lead-time flow forecasting index for Jamuna (FI = 0.53) also indicates a considerably successful forecast. Incorporating large-scale climate information in a forecasting model can produce more skilful, longer lead-time forecasts. This can produce reliable forecasting and thus improve water resources operations and planning. The flood forecast models show considerable accuracy at different lead time. It has been found that the forecast skills of the models are dependent on the SST forecast. The accuracy of the forecast decreases with increase of forecast lead time.

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USE OF HIGH STRENGTH CONCRETE IN COLUMNS OF RC BUILDING FOR COST EFFECTIVENESS AND SUSTAINABILITY

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ABSTRACT
In recent time resource consumption, environment pollution, global warming are the prime concerning issues all over the world. Unfortunately, any sort of development activities adversely affect the environment and resources. For that reason civil engineers are looking for sustainable development. One of the ways to minimize pollution and build sustainable infrastructure is to reduce the consumption of materials and resources. For this reason high strength materials are often used in the structural elements of buildings. Column is one of the most important structural elements of a RC building. The main objective was to find the cost effectiveness of using high strength concrete in columns compared to normal concrete. Columns of a building cover nearly 10%-12% of total concrete volume of a building. This study focuses on comparing material cost of columns of a 10 storied building made of 3500 psi normal concrete with the same columns of that building made of high strength concrete having strength of 5000 psi and 10000 psi respectfully. The 10 storied residential building situated at Dhaka city has been analysed and designed with the help of a finite element software ETABS. It has also ensured that the columns and the structure fulfil all the design criteria specified in the building code (BNBC 2006). The results indicate that using 5000 psi concrete instead of 3500 psi normal concrete reduces up-to 20%-25% of total column cost and using 10000 psi concrete can save up-to 45%-55% of total column cost. The use of high strength concrete is very much available throughout the world. It has been shown that mix design with water reducing admixture can ensure attainment of high strength concrete of 10000 psi and high strength concrete can be produced using local materials and its use particularly in columns of high rise buildings can be cost effective.

Keywords: High strength concrete; Sustainable development; Column; Cost-efficiency; RC Structure.

INTRODUCTION
Concrete is the mostly used material in our modern society. A concrete structure is composed of beam, column, slab, footing etc. Columns are the most important structural element of a building (Islam et al.,2017).The overall capacity of a structure depends on the strength and deformation capacities of the individual components of that structure (Rahman et al., 2017).The strength of Columns governed by the strength of its material. The behaviour of short, axially loaded members for a lower loads for which both material remains in their elastic range of response, the steel carries a relatively small portion of the total load (Mamun, 2012).The nominal ultimate strength of an axially loaded column can be found from formulae. When the column is in biaxial bending we use load contour method to design a section of a column. The ratio of longitudinal steel area to gross concrete section is kept in the range from 0.01 to 0.08. The lower limit is necessary to reduce the effects of creep and shrinkage of concrete under sustained compression. Ratio higher than 0.08 not only are uneconomic but also would cause difficulties in constructing owing to congestion. Here we design columns of a building for various strength of concrete with corresponding various percentage of reinforcements for a specific load condition. We have analysed the required cost for a 3.048 m column for different strength of concrete.

SELECTION OF A STRUCTURE

A 10 storied residential building assumed to be situated at Dhaka City has been considered for analysis. The other parameters of the structure are described below:

Material Property

Yield strength of steel, Fy is 60 ksi.

Loading Condition

Floor Finish = 30 psf
Partion Wall = 80 psf
Live Load = 40 psf
Site location = Dhaka
Basic wind speed = 210 km/hr
Exposure = A
Structure importance factor = 1.00
Seismic zone = 2
Seismic zone factor, Z = 0.15
Site coefficient, S = 1.5
Seismic modification factor for RCC building,
R = 8 (IMRF)
Time period for RCC building,
Ct = 0.030 (ft-lb units)

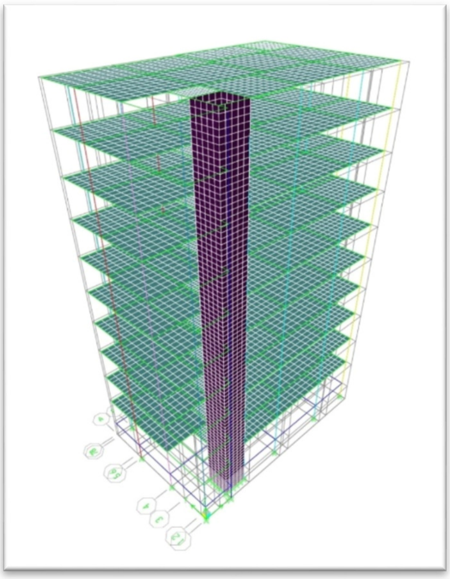

Fig. 1: 3D model of the 10 storied residential building

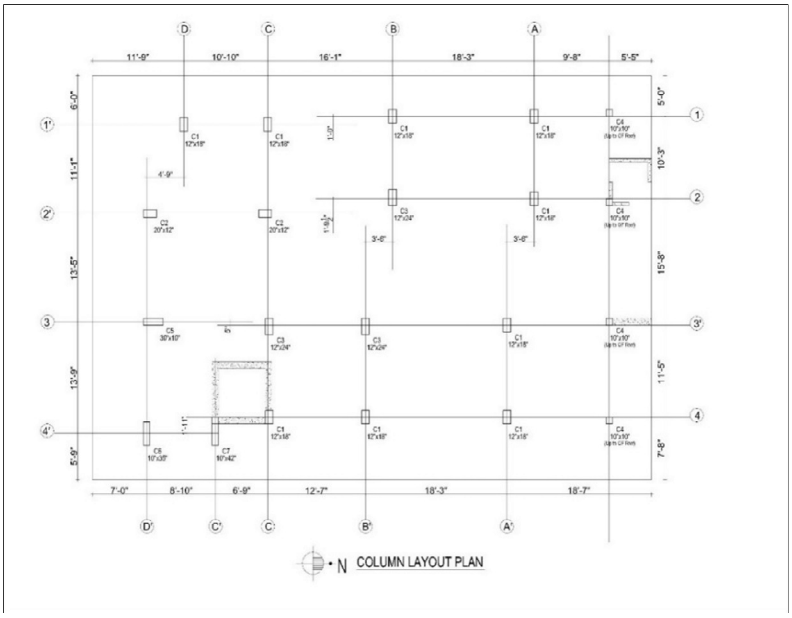

Fig. 2: Column layout plan

RESULTS AND DISCUSSIONS

The required cost for a 3.048 m column from ground level to first floor.

For simplification only 60 grade reinforcement is considered. The prices which are taken into consideration is as follows:

Cost of 1 kg Cement = 8.4 Taka, Cost of 1cft stone aggregate = 180 Taka, Cost of 1 cft sand = 50 Taka, Cost of 1 kg Water Reducing Admixture (Master Glenium ACE 30 JP) =300 Taka Cost of 1 kg Reinforcement including fabrication = 80 Taka

Table 1: Mix ratio for 1 m^3 fresh concrete

	Mix 1	Mix 2	Mix 3
Ingredients	f_c'=3500 psi	f_c'=5000 psi	f_c'=10000 psi
Cement	394.6 kg	532 kg	765 kg
Stone Chips	1100 kg	812 kg	812 kg
Sand	591.8 kg	735 kg	502 kg
Water	197.3 kg	202 kg	198 kg
Admixture	0 kg	4.8 kg	7.65 kg

Table 2: The cost of fresh Concrete for various mix ratios

Strength of concrete, f_c'	Cost of fresh concrete (per cft)
3500 psi	245 Taka (BDT)
5000 psi	288 Taka (BDT)
10000 psi	360 Taka (BDT)

Table 3: 28 day strength of various concrete mixtures

Days	Mix	Specimen	Dia. in	Area in^2	Dial Reading KN	Actual Load KN	Stress psi	Strength psi
28	Mix 1	1	4.02	12.71	170	176	3104	3550
		2	4.01	12.65	182	188	3334	
		3	4.00	12.58	230	236	4212	
28	Mix 2	1	4.02	12.7	394	287	5073	5220
		2	4.02	12.71	391	283	5012	
		3	4.04	12.8	424	317	5572	
28	Mix 3	1	3.99	12.48	607	596	10736	10460
		2	4.02	12.68	585	574	10170	
		3	4.02	12.68	602	591	10476	

Table 4: Cost estimation for column C1 (Edge Column)

Parameters	f_c'=3500 psi	f_c'=5000 psi	f_c'=10000 psi
Column Size (inch × inch)	12×18	12×18	12×18
Reinforcements (sq.in)	13.82 (6.4%)	8.45 (3.91%)	2.16 (1.0%)
Volume of Concrete (cft)	14.04	14.41	14.85
Cost of Reinforcement (Taka)	17100.51	10455.81	2672.73
Cost of Concrete (Taka)	3439.80	4150.08	5346.00
Total Cost (Taka)	20540.31	14605.89	8018.73

Table 5: Cost estimation for column C3 (Interior Column)

Parameters	f_c'=3500 psi	f_c'=5000 psi	f_c'=10000 psi
Column Size (inch × inch)	12x24	12x24	12x24
Reinforcements (sq.in)	9.71 (3.37%)	4.46 (1.55%)	2.88 (1.0%)
Volume of Concrete (cft)	19.36	19.69	19.80
Cost of Reinforcement (Taka)	12009.45	5523.64	3563.64
Cost of Concrete (Taka)	4743.69	5670.72	7128.00
Total Cost (Taka)	16753.14	11194.36	10691.64

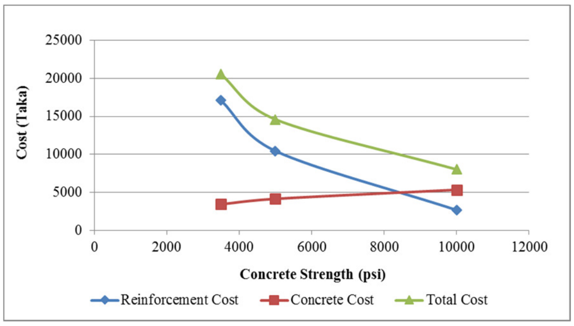

Fig. 3: Cost variation of column C1

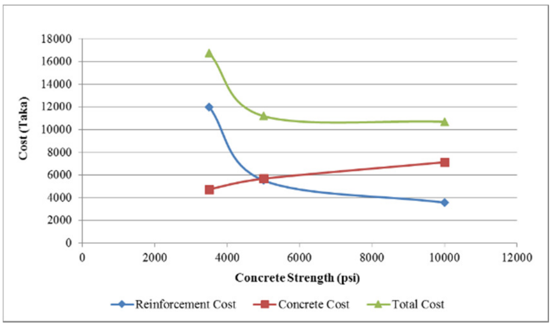

Fig. 4: Cost variation of column C3

Table 6: Cost estimation for column C4 (Corner Column)

Parameters	f_c'=3500 psi	f_c'=5000 psi	f_c'=10000 psi
Column Size (inch × inch)	10x10	10x10	10x10
Reinforcements (sq.in)	5.18 (5.18%)	2.70 (2.70%)	1.00 (1.0%)
Volume of Concrete (cft)	6.58	6.76	6.88
Cost of Reinforcement (Taka)	6409.60	3340.91	1237.37
Cost of Concrete (Taka)	1613.08	1945.99	2475.00
Total Cost (Taka)	8022.68	5286.90	3712.37

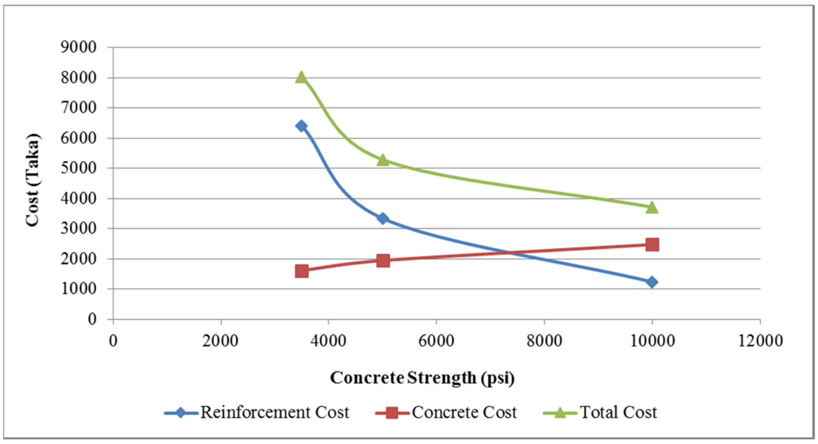

Fig. 5: Cost variation of column C4 for various concrete strength

CONCLUSION

Design and cost impact assessment of columns of a typical ten story building have been carried out with 28 days concrete strength (f_c') varying from 3500 psi to 10000 psi. It has been demonstrated that such strengths are achievable with proper mix ratio. From the design presented it is observed that required amount of reinforcement decreases with the increase of concrete's strength for a code specified loading condition keeping column sizes unchanged. It is also found from the presented results that increase in the cost of concrete with the increase of the strength is very small compare to the decrease in the cost of reinforcement. The results further indicate that using 5000 psi concrete instead of 3500 psi normal concrete reduces up-to 20%-25% of total cost of column construction and using 10000 psi concrete can save up-to 45%-55% of total cost of column construction assuming other costs of building elements remaining the same. It has also been shown that high strength concrete in the range of strength considered in this paper can be produced using local materials and its use particularly in columns of high rise buildings can be cost effective.

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IMPACTS OF WATER MANAGEMENT PRACTICES ON LIVELIHOOD OF FARMERS IN A LOWLAND AREA OF BANGLADESH

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ABSTRACT

This study was carried out to understand the impacts of water management practices on the livelihood of Boro rice and potato farmers in Munshiganj district of Bangladesh. Munshiganj is one of the largest producers of potatoes in the country and occupied by a majority of lowland area. The study was conducted during the Rabi (dry) season of 2015-16 in two Upazila, namely Sreenagar and Lauhajang Upazila of Munshiganj district. The individual interview (II) was conducted to collect information on number, amount, and timing of irrigation and yield for the selected Rabi crops (Boro rice and potato). Focus group discussion (FGD) was conducted on the selected farmers to develop Boro rice and potato producing farmers livelihood security index (FLSI) based on selected indicators of five livelihood assets (Social, Human, Natural, Financial and Physical). From the water management practiced by the farmers, it was found that the average seasonal amount of irrigation water of Boro rice and potato was1187mm and130 mm respectively. On the other hand, the calculated seasonal irrigation water requirements (IWR) for Boro rice and potato were 1336 mm and 110mm respectively. The farmers followed Alternate Wetting and Drying (AWD) method for Boro rice and used hose pipe for potato to apply irrigation water. The yield of Boro rice and potato varied from 5.5 to 6.5 t/ha and 30 to 40t/ha respectively. The farmers of Sreenagar Upazila cultivated more Boro rice than potato. Due to the presence of high water depth during potato sowing time in the field the farmers of Sreenagar Upazila could not go to the potato cultivation. The water management result has ultimately shown that the levels of security for farmers' livelihood were higher (80%) in Lauhajang Upazila than that of Sreenagar Upazila (60%).

Keywords: irrigation water requirement; irrigation method; yield; livelihood security index.

INTRODUCTION

The duration of inundation and lowland for cultivation is the general problems during Rabi season in the lowland areas. In spite of these problems, some farmers grow potato and others grow Rabi crops like Boro rice, mustard, wheat etc. The water management affect the farmers' livelihoods in the inundated area. There are relationships between the water management and income. The farmers' livelihoods depend on the yield of potato and Boro rice.

The livelihood system may be defined as a process of income for living. So, there is a close contact between income and livelihood. Livelihood security has a direct relation to the income security (Mutahara, 2009).Livelihood security is an integrating concept where a livelihood comprises of the capabilities, assets (including both all material and social resources) and activities required for a means of living (Scoones, 1998). A livelihood is sustainable when it can cope with and recover from the stress and shocks, maintain its capability and assets, and provide sustainable livelihood opportunities for the next generation (Chambers and Conway 1992). Livelihoods are secured when households have secure ownership of, or access to resources and income earning activities, including reserves and assets, to offset risks, ease shocks and meet contingencies (Chambers, 1989).

In this study a livelihood security index has been developed for the farmers of the lowland area to understand the level of their subsistence.

The Study Area

The study was conducted in two Upazila namely Lauhajang and Sreenagar Upazila of Munshiganj district during the Rabi season in 2015-2016. The Munshiganj zilas located in the central of Bangladesh. The study area is situated between 23°29' and 23°45' north latitudes and between 90° 10' and 90° 43' east longitudes. The zila is bounded on the north by Dhaka and Nnarayanganj zila, on the East by Comilla and Chandpur zila, on the west by Dhaka and Faridpur zila and on the South by Shariatpur and Madaripur zila. The total area of the zila is 2954.96 square km of which 93.08 square km is riverine. Sreenagar Upazila is the largest with an area of 202.98 square km which is about 21.26% of the total area of the zila. Lauhajang Upazila is the smallest with an area of 130.12 square km which is about 13.62 % of the total area of the zila. The location map of the study area is shown in Fig. 1.

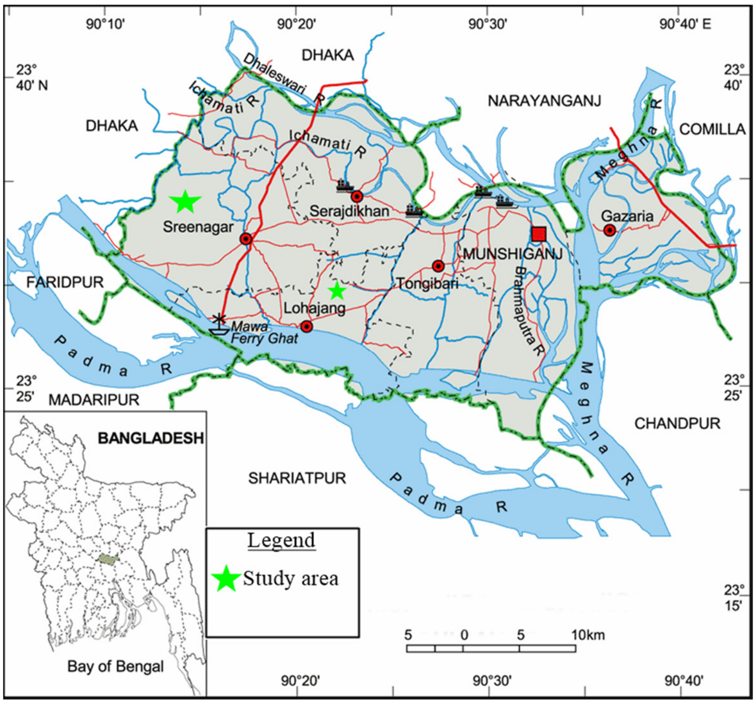

Fig.1: Location map of the study area.

The total cultivable area of Munshiganj zila is 65691 hectares. The temporary fallow land in the study area is 373 hectares during the Rabi season. In this area, 47% is medium lowland or F2 (0.9-1.8 m flooded continuously for several months) and 17% of cultivable lands are medium highland or F1 (flooded depth of 0.9 m from two weeks to three months)(DAE, 2016). The cropping intensity of Munshiganj zila is 184 % (DAE, 2016).

Methodology and Data Collection

For this study, the farmers' survey through participatory tools (individual interview and focus group discussion) was conducted in Sreenagar and Lauhajnag upazila to understand the farmers' application of irrigation water and irrigation method about growing Boro rice and potato crops and to understand the impacts of water management on the livelihood of the farmers. Focus Group Discussions (FGD) was conducted with Boro rice and potato producing farmers in Sreenagar and Lauhajang Upazila. FGD was conducted to receive qualitative information as to understand the impacts of water management on the livelihood of the farmers. In each upazila, twelve FGD's were conducted with the farmers. About 240 participants (120 in Sreenagar and 120 in Lauhajang upazila) were participated in the FGD. The indicators of livelihood assets (Social, Human, Natural, Financial and Physical) were selected from FGDs. The FGD was conducted to find out the actual value, standard value of indicators as well as to elicit appropriate weights to the various indicators. The Farmers Livelihood Security Index (FLSI) was developed on the basis of FGD using the standard value of indicators and appropriate weights to the various indicators.

A total of 10 indicators were selected based on FGD following DFID framework. The selected indicators are:Access to water institutes services and availability of effective extension services, training of the farmers and tradition of the farmers, topography and Beel, market price and yield, duration of inundation and artificial water ways. First FGDs have been conducted to understand the situation of crop farmers' livelihood security and indicators have been developed from that. The second FGDs have been conducted to find out the actual, minimum and maximum value of indicators by full, half, one-third and two-third ranking of indicators.The selected indicators used in the construction of the farmers' livelihood security index, all indicators were standardized following the UNDP (2007) procedure of standardizing indicators for the index value (Eq. 1).

$$\text{Index value (standardized value)} = \frac{Actualvalue - minimumvalue}{Maximum\ value - minimumvalue} \qquad (1)$$

The number of times a particular indicator was cited was used to generate the weighting system. The farmers' livelihood security index for producing Boro rice and potato was calculated using the following model (Vincent, 2004).

$$FLSI = (Ssvi \times Wi) + (Hsvi \times Wii) + (Nsvi \times Wiii) + (Fsvi \times Wiv) + (Psvi \times Wv) \qquad (2)$$

Where, FLSI = Farmers Livelihood Security Index, Ssvi = Standardized value of social asset sub-index, Hsvi = Standardized value of human asset sub-index, Nsvi = Standardized value of natural asset sub-index, Fsvi = Standardized value of financial asset sub-index, Psvi = Standardized value of physical asset sub-index and Wi terms refer to the weighting that was applied to each standardized value.

RESULTS AND DISCUSSIONS

Irrigation Water Management for the Irrigated Crops in Sreenagar and Lauhajang Upazila:

Most of the farmers cultivated Boro rice in the Sreenagar upazila. The period of inundation is lengthy in Sreenagar than Lauhajang during Rabi season. The farmers failed to cultivate potato crops at the time of Rabi season in Sreenagar. From the discussion with farmers, the farmers applied Alternate Wetting and Drying (AWD) method for the cultivation of Boro rice. Some of the farmers applied irrigation at 6 days interval and some farmers applied irrigation at 7 days interval. The number of irrigations varied from 10 to 14 both in Sreenagar. Some of the farmers used AWD pipe to measure when irrigation should be applied. Other did not use any AWD pipe and applied irrigation by the traditional method. So, the number of irrigation varied from one farmer to another farmer. For BRRI Dhan-29, in Sreenagar the seasonal amount of irrigation water was 700 mm and 1000 mm respectively and yield was 5.5 t/ha and 6.5 t/ha respectively. From the discussion with farmers, most of the farmers cultivated potato in Lauhajang upazila. But they did not use the same amount of irrigation water. Some of the farmers applied two irrigations and some applied three irrigations. As the amount of moisture available in land was sufficient they did not apply third irrigation. In Lauhajang, the farmer applied 130 mm irrigation water with two irrigations and got the yield 30t/ha. In another, the farmer applied 200 mm irrigation water with three irrigations and got the yield 35 t/ha. The farmers followed hand shower irrigation method to irrigate the potato field.The main source of irrigation water was canal/khal both in Sreenagar and Lauhajang upazila.

The Development of Farmers Livelihood Security Indicators in Sreenagar and Lauhajang Upazila

Development of livelihood security indicators has been performed through the specific understanding of the topography, irrigation water management, yield and profitability in Sreenagar and Lauhajang Upazila. Farmer's livelihood security indicators have been formed as the functional unit of the crop producing farmers in lowland area (Doorenbos, 1977; Smith, 1992; Rahman, 2015).The farmers' livelihood security indicators have been developed based on areas in which they live, observed living status, their individual access to irrigation water, irrigation water facility, their knowledge, and tradition and training to begin Rabi season. The topography, beel, duration of inundation, tradition, market price and yield has been major concern in indicator development. A set of indicators of crop farmers' indicators (shown in the Table 1) has been formed based on simple form of DFID framework and primary information from general field observation of the selected lowland area.

The selected DFID framework indicators are the simply form according to the definition of DFID framework. All indicators were normalized to have a relative position between 0 and 1. FGD of crop producing farmers in the study area was conducted in order to develop farmers livelihood security index (FLSI). According to the DFID livelihood asset model, each livelihood group has five types of assets- (i) Natural assets, (ii) Financial assets, (iii) Human assets, (iv) Physical assets, and (v) Social assets (Islam, 2004).In Sreenagar and Lauhajang, during focus group discussions, farmers were asked to highlight indicators linked to each form of asset (i.e. Human, financial, natural, physical and social assets).

Table 1: Selecting criteria for developing the crop farmers' indicators

Assets	DFID framework indicators	Crop farmers' indicators
Social	Networks and connectedness, access to wider institutions of society	Access to water institutes services and availability of effective extension services.
Human	Skills, knowledge, ability, education/training personnel	Training of the farmers and tradition of the farmers.
Natural	Land, forests, marine/wild resources, water	Topography and beel
Financial	Availability of cash or equivalent, productivity	Market price and yield
Physical	Infrastructure, access to water supply	Duration of inundation and artificial water ways

Development of Farmers Livelihood Security Index (FLSI) of Boro Rice and Potato Producing Farmers in Sreenagar and Lauhajang Upazila

The Farmers' Livelihood Security Index (FLSI) of Boro rice and Potato crop producing farmer was calculated using equation (2) for both Upazila (shown in the Table 2)

Table 2: Comparison of livelihood security among Boro rice and Potato producing farmers

Name of the crop producing farmer	FLSI (Sreenagar)	FLSI (Lauhajang)
Boro rice	0.60	0.42
Potato	0.53	0.80

The higher the index value indicates the higher security. From the index value analysis, the livelihood of potato producing farmers was secured compared to Boro rice producing farmers. From the analysis, the livelihood of farmers in Sreenagar was more secured compared to the livelihood of farmers in the Lauhajang. The different index value, it can be explained that the existing of Beel, maximum duration of inundation and lowland area favours to cultivate Boro rice in Sreenagar. But the farmers get better yield and market price cultivating the potato than Boro rice.

CONCLUSIONS

The measured security index value of farmers' livelihoods for producing Boro rice and potato shows different level of security both in Sreenagar and Lauhajang. The security levels of farmers' livelihood vary with duration of inundation, artificial waterways, existing of Beel, topography, training and tradition of farmers, availability of effective services from both agriculture and water institution. The livelihood security level was 60% in Sreenagar and 42% in Lauhajang for Boro rice producing farmers. The livelihood security level was 53% in Sreenagar and 80% in Lauhajang for potato producing farmers. For potato producing farmers the highest livelihood security level is 80% in Lauhajang whereas for Boro rice producing farmers is 42% in Lauhajang.

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ECONOMIC VALUE DETERMINATION OF A WETLAND USING CONTINGENT VALUATION METHOD: A CASE STUDY ON CHALAN BEEL IN NATORE DISTRICT, BANGLADESH

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ABSTRACT
Wetland is a valuable ecosystem for the sustainable environment both for present and future generations. Wetlands are used for multiple purposes, and it has significant role in the livelihood of the local people in beeline country like Bangladesh. A particular wetland was selected named “Chalan Beel” in Natore district of the northern part of Bangladesh for the purpose of estimating the economic value. Wetlands possess a high economic value. The economic value of wetland includes both use and non-use values. Wetland use values are associated with a diverse and complex array of direct and indirect uses. Wetland direct use values/benefits are those which can be consumed directly from wetland such as food, water supply, recreation, transport, timber etc. whereas indirect uses benefited people indirectly and arises from the functions occurring within the ecosystem, such as water quality, flood control, ground water recharge and other such functions. Therefore, the objectives of the present study were to estimate the total economic value of non-use attributes of the beel at the present with the help of Contingent valuation method (CVM). CVM is one of the important methods in environmental valuation, which gives empirical estimates of both use and non-use values of environmental resources. Data collected from questionnaire survey, key informant interview and focus group discussion. The results of the study show that the proposed annual economic value is greater than the present annual economic value. This study would guide the government in identifying the sectoral priorities regarding conservation of wetland and to formulate strategies for the short term and long term effective management of wetland of Rajshahi Division.

Keywords: Wetlands, Economic Valuation, Non-use values, Contingent Valuation Method (CVM), Natore District

INTRODUCTION

Wetlands have a crucial importance on sustainable ecological system, improving habitat of different flora and fauna, enhancing surrounding livelihood options and restoring hydrological resources. These Wetlands are described both as "the kidneys of the landscape". (Brander et al., 2006). The nation's wetlands play a dynamic character in our social and economic well-being. Wetlands provide services such as amended water quality, groundwater restoring, shoreline securing, natural flood control, and support a diverse variety of fish, wildlife, and plants (Lupi et al., 1991). Bangladesh has the vast area of wetlands including beel and streams, freshwater lakes and water storage reservoirs. The livelihoods of the people of surrounding area are mostly depended on this wetland resource (Kostori, 2012). Additionally, a large source of fresh water fish and aquatic resources keep ecological systems in balance. The haors, baors, beels, and jheels are of fluvial origin and are commonly identified as freshwater wetlands (Ghosh, 2010). Among the wetlands of Bangladesh, Chalan beel is the largest, most important watershed in the North Central Bangladesh, and covers an area of about 375 km^2 during the monsoon season.

The population of Bangladesh don't pay much consideration for the economic value of the use and non-use attributes of this wetland in present days. But an understanding of such values is vital for the better management of the wetland resources for present and in near future (Cameron, 1992). The most crucial issue of Bangladesh is the rural poverty causing the intensive exploitation and depletion of the wetland resource base of the country. The current practice of wetland management is mainly regulated by direct economic profitability without considering proper ecological benefits and uses of wetlands (Billah, 2003). The study focused on the estimation of the economic value of Chalan Beel with the help of Contingent Valuation Method (CVM). Therefore, the total economic value of Chalan Beel wetland has been estimated by taking into account the non-use attributes of the Beel which help to formulate resource management strategies in future for better conservation of this valuable wetlands.

METHODOLOGY

The Chalan beel is situated between 24.35° to 24.70°N and between 89.10° to 89.35°E [Fig. 1]. (Google earth, 2018).It presently spreads over only 10 upazilas, however, including Singra, Gurudaspur, Boraigram, Chatmohar, Bhangura, Faridpur, Shahjadpur, Ullapara, Tarash and Raigonj, in the three districts of Natore, Pabna and Sirajgonj (BBS, 2013).

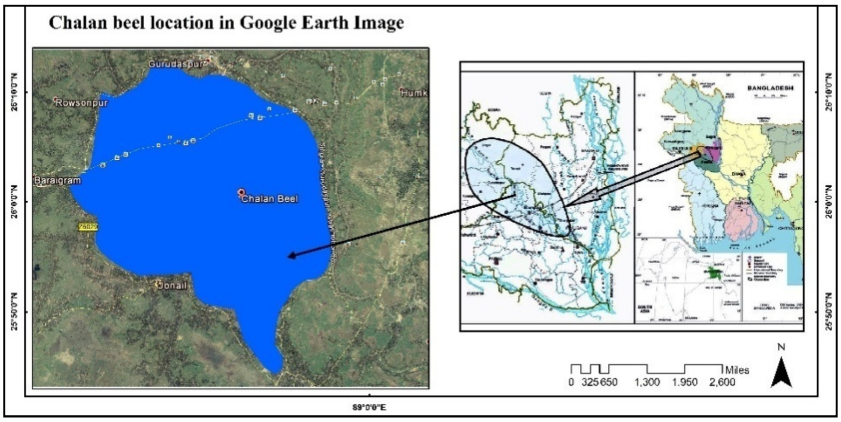

Fig.1: Location of Chalan Beel

The CVM is a mostly applied method in estimating the non-use values of a wetland which estimate values for valuing changes in the provision of nonmarketable goods and services. The CVM is a survey-based methodology which relies on obtaining monetary estimates for the economic value of a specified change in the provision of the environmental good of interest, which typically is not traded in the conventional markets. Monetary estimates are obtained either as individual's Willingness to Pay (WTP) or Willingness to Accept (WTA). WTP measures the amount of income a person is willing to contribute in exchange for an improved state of wetland goods and services (Marta-Pedroso et al., 2007). To evaluate the economic value of Chalan Beel covered natore district Data was collected from questionnaire survey, key informant interview and focus group discussion. Disproportionate stratified systematic random sampling of 300 households was conducted in the CV survey. The size of sample is considered to be reliable because based on a simple statistical tolerance formula, sample size between 200 and 2500 are probably appropriate (Mitchell and Carson, 1989). Natore District consists of 6 Upazila, 120, 60,38,32,30 and 20 samples were collected from Natore Shadar Singra Upazila, Gurudaspur Upazila Baraigram Upazila, Lalpur Upazila , and Bagatipara Upazila respectively. Samples size distributions varies according to the number of population present in the Upazila. Key Informant Interview (KII) was conducted with boatmen, Businessmen, Students, Wetland experts, livestock experts, agriculture officials and Planners. Focus Group Discussion (FGD). Three FGDs were conducted with each group consisting of adult men and women (age belongs to 18 or above) considering gender issues. Each FGD took time about one hour to two hours. Each FGD consisted of at least 8-10 persons with homogeneous mixture. During FGDs, people of the Chalan Beel area chosen the payment vehicle for the CV survey and identified the non-use attributes of Chalan Beel. Different statistical analyses have been performed to analyze the gathered quantitative data. The WTP responses have been analyzed using two statistical models, such as logit model and multiple regression model. This model shave been analyzed using SPSS software. The logistic probability or logit model has been used to separate those respondents who are willing to pay from those who are not (Langford and Bateman, 1993). Subsequently, the multiple regression model indicates the relationship between the explanatory variables and the stated amount of money for those who were willing to pay. Mathematically, the WTP can be written in the form of Eq. (1):

$$WTP = f\,(R_s, R_a, Y_i, R_e, DIST, USR) \quad (1)$$

Where, WTP refers to the amount of money a household is willing to pay monthly for the wetland resource management, R_s denotes respondent's sex, R_a denotes respondent's age, Y_i denotes household income, R_e stands for individual's education level, DIST denotes distance of the respondent's residence from the Chalan Beel and USR denotes variable for non-user individuals(Ghosh, 2010). The logit model for the present study written in the form of Eq. (2):

$$L_i = \ln \frac{Pi}{1-Pi} = X_{i1} + X_{i2} \quad (2)$$

Where, L_i which is called Logit, is the log of the odd ratios. Pi is a probability that has a probability of 1, X_{i1} is a set of explanatory variables while and X_{i2} are an intercept and a set of coefficients to be estimated corresponding to a logistic distribution (Ghosh, 2010).

RESULTS AND DISCUSSION

Economic Value of Chalan beel at Present state for non-Use attributes

The characteristics of survey respondents need to be demonstrate for establishment of Economic Value of Chalan Beel at Present state for non-Use attributes. During the CV survey, different socio-economic characteristics of the respondents were asked and recorded. The responses of the respondents have been analyzed using frequency table. The sample consisted of 72.3% men and 27.7% women. The distribution of age of the respondents [Fig.2] was heavily skewed towards the younger generation with the majority of people being between 18 and 30 years old (41.2%) and this was mainly due to the fact that young people were willing to participate more in the CV survey. The majority of the respondents have attended up to or continue Bachelor degree of education i.e. almost 29%, also 29% respondent are illiterate because they are mainly farmers and fisherman [Fig.2].Majority of the survey Participants in the study area were student [Fig.3]. In addition, the majority of income group for the survey households was Tk. 4001-5000 [Fig.4]. 35% and 55% people households were 1-10 km and more than 10km from Chalan Beel respectively and 82% people visit Chalan beel area for different activities.

The present study has adopted the ranking method to estimate the present non-use value of Chalan Beel. In estimating the present total non-use value of the Beel, protest responses who think the wetland are in 'bad' condition has been eliminated from the data collected to estimate willingness to pay (Mitchell and Carson, 1989).So, from the table it is found that the present non-use value of Chalan Beel is 13% of the total non-use value estimated for the proposed state of the Chalan Beel (Table 1). It is found that the total annual average non-use value of Chalan Beel for the proposed state is Tk. 93.48 million. Therefore, the total annual average non-use value of the Chalan Beel for the present state is Tk. 12.15 million.

Economic Value of Chalan Beel at Proposed state for non-Use attributes

The CVM of estimating values for non-market goods in terms of Willingness to pay (WTP) has gained widespread acceptance in the world. The results of the logit model are shown in Table 2. Females are 4.623 times more likely to say 'yes' to a WTP question than males. This indicates that females are more aware of the environment. In case of education, Income level and user the result of the logit model indicates that the higher the education, Income level and User the higher the probability of WTP 'yes' saying. For the variable distance, it is found that the longer the distance of the residence from Chalan Beel, the lower the probability of WTP 'yes' saying. Finally, the result of the logit model shows that almost 68% of the respondents have correctly allocated (i.e., percentage of correctly predicted values) to predict WTP either 'yes' or 'no' in the model which indicates a relatively good fit to the CV data and model (Ghosh, 2010).

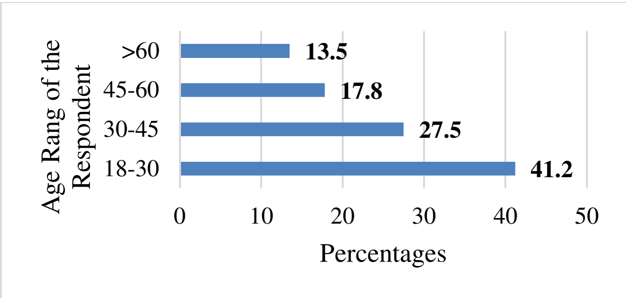

Fig.2: Age group distribution of the respondents

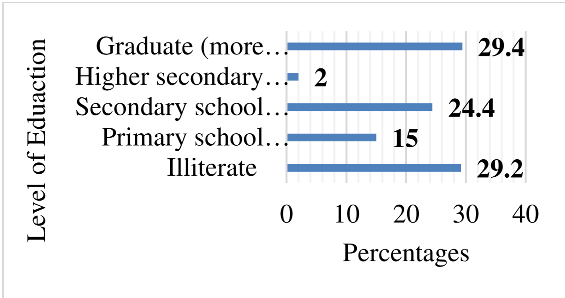

Fig.3: Education status of the respondents

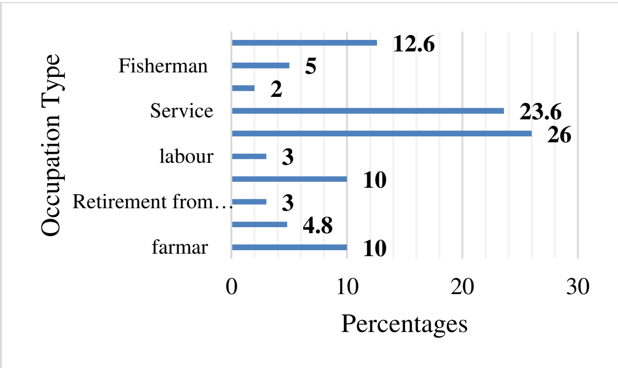

Fig.4: Occupation pattern of the respondents

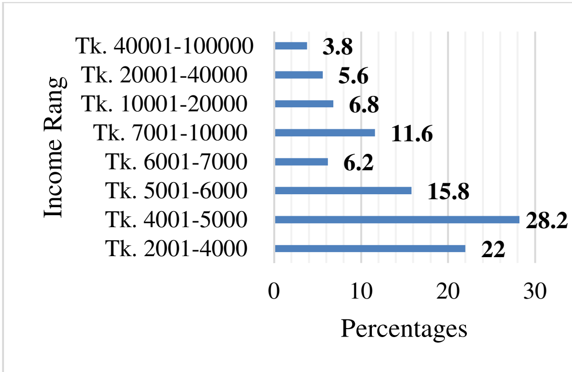

Fig.5: Distribution of household income

Table 1: Ranking of the present state of Chalan Beel

Present environmental state based on non-use value	Score	Present non-use value as a percent of the proposed state non-use value
Very bad	-1	4%
Bad	-2	13%
Neither good nor bad	0	23%
Good	1	35%
Very good	2	25%

The results of the multiple regression model are shown in Table 3. The age of a respondent has a negative influence on the mean amount of money to pay. So, the WTP decreases as age increases. As a result, younger generations are more willing to contribute money than older ones because younger generations are more aware of the environment. The coefficient of education appears to be significant at the 5% level which indicates that the higher educated people are more willing to contribute money compared with the lower educated people. Income level value indicates that WTP increases with the increase in income. So, the people having more money are willing to contribute money more for management of the Chalan Beel resources (Table 3). In the present study, the respective R^2 values for the logit model and the multiple regression model have been obtained. But the R^2 value of the multiple regression model (46%) is lower than the logit model (68%). This is due to the fact that the increment of the values of WTP was very small which makes it difficult for a model to precisely determine each individual figure.

The total non-use values divided into three component values which are shown in Table 4. From the table, it is found that the bequest value is higher than the option value which is followed by the existence value. For Chalan Beel, wildlife value is not the largest of all non-use values or as a proportion of the total non-use value. This difference in the present study is due to the fact that the majority of the people in the study area are not aware of the environment.

Table 2: Results of logit model for non-use values of Chalan Beel

Explanatory variable	Coefficient	Standard error	Wald statistic	Odds ratio
Sex	1.902	0.545	11.777*	5.321
Income	1.639	0.483	8.322*	2.978
Education	1.523	0.215	8.520*	1.789
Distance	-0.708	0.294	5.196*	0.403
User	1.303	0.421	6.238*	3.841

Note: R^2 = 0.68; *Significant at the 5% level

Table 3: Results of multiple regression model for non-use values in Chalan Beel

Explanatory variable	Coefficient	Standard error	t-statistic
Age	-1.203	0.793	-1.501*
Education	2.231	0.983	2.230*
Income	2.010	0.523	3.502*
Distance	-1.436	0.673	-1.713*

Note: R^2 = 0.46; *Significant at the 5% level

Table 4: Non-use component values of Padma River

Non-use component	Min	Max	Avg
	WTP (Tk./month)		
Fauna and flora resources do not weaken and Padma river simply continue to exists (Existence value)	1.5	20	3.10
The wetland exists so that its value can be enjoyed in future (Option value)	2.5	35	4.60
The wetland exists so that future generations can enjoy the value and can be used for research, education etc. (Bequest value)	3	68.5	10.30
Total non-use value (Tk./month)	7	123.50	18

Table 5: Estimated annual average non-use value of Chalan Beel

Category of characteristic	Value
Total number of households in Natore District at present	423875
Household’s average WTP value per month (Tk)	16.36
Proportion of households willing to contribute money (percent)	69.23
Annual average value of respondent’s money contribution (million taka)	57.60 million
Household’s average WTP value per month for willingness to contribute time (Tk)	27.58
Proportion of households willing to contribute time (percent)	21.57
Annual average monetary value of respondent’s time contribution (million taka)	30.25 million
Total annual average value of the non-use attributes of the Chalan Beel (million taka)	93.48 million

The respondent’s contribution of time is monetized to estimate total WTP for the wetland resource management. The total time that the respondents wanted to contribute is 4980 minutes and people contribute more time for recreational activities. The monthly monetary value of time contribution is shown in Table 5 and the respondent's average monetary value of willingness to contribute time is estimated to be Tk. 27.58/month/household. The annual average total economic value of the non-use attributes of Chalan beel for the proposed state is estimated to be Tk. 93.48 million and shown in Table 5. From above analysis it is found that the non-use value of Chalan Beel is not very high at present state (Tk.12.15 million). This is due to the fact that non-use value of the beel is not confined only in the locality and people of the area are not aware of the environment. Therefore, the non-use value is an underestimated value. The non-use value at the present state of the beel is insignificant because the beel is in bad condition in terms of its fauna and flora resources.

CONCLUSIONS

The present study estimate the economic value of Chalan beel wetlands with the help of non-use attributes which will be helpful for wetland resource management and valuation of wetlands in decision making. The estimation of the chalan beel wetland is done both for present state as well as proposed state using CVM method. The results of the CV estimates have shown that the annual average non-use value of the Chalan Beel for the present state is about Tk. 12.15 million, while the annual average value for the proposed state is about Tk. 93.48 million which is much greater than the present non-use value of the Chalan Beel.This non-market benefit of Chalan Beel at the proposed state indicates that there is a public fund (i.e., peoples' WTP) towards a better wetland resource management and it is possible to implement the management strategies in the area. If better management is adopted for chalan beel wetland the economic value of this wetland will be increase six times from the present economic value.The estimated economic value in the present study is only an approximation and not the true value. The value of the beel is underestimated because value of all functions of the beel was not possible to estimate.So, if the developed strategies are adopted for better management of Chalan Beel, a significantly healthier outcome will be achieved from the beel in terms of economic and environmental perspectives and this progress will promote Chalan Beel management towards sustainable resources management in future.

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THE COMPLETE RECENT SCENARIO OF HAKALUKI HAOR BASED ON THE ENVIRONMENTAL AND SOCIO ECONOMIC ANALYSIS

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ABSTRACT

Hakaluki Haor is situated in the eastern part of Bangladesh. The last few decades we have witnessed an enormous rise in awareness of the importance of wetlands. Wetlands provide a wide range of economic, social and ecological benefits. Hakaluki Haor has been assumed to take the attention in recent years because of its ecological significance in terms of flood control, aquatic productivity, and micro climatic regulation etc. Hakaluki Haor once had plenty of wildlife and aquatic resources and has been covered with swamp forest, which in the recent time has become a fast degraded landscape facing increased pressure and threats. The aim of this paper is to present a complete scenario of Hakaluki Haor and the adaptation practices of local people through DPSIR framework analyses. To materialize the main objective, the environmental condition analysis, Socio economic analyses, wetland use and wetland threat are considered separately. In this study, the objective was extended to observe the complete integrated environmental assessment (IEA) and a detailed perceptional study on wetland use, wetland threat, and ecosystem based adaptation. At the end of the study, detailed management options have been given to protect and to conserve the economy and the eco system of Hakaluki Haor.

Keywords: Haor; DPSIR framework; Integrated Environmental Assessment; Perceptional Study; Haor Management.

INTRODUCTION

Wetlands are considered as invaluable components of the ecosystems with economic, ecological and commercial perspectives. The fresh water wetlands of Bangladesh support a wide variety of floral and faunal diversity, some of which are globally as well as locally endangered. However, these aquatic resources have been subjected to rapid degradation due to the increasing population pressure, habitat destructions and other anthropogenic as well as natural causes (IUCN, 2005). It is believed that the basin is technically active and is undergoing subsidence (Morgan et al., 1959). During monsoon the basin receives the huge discharges of large number of rivers flowing down from the hills of Assam and Meghalaya and takes the form of a vast inland sea. According to (World Resource Institute, 1990) Sylhet basin covers a large number of haors and wetlands like Hakaluki haor, Tanguar haor, Hail haor etc. the haor basin is an extensive alluvial plain supporting a variety of wetland habitats. It contains about 47 major haors and more than 6,000 beels, or freshwater lakes, nearly half of which are seasonal (Haque, 2008).

Haor is a unique type of wetland in the universe. Haors are back swamps that are bowl shape depressions adjacent to rivers. There are 411 Haors comprising an area of about 8000 km^2 dispersed in the districts of Sunamgonj, Sylhet, Moulvibazar, Hobigonj, Netrokona and Kishoreganj in the northeast region of Bangladesh. The Haors are flooded during monsoon. During the dry season, the floodwater drains out, leaving one or more shallow beels. Then the rich alluvial soils are exposed around the peripheral region of the Haor, and these are cultivated for Boro rice, which is the principle

crop of this region Hakaluki Haor is situated in the eastern part of Bangladesh adjacent to the Assam-Bangladesh border. 5 upzillas comprise this haor's total area. 3 of them Kulaura, Juri and Baralekha are under Moulvibazar district. While the other 2 upzillas Golapganj and Fenchuganj are under Sylhet division. It covers a large surface area of about 181.15 km^2. Around 40% of this land falls in the territory of Baralekha upzilla. This huge land coverage makes it Bangladesh's largest haor and one of Asia's larger wetlands. There are more than 238 small, medium and large interconnecting beels, some of which are perennial and others seasonal. During the dry season, approximately 4,4000 ha are is covered by the beel, but with the onset of the rains in the summer, the entire area floods to about four and half times of this size (18,383 ha) and remains under water for up to five months. During this period, all the beels are united as one large lake, or haor, making Hakaluki Haor the largest freshwater wetland in Bangladesh. The haor is mainly fed by the Juri/ Kantinala, Sonai/ Bordol, Damai. Fanai, and Kuiachara Rivers, out of which the Bordol/ Sonai, and Juuri/ Kantinala Rivers are originated in India. In the recent time has become a fast-degraded landscape and facing increased pressure and threats. Such rapid degradation of the wetland ecology is causing devastating consequences on the community people living in, around and downstream of the Hakaluki haor, who, for generations, were dependent for their livelihoods upon vital functions, services and benefits provided by this wetland. About 200,000 people live around the haor. All of them, more or less, are dependent on the resources of the haor for their livelihoods. As the haor floods annually, settlements are clustered along its slightly raised fringes. On ground of such threats and rapid degradation of the resources and in recognition of the urgent need to protect the unique ecology and biodiversity of the haor, Government of Bangladesh has declared Hakaluki Haor as an 'Ecologically Critical Area' (ECA) under the provision of the Bangladesh Environment Conservation Act (BECA), in 1999. (CNRS, 2002).
The objective of this study is to:

- Illustrating the interactions between the people, resources and economic activities.
- To know about the life style of Haor adjacent local peoples and their economic activities on Haor areas.
- To assess inter-linkages between economic and ecological function of the Haor system that is directly linked with local livelihoods.

Study Area

Hakaluki Haor is administrated under five Upazilas i.e., Kulaura, Borolekha, Fenchugong, Juri and Golapgong. The study was conducted at Chata beel and Jolla beel of Hakaluki Haor, situated respectively under Kulaura, & Barolekha Thana, Jaifarnagor and Talimpur Union. In here, Chatla beel is situated under the Zafarnagar union, and Juri Thana, adjacent respective villages are Sonapur, Vela Gau, Bachirpur, Kandi gau, Chalbon etc. Total area of Chatla beel is 302.9630 ha (CWBMP, 2005). The physical status of Chatla beel is moderately degraded. Ownership criteria are khas. (Community agrees with Govt. list). The study was conducted on Sonapur, Vela Gau. Village was selected on the basis of distance from the beel. On the other hand, Jollar beel is situated under Talimpur union and Barlekha Thana and adjacent respective villages are Sreerampur, Ranginagar, Molajuri, Dasghori etc. Total area of the Jolla beel is 181.3670 ha. (CWBMP, 2005). Physical status of Jolla beel is moderately Rich But, the study was conducted on Sreerampur and Molajuri on the basis of distance from the beel. In here also, ownership criteria are khas (Community agree with Govt. list).

METHODOLOGY

To determine the nature of dependence of the people on the haor resources and to estimate the used value of haor resources, household level survey of 84, randomly chosen households were conducted between June-August 2016. A modular questionnaire was developed to elicit information from these households. To value the productivity value of the Hakaluki haor, a structured questionnaire was used with the following modules:

General Information

This included general information about the households such as total number of family members, number of earning members, education, religion, occupation, food habit, sanitation, drinking water, energy source, involvement with micro-credit system etc. This part was designed to find out the socio-economic condition of the population living around the haor area.

Agricultural Activities
This part includes questions on agriculture, land ownership, expenditure and income from agricultural production, types of crops grown in the haor area, irrigation etc. It was designed to investigate agricultural production functions and income generation from agro-products in the haor area.

Fisheries
This part was designed to collect data on fish diversity of the study area; existing fish catch system, fishing expenditure, production cost and earnings from fishing.

Access and Rights to Collect Haor Resources
The questions of this section concerned rights of the inhabitants to haor resources, obstacles and hindrance they face during resource collection, labour market, partnership and economic activities based on haor resources.

Livelihood, Haor Resources and Other Non-use Value
This segment of the questionnaire consisted of questions on livelihood aspects such as full time/part time fishing, fish cultivation, livestock, collection of wetland plants and other resources.

ANALYSIS AND DISCUSSION

Dependence of Households on Haor Recourses
About two thirds of the households living in the region regularly visit the haor in order to collect wetland resources. However, they face the threats from private operators. Our survey reveals that 46% of them face such obstructions during collection of resources. 90% of them mentioned that the barriers come while fishing in the beels (whereas big beels are leased out there are many small beels inside the haors which are part of the rural commons but the leaseholders often encroach into their rights as common people do not have legal papers to defend their access to these commons); (29%) have reported resistance during bird hunting (which shows that government campaigns to protect birds in the haors have found its footage); (19)% faced hindrance during fuel wood collection and (14%) faced difficulties while grazing herds in the commons.

Economic Activities in the Haor
Other than fishing and rice cultivation, there are various economic activities from which people benefit. Illustrating that fishing and fish related activities were the major source of livelihood for the people. Nearly 83% of people were involved in activities related to fish production from the haor. Cattle grazing and duck rearing were also very common in the haor and nearly 97% and 87% of the people were involved in it respectively. Fuel wood collection is also an important economic activity while poaching of birds was also crucial for nearly 16% of the people. About 9% people were involved in sand extraction while about 6% were engaged in reed collection. Initiators are so much important because without them, it is not possible to manage the whole activities were happened in the Haor areas. Around 9 % of the jobs were initiated by the Lessee of the beels. Similarly, local Member of The Parliament, or members of the elected local government institutions are responsible for nearly 36% of the economic activities.

Resources used pattern by the local people
Most of the people In the Haor areas are poor, Illiterate. Most of the time, they lead their life by practicing farming, sometimes it's converted to farming. It's mainly depending on the seasonal variation. Using pattern of resources of the Haor areas also depend on the social condition of the Haor adjacent people's. Illustrating in the Table 1, in case of poor men, Main occupation was the Farming, Labor was the secondary occupation. In cause of them, Most of the family members like male, Female, and Child are involve for doing such types of work. Here, noted that their monthly income varies from 3000-3500 BDT. In case of middle man, their main income source was also farming, secondary income sources were poultry, take lease Beel from the Government. In here, male were involve for doing their work. Their average monthly income varies from 5000-5500 BDT. Most of the people are such type of group in the Haor areas. And, in case of

Rich man, their main income also come from the farming, but a major part of the income also come from the remittances, also come from the leased Beel. Here also only involve male person. Their average monthly income varies from 15000-16000 BDT. Here we see that, adjacent peoples in the Haor area are fully depend on the Haor resources, specially middle man and poor man are fully involve on Hakaluki Haor for their livelihood activities. Here also noted that most of the people are under the poor and middle criteria. So, we can easily say that every person in the adjacent Haor area is depending on The Hakaluki Haor. So, Hakaluki Haor deals a great value for every living stage of the adjacent peoples.

Table 1: Summary of haor resource used and the income from the haor resource (Tk. /yr)

Condition	Main sources	Secondary sources	Engaged people (M/F/C)	Income From Haor (Tk.)/ yr
Poor man	Farming Fishing	Labor	M, F,C	40,000
Middle man	Farming	Poultry,Leased Beel, Small Business.	M	60,000
Rich man	Farming	Leased Beel, Remittances	M	2,00,000

CONCLUSION

The fact that Hakaluki haor has been designated as an Ecologically Critical Area signifies its importance as a reservoir of disappearing natural resources. This study underscores the reality that that Hakaluki also constitutes an important source of natural capital, which yields high economic and livelihood values to surrounding populations and the country as a whole. Survey findings show that more than 80% of local households depend on wetland resources, and that the bulk of income-earning and livelihood opportunities in the area are wetland-based. The wetland also generates a series of economically important ecosystem services, which function to underpin, support and safeguard essential production and consumption processes. In total, it has been estimated that Hakaluki haor is worth at least BDT 585 million, or an average of BDT 48,000/ha. (CWBMP, 2000). The study describes inter-linkages between wetland ecology and economic processes. In addition to confirming the economic value attached to wetland conservation, it highlights the costs associated with the loss or degradation of wetland goods and services in terms of losses to livelihoods and the economy. To conserve biodiversity and protect the natural resources of Hakaluki Haor the initiative and measure should be taken which are swamp forest restoration and conservation, sustainable management of fisheries resources, production of wildlife, resources substitution for conservation of wetland ecology, ensure alternative sources of income and development of community based organization. Government should formulate appropriate policy and necessary law and should to create awareness among the people to preserving it biodiversity. It is also necessary to co-ordinate among different Ministry, specially Ministry of Forestry and Environment, Ministry of water resource, Ministry of land.

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HALDA RIVER FRONT DEVELOPMENT IN CHITTAGONG, BANGLADESH

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ABSTRACT
In Bangladesh there are so many rivers. Every river has some specialty and historical background. Thus, the river can be an attractive place for recreation and social interaction. The Halda river front development project has been under taken to develop the condition along the river bank and to increase the natural beauties of the river as well as the surrounding areas. The unplanned situation of the Patenga-Sadarghat-kalurghat has been reducing the beauty of the river as well as the city. This study is prepared to provide some recommendation and some design to enrich and beautify bank of the Halda River with SOWT (Strength, Opportunity, Weakness, Threat) analysis (Upper Eastern side) so that the people of the Chittagong city can go there and can enjoy the beautiful scenario of the river.
Keywords*:* River front development, Halda River, Recreation, social interaction.

INTRODUCTION
Bangladesh is a land of rivers. The total area of this country is 147,998 sq km. Among this area, the total amount ofarea of water land is 13,830 sq km. Around 800 rivers including their branches run through the country and create 24,140 km of water way (Wikipedia). Most of the area in our county is created through the silt of rivers. There are many more rivers in Bangladesh; Among them are Halda, Padma, Meghna, Jamuna etc. are important (Islam andChowdhury, 2014). Halda is one of the most important river in Bangladesh. Its waters have some exceptional physical, chemical and biological features which generate a favourable atmosphere(Zaman, 2014). With the rapid growth urbanization of Chittagong city, it is necessary to undergoing several developments of Halda river and needs emergency attention for controlled development to the disorganized construction and river pollution(Sufian, 2014).Goal of the study is to propose development activity in the front side (Upper Eastern)of Halda river in Chittagong city.

- To study and analyse the existing condition of Upper Eastern side of HALDA river.
- To propose recommendation for substantial river front developments.

Beautiful scenery of different places on the bank of the river front can be identified. Various places with scope for further beautifications by needs plantation, street furniture, open space, utility services etc. can be demarked. River side slope which require protect in erosion of the ground through plantation or block treatment can be recognized. Limitations of the study includes:

- Limitation of identifying the ownership of the open space whether it is public or private.
- There are some restricted areas where outside persons are not permitted to enter and that area could not be studied.
- Communication system area is very poor in some part of the study area.

METHODOLOGY
The project area is the downstream from the Moduna Ghat bridge, eastern part of the Halda River. By analysing the existing condition, the condition of land use of the study area is along with the site of building and most of the buildings are using in commercial and residential purposes, area, open space and

aesthetic beauty of the river. After analysing the study area, selecting the problem and scope of study area are identified. Finding the main problem of the study area and the scopes which are destroying day by day. A literature review is important because past information is helpful for present studies. Applicable findings and solution of the problems can determine from the literature review. It can be worked as a theoretical or methodological contribution on particular purpose. There are two types of data collection process. Primary Data was collected by photographic survey. Primary data also collected from discussion with local people.

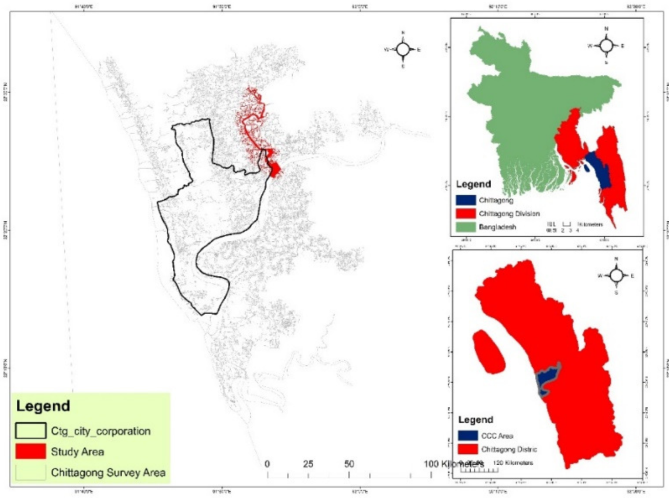

Fig1: Base map of Halda River and study area

Secondary data have been collected from CDA (Chittagong development authority), CCC (Chittagong City Corporation), and ARC GIS map. After collecting the primary and secondary data SWOT analysis is used for analysing both data. After SWOT analysis some plan will be prepared including Embankment and Road along Halda River, Improvement of river ghat, Leisure, Recreation facility, Park and sitting arrangement.

RESULTS AND DISCUSSION

All kinds of waste both in solid or liquid are discarded into the water, as a result there is corrosion of the marine environment. Most of the pollutants are in sediment form, municipal and industrial wastes, agrochemical scums and pollutant discharges from ships and boats. The regular growth of industry in current years has resulted in a serious problem of environmental pollution. The significant discharge of untreated industrial wastes has led to the degrading of the marine ecosystems of Bangladesh and creates an impact on fisheries. There is no proper waste disposal system in the bank of the Halda River. Different types of waste like human waste, Residential waste, unused products, fertilizer, Bags, oil etc. are thrown into river. There is also many hanging latrine in the bank of the river. While using the toilet, the dirt goes to the river and pollutes water. Different illegal activities increase day by day in river side. Many people playing card with money. Sometimes they playing card in different illegal way. Local people have no safety approach in this area for preventing these illegal activities. Erosion is also a big problem in this river side, because of erosion there is no embankment of the river side. There is no enough deck for good loading and unloading. Though existing deck is made of wood this deck is destroyed any time which create a great lose in economics field.

SWOT Analysis Findings:

After analysing the existing condition, SWOT analysis is useful for finding. Result of the SWOT analysis is given below:

Strength:

- The site is located near to the meeting place and well outside the zone where no physical implementation is allowed by CDA(DPZ,4).
- Being near to the river it can serve as a base for water based recreational activities.
- There are a number of tourist places around such as the fisher village, Borua para, CUET, the hillsides towards the west, the hatcheries and places where fishing culture is practiced.
- The site is only 25 minutes' boat ride from Moduna Ghat and 10 minutes by road form Moduna Ghat bridge, and so can act as a day stoppage for visitors to Kaptai and Rangamati.
- Having still being untouched by urbanization, the site allows the nature to be realized as the wild.

- This area has the advantage of being away from noise pollution.

Weakness:
- Roadways are not developed leading to this site.
- The site experiences flooding and is in a flat muddy area.

Opportunity:
- The site experiences flooding and is in a flat muddy area so construction can be explored.
- The project may help preserve the untouched experience of nature that is present in the site.
- Increase the economic growth in the sense of providing more employment.
- Traditions can be preserved and enhanced.

Threats:
- Being very near to the river may experience landslide.
- The river is in danger of losing its ecological balance due to spontaneous unplanned growth, brick fields, and improper drainage.
- Proper awareness must be provided to a natural heritage of our country which will otherwise be lost.
- Serves the economy of the country which will be affected.

PROPOSALS

Embankment and Road along Halda River

In order to provide protection to the riverbank and to enhance traffic circulation in the upper eastern part of this zone, an embankment has been proposed by CDA in DAP-4 between Modunaghat and Noapara road.

Improvement of River Ghats

It is proposed that all the river Ghats and areas surrounding Halda River should be improved and reorganized to better serve the traffic which uses them.

Leisure, Recreation

For better mental and health improvement of the local people it is mandatory to provide land for different types of recreation activities like leisure centre, parks, playground, green and sports complex. Taking into consider this demand for recreational purpose the present study of DAP recommends a certain amount land in the study area for this purposes. The river side can be a turned into an attractive place if any picnic spot is available in this side. Some specials project should be taken to develop this place. There are no felicities to travel with boat along the river side. So there should be some option to travel with boat. This will create an employment of the people in this region.

Shops

There should be some small shops. For example- shops of *tea stall, Chotpoti*, various types of flowers shops should be available along the river side. But there should not be any large shops or departmental shops in the river side.

Vehicles

Motors vehicles are not allowed here. Non-motorized vehicles are allowed for this study area. The terminals are to be developed taking into account environmental enhancement and proper traffic circulation. It is mandatory to design a green buffer of trees surrounding the terminals.

Illegal encroachment

Any illegal development, infrastructures are allowed to the river side. Some special rules should be made to protect illegal encroachment along the river side.

CONCLUSION

Halda River developing is very important for the people of Chittagong whose lives are dependent on this river. It has taken up to help generate awareness, starting from the workplace itself and then further. People today know very less about the rivers, their ecology and little do they realize how dependent our daily lives are on rivers. It has helped achieve this goal, of making people aware of the nature and how we are dependent on each other. The aim was not to generate architecture only but to help people relate to bigger issues which they neglect.(Sufian, 2014). Government and policy maker are required to more responsible for strengthen and guideline river front development in Chittagong(Desfor and Jorgensen , 2016). In this paper here identified some proposals. It can be included in the HALDA river front development. Improvement is required to maintain and increase river front development in the future(Islam & Chowdhury, 2014).

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UTILIZATION OF WASTE PLASTIC TO MANUFACTURE PLASTIC SAND BRICKS

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ABSTRACT
Plastic is a non-bio-degradable substance which takes thousands of years to decompose that creates land as well as water pollution to the environment. The study aims to evaluate plastic to use as building blocks. Collect plastic form different sources and then melted it to give a form of a brick for characterizing its suitability for building material. The study showed that the brick made from plastic waste has the Potential to be used as a brick having average compressive strength 4 N/mm^2 , Water absorption less than 1 %, nil efflorescence effect. Also, hardness, fire resistance & soundness respectively high quality, good & gives a ringing sound which indicates that it could be used as a compressive block. In comparison to normal clay brick, the plastic made brick can be used as a civilian brick replacement.

Keywords: Non-Biodegradable; Bricks; Utilization; Compression strength; Efficiency.

INTRODUCTION
One of the everyday plastic components increases its effectiveness and is dangerous. At the time of need, it is seen that the plastic is very useful, but is discarded only after its use, all the risks made of plastic are not biodegradable and it is a dangerous element for more than a century. Nowadays, it is impossible to work effectively for a key sector without using plastic from agricultural and industrial. Therefore, we cannot ban the use of plastic, but the recycling of plastic waste is used in building construction, industries are considered to be the most effective applications. In a remote area like Saint Martin which is a tourist area, there are many plastic bottles are wasted and they cannot be recycled. It's harmful to Marine environment. So if we can collect them and recycled in manufacturing bricks, it will be more effective for the people of the area. Our project will aware the people about the recycle way of plastic as well as it will be cost effective for construction. To fulfill the above need, this study is based on two objectives namely: to characterize plastic waste's potential for reuse in civil construction and to compare its properties with conventional brick used in civil construction.

METHODOLOGY
Two sacks of waste plastics have been collected from different CUET canteen. Natural river sand was used as a fine aggregate. Which have been collected from a construction site in CUET. Plastic PET categories such as single-use bottles as water, soft drinks, juice etc. are collected from CUET canteens. Moulds have been made according to Bangladesh standard specification for brick and compression test. Collected plastics were clean with water and dried in sunlight. Collected sand was sieved through #50 sieve. After batching the plastics were taken for melting in which the plastic bottles are thrown one by one into the pan and allowed to melt. The mixture was stirred with a steel rod. When all plastics have melted the mixture was poured into the mould. After cooling for 4 hours specimen was being demoulded. Then the tests required for standard brick were conducted on Plastic sand brick. Mould size and tests list are given in the roadmap of the study.

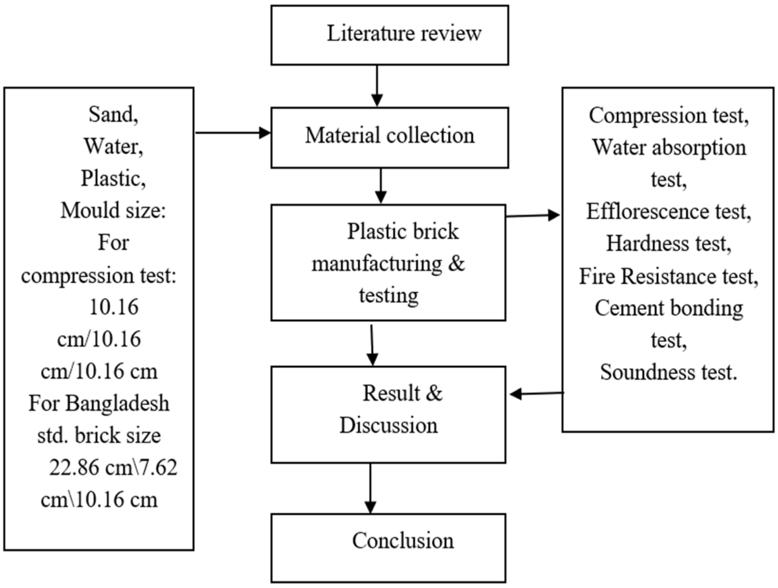

Fig 1: Flowchart of the adopted method.

Fig 2: Demolded specimen

Fig 3: Bangladesh standard sized plastic sand bricks

Fig 4: Cemented plastic sand bricks

Fig 5: Cemented plastic sand brick

Table 1: Properties of sand

Serial number	Tests	Results
1	Specific Gravity	2.53
2	Bulk Density	1578 kg/m3
3	Fineness Modulus	2.31

Table 2: Plastic properties (for general plastic)

Serial	Properties	Results
1	Density at 23˚C	0.958 kg/m^3
2	Elastic modulus	9 N/m^2
3	Tensile creep strength	8 N/m^2
4	Bending creep modulus	1 N/m^2
5	Tensile strength at 23˚C	2 N/m^2
6	Thermal conductivity	0 W/(m. K)
7	Ignition temperature	3°C

$$\text{Compressive Strength} = \frac{P}{A} \quad (1)$$

$$\text{Water absorption} = \frac{W_2 - W_1}{W_1} \times 100 \quad (2)$$

Where, W_1= Weight of dry brick (kg)
W_2 = Weight of wet brick (kg)

RESULTS AND DISCUSSIONS

According to test plastic sand bricks gives satisfactory results. The minimum compressive strength of clay bricks is 3.5 N/mm^2 . A grade (1st Class) bricks compressive strength is 7 to 14 N/mm^2 .Our result shows that the plastic sand bricks compressive strength is minimum 4 N/mm^2. It is increased with the plastic ratio. Hence it can be used as a compressive block. Also plastic sand bricks durable long lasting and recyclable.

Table 3: Test results of Plastic Sand bricks

Test Name	Result
Compressive strength test For difference plastic sand ratio	4 N/mm^{2}for 1:3 5 N/mm^{2}for 1:4 5.57 N/mm^2 for 1:5
Water absorption test	0.921% for 1:3 0.701% for 1:4 1.04% for 1:5
Efflorescence test	Nil
Hardness test	Hard (tested with steel rod)
Fire resistance test	Increase due to presence of sand
Soundness test	Ringing Sound (Good)
Cement bonding test	Good
Physical properties	Size: 22.86 cm/7.62 cm/10.16 cm; Weight: 3000 gm. Colour: Deep Brown

CONCLUSIONS

It is seen that plastic brick made of waste plastic bottles has its suitability for civil construction uses with a few reservations. The made-up bricks showed strength similar to class 3 clay brick as per Bangladesh standard in accordance with other properties, are approvable. The plastic that used in making bricks will not pollute the water. It is highly recommended controlling the melting of plastic while mixing because of the burning of plastic can cause an environmental effect by emitting harmful gas. For this reason Plastic should be grinded in small pieces to control the burning of plastic. We recommend that since plastics are volatile to fire and heavyweight we recommend according to test result no to use in the residential building, factory, hospital, school, market etc. We can use it as a pavement block in footpath and decoration purpose like a garden wall.

Table 4: Comparison of Plastic-sand bricks and clay bricks.

Compressive strength			
Plastic sand bricks		Clay Bricks	
Plastic: Sand	Strength	Category	Strength
1:3	4 N/mm^2	1st Class	>10 N/mm^2
1:4	5 N/mm^2	2nd Class	>7 N/mm^2
1:5	5.57 N/mm^2	3rd Class	>3.5 N/mm^2
Remarks: Required Strength can be gained by controlling plastic sand ratio.			
Water absorption			
Plastic sand bricks		Clay Bricks	
Plastic: Sand	Percentage	Category	Percentage
1:3	less than 1%	1st Class	<12%
1:4	less than 1%	2nd Class	<20%
1:5	less than 1%	3rd Class	<25%
Remarks: Plastic sand bricks showed the significant reaction of water absorption.			
Efflorescence			
Plastic sand bricks		Clay bricks	
Nil		Can be slight, moderate and heavy.	
Remarks: Resist salt attack			
Hardness			
Plastic sand bricks		Clay bricks	
No impression on the surface while scratching.		1st class bricks are good but 3rd class isn't.	
Remarks: Hard.			
Soundness			
Plastic sand bricks		Clay bricks	
Ringing sound.		Ringing sound by 1st class bricks.	
Remarks: Good.			
Fire resisting ability			
Plastic sand bricks		Clay bricks	
Not good. Slightly increased by the presence of sand.		Excellent fire resisting ability.	
Remarks: Not good.			

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Rai, B., S.T. Rushad, B. Kr, and S.K. Duggal. Study of Waste Plastic Mix Concrete with Plastic.

A REVIEW ON GROUNDWATER RESOURCES: CHALLENGES & OPPORTUNITIES

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ABSTRACT

Bangladesh is the largest deltaic plain in the world formed by the confluence of the Ganges, the Brahmaputra (Jamuna) and the Meghna River and their tributaries which drains along around 1.72 million km^2 of land. This small mass of land has the highest population density (1111 persons/km^2) of any country with the exception of small states such as Bahrain, Malta and Singapore. Growing population and limited arable land does not give us freedom to choose any other options rather than groundwater and surface water. Some research data from WASA, BWDB, BMD, DPHE and previous studies reflect the present situation of water in Bangladesh. The internal renewable water resources are estimated to be 105km^3/year which includes 84km^3 of surface water produced internally as streamflow from rainfall and about 21km^3 of ground water resources produced within the country. According to UNESCO, around 50% of potable water, 40% of industrial water and 20% of the water used for irrigation in Bangladesh is provided by ground water. But the availability of Ground Water for drinking purpose has often been threatened by arsenic. Arsenic was discovered in shallow aquifer of Bangladesh in 1990's. More than 66 million people are exposed to this danger. Besides excessive dissolved Iron and Salinity in shallow aquifer in the coastal areas are also obstacles to potable ground water. Further lowering of ground water level in the northern regions and rocky layers in the hilly areas are also indicated as obstacles to safe water. Seasonal variation of groundwater has shifted upto 4 m during last 34 years and according to DPHE within 2020 the lowering of ground water level might be upto 20 m. The study is an assessment on current ground water situation in Bangladesh basing on Arsenic, Hardness, Salinity and aquifer depth and scope of further development.

Keywords: Groundwater; Renewable Water; Arsenic; Iron; Salinity; Lowering of Groundwater Level

INTRODUCTION

Bangladesh is a low laying riverine country located in Southern Asia cover a total area of 147,610 km^2 having 6.4% water and about 162,951,560 population (WPP, 2017). The country has been formed as the greatest deltaic plain at the confluence of the Ganges, The Brahmaputra (Jamuna) and the Meghna River and their tributaries (Singh et al., 2004). Groundwater is an important resource for livelihoods and the food security of billions of people and especially in booming Asia's agriculture economies. Groundwater makes up nearly 30% of all the world's freshwater. Globally, groundwater provides approximately 50% of current potable and 20% of the water used for irrigation (UNDESA, 2017). Bangladesh has a tropical monsoon climate with significant variation in rainfall and temperature throughout the country. It receives 80% of annual precipitation averaging 2320 mm but varying from as little as 1200mm in the west to over 5000mm in the east. Runoff from adjacent riparian is generated by rainfall which averages 5000mm over the Himalays and exceeds 10,000mm over the Meghalaya plateau north to Sylhet (BMD, 2017). The sources of water in Bangladesh are mainly rainfall, river, standing water bodies and seasonal wetland. Rivers provide 1000 billion cubic meters, standing water bodies 0.61 billion cubic meters, seasonal wetland 2.69 billion cubic meters and in stream water storage 0.5 billion cubic meters. An estimated 795,000 million cubic meter of surface water is discharged per year through the Ganges-Brahmaputra system (Nayem et al., 2016).

The total length of rivers within Bangladesh is about 22,000 km. The internal renewable water resources are estimated 105 km^3 per year, which includes $84km^3$ of surface water produced internally as stream flows from rainfall and $21km^3$ of ground water produced within the country. The total abstraction of water volume (annually) is about $35.87km^3$ where $31.50km^3$ for agriculture purposes, $3.60km^3$ for domestic purposes and $0.77km^3$ for industrial purposes. Share of ground water in total abstraction is 79% and the volume is $28.48km^3$ (Rajmohan and Prathapar et al., 2013). Currently about 4.2 million ha of land is irrigated by groundwater whereas only 1.03 million ha is irrigated by surface water using low lift pumps. The area irrigated by surface water declined from 76% in 1981 to 23% in 2012, whereas for the same period, area irrigated by grou7ndwater has jumped to 80% from 16% (BADC, 2013).

AQUIFER CHARACTERISTICS OF BANGLADESH

Bangladesh consists of some varying nature of aquifers. The major aquifers are: Upper Holocene Aquifer, Middle Holocene Aquifer, Late Pleistocene Aquifer and Plio-Pleistocene Aquifer (GWTF, 2002).

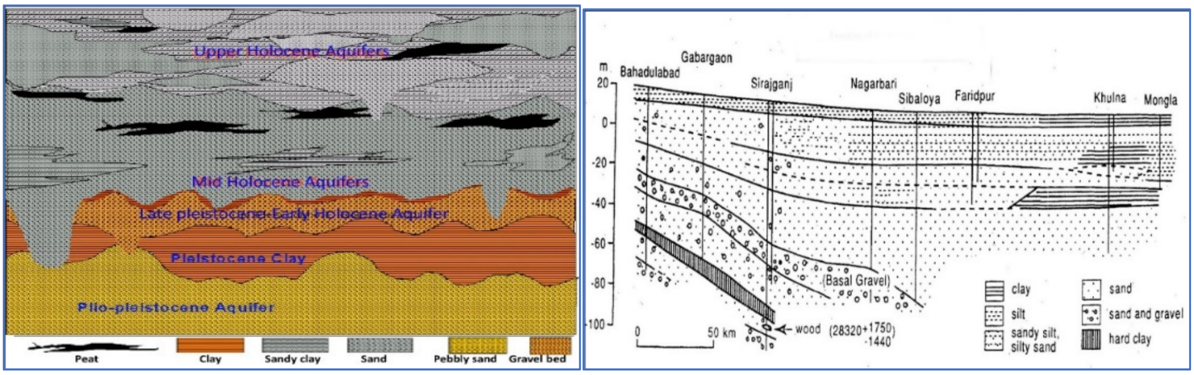


Fig. 1:Schematic Geological classification of aquifers of Bangladesh and Cross section of deposits in Bengal delta(Source: Islamand Uddin, 2002; Umitsu, 1987).

In the shallow aquifer, groundwater flows from north to south with localized outflow into the major rivers. Groundwater gradient varies from 1:1,000 in the northwest to 1:13,000 in central Bangladesh to less than 1:20,000 in the coastal area. Permeability of the aquifers are high and vary from 10 to 200 m/day. Transmissibility of the main aquifer range from 100 to 10,000 m^2/day with an average value of 2,000 m^2/day (MPO, 1991). A sub surface geological cross-section across Banglasesh in NW-SE direction indicates the presence of six deep fresh water artesian aquifers. Except for the aquifer which is regionally extensive from Rajshahi to the Chittagong hill tracts, the other five aquifers appear to be separated by regionally extensive clay aquitards. However, there is a strand of saline water with a significant dip in the central region (Palmer, 1989). First aquifer gets sizeable recharge from inundation. The artesian aquifers underlying the Bangladesh plains are hydraulically unconnected with either first aquifer or any rivers or streams. These fresh water deep aquifers underlie around half the delta area (Paul, 1987).

GROUNDWATER AVAILABILITY AND PROBLEMS

As mentioned earlier maximum demand of water supply in Bangladesh depends on groundwater due to its adequacy in nature. But the availability of groundwater has become a problem due to (BUET, 2004):

- Salinity in the shallow aquifers in the Coastal areas;
- Arsenic in groundwater;
- Excessive dissolved iron;
- Lowering of groundwater level;
- Rock/stony layers in hilly areas;

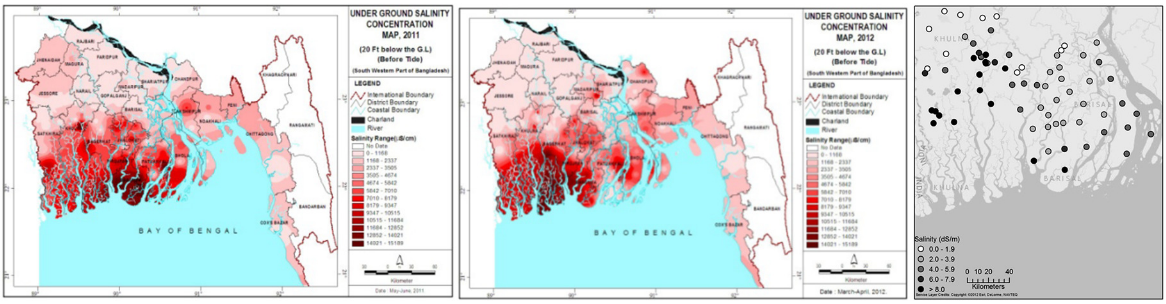
Salinity issues in the Coastal areas

The coastal area of Bangladesh consists of 19 Districts with an area of approximately 46,271 Km^2. This is around 31 percent of the country's total area. The coastal zone covers an area from the shore of 37 to 195 kilometres, whereas the exposed coast is limited to a distance of 37 to 57 kilometres (Hoanh *et al.*, 2006). A higher value of salinity up to 1000 mg/L for problematic areas including coastal belt is considered (DPHE, 2006) for drinking. There are 17 towns located in the coastal region which are relatively in high risk of salinity in groundwater due to high salinity penetration in the upstream area. Table 1 shows the severely affected coastal towns in southern Bangladesh.

Table 1: The coastal town's area affected by salinity (Islam and Gnauck, 2010)

Name of the City	City Area (Km²)	Area affected by Salinity(%)	Name of the City	City Area (Km²)	Area affected by Salinity(%)
Barguna	15.57	46	Botiaghata	8.30	69
Mathbaria	15.92	65	Dumuria	6.39	68
Pathorghata	18.31	68	Rupsha	2.30	45
Galachipa	9.60	72	Mongla	17.79	78
Kalapara	19.49	74	Paikgacha	2.12	81
Munchiganj	2.10	88	Bagerhat	7.53	56
Kaliganj	7.96	77	Morelganj	15.36	65
Ashasuni	6.81	85	Koira	10.06	81
Satkhira	27.84	45			

An analytical data from BADC Fig. 2(A) and Fig.2 (B) shows the change of salinity in the coastal regions of Bangladesh from 2011 to 2012. The study illustrated a slight decrease in overall salinity of the coastal areas in twelve months. Later on, Fig: 2(C) shows the Projections of future 2050 river water salinities (Dasgupta et al., 2014). A slight decrease in river water salinity is expected to occur within this period of time.



(A) (B) (C)

Fig. 2: (A) Variation of salinity in 2011, (B) Variation of salinity in 2012 (Source: BADC) (C)Projections of future 2050 river water salinities based on (Dasgupta et al., 2014)

Arsenic Contamination of Groundwater

According to the data provided by UNICEF in 2008, there are approximately 8.6 million tube-wells in Bangladesh. Of these, 4.75 million tube wells (55%) have been tested for arsenic among which 3.3 million (39%) were marked green indicating that the ground water is safe; while 1.4 million (16%) were marked red indicating that they are unsafe to use as sources of drinking water due to the high arsenic level. According to survey data from 2000 to 2010, an estimated 35 to 77 million people in the country have been chronically exposed to arsenic in their drinking water in what has been described as the largest mass poisoning in history (Smith et al., 2000; Kinniburgh et al., 2001). Spatial distribution of arsenic in drinking water of Bangladesh, 2009 shows that 13.4% of sample exceeding the Bangladesh drinking limit of 50μg per litre and 32.0% of samples exceeding the WHO guideline value of 10 μg per litre. In 268 (at present 271) out of 463 Upazilas of the country the Problem identified from the Survey of DPHE-UNICEF -BGS (British Geological Survey). Survey of DPHE–UNICEF in 198 safe Upazilas identified 12 more Upazilas having arsenic problem. The survey also identified 3.50 million tube wells are free from arsenic contamination and 1.44 million tube wells are found to be arsenic contaminated among 4.95 million screened tube wells of these Upazillas. Approximately 20% of the national wide tube wells are found contaminated with arsenic. The worst affected Districts are Chandpur(90%), Noakhali(69%), Shriatpur(65%), Munsiganj(83%), Satkhira(67%), Meherpur(60%), Gopalganj(79%), Comilla(65%), Bagerhat(60%), Madaripur(69%), Faridpur(65%) and Laxmipur(56%). Arsenic concentration in drinking water and proportions exposed as determined by testing during national surveys, Bangladesh is shown in Table 4. A detailed Review Study (IPAM-2009) of the National Policy and Implementation Plan for Arsenic Mitigation 2004 was carried out and Number of Arsenic- Contaminated Tube Wells and Arsenic Patients in different unions shown in Table 2.

Table 2: Arsenic-contaminated tube wells and arsenic patients in different unions (IPAM-2009)

Public safe water coverage	Percentage of tube wells with arsenic contamination											
	Tube wells	People	Tube wells	People	Tube wells	People	Tube wells	People	Tube wells	People	Total	
	<20%		20-40%		40-60%		60-80%		80-100%		Tube wells	People
<20%	143	189	35	223	51	370	67	535	188	7204	484	8521
20-40%	115	428	75	666	86	935	94	1034	145	8888	515	11951
40-60%	449	1885	140	1890	89	1213	68	792	76	1708	822	7488
60-80%	507	1682	120	1049	37	631	57	1348	31	509	752	5219
80-100%	213	770	46	490	21	148	14	214	12	245	306	1867
>100 %	149	418	32	674	22	483	25	274	13	118	241	1967
No data	9	18	1	8	1	0	0	0	1	0	12	26
Total	1585	5390	449	5000	307	3780	325	4197	466	18672	3132	37039

Iron Contamination in Ground water

Bangladeshis ingest approximately 12%, 62%, and 26% of their dietary Fe from drinking water, eating rice, and ingesting soil, respectively in Bangladesh.

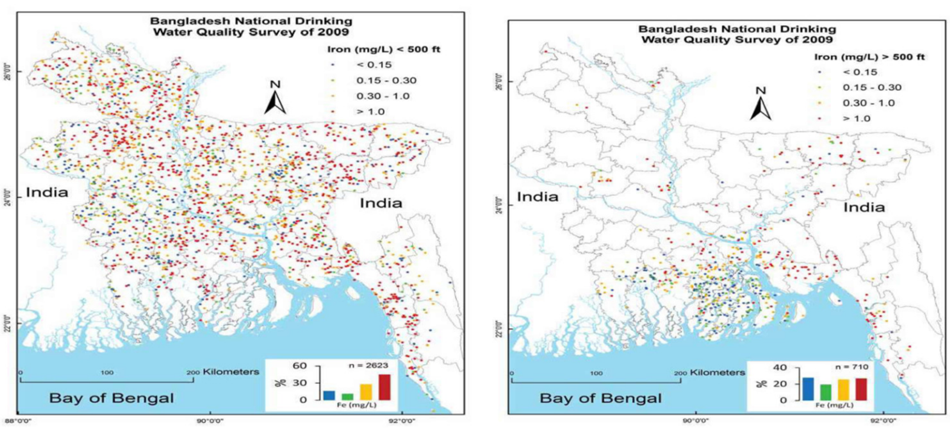


Fig. 3: Iron in shallow and deep tube wells in Bangladesh (BNDWQS-2009)

Fe is ingested at almost twice its recommended dietary allowance (Ortega et al. 2003). Ground water quality data of about 1000 deep tube well samples from about 124000 sq.km. area which covers 56 administrative shows that ground water about 51000 sq.km. (41%) of the studied area contain more than 1.0 lm/l of iron. Whereas about 2800 sq.km. (22.5%) of the studied area contain iron more than 5.0 mg/l. Iron problem is acute in ground water in the district of Manikgong, Gopalganj, Norshindi, Narayanganj, Rajshahi, Bagerhat, Sylhet, Sunamganj, Noakhali, Khulna and Kurigram (Hossain and Huda, 1997). Fig. 3 shows that iron in shallow tube well (<150m) and deep tube wells (>150m).

Variability of Groundwater level

Due to over-exploitation of ground water, the drawdown of water table becomes significant during last decades. The variation in groundwater levels but detected decline of ground water levels (> 1 m/yr) areas around capital Dhaka as well as in north-central, north-western and south-western parts of the country (0.1-0.5 m/yr) due to intensive abstraction of groundwater during dry season rice cultivation (Hossain and Siddique, 2015). The areas with water tables less than 8 m in depth, decline has increased significantly over time. Between 1998-2002, the area was only about 4% of the country's total, but increased to 11% in 2008 and 14% in 2012. [Fig. 1]. The most significantly affected areas lies in the north-west and north central (Qureshi et al, 2015). The average depth of groundwater level in wet season has found about 5.33 m And in dry season about 6.5 m in 2010. The average depth of water level has declined about 7.8% in wet season and 7.2% in dry season in 2010 than that of 1985. About 1.8% of the total area had a water depth of more than 10m in wet season whereas it was about 2.7% in dry season in 1985. The northern region have experienced a decline of more than 5 m within last 25 years (Sumiya and Khatun, 2016). In contrast, groundwater levels are slowly rising in southern Bangladesh, a consequence of seawater intrusion and tidal movement (1.3-3.0 mm per year), creating waterlogged conditions (Brammer, 2014).

CONCLUSIONS

The findings from available literatures and information and the analysis of groundwater level, use, recharge and quality indicate that the declining groundwater level is the threat to drinking water supplies especially in the barind and hilly areas. However, the quality of groundwater, in particular arsenic, salinity, iron and manganese, is a major threat to safe drinking water supplies in these areas. A number of options based both alternative water sources and water treatment technologies (tapping targeted aquifer, piped water supply, desalination etc.) are in practice particularly in coasts, hilly and salinity affected areas. These multiple options should continue at least near future. Adaptive management, based on a principle of learning by doing, with monitoring of groundwater quality, mining and regulation of groundwater use should be adopted for sustainable management strategies. Government organizations including BMDA, BADC, DPHE, BWDB, WARPO, Department of Environment and local government agencies should work together for a common vision instead of isolated vision. Moreover, unified national network, protocol for groundwater monitoring, national groundwater database are urgently need.

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RANK BASED HAZARD SEVERITY ANALYSIS AFTER TIDAL RIVER MANAGEMENT (TRM) IN BEEL BHAINA

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ABSTRACT
In Bangladesh, 19 districts are accounted as coastal zone and one-third of the total population lives in the south-west part of the country. To manage the entire area under the coastal zone, many initiatives are taken to control but some doesn't work at all like Khulna Jessore Drainage Rehabilitation Project (KJDRP). The KJDRP became a great failure for building the embankment around the polder area to trap water which leads to flood, water logging, long-term salinity etc. in the affected area. To get rid of these consequences, general people cut the polder for allowing tidal flow and accumulating sedimentation inside the polders. These allowed the land to upgrade which termed as Tidal River Management (TRM). After cutting these, like other beels, Beel Bhaina became vulnerable to many disasters like river erosion, salinity, water logging, flood, drought following long-term land upgradation procedure. It was found that affected people reported a different kind of hazard in different parts of beel. The detection of hazardous areas and collection of information are conducted according to the ownership and activity of people. Beel Bhaina and its adjacent affected villages Agarhati and Bharat Bhaina in Keshabpur Upazila in Jessore were selected for the study focusing on the questionnaire survey. The objective of the study is to analyse the severity of one hazard which might need attention more than others and also find out the origins of that hazard. On the interpretation of these studies, the ranking procedure was conducted based on people's opinion, affected area, time duration and economic losses and achieved highest scored hazard. Some hazards like water logging, salinity, river erosion, and drought have become more frequent in the area according to local people which lead to migration and infertility of land.

Keywords: TRM, Beel Bhaina, Hazard, Severity Analysis, Weighted Ranking.

INTRODUCTION
As most vulnerable region in the world, Bangladesh is vulnerable to climate change as well as sea level rise due to a continuous process of land subsidence (Huq et al., 1999).In southern part especially in Khulna Jessore District is facing huge amount of water logging problem in recent years. Most of the part of that area specially beel area like Beel Bhaina, Beel Khuksia etc are inundated for long time which destroy the land fertility and increase salinity problem for long term. There was scarcity of dry cultivable land. To increase the amount of dry cultivable land, Tidal River Management (TRM) practice has been introduced by local people. Tidal River Management (TRM) is an eco-technological concept and designed to solve the water-logging problem and also improve the environment problem. (Amir et al., 2013). It was not originally conceived as a way to adapt to climate change, the technique employed may offer hope for communities as risk of sea level rise in similar areas (Oxfam, 2011). As unique indigenous ecological knowledge of river management and collective effort of local communities is to raise coastal land to a desired height. Bangladesh Water Development Board (BWDB) learned the concept in 1990s from the local communities and about 31.32 km^2 of land had been raised by local communities themselves in Beel Bhaina and Beel Dakatiya applying TRM. (Kibria & Mahmud, 2010). It also found that flap gate is used to control the salinity of water by reducing the discharge of brackish water in agriculture land. In this project, the environmental impact assessment has not been done. (Kibria & Mahmud, 2010).

After then, the govt. took this coping strategy to control river sedimentation. It also increases the navigability of rivers. Because of coastal embankment, the tidal wetland has experienced severe environmental impairments in this region. (Rejve, 2006). For long term inundated under saline water, it increased the effect of different type's hazard according to local people. Many people's land face water logging still now, some response to river erosion, some land near river still face flooding during tidal wave and salinity intrusion is common to all for they face this kind of phenomena all the year round. The main purpose of the study is to identify the most divested hazard which is faced and affected by local people living around and in Beel Bhaina.

METHODOLOGY

The whole study was conducted on the basis of focusing three parts. (1) Study area selection, (2) Data collection procedure and (3) Rank Based Hazard Severity

Study Area Selection

Under Gaurighona union, Agarhati Bharat Bhaina village is one of the well-known parts of Keshabpur upazila because of Tidal river management. The project area is situated on beside of Bharat Bhaina north-south and east of the Hari river and Sherpur of Raghunathpur, the west-Bherchi village. It is located on 22°52'00" north latitude and 89°22'00" east longitudes. The main area of this assessment was on the adjacent villages. The total beel area is 600 acres. (Sengupta, 2009)

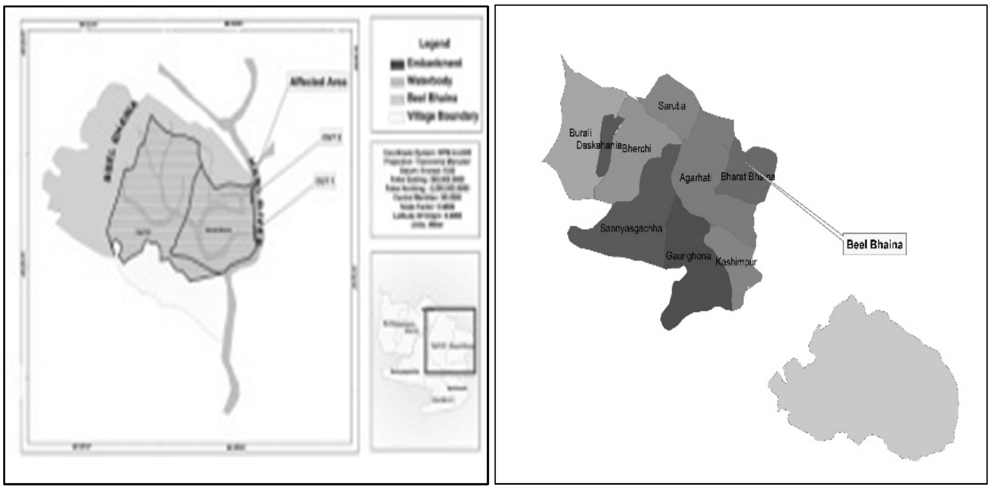

Fig. 1: (a) Study Area, (b) Location of Tidal River Management Project Site in Gaurighona Union

Data Collection Procedure

For ranking hazard severity analysis, Data have been collected from primary data source. Primary data collections are based on questionnaire survey and Participatory Rural Appraisal (PRA). In questionnaire using stratified sampling, the sample size determined was 284 but for lacking of manpower, 100 households were surveyed finally. Data had been collected with the following timeline before implementation of TRM practice October 1997 and after implementing TRM the time line is December 2001 to current.

Rank Based Hazard Severity

Assessment of People's opinions is giving for different kind of hazard problems. In the study area it is important to find out the most effected hazard which could possibly affected the people. So, in here, it is found that water logging problem gets the highest responses. For TRM practice people mostly feel water logging and salinity problem is emerging. This problem is supposedly reduced after implementing TRM but the problem is still present. Third problem is River Erosion which induces after TRM. This causes loss of land in huge amount than before. Lots of people claimed there are being affected by losing land. For changing the topographical condition and reducing the amount of wet land, there is some place which faces drought problem now and then. Especially in the month of April to June, Flood is also found for tidal surge but the amount is not as noticeable.

Table 1: Hazard severity problem ranking

Problem	Peoples opinion	Score	Remarks
Water logging	95	10	0-10=1 51-60=6 11-20=2 61-70=7 21-30=3 71-80=8 31-40=4 81-90=9 41-50=5 91-100=10
River Erosion	76	8	
Salinity intrusion	88	9	
Flood	46	5	
Draught	57	6	
10= Highly importance, 1= Low importance			

Assessment is given for different amount of affected area to different kind of hazard problems. Area is very important in assessing the problem severity. In the data view, the water logging and Flood problem in study area is huge than any other hazard. This is because the severity of this problems greater.

Table 2: Problem ranking based on affected area

Problem	Affected area (sq. m)	Score	Remarks
Water logging	11758.27	3	0 to 5000 sq.m=1 5001 to 10000 sq.m=2 10001 to 15000sq.m=3
River Erosion	308.2655	1	
Salinity intrusion	5153.45	2	
Flood	14281.93	3	
Draught	7467.54	2	
3= Highly Affected area, 1= Low affected area			

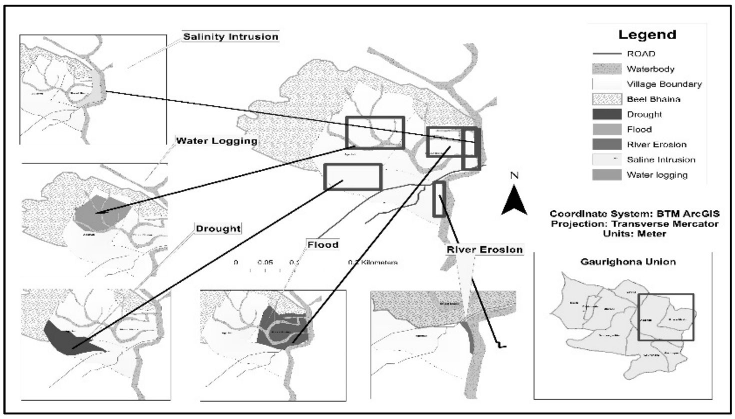

Fig. 2: Different hazard affected area identify

This analysis has been conducting with the following PRA techniques (i.e. focus group discussion.). Assessment is given for different time duration of different kind of hazard problems. The long-time duration may cause loss of livelihood and also production. So, it is important to identify the long term affected hazard. Example like, long term saline water intrusion can cause damage of land fertility and also cause damage to the structure.

Assessment is given for income loss of different kind of hazard problems. The study has been found that around 46% people's income have negative impact means they lost their income after TRM. So, scoring of these criteria has been selected according to the range of income loss with the percentage of people's number. Like within TK. 500 to 1000 income loss have been faced by 59% people who responses River Erosion as less loss problem.

Table 3: Problem ranking based on time duration

Problem	Time duration (month)	Score	Remarks
Water logging	3	1	1 month-4 month=1 5 month-8 months=2 9 month-12 months=3
River Erosion	12	3	
Salinity intrusion	9	3	
Flood	3	1	
Draught	6	2	
3= Long term affected, 1= Short term affected			

Table 4: Problem ranking based on loss of income

Problem	Loss (income loss)	Score	Remarks
Water logging	43.47%	2	TK.500-1000=Less Loss=1 TK.1001-2500=Moderate Loss=2 TK.2500-5000=High Loss=3
River Erosion	59%	1	
Salinity intrusion	43.47%	3	
Flood	50%	2	
Draught	50%	1	
3= High amount of loss, 1= Low amount of loss			

According to importance of criteria, the weight has been provided. People's opinion has been collected primarily, affected area is collected with Focus group discussion and secondary data collection, and time duration is collected with focus group discussion and at the last loss of income collected with questionnaire analyzed data.

Table 5: Weighted according to priority basis

Criteria	Weight according to priority
Peoples opinion	40
Affected area	30
Time duration	20
Loss	10

So, the final scoring has been provided with numerically to find out the top most important hazard. From the calculation it is found that the final score is highest for Water logging and lowest for flood.

Table 6: Scoring on problem based on different criteria

Problem	Ranking of criteria				Final score	Ranking
	Peoples opinion	Affected area	Time duration	Loss		
Water logging	10	3	1	2	530	1
River Erosion	8	1	3	1	420	3
Salinity intrusion	9	2	3	3	510	2
Flood	5	3	1	2	330	5
Draught	6	2	2	1	350	4

Final Scoring= Peoples opinion×40+ Affected area×30+ Time duration×20+ Loss×10

RESULTS AND DISCUSSIONS

Overall findings from the study have been gathered to identify the core reason why hazard become main concern for Beel Bhaina adjacent living community after TRM. The findings are given below:

- After TRM, River Erosion problem has been introduced. In recent years 61.1 sq. m is being gone to river bed. Mostly these lands come from settlement.
- In Beel area, the elevation has been only emerged the point of river water entrance and its some adjacent areas.
- All the year round the land becomes flooded with saline water through swage gate of Beel Bhaina but after rainfall the Hari river supply fresh water
- The amount of respondent outside the Beel area also affected by River Erosion.
- Water logging and Flood is reduced but salinity, river erosion increased.

- For changing topographical condition and reducing wet land, some place faces drought problem.
- The time duration for Boro rice with water logging is quiet adjusting.
- Water logging problem getting highest response among all kind of hazard not only in public response but also other secondary issues of assessment.

Specific Water Logging Problem Analysis

For high scoring of water logging problem, the analysis has been conducted more precisely than other problems. The reason behind this problem is the low elevation for specific area. For 18 years of siltation in Beel area, there very few areas have been enabled to emerge. In far most the siltation in first 2 years is marvelous but after that the process is slow. The elevation has been only emerged the point of river water entrance and its some adjacent areas. The inside area has been untouched but at some point, the elevation is around 1m. (Data source: Terrain website) After implementation of initial TRM practice, BWDB appointed SWMC (Surface Water Modeling Centre) for monitoring and evaluation of TRM. They worked for 27 months since February 2000 to April 2002. Beel Bhaina has been cut unplanned way as like Beel Dakatia. In November 1997, local people decided to open the Beel Bhaina of the Hari River System and the embankment was cut in two places. One of these cuts was closed towards the end of 1998 but cut again in February 1999. In the process, Beel Bhaina started to function as tidal basin. Both cuts are closed in 2001 (Alam, Undated). During this period about 600-acre land of the Beel area reclaimed from severe water-logging (CEGIS, 2003). After monitoring of 27 months, the SWMC had left the Beel. This long time Beel have not being monitored or maintained the siltation process. So, this cause slows the siltation process. There is another analysis showed the data that the land has been emerged near the river area.

To make the progress speedy there is need systematic management and control of sedimentation. For water logging there is a possible reason found in flow direction map in figure that the flow of water come from upper portion of Beel. This may be caused for Beel Khuksia. Beel Khuksia is still under developed which cause water flow directed to middle space of Beel Bhaina. In river basin one at a time only one Beel should be used as a tidal basin for TRM. (Shampa and Paramanik, 2012) this will help to maintain the biodiversity of other Beel. But in this case Beel Bhaina and Beel Khuksia both are being used as TRM practice which may cause these phenomena.

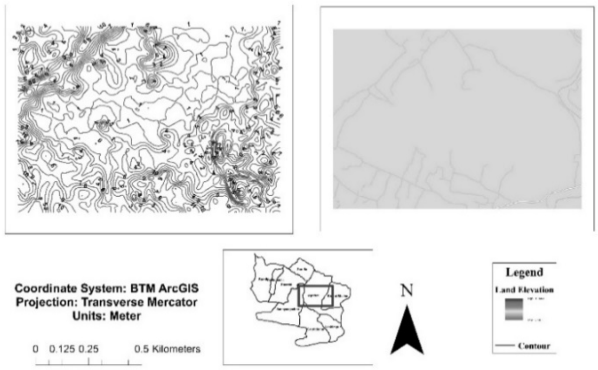

Fig. 4: Land elevation with contour line and affected study area

Before and After TRM Overall Problem of Water Logging

From different timeline, water logging affected in different land use in differently. 48.1% agriculture present in Beel Bhaina in between 2 villages. But with time the amount is changing. It is decreasing around 3.5% and this also cause reduction in settlement. This data provides the understanding that water logging problem reduce with time. Within available area of use, this problem is losing its tale. Deposition in the basin is high at close to the opening and less at the furthest end of the basin, which varies from few 10 of cm to more than 2 m at Beel Bhaina (Ullah and Rahman, 2002). After closing of Beel Bhaina tidal basin, the Beel has been brought under agriculture practices. However, the uneven sedimentation is causing drainage congestion in some parts of the Beel (Paul and Nath, 2011). Tidal basins to control riverbed sedimentation are not only used in tidal rivers in the southwest delta of Bangladesh. It is also found similar water management practices in the Netherlands, the United States and Belgium in tidal rivers. In some cases, it is also found an economically and environmentally sustainable alternative to dredging or pollution control (Die, 2013). Some Study provide positive response on this matter. Uttaran and communities involved in the project worked with the institute of water modelling to conduct a detailed technical study and monitoring survey on one of the TRM sites, Bhaina Beel, and found that TRM had helped increase river flow and depth and had reduced the incidence of water logging (Oxfam, 2011).

Table 7: Overall Problem of Water Logging Before and After Tidal River Management

Type of land	Overall problem before water logging		Total	Overall problem after water logging		Total
	Yes	No		Yes	No	
Agriculture/ shrimp	48.1	4.7	52.8	44.58	8.44	53.02
Settlement	40	1.2	41.2	38.55	2.41	40.96
Commercial	6	0	6	4.82	1.2	6.02
Total			100			100

CONCLUSIONS

The research was conducted to identify the impact on Beel Bhaina after implementation of TRM. The assessment of People's opinions and analyzing the claim of arising different kind of hazard. In the study area it is important to find out the most effected hazard which could possibly affected the people. Not only the data was analyzing in the base of people's opinion but also data was justifying with other factors. So, the result came up as water logging and it was proved that water logging I the main reason which imposed the hazardous situation. TRM have long term affect in human life as well as climate change. It catalyst the hazard very gradually.

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USING CONTINGENT VALUATION METHOD TO DETERMINE ECONOMIC VALUE OF PADMA RIVER WETLAND IN RAJSHAHI DISTRICT, BANGLADESH

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ABSTRACT
Wetland is a valuable ecosystem for the sustainable environment both for present and future generations. Wetlands are used for multiple purposes, and it has significant role in the livelihood of the local people in riverine country like Bangladesh. A particular wetland was selected named “Padma River” in Rajshahi district of the northern part of Bangladesh for the purpose of estimating the economic value. Wetlands possess a high economic value. The economic value of wetland includes both use and non-use values. Wetland use values are associated with a diverse and complex array of direct and indirect uses. Wetland direct use values/benefits are those which can be consumed directly from wetland such as food, water supply, recreation, transport, timber etc. whereas indirect uses benefited people indirectly and arises from the functions occurring within the ecosystem, such as water quality, flood control, ground water recharge and other such functions. Therefore, the objectives of the present study were to estimate the total economic value of non-use attributes of the River at the present with the help of Contingent Valuation Method (CVM). CVM is one of the important methods in environmental valuation, which gives empirical estimates of both use and non-use values of environmental resources. Data collected from questionnaire survey, key informant interview and focus group discussion. The results of the study show that the proposed annual economic value is greater than the present annual economic value. This study would guide the government in identifying the sectoral priorities regarding conservation of wetland and to formulate strategies for the short term as well as the long term effective management of wetland of Rajshahi Division.

Keywords: Wetlands; Economic Valuation; Non-use values; Contingent valuation method (CVM); Rajshahi District

INTRODUCTION

Wetlands are surrounded by the Earth's most productive ecosystems. These Wetlands are described both as "the kidneys of the landscape". Because of the functions wetlands perform in the hydrological and chemical cycles, and as "biological supermarkets" because of the widespread food webs and amusing biodiversity wetlands sustenance. (Barbier et al., 1997). The nation's wetlands play a dynamic character in our social and economic well-being. Wetlands provide services such as amended water quality, groundwater restoring, shoreline securing, natural flood control, and support a diverse variety of fish, wildlife, and plants (Lupi et al., 1991).

Bangladesh has the vast area of wetlands including rivers and streams, freshwater lakes and marshes, haors, baors, beels, water storage reservoirs, fish ponds and estuarine systems with extensive mangrove swamps. The haors, baors, beels, and jheels are of fluvial origin and are commonly identified as freshwater wetlands. (Ghosh, 2010). Among the wetlands of Bangladesh, Padma River is an important wetland in Rajshahi City Corporation area under Rajshahi District which now experiences a threat of.

resource degradation. Our country doesn't pay much consideration for the economic value of the use and non-use attributes of this wetland in present days. But an understanding of such values is vital for the better management of the wetland resources. Most of the studies about wetland valuation focused on total economic valuation which describes suitable management system of various wetlands for present and in near future (Lupi et al., 1991). The study focused on the estimation of the economic value of Padma River with the help of Contingent Valuation Method (CVM). Therefore, the total economic value of Padma River wetland has been estimated by taking into account the non-use attributes of the River which help to formulate resource management strategies in future for better conservation of this valuable wetlands.

METHODOLOGY

Rajshahi town (City Corporation) stands on the bank of the river Padma. The area of the Rajshahi City Corporation is 96.72 sq. km.The total area of the rivers and rivulets within the boundary of the district is about 96.80 sq km. which is about 03.99 % of total area of the district (BBS, 2013).The Padma River [Fig1] is located between latitude 24º20' and 24º22' N and longitude 88º32' and 88º34' E (Google earth, 2018).

The CVM is a mostly applied method in estimating the non-use values of a wetland for valuing changes in the provision of nonmarketable goods and services. The CVM is a survey-based methodology which relies on obtaining monetary estimates for the economic value of a specified change in the provision of the environmental good of interest, which typically is not traded in the conventional markets. Monetary estimates are obtained either as individual's Willingness to Pay (WTP) or Willingness to Accept (WTA). WTP measures the amount of income a person is willing to contribute in exchange for an improved state of wetland goods and services (Marta-Pedroso et al., 2007).

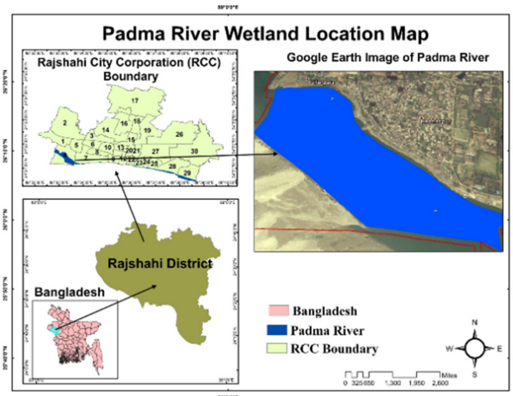

Fig.1: Location of Padma River

To evaluate the economic value of Padma River situated in RCC area the Data was collected from questionnaire survey, key informant interview and focus group discussion. Disproportionate stratified systematic random sampling of 200 households was conducted in the CV survey. The size of sample is considered to be reliable because based on a simple statistical tolerance formula, sample size between 200 and 2500 are probably appropriate (Mitchell and Carson, 1989). Rajshahi City corporation (RCC) area consists of 4 thana which includes Rajpara, Matihar, Shah Mukdum and Boalia Thana. 90 samples were selected from Boalia Thana, 58 samples were selected from Rajpara Thana, 32 samples were selected from Matihar Thana and 20 samples were selected from Shah Mukdum thana. Samples size distributions varies according to the number of population present in the Thana. Key Informant Interview (KII) was conducted with boatmen, Businessmen, Students, Wetland experts, livestock experts, agriculture officials and Planners. Focus Group Discussion (FGD). Three FGDs were conducted with each group consisting of adult men and women (age belongs to 18 or above) considering gender issues. Each FGD took time about one hour to two hours. Each FGD consisted of at least 6-8 persons with homogeneous mixture. During FGDs, people of the Padma River and RCC area chosen the payment vehicle for the CV survey and identified the non-use attributes of Padma River. Different statistical analyses have been performed to analyze the gathered quantitative data.The WTP responses have been analyzed using two statistical models, such as logit model and multiple regression model. This models have been analyzed using SPSS software .The logistic probability or logit model has been used to separate those respondents who are willing to pay from those who are not (Langford and Bateman, 1993). Subsequently, the multiple regression model indicates the relationship between the explanatory variables and the stated amount of money for those who were willing to pay. Mathematically, the WTP can be written in the form of Eq. (1):

$$WTP = f(R_s, R_a, Y_i, R_e, DIST, USR) \quad (1)$$

where, WTP refers to the amount of money a household is willing to pay monthly for the wetland resource management, R_s denotes respondent's sex, R_a denotes respondent's age, Y_i denotes household income, R_e stands for individual's education level, DIST denotes distance of the respondent's residence from the Padma River and USR denotes variable for non-user individuals. The logit model for the present study written in the form of Eq. (2):

$$L_i = \ln\frac{Pi}{1-Pi} = X_{i1} + X_{i2} \quad (2)$$

Where, L_i which is called Logit, is the log of the odd ratios. P_i is a probability that has a probability of 1, X_{i1} is a set of explanatory variables while and X_{i2} are an intercept and a set of coefficients to be estimated corresponding to a logistic distribution.

RESULTS AND DISCUSSION

Economic Value of Padma River at Present state for non-Use attributes

For establishment of Economic Value of Padma River at Present state for non-Use attributes characteristics of survey respondents need to be demonstrate .During the CV survey, different socio-economic characteristics of the respondents were asked and recorded. The responses of the respondents have been analyzed using frequency table. The sample consisted of 68.2% men and 31.2% women. The distribution of age of the respondents [Fig.2] was heavily skewed towards the younger generation with the majority of people being between 18 and 30 years old (37%) and this was mainly due to the fact that young people were willing to participate more in the CV survey. The majority of the respondents have attended up to or continue Bachelor degree of education i.e. almost 37% [Fig.3], while the majority of the survey Participants in the study area were student (Fig.3). In addition, the majority of income group for the survey households was Tk. 10001-20000 [Fig.4]. 45% and 40% people households were 1-10 km and more than 10km from Padma River respectively and 89% people visit Padma river area for different activities.

The present study has adopted the ranking method to estimate the present non-use value of Padma River. In estimating the present total non-use value of Padma River, protest responses are eliminated from the data collected to estimate willingness to pay (Mitchell and Carson, 1989).The result obtained from the CV survey shows that all of the respondents think that the wetland is in 'bad' state in terms of its availability of fauna and flora species. So, from the table it is found that the present non-use value of Padma River is 7% of the total non-use value estimated for the proposed state of the Padma River (Table 1). It is found that the total annual average non-use value of Padma River for the proposed state is Tk. 1.06 million. Therefore, the total annual average non-use value of the Padma River for the present state is Tk. 0.0742 million.

Economic Value of Padma River at Proposed state for non-Use attributes:

The Contingent Valuation Method (CVM) of estimating values for non-market goods in terms of Willingness to Pay (WTP) has gained widespread acceptance in the world. The results of the logit model are shown in Table 2. Gender is found to be statistically significant at the 1% level and the sign is positive. Therefore, the finding suggests that males are 5.321 times more likely to say 'yes' to a WTP question than females. This indicates that males are more aware of the environment. In case of education, Income level and user the result of the logit model indicates that the higher the education, Income level and User the higher the probability of WTP 'yes' saying. For the variable distance, it is found that the longer the distance of the residence from Padma River, the lower the probability of WTP 'yes' saying.. Finally, the result of the logit model shows that almost 76% of the respondents have correctly allocated (i.e., percentage of correctly predicted values) to predict WTP either 'yes' or 'no' in the model which indicates a relatively good fit to the CV data and model (Ghosh, 2010).

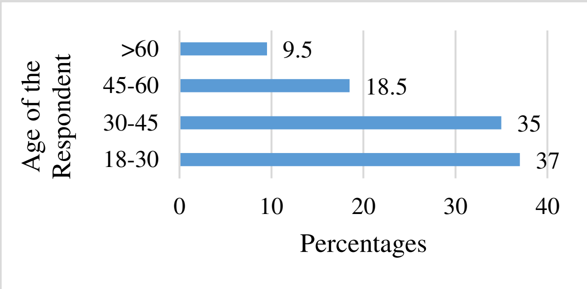

Fig.2: Age group distribution of the respondents

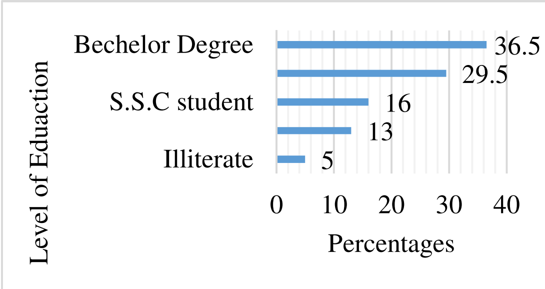

Fig.3: Education status of the respondents

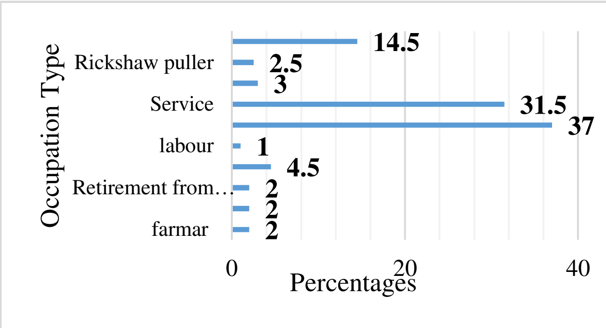

Fig.4: Occupation pattern of the respondents

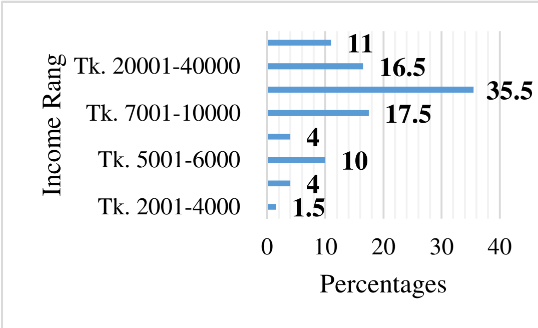

Fig.5: Distribution of household income

Table 6: Ranking of the present state of Padma River

Present environmental state based on non-use value	Score	Present non-use value as a percent of the proposed state non-use value
Very bad	-1	3%
Bad	-2	7%
Neither good nor bad	0	28%
Good	1	42%
Very good	2	20%

The results of the multiple regression model are shown in Table 3. The age of a respondent has a negative influence on the mean amount of money to pay. So, the WTP decreases as age increases. As a result, younger generations are more willing to contribute money than older ones because younger generations are more aware of the environment. The coefficient of education appears to be significant at the 5% level which indicates that the higher educated people are more willing to contribute money compared with the lower educated people. Income level value indicates that WTP increases with the increase in income. So, the people having more money are willing to contribute money more for management of the Padma River resources (Table 3).

Table 2: Results of logit model for non-use values of Padma River

Explanatory variable	Coefficient	Standard error	Odds ratio
Sex	2.102	0.445	4.371
Income	1.536	0.383	2.567
Education	1.672	0.205	1.709
Distance	-0.908	0.221	0.403
User	1.423	0.321	2.841

Note: $R^2 = 0.76$

In the present study, the respective R^2 values for the logit model and the multiple regression model have been obtained. But the R^2 value of the multiple regression model (57%) is lower than the logit model

(76%). This is due to the fact that the increment of the values of WTP was very small which makes it difficult for a model to precisely determine each individual figure.

Table 7: Results of multiple regression model for non-use values in Padma River

Explanatory variable	Coefficient	Standard error	t-statistic
Age	-1.672	0.781	-1.321*
Education	2.601	0.973	2.170*
Income	2.120	0.503	2.902*
Distance	-1.987	0.623	-1.523*

Note: $R^2 = 0.57$; *Significant at the 5% level

Table 8 Non-use component values of Padma River

Non-use component	WTP (Tk./month)		
	Min	Max	Avg
Fauna and flora resources do not weaken and Padma river simply continue to exists (Existence value)	2.5	15.50	3.12
The wetland exists so that its value can be enjoyed in future (Option value)	1.5	33.50	4.47
The wetland exists so that future generations can enjoy the value and can be used for research, education etc. (Bequest value)	3.5	63.50	7.10
Total non-use value (Tk./month)	7.5	112.50	14.69

In the present study, the total non-use values divided into three component values which are shown in Table 4. From the table, it is found that the bequest value is higher than the option value which is followed by the existence value. For Padma River, wildlife value is not the largest of all non-use values or as a proportion of the total non-use value. This difference in the present study is due to the fact that the majority of the people in the study area are not aware of the environment.

Table 9 Estimated annual average non-use value of Padma River

Category of characteristic	Value
Total number of households in Rajshahi City Corporation at present	99549
Household's average WTP value per month (Tk)	11.67
Proportion of households willing to contribute money (percent)	73.57
Annual average value of respondent's money contribution (million taka)	854689.7858 Lakh (0.85 million)
Household's average WTP value per month for willingness to contribute time (Tk)	35.96
Proportion of households willing to contribute time (percent)	17.36
Annual average monetary value of respondent's time contribution (million taka)	207380.4768 Lakh (0.21 million)
Total annual average value of the non-use attributes of the Padma River (million Tk)	1062070.263 Lakh (1.06 million)

The respondent's contribution of time is monetized to estimate total WTP for the wetland resource management. The total time that the respondents wanted to contribute is 4541 minutes and people contribute more time for recreational activities. The monthly monetary value of time contribution is shown in Table 5 and the respondent's average monetary value of willingness to contribute time is estimated to be Tk. 35.96/month/household. The annual average total economic value of the non-use attributes of Padma River for the proposed state is estimated to be Tk. 1.06 million and shown in Table 4. From above analysis it is found that the non-use value of Padma River is not very high at present state (0.0742 million). This is due to the fact that non-use value of the River is not confined only in the locality and people of the area are not aware of the environment. Therefore, the non-use value is an underestimated value. The non-use value at the present state of the River is insignificant because the River is in bad condition in terms of its fauna and flora resources.

CONCLUSIONS

The present study focuses the wetland resource management which is damaged day by day.To estimate the economic value of Padma river wetlands, CVM has been adopted. The CVM method has been applied to estimate the non-use value of Padma River. Based on the developed strategies, the non-use value of Padma River at the proposed state has been estimated. The results of the CV estimates have shown that the annual average non-use value of the Padma River for the present state is about Tk. 0.0742 million, while the annual average value for the proposed state is about Tk. 1.06 million which is much greater than the present non-use value of the Padma River. This non-market benefit of Padma River at the proposed state indicates that there is a public fund (i.e., peoples' WTP) towards a better wetland resource management and it is possible to implement the management strategies in the area.Results of the study also suggest that the estimated economic value in the present study is only an approximation and not the true value. The value of the river is underestimated because value of all functions of the river was not possible to estimate. So, if the developed strategies are adopted for Padma River management, a better outcome will result from the river in terms of economic and environmental perspectives which will promote Padma River management towards sustainable resources management.

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IMPACTS OF CLIMATE CHANGE ON WATER QUALITY IN COASTAL PARTS OF KHULNA, BANGLADESH

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ABSTARCT

Climate change represents a genuine risk to monetary and social existence of the general population in Bangladesh. Being closer to the ocean, environmental change affect is particular for this nation. The seaside biological system is supporting over 15% of the aggregate populace of the nation, is under differing degrees of ecological dangers because of anthropogenic and environmental change impacts. Water quality is the basic ecological determinant that impacts the farming creation and in this manner, the economy that exclusively relies upon its agrarian preparations. This research article tends to explore the environmental characteristics like groundwater quality, sanitation in coastal area of Khulna. Primarily it attempts to depict the impact of climate change on water quality and socioeconomic effect from that. This study collected data by reviewing diversified secondary sources, reports, research papers and newspapers. The findings of the study clearly portrays the critical environmental situations, its driving factors and underlying pressure in coastal region of Khulna, Bangladesh. It also shows impacts of climate change on water quality, saline intrusion and its effect on local lifestyle, sanitation and health of the respected area.

Keyword: Climate Change; Coastal Region; Water Quality.

INTRODUCTION

It is estimated that approximately one-third of the world's population use groundwater for drinking (Nickson et al. 2005). Khulna, the south western coastal part of Bangladesh is experiencing the effect of climate change especially on water. TDS and TH is high in the groundwater thereby, causing the groundwater to be unsuitable for drinking (Bahar, 2010). The surface water salinity increases with time in a year from January to May (Rahman, 2000). In the fourth assessment report of Intergovernmental Panel on Climate Change (IPCC) and Stern Review it is concluded that the impacts of climate change on humanity will be felt 'mainly through water' (DoE, 2007; GoB, 2008). There are undoubtedly clear links between access to safe, reliable water sources and human health which could be exacerbated by greater climate variability (Hunter et al., 2007). According to the Intergovernmental Panel on Climate Change (IPCC), groundwater, crop soils, and many rivers are likely to become increasingly saline from higher tidal waves and storm surges, as a result of climate change impacts (Parry, 2007). Hence, this paper aims about studying about the water quality and impact of climate change on it.

STUDY AREA AND METHODOLOGY

This paper mainly discusses about the environmental situation in respect of water and impact on its quality and society. It selected coastal town Khulna, Bangladesh as study area. To achieve its objective it reviews various multidisciplinary article, research papers, national and international reports. After a systematic review of significant amount of literature it illustrates its objective with the help of other document, report etc.

ENVIRONMENTAL CHARACTERISTICS (situation, driving factors, underlying pressure)

Khulna district is in the southwest coastal region of Bangladesh where saline water intrusion is the most severe (Karim *et al*., 1990). The use of groundwater as sole source of irrigation remains a risky venture, owing to the possible intrusion of saline water from the river into the coastal aquifers if the water level of the aquifers is lowered because of excessive withdrawal of water for irrigation (Mondal, 2006). The shallow groundwater quality of Khulna City Corporation of Bangladesh was highly associated with high levels of salinity and iron problem, and the problem aggravates especially in dry season (Adhikary, 2012). The total area under irrigation in Bangladesh is 5,049,785 ha and 78.9% of this area is covered by groundwater sources including 3,197,184 ha with 1,304,973 shallow tube-wells and 785,680 ha with 31,302 deep tube-wells (DPHE and JICA, 2010). The groundwater is dominantly of Na–Cl type brackish water (Halim *et al*., 2010).

In terms of the tectonic framework of Bangladesh, the study area is within the western part of the Faridpur through of the Bengal Fore deep (Guha, 1975). The mean annual groundwater head fluctuates from 0.57 to 2.43 m, where the maximum and minimum is 3.42 m and 0.60 m respectively. The transmissivity is 3900 m^2/day at Khulna and the storage co-efficient is 2.0×10^{-3} at Khulna. Specific yield (based on lithology) of the aquifer materials vary from 12.50 to 16.60% (Hassan and others 1998). Bahar (2010) studied the pH values and its average value is 7.37, indicating alkaline nature of the samples. The average value of Electrical Conductivity (EC) is 4,144 ls/cm. Total Dissolved Solids (TDS) values ranges from 480 to 4,640 mg/L with an average value of 2,147 mg/L. Cl^- is the most dominant ion, followed by Na, HCO^{3-}, Ca^{2+}, Mg^{2+}, K, SO_4^{2-}, NO_3^- and PO_4^{3-}. The average Cl^- concentration accounts for about 42% of the total major ions. He classified the groundwater depending upon their hydro chemical properties based on their TDS value (Freeze and Cherry, 1979) and found 3.84% of the total sample locations are desirable for drinking, 19.23% can be used for drinking and 46.15% can be used for irrigation purpose. 30.77% of the samples are unfit for any of the purposes. The TH ranges from 69 to 774 mg/L with an average of 335 mg/L. The maximum allowable limit of TH (Total Hardness) for drinking purpose is 500 mg/L and the most desirable limit is 100 mg/L as per the WHO international standard. Another study found TH values of surface water of the study area ranged from 118 mg/L to 624 mg/L with an average value of 287.63 mg/L. The average values of TH in STW water were 198 mg/L, fulfill the requirement of irrigation water quality in case of total hardness by MOEF/DoE/GOB (Shammi et al., 2016).

The minimum surface water head occurs between January and May and during this time the maximum chloride concentration is observed. During the time periods January, March and May, there is a progressive/gradual decline in both ground and surface water head, which influences groundwater quality of both shallow and deep tube wells. (Rahman et al, 2006) found that the Ganges discharge value (1500 m 3/s) required to maintain the Rupsa River salinity (1000 mS/cm, a suitable limit for many industrial and domestic use) is less than the pre-Farakka average minimum flow (2006 m^3/s) (Rahman 1994). It has also been found that salinity increases downstream. (Hassan and others 1998). May is regarded as the most salinity affected months from the data as Kazibaccha River with EC of 26.30±3.35 dS/m and Rupsa River 24.47±2.41 dS/m. It is observed that the cations trend in both surface and groundwater of the study area were following the trends of $Cl^- > SO_4^{2-} > PO_4^{2-}$ It is evident that the cations trend in both surface and groundwater of the study area were Na+ > K+ > Ca2+ > Mg2+. TH values of surface water of the study area ranged from 118 mg/L to 624 mg/L with an average value of 287.63 mg/L (Shammi et al., 2016). In a nutshell, the groundwater in the Khulna City area is hard, fresh to brackish and alkaline in nature. Intrusion of seawater and the hydro geochemical processes causes the brackish nature in most of the groundwater.

IMPACT ON WATER QUALITY AND SOCIAL LIFESTYLE

Aquifers in the coastal area are generally fragile and in most of the regions, the shallow aquifers are easily depleted due to over exploitation of groundwater (Chidambaram et al. 2008). For encroaching sea towards land during rainy seasons, and saline water finding its way through tidal channels during summer seasons, the quality of shallow and deep ground water becomes brackish (Kumar 2001). Added up problems such as urbanization, industrialization, unscientific landuse, lack of awareness of people and saline intrusion all makes the quality of groundwater in coastal area worsen (Laluraj, 2005).

Some anthropogenic reasons are also making impact in this regard. The massive withdrawal of dry season Ganges outflow has already had a serious impact on water quality, agriculture, fishery, forestry, industry and navigation over the last two decades (Hassan and Islam 1997). The average lowest discharge between the years 1988 and 1995 was 593 m^3/s, which is about 73% less than that before the Ganges water diversion, Hossain (1987). Consequentially, the low discharge level, the seawater tends to intrude upstream fresh water. Fresh water is the only agent that can move this saline water back out of the estuary (Hannan 1981). The Padma flows at less than a quarter of its capacity during the dry season (October–April), and water flow in the downstream network of rivers, which often stops altogether, is insufficient to wash tidal water back out to sea (Mirza and Sarker 2004).

About 5 million people in the southwestern coastal region suffer from drinking water problems (Uttaran 2004). As a result, individuals drink pond water, which is often microbially unsafe (Frisnie, 2002) and heavily contaminated with fecal coliforms and other pathogenic bacteria (Islam et al. 1994, 1995; Alam et al. 2006). Thus, the use of pond water for drinking purposes may threaten public health. Howard et al. (2006). However, Islam et al. (1994) found that if a pond is protected from human use, has a high bank and no drain, it can provide water with a FC count ,1 cfu/100 ml year round compliant with WHO guidelines (Helmer et al, 1997). E. coli concentrations for ponds were very high when compared with other options. The pond water had the widest interquartile range of E. coli concentrations. The minimum concentrations of E. coli and FC for RWHSs (Rain Water Harvesting System) and CRWHSs (Community Rain Water Harvesting System) during both seasons were less than 1 cfu/100 ml, which indicates that harvested rainwater can ensure good microbial quality.

The saline front along the 720-km coastline has encroached > 100 km inland into domestic ponds, groundwater supplies, and agricultural land through various estuaries and water inlets, which are interlinked with the major rivers (Allison et al. 2003; Rahman and Bhattacharya 2006). Since 1948, river salinity in the southern districts of Patuakhali, Pirojpur, Barguna, Satkhira, Bagerhat, and Khulna has risen by 45% (Integrated Regional Information Networks 2007). Domestic ponds are primarily rain fed but can also mix with saline water from rivers, soil runoff, and shallow groundwater (Rahman and Ravenscroft 2003).

Water quality in this area has a deleterious effect on health issue. The most common category of water-borne diseases is diarrhea (Copeland et al. 2009). The records of the Dacope and Mongla Upazila Health complex showed higher diarrhea complaints during the wet season (June to October) (Islam et al, 2011). In a survey conducted in 2008, higher rates of (pre)eclampsia and gestational hypertension in pregnant women living in the southwestern coast of Bangladesh, compared with noncoastal pregnant women, were hypothesized to be caused by saline contamination of drinking water. (Khan et al. 2008). 47% of respondents felt that their drinking water supply system somehow polluted during the monsoon. Nearly all households (95%) have reported suffering from water borne disease due to bacteriological contamination. This scarcity was severe during the months from December-August. PSF (Pond Sand Filter) are also not satisfactory as those are often polluted with cow dunk, human sludge and other things. The water storage system needs attention. Poor people have very few or worse options available to store water. (Islam, 2017).

CONCLUSION

Climate change is likely to have a significant impact on water and sanitation, and the greatest change is predicted in coastal aquifers, where it is very likely there will be significant incursion of salt water directly associated within sea-level rise (Godfrey et al., 2005). Bangladesh is often cited as one of the most vulnerable countries to climate change in the world. The vulnerability to climate change is high due to a number of hydro-geological and socio-economic factors. The country often experiences natural disasters as an effect of climate change, particularly in coastal areas. Crop agriculture is often constrained by different hazards and disasters such as floods, droughts, soil and water salinity, cyclones and storm surges. Salinity is a great constraint to growing crops, especially in Robi season (dry months) when water and soil salinity arises and reaches to the peak in March-April before monsoon starts. The distance of the salinity intrusion inland, as well as the extent of salinity in the coastal areas, is expected to increase with rising sea levels (MOEF 2006). Estimates of the amount of sea-level rise over the coming century range from 0.2 to 0.6 m (Parry et al. 2007). Salinity causes unfavorable environment and hydrological situation that restrict the normal crop growth. The factors which contribute significantly to the development of saline soil are tidal flooding during wet season (June-October), direct inundation by saline water, and upward or lateral movement of saline ground water during dry season (November-May). The climate change impact is a negative circumstances especially for people of the coastal area. It is high time we all should come forward to take necessary adoptive measures to combat it for our own existence.

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A PROPOSAL FOR CONCRETE STRUCTURES' ENVIRONMENTAL EXPOSURE CLASSIFICATIONS IN BNBC DRAFT

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ABSTRACT

Sustainability of concrete construction relies on long-term durability and prolonged service life of the structures. Majority of international codes on structural concretes has specified the factors affecting durability into four parameters including i) minimum cement content, ii) maximum free water-binder ratio, iii) minimum concrete grade and iv) cover to reinforcement. These parameters depend on the environmental conditions to which the structure is subjected during its service life. The draft Bangladesh National Building Code (BNBC, 2015) specifies five exposure classifications viz. mild, moderate, severe, very severe and extreme and the limiting values of concrete properties are defined for those. However, the draft code has not been adequately addressed guidelines against significant deterioration mechanisms such as corrosion due to carbonation and chloride attack, sulphate and chemical attack. Given the importance of weathering conditions of concrete structures it is important to provide detail classifications providing the exposure conditions to address appropriate deterioration mechanism. This paper reviewed relevant international codes and researches to propose new inclusion of exposure classes in the draft BNBC based on severity of environmental conditions and degradation mechanisms.

Keywords: Durability requirement; exposure classification; carbonation; chloride induced corrosion.

INTRODUCTION

Concrete is the most widely used building material. Reinforced concrete has the potential to be durable and capable of withstanding in a variety of adverse environmental conditions. Although there is abundance of knowledge and equipment for quality concrete construction, in recent years many concrete structures have faced premature deterioration leading to early rehabilitation or reconstruction at enormous expenses (Gjørv, 2014). With the upsurge in infrastructure growth and exigencies of residential accommodation, the premature deterioration should be dealt effectively. Sustainability is another important issue for concrete industry in addition to durability of concrete structures. Since concrete consumes no renewable source of aggregates and large amount of carbon dioxide is emitted for cement production, sustainability has to be considered seriously. Ensuring durable concrete could certainly be a solution to this predicament (ACI Committee 318, 2014; EN 206: 2016; CSA, 2014; Standard Australia, 2014).

Common durability issues including corrosion of reinforcement due to carbonation and chloride attack, sulphate attack, alkali-silica reaction and freezing and thawing, could act combined or independently (PCA, 2002). Durability of concrete structures could be achieved through proper mix design, compaction and curing, adequate cover and concrete strength by forestalling severity of exposure. The draft BNBC (2015) defined exposure conditions into five categories viz. Mild, Moderate, Severe, Very Severe and Extreme. Limiting values of key parameters including minimum compressive strength, maximum water cement ratio, minimum cement content and nominal cover have also been proposed for each classification. Concrete fulfilling this criteria are considered to be durable. The shortcomings of the general characterisation of exposure conditions have been expanded in various countries or regions and new sets of classifications for exposure have been introduced (BIS, 2000; Haque *et al.*, 2005; Kulkarni, 2009; Ramalingam and Santhanam, 2012; ACI Committee 318, 2014; CSA, 2014;Standard Australia, 2014; EN 206:2016).This research aims to compare the draft BNBC exposure classifications with those and suggests rational exposure conditions against deterioration mechanisms such as carbonation or chloride induced corrosion and chemical attacks.

EXPOSURE CLASSES INFINAL DRAFT OF BNBC (2015)

The Bangladesh National Building Code was first published by the Housing and Building Research Institute (HBRI) under the Ministry of Housing and Public Works in 1993 and then in 2015 the final draft of its first revision has been published. In this draft the guideline for durability has been elaborated and acceptance criteria for concrete have been reviewed. Various concrete key parameters for different environmental exposure conditions are defined in the draft BNBC (2015). However, the simple form of exposure classifications (Mild, Moderate, Severe, Very Severe and Extreme) given in the Article 8.1.7 (Table 6.8.3) appears to be insufficient and needed more explanation compared to other international codes and practices. Degradation mechanisms, provisions for identifying coastal zone, tidal zone, should be considered in the classifications. To align the exposure classifications of BNBC in line with the existing international codes, adjustment to the existing exposure classifications has therefore, become an inevitability. In the next section, the existing international exposure classifications are discussed.

DURABILITY CENTRIC PROVISIONS IN MAJOR INTERNATIONAL CODES

1. American Standard (ACI 318:2014)

The American Concrete Institute's (ACI's) building code requirement for structural concrete, known as ACI 318 was last published in 2014 (ACI Committee 318, 2014). This standard includes an improved definition of exposure classes based on the anticipated severity of exposure. Exposure classes are divided into four classes viz. (i) Class 'F' for concrete exposed to freezing and thawing; (ii) Class 'S' for concrete exposed to sulphates; (iii) Class 'C' for concrete subjected to corrosion; and (iv) Class 'W' for concrete requiring low permeability. Based on the degree of contact with moisture, chlorides, sulphates, etc. these classifications again sub-classed. In addition, for each category a "not applicable" class is provided for the design engineer to indicate that the exposure category does not apply to a structural member. Concrete properties such as maximum water cementitious ratio, minimum compressive strengths and certain additional requirements are specified for each of the sub-classes. The designer needs to choose related exposure for each structural component while designing and select the one which needs greatest resistance with respect to lowest w/c ratio, minimum concrete strength and any other requirements if necessary. This indicates that different components in structures should be designed for different exposure conditions.

2. Canadian Standard (CSA A23.1:2014)

The Canadian Standards Association's (CSA's) main standard on concrete is CSA A23.1-14/A23.2-14 (CSA, 2014) of which latest version included five major classes of exposure viz.(i) Class C for concrete exposed to chloride exposure; (ii) Class F for concrete exposed to freezing and thawing without chlorides; (iii) Class N for concrete exposed to neither chlorides nor freezing and thawing; (iv) Class A for concrete exposed to severe manure and/or silage gases and liquids; and (v) Class S for concrete subjected to sulphates exposure. For better understanding these classes are sub-classed and explicated with typical examples. Prescriptive requirements including w/c ratio, minimum compressive strength including the test age, air content, curing regime, limits on cementitious material and maximum chloride ion permeability. Unlike other standard Canadian standard has specified 56-day compressive strength for certain exposure classes in place of the usual 28 day strength. In addition to this standard has specified limits on chloride ion permeability for extreme exposure.

3. European Standard(EN 206:2013+A1:2016)

The European Standard EN 206-1 from European Committee for Standardization (CEN) was last revised in 2016 gives a fundamental method on classifying the exposure conditions based on degradation mechanisms such as carbonation, chloride induced corrosion, chemical attack, freeze thaw etc. In fact, this was one of the first attempts to secede from the previous classifications of exposure conditions. EN 206 defines aggressive environment exposure class such as risk of i)corrosion induced by carbonation (XC), ii) corrosion induced by chlorides other than from sea water (XD), iii) corrosion induced by chlorides from sea water (XS), iv) freeze/thaw attack (XF) and v) chemical attack (XA). The document also provided guidelines for concrete design in these environment such as i) minimum w/c ratio, ii) minimum concrete strength class, iii) minimum cement content and iv) minimum air content.

4. British Standard (BS 8500:2015+A1:2016)

The British Standard BS 8500 (BSI, 2015a; BSI 2015b) is complementary to EN 206 1:2000 with a major distinction on sulphate and other chemical attack. Guidelines for different features such as service life spans explicitly, 50 and 100 years are described with details example of environmental condition of United Kingdom. In addition nominal cover is provided as minimum cover plus and allowance in design for deviation (Δc) to adjust fixing accuracy. The allowable range for surfaces against formwork is 5mm to 15mm. On the other hand a higher allowance (up to 50mm) is required in design for deviation where concrete casting against ground will take place.

5. Australian Standard (AS 3600-2009 SUPP 1:2014)

The Australian Standard AS 3600:2009SUPP 1:2014 (Standards Australia, 2014) categorised exposure environment into five main classes and 17 sub-classes as follows:

i) In contact with ground 4 (A1, A2, U)
ii) In interior environment 2 (A1, B1)
iii) Above ground 6 (A1, A2, B1, B2)
iv) In water 4 (A1, B1, B2, U)
v) Other environment 1(U)

In addition to other, geographical location was used to define exposure classes in this standard. Based on a climatic map of Australia the requirements for concretes were set for tropical, arid and temperate zones. In addition, depending upon distance from the coastline, structures above ground are further sub-divided to three areas including (i) coastal (up to 1 km from coastline);(ii) near-coastal (1 km to 50 km from coast) and (iii) inland (>50 km from coast). The classifications A1, A2, B1, B2 and U characterized degree of severity of exposure. In addition to the characteristic compressive strength of concrete for different exposure conditions, the standard also specifies minimum initial period of continuous curing and the average compressive strength requirement at the completion of curing. This standard has defined required cover to reinforcement along with the compressive strength and specified cover thickness for different classes of concrete in cases of (i) standard formwork and compaction and (ii) rigid formwork and intense compaction are used. The minimum strength required for different abrasion-resistance characteristics is also specified here.

6. Indian Standards (IS 456:2000)

The Indian Standard for plain and reinforced concrete, IS 456 was reviewed in the year 2000 accentuated on improving durability of concrete (BIS, 2000).It promoted the use of supplementary cementitious materials namely fly ash, ground granulated blast-furnace slag, silica fume, rice husk ash, etc. in concrete. Kulkarni (2009) has suggested detail exposure classes for Indian conditions to which concrete structures are exposed to such as carbonation, corrosion, sulphates and permeability. Another development was durability provision in the Code of Practice for Concrete Road Bridges (IRC 112, 2011). Four environments related to carbonation and chloride induced corrosion are described here along with concrete parameters including maximum w/c, minimum cement content, minimum concrete grade and cover to reinforcement for a design service life of 100 years. Ramalingam and Santhanam (2012) proposed modified exposure classes based on the exposure environments namely concrete exposed to air borne chloride direct or indirect contact with sea water, concrete exposed to sulphates and concrete exposed to corrosion due to carbonation.

PROPOSED EXPOSURE CLASSES FOR BANGLADESH CONDITIONS

Based on the recent changes adopted in the durability provisions of international standards, present classification of exposure conditions in BNBC seems insufficient and restrictive. Considering the international developments it is necessary to update the exposure classes based on the anticipated severity and deterioration mechanisms during the service life of structures. Bangladesh is a tropical country and the key environmental factors affecting the degradation mechanisms of concrete structures are temperature difference and fluctuations in the moisture, chlorides, sulphates and carbon di oxide. Kulkarni (2009) has suggested different exposure classes for India based on the exposure classes defined by several international standards and the corrosivity map prepared Corrosion Advisory Bureau, Metals Research Committee (Council of Scientific &Industrial Research) Jamshedpur drawn on the basis of data collected over the 5 year period from1963 to 1968 and published in 1970. However, exposure classes proposed by Ramalingam and Santhanam (2012) seems more suitable owing to its similarity with environmental conditions of Bangladesh. In order to classify the exposure classification primary deterioration mechanisms of concrete are considered namely (i) chloride induced corrosion; (ii) carbonation induced corrosion; (iii) sulphates and other chemical attack. Concrete freezing and thawing mechanism is not applicable for Bangladeshi weather and hence might be excluded. The updated exposure classes proposed in this paper is therefore limited to the three deterioration mechanism mentioned above. These exposure classes are suggested based on the international standards and previous researches incorporating with various exposure conditions given by BNBC (2015). For each exposure classification a minimum clear cover was proposed based on guidelines suggested by Ramalingam and Santhanam, (2012), Haque *et al.*, (2005), EN 206:(2016), ACI (2014) and other international codes.

1. Exposure classification for corrosion induced by air borne chloride

The Draft BNBC (2015) does not specify the distance from seawater to be considered as coast. Study by Hossain and Easa (2011) has shown that, high deposition rate of sea salt on concrete structure is significant up to 200 m from sea shore in Chittagong, Bangladesh. Ramalingam and Santhanam(2012) suggested that distance up to 10 km to be treated as coast. Another study by Haque *et al*. (2005) shows that, 100 m from shore line could be treated as the most severe zone.AS 3600 (Standards Australia, 2014) considered inland beyond 50km of coastline and therefore low risk to corrosion induced by air borne chloride. Based on the studies mentioned above and other international codes, the exposure classifications for Bangladesh for corrosion induced by air borne chloride is proposed into four classes shown in Table 1.

Table 1: Classification for corrosion induced by air borne chloride

Distance from coast	**Exposure classification**	**Minimum grade of concrete, N/mm^2**	**Minimum clear cover, mm**
Beyond 50 km (Inland)	CL0	C 25	25
Beyond 10 km to 50 km	CL1	C 30	30
Beyond 200 m to 10 km from coast	CL2	C 40	50
0 m to 200m from coast	CL3	C 45	60

2. Exposure classification for corrosion induced by chloride from sea water

Considering the severity of exposure two classifications are proposed namely W1 and W2 shown in Table 2. In this case category the properties of W1 and W2 aligns with “Moderate” and “Very Severe” category according to the exposure classification given by BNBC (2015). However the minimum clear cover to reinforcement is modified according to classifications given by other standards. According to BNBC (2015) concrete exposed to brackish water, sea water or spray from these sources, the minimum w/c ratio is shall not exceed 0.40 which is considered in this classifications.

3.Exposure classification for corrosion induced by carbonation

Corrosion due to carbonation in concrete can be caused by several factors such as humidity level, wetness of concrete etc. Three classifications are proposed and shown in Table 3. The category C0, C1 and C2 corresponds to the Mild, Moderate and Severe conditions defined by BNBC (2015). Here the clear cover to reinforcement is selected in line with other codes.

Table 2: Exposure classification for corrosion induced by chloride from sea water

Exposure classification	Minimum grade of concrete, N/mm^2	Minimum clear cover, mm	Remarks
W1	C 45	50	Concrete structures completely immersed in sea water
W2	C 50	75	Concrete in spray and tidal zone.

Table 3: Exposure classification for corrosion induced by carbonation

Exposure classification	Minimum grade of concrete, N/mm^2	Minimum clear cover, mm	Remarks
C0	C 25	35	No risk of carbonation. Concrete will remain dry during its service life or concrete permanently submerged in water
C1	C 30	40	Concrete inside buildings with moderate to high humidity and exposed concrete sheltered from rain.
C2	C 35	40	Cyclic wet and dry. Concrete exposed to rain and not sheltered.

4. Exposure classification for concrete exposed to sulphates

Sulphate attack in concrete depends on the concentration of water-soluble SO_4^{2-} in soil and ground water. Based on requirements for concrete exposed to sulphate containing solutions and requirements for various exposure conditions given in BNBC (2015) sulphates are categorised as S0, S1, S2 and S3 shown in Table 4. Among which, S1, S2 and S3 corresponds to “Moderate”, “Severe” and “Very Severe” conditions mentioned in BNBC (2015).

Table 4: Exposure classification for concrete exposed to sulphate

Exposure classification	water-soluble SO_4^{2-}		Min clear cover, mm	Types of Cement	
	in soil (%)	in water, ppm		ASTM C150	ASTM C1157
S0	SO_4^{2-}<.10	SO_4^{2-}<150	30	-	-
S1	0.10<SO_4^{2-}<0.20	150≤SO_4^{2-}<1500	40	II	MS
S2	0.2<SO_4^{2-}<2.0	1500≤SO_4^{2-}≤10000	50	V	HS
S3	SO_4^{2-}>2.0	SO_4^{2-}>10000	50	V + Pozzolan or slag	HS + Pozzolan or slag

CONCLUSION

This study reviewed available major international codes and published research papers on durability of concrete. Based on these a new set of environmental classifications has been proposed to update the exposure conditions drafted in BNBC (2015) in line with the existing international standards to anticipate severity of exposure during the service life of structures. Additionally, this paper has suggested minimum clear cover to reinforcement for proposed exposure conditions. To set a minimum concrete parameters requirement for Bangladesh further study needs to be conducted. The country could be divided into different zones based on climate, severity of exposure and deterioration mechanisms. Suggested classifications need to be validated considering a definite service life of 50 or 100 years with systemic laboratory work and computer programs.

ACKNOWLEDGEMENT
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WATERLOGGING VULNERABILITY ASSESSMENT IN CHITTAGONG CITY

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ABSTRACT

Due to climate change, rainfall increase and thus poses threat to the rain induced stagnant runoff causing water logging problem which recently taken a heavy toll on the export oriented business city of Chittagong, known as the commercial capital of Bangladesh. During every monsoon, about one-third of the port city goes under water while the southern part gets inundated during high tides even with no rainfall. As the city is very important for trade and commerce along with around 350 apparel factories, to overcome the water logging issue as well as to reduce the subsequent losses, detail analysis like land use, climate, topography etc. is essential. This paper aims to find out the overall scenario of water logging in Chittagong city through field survey during March, 2017 to September, 2017 and a questionnaire survey with the support of secondary data source viz. daily newspaper, Chittagong City Corporation (ChCC), Bangladesh Meteorological Department (BMD), Chittagong Development Authority (CDA) due to absence of proper literature and researches. Finally identified 27 most vulnerable and other 24 moderately vulnerable points of the study area based on experiences and secondary information and confirmed by visual. The study also found the depth of the logged water rises 0.2m-2.1m causing suffering 8-15 times per year and remains inundated about 48-72 hours sometimes. The study further emphasises on causes, losses, government steps and measures regarding water logging. The findings of the study help to improve risk mitigation, response system for optimizing the losses due to water logging.

Keywords: ChCC; BMD; CDA; BWDB; Waterlogging

INTRODUCTION

Chittagong city is the second largest city of Bangladesh comprising hills formed during tertiary time. Majority of the people along coastal areas living between 0 to 5 meter elevation from mean sea level (Islam and Raja, 2014).It lies at the coastal area and the most prominent natural hazards are cyclone with storm surge, water logging, landslide, earthquake and flash flood are the dominant ones. But at present water logging and landslides are the most burning issues (Fahim and Sourav, 2014). Due to rapid urbanization along with climate change, Chittagong city dwellers are facing water logging problem in last few years. Naturally hydrological condition of an area comes first as it directly involve in water logging events (Zhang and Pan 2014). The land use patterns of an area have influences over the hydrological condition while the increasing urbanization reduces water body and natural streams. There is an increasing trend observed for land use change due to migrating people from rural parts and this has an advance effect on the hydrological condition of city areas which sooner or later leads to water logging (Mohit et al., 2014).Chittagong District is bounded on the north by Tripura State of India, on the east by Khagrachhari, Rangamati and Bandarban Districts, on the south by Cox's Bazar District and on the west by the Bay of Bengal, Feni and Noakhali Districts. The district lies between 21º54' and 22º59' north latitude and between 91º17' and 92º13' east longitude. The total area of the district is 5282.92 sq. km. (2039.74 sq. miles) of which 1700 sq. km. (456.37 sq. miles) including coastal area (Cencus, 2011; Banglapedia, 2014). The average rainfall of Chittagong is 3378 mm which is quite high than other locations in Bangladesh. Mostly rainfall occurs between May to October. In July, the precipitation reaches its peak, with an average of 743 mm (BMD, 2017). As Chittagong belongs to coastal area and north-south hill range crosses the city area, so the waterlogging the occurrences of water logging is severe than anylocation in Bangladesh. So it would be rational to identify vulnerable locations, causes and losses which can provide supportive information for disaster management. This study examines the existing situation, assessing causes behind the problems, inquiring about the likings and disliking of the stakeholders, and identifying possible solutions.

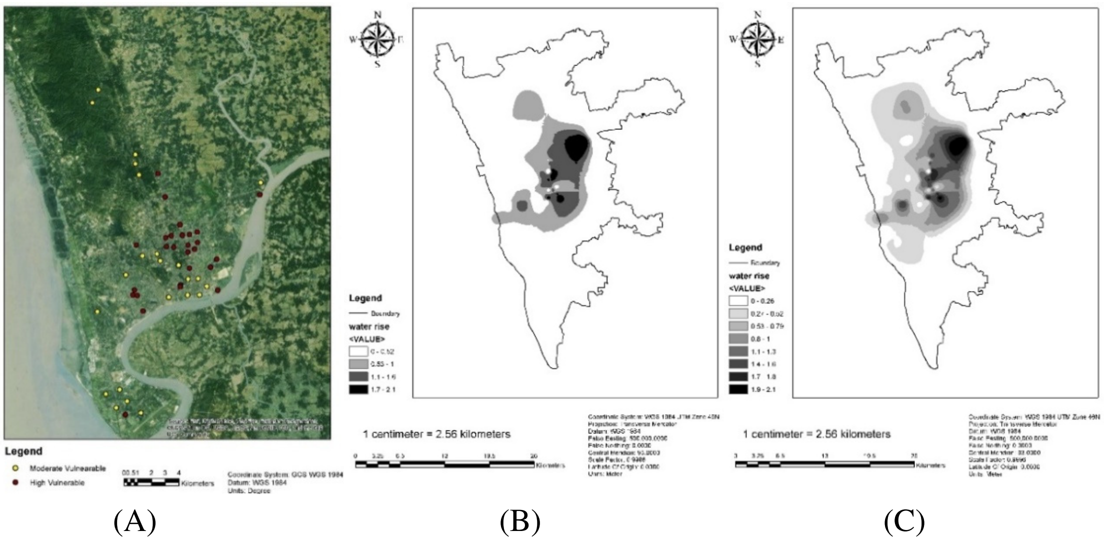
METHODOLOGY

The Chittagong Metropolitan Area (CMA) was selected as the study area and the whole work was conducted in four steps (Reconnaissance survey, Secondary data collection, Field Investigation, Analysis and discussion). Reconnaissance survey was based on physical verification of the study area and literature review. Secondary data was collected mainly from daily newspaper, Chittagong City Corporation Bangladesh Meteorological Department (BMD), Chittagong Development Authority (CDA) which includes information about water bodies, city boundary, drainage pattern, and undertaken projects. Questionnaire survey and visual inspection was carried out in field survey between May to October, 2017 in the water logged area. There were 12 questions in questionnaire survey which includes hydrology, drainage pattern, causes and effects as far water logging is concerned in the study area. Water logging vulnerable locations were identified based on experiences, water rise during heavy rainfall and secondary information then confirmed by visual inspection. After identifying the vulnerable locations, causes and effects of water logging of these locations were discussed. Finally the study was concluded with recommendations on optimization of water logging of the city.

RESULTS AND DISCUSSIONS

Identifications of water logging vulnerable area

After preliminary study and visual inspection, locations are identified and water rise depth during heavy rainfall was recorded. Initially moderate and high vulnerable areas are identified based on water rise depth that shown in Fig 1(A). Detailed analysis was conducted using Arc GIS 10.4 software using collected data by IDW method.



(A) (B) (C)

Fig. 1: Water Logging Vulnerable Areas.
(A) Waterlogging inventory map (B) Direct Vulnerable areas to water logging
(C)Indirect Vulnerable areas to water logging

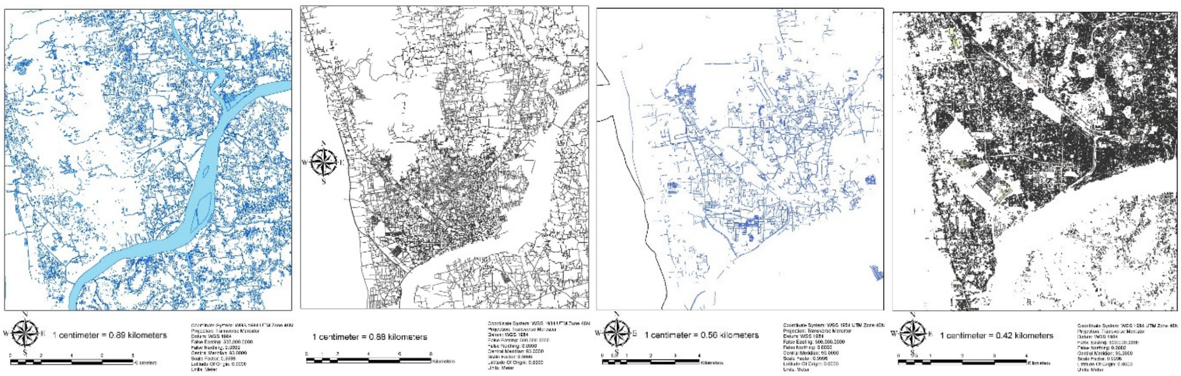
It shows that water logged areas are situated in the near middle zone of the study area. Water affected community among Panchlais, Shaloshahor, Muradpur, Chaktai, Agrabad, Halishahar and Pathorghata has gone for more than 4 feet under water during water logging phenomena. Approximately 63 sq. km areas are found indirectly vulnerable due to water logging hazard. About 43% of city's people, 30% of residential structures, 54% roads, 23% educational institutions and more than 3300 structures used for economic activities are vulnerable. After smooth field survey and details analysis the following observations are found:

Table 1: Allocation of waterlogging affected community.

Vulnerability classes	Water Rise Depth(m)	Vulnerable Areas Name
Low	< 0.75	Pahartoli, Dewan bazar, Pathantuli, North Halishahar, West Madardari, East West Madardari, North Potenga, Bayezid, Oxygen, Nazirpala, Reazuddin Bazar.
Moderate	0.75 – 1.25	Panchlais, West Shaloshahor, Shulok Bohor, South Bakalia, North Agrabad, Badurtala, Gosailbhanga, Gate No. 2, Bibirhat, Kathalgang, Kalurghat.
High	1.25 – 2.1	Chadgaon, Chawkbazar, Pathorghata, Mohora, East Shalosahor, West Bahlia, Pathantuli, Firingi Bazar, Boxir Hat, Potenga, Halishahar, Chaktai, Kapashgola, Muradpur, Nasirabad, Prabartak , Bahadderhat.

Causes of Water Logging

Water logging is caused due to filling of canals with garbage, earth sedimentation and encroachment deterring the excess flow of water during monsoon. About 800,000 garbage bins were setup across the city (Chowdhury, 2017). But due to lack of proper attention from the authorities concerned and irregular dredging, water is overflowing with garbage dumped into it. "Storm Drainage and Flood Control Master Plan and Feasibility Report for Chittagong" is the master plant which identified 34 canals (JR shell, a USA based engineering firm, 1969). Chittagong city saw at least 12 canals vanish in the last 48 years, during which time the waterlogging problem accelerated. A mere 22 canals were found to be emptying into the Karnaphuli River and there was no trace of 12 canals in the premier port city where 8 of the 22 existing canals are also dying (Chowdhury, 2017). In recent years, major canals lost 42% carrying capacity due to siltation, with 87% of the existing silt traps being dysfunctional (Hussain, 2017).



(A) (B) (C) (D)

Fig. 2: Attribute maps of the water logged area. (A) Water Bodies (B) Road pattern (B) Drainage pattern (D) Existing Building (Prepared from collected data of CDA and ChCC using ArcGIS 10.4)

Over 14,000 ponds and other water bodies have disappeared is last 18 years in Chittagong. According to a survey conducted by District Fisheries Department in 1991, the number of water bodies in Chittagong city was 19,250 while the Featured Survey conducted by CDA in 2006-2007 indicated existence of 4,523 water bodies there. About 100 sq. km. water of Chittagong city is pumped out through five canals- Chaktai khal, Mahesh khal, Sub area khal, Monohar khal and Hizra khal. Lack of co-ordination between the concerned authorities is also responsible for water logging. In 1995, CDA prepared a master plan in five phases by 2015. In last 22 years the proposal was not implemented resulting in the complete collapse of the system as was not mentioned which organization will implement this. Under the project, 5.28 lakh m^3 dirt and 4.20 lakh m^3 of sludge would be removed from 36 canals. About 11 km of connecting drains would be built and 107 acres of land would be acquired. Under the project, 5.28 lakh m^3 dirt and 4.20 lakh m^3 of sludge would be removed from 36 canals. About 11 km of connecting drains would be built and 107 acres of land would be acquired (Ahasan, 2017). Existing tertiary drains cover only 45% of the total drainage area (Hussain, 2017). There are also no planned drainage and sewerage system for which rainwater from the Karnaphuli River floods the shops and the houses. Irrespective of the width of the roads, sizes of the drains remains almost similar everywhere. The most common section was found 1' x 1.5' with depth varying 1.5' to 2.5'. Primary, secondary and tertiary Drains found having no fixed dimensions. Due to indiscriminate hill cutting in the city, soil is washed down with rainwater and fills drains and nearby water bodies, causing water stagnation. Used polythene bags also clog the drain and it causes water logging. Change in hydrological cycle i.e. uneven distribution of precipitation in time and space, land use changes viz. decrease of green area, occupying water bodies for land development, absence of proper management and inadequate emergency response system are also some of the reasons of waterlogging (Akter *et al.* , 2017). Sometimes waterlogging caused due to erratic weather pattern, above average rainfall, high tide in adjoining river, unplanned urbanization, flash floods, the rise in seawater level and silt at the bed of canals and sewerage drains. Nearly one third of the city goes underwater every monsoon while its southern part gets inundated during high tide even with no rainfall (Mohit et al., 2014).

Effect of Water Logging

The water congestion damage large quantities of perishable commodities including onion, garlic, rice, lentils, sugar, tea and spices after water flooded into the business shops at the whole sale market. The daily turnover in the wholesale market is about Tk1200-1500cr (Chowdhury, 2017. According to the BICDA, a total of 16 private inland container depots or off-docks are located in the port city with a total capacity of 55,000 TEUs (twenty-foot equivalent units) of containers. As many as 1,000 containers laden with import goods enter the 16 off-docks while a total of 2,000 containers carrying export goods. Each container usually carries goods worth Tk80 lakh to Tk1.20 crore. The water often enters the off-docks disrupting the overall operations. The battered road makes matters worse. The exporters are hard pushed to meet the shipment deadlines as the containers carrying export items cannot leave the off-docks on time. They have had to count massive losses amounting to $10,000-$15,000 for every day that a vessel overstays at the outer anchorage of Chittagong port (Chowdhury, 2017).Transportation system gets collapsed and costs both time and cost. 15 roads -totaling 57km in length have been badly damaged, and that the extent of the loss could shoot up to Tk 500 crore (Chowdhury, 2017). Table 2 shows the result of a survey done through a common questionnaire in the water logged area about the problems caused by water logging.

Table 2: Different types of problems Faced due to water logging.

Problems	Percentage	Problems	Percentage
Water borne diseases	57	Water pollution	72
Damage of trees and vegetation	52	Increase of construction and maintenance cost	34
Damage of roads	85	Damage of household goods	37
Damages of houses	71	Damage of Household goods	51
Death and damage of fisheries	05	Disruption in normal life	93
Increase of insects	43	Disruption in traffic Movement	87

Response to Water Logging

This section addresses the results of Water logging occurrences per year. It shows the percentage for numbers of times of water logging occurrences per year in the water logging prone areas. Here it has observed that the occurrence of 10 times and above water logging is about 63.57% which is highest, 14.23% occurrence for 1 to 3 times, 12.58% occurrence for 4 to 6 times and only 9.62% occurrence for 7 to 9 times water logging.

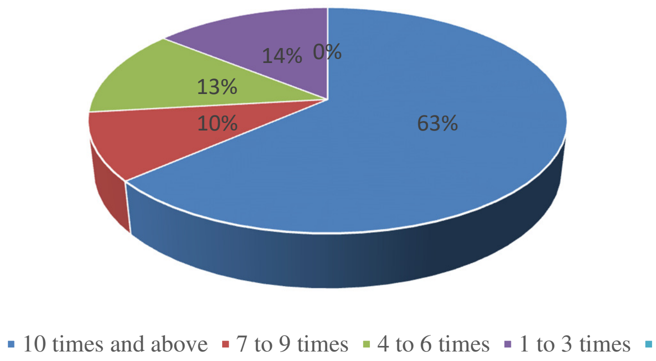
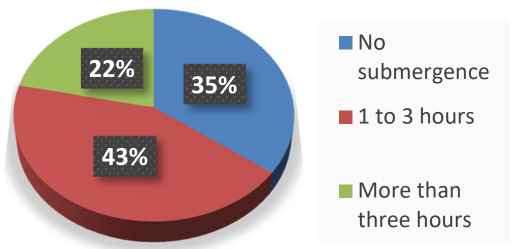


Fig. 3 Water logging occurrences per year.

In this section, the study is based on the efficiency of drain size of the water logging prone area. Here it is observed that, existing drainage system in 37.54% area is sufficient where drainage system in 57.32% area is still insufficient and in about 5.14% area there is no drainage system for removing the excess water.



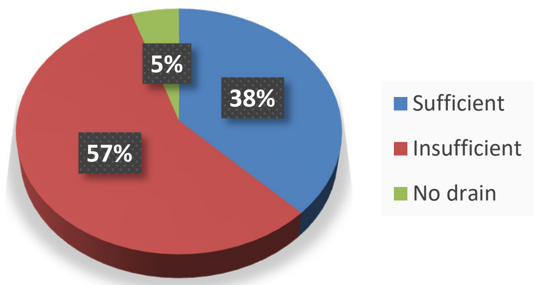


Fig. 4: Duration of Submergence of Roads. Fig. 5: Efficiency of drain size.

Results obtained here based on duration of submergence of roads due to water logging in the water logging prone areas. Here, it is observed that about 43.23% roads remain submerged for 1 to 3 hours, 21.68% road remain submerged for more than three hours and 35.09% roads do not submerge.

CONCLUSIONS

Water-logging is the resultant function of relationships between geological structure, soil types, surface elevation, slope, drainage density, haphazard embankments, and depth of ground water, human activities and so forth, from the spatial as well as environmental perspective. Findings of the study and recommendations to improve the urban water logging are given below.

1. In Chittagong city, Water logging mainly occurs in different places due to absence of adequate gravity drainage provision, heavy rainfall within a short span of time, occupying water bodies for land development, decrease in green area, and absence of proper management and also choked up with solid wastes.
2. Due to induced water logging, 24 moderate and 27 high vulnerable points were identified in the first phase of the study. After analysis using Arc GIS 10.4 with experiences and visual inspection low moderate and high vulnerable areas are identified. Among these areas Chawkbazar, Pathorghata, Mohora, East Shalosahor, Chadgaon, West Baklia, Pathantuli, Firingi Bazar, Boxir

Hat, Potenga, Halishahar, Chaktai, Kapashgola, Muradpur, Nasirabad, Prabartak and Bahadderhat are facing severe logged water depth (1m - 2.1m) along with longer duration (above 7 times with the duration above three hours).

3. Dredging, cleaning and removal of blockage from existing drains and canals on regular basic is required also repair and rehabilitation of existing primary, secondary and territory drains should be done. Sluice gate and silt trap at the mouth of the canals can be set up. Moreover utility services including gas, water and land lines running through drains have to be removed. In the event of installation of underground sewer lines, sewer treatment plant near the mouth of these primary khals, with the aim of discharging treated effluents to the river Kharnaphuli will be required. Site selection and land allocation for the treatment plant will require planning clearances and decisions. 25 percent of the width of the road is to be kept for drainage. Covers drains can be used with the duel function of a drain and a footpath.
4. All illegal structures from the banks of Karnaphuli River should be evicted and restoration of navigability of the Karnaphuliu and it's connecting canals through regular dredging should be executed. Existing water bodies and open spaces should be preserved and tidal regulations with water retention points could be installed.

The findings of the study can be used to prioritize risk investment, measures to strengthen the emergency preparedness and response mechanisms for reducing the losses and damages due to water logging in Chittagong. Finally it can be concluded that if the government and other concerned authorities take necessary steps, vulnerability of water logging hazard can be reduces to an extent tolerable limit.

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EXPLORING THE ASSOCIATION OF SURFACE WATER BODY CHANGE AND RAPID URBANIZATION IN RAJSHAHI CITY CORPORATION (RCC) AREA USING RS AND GIS

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ABSTRACT
Water body extraction is an important task in evaluation of water resources disciplines of developing country especially in Bangladesh. In Rajshahi metropolis, there were 729 ponds and canals in 2002, but the figure had been fallen to 393 in 2013 because of indiscriminate land filling and unplanned urbanization. Therefore, the aim of the study is to explore the association of decadal changing pattern of decreasing surface water body in 30 years (1996, 2006 and 2016) of Rajshahi City Corporation (RCC) area and to identify the persistence where water bodies are filled up because of rapid urbanization activities. Decadal Land Cover and Water Body Maps of the study area have been prepared for 1996, 2006 and 2016 using Landsat satellite images. A change detection technique which gives automatic water body extraction and mapping of the location, scarcity and morphometric of water body has been applied to extract the water body changes by integrating Remote Sensing (RS) and Geographic Information System (GIS) applications. The association has been established by the locations of rapid urbanization areas. The study finds that most of the water bodies are filled up due to rapid urbanization where people used to fill up the surface water bodies for residential and commercial settlements which affects climate change, biological diversity and human wellbeing. The study describe a national problem named urbanization which increases rapidly and damages our biodiversity and climate. The findings will help the concerned authority who can use this information for further planning and strategy making policy about better management of water bodies in future.

Keywords: Extraction; Persistence; Remote Sensing; Land Cover Maps; Morphometry; Urbanization; Strategy Making Policy.

INTRODUCTION
Urbanization now-a-days is occurring very fast and one of the most principle demographic development especially in developing countries. Due to urbanization, environmental sustainability would be wrecked down continuously (Brookfield, 1988). These urban growth causes adverse effect on water land which is not only land but also a worthy resource for any country. Urbanization results declination of water bodies by increasing impervious layer as well as built-up area (Faridatul, 2017). Obtaining Remote Sensing and GIS environment, changes of wetland can be quantified through image classification algorithm (Faisal and Khan, 2017). Remote Sensing (RS) has been used for classifying land cover whereas it covers larger scale and also supervised classification techniques can help to detect the particular land cover like water bodies and built-up areas (Ozesmi, 2002).

Rajshahi is the fourth largest metropolitan city of Bangladesh. Rajshahi City Corporation (RCC) stands on the bank of Padma River covering 96.72 km^2 area. The number of total ponds in the year of 2011 was 373 including 1 deghee (BBS, 2011). The number of water bodies was also decreased from year after year due to urbanization. Most of the wetland area was converted to built-up area which negatively affected the environmental suitability. Many studies used to find and moderate spatial resolution multispectral images from different sensors and to extract land cover information like water bodies (Kafy et al., 2017)). This study aims at an integration of RS imageries and GIS Application for decadal changes of RCC waterbodies and can find the area which is converted from water body to built-up area. It is a modern technology for analyzing land covers and its nature. The study illustrates the extraction of the persistence of water body over time using Remote Sensing (RS) image and Geographic Information System (GIS) applications to understand the decreasing pattern of water body which help to solve complex planning and decision making policies.

METHODOLOGY

Rajshahi is the fourth largest metropolitan city of Bangladesh which lies between 24°07′ to 24°43′ north latitudes and between 88°17′ to 88°58′ east longitudes (BBS, 2011). It was one of the first Municipalities in Bangladesh, established in 1876 and declared as a City Corporation in 1987. The region consists of Barind tract, Diara and Char lands. Rajshahi town (City Corporation) stands on the bank of the river Padma. The area of the Rajshahi City Corporation is 96.72 sq. km (BBS, 2011). The location of RCC area shown in Fig.1.

The land cover maps of RCC were prepared for 1996, 2006, and 2016 using supervised classification technique to identify the decadal land-cover change. Landsat 4–5 thematic mappers images-dated 13 October 1996 and 25 November 2006 and Landsat 8 operational land imager (OLI) images dated 21 November, 2016 were downloaded from the global visualization viewer of the United States Geological Survey (USGS). The Images are collected from late autumn (October and November) since this season is cloud free (Kafy et al., 2017).

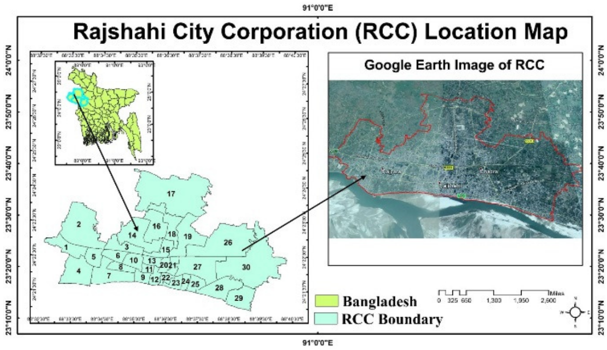

Fig.1: Location map of study area

Images for three different years are collected within one month to avoid the season variation in this area. To cover the whole study area one Landsat scenes path-row 138-43 was required. For preparing decadal land cover maps for RCC area with supervised classification techniques, only visible and near infrared bands of the Landsat scene are considered (Kafy et al., 2017). On the knowledge of local geography and purpose of the study, four broad land cover categories are selected and mapped for the study area: waterbody, buildup area, Agricultural land and Vegetation and bare soil. Each classified map thus evaluated with available field data and Google earth image over randomly selected points for accuracy assessment (Kafy et al., 2017). To identify the location of water body reduction for the purpose of rapid urbanization which is identified as built up area in image classification classes, a post classification change detection might be appropriate for this kind of study. Two decadal change maps are prepared based on the post-classification land cover change between 1996 and 2006 as well as between 2006 and 2016. Since identification of one type of changes which is water body to buildup occurrence will be the aim of this paper, the locations of water body fill up location because of urban area expansion will be estimated using matrix union in ERDAS imagine software which is described with the help of two changes maps.

RESULTS AND DISCUSSIONS

Land use Change assessment

Fig. 2shows the land use images of 1996, 2006 and 2016 of the study area. Changes of urban land use can be easily determined by the image. During the urbanization process of Rajshahi city, water body is reducing day by and replaced by urban area. With the growth of Rajshahi city and increasing population rate, demand for urban area is increasing and as a result, water body is transforming into urban area.

In 1996, total amount of waterbody in Rajshahi was 4.7547 sq.km. Urban area was 8.8542 sq.km. In 2006, a little change over the waterbody would be noticed. Waterbody reduced to 4.4991 sq.km. and turned into urban area, which results increase in urban area from 8.8542 sq.km to 10.2294 sq.km. A significant change occurred in last decade. Population and human settlement forced upon waterbody and reduced it to 2.0151 sq.km. Noticeably, urban area increased 16.6716 sq.km, which is double than the year of 1996.

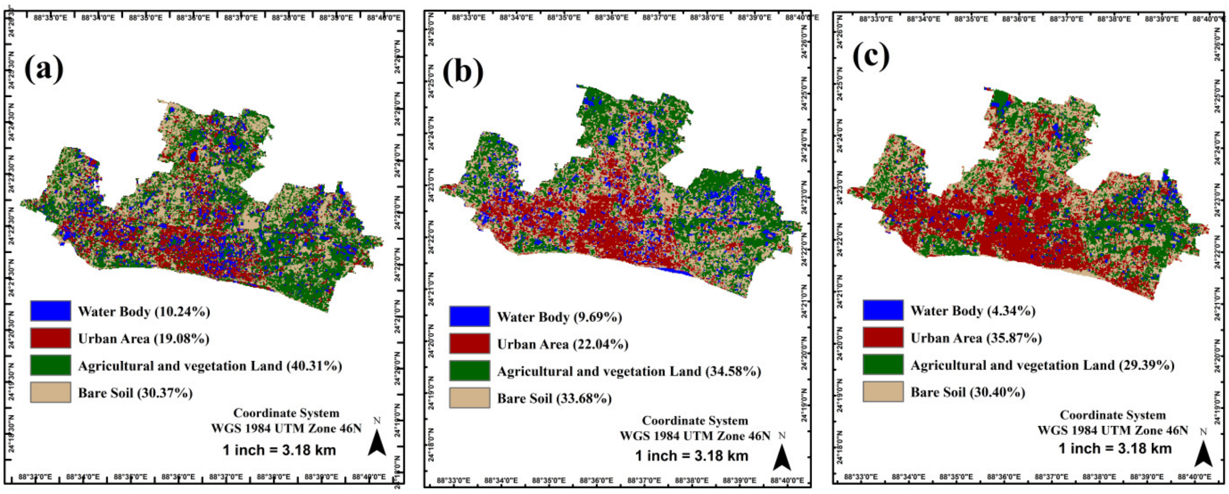

Fig.2: Land use map of Rajshahi City Corporation in 1996(a), 2006(b), 2016(c)

Table 1: Decadal land use change year 1996-2016 in RCC

Land use	1996(km^2)	2006(km^2)	2016(km^2)
Waterbody	4.7547	4.4991	2.02
Urban Area	8.8542	10.2294	16.67
Agricultural & Vegetation land	18.711	16.0533	13.66
Bare Soil	14.0976	15.6357	14.13

Water body fill up assessment for urbanization

Fig. 3 shows the direct association of water body filled up occurrence with rapid urbanization. In figure 3(a), blue dots indicate waterbody which remained unchanged from 1996 to 2006 and red dots indicate change of waterbody to urban area. 0.423 sq.km of area has changed from waterbody to urban area. In figure 3(b), it shows the change of 2006 to 2016. In this decade 1.03 sq.km of waterbody has changed to urban area. The most important finding is that, in the last decade, change of waterbody to urban Area is about double and it has a side effect on the environment as well as. Table 2 describe the loss of surface water bodies in year 1996-2006 and 2006-2016.The water body loss increasingly in very alarming way. About 9% of water bodies was fill up in year 1996 and 2006. The parentage of loss of water bodies is very high (51%) which indicated very alarming situation for environmental degradation in RCC area.

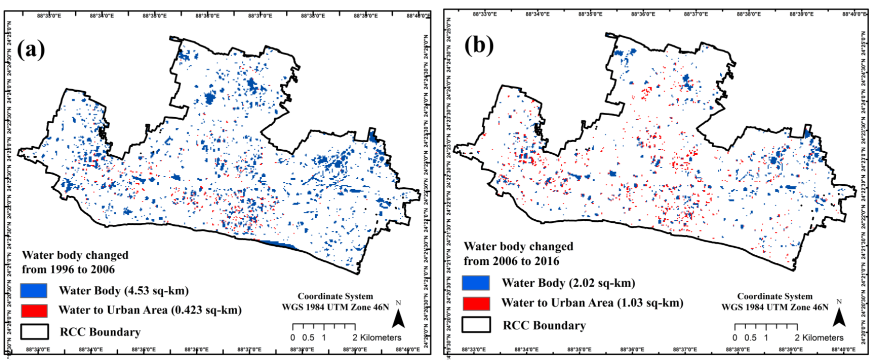

Fig. 3: Association of water body fill-up occurrence with urbanization (a) 1996-2006 (b) 2006-2016

This situation occurred because of haphazard and unplanned growth of urbanization in RCC area in recent few years. People are willing to fill up the water bodies and developed residential as well as commercial areas. Planned urbanization might meet the demand of increasing population as well as protect the water bodies from the massive destruction.

Table 2: Loss of water bodies in RCC within 20 years

Year	Total surface water bodies (km^2)	Area (km^2)	Percentages of loss
1996-2006	4.5315	0.423	9.33
2006-2016	2.0196	1.0314	51.06

CONCLUSIONS

Although there are diversified reasons behind the water bodies fill up in the study area, this study finds the rapid urbanization is the primary causes for water body fill up. Urbanization is a major cause of damage of water bodies. Urbanization has resulted in direct loss of water bodies as well as degradation of water bodies. Construction activities are a major source of suspended sediments that enter into the water bodies through urban runoff. Water bodies fill happen also due to encroachment. The first step of encroachment is to build structures along the surroundings of water bodies and further out on the water bodies itself. To do this, rows and bamboo posts are positioned and fixed on the water body bed along the bank and extending into the main body of the pond. Then huts and shops are built on these stilts. The owners of these structures are then start reclaiming land by earth fills and dumping garbage. Water bodies fill up has some other reason as well. Such as, political pressure in unlawful land grabbing, unplanned urbanization and district expansion, unplanned constructing of government building etc. The serious effects of the Water bodies fill up are the damage of biodiversity, serious environmental humiliation, Water logging, metropolitan flooding and loss of valuable water resources. To improve the enhancement of RCC area measure should be taken like conserve surface water bodies and develop scenic view around the water bodies to create more attraction to the city dwellers. The conservation of surface water bodies is crucial for RCC to keep the ecological balance, especially to reduce the urban flooding. Necessary measures should be taken like social awareness, maintain of strict law and the Local government could play an important role in pond fill restriction.

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ASSESSMENT OF STORM WATER CARRYING CAPACITY OF NATURAL DRAINAGE CHANNELS FOR SYLHET CITY

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ABSTRACT

Storm water drainage system in Sylhet, Bangladesh is very conventional and centralized. There is partial storm water drainage system in this city. A total of nine natural drainage channels locally called chara are mainly responsible for the drainage of storm water to the Surma River. These natural drainage channels are being filled up due to unplanned land development and encroach by people. In some parts of this city, roads and their surrounding areas are experiencing severe inundation problem during heavy rainfall. It is therefore necessary to provide sustainable storm water drainage systems for this city. That's why this study sets three main objectives; such as the development of IDF curve based on rainfall data, (Bangladesh Meteorological Department) computation the discharge of a sub catchment area by rational method and determination the carrying capacity of existing natural channel .The frequency and intensity of rainfall in Sylhet is higher than other districts of Bangladesh. Due to the improper establishment of proper storm water drainage system, water logging and other environmental effects is common scenario. So to minimize the water logging and other environmental effects a step has been taken to storm water drainage design by using rational method to compute peak discharge and determine the cross sectional area of all natural canals (chara) using Manning's hydraulic design with various options. Also design of the road side drainage system of two main road passing through the city (one is North-South direction and another is East-West direction) using guidance notes on road pavement drainage design based on Transport Research Laboratory (TRL). The hydraulic parameter of natural channel and storm water drainage system was design based on 20 years. So, proposed drainage system and storm water management will keep the city free from water logging problem.

Keywords: Storm Water, IDF Curve, Urban Drainage, Water Logging, Discharge

INTRODUCTION

The consequences of urbanization are widely known in hydrologic studies since there have been increasing problems in urban storm water drainage management. One of the most important facilities in preserving and improving the urban environment is an adequate and properly functioning storm water drainage system, which includes storm water conveyance and storage facilities. Traditionally, urban drainage in developing countries is designed based on the concept of draining water from urban surfaces as quickly as possible through pipe and channel networks, it increases the peak flow and the cost of the drainage system(IHP-V,2001). Many catchments in Bangladesh are now under intense pressure from urban, industrial, and infra-structural development where downstream receiving water bodies such as rivers, lakes, ponds and reservoirs has become sensitive to increased rates and volumes of runoff and pollutant discharge. These discharges have posed major issues to many urban and residential centers. The problems become even more aggravated by frequent intense rainfalls, the physiological nature of basins, and the pattern of urbanization with relatively poor urban services. From a functional point view, urban storm water management consists of planning, design, construction, and operation functions, ideally carried out in the. These functions are shared with or are common to most public services and facilities. Unfortunately, the planning function receives too little attention in urban storm water management as well as in the other public services and utilities.

Sylhet city, one of the rapidly development urban areas is located in the north-east region of Bangladesh and situated at 28.85^0 longitude. The region is in the hilly portion of the country. The study area is Sylhet City Corporation (SCC) area. The City occupies a total area of 26.5 sq.km with a population of around 0.5 million (SCC, 2005).The River Surma flows dividing the city onto two parts and the city is developing on both sides. It has prime importance for its tourism, religious places, shopping and trade centers, the city have no structured sewerage and drainage systems. A total of nine natural drainage channels (locally called Chara) are responsible for draining storm water to the Surma River. Sylhet City Corporation was previously known as the 'Municipality of Sylhet'. The new name has been in use since 28 July, 2002. Sylhet became a municipality in 1878 covering an area of 5.82 square kilometer. Sylhet belongs to a group of medium urban centers that have grown rapidly in the recent years and has steadily improved their ranks in the urban hierarchy. Although Sylhet municipality was established almost 127 years ago, actual expansion of municipal area has been started since 1971. The 1971 war of liberation accelerated the rate of migration from rural to urban areas and this led to rapid urbanization in Sylhet.

METHODOLOGY

Hydrologic Analysis

The area selected for the study is in the Northeast region of Bangladesh. The region has many rainfall stations of Bangladesh Water Development Board (BWDB) and for the present study Sylhet rainfall station has been selected. A total of 33 years (1970-2002) of daily rainfall data were made available from BWDB. The entire record of the gauging station was verified for the continuity of the data. The yearly 1-day maximum rainfall from the Sylhet station was extracted from the computerized data.

Development of 1-hour maximum rainfall data

In developing countries like Bangladesh, although short duration rainfall data are scare, the rainfall records for 24-hour duration are available for rain gauge stations. Estimation of 1-hour maximum rainfall data has been made by using Indian Metrological Department (IMD) empirical reduction formula.

Frequency analysis of 1-hour maximum rainfall

In Matin (1984), Extreme Value Type I (EV-I) or Gumbel distribution (Chow *et al,* 1998) was found suitable for the frequency analysis of daily maximum rainfall magnitudes of Sylhet station. In this study, Gumbel distribution has been applied for the frequency analysis of 1-hour maximum rainfall of Sylhet. The probability distribution function for EV-I is given by:

$$P_r = P_m + K\,s$$

$$K = (y - y_n)/\,S_y$$

$$y = -\ln\,[-\ln\,(1 - 1/T)]$$

Where, P_r is the expected 1-hour T-year rainfall depth, P_m and s are the mean and standard deviation of 1-hr maximum rainfall respectively. y_n and S_y are reduced mean and reduced standard deviation. 1-hour rainfall magnitude – frequency relationship has been established for the study area based on EV-I distribution.

Short duration data

Rainfall data of short duration such as 5 min, 10 min, 15 min, 30 min and 120 min have been developed using the depth-duration ratios given by US Weather Bureau.

Development of Rainfall Intensity-Duration-Frequency Curve

Once the rainfall depth for a specified return period T and duration t is calculated, its mean intensity I_m has been obtained dividing it by the duration t (hour). The IDF curves now could be obtained by plotting, on a graph, the mean intensity I_m (mm/hour) against the duration t (hour).

Catchment Area of Different Chara

Catchment area of all different chara in Sylhet city has been identified through field survey and from contour map. Runoff flow direction has been identified during field survey and consulting local people. The points for designing hydraulic parameters (width of channel) were chosen considering intersections between two natural channels. Further four intermediate points were chosen randomly.

Runoff coefficient

Runoff coefficient given below (Table 1) used for Dhaka City in PCI (1993) is used for calculation of the design peak discharge by the rational formula.

Time of Concentration

The Catchment area of Malnichara, Guali chara & Mongoli chara in Sylhet city has been divided into three, four & two sub-areas each of which is drained by a single channel. Time of concentration (t_c), in minutes, for each sub area was estimated using the Federal Aviation agency (FAA) formula (ASCE, 1996) and California culverts Practice (1942).

Table 1: Runoff coefficient

Land Use	Runoff Coefficient
Commercial Area	0.65
Industrial Area	0.55
High Class Residential Area	0.3
Middle and Low Residential Area	0.5
Green Zone and Others	0.2
Water Bodies	1.0

Design discharge is calculated by the rational formula as used for Dhaka City in JICA (1991) has been given below:

$$Q = CiA/360$$

Where, Q = Peak discharge (m^3/s)
C = Runoff Coefficient
i = Rainf all intensity during time of concentration (mm/hr)
A = Drainage area (ha)

5-year frequency rainfall intensity has been used for determining peak runoff as used in JICA (1991) for the Dhaka city.

RESULT AND DISCUSSION

24-hr maximum rainfall data of Sylhet station (BWDB) for the period of 1970-2002 has been analyzed in order to develop rainfall intensity has been used for runoff calculation of sub areas. Peak discharges of Kalibari chara, Gavier Khal and Malnichara have been calculated to 29.2 m^3/s, 14.22 m^3/s and 98.49 m^3/s respectively using rational formula. Catchment area of Goali Chara in Sylhet city has been divided into four sub area namely Bhubi Chara Sub area I, Manikpeer-Naiorpul-Sobhanighat Chara Sub area II, Sondha Bazar Sub area III and Goali Chara Sub area IV. Catchment area has been measured to be 0.9 sq.km, 0.5 sq.km, 0.42 sq.km and 4.7 sq.km respectively. 24-hr maximum rainfall data of Sylhet station (BWDB) for the period of 1970-2002 has been analyzed in order to develop rainfall intensity has been used for runoff calculation of sub areas.

Peak discharges of Bhubi Chara, Manikpeer-Naiorpul-Sobhanighat Chara, Sondha Bazar chara and Goali Chara have been calculated to 15.5 m^3/s, 13.09 m^3/s, 11.53 m^3/s and 71.35 m^3/s respectively using rational formula. Catchment area of Mongoli Chara in Sylhet city has been divided into two sub area namely Boloramer chara Chara Sub area I and Mongoli Chara Sub area II. Catchment area has been measured to be 0.9 sq.km and 3.14 sq.km respectively. 24-hr maximum rainfall data of Sylhet station (BWDB) for the period of 1970-2002 has been analyzed in order to develop rainfall intensity has been used for runoff calculation of sub areas. Peak discharges of Mongoli Chara and Boloramer Chara have been calculated to 65.12 m^3/s, and 24.21 m^3/s respectively using rational formula.

CONCLUSIONS

This study encompasses the present condition and integrated drainage management of Sylhet city. Following conclusions have been made from the study:

i) Average intensities of rainfall for different return periods have been calculated by dividing t-minute rainfall depths by the corresponding duration of T (hour). Intensity-duration-frequency (IDF) curve has been developed by plotting average intensities against the duration of rainfall.
ii) Catchments area of all natural canals (chara) in SylhetCity has been identified through field survey and from contour map. Runoff flow direction has been identified during field survey through consulting with local people so that the catchment area of each charas can be locate.
iii) Design discharge is then calculated by the rational formula, Rainfall intensity has been calculated from the IDF curve at the duration equal to time of concentration (t_c). 5-year return period has been selected for calculating rainfall intensity.
iv) Cross sectional area required at the outfall of Kalibari Chara, Gaviar Khal , Malnichara, Bhubi Chara, ManikpirNaiorpul-Sobhanighat Chara, Sandhabazar Chara, Guali chara, Bolramer Chara, Mongoli Chara, has been calculated which shows irregularities for all charas.
v) Finally the size of various options (natural as well as box culvert) of different chara improvement have been designed on the basis of calculated peak discharge of all chara using Manning's formula.

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WATER URBANISM AND RESPONSIVE SOLUTIONS: A CASE STUDY OF MAHESH CANAL IN CHITTAGONG, BANGLADESH

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ABSTRACT
Bangladesh is a riverine country located in South Asia with a coastline of 580 km on the northern littoral of the Bay of Bengal where many cities and urban areas are inundated due to water clogging, tidal flow, and floods and so on. Chittagong, the port city was full of water bodies which were draining the city as well as serving as water reservoirs, communication line and playing a significant role to perform many functions that maintain ecological integrity. Despite the diverse benefits that wetlands provide, lack of effective management led to their continued degradation that includes unplanned Water Urbanism such as converting wetlands into residential land, using them as a waste disposal site. Mahesh canal in Agrabad area is inundated caused by high tide twice a day, disrupting the normal civic life of thousands of families during rain. These problems are arisen acutely for the damage of Mahesh canal dam. Not only engineering outlooks, but also socio-economic and environmental aspects should be considered. Natural water conservation might be one of the best solution to mitigate these existing problems. The main objective of this study is to change the circumstances by reviving the canal, recommending ideas about what would be the structure in surrounding the canal, promoting transport route through water, conserving biodiversity of water, modern engineering solution for tidal flow, creating recreational space for city people. Finally, the paper is an attempt to investigate the present problems caused by water clogging, tidal flow and human intervention and formulate responsive design ideas for the betterment of people in Agrabad.

Keywords: Water Urbanism; Conservation; Human Intervention; Water Clogging; Tidal Flow.

INTRODUCTION
Water Urbanism represents a set of design practices to incorporate water bodies in urban life as it is blended with urban life through involving people and environment to revive urban eco-system. (GSAPP, 2016) . Chittagong city is known as a port city as well as comprises a lot of water bodies which have a great impact on society and environment of urban life. Water bodies serving as water reservoir, drainage of the city, functional communication way and also maintains ecological integrity. Besides canal sides play a vital role in building through creating a natural urban fabric. (Sairinen, 2005).

Moreover, Urbanization particularly rapid growth in developing countries that is an important cause of the degradation of natural water resources. Ill planned and neglected management of urban canals are creating miserable situation in urban life and is even worsening day by day. The United States Geological Survey (USGS) defined as a land areas which are seasonally or permanently waterlogged, including lakes, rivers, estuaries, and freshwater marshes; an area of low lying land submerged or inundated periodically by fresh or saline water is known as wetland. (Phukan, 2014). In 1994 'Ministry of Environment and Forests (MoEF)' has taken an initiative toidentify10 polluted urban lakes for conservation (S.Koduru & Dutta, 2013) Hatirjheel project is developed in inflow of Begunbari Khal, which was one of the major drainage canals of the Dhaka city. This type of water urbanism projects has a vital impact reducing adverse environmental effect and improving quality of urban living. In addition, Avoimitro ghat is another example of conservation of canal in Chittagong urban fabric.

Chittagong is situated on the bank of the Karnafuli River and it has a numerous number of canals flowing through the city. These canals were used for drainage purpose of the city as well as serving water reservoir, communication line and playing a significant role to maintain ecological balance like regular tidal flow, flood, and rain water reservoir Mahesh canal in Agrabad was used as water reservoir, communication line and draining the surroundings but unplanned & insensitive water urbanism such as converting wetland into residential land, using as a waste disposal site creates unhygienic environment. For successfully reviving issues need to identify by investigating the present situation and provide responsive solutions through sustainable urban policies, human awareness and responsive design is an essential task.

Literature Review

From the very beginning Chittagong Town started to grow as a small Municipality in 1863. It was finally upgraded as Chittagong City Corporation (CCC) in 1990. (Hashemi, 2006) The Master Plans for Dhaka and Chittagong were produced in the year 1960 and 1961 respectively. The plans were produced basically zoning maps and drainage reference was very little. (M.A.Ashraf et al., 2009). In recent times 10 to 11 canals were existing out of the total 34 canals. (Newage, 2016)Many canals were dead because of unplanned urbanization, lack of management, throwing the wastes into the drains by the city dwellers. Due to incessant rainfall water-logging in the port city of Chittagong has turned worse mostly Chawkbazar, Muradpur, Bahaddarhat, Gate No 2,, Bibirhat, Agrabad CDA Residential Area, Probartak intersection, Katalganj, Bepari Para, Muhuri Para and Halishahar Shantibagh have gone under ankle- to knee-deep water bringing the city life to a dead end. (thedailystar, 2017) Besides the natural process of high tide twice a day, disrupting the normal civic life .During the rainy season the suffering knows no bound specially the school going children. Moreover, there are no proper published literatures covering history of urban storm water logging (USWL) in Chittagong city that can help to mitigate recent situation. (Akter et al., 2017). Though wetland have dynamic benefits but government did not take any initiative in Chittagong city.

METHODOLOGY

The study is based on primary and secondary data collected from various sources such as journals, books, internet and other published, unpublished works and wetland related government policies. In order to gather background and historical information, an extensive literature review was explored. Moreover, for policy making and design ideas multiple different international conventions and other countries experiences were assessed. To create an insight about the existing situation of Mahesh canal, observation, reconnaissance survey, focus group discussion with Community members, SWOT analysis were performed.In the surveying process direct observation help to understand the present situation of the area, people activity and participations, problems and data recorded in the form of photographs, sketches and writing records were documented and received. The reconnaissance survey was performed by walking through the adjacent area. For the time limitation some portion of the canal has randomly selected for sample survey. Finally, all the collected data regarding different sources were analysed by Google Earth, MS Word, MS Excel, Adobe Photoshop, PDF Converter etc.

Study Area and Existing Situation

Chittagong is the commercial capital of Bangladesh and is densely populated, with a total population exceeding 2,84,23,019 (BBS & SID, 2011). At present the city area is around 155 Sq. Km. and is inhabited by around 4.00 Million population (Hashemi, 2006). Mahesh canal is situated in 22°18'12.39"N and 91°47'41.98"E in Agrabad, Chittagong which is connected to the Karnafuli river. The canal is the only waterway through the city to drain away run-offs into the Karnafuli River in times of heavy rains.Due to heavy downpour reason the civic life almost came to a standstill as almost all the Agrabad residential areas went under water. The Mahesh canal dam was being removed on people's demanddue to heavy rainfall. But the after effect was devastating. City dwellers have suffered regular tide and flow since then. CCC (Chittagong City Corporation) and CDA (Chittagong Development Authority) jointly started a project where 19 tertiary canals scheduled to be excavated at a cost of Tk 140 crore. With the completion of these projects, water-logging would be eased remarkably. But, the project was not completed (The Asianage,2017)

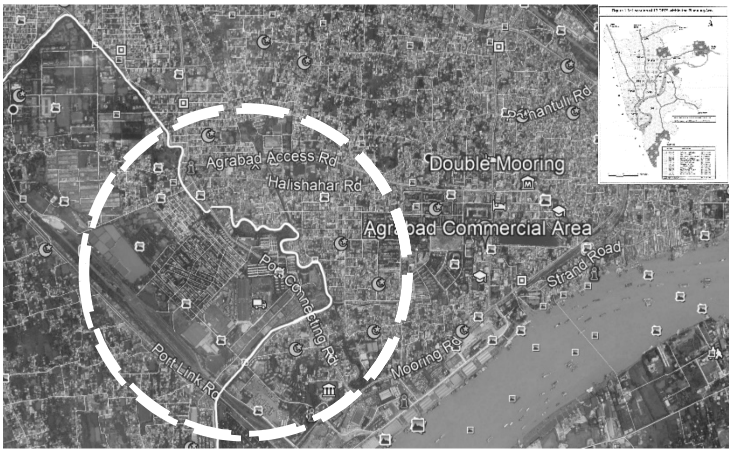


Fig.1: Satellite view of Mahesh canal and survey area

Fig.2: A dam along the Maheshkhal canal responsible for frequent waterlogging in the port city of Chittagong is finally being removed. Source: (bdnews24.com, 2017)

Fig. 3: A boat carries passengers as heavy downpour Floods parts of Agrabad in Chittagong city. Source: (Theindependent, 2017)

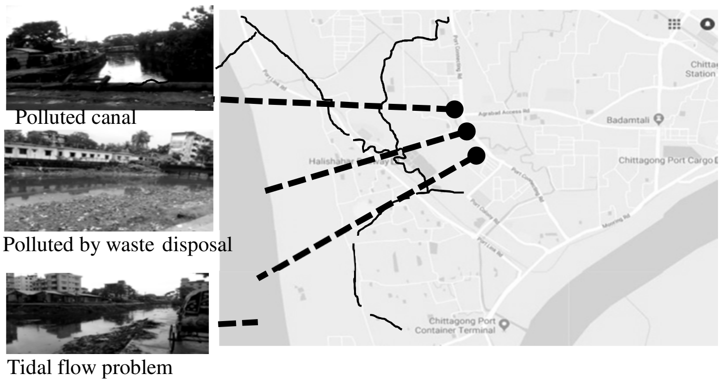


Fig. 4: Mahesh canal present condition (Google map and field survey)

It serves mainly as a water reservoir for the community. Continuous pollution creates unhygienic environment and degrades its quality day by day .Besides converting wetland into residential land, waste disposing into the canal, using as drainage, inadequate width of the canal, the tidal flow problem is disrupting the normal civic life.[Fig. 4] shows the present scenarios of polluted canal water, waste disposal situation and tidal flow problem and [Fig. 5] shows the inadequate width of canal, no attachment of green, using the canal as drainage.

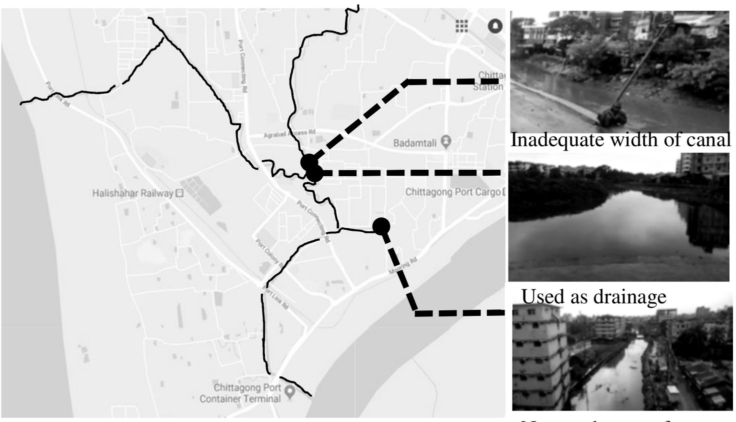


Fig.5: Mahesh canal present condition
Source: Google map and field survey

From field survey in residential area, around 10% people use dustbin for dumping waste, 30% residents dump their waste in road side. Majority around 60% use the canal for the same purpose. Maximum people in commercial and industrial areas, dump their waste into the canal water. This data is collected from field survey on the commercial and industrial areas [Fig. 6]. This area suffers from water clogging because of tidal flow and rainy heavy rainfall. Water level rises 3 feet in regular tidal flow and during flood the water level approximately rises upto 3 feet [Fig.7].

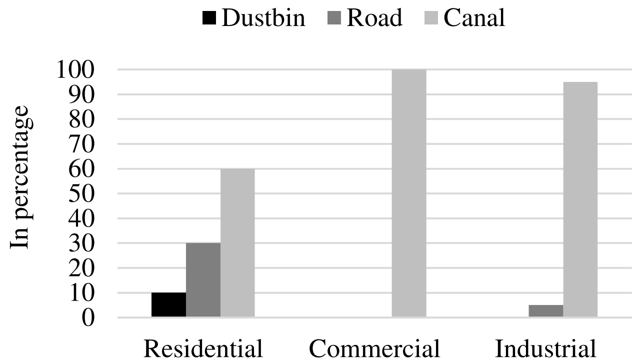


Fig. 6: Percentage of dumping waste in different location.

The tidal flow occurs two times in a day .The duration is 4 hours from 1pm to 4pm at daytime and 2 hours from 2am to 4am at night. Damaged of dam causes the regular tidal flow which creates a miserable situation in urban life. The canal is polluted by waste disposal, waste contains many soluble and dissoluble pollutants, the color of the water being black for the contamination of sewerage waste. There is no green breathing space for urban people. Besides dumping of waste filled up the canal and creates odor .Due to the lack of monitoring the excavation of the canal is not done appropriately.

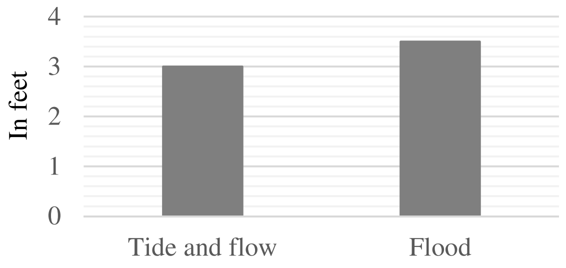


Fig.7: Tidal flow timing.

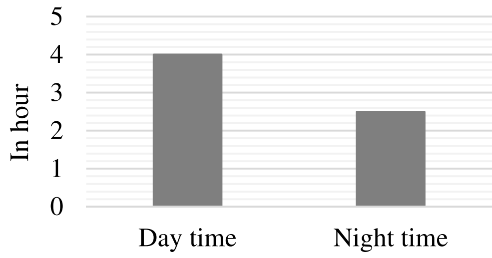


Fig.8: Water clogging situation in Mahesh canal

RESULTS AND DISCUSSION

The SWOT analysis from field survey helped to understand the strength, weakness, opportunities and threat of the present situation of the canal. It also helps to identify issues more closely. The Mahesh canal is the main strength of this urban area that covered large areas which is surrounded by an increasing residential area. The canal and adjacent area have many weaknesses which have to overcome through reviving the canal. There is no waste dumping area .People dump waste in the canal and roadside .For the lack of proper waste management during regular tidal flow, it washes away into the canal. The incorporation of strength and opportunities will help to revive the canal and promote water urbanism. The opportunities of breathing space for people gathering, buffer zone, transportation route through water, walking, jogging, cycling and recreational activities will increase the adjacent housing value dramatically.The present threats is to revive canal and recycling the canal water as early as possible. Due to water logging, waste dumping and the canal is becoming a health and harmful for local people. The damage to the Mahesh canal dam and extensive land filling disrupting the normal civic life during regular tidal flow and the rainy season. It is emergency to take engineering solution to mitigate this problem.

Proposal

According to Bangladesh gadget, 250m from both side of the canal can be taken (according to Bangladesh National Building code, 2008). Elevated pedestrian and structures proposed to welcome the canal water to flow naturally during regular tidal flow and rainy season [Fig. 10]. Sewerage line connection and dumping waste should be prohibited. Moreover, water recycling, excavation of the canal and proper waste management will help to improve the living conditions of the surroundings. Repairing dam will control the water flow. Besides urban pocket space and water transportation system can be promoted [Fig.12, 14, 15]. To avoid dumping waste in the canal, door to door solid waste collection should be ensured.

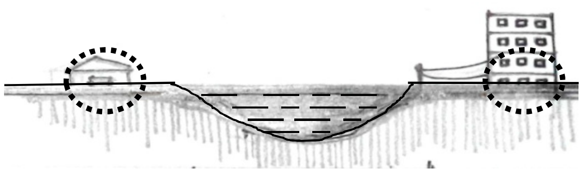


Fig 9: Existing condition while tidal flow.

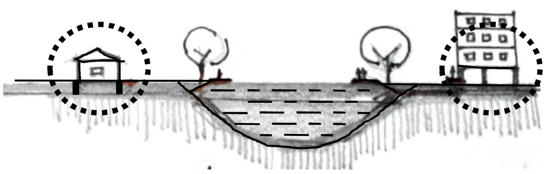


Fig 10: Proposed elevated pedestrian and structures.

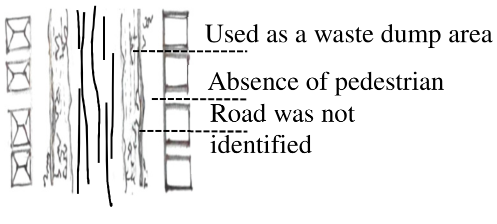


Fig 11: Existing plan of canal surroundings

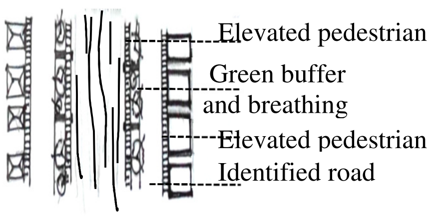
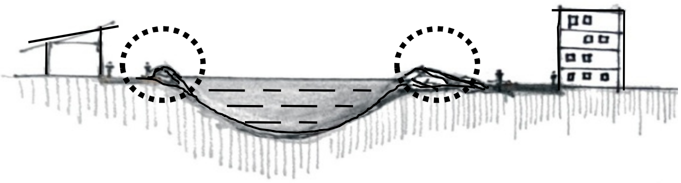


Fig.12: Proposed plan of canal surroundings



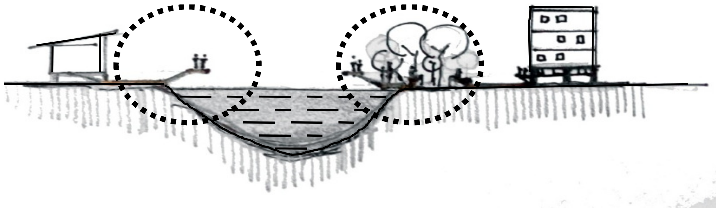


Fig.13: Existing areas used as a waste dumping area. Fig.14: Proposed canal side urban pocket

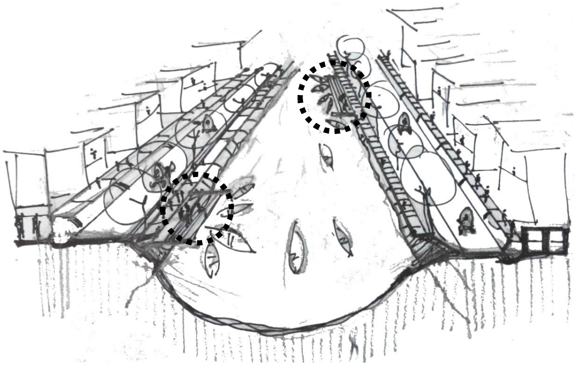


Fig. 15: Perspective view of proposed transportation route through the canal

CONCLUSION

As population increases urbanization are expanding so that it causes to lose its desirable urban natural spaces.When we destroy wetlands, there can be enormous impacts. If we preserve the health of waterbodies and restore waterbodies, ecosystems, it simply follows that we generate associated environmental, social, and economic benefits at the same time it has potentials to accommodate urban facilities which anyhow overcome the pollution as well as desirable urban spaces. Nevertheless, the study shows the need for initiating wetland policies and incorporating strategic plans for creating sustainable environment for the betterment of the surrounding habitat.

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WATER LOGGING AND ITS MANAGEMENT IN SOUTH-WEST REGION OF BANGLADESH: A CASE STUDY ON POLDER NO. 26

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ABSTRACT

Bangladesh, the largest river delta in the world, has about 710 km of coast line along the Bay of Bengal. A total of 139 flood control polders involving 5,107 km of embankment have been constructed covering approximating 1.5 million ha of the coastal area under the Coastal Embankment Project (CEP).The objective of the polders is to prevent inundation of floodplain agricultural land by saline water during high tide. But day by day, the improper operation and poor management of polders and their sluice gates, accordingly within a few years, the negative impacts of the project began to appear including the siltation of riverbeds, increase of saline intrusion, the narrowing of river estuaries and changes in the normal morphological processes of river. Thus rainwater could not drain from the area's leading to chronic water logging. The study aims at exploring the present scenario of Polder 26 which is one of the waterlogged polders located in Dumuria upazila of Khulna district. Moreover, the waterlogging problem in the south-west coastal region of Bangladesh has been reviewed. This study finds that construction of more new sluices, and renovation of damaged sluices can be the probable solutions to eradicate the waterlogging situations of Polder-26.

Keywords: Waterlogging; Polder; Sluice Gate.

INTRODUCTION

The objective of the polders is to prevent inundation of floodplain agricultural land by saline water during high tide. The polders have brought major changes in the tidal regime by reducing storage area for flood tide. The review of CEP in FAP4 studies by Halcrow & Others (1993) considers that the polders have caused rise in channel bed which in turn has resulted drainage congestion. In current year water logging has been spread to Kolaroa, Jhikorgachha and Sharsha. This area is known as Bhabadaha area (Awal et al, 2014). Dumuria upazila of Khulna district which is under the area of polder 26 [Fig. 1] is facing severe water logging for some years. Polder 26 is surrounded by Mora Bhadra River and Teligati River. There are 3 drainage sluices constructed by BWDB on the other side of the polder area by the Teligati River. At present, only two sluice gates (Baloijhaki 1-V Sluice and Zialtola 3-V Sluice) are located along the side of Teligati River, and only one sluice gate (Kakmari 3-V Sluice) exists along the Mora Jaykhali River. With only two sluice gates in place, the polder suffers from tremendous drainage congestion problems after any major rainfall events. Water cannot drain out from the internal Khals timely, and it sometime stakes more than a week to drain water out from the polder through the Teligati River. Furthermore, the siltation of some of the khals inside the polder also aggravates the drainage congestion problems. From field observations and spatial studies, it can be inferred that around 70% of the internal water courses (Barobeeler Khal, Sakha Bai Khal, Zialtola Khal etc.) of the polder suffer from drainage congestion problems. The objectives of this paper are to study drainage congestion and water management for polder no 26 which covers the Shobhana union of Dumuria upazila in Khulna district and to determine the hydrograph of sluice catchment using HEC-HMS model and compare with rational method result.

METHODOLOGY

The first approach of this study is to conceptualize the drainage congestion and its management in southwest region of Bangladesh through secondary data and previous studies. Primary data of Polder 26 have been collected through field visit. The embankment conditions of the polder, surrounding river conditions of the polder, drainage sluice conditions have been observed through field visit. Questionnaire survey with the affected people has been conducted. People's participation and feedback have been assessed. Drainage congestion and water management in polder 26 have been analyzed based on the collected data. HEC-HMS model has been developed for a sub-catchment of the study area. Model simulated drainage volume has been compared with the existing sluice capacity. Finally some recommendations on proposed intervention in polder 26 have been made based on the study.

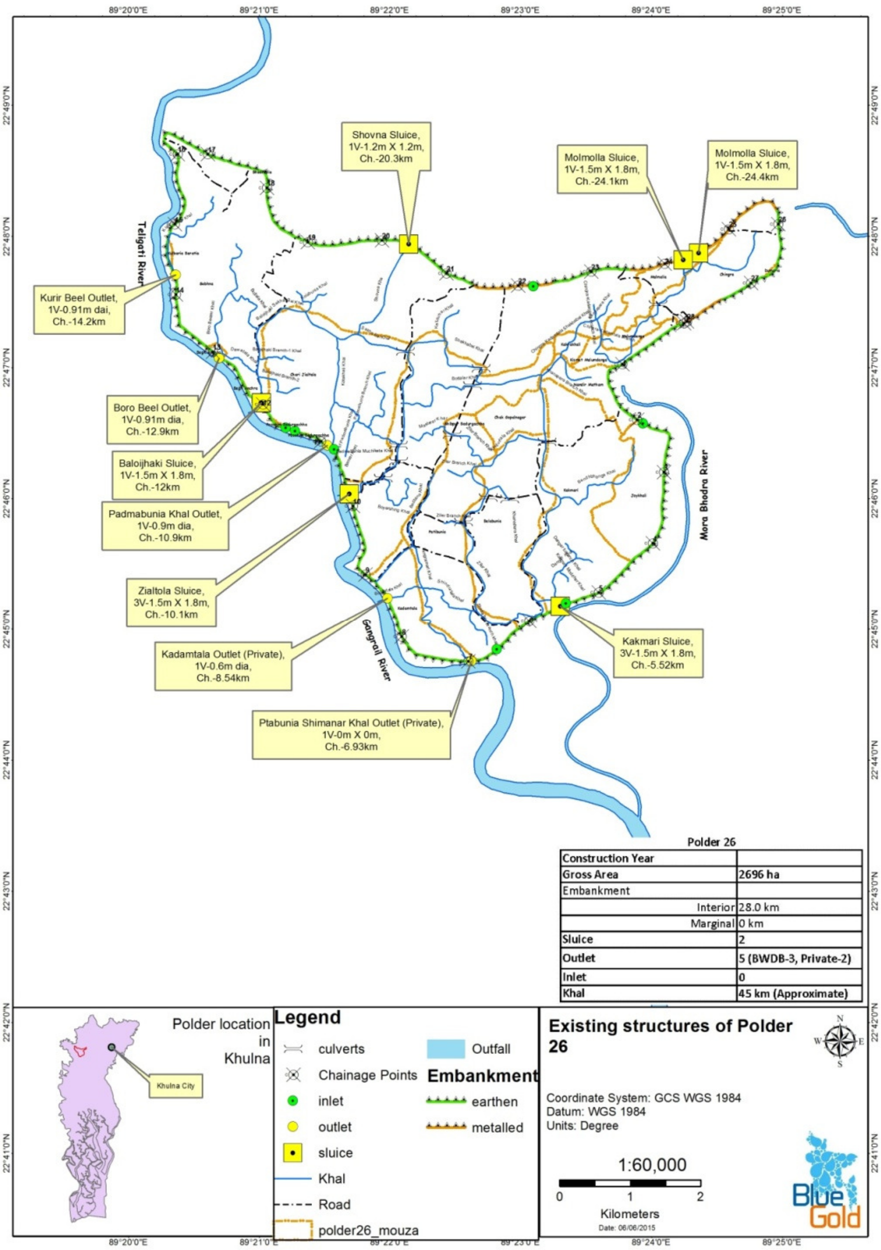

Fig. 1: Map of Polder-26 (study area)

DATA ANALYSIS, RESULTS AND DISCUSSION

Three coastal districts of the South West Bangladesh (SWB) have been experiencing problems of water logging since the early 1980s, which are Khulna, Jessore and Satkhira. Upazilas from Jessore (3), Satkhira (3) and Khulna (2) were affected most. The waterlogged upazilas from Jessore are Monirampur, Keshobpur and Avoynagar. Upazilas from Khulna are Dumuria and Fultala. Upazilas from Satkhira are Satkhira sadar, Tala and Kolaroa Upazila. Fig. 2 showing the area under water logging with respect to total area. The causes of water logging have been listed b elow: 1.Silted up rivers, with river beds higher than polders preventing natural draining out, 2. Badly planned or executed infrastructure projects (such as roads) which block drainage, 3. Water infrastructure not working properly and not being properly maintained, 4. Aquaculture, and other economic activities which may obstruct drainage, 5. poor drainage of monsoon rain, Some negative impacts of water logging after analysis are stated as follows: 1. Social disruption (school, housing, health, sanitation, markets, women's mobility), 2. Clean drinking water supply, 3. Less opportunities for paid work (reduced cropping, transport disrupted, stifled non-farm activities), 4. In agriculture, depressed Aman season production; possible reduced yield & returns from Boro, 5. Conversion of crop land to shrimp, but landless/ tenants particularly affected (one source of conflict).

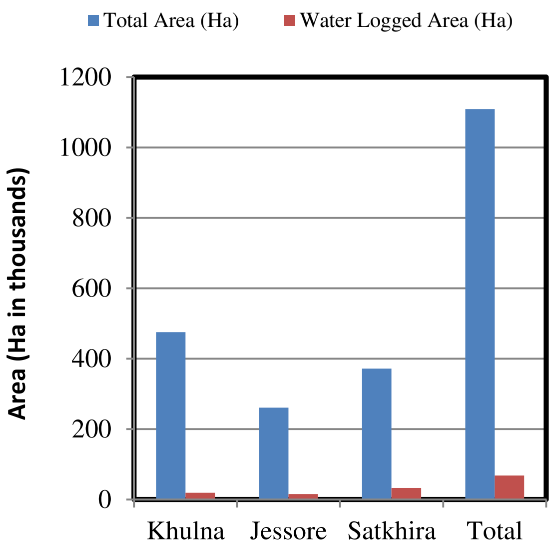

Fig. 2: Area under water logging of south west region of Bangladesh

Fig. 3: Zialtola Sluice of Polder-26 (View from country side)

Water Logging Problems in Polder 26

Polder 26 is facing the problem of water logging for around 15 years. The sluices of Polder-26 have been observed during field visit [Fig. 3]. The catchment contributing to drainage of Baloijhaki sluice of polder 26 is mainly agricultural land with an area of 3.42 km^2 and low percentage of imperviousness. Local khals play a vital role to retain drainage water. Drainage volume of Baloijhaki sluice catchment has been simulated using HEC-HMS model as described below.

Watershed Delineation

Watershed has been delineated for Baloijhaki sluice outlet [Fig. 4]. This has been done using Arc-GIS tools, DEM, Shape file (Khan, 2016).Watershed area has been calculated. Length of watershed to outlet from a remote has been reckoned. Summation of the length of the contour lines that pass through the watershed drainage has been calculated. Contour interval used, average land slope percentage have been calculated.

Data Collection for HEC-HMS Model

IDF curve for the polder area has been generated. From IDF curve precipitation for various duration and return period has been calculated. Specified hyetograph has been created from the data. Basic characteristics have been calculated from Arc-GIS calculations and various assumptions.

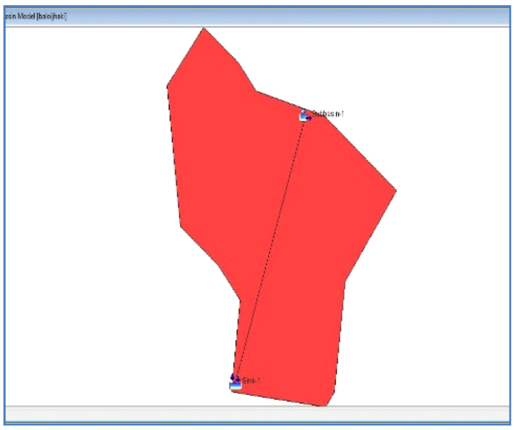

Fig. 4: Watershed of Baloijhaki Sluice

Design Rainfall Depths Data analysis

The equation of IDF curves of Khulna City was obtained as: $I = 652*T_r^{0.2198}/T_d^{0.67}$, where, I= intensity in mm/hr, T_r = return period in years, T_d= duration in minutes. Usually for design of drainage structures or pumping stations, short duration rainfall is selected as design rainfall. In this case, the model was simulated with the following rainfall events: 1h 2-Year Return Period, 2h 5-Year Return Period, 2h 10-Year Return Period, 2h 20-Year Return Period, 2h 50-Year Return Period, 2h 75-Year Return Period, 2h 100-Year Return Period. The design rainfall hyetographs are produced for different the rainfall events. Then from the hyetographs "Peak Rainfall vs Return Period" graph is produced.

Determination of Peak Discharge to Baloijhaki Sluice using Rational Method

The rational formula is: $Q_p = CIA$, where Q_p, I and A denote peak discharge, rainfall intensity and drainage area, and C is a dimensionless runoff coefficient. ($0 \le C \le 1.0$). Peak discharge for Baloijhaki catchment for different return period has been calculated as:

Table 1: Peak discharge for different return period for Baloijhaki catchment

Return period	Area (km^2)	Runoff coefficient	Rainfall intensity (mm/hr)	Peak Discharge (m^3/s)
2 hr 5 year	3.42	0.2	37.03	25.329
2 hr 10 year	3.42	0.2	43.12	29.49
2 hr 20 year	3.42	0.2	50.22	34.35048
2 hr 50 year	3.42	0.2	61.43	42.01812
2 hr 75 year	3.42	0.2	67.15	45.9306
2 hr 100 year	3.42	0.2	71.54	48.93336

Determination of Discharge to Baloijhaki Sluice using HEC-HMS Model

NRCS developed the following equation for watersheds with areas of less than about 8 km^2 (2000 ac) and CN between 50 and 95 (NRCS 1985; Haan, Barfield, and Hayes, 1994; McCuen, 1998). $t_L = l^{0.8}(1000-9CN)^{.7} / 1900CN^{0.7}Y^{0.5}$ and Y= (100 CI)/A, C=Summation of the length of the contour lines that pass through the watershed drainage area on the quad sheet, ft, I=Contour interval used, ft, A=Drainage area, ft^2, Y= Average land slope %. Calculation of lag time for the catchment of Baloijhaki sluice (NRCS method) is shown in Table 2.

Table 2: Calculation of lag time for the catchment of Baloijhaki sluice

Catchment	Summation of length of contour lines C (m)	Area, A (m^2)	Contour Interval, I (m)	Contour Interval, I (ft)	Average Land slope, Y (%)	CN	Hydraulic Length, L(m)	Lag time ,t_L (hr)	Lag time ,t_L (min)
Baloijhaki	102357	3421751	30	0.984	0.93	80	2067.33	1.009	72.04

Model Simulated Flow Discharge

Simulation of discharges at the Baloijhaki sluice has been done for various rainfall duration and return periods. One typical hydrograph for 2hr rainfall with 20 yr return period has been given in Fig. 5.

Existing Capacity of Baloijhaki Sluice

Discharge $Q = C H^{1.5}B$, C= a co-efficient depends on H/D ratio, H= Height, B= Width. Here C=2.68 for H/D <1.5. H= 5.90 ft, B= 14.76 ft, Q is calculated as Q = 667.035 ft^3/s (cusec).

This calculated discharge is greater than peak discharge of 1hr 2 yr return period (388.52 cusec) but it is a little bit smaller than 2 hr 5 yr return period (806.4 cusec) and 2 hr 10 yr return period (962.3 cusec)

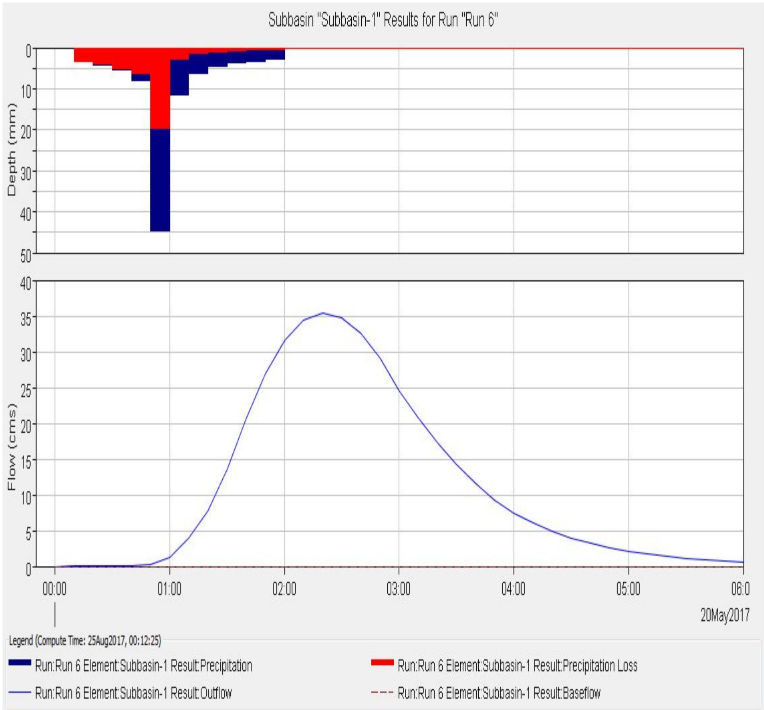

Fig. 5: Model simulated hydrograph for 2hr rainfall with 20 yr return

CONCLUSIONS

Polders of South-West Region of Bangladesh have been experiencing water logging problem over 15 to 20 years. Area of these polders remains waterlogged during almost the rainy season. 50 to 80 percent area of these polders remains inundated from 15 days to 3 months. Polder 26 is facing the problem of water logging for around 15 years. The catchment contributing to drainage of Baloijhaki sluice of polder 26 is mainly agricultural land with an area of 3.42 km^2 and low percentage of imperviousness. Local khals play a vital role to retain drainage water. However, discharge capacity of Baloijhaki sluice is calculated. The calculated discharge is sufficient for 1 hr 2 yr return period discharge but less than the discharge of 2 hr 5 yr return period and 2 hr 10 yr return period. The discharge capacity depends on the H/D ratio of the sluice where D is the difference of upstream and downstream bed elevation. Due to siltation D is decreasing for the sluice and reducing the capacity of drainage. Construction of new sluices, repairing of existing sluices and re-sectioning along existing embankment can be the probable solutions to eradicate the waterlogging situations of Polder-26.

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DEVELOPMENT MEASURES FOR AN EFFICIENT DRAINAGE SYSTEM AT BAHADDARHAT-CHAWKBAZAR IN CHITTAGONG

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ABSTRACT
Rapid and unplanned urbanization of Chittagong, the commercial capital of Bangladesh has experienced immense pressure on its urban services including apposite drainage system. Drainage engineering is implemented mostly on an ad-hoc basis rather implementing Drainage Master Plan. Thus, there is a lack in proper drainage planning and implementation. Bahaddarhat to Chawkbazar Kanchabazar residential portion has been selected for this study aimed to exploration, extrapolation and analysis to perceive the factual drainage problem in Chittagong city. This case study examines the existing circumstances, assessing causes behind the problems, and identifying probable resolutions for the future. Considering physical characteristics, topography, catchment area and the routes of existing drainage channels such as Mirza Canal, Hijra Canal, Chaktai Canal, Bijjakhali Canal etc., a new cross section of drainage channel has been designed to mitigate the contemporary problem. After estimation of the runoff generated from existing population of about 0.35 million in 9.12 sq km projected area, it is found that the total discharging wastewater is about $10m^3$/sec and maximum runoff in rainy season is about $42m^3$/sec those make a sum of $52m^3$/sec. The existing drainage capacity is about $49m^3$/sec that implies an overflow during peak rainfall. Thus, a new channel has been designed with effective cross-section of $24m^2$, effective wetted perimeter of 13m, depth of channel of 4m and slope is 0.5:1. Existing drains have been abridged mainly because of dumping solid waste and siltation on channel bed surface, thus the city experiences water logging. With the proposed design along with the proper management, this is expected to provide guidance in reducing water logging.

Keywords: Drainage; Water Logging; Mirza Canal; Chittagong; Drainage Master Plan.

INTRODUCTION
Chittagong, the second largest as well as the commercial capital and one of the most important cities in Bangladesh is experiencing environmental degradation due to rapid urbanization, increasing population and unplanned industrialization in last few decades. The process of urbanization and industrialization is linked with some influential parameters like new settlement of population, dwindling of open earth and marshy land, pressure on social and health services and transportation systems etc. Provision of infrastructural services i.e. water, drainage and sanitation along with waste disposal are greatest concern to human settlements. Failure to provide these services adequately results in many of well-known costs of rapid urbanization: threats to health, loss of urban productivity and environmental quality. During last two decades, the population growth rate in Chittagong and expansion of city were notable (Ahmed and Rahman, 2000.). However, when the growth of urban population takes place at an exceptionally rapid rate, like most cities and towns, Chittagong is unable to cope with changing situations due to its internal resource constraint and limitation of managerial skills of responsible personnel. Chittagong is a coastal city and during rainy season, intense rainfall occurs. Thus, in rainy season during peak rainfall with the excess discharging waste water from city people may lead to a runoff that exceeds the capacity of existing drainage system. The city dwellers are experiencing different sort of severe problems those are directly related to drainage system. Overflow and blockage of drains cause disruption of smooth drainage system.

Overflow leads water logging when the total runoff is much greater than the capacity of outlet Channels. Water logging results a serious damage to transportation roads and infrastructures and it impedes traffic movement that results traffic jam. It causes interruption of normal life of local people mostly in Bahaddarhat, Muradpur, Agrabad, Bakalia, Chawkbazer areas. Every year the city inhabitants face ineffable distress due to wrecked roadway after rainy season and authority needs lots of money to repair the damaged roads. Water logging further causes water pollution and spreading of water borne diseases those are common threat to human health and safety. It eventually makes a huge loss of assets and impedes to smooth economic development. However, 70 canals existed in Chittagong according to a master plan in 1969, but recent survey shows only 22 of those are existed now a day. The recent research on climate change indicates that 10-15% more rainfall will occur in Bangladesh by 2030, and further it will increase. Thus, to mitigate the water logging and its consequences, a case study area has been taken where existing Mirza Canal has been redesigned pondering over the potential factors. This study may lead to redesign the whole drainage system in Chittagong city that may help the city dwellers to get rid of the problems from water logging.

DRAINAGE MASTERPLAN OF CHITTAGONG CITY

The Government of Pakistan under Ordinance No 51 established the Chittagong Development Authority (CDA) in 1959 as an autonomous body to cope with the expansion and development of the city in a planned way. One of the principal responsibilities of CDA under this Ordinance is to delineate a Master Plan for drainage and flood-protection of Chittagong City. Under the drainage master plan, the city was divided into 12 drainage areas. Further researches are required to:

- prevent water logging in the assigned area;
- keep the environment free from pollution in the selected area;
- control odor, mosquito, nuisance etc., and
- reduce the sufferings to people concerning waste water, sullage and storm water related problems in the selected area.

The specific objectives of the study includes: to study the topographical features of the selected area, thus, to observe the existing drainage condition and to find the scope for developing an efficient drainage system.

TYPES OF DRAINAGES

Drains can be classified into many groups considering different perspectives. According to waste water carrying nature, drains are classified as: primary drains, natural and manmade secondary drains and area drains. On the other hand depending upon the size and location of the treatment facilities, drains are classified as: building drains, lateral or branch drains, main drains, trunk drains, intercepting drains and outfall drains. Depending on the discharging networks and layout, drains are: surface drains and sub-surface drains.

DESIGN PROCEDURES

Analysis from the drainage sector reveals that 60% of Chittagong city area lacks of proper drainage system. The existing network is inefficient, inadequate and majority of the drains are in filthy conditions. A number of identified areas in the city are frequently flooding during even moderate rains. The drainage systems discharge their water and waste loads into water bodies and backwaters through the fairly flat terrain subjected to tidal effects. To conduct this work, there are four types of data those have been collected to design an efficient drainage network [Fig.1].

Rational formula,Peak discharge, Q= F C I A

Where, Q = peak discharge m^3 / sec)

F = A factor of proportionality

= 0.278 when A in Sq: km and I in mm per hr

= 1.0 when A in m sq. and I in mm per sec

C = co-efficient of run-off which depends on the type of area, soil condition, soil cover, storage, depressions etc.
I = rainfall intensity with the selected recurrence interval
A = area of catchments

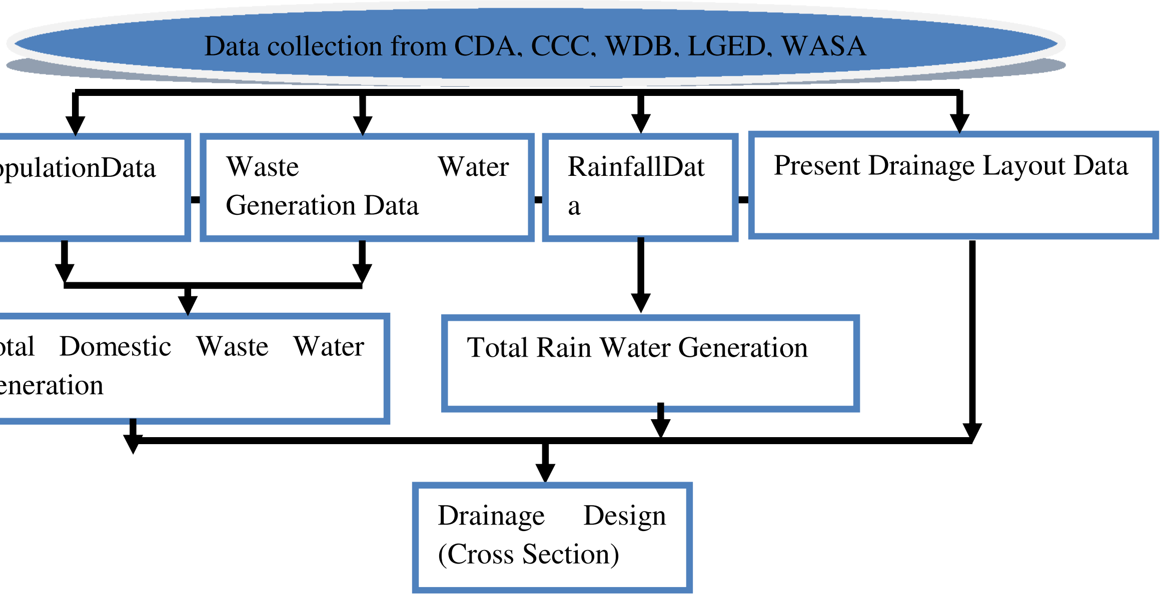

Fig.1: Flow chart of methodology

WASTE WATER CALCULATION

From Manning's equation(Chow 1959), $Q = \frac{1}{n} A R^{2/3} S^{1/2}$
Freeboard equation, F= $\sqrt{(C\ y)}$
Where, F = freeboard height in ft, y is the depth of water in the drain in ft, and C is a coefficient varying from 1.5 for a drain capacity of 20 cfs to 2.5 for a drain capacity of 3000 cfs or more.
Empirical Method (Aziz, 1975and Garg 1976)
Empirical formula was suggested by Hardenberg:
$P_f = P_p(1 + r)^n$
Where, P_f= Future population
P_p= Present population
r = Probable rate of yearly or decade increase
n = Number of years

LIMITATIONS OF WORKS

Some limitations we encountered during the study period to complete research work according to the selected objectives. These limitations are described below:

- Few studies were conducted related to water logging and drainage system;
- No sufficient secondary data were collected relating to past drainage system in terms of width, length, depth, capacity, pick flow rate, drainage coefficient and layout etc. ;
- Lacking of detailed elevation data of the projected area; and
- Introversion and low participation of interviewee during the questionnaire survey.

RESULT AND DISCUSSION

The maximum discharge at peak rainy season= 42 m^3/sec,
The waste water from the projected catchment area= 10 m^3/sec.
Thus, total discharge at peak rainy season= 42+10= 52 m^3/sec.

The existing Mirza Canal has been redesigned through analyzing and calculating the collected data. The new design parameters those have been found are as follows-
Freeboard of Channel= 1.17 m,
Total depth of Channel= 4 m,
Effective cross sectional area= 24 m^2
Effective wetted perimeter=13 m
Effective hydraulic radius= 1.84 m

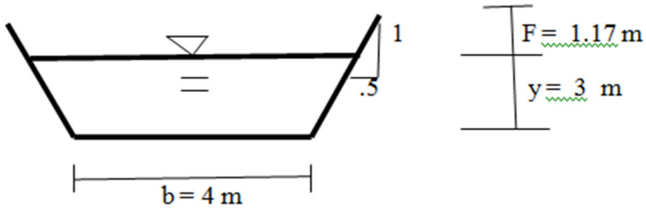

Fig. 2: cross section of the proposed canal

Mirza Canal includes many places where excessive bend has taken place. Formation of excessive bend reduces water velocity that leads to siltation and vegetation in canal bed. It shrinks effective depth of canal, eventually reducing the normal flow passage of water. Illegal construction work on the bank of the canal is another cause that reduces effective carrying capacity of canal. The artificial cut off at the excessive bent points may be a solution that could lessen the canal length and sharp bend. As a result, waste water would be flown smoothly.

Fig.2:Vegetation problem inMirza Canal

Fig.3: Solid waste disposal in MirzaCanal

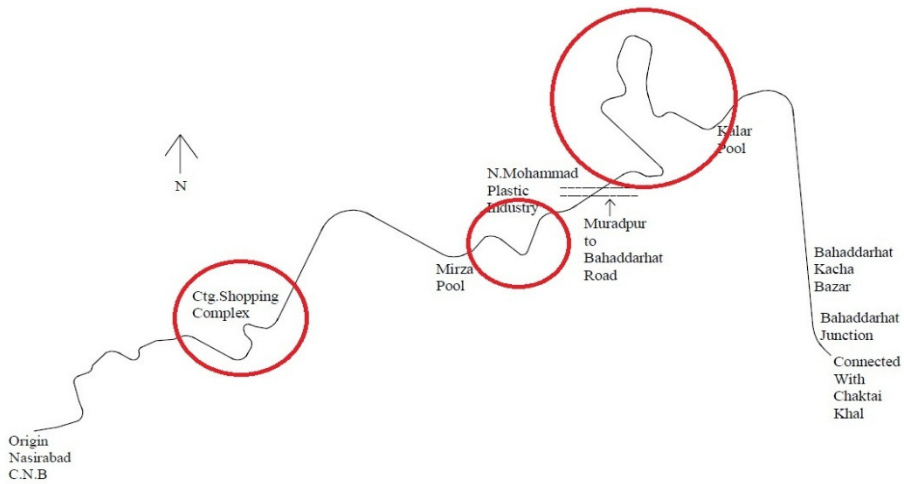

Fig.4 : Existing alignment of Mirza Canal

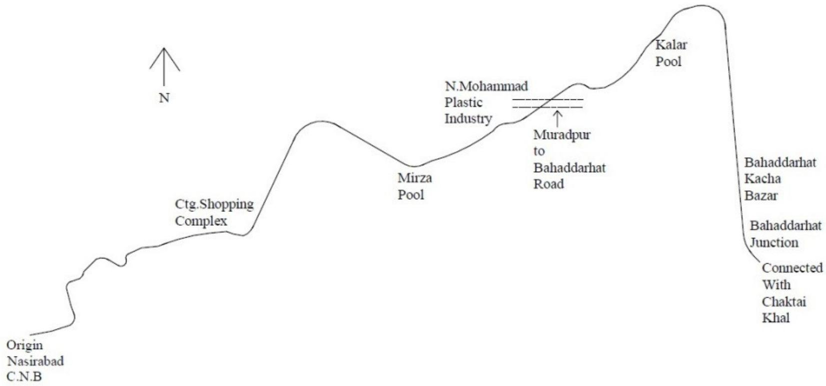

Fig.5: Proposed alignment of Mirza Canal

CONCLUSION

Drainage system has become one of the most inalienable parts of any city now a day. With the advancement of modern civilization, the requirement of proper and efficient drainage system is getting high. Due to rapid urbanization with unplanned construction, most of the existing drains & canals in Chittagong city have been encroached, filled up, diverted those impedes to the smooth flow of water to the outfall-rivers. Thus, severe water-logging creates in the city every year during monsoon and it induces adverse social, physical, economic and environmental costs. to mitigate the water logging problem along with new canal excavation and maintenance of existing drains, awareness is required regarding detrimental effects of solid waste dumping into drains, encroachment, fill-up, diversion etc. Thus, proper maintenance of drain along with public awareness are the key factors to make the drainage system efficient and to increase its design period.

ACKNOWLEDGEMENT

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STORM WATER DRAINAGE OF ARMY HOUSING SCHEME IN JOLSHIRI ABASHON

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ABSTRACT
Water logging and drainage problem is a regular phenomenon for any newly developed area in Dhaka city. Jolshiri Abashon situated in flood plain between Blau and Shitalakshya which previously used as storage of Drainage discharge of the Dhaka city. So development of this area for accommodation purpose has some adverse effect to the environment as well as the water logging problem. The elevation of the area is increased above the high flood level of the Balu River to overcome the flooding problem. Besides the some new cannel are constructed which has divided the area into small parts. The peak Runoff of the each sub catchment is determined using the model SWMM. It's also determined using the modified rational formula to check the accuracy of the model and hence it is observed that these two values are closed enough. Design of the drainage conduit is the prime objective of this study. This is done by the using the model simulated value of flow and depth and scatter plot comprising the flow of the conduit with the sub catchment runoff and node depth with the link flow measurement. During the monsoon (May to October) the drainage discharge from the Dhaka city and over all catchment areas may increase the high flood level (HFL) of the Balu River. Drainage operation at that condition become difficult as the water level of the Cannel is significantly lower than the HFL of Balu River. To overcome this problem automated pumping stations are introduced in each outlet.

Keywords: SWMM Model; Design of Drainage Conduit; Drainage Operation.

INTRODUCTION

Flooding is the major problem of most of the cities in Bangladesh during monsoon. It appears to a severe tormentor to the common people especially in Dhaka city. Drainage contraction and reduction of the flood plain clinch the problem badly. The first master plan was prepared to protect the developed area of 75 km^2 from floodwater and to drain internal storm water (DPHE, 1968).In 1981 "Dhaka Metropolitan Integrated Urban Development Project" was completed in which a framework for the future Urban Development of Dhaka was prepared and future detailed study for the drainage system improvement was recommended.As the existing storm water drainage system is still inadequate for coping with the recurring heavy storms and flood.JICA, (1887), carried out a study on storm Water Drainage System Improvement Project in Dhaka City to solve the water logging problem. LBI, 1991, A FAP (8B) study was undertaken to identify drainage, flood protection. After that (Das and Islam, 2010), analysed the Proposals of FAP 8B Project of Dhaka and Present Context of Retention Pond Areas and Cannels. After the devastating flood of 1988, the government adopted a program under FAP-8B to protect Dhaka city from flooding. Surface Water Modeling Centre (present IWM), (1997), carried out a pilot study about Storm Water Drainage Modeling for Dhaka city and analyzing drainage system together with suggestion of alleviation scenarios to relieve flood problems. Olofsson, (2007), investigated the hydraulic impact in an urban drainage system due to presumed increase in intense rainfall in Sweden. Besides several other studies was conducted by (Qualili, M.U.R. 1998; Islam and Hossain, 2001; Ahmed, 2011; Mowla and Islam, 2013). In those studies they have investigated the causes the drainage problem in Dhaka City and Check the adequacy of existing storm water drainage facilities. The proposed site of the Army Housing Scheme is situated in a flood plain between Balu and Shitalakshya River. The reduction of the flood plain may contribute to water logging. So, flooding is the prime problem in this regard. The main objectives of this study with regard to the study area are-: i) to estimate the maximum runoff for different sub catchments ii) to design of the drainage network and iii) to assess the drainage operation during flood period.

METHODOLOGY

Overview of the Projected Area

The study area AHS Jolshiri Abashon a unique residential project for the members of Bangladesh Army is located in latitude 23.804118 and longitude 90.502159 on Naora, Rupganj next to Gajaria in RAJUK planned greater Dhaka City [Fig. 1]. The average elevation of the area is 7m above the Mean Sea Level (MSL) and covered an area of about 8612976m^2. Where the high flood level of the Balu River is 6.5m MSL. The internal Drainage pattern is flood affected by Balu River in monsoon. It has many internal canals which are passing through the terrain connecting with the Balu and Shitalakshya. Those canals divided the land in small unit. It is flooded in high tide and in monsoon season when the rainfall is very high.

The proposed site of the AHS in Rupganj includes designated flood flow zone, water bodies and rural homesteads, where no construction or earth-filling is permitted by the Dhaka Metropolitan Development Plan. The Dhaka Metropolitan Development Plan (DMDP) designates the area as flood flow zone for controlling pollution in Shitalakkhya river and protecting it as a viable alternative source of potable water for Dhaka city.

Fig.1: View of the Project Area from Google Earth

Model Setup

To determine the storm water drainage here Storm Water Management Model (SWMM) is used.

For simulating the model and to full fill objectives model required some input data those are: sub catchment, conduit, junction, flow divider, cut off divider, overflow divider, rainfall, land use map and outfalls.

Method of Determination

SWMM uses the Manning equation to express the relationship between flow rate (Q), cross sectional area (A), hydraulic radius (R), and slope (S) in all conduits*(EPA.2014)*. For standard SI unit:

$$Q = \frac{1}{n} A R^{2/3} S^{1/2} \quad (1)$$

For pipes with Circular Force Main cross-sections either the Hazen-Williams or Darcy-Weisbach formula is used in place of the Manning equation for fully pressurized flow*(Chow, V.T. 1959)*.

Pump design formula is provided below:

$$WHP = (Q \times H)/3960 \quad (2)$$

Where WHP is the Wheel Horse Power, Q is the peak discharge (m^3/s), H is the total head (m).

The Modified Rational formula for calculating the peak discharge-

$$Q_P = C_S \times C_R \times I \times A/360 \quad (3)$$

Where, Q_P = Peak flow (m^3/s), C_S = Storage coefficient,C_R = Runoff coefficient, I = Rainfall Intensity (mm/hr),A = Catchment Area.

RESULTS AND DISCUSSIONS

The study so far undertaken have attempted to determine the max runoff of each sub catchment, design of the drainage conduit and pumping operation in high flood condition. From the Status report of the model it is found that the maximum runoff is obtain for 2h time interval rainfall simulation. The volume of total runoff of the catchment is V=179.3 ha.m. The study area has five catchment divided by the cannel network. For simulating purpose three of the five catchments are divided in equal part hence the runoff of these catchments are equal. The runoff values of each sub catchment are given in Table 1.

Peak runoff from different sub catchments is further used to design the conduit and node depth corresponding to the joining point of different conduits.

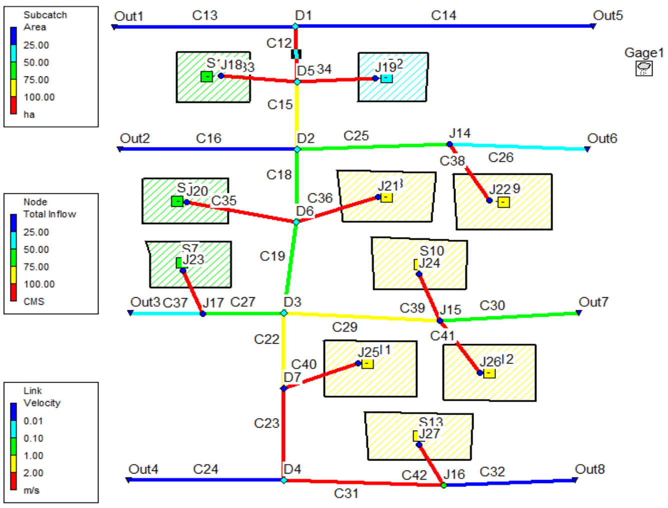

Fig. 2: Schematic diagram of the project

Table 1: Runoff value for different sub catchment

Sub catchment ID	Total infiltration mm	Total Runoff Mm	Total Runoff 10^6ltr	Peak Runoff m^3/s
S1	1.70	237.32	130.53	12.18
S2	1.60	237.95	117.31	10.92
S6	1.65	237.67	137.61	12.82
S7	1.65	237.67	137.61	12.82
S8	1.62	237.82	221.18	20.60
S9	1.62	237.82	221.18	20.60
S10	1.63	237.77	221.13	20.60
S11	1.57	238.09	202.38	18.83
S12	1.57	238.09	202.38	18.83
S13	1.59	238.01	202.31	18.83

Table2: Node depth at various sections

Node	Type	Average Depth (m)	Maximum Dept(m)	Maximum HGL(m)
J23	JUNCTION	0.55	0.95	4.95
J24	JUNCTION	0.89	1.61	5.61
J25	JUNCTION	0.88	1.59	5.59
J26	JUNCTION	0.77	1.37	5.37
J27	JUNCTION	0.84	1.54	5.54
Out1	OUTFALL	0.31	0.62	0.62
Out2	OUTFALL	0.31	0.62	0.62
Out3	OUTFALL	0.32	2.00	2.00
Out4	OUTFALL	0.31	0.68	0.68
Out5	OUTFALL	0.31	0.62	0.62
Out6	OUTFALL	0.29	0.90	0.90
Out7	OUTFALL	0.31	0.62	0.62
Out8	OUTFALL	0.30	0.65	0.65
D1	DIVIDER	3.23	3.73	0.73
D2	DIVIDER	3.30	3.74	0.74
D3	DIVIDER	2.34	7.50	5.49
D4	DIVIDER	3.22	3.86	0.86
D5	DIVIDER	2.28	2.76	0.76
D6	DIVIDER	2.34	7.50	5.50
D7	DIVIDER	2.28	2.90	0.99

Node depth at various sections is given below: A profile plot is a graphical data analysis technique for examining the relative behaviour of all variables in a multivariate data set. Profile plots provide another useful graphical summary of the data. Profile plot for water elevation from Node D5 to J18 is given in Table 2. From the Profile Plot it is observed that the elevation of the conduit is increased from RL -2m to RL 5m with the increase of the distances from sub catchment to the main channel network. As the elevation of the sub catchment is higher than the channels mean water level.

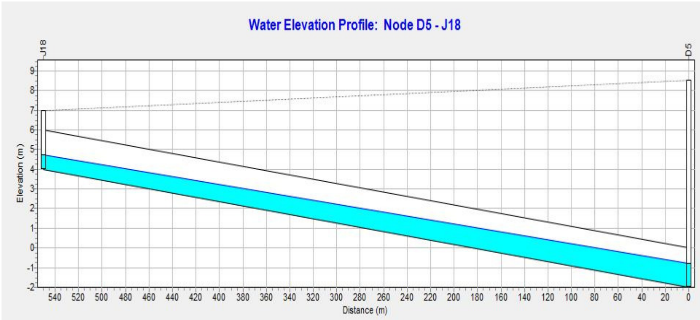

Fig. 3: Profile Plot for Water elevation Node D5 to J18

Design of the Conduit

The maximum depth occupied by a conduit say C34, considering series of four conduits instead of a large conduit for practical purpose. So the design depth of the conduit connecting the sub catchment to the main channel network is considered as 0.50m. Design depth of others conduits with respective flow are given below in tabulated form. Different conduit design depth with respect to flow in each conduit is shown in Table 3. Final back drop image of the study area with different design depth of conduit indicated by different colour pattern is shown in [Fig. 4].

Table 3: Conduit design depth

Conduit Id	Flow in each conduit (m^3/s)	Design Depth (m)
C33	12.17	0.60
C34	10.92	0.50
C35	12.82	0.60
C36	20.63	0.85
C37	12.42	0.50
C38	14.98	0.55
C39	20.60	0.85
C40	18.89	0.80
C41	18.43	0.70
C42	18.83	0.80

Pump Operation

By operating the drainage system in adverse effect 2HP pumps are selected at each outlet of the channel. The total head which is observed according with the elapsed time is plotted as shown in [Fig. 5].

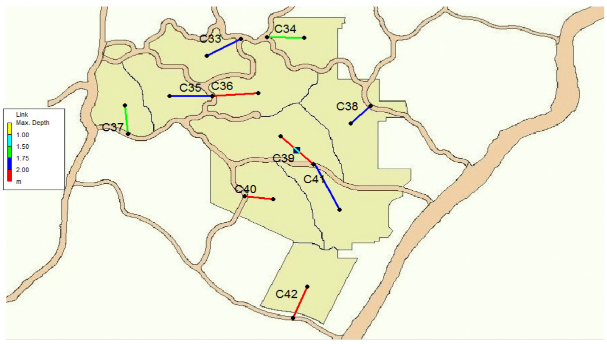

Fig.4: Final design of the Conduit

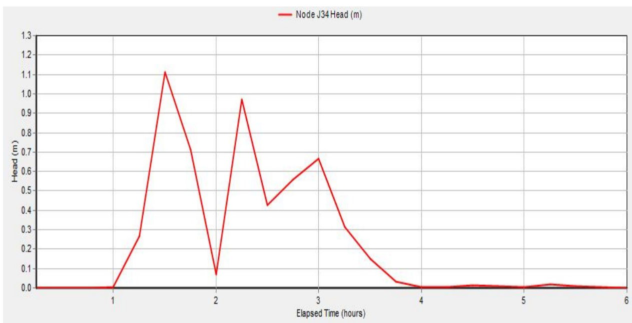

Fig.5: Head vs Elapsed Time curve

Peak Discharge from the Modified Rational Method

Here the model simulating values are checked for accuracy. For sub catchment S1, Run-off value in computed by rational method *(Subramanya, S.K. 2008)*. Peak Run-off values being calculate for 6-hr rainfall distribution for 10years return period. Peak discharge generated from Sub catchment S1 is 12.05 m^3/s.Where the model simulated value is 12.18 m^3/s.Here the model estimated value is reasonably accurate for determination of the peak discharge of the Sub catchments. So model can use for determination of the drainage discharge and hence the drainage depth of each conduit correspond to the sub catchments.

CONCLUSIONS AND RECOMMENDATIONS

Unplanned urbanization has adverse effect to the runoff generation and storage pattern and drainage system of the whole area. Implementation of the project may introduce drainage problem of the Dhaka city as well as the study area. So, it is more important to develop the Management and maintenance system. This ensures a smooth drainage system by periodic observation. The storage capacity of the drainage canals are above the required capacity of the rainfall runoff generated from the catchment. Thus, the drainage facility of the cannel is adequate to operate in normal condition. Model simulated design flow is similar to those estimated with the manual calculation using Modified Rational Method. The design depth of the each conduit keep 0.5 m larger than the model simulated value for considering any future adverse condition that may increase the dry weather flow with the increase of the intensity of rainfall. Pumping facilities provided are automated system. When the water level of the BaluRiver is increased above the mean design water level of the canal the flap gate of the outlet get closed and the pump will be operated. As the land use pattern has changed drastically. It is required to simulate the model to estimate the land use pattern and hence calculate the contributing area for SSDSs. Waste disposal and processing system should be developed. Different urban drainage simulating model such as HydroCAD, ICPR, StormCAD, HEC-HMS, and HEC-RAS can be used instead of SWMM for storm water drainage modelling.

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SEASONAL WATER LOGGING PROBLEM IN AN URBAN AREA OF BANGLADESH: A STUDY ON PABNA POURASHAVA

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ABSTRACT
More than half of the world's populations now live in urban areas. Cities are lifelines of society and engines for economic growth. However, rapid urban growth poses many challenges to city authorities and if not well managed, cities can become generators of new vulnerabilities and hazards. Disasters are acute problem in most countries of the world. Bangladesh is probably the most disaster prone in the world. Pabna is one of the oldest Pourashava in Bangladesh. Temporary and seasonal water logging is a common phenomenon of this Pourashava like many others urban area of Bangladesh. Due to this phenomenon people have to face physical and economical loss with lot of sufferings on a specific session. The present study give an overall scenario of water logging in Pabna Pourashava and try to find out the specific causes of water logging and its impact is different sector in several scales. The causes of water logging will play an important role for identifying the solution of this hardship situation along with improving the socioeconomic conditions of the peoples of that water logged area.

Keywords: Water logging; Urban Area; Drainage System; Pabna.

INTRODUCTION
More than half of the world's populations now live in urban areas. Cities are lifelines of society and engines for economic growth. However, rapid urban growth poses many challenges to city authorities and if not well managed, cities can become generators of new vulnerabilities and hazards (Mortaza, 2001). Disasters are acute problem in most countries of the world. Bangladesh is probably the most disaster prone in the world. The geographical setting of Bangladesh makes the country vulnerable to natural disasters. Water logging is one kind of disasters (Anisha, 2014). Water logging is not just related to heavy rainfall and extreme climatic events; it is also related to changes in the built-up areas themselves. When the water cannot go off because of any kind of constrain it makes a water logged condition in that places. In some part of Bangladesh, it is observed temporary water logging during heavy rainfall or a specific season and in some other part it is observed permanent water logging caused heavy rainfall. It is the continuation of natural and manmade disaster. The severity of natural and man-made water logging enlightens in different sectors like economic, social, industrial etc (Gazi, 2014). The water logging of Pabna city is one of the eye catching matters for the Pabna municipality authority. In rainy season, it creates a lot of problems for the inhabitants of this area. It hampers their economic activities and as well as day to day life. As a result water logging is a very emerging issue and it is very often occurred in almost every urban area of Bangladesh. So it is quite rational to deal with water logging and its economic effects and consequence. The objectives are: to identify reasons and consequences of water logging problems in Pabna Pourashava area and to suggest some recommendations to mitigate water logging problem in the study area.

METHODOLOGY
Before going to a final study a procedural setup has to be fixed to undertake the possible all work to fulfil the objectives. Criteria fixation, types of data collection, time duration, quantity of data etc. are some major tasks have to be done.

This organizational setup and working procedure is called as methodology as our concern. The scoping study relied on both primary and secondary information. Primary data was collected through reconnaissance survey, direct observation, stakeholder and community consultations and key informant interviews. Secondary data was collected from different sources including published and unpublished literature, different databases, newspapers and the World Wide Web. Secondary information, preliminary stakeholder discussions and field visits led to selection of preliminary study sites for detailed baseline study. At this stage, an inventory of the peri-urban characteristics, vulnerabilities and major concerns were discussed in field visits by the study team. Urbanization and climate change impacts were considered with a particular focus on heterogeneity of land use, mixed institutional arrangement and livelihood linkages between urban and peri-urban areas. Finally the study attempts to suggest some policy guideline that could contribute to remove water logging problem to the study area as well as others urban area of Bangladesh.

Study Area

Pabna Pourashava is located between $23^0 53''$ N and $24^0 05''$ N Latitude and $89^0 09''$ E and $89^0\ 25''$ E Longitudes. It is bounded by Shalgaria and Laskorpur beyond the river Ichamoti on the North, Dakshin Ramchandrapur on the South, Arifpur-Mahendrapur-Madarbaria on the East and Hemayetpur and Pailanpur on the West part of the Paurashava. Pabna Paurashava is a land of mixed topography. The Ichamoti river is passing through the middle of the Pourashava along the north-south direction. But presently this river is in dead condition. The Ichamoti river is filled with water weeds and siltation. The river is lost her navigation during the long years.

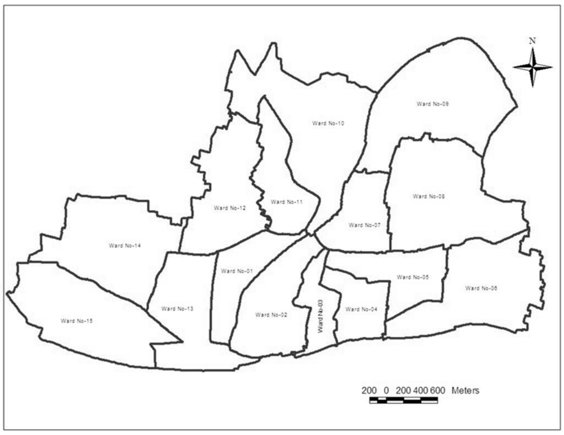

Fig.1: Pabna Pourashava Area

External flood is not likely to occur in the Pourashava area. Ichamoti river has been blocked due to BWDB cross dam near Ataikula. The downstream part of the river silted up by encroachment during the long agesb. Erosion is not occurred in the Pourashava area. The Ichamoti river has already been lost her natural levy in many years ago. Other rivers like Padmar kul, Shib Ganga river and Arifpur river are embanked at different section. So, erosion is absolutely absent in Pabna Pourashava area. Pabna enjoys a tropical monsoon type of climate where mean annual rainfall is 1521mm and annual mean temperature is about 25.08^0C.

Table 1: Mean Monthly Rainfall and Temperature of Pabna Pourashava (BBS,2011)

Month	Rainfall (mm)	Temperature (^{0}C)	Month	Rainfall (mm)	Temperature (^{0}C)
January	5	16.4	July	292	28.5
February	22	20.0	August	224	28.7
March	35	24.9	September	314	28.2
April	70	28.6	October	129	26.6
May	165	29	November	18	22.7
June	241	29	December	6	18.3

RESULTS AND DISCUSSIONS

Success and Failure of Drainage Master Plan

Urban Development Directorate (UDD) prepared a Master Plan for Pabna Pourashava under Upazila Town Master Plan for the first time in 1987 with the support of Ahmed Associates and Consultants Ltd. On that plan in the “Drainage, Sewerage, Water and Electricity” field the plan recommended to work out a special drainage plan for the city using the Ichamoti river. After that especially a Drainage Master Plan for Pabna Pourashava was prepared in 1993 under Secondary Town Infrastructure Development Project (STIDP). Local Government engineering Department (LGED) was the main custodian of the project and funded by Asian Development Bank (ADB). According to the drainage master plan seven major drains were constructed out of eighteen proposed drain.

Main Proposal of that Drainage Master plan was:

- ✓ New secondary drains will be constructed/ developed along Ali Bordi road, Tipu Sultan road, Fazlul Haque road, Aorangojeb road, Amirgaroan road, Talukdarpara road, Shayesta Khan road, Sir Salimullah road which will enable the storm water discharge to be efficiently drained out from the core area of the Pourashava.
- ✓ The river Ichamoti will be re-excavated to proper slope and size to accumulate runoff from the Pourashava area following a proper drainage network.
- ✓ The existing katcha drains throughout the Pourashava area have to be progressively upgraded with RCC lining.

After reviewing the Drainage Master Plan- 1993, it is found that Pourashava have implemented only 30% drains as per Drainage Master Plan. Lack of financial resources was the prime cause for non-implementation of drainage master plan proposals. Physical surveys were carried out by Pourashava authority in both the core and fringe areas of Pabna Pourashava in order to identify and prepare a physical inventory of existing physical infrastructure facilities in terms of drainage, culverts and bridges (Table 2).

The Ichamoti River serves as main drainage channel of the surface runoff for the Pourashava area. At some of the places, the waterways namely secondary and tertiary drains are obstructed by solid wastes, encroachments etc., resulting in decreasing the discharge capacity of the drainage capacity of the drainage system and eventually creating inundation of water. Inundation of water in some places are causing environmental hazard.

Table 2: Types & Length of Drains

Sl No	Drain Type	Length (Km)
01	River	7.9
02	Borrow pit	3.25
03	Primary Drain	11.29
04	Secondary Drain	56.23
05	Tertiary Drain	28.16
	Total	106.83

Source: Drainage Inventory Survey, 2007

It should be mentioned here that the Pabna Pourashava area has no proper drainage system. In the core areas drains lies along the bank of the river Ichamoti. As the Ichamoti River is found to be a dead channel, there is no possibility of backflow from the river Ichamoti. There are some borrow pits namely bypass borrow pit, Radhanagar borrow pit along the PI road and police line-technical borrow pit. Arifpur khal which outfall into the Padmar kul river.

Flooding and Water Logging Situation

Inundation occurs due to localized storm rainfall and also due to other causes affecting drainage system within Pabna Pourashava. External flood is not likely to occur in the Paurashava area. Ichamoti river has been blocked due to BWDB cross dam near Ataikula. The downstream part of the river silted up by encroachment during the long ages. During the peak monsoon period only internal flow occurs at some part of the Pourashava and creat water logging. Erosion is not occurred in the Pourashava area. The Ichamoti river has already been lost her natural levy in many years ago. Other rivers like Padmar kul, Shib Ganga river and Arifpur river are embanked at different section. So, erosion is absolutely absent in Pabna Paurashava area. Some major water logging area of Pabna Pourashav are as follows:

Pathortola	Uttar Shalgaria	Name of the location
Old passport office road	Islamic Degree college area	Thongapara area
Doharpara	Homiopathy Medical College area	Noynamoti area
South Raghabpur area	Radhanagar area	Pailanpur area
Arifpur area	Chatiani area	Mental hospital area
Jorebangla area	Kismotprotappur	

Table 3: Average frequency of water logging in Pabna city (in percentage)

Total word	Percentage of area which affected in Every year (%)	Percentage of area which affected in By annually (%)	Percentage of area which affected in every five years (%)	Total affected households (%)
15	86	8.4	5.6	56

(Source: Field survey, 2016)

Table 4: Affected area in respect of average duration of water (in percentage)

Total word	1 Day Avg.	1-3 Days Avg.	3-15 Days Avg.	15-30 Days Avg.	More than 30 Days Avg.	No water logging Avg.	Total households
15	44.6	11	4	0.9	1.5	38	100

(Source: Field survey, 2016)

Existing Drainage Network and Outfall

Since long, storm water of Pabna city had been drained out through some natural drainage (e.g. creek and khal). But during the last three decades most of these natural drains are either filled up or encroached by human intervention. Some of them are replaced by narrow surface drains. But the overall drainage system in the city has not been developed and maintained properly keeping in pace with urbanization. Due to rapid urbanization and increasing development these natural drainage and other water retention areas are gradually being converted into built up areas.

Among these disappeared natural drains are well known and effectively contributed to washout storm water from certain part of Pabna city is now filled up for construction of road or development of residential areas. As a consequence of disappearance of these natural drains, some parts of the city already mentioned are subject to annual water logging during intense rainfall particularly in the late monsoon.

It is evident that poor drainage network along with others reasons such as encroachment on drainage paths, inadequate drain sections, absence of adequate number of drainage outlets, lack of proper maintenance of existing drainage system, disposal of waste into drainage paths are the major causes for water logging in Pabna city.

Causes of Water Logging

There is no doubt about the precise effect of water logging. The summarized information from the expert person, focus group discussion and the visual observation describes the actual causes of water logging.

- The sedimentation of Ichamoti River is the main cause of water logging in Pabna city.
- There is no proper drainage facility in Pabna city. Drainage system of the city is not well established. Most of the drains has blocked with several waste materials.
- The existing drains are too narrow to outlet large volume of water.
- There is no furnished outlet way of water which causes water logging.
- Some political bound also exists in creating barrier for water logging.
- There are no proper activities to pump out the water in rivers.
- There are no enough natural water reservoirs to hold that large amount of water during the rainy season.
- No Government priorities and initiatives are taken to solve this serious water logging problem in Pabna city.

Consequences of Water Logging

Water crisis and spread diseases

The environmental quality is degrading day by day because of water logging. The floating plants in water making the water dirty and this dirty water act as a breeding heaven for the mosquitoes. In rainy season, the drains are filled with rain water and sometimes it overlapped on the road. As a result it creates serious environmental degradation. For water logging the available drinking water become highly contaminated and lead to shortage of pure drinking water. Water borne diseases such as Cholera, Diarrhea, skin diseases etc breakout in an epidemic form.

Poverty

During water logging a large number of people cannot go their working place. The day-laborer cannot go out in search of livings. Then they become unemployed and cannot afford daily expenses. Sometimes it washes away their physical properties. It is the direct threat for on the local economy.

Roads and Transport Management

About two-thirds of the road networks of the study area become affected due to water logging. Holes are created due to stagnant water on the roads making those very risky and the roads remain unrepaired for many days.

Sewerage Management Collapsed

The overall sanitation condition of Pabna city is being well. But people face a lot of problems for their sanitation facilities in rainy days. During water logging it becomes difficult to provide solid waste management facilities because there's water all around. On other hand, it is observed that most of the household wastes are thrown on drain. It not only creates environment problems but also creates blockage on the drain. As a result water cannot move freely and drain out in the rainy season resulting severe water logging.

Disturbance in Education System

Education also becomes hampered due to water logging. When the problem is severe the students cannot attend the institutions. Government schools, several private cadet schools and high schools and many coaching centre are established within Pabna city. They face a lot of problems for going outside in rainy season. As a result, their education is seriously hampered.

Effect on infrastructure

Mosques, temples, several renowned private companies (e.g. Square, Universal), business buildings, small readymade garments etc are located within Pabna city which face a lot of dirt related problem caused by water logging.

Mitigation Measures

The impact of water logging may cause permanent vulnerability on human being as it is affected the surroundings economy, income generating activities as well as overall socio-economic condition directly or indirectly changes the nature of ecosystem. The government should take proper initiatives to solve the problems of water logging. The government should also take immediate action on the basis of causes of water logging. In this regard the following mitigation measures may be effective either combined or individually:

- Creating proper drainage system so that the water can be shift away easily
- There should be communication of water flow among the rivers.
- As a number of people affected by water logging by income generation, there should be create alternative livelihood for them through Government initiatives on the basis of water resources.
- As there is a manmade cause behind water logging the overall population of the areas should be aware about the impacts of water logging.
- Solid waste management should be conducted properly so that water can flow easily at their natural speed,
- we have to concern about the proper run-off of rain water which creates water logging on the road;
- Initiate formulation of a comprehensive action plan for the sustainable recovery of the affected people

CONCLUSION

Water logging problem is not a new phenomenon at current time. Over the last few years the study area is flooding and the water logging problem has become a common phenomenon. Diversity in livelihood options including dependence on urban resources, urban-peri-urban hydrological linkages, urban-peri-urban water use nexus, and vulnerability to water stress is some of the major characteristics of our study area.

With the help of new drainage system and linkages among the other wards, a good drainage system should be developed. The incomplete drainage is one of the major causes of water logging. The connections between water bodies, river to river water free channel, and good working capacity of institutions regarding water related issues must have introduced for the sake of the above analysis. This report is been prepared intentionally to find out the relative consequences of water logging and remedy measures can be taken by various responsible authorities present in Pabna city. This report mainly address the vulnerability issues, present condition, emerging factors to be dealt with and to assess the vulnerabilities and monitoring framework to find out the way to mobilize the risk in the community.

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A CASE STUDY ON WATER LOGGING IN WARD NO.12 OF PABNA MUNICIPALITY

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ABSTRACT
Water logging is one of the most common problems in Bangladesh. Increased urban development's not providing sufficient drainage system to reduce water logging problems. This causes naturally large infrastructural problems for an area. Water logging creates adverse social, physical, economic and environmental impacts. Disruption of traffic movement and normal life; damage of structures and infrastructure; loss of income potentials are the effects of water logging on the life of the study area. Inadequate drainage sections, conventional drainage system with low capacity and gravity, natural siltation, absence of inlets and outlets, indefinite drainage outlets, lack of proper maintenance of existing drainage system, and over and above disposal of solid waste into the drains and drainage paths are accounted for the prime causes of blockage in drainage system (WARPO, 2005). This study will give a clear idea of the current drainage system of the ward no 12 and will also be helpful for identifying the responsible factors of urban drainage congestion. Besides this study will attempt to find out proper mitigation measure for the existing problem. Upper level decision-makers as well as development partners will be able to use the findings of this report for future policy recommendations. The highlight features of the urban area of Pabna Municipality is water logging and the existing drainage system, many of the drainage line are connected with "Ichamoti River". The water logging brings some negative impact on the physical environment. The overall condition of our study area is becoming poor in rainy season. If the water logging increases more and more in our study area, the area will face a serious problem in a very near future.

Keywords: Water logging; Pabna Municipality; Drainage problem; Blockage; Water flow.

INTRODUCTION
Pabna District is a district in north-western Bangladesh. Water logging has become a severe problem in Pabna Town with the increase of the Population and the number of increasing buildings. It has made this district more congested also. The drainage system of the Pabna Municipality is becoming worse day by day due to unscientific land use system in the town. Mainly in the central portion of this town, there is a river named "Ichamoti" but it's has no current flow but the drainage water flow of the whole municipality's slope is running in this river. This river can't catch the whole discharging water coming from the drain. Rainfall and consequently there leads a bad condition for the existing livelihood group. As a result this municipality (ward no 12) area is badly affected in water logging after a small rainfall. All of the urban area in the our country are experiencing water logging for the last few years even a little rain is causing a serious problem for certain areas(Tushar.A, 2001). It is very difficult to cope with the increased urban development and along with to provide a sufficient drainage system. Objectives of this present study are: to identify the existing condition and responsible factors of water logging in the study area. and to provide some guidelines to remove the blockage of existing drains and promote the water flow of existing primary, secondary and tertiary drains.

BACKGROUND OF THE STUDY AREA
Our study area is 12 no. ward of Pabna Municipality. People are engaged in several occupations. This area is seriously affected by water logging due to the rainy season. Water logging is especially

responsible for land use change of our study area. It hampers their economic conditions and day to day life. The 12 no.ward of Pabna Municipality is taken as the study area because it affects a large community. This ward is densely populated with an approximate house hold of 2354(BBS, 2011). We select this study area should have extensive water logging and where the water logged area is large enough to affect the area. The main cause of water logging is run off rain water. The drainage system of this ward is not well designed. Due to the unconcern of people, most of the drain are blogged by sever ways. So, the water cannot drain away to the "Ichamati" river and that is why the water is over flowed on my study area and makes the water logging. Average maximum temperature 36.8 °C, minimum 9.6 °C; annual rainfal 1872 mm in Pabna District (BMD,2009).

GENERAL INFORMATION ABOUT THE STUDY AREA

Our study area is situated in the Pabna Municipality. The communication network is well enough to develop the economic activity of the area. The area is divided into four villages.

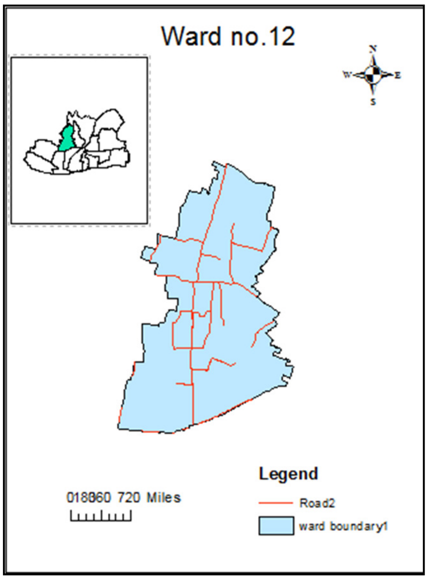

Fig. 1: Map of the study area

Table 1: The Climatic Condition of Pabna District

Climate data for Pabna District													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average precipitation mm	19	18	34	56	159	300	260	294	242	201	17	3	1,603
Average relative humidity (%)	45	36	39	44	59	73	74	76	72	68	52	49	57.3

METHODOLOGY

In this study, both primary and secondary data has been used. Since water logging is a natural, as a result the study is mostly depended on primary data and information. It would also help to identify the drainage pattern and the trend of water logging and changing pattern of ward no 12 in Pabna Municipality. Secondary data collection includes necessary maps collection, detailed information about drainage pattern, duration of water logging, frequency of water logging, types of water logging areas etc. These information are collected several important institution of Pabna town such as Pabna Municipality and Water Development Board. After collecting data from primary and secondary sources, all have been processed in a certain manner. Several valuable analyses are also conducted to extract a meaningful report from the raw data. After the analysis of data, a draft report was prepared and submitted to supervisor for necessary correction. After completing these entire correction final has been prepared.

Table 2: Some basic information of ward no. 12

Ward no. 12 of Pabna Municipality (at a glance)	Category	Data
1	Total Household	2354
2	Total population	9662
3	Male-female ratio	98
4	Percentage of literacy rate	66%

RESULTS AND DISCUSSIONS

During heavy rainfall various depth of water logging are seen. The highly waterlogged depth areas are from the Shideshwari Temple to the Radhanagar Wazed Ali road, central part of the Chackpailanpur Mathpara road, Naynamoti road, Lebu Sipahi road. In these areas water is at the height of knee length and even if the drains are over flow a small precipitation. It causes the direct adverse effect to the transportation system and daily life. At the time of monsoon it happens at high level where the areas are low lying and poor sewerage system. On the other hand the Pailanpur road, south Naynamoti area, Powerhouse road areas are satisfactory.

Water Logging Zone

Wazed Ali road: The major road that runs towards the Govt. Edward College and there is a left turn that is from the Adwarshaw Girls' High School this is Wazed Ali road. In this road the water logging is maximum . The width and the structure of this drain so poor.

Chalkpailanpur road: Not only the drainage condition but also the road condition is seriously damaged. After a small rainfall the water level becomes the height of knee.

Lebu Shipahi road: It is one of the congested zone of water logging. Here width of the minor road is not very satisfactory.

Mathpara road: The population density is very high in this zone. Again the drainage condition and the accessory road is not pucka. Water remains stands a long time after precipitation.

Haji Akkel Ali road: There was a large ditch in this area. After constructing the drain of Naynamoti this ditch has filled up somehow or the owner of the land. As a result the water flow has damaged.

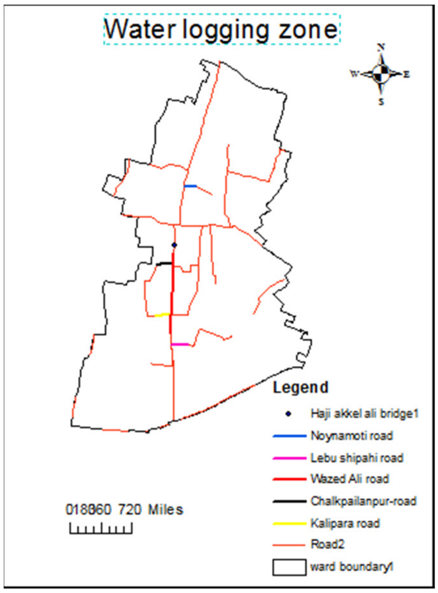

Fig. 2: Water logging zone map

Table 3: Duration of Water Logging in 12 no. ward (in Percentage)

Ward no	1-3 days	3-7 days	7-10 days	10 -15 days	More than 15 days	No water logging
12	73	34	21	12	2	35

Effects of Water Logging in this Area

- *Water Crisis* :the environmental quality is declined day by day because of water logging. The floating plants in water making the water dirty and this dirty water act as a breeding heaven for the mosquitoes. As a result it creates serious environmental problem. For water logging the available drinking water become highly contaminated and lead to shortage of pure drinking water.
- *Poverty:* During water logging a large number of people in our study area cannot go their working place. The day-laborer cannot go out in search of livings. Then they become unemployed and cannot afford daily expenses. It is the direct threat for on the local economy.
- *Road & Transport Management:*about two-thirds of the road networks of our study area become affected due to water logging. Holes are created due to stagnant water on the roads making those very risky and the roads remain unrepaired for many days.
- *Sewerage Management Collapsed:* the overall sanitation condition of 12 no. ward is being well. But people face a lot of problems for their sanitation facilities in rainy days. During water logging it is impossible to compose solid waste management of our study area because there is water all around.

Table 4: Sewerage Management System (in percentage)

Ward no	Households	Sanitary(with water seal)	Sanitary (no water seal)	Non-sanitary	None
12	2353	48.7	31.4	18.6	1.3

- *Disturbance in Education System: Education* also becomes hampered due to water logging. When the problem is severe the students cannot attend the institutions. As a result, their education is seriously hampered.
- *Effects on Infrastructure:* All these infrastructures face a lot of problem caused by water logging. Semi-pucka and kutcha houses are greatly damaged by the water logging. For this reason, the infrastructures have been spoiling in this area. *Effects on Solid Waste Management:* In our study area there are about 25 dustbins. In the rainy season, the drain water comes into the road due to the drainage problems. As a result waste materials are mixed with the drain water. Several diseases are breakout

due to this horrible management system. We can see that most of the households throw their wastes on drain. It not only creates environment problems but also creates blockage on the drain. As a result drain water cannot move freely in the rainy season and creates water logging.

Table 5: Toilet facilities in the area (in percentage)

Ward no.	Number of Household	Pucka	Semi-pucka	Kutcha	Jhupri
12	2354	25.2	33.7	40.2	1.0

RECOMMENDATION

The impact of water logging may cause permanent loss on the surroundings economy, income generating activities as well as overall socio-economic condition directly or indirectly changes the nature of ecosystem. The government should take proper initiatives to solve the problems of water logging. The government should also take immediate action on the basis of causes of water logging. There should be communication of water flow among the "Ichamoti" river within the municipal area. Creating proper drainage system so that the natural water can be shift away. As there is a manmade cause behind water logging the overall population of the areas should be aware about the impacts of water logging. Solid waste management should be conducted properly so that water can flow easily at their natural speed have to concern about the proper run-off of rain water which creates water logging on the road; Initiate formulation of a comprehensive action plan for the sustainable recovery of the affected people. Give box culverts or pipe culverts will be required to cover the drain. The existing drains and also those will be constructed shall have to cleaned at regular interval. The Municipal authority will monitor the water level of "Ichamoti" Rivers, record the drainage congestion area of each significant storm, and maintain the existing river and also will have institutional linkages with all relevant line agencies such as BWDB, LGED and in particular with DPHE in connection with operational planned system and for maintenance of appropriate section all through its natural drainage routes.

CONCLUSIONS

Water logging in 12 no. ward has profoundly affected people of all Socio-economic background. There has been far reaching consequences of water logging on both natural and social environment. Due to water logging the income, employment and livelihood pattern of the people of our study area is dramatically changing that has significant implications on economy. The water logging brings some negative impact on the physical environment. So, logged water is a threat for public health, different production and biodiversity, etc. healthy living environment could not arise there and privacy was usually lacking. The using water is also becoming unhygienic and non-use able. The overall condition of our study area is becoming poor in rainy season. If the water logging increases more and more in our study area, the area will face a serious problem in a very near future.

ACKNOWLEDGMENTS

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IMPACTS OF OVERFLOWING OF CHAKTAI KHAL

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ABSTRACT

Chittagong is called the commercial capital of Bangladesh. The economic and financial growth of Bangladesh largely depends on it. But overflowing in rainy season from different drainage systems creates adverse effects on the surrounding areas and on the roads badly which affects the economy of the country. For ensuring a normal city life, overflow must be prevented by any means. The present investigation on the overflowing of Chaktai Khal reports the identification of the causes of overflow and finding out the existing alignment. It also includes the identification of bad impacts created by overflowing of Chaktai Khal on its surrounding areas. The geometrical shape, existing alignment, impedance etc are observed physically to compare with the drainage master plan (1969) which was prepared under the guidance of Directorate of Public Health Engineering. From field investigation, it has been observed that illegal possession and construction work on the bank of the khal leads to excessive bend formation and reduction of width cause overflowing during rainy season. Besides siltation, vegetation, disposed solid wastes are the main causes of overflowing. A comparison has been made between the existing and 1969 alignment of the khal to see whether shape, alignment etc have been changed or not. Overflowing problem mainly affects on environment, social life, business sector, roads and communication systems. To eradicate the overflow problem, some remedial measures have been suggested.

Keywords: Chaktai Khal; water logging; Encroachment; Alignment; Drainage Master Plans (1969; 1995)

INTRODUCTION

Chaktai khal, considered to be the life-line of the Chittagong city as the main drainage system for removing rain water along with usual sewage outlet, has been choked with solid waste and filth along with encroachments causing overflow of water flooding both sides from Bahaddarhat to Chaktai areas. Chaktai, Khatunganj & Asadganj are the main seat of trade and commerce in Chittagong. But nowadays, Chaktai-Khatunganj areas, unlike in the past are losing their importance and failing to attract new business due to overflowing of Chaktai khal. Some of the occurrences in the recent past have shown in Fig. 1. City dwellers lamented that it now become a history that once high tide and flash flood passed and swept away all waste through Chaktai khal linked with the Karnaphuli river and goods-laden boats operated in the canals. The khal once served the business hub of Chittagong is now called grief of Chittagong City. People of surrounding areas face a lot of problems due to water logging created from overflowing of Chaktai khal.

Siltation, vegetation, topography, poor management system, lack of public awareness etc. are responsible for overflowing. Overflow causes various problems like disruption of traffic movement, disruption of normal life of the urban inhabitants, damage of structure, water pollution and increase of water borne diseases (Hossain & Palit, 2016). Hence, Department of Civil Engineering, CUET, has been taken an initiative to find out the causes of overflow of Chaktai khal and to provide some remedial measures.

Study Area

Chaktai khal is one of the most important natural drainage systems in Chittagong city. In this study, drainage system covers the area like Bahaddarhat, Chawkbazar, Bakalia, Chaktai, Asadganj, Khatunganj and up to confluence point of river Karnaphuli.

Fig. 1: Distress due to overflow of Chaktai Khal at Khatunganj

METHODOLOGY

The investigation is carried out on the study area in the following manner which is shown in Fig. 2.

Fig. 2: Work plan of the present investigation

The investigation has been done by observing the site physically. Chittagong Storm Water Drainage & Flood Control Master Plans (1969 & 1995) have been collected from CDA. Some major causes of overflow as well as its impacts have been identified & shown in the paper. Then existing alignment has been prepared by using field investigation data such as bearings, approximate length, width etc. Studying the Drainage Master Plans (1969 & 1995), a comparison between existing and previous condition has been prepared.

Field Investigation Data

The site of the Chaktai khal has been observed physically and various dimensions like canal width, depth, silt depth, RL of the canal bed & top have been measured at various distances starting from Bahaddarhat junction to confluence point of the Karnaphuli River. This information has been shown in Table 1.

Table 1: Essential information of Chaktai khal collected from field survey

Location	Distance (ft)	Width (ft)		Depth(ft)			Total Depth (ft)	Canal Top RL (ft)	Canal Bed RL (ft)
		Existing	1969 DMP	Water Depth	Avg. Silt	Water to Wall Top			
Bahaddarhat *(Police Box)	*Starting	21.5	31	1.64	0.66	6.56	8.86	21.5	14.14
	590	45	60	0.82	0.50	6.56	7.87	45	25.13
	852	46	75	0.50	0.33	5.90	6.73	46	20.27
	1246	39.5	68	0.98	0.50	6.56	8.10	39.5	11.90
	1640	36	45	0.98	1.31	3.94	6.25	36	16.75
	1950	34.5	46	1.15	0.50	6.56	8.20	34.5	8.80
	2100	34	46	2.13	1.15	3.61	6.89	34	13.11
	2428	43	44	2.46	0.82	5.00	8.28	43	11.72
Hares Shah Mazar Lane	2822	44	50	1.15	0.50	5.00	6.56	44	16.44
	3642	46	68	3.28	0.98	5.00	9.20	46	23.80
Bakalia	3872	43.5	69	3.94	0.94	4.30	9.30	43.5	10.70
Chawkbazar	4790	39.5	67	3.94	0.66	3.94	8.54	39.5	18.46
Dewanbazar	8070	44.5	37	3.28	0.98	5.90	10.20	44.5	12.80
	8200	46	39	4.10	0.82	5.00	10.00	46	20.00
	8430	36	37	2.79	1.15	6.00	10.00	36	17.00
	8988	40	50	2.46	1.31	6.60	9.56	40	17.44
Master Pool	9250	59	61	1.64	0.66	6.56	8.86	59	14.14
Mia Khan Nogor	11710	43	80	2.62	1.64	6.54	10.80	43	12.20
	11841	52.5	89	2.62	1.64	6.54	10.80	52.5	16.20
	12333	43	101	2.00	0.82	8.20	11.02	43	21.98

Table 1: Essential information of Chaktai khal collected from field survey

Chaktai area	12825	43	110	0.66	1.31	6.54	8.54	43	21.46
**Confluence	14137	99	152	0.33	0.33	9.90	10.56	99	12.44
Point	**14465	187	101	0.50	0.33	10.00	10.83	187	6.17

Comparison Between Existing & Previous Conditions (Dmp-1969) of Chaktai Khal

From Table-1, it is found that the reduction of canal width is up to 50 feet. The difference between canal bed RL of starting and confluence point is only 8 feet that was 46 feet in DMP' 1969. The variation of RL from starting to end is not uniform. So, the existing bed slope is not sufficient to flash out water into Karnaphuli River.

Causes of Overflow

Overflowing occurs mainly during the period of heavy rainfall. The drainage system can't drain out of excess water. Also during monsoon period, tidal flows enter into the natural drainage systems which are connected with the Karnaphuli River. Inadequate drainage system, excessive bending, inadequate bed slope, siltation, vegetation, inadequate maintenance, lacking of interconnectivity of various drainage systems etc. are responsible for overflowing.

Excessive Rainfall

Heavy rainfall is one of the main reasons for water logging in Chittagong City. Relatively low intensity of rainfall also causes serious water logging problems for certain areas of the city. The capacity of Chaktai khal is not sufficient to drain out huge rain water.

Disappearance of natural drainage system

Rapid population growth, unplanned development & land filling to develop new residential areas and encroachment on khals with unauthorized construction are the summarized general man made physical and social activities related to the disappearance of natural drainage system.

Siltation Problem

Siltation mainly occurs at the concave side of bending due to lower velocity at that side. Siltation problem reduces the width of the canal. So that Chaktai khal lost its capacity and increased impervious area due to siltation. Significant amount of siltation in Chaktai khal has taken place during the last few years which is shown in the following Fig. 3.

Silt with Vegetation Problem

Water logging tends to exclude oxygen from the soil and plants have evolved many ways to deal with this, leading to the evolution of hundreds of specialist wetland and waterside species which is known as vegetation. Vegetation problem arises after siltation takes place in the canal. Many places along the Chaktai khal are covered by the vegetation problem which is illustrated in Fig. 4.

Solid Waste Disposal

Municipal solid waste consists of household waste, construction and demolition debris, sanitation residue and waste from streets along the Chaktai khal is creating obstacles in the flow path of water is shown in the Fig. 5.

Inadequate Maintenance

Inadequate maintenance of existing natural drains due to lack of planned maintenance program,

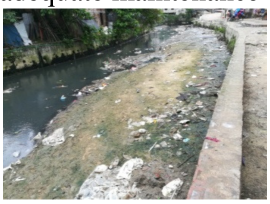

Fig. 3: Siltation

Fig. 4: Vegetation

Fig. 5: Solid waste

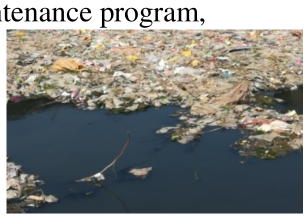

Fig. 6: Inadequate Maintenance

equipments, adequate budget, staffing, proper monitoring program and institutional set up to effectively operate and maintain the drainage network. There is often poor communication and co-ordination between the different urban authorities responsible for operating and maintaining the various components of the drainage network. This is shown in Fig. 6.

Impacts of Overflow

Rapid urbanization disrupts natural drainage pattern. Natural water course are spoiled, and existing drainage system can't drain excess water and it results overflow. The increase in volume and rate of runoff causes erosion and siltation which accelerate overflow problem. Due to overflow; problems like disruption of traffic movement, damage of structure, water pollution and increase of water borne diseases appears.

Social problem

Overflow invades various social sectors. People endure the brunt of bad drainage through direct flood damage, pollution of water supplies and the aquatic environment, the breeding of vectors and soil erosion. It also disrupts normal traffic movement which is shown in Fig. 7 & 8.

Physical problem

Overflow accelerates the damage of structures, infrastructures and underground service lines. It contributes to ground heave, subsidence and dampness. Metalloid pipes of various underground utility services are damaged and lose longevity. Water logging causes damage of roads (both paved and unpaved) in rainy season which interrupts journey. Serious damage of road has occurred in many locations near Chaktai Khal. Roads are greatly damaged that is shown in Fig. 9.

Fig. 7: Social problem

Fig. 8: Communication problem

Fig. 9: Road damaged by water logging

Environmental problem

Overflow attacks the environment by polluting water, spreading water borne diseases. Storm water gets polluted as it mixed with solid waste, clinical waste, silt contaminants and sewage from overflowing latrines and sewers causing pollution and wide range of problems associated with water borne diseases. People cannot get pure potable water because surface water and shallow groundwater sources are polluted due to water logging. Contamination of groundwater also leads to adverse health impacts.

Economic problem

Water is an economic burden. Water logging reduces the life span and damages the roads and metalloid pipes of various underground utility services such as water, telephone, sewerage etc. It requires a huge cost to replace these facilities. The city authority had to spend about taka 7 to 8 billion every year to replace and maintain infrastructures damaged by water logging. Damage of sub structures, brick foundations, houses in slums due to water logging means the huge economic losses for the inhabitants.

Business problem

Water logging causes serious havoc at the port city's main business hubs Chaktai and Khatungong damaging essential commodities inside the water houses. Due to heavy downpour and water logging in June 2017 causes a loss over taka 100 crores. Khatungong and Chaktai alone faced a financial loss of about taka 70 crores. Above scenario shows the burden of overflow in business sector which leads to serious economic loss to the country.

ALIGNMENT OF CKAKTAI KHAL

Fig. 10 shows the alignment of Chaktai khal. It is collected from Flood Control and Strom Drainage Master Plan for Chittagong Area (Southern Sector, Map No-20). Based on field investigation data, an existing alignment is prepared that is shown in Fig. 11.

Fig. 10: Alignment of Chaktai khal according to 1969 Drainage Master Plan

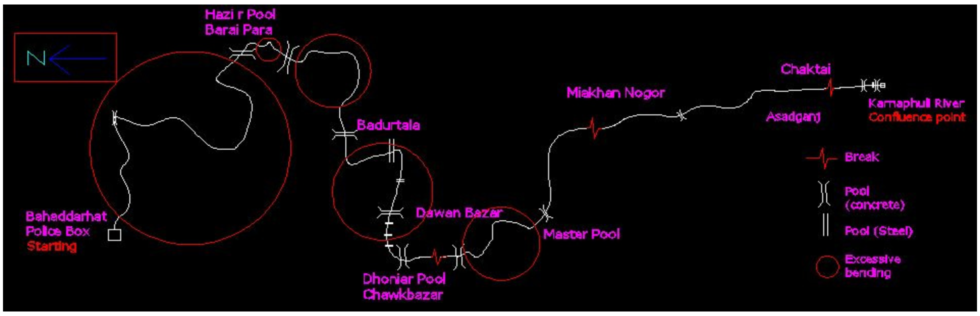

Fig. 11: Existing Alignment of Chaktai khal

Remedial Measures

The Chaktai khal which earlier had a depth of 50 feet (DMP-1969) has now become as shallow as 10 feet. As a result the canal becomes unable to pass the water fully in a normal way due to the obstruction in natural flow path and turning into a wide flow path into a narrow one. Due to the high tidal flow in full moon water level rise to great extend which submerge vast area causing immeasurable trouble. Following are the some remedial measures proposed to minimize the problem.

Reducing excessive bends

Chaktai khal comprises many places where excessive bend has taken place. The excessive bends along Chaktai khal should be reduced by ensuring that the bank of the canal is free from illegal possession. The channel with excessive bends can be abandoned by the formation of a straighter and shorter channel or by introducing artificial cut-off. Five important junctions have been identified and shown in Figure 12 where artificial cut-off can be applied to reduce the excessive bend. The proposed alignment after artificial cut-off is shown in Fig. 13.

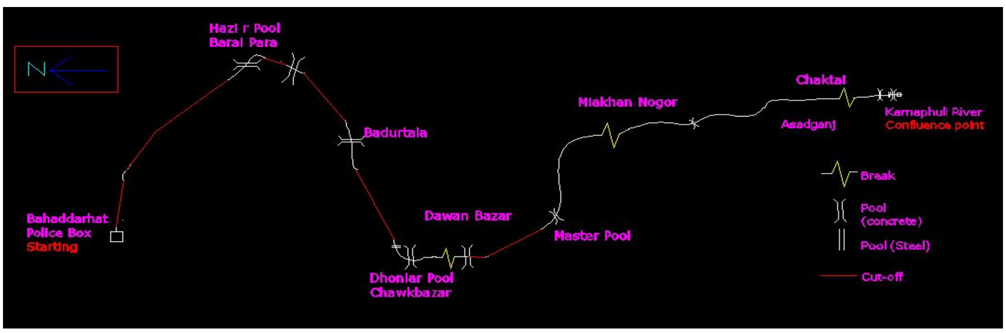

Fig. 12: Proposed Alignment of Chaktai khal

Silt trap construction

Silt trap can be placed at that point of the canal where siltation occurs frequently. It has a basket with an approximate 50 liters capacity which is easy to remove, ensuring simple, low cost servicing and maintenance of the canal. When water flows along the canal, carrying silt, the silt will be trapped into the box. Regular cleaning of the box will help to keep the water depth sufficient enough.

Overall remedies

Construction of abutment wall, lining of side slope, reprofiling of downstream end of the khal and bed lowering up to the river Karnaphuli were proposed for Chaktai khal (1995 Drainage Master Plan). A 21 meter wide tidal regulator with the provision of a navigation gate at the mouth of the Chaktai khal (1995 Drainage Master Plan). Rehabilitation of secondary khals flowing into the west of the Chaktai khal was proposed (1995 Drainage Master Plan). Since RL of confluence point at Karnaphuli River and starting point at Bahaddarhat junction point is not much higher, as a result during tidal period of the Karnaphuli River, roads are flooded. So, road level is to be higher than that of existing level.

Drainage capacity of Chaktai khal is not sufficient. So, by measuring actual discharge & using rainfall intensity, runoff coefficient etc, the khal should be redesigned. Proper disposition of solid waste have to be ensured and the inhabitants should be motivated for cooperation for maintenance of drainage system. Illegal construction works near the bank of the khal have to be stopped and connectivity between the existing drainage systems near the khal should be developed. By installing landing berth at important places, Chaktai khal can be used for mass transit.

CONCLUSION

Inadequate drainage system, excessive bending, inadequate bed slope, siltation, vegetation, inadequate maintenance, lacking of interconnectivity of various drainage systems etc are mainly responsible for overflowing. The amount of encroachment is up to 50 feet. The concerned authority should ensure proper monitoring program to stop illegal construction works.

There is insufficient interconnectivity between the existing drainage systems of areas surrounding the Chaktai khal. Overflowing effects on environment, social life, business sector, roads and communication systems etc. Providing sufficient bed slope, reducing excessive bends, construction of silt trap, tidal regulator & landing berth etc. are some remedial measures to eradicate overflowing problem.

Moreover, coordination among CDA, CCC, CWASA & WDB is required to solve this problem.

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ESTIMATION OF THE CHANGES IN WETLANDS OF DHAKA CITY FROM LANDSAT IMAGES

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ABSTRACT
Wetlands form a unique mosaic of habitats with an extremely rich diversity of flora and fauna, which are invaluable components of the environment, ecology, resource potential and biodiversity in Bangladesh. Wetland systems are vulnerable to changes in quantity and quality of their water supply, and it is expected that climate change will have a pronounced effect on wetlands through alterations in hydrological regimes with great global variability. Especially, wetlands of Dhaka city have experienced significant changes in recent periods, which has triggered the heat island effect. This study aims to detect the change in wetland areas of Dhaka city using the Landsat images of post monsoon period of the year 1988, 2002 and 2016. For identifying the wetlands, threshold value of Normalized Difference Water Index (NDWI) has been used. Analysis revealed that the wetland area of Dhaka city has been decreasing day by day. Almost half of the wetland areas have been converted into other land uses during 1988 to 2016. In 1988, 43.08% areas were under wetland category, where it has reduced to 26.97% in 2002 and 12.13% in 2016. The decreasing rate of wetlands is 71.84% between these 28 years. For this significant reduction of wetlands, the microclimate of Dhaka city has experienced warming, urban heat island effect in concise. Habitats of diversified flora and fauna have destroyed. Moreover, it has destroyed the connectivity among the water bodies of Dhaka, which may cause severe waterlogging problem in Dhaka. Urban flooding may induce by this change in wetlands as they are not capable of holding a huge amount of rainwater at present. So conservation of wetland areas is a prerequisite task to promote sustainable development plan for Dhaka city. Policymakers should focus on this topic before formulating any land use or detail area plan for Dhaka City.

Keywords: Dhaka; Landsat; NDWI; Waterlogging; Wetlands.

INTRODUCTION
Wetlands are the invaluable components of the environment, primarily controlled by water. The Ramsar Convention defined wetlands as “areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters” (Ramsar Handbooks, 2016). Wetlands have significant ecological and economic values. Wetlands are important for improving water quality, controlling flood, recharging groundwater, and retaining the sediments etc. (Curie et al., 2007). Wetlands are also the habitats of diversified ecosystems. Moreover, they support the livelihood of millions of people engaged in diverse activities in the wetlands.Dhaka, the capital of Bangladesh had numerous wetlands, which has beenreduced significantly over the decades due to the fast growth of urban areas (Kamal and Midorikawa, 2004; Dewan and Nishigaki, 2006). Rapid urbanization of Dhaka city causes the unplanned transformation of thelandscape without considering the possible consequences and requirement for environmental sustainability (Sultana et al., 2009). Urbanized area means impervious surface and shorter runoff time, which increases susceptibility to flood hazard (Nirupama and Simnovic, 2007). Encroachment of wetlands for various urban uses exaggerates the risk of urban flood and

waterlogging. The previous disastrous floods in Dhaka city are believed to be the result of infilling the low lying areas (Dewan and Yamaguchi, 2008). The rapid rise in urban population is one of the major driving force for the expansion of the city towards the surrounding floodplain and low-lying areas (Islam et al., 2012). So the regular monitoring of wetland areas is very vital for sustainable wetland management system (Das and Pal, 2016). Remote sensing technique with its vast time series data provides a great opportunity to identify the wetlands and to detect the change within and surrounding the wetlands (Wenbo et al., 2013). Wetlands can be detected by both the feature classification method and thematic information detection method (Feyisa et al., 2014). Thematic information detection method employs several indices that automatically detect wetlands considering corresponding threshold values (Rokni et al., 2014). Normalized Difference Water Index (NDWI), Normalized Difference Moisture Index (NDMI), Modified Normalized Difference Water Index (MNDWI), Water Ratio Index (WRI), Normalized Difference Vegetation Index (NDVI) and Automated Water Extraction Index (AWEI) are some examples of indices which have been used to detect wetlands in several studies (Feyisa et al., 2014; Gautam et al., 2015; McFeeters, 1996; Rouse et al., 1973; Shen et al., 2010; Wilson et al., 2002; Xu, 2006). Among these indices, NDWI has been proved to be best suited for water body extraction (Ahmed et al., 2017; Das and Pal, 2016; Rokni et al., 2016).Several studies have focused on the wetlands of Dhaka city and detected the change using GIS and remote sensing techniques (Hossain et al., 2012; Islam et al., 2010; Islam et al., 2012; Mahmud et al., 2011; Sultana et al., 2009). Due to its significant impact on the environment, wetland areas should be regularly monitored. So this study aims to detect the change in wetland areas of Dhaka city between 1988 to 2016 from Landsat images. The transformation from wetland to other land uses has been monitored and present uses of transformed areas have been discussed.

Study Area

A portion of Dhaka Metropolitan Area has been selected for this study, which can be extracted from a single scene (WRS2: 137/43) of Landsat Images (Fig. 1). The area of investigation is about 259 sq. km. Dhaka is one of the fastest growing cities, which has experienced rapid urbanization and changing nature of land cover (Ahmed et al., 2013; Alam and Rabbani, 2007). It is mainly located on the Modhupur terrace of the Pleistocene period, which is characterized by mainly flat land with the surface elevation ranging between 1 and 14 m (Dewan and Yamaguchi, 2008; FAP 8A, 1991). Four main rivers named the Buriganga, Turag, Tongi Khal and Balu surround Dhaka city. Dhanmondi lake, Ramna lake, Gulshan lake and Cresent lake are the main lakes of the city (Islam et al., 2010).

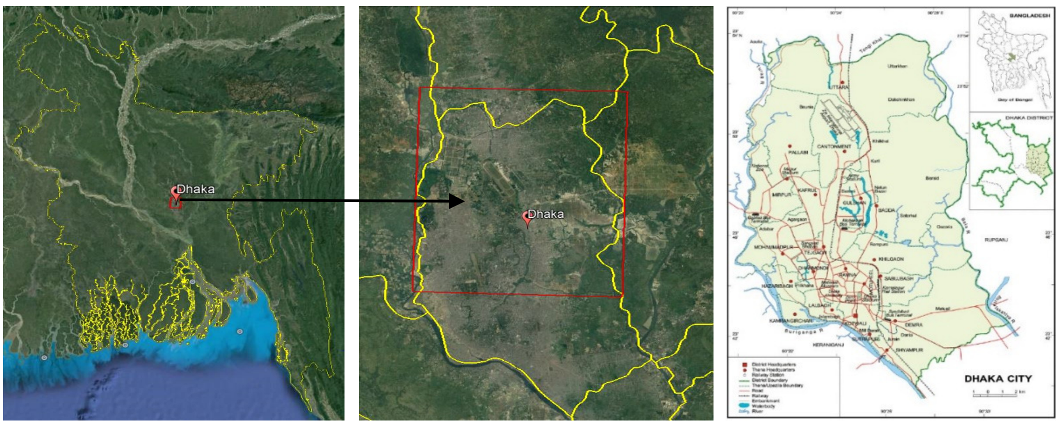

Fig. 1:Study Area (Part of Dhaka Metropolitan Area)

METHODOLOGY

For detecting the change in wetland areas of Dhaka city, Landsat images (WRS2: 137/43) of the year 1988, 2002 and 2016 have been collected from United States Geological Survey (USGS) Website (Table 1). All the images have spatial resolution of 30 m. The images were taken from same season as it is required for comparing images of different time period (Parsa and Salehi, 2016).Necessary radiometric correction has been performed prior to calculate NDWI as this study employs images of three different sensors. For converting the digital number (DN) values to reflectance values, standard procedures have been followed (Rahman and Ferdous, 2017).

Table 1. Information regarding satellite images

Sensor	Path/Row	Acquisition Date
Landsat 5 Thematic Mapper (TM)	137/43	16 October 1988
Landsat 7 Enhanced Thematic Mapper (ETM+)		31 October 2002
Landsat 8 Operational Land Imager (OLI)		14 November 2016

From the corrected Green and Near Infrared bands of Landsat images, NDWI has been calculated for the selected years. Then by applying threshold value (NDWI>0), wetland areas have been identified for the year 1988, 2002 and 2016. Change detection study has been carried out by area statistics. Change map between 1988 to 2016 has been prepared, which shows the common wetland areas and the areas that transformed from wetlands to other uses. Finally, the present land uses in the transformed areas have been identified from Google Earth and the impacts of change in wetland areas have been discussed.

RESULTS AND DISCUSSIONS

From the analysis of NDWI, it is revealed that 43.08% areas were under wetland category in 1988. In 2002, it reduced to 26.97%, which means around 42 sq. km. areas had been converted into other land uses between 1988 to 2002. The decreasing trend has been continued to 2016 too. Wetland areas reduced to 12.13% in 2016, resultingin transformation of further 38.4 sq. km. areas to other land uses. So 71.84% wetlands have been encroached by other land uses between 1988 to 2016, which leaves a significant impact on the microclimate of Dhaka city (Fig. 2).

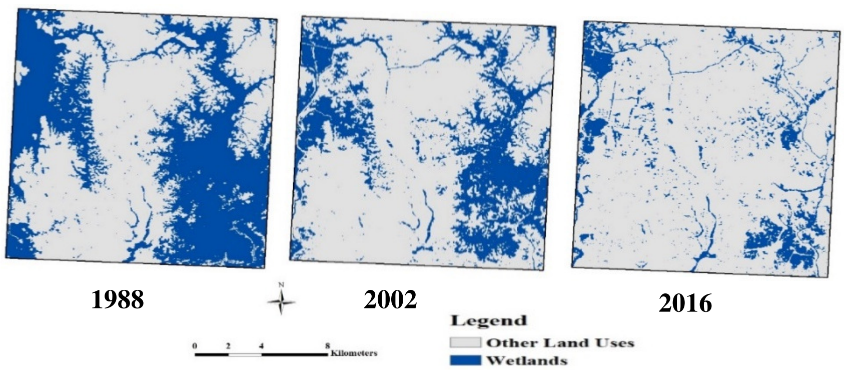

Fig. 2. Change in wetlands in Dhaka City between 1988 to 2016

Wetlands of Dhaka city were concentrated in the eastern and western part mainly in 1988. They reduced from both parts in 2002 and the wetlands of eastern part got almost vanished in 2016. The eastern part was proposed as retention basin in the city development master plan to keep the city free from urban flood (Dewan and Nishigaki, 2006). For the encroachment of this part, waterlogging and urban flood become severe problem in the rainy season in Dhaka city. The eastern part is converted into residential areas by different private land development projects. Bashundhara Residential Area, Lake City Concord, Pink City Model Town etc. are some of the housing projects that encroach the middle part of east Dhaka [Fig. 3]. South eastern part of study area has been encroached by Aftab Nagar and other housing projects of Rampura and Badda area [Fig. 3]. There are still some wetland areas in between the middle and south eastern part, which in future can be grabbed by other projects like Kapotakkha Green City and Jalshiri Abason or these existing projects [Fig. 3].The north western part of Dhaka city has been grabbed by Uttara Residential Model Town, which is expanding day by day by infilling the low lying wetland areas. South western part has also some housing projects like PC Culture Housing, Dhaka Uddan Housing etc.

[Fig. 3], which is the result of ground filling works in the low lying areas of Mirpur and Mohammadpur area (Kamal and Midorikawa, 2004).

Growing demands of urban population has created huge pressure on land for agricultural lands and residential area and infrastructure development (Das and Pal, 2016). Due to lack of documented record of wetlands, land grabbers can easily encroach the wetlands (Islam et al., 2010). Unplanned urbanization or housing projects have destroyed the connectivity of water bodies and compartmentalized the wetlands, which results in severe waterlogging and drainage congestion in Dhaka city in the wet season (Dewan and Nishigaki, 2006; Kamal and Midorikawa, 2004; Reza and Alam, 2002; Tawhid, 2004).

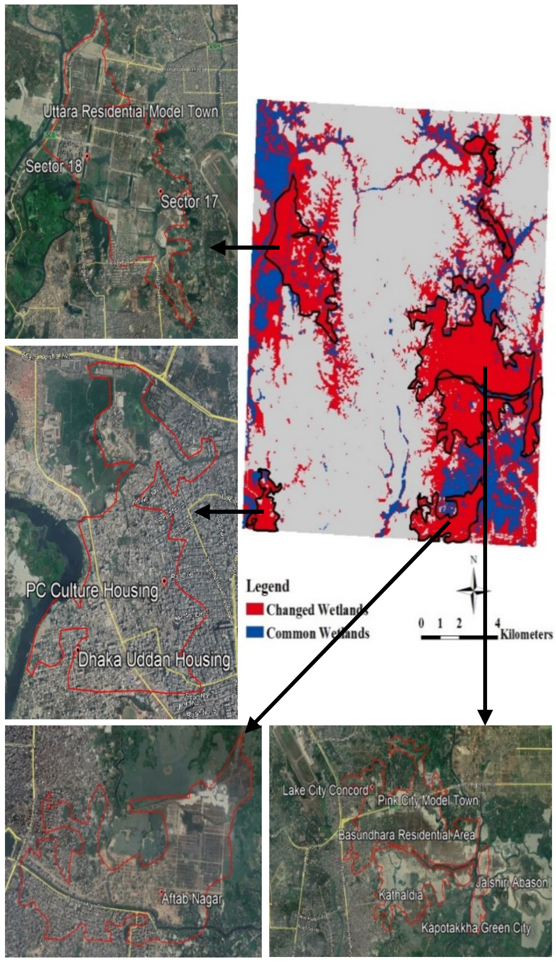

Fig. 3. Transformation of wetlands to other land uses between 1988 to 2016

Waterlogging has been identified as one of the major problem of Dhaka city (World Bank, 2007).The wetlands of Dhaka were distributed naturally such a manner that it could drain the rainwater efficiently to the large streams (JICA, 1991). But these wetlands have been filled up both for infrastructure development and housing projects to accommodate the increasing urban population (Kamal and Midorikawa, 2004; Mahmud, 2017). So they have lost their efficiency to drain out the rainwater and connection with the large streams, which is one of the major reasons of urban flood and waterlogging in Dhaka city (Dewan and Nishigaki, 2006; Islam et al., 2010). Every year the city dwellers experience waterlogging in the monsoon period and this problem is acute in the low lying areas which were infilled (Mahmud, 2017). Report stated that potential damage for waterlogging between 2014 and 2050 will be BDT 11,000 crore in Dhaka without considering the impact of intense rainfall due to climate change (Mahmud, 2017).Besides, due to the infilling in wetland areas the recharge areas for ground water has decreased significantly, which will lead to depletion in ground water level (Mahmud et al., 2011). So conservation of wetland areas is an essential task for Dhaka city which should be carried by both the Government and private sectors. Government should impose laws and regulations strictly and private sectors should oblige these.

CONCLUSIONS

Wetlands are the integral part of local ecosystem and habitats of rich diversity of flora and fauna. For its tremendous impacts on the environment, it should be conserved immediately. The rapid urbanization of Dhaka should be regulated by proper planning to stop the encroachment of wetlands by any development projects. Already Dhaka has lost 71.84% wetlands between 1988 to 2016, which is a threat for the environmental balance and the microclimate of Dhaka. This reduction of wetlands will result in accelerating the urban heat island effect, as spatial distribution of wetland and low temperature zone has a very good positive correlation (Cao et al., 2012). So to control the warming of microclimate and solve the waterlogging problem of Dhaka city, conservation of existing wetlands is must.

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ASSESSMENT OF HYDRO-GEOLOGICAL PARAMETERS AND GROUNDWATER QUALITY FOR SOUTH EAST AND SOUTH WEST REGIONS OF BANGLADESH

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ABSTRACT
Groundwater is the most essential input for drinking purpose, increasing crop production as well as for the sustainable agricultural development in the SE and SW regions of Bangladesh. Groundwater irrigation has probably been the most dramatic development in Bangladesh agriculture during the past 25 years. Groundwater will continue to be the most important water resource to help attain the Sustainable Development Goals (SDG) of basic water access for the poor people as well as securing water for expanding agricultural and industrial production. The main objective of this study is to assess hydro-geological parameters and groundwater quality for the South-East (SE) & South-West (SW) regions of Bangladesh for efficient planning, assessment and management of groundwater resources. In SW & SE regions the dominating water quality parameters are Arsenic (As) and Salinity. According to drinking water standard of Bangladesh for coastal area, the allowable salinity limit of drinking water is 1000 mg/l. For deep aquifer around 98.9%is within this allowable limit for SE region and40.3% for SW region. But for shallow aquifer only 2.3% is within this standard limit for SE region and 29% for SW region. Again in Bangladesh Standard, the drinking water limit of As is 0.05 mg/l. For deep aquifer around 96.3% is within this allowable limit for SE region and 81%forSW region. But for shallow aquifer only 20% is within this standard limit of drinking for SE region and 5.9% for SW region. The result demonstrates that SW region is more vulnerable to Arsenic & Salinity than SE region. Based on this study an important tool "Interactive Information System (IIS)" has been developed and effective training has been provided to the relevant professional from all the collaborative agencies (IWM, BWDB, WARPO and DPHE) which has been highly appreciated. This paper discusses the salient features of some of the important hydrogeological parameters for SE and SW regions of Bangladesh.

Keywords**:** Aquifer Vulnerability**;** SDG; Hydro-geological Parameter; Interactive Information System .

INTRODUCTION
Bangladesh, located mostly in the flood plains of the Ganges, the Brahmaputra and the Meghna Rivers, is one of the largest deltas in the world with a total area of 147,570 km2. The seasonal variation of availability of water, along with the competing demands of water for the water supply and sanitation, agriculture, industry, fisheries and wildlife, navigation, hydropower and recreation as well as the environment and the preservation of water bodies has made the water management and planning a very challenging task. Accurate estimation of hydro-geological properties (hydraulic conductivity, transmissivity, specific yield etc.) is a pre-requisite for sound and sustainable development of groundwater resources. Decision makers and planners need spatial distribution of hydro-geological information for groundwater development.

In view of that, it is an essential initiative and research for Determination of Hydro-geological Parameters for SW and SE Regions of Bangladesh: Phase-II. Hydro-geological data greatly help to delineate the geometry of the aquifer, groundwater levels and its evolution, the recharge, the flow direction (underground flow with the sea, drainage, underground flow towards the interior, groundwater abstraction by pumping) and the assessment of groundwater resources. Spatial Distribution Map of Land Use, Cropping Pattern, Soil Type, Specific Yield, Hydraulic Conductivity and Transmissivity, Hydro stratigraphic cross section and areal distribution of sub-surface formation, Hydro stratigraphic cross-section at different locations of the study area, Spatial distribution map of groundwater level and historical Groundwater Level Time Series Data, Database Interfaces and Analysis Tools have been obtained through this study.

DESCRIPTION OF THE STUDY AREA

The study area covers South-East Region and South-West Region of Bangladesh. The South-West Region lies between 20°38/ to 24°08/ N latitudes and88°35/ to 90°40/ E longitudes. The area is bounded on the north by the Ganges and the Padma River, on the east by the Lower Meghna and the Shahabazpur River, on the west by the Indian border and on the south by the Bay of Bengal. The South-West Region covers 130 nos Upazillas under 15 nos Districts and area is approximately 37,660 Km2. The South-East Region lies between 22°30/ to 24°00/ N and90°45/ to 91°31/ E. The South-East Region comprises an area 9,100 Km2 and covers 42 nos Upazillas under 10 nos Districts.

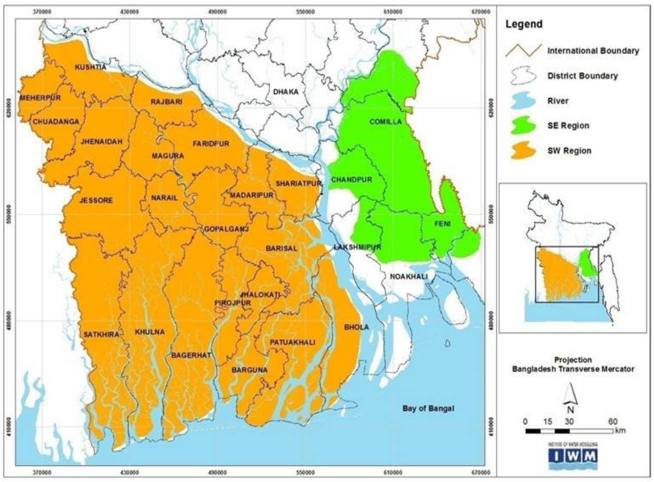


Fig. 1: The base map of the study area

It is surrounded by the Lower Meghna River in the west and the Upper Meghna River as well as the Titas River in the North. In the east, it follows the international boundary is defined by the Feni River. The base map of the study area has been shown in [Fig. 1].

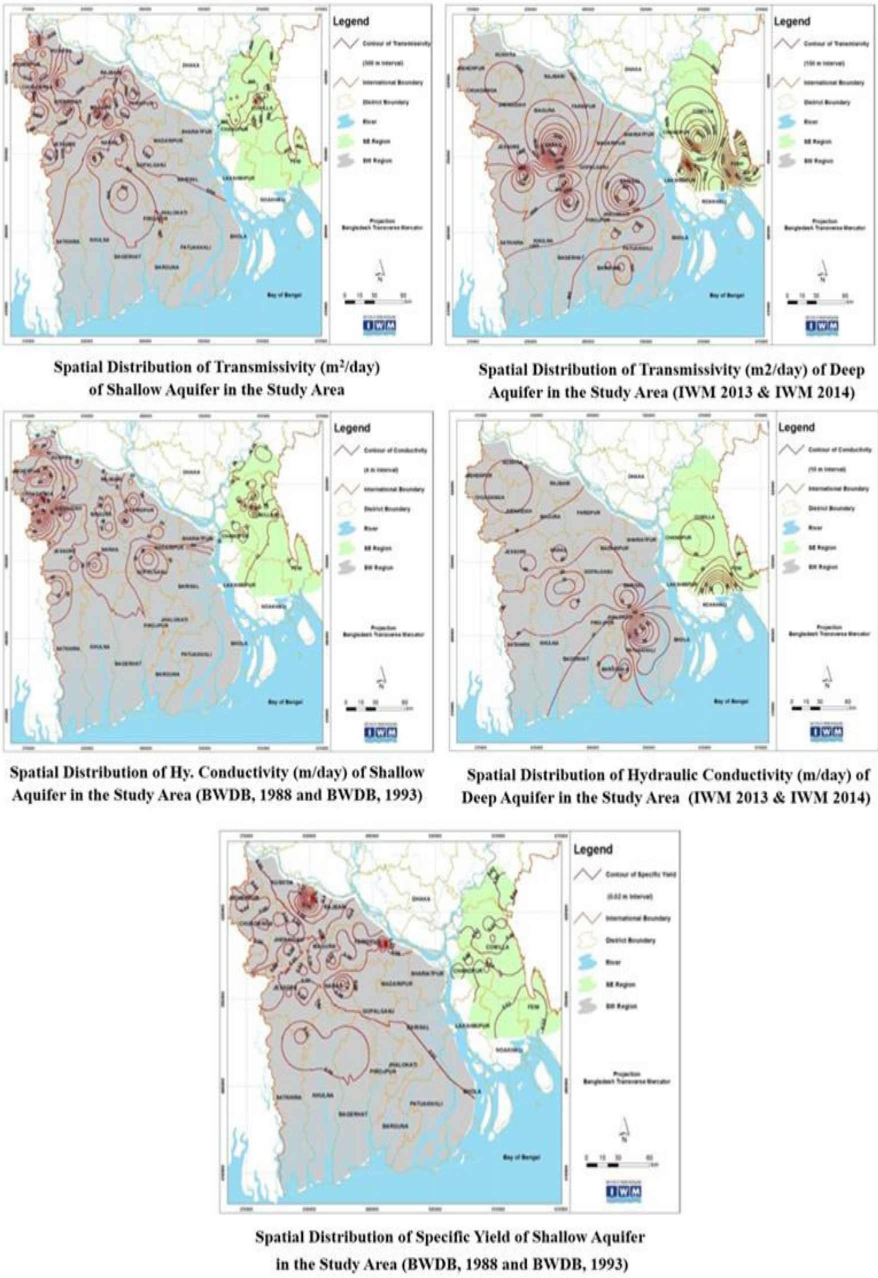
METHODOLOGY

The main component of this study is to assess lateral and vertical extent of main aquifer and its hydro-geological parameters for efficient planning and management of groundwater resources. For assessment and development of groundwater resources, accurate estimation of hydro-geological parameters for main aquifer is vital. In this respect, collection of hydro-geological data from relevant organizations is required. The agencies are mainly responsible for collection of hydro-geological data in Bangladesh are BWDB, BADC, DPHE, WASA and BMDA. Looking at the national importance of this project, this study has been carried out in collaboration with BWDB, WARPO and DPHE who have plenty of hydro-geological data, information and knowledge. They have contributed with data and resource personnel for establishing the hydro-geological parameters. In addition to the estimation of the hydro-geological parameters, analysis of groundwater level and water quality data have also been performed for assessment of suitability of groundwater resources. The other major component of this study is to develop a database interface and analytical tools for improved data management, precise analysis and effective dissemination of data. Science this study is based on secondary data, so collection of different data from respective organization and process of these data are the major tasks.

The major data collection works include: (i) Collection of Exploratory drilling and sediment sample data; (ii) Collection of Aquifer test data; (iii) Collection of groundwater level data; (iv) Collection of Groundwater quality data; (v) Collection of soil and land use data.

FINDINGS AND DISCUSSION

Subsurface sediment formations have been classified into different units considering its lithological variations and groundwater flow capacity. Total 62 nos of hydro-stratigraphic cross sections have been prepared for determining the lateral and vertical extent of the subsurface sediment formations in the study area. The study area covers the south west region and south east region. 30 nos of hydro-stratigraphic cross sections for South-West Region and 32 nos hydro-stratigraphic cross sections for South-East Region have been prepared. Chronologically hydro-stratigraphic units of the study area are as: Aquitard1, Aquifer1, Aquitard2 , Aquifer2, Aquitard3 and Aquifer3.



Spatial Distribution of Transmissivity (m^2/day) of Shallow Aquifer in the Study Area

Spatial Distribution of Transmissivity (m2/day) of Deep Aquifer in the Study Area (IWM 2013 & IWM 2014)

Spatial Distribution of Hy. Conductivity (m/day) of Shallow Aquifer in the Study Area (BWDB, 1988 and BWDB, 1993)

Spatial Distribution of Hydraulic Conductivity (m/day) of Deep Aquifer in the Study Area (IWM 2013 & IWM 2014)

Spatial Distribution of Specific Yield of Shallow Aquifer in the Study Area (BWDB, 1988 and BWDB, 1993)

Fig. 2: The Hydro-geological parameters for the study area

In the present study, after analysis of all borelogs data, 381 no. of borelogs data for the south-west region and 201 no. of borelogs data for South-East region were selected for defining the hydro-stratigraphic layers and as a result sub-surface geology of the study area has been defined by six hydro-stratigraphic layers. To define the geology of the upper aquifer data is taken from the borelog data collected by different organizations. For the deeper aquifer fewer nos of borelog data which is collected under present study have been used to define the deeper aquifer. The results are shown below in the [Fig. 2 & Fig. 3]. In SW & SE regions the dominating water quality parameters are Arsenic(As) and Salinity. According to drinking water standard of Bangladesh for coastal area, the allowable limit is 1000 mg/l. For deep aquifer around 98.9% / 40.3% portion is within this allowable limit and only 1.1% / 59.7% is beyond this limit for SE and SW region respectively. But for shallow aquifer only 2.3% / 29% portion is within this standard limit of drinking and 97.7% / 71% portion is beyond this limit for SE and SW region respectively. Again in Bangladesh Standard, the drinking limit of As is 0.05 mg/l. For deep aquifer around 96.3% / 81% portion is within this allowable limit and only 3.7% / 19% is beyond this limit for SE and SW region respectively. But for shallow aquifer only 20% / 5.9% portion is within this standard limit of drinking and 80% / 94.1% portion is beyond this limit for SE and SW region respectively. *SE region is also considered as a coastal region because most of its area falls on coastal zone except some areas and for SW region all calculations have been done excluding Sundarban because no data on water quality and bore-logs have collected from/in Sundarban. Analysis of data of hydro-geological investigations done under IWM together with existing data, information and reports are summarized in Table 1.

Table 1: Hydro-geological parameters for the study area

Name of Region	Transmissivity m^2/day	Hydraulic Conductivity, m/day	Specific Yield %	Storage Co-efficient	Annual minimum depth to water table, m	Annual maximum depth to water table, m	Range of Annual fluctuation, m
South-West Region	200 - 3200 (Shallow Aquifer) 438 – 2845 (Deep Aquifer)	11 - 65 (Shallow Aquifer) 22 – 65 (Deep Aquifer)	01 - 25	5.2×10^{-5} – 8.5×10^{-2}	0.19 - 5.26	1.36 – 11.90	In Barisal, Khulna, Bagerhat, Madaripur, Shariatpur and Gopalganj Districts varies from 0.37 to 2.08. In Kushtia, Rajbari, Faridpur, Magura, Jhenaidah and Jessore District varies from 5.02 to 8.8. Rest of area varies from 2.12 to 4.99
South-East Region	250 - 1900 (Shallow Aquifer) 148 - 2990 (Deep Aquifer)	05 - 50 (Shallow Aquifer) 22 – 65 (Deep Aquifer)	01 - 07	2.7×10^{-4} – 3.1×10^{-3}	0.00 - 5.70	2.10 – 17.75	Generally, varies from 1.18 to 5.5 but east side of Comilla District varies from 5.72 to 11.65

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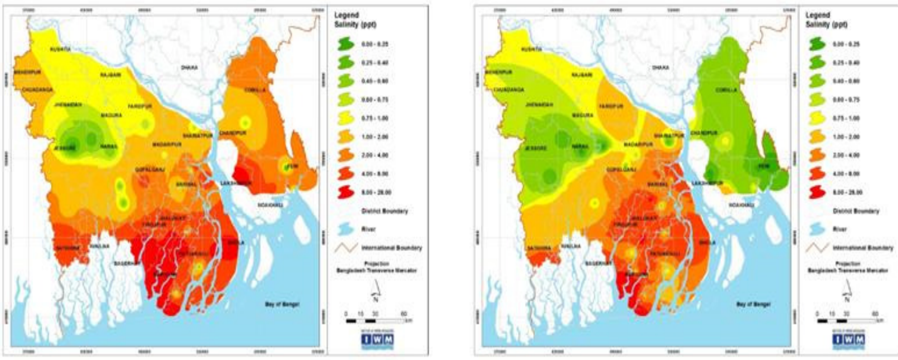

Groundwater Salinity Map of Shallow Aquifer on Dry Period 2012 in the study area (IWM, 2013)

Groundwater Salinity Map of Deep Aquifer on Dry Period 2012 in the study area (IWM, 2013)

Fig. 3: The Groundwater quality parameters in the study area

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ADSORPTION PARAMETERS & ISOTHERM STUDY OF A PROCESS TO UPTAKE HAZARDOUS DYE FROM WASTEWATER USING EICHHORNIA CRASSIPES AS BIO-ADSORBENT

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ABSTRACT
The existing study demonstrates that water hyacinth (*eichhorniacrassipes*) is a potential adsorbent for the removal of congro red dye from industrial wastewater by batch process. This experiments were conducted to study the influence of various parameters such as initial dye concentration, P^H and adsorbent dosage at different operating conditions. The effect of p^H and dye concentration was found to be significant and the maximum recovery (~96%) was detected at p^H 5 and concentration 100 ppm; considered to be optimum values. The recovery of congro red is proportionally consistent to the adsorbent dosage, and up to 85% dye was recovered for the dose of 1.0 g/L. The adsorption process followed Langmuir adsorption isotherm model; point out that the process supported monolayer adsorption of congro red on the adsorbent surface. These results point out the suitability of the locally available low cost adsorbents in the niche area of wastewater treatment and can be implemented in commercial dye enriched industrial effluent.

Keywords: Adsorption; Water treatment; Water hyacinth; Congro red; Isotherm.

INTRODUCTION
Dye is a coloured substance which is used in various industries such as paper and pulp, textiles, plastics, leather, cosmetics and food industries to enhance product appearance but these industries release effluent having hazardous materials. Dyes usually have complex aromatic molecular structures which make them more stable and difficult to biodegrade. Adsorption is the method for separation of mixtures on a laboratory and industrial scale where it is a surface phenomenon that can be defined as the increase in concentration of a particular component at the interface between two phases. In this section we want to represent that how can we separate dye from solution by using water hyacinth as bio-adsorbent. A number of agricultural waste and by-products of cellulosic origin also have been studied for their capacity to remove dyes from aqueous solutions such as peanut hulls (Brown et al.,2000), maize bran (Singh et al.,2006), sawdust (Taty-Costodes et al.,2003), sugar beet pulp (Reddad et al., 2002), crab shell (Vijayaraghavan et al.,2006), corn starch (Kweon et al.,2001), rice husk (Kumar, 2006), chitin (Ghimire et al.,2001), orange waste (Dhakal et al.,2005), lemon peel (Kumar, 2007), granular kohlrabi peel (Gong et al.,2007),raw barley straw (Husseien et al., 2007) and eggshell (Pramanpol,2006). The potentiality of low–cost adsorbents to remove organic pollutants needs to be assessed. This would make a significant impact on the practical application of cost-effective adsorbents to the industrial system. There is a scarcity of available data for the competitive adsorption of aquatic pollutants. Therefore, more investigations need to be conducted in this trend. In the present work, naturally available low–cost adsorbents such as locally available water hyacinth has been used as adsorbent for congro-red dye removal from aqueous solution. The influence of the experimental parameters such as initial pH, concentration of dye, adsorbent dosage has been investigated. The results of the experiments are analyzed using Langmuir adsorption isotherm.

Preparation of Adsorbent
All of the waste of water hyacinth was carefully washed by doubled distilled water to remove the dirt and mud.It was then sun dried and acid washed to eliminate the soluble impurities.

Then acid washed sample was dried again in an oven at 105°C for 2 hrs to leave out the moisture from it. The dried adsorbent were crushed in a micro plant grinding machine and converted into fine powder which were used to uptake CR dye in whole experiment.

Adsorbent Characterization and Analysis

UV-1650 spectrophotometer (SHIMADZZU Co., Japan) was used to measure the concentration of solution where maximum absorbance wavelength was 450 nm. P^H of the solutions were studied over the range from 4 to 8 through P^H meter**.**

Adsorbent Dosages

The effect of powdered water hyacinth dosage on the amount of congro-red dye adsorbed was obtained by selecting various adsorbent doses of 0.5 to 5g/L. The p^H of each sample was maintained at a optimum value of 5. The solutions were then shaken by a shaker (Vision Scientific Co. Ltd. S. Seriker) for 3.5 h at a constant oscillation of 211 osc/min. After that the samples were centrifuged and analyzed to determine the proportion of removal of congro-red for each case of inconsistent dosages.

Equilibrium Adsorption Isotherm

Adsorption studies were executed by batch technique. For isotherm studies, a series of 250 ml conical flasks were in used. Each flask was crammed with 100 ml of adsorbate solution of changeable concentrations 25, 50,100, 200, 300, 400 and 500 ppm and a desired p^H was maintained for each sample. A known amount of adsorbent (0.5 to 5g/L in variable proportions) was added into each flask at different moment at different condition and shaken continuously at a constant oscillation of 211 osc/min for 3.5 h. After the accomplishment of equilibrium, the samples of diverse concentrations were filtered and analyzed. Each experiment was repetitive under indistinguishable conditions and the average values were taken.

RESULTS AND DISCUSSIONS

Effect of Initial P^H, Adsorbent Dosage and Concentration

The uptake of congro-red as a group of hydrogen ion concentration was examined over a p^H range of 4-8 and the optimum p^H range for removal of congro-red dye was found to be 5 and the maximum dye adsorption (~96%) was observed at this range.The outcome of congro-red dye removal at p^H 5 with varying amount of adsorbent dosages was depicted. It was found that the concentration of dye had very modest effect on dye removal at any fastidious adsorbent dose. However, sample of 100 ppm and 1.0g dose showed preeminent results. Detailed results of optimization of adsorption parameters were discussed in our previous works (Khan et al.,2015; Ali et al.,2016; Alam et al.,2014).

Adsorption Isotherm Study

The adsorption isotherms for the congro-red amputation were premeditated using initial concentration of congro-red 100 mg/L at an adsorbent dosage level of 1.0 g/L. The adsorption equilibrium data are expediently represented by adsorption isotherms, which correspond to the correlation between the mass of the solute adsorbed per unit mass of adsorbent q_e and the solute concentration for the solution at equilibrium C_e.

The tentative data obtained were built-in to the Langmuir adsorption isotherm (I.,1918) applied to equilibrium adsorption assuming mono-layer adsorption onto a exterior with a finite number of duplicate sites and is represented as:

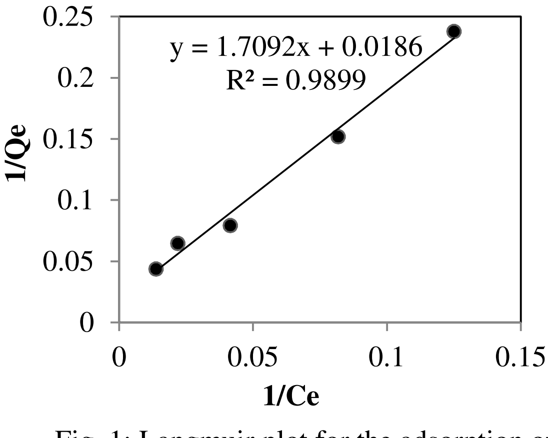

Fig. 1: Langmuir plot for the adsorption of congro-red by the adsorbent: pH 5; adsorbent dosage 1.0 g/L; contact time 3 h.

$$\frac{C_e}{q_e} = \frac{1}{q_{max} b} + \frac{C_e}{q_{max}} \qquad (1)$$

Fig.1 shows the linear plots of C_e/q_eversus C_e and is used to find out the value of q_{max} (mg/g) and the maximum capacity obtained to be 57.80 mg/g.

CONCLUSIONS

Water hyacinth is an efficient adsorbent for the confiscation of congro-red from the industrial wastewater. Solution P^H and initial concentration were optimized for the maximum recuperation and the upshot of the adsorbent dosages as well evaluated. The effect of equilibrium concentration on congro-red subtraction was enthused by Langmuir adsorption isotherm**.**

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REMOVAL OF HEXAVALENT CHROMIUM FROM TANNERY WASTEWATER BY RICE HUSK AND RICE HUSK ASH

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ABSTRACT

The purpose of this research was to investigate the adsorption ability and determine the suitable condition for adsorption of hexavalent chromium in synthetic aqueous solution and tannery wastewater by Rice Husk (RH) and Rice Husk Ash (RHA). Influences of pH, initial Cr(VI) concentration, contact time and adsorbent dose on removal of Cr(VI) from effluent was investigated. The results revealed that Cr(VI) removal efficiency increase with an increase of adsorbent dose, but the removal efficiency decrease with an increase of initial Cr(VI) concentration, while keeping all the other parameters constant. At the suitable condition for synthetic wastewater (pH 2, contact time 150 min, adsorbent dose 20 g/l, room temperature and agitation speed 200 rpm), the removal efficiency for RH was 94% and for RHA it was 88.4%. For tannery wastewater initial Cr(VI) concentration was 44.8 mg/l. In batch experiment the removal efficiency for RH was 85.49% and for RHA it was 84.38%. Among Freundlich and Langmuir isotherms, the latter had a better fit with the experimental data. The maximum Langmuir adsorption capacities were 3.7836 and 2.2696 mg/g for rice husk and rice husk ash, respectively. A comparison of kinetic models applied to the adsorption of Cr(VI) ions on the adsorbents was evaluated for the pseudo first-order and the pseudo second-order. The pseudo-second-order model was superior to pseudo-first order model in adsorption, and was controlled by chemisorptions and interparticle diffusion process. So waste recycle products RH and RHA has been proved to be an effective low or no-cost adsorbent, useful for the removal of Cr(VI) from aqueous solution.

Keywords: Rice Husk and Rice Husk Ash; Hexavalent chromium; Adsorption isotherm; adsorption kinetics.

INTRODUCTION

Chromium in the hexavalent form Cr(VI) is a significantly heavy metal is widely used in various industries such as electroplating, leather tanning, metal processing and wood preservatives including paint and pigment (Raji and Anirudhan, 1997; Garg et al., 2004). Chromium exists in two oxidation states as Cr(III) and Cr(VI). The hexavalent form is 500 times more toxic than the trivalent (Kowalski, 1994). It is toxic to microorganism plants, animals and humans. Human toxicity includes lung cancer, as well as kidney, liver, and gastric damage (US Department of Health and Human Services, 1991; Cieslak-Golonka, 1995). The tanning process is one of the largest polluters of chromium all over the world. Its concentrations in industrial wastewaters range from 0.5 to 270.000 mg/l (Patterson, 1985). The tolerance limit for Cr(VI) for discharge into inland surface waters is 0.1 mg/l and in potable water is 0.05 mg/l (EPA, 1990). In order to comply with this limit, it is essential that industries treat their effluents to reduce the Cr(VI) to acceptable levels. A number of treatment methods for the removal of metal ions from aqueous solutions have been reported, mainly reduction, ion exchange, electrodialysis, electrochemical precipitation, evaporation, solvent extraction, reverse osmosis, chemical precipitation and adsorption (Patterson, 1985). Most of these methods suffer from drawbacks such as high capital and operational costs or the disposal of the residual metal sludge. For Bangladesh perspectives rice husk is an important and low cost biological waste. Every year a large quantity rice husk is produce. It is usually use as a fuel material in many industry. Its utilization as a fuel produces rice husk ash which may cause damage to human health and environment, such as occurring particulate matter, destroying good landscape, etc.

So, in this research investigated the mechanism of Cr(VI) adsorption, adsorption isotherm and removal capacity of rice husk and rice husk ash. The effect of adsorption parameters such as pH, initial concentration, and contact time and adsorption dose were examined.

METHODOLOGY

Preparation of Adsorbate Solution

The stock solutions of Cr(VI) were prepared by dissolving analytical grade K_2CrO_4 in deionized water. The stock solution is further dilute with distilled water to get desired concentration for absorbance measurement. Cr(VI) concentration were measured by Atomic Adsorption Spectrophotometer HACH Model DR 2700. pH adjustment is carried out by using 0.1 M HCl and 0.1 M NaOH solutions.

Preparation of Rice Husk (RH) and Rice Husk Ash (RHA)

Rice husk was collected from Dougachia Jessore and rice husk ash was collected from Darmotala Rice mill Jessore Bangladesh mixed together to form a homogeneous mixture and sieve to avoid powder part of rice husk and washed with tap water until color removed for RH and until the pH was constant for RHA. Then dried in an oven at 105°C for 24 h. After that it was cooled in room temperature. Finally RHA was stored in airtight glass container for future use.

Batch adsorption experiments

The adsorption batch experiments were carried out in 500 mL beaker with 200 ml working volume solution with adsorbent. A given mass of either RH or RHA was added to the solution and stirring speed was kept at 200rpm for an equilibrium contact time of 150min. The effects of pH (2–8), adsorbent dose (5–25 g/L) and initial Cr(VI) concentration (5–100 mg/L) on Cr(VI) adsorption were studied, while all the other parameters constant. Upon completion, a sample of the suspension was removed from the beaker and filtered through a filter paper to remove adsorbent particles. The filtrate was diluted and analyzed for residual Cr(VI). All batch experiments were conducted in a Jar test instrument (JLT4, VELP Scientifics, Italy) and performed in duplicate. Under the experimental conditions, the amount of Cr(VI) adsorbed at equilibrium was calculated using Eq. (1)

$$q_t = \frac{(C_o - C_t)V}{m_s} \quad (1)$$

Where, C_o and C_t are the Cr(VI) concentrations in mg/l initially and at a given time t, respectively. V is the volume of the Cr(VI) solutions in ml and m_s is the weight of adsorbent in g. The percentage of removed Cr(VI) (R_{em} %) in solution was calculated using the following Eq. (2)

$$R_{em}(\%) = \frac{(C_o - C_t)}{C_o} x\ 100 \quad (2)$$

Isotherm experiments

In order to carry out the adsorption isotherm experiments, Cr(VI) adsorption on RH and RHA were conducted at the optimum conditions using a contact time of 150 min at pH 2 with each adsorbent dose of 5,10,15, 20 and 25 g/L and a fixed Cr(VI) concentration of 50 mg/L. Adsorption isotherms describe how adsorbates interact with adsorbents and are critical in optimizing the use of adsorbents. In this research two isotherm models were used to study the equilibrium sorption as Langmuir and Freundlich model. The Langmuir model assumes that the uptake of metal ions on a homogenous surface by monolayer adsorption without any interaction between adsorbed ions. The linear form of Langmuir model for equilibrium ion removed is given in Eq. 3:

$$\frac{C_e}{q_e} = \frac{1}{q_{max} b} + \frac{C_e}{q_{max}} \quad (3)$$

Where, q_e is the metal ions concentration on the adsorbent at equilibrium (mg of metal ion/g of adsorbent), q_{max} is the maximum metal uptake per unit mass of adsorbent (mg/g). b is Langmuir constant (l/mg), C_e is equilibrium concentrations (mg/l). The Langmuir isotherm can be described by an equilibrium parameter, RL defined as Eq. (4) (Weber and Chakkravorti, 1974)

$$R_L = \frac{1}{1 + bC_o} \quad (4)$$

RL indicates the nature of the adsorption process (Aksu and Donmez, 2003) where, RL > 1 Unfavorable, RL = 1 Linear, 0 < RL < 1 Favorable, RL = 0 Irreversible.
The Freundlich equation is an empirical equation employed to describe heterogeneous systems, characterized by the heterogeneity factor 1/n, describes reversible adsorption and is not restricted to the formation of the monolayer. A linear form of the Freundlich expression can be obtained by taking logarithms shown in Eq. (5)

$$log\, q_e = log\, K_F + {}^1\!/_n \,.\, log\, C_e \qquad (5)$$

Where, K_F is Freundlich constant (mg/g) and 1/n is the heterogeneity factor.Values of n > 1 represent favorable adsorption condition.

Kinetic experiments
Kinetic experiments were performed using beakers containing 200 mL of Cr(VI) solution at concentrations of 50 and 100 mg/L, and 20g/L of either RH or RHA. In each test, 200mL of Cr(VI) solution with the desired concentration was added to each flask and the pH was adjusted to 2. After the adjustments, 20 g of RH or RHA was added and the resultant suspension was stirred at 200 rpm. Samples were drawn from the solution mixture at time intervals of 5, 10, 15, 20, 30, 60, 90, 120 and 150 min and analyzed for kinetics study. In order to investigate the kinetics of biosorption, two kinetic models, Lagergren's pseudo-first-order model (Lagergren, 1898) and Ho's pseudo-second-order model (Ho et al., 2000) were employed. Lagergren first order model can be represented in linear form as Eq. (6)

$$log(q_e - q_t) = log(q_e) - \frac{K_1}{2.303} t \qquad (6)$$

Where,Where, q_e and q_t are the adsorption capacity at equilibrium and at time t, respectively (mg/g), K_1 is the rate constant of pseudo first-order adsorption (1/min).The values of log ($q_e - q_t$) were linearly correlated with t. The plot of log ($q_e - q_t$) vs. t should give a linear relationship from which K_1 and q_e can be determined from the slope and intercept of the plot, respectively. The pseudo-second-order model can be represented in linear form (with boundary conditions t = 0 to t = t and q_t = 0 to q_t = q_t) as Eq. (7)

$$\left(\frac{t}{q_t}\right) = \frac{1}{K_2 q_e^2} + \frac{1}{q_e}(t) \qquad (7)$$

Where, K_2 is the rate constant of pseudo second-order adsorption (g/mg/min).Replacing the term $K_2 q_e^2$ by h in Eq. (7) we have Eq. (8)

$$\left(\frac{t}{q_t}\right) = \frac{1}{h} + \frac{1}{q_e}(t) \qquad (8)$$

Where h is the initial adsorption rate (mg/g/min).
The adsorption rate parameter, which controls the batch process for most of the contact time, is the intraparticle diffusion. The possibility of intraparticle diffusion resistance affecting adsorption was explored by using the intraparticle diffusion model, as was explored using the Weber and Morris equation. The applicability of this model indicates the presence of the intraparticle diffusion process. The intraparticle diffusion model is expressed in Eq. (9)

$$q_t = Kt^{0.5} + C \qquad (9)$$

where, q_t is the amount adsorbed at time t, C is the intercept and k is the intraparticle diffusion rate constant (mg/g $min^{0.5}$) which can be evaluated from the slope of the linear plot of q_t vs. $t^{0.5}$.

RESULTS AND DISCUSSION

Effect of pH on adsorption
The pH of the solution has been identified as the most important variable governing metal adsorption. This is partly due to the fact that hydrogen ions themselves are strong competing ions and partly that the solution pH influences the chemical speciation of the metal ions as well as the ionization of the functional groups onto the adsorbent surfaces (Kadirvelu and Namasivayam, 2003). The [Fig. 1] shows the effect of pH on removal of Cr(VI).The selected pH ranges was (2-8). The RH and RHA dose was 20 g/l contact time of 150 min Cr(VI) concentration was 5 mg/l, agitation speed 200 rpm and room temperature. From [Fig. 1] the results show that the Cr(VI) adsorption decreased with an increase of pH. Maximum removal of Cr(VI) is 94% for RHA and 96.8% for RH when pH 2.

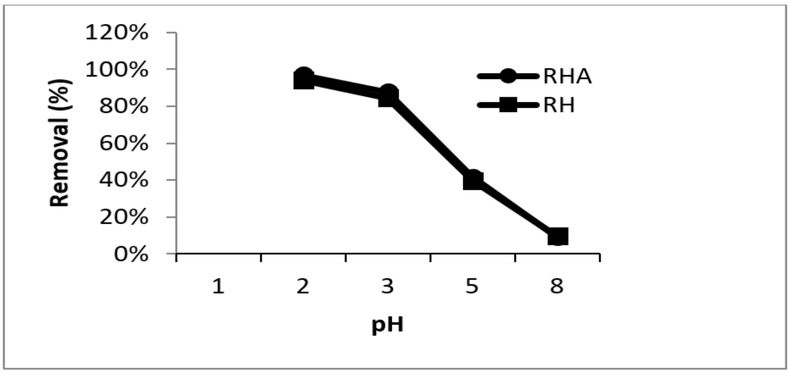

Fig.1: Effect of pH on removal of Cr(VI) by RH and RHA.

Effect of contact time and initial Cr(VI) concentration

The [Fig. 2] shows the effect of contact time and initial Cr(VI) concentration on removal of Cr(VI). The results show that the Cr(VI) adsorption decreased with an increase of initial Cr(VI) concentration and the Cr(VI) adsorption increase with an increase of time it may be observed that till the contact time (0-150) min. During the initial stage of sorption, a large number of vacant surface sites are available for adsorption. After a lapse of some time, the remaining vacant surface sites have difficulty in becoming occupied due to repulsive forces between the adsorbate molecules on the solid surface and in the bulk phase. Besides, the metal ions are adsorbed into the mesopores that get almost saturated with Cr(VI) ions during the initial stage of adsorption (Lu et al., 2009).

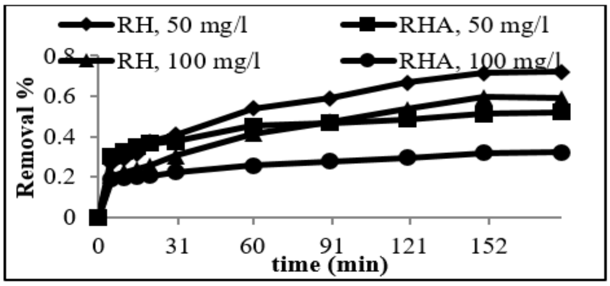

Fig. 2: Effect of contact time on removal of Cr(VI) by RH and RHA. (Dose 20 g/l, initial concentration 50, 100 mg/l).

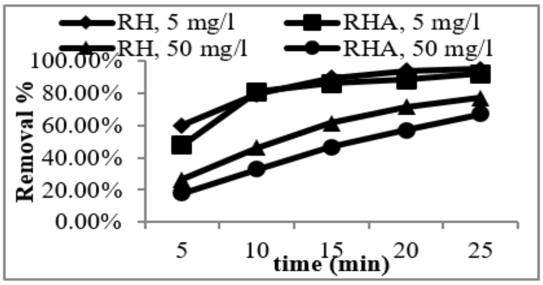

Fig. 3: Effect of adsorbent dose on removal of Cr(VI) by RH and RHA.

Effect of adsorbent dose on adsorption

The [Fig. 3] shows the effect of adsorbent dose on removal of Cr(VI). The selected adsorbent dose for RH and RHA was (5-25) g/l. Cr(VI) concentration was 5, 50 mg/l, contact time of 150 min at pH 2 and agitation speed 200 rpm. From (Fig. 3) the results show that the Cr(VI) removal increase with the increase of adsorbent dose. It is readily understood that the number of available adsorption sites increases by increasing the adsorbent dose and it therefore results in the increase of amount of adsorbed Cr(VI). The decrease in adsorption density with increase in the adsorbent dose is mainly because of unsaturation of adsorption sites through the adsorption process (Yu et al., 2003; Pehlivan et al., 2008).Moreover adsorption of Cr(VI) by RH has been found to be higher than RHA. Maximum removal of Cr(VI) is 95.20% for RH and 92% for RHA when adsorbent dose 25 g/l and concentration 5 mg/l. For concentration 50 mg/l maximum removal of Cr(VI) is 77.20% for RH and 67% for RHA when adsorbent dose 25 g/l.

Sorption isotherm

Adsorption isotherms, which are the presentation of the amount of solute adsorbed per unit of adsorbent, as a function of equilibrium concentration in bulk solution at constant temperature, were studied. The equilibrium data obtained were fitted to Langmuir and Freundlich isotherms. Adsorption isotherms for adsorption of Cr(VI) on RH and RHA were calculated from the results of studying effects of initial Cr(VI) concentration.

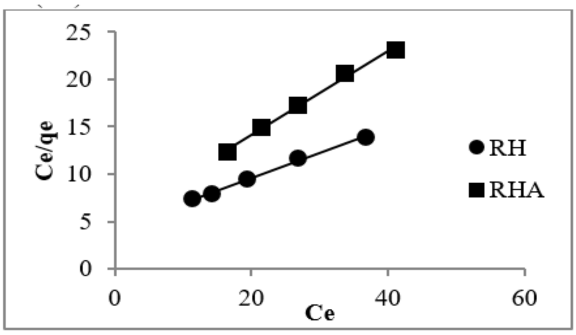

Fig. 4: Langmuir plot for adsorption of Cr(VI) by RH and RHA.

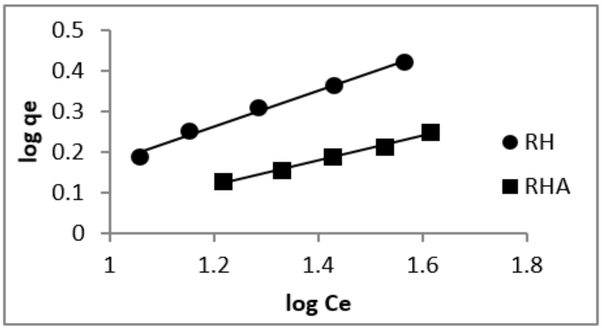

Fig. 5: Freundlich plot for adsorption of Cr(VI) by RH and RHA.

The [Fig. 4] shows the plot of (C_e/ q_e) and $C_e$from which $q_{max}$and bcan be determined from the slope and intercept of the plot, respectively. From the present study R_L value 0.2466 for RH and 0.1963 for RHA lies within 0 and 1; this indicates a favorable adsorption process. The [Fig. 5] shows the plot of log q_e and log $C_e$from which $K_F$and 1/n can be determined from the intercept and slope of the plot, respectively. From the present study the n value is 2.2624 for RH and 3.2744 for RHA.The value of n from the adsorption process is favorable for the removal of Cr(VI) because n > 1. From the study correlation coefficients R^2 for Langmuir isotherm are (R^2_{RH} 0.9973, R^2_{RHA} 0.9931) and the correlation coefficients R^2 for Freundlich isotherm are (R^2_{RH} 0.9895, R^2_{RHA} 0.99).

Adsorption kinetics

A kinetic study was carried out for the prediction of adsorption rate constants, equilibrium adsorption capacity and adsorption mechanism. The capability of pseudo-first and second order kinetic models was examined in this study. The [Fig. 6] shows the plot log (q_e - q_t) vs. t from which K_1 and $q_e$can be determined from the slope and intercept of the plot, respectively. The [Fig. 7] shows the plot of (t/ q_t) and t from which $q_e$and K_2can be determined from the slope and intercept of the plot, respectively.

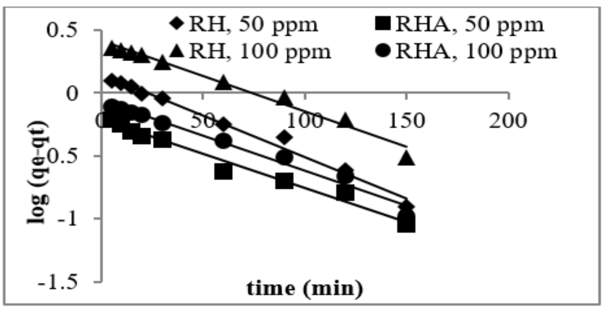

Fig. 6: Pseudo-first-order kinetic plot for the adsorption of Cr(VI) at different adsorbent RH and RHA (Initial Cr(VI) conc. 50, 100 mg/l).

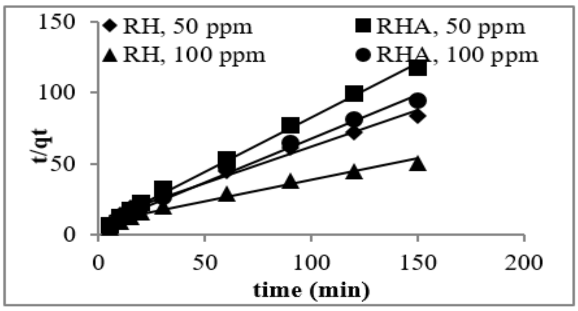

Fig. 7: Pseudo-second-order kinetic plot for the adsorption of Cr(VI) at different adsorbent RH and RHA (Initial Cr(VI) conc. 50, 100 mg/l).

The kinetic data tends to fit well in the pseudo-first-order and pseudo-second-order kinetics model with high correlation coefficients.

Intraparticle diffusion model

The possibility of intraparticle diffusion was explored by using the intraparticle diffusion model with varying chromium concentrations. The rate limiting step may be film or intraparticle diffusion. The plot in Fig. 8 shows the intra-particle diffusion results for different concentrations, and indicates that it is a single-step adsorption process. The divergence in the value of the slope from 0.5 indicates the presence of the intra-particle diffusion process as one of the rate limiting steps, in addition to many other processes controlling the rate of adsorption, all of which may be operating simultaneously (Weber and Morris, 1963).

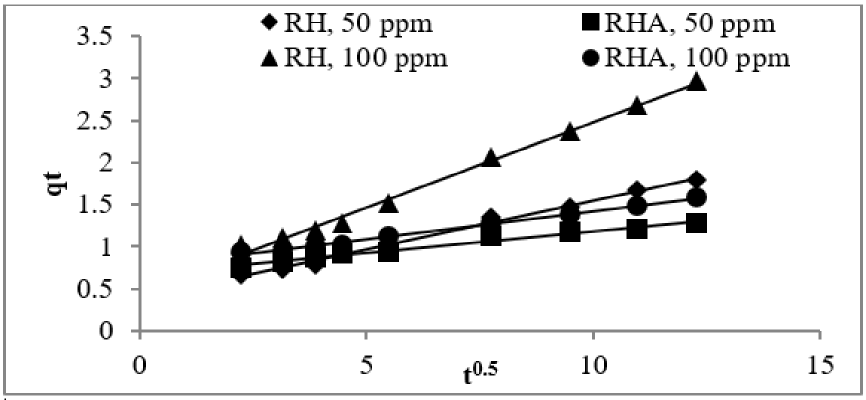

Fig 8: Intraparticle diffusion plot where Cr(VI) concentration 50, 100 mg/l.

Removal of Cr(VI) from real wastewater by RH and RHA

After completion of basic adsorption experiments, the efficiency of RH and RHA in the removal of Cr(VI) from industrial wastewater was evaluated. Wastewater sample was collected from Hazaribagh Tannery Area, Dhaka. The pH, EC, TDS, salinity and Cr(VI) concentration of collected wastewater was determined at the beginning of adsorption experiments, where values of 2.25, 37.2 ms/cm, 24.3 g/l, 22.7 g/l and 44.8 mg/l respectively, were tested in EST lab from Jessore University of Science and Technology (JUST), Jessore. The pH of the wastewater and the optimal pH obtained from basic adsorption experiments were identical; thus, chemical adjustment of the pH was unnecessary. Experiment studies were carried out at the room temperature. The selected time ranges was (5-180) min. The RH and RHA dose was 20 g/l, initial Cr(VI) concentration 44.8 mg/l, at pH 2 and agitation speed 200 rpm.

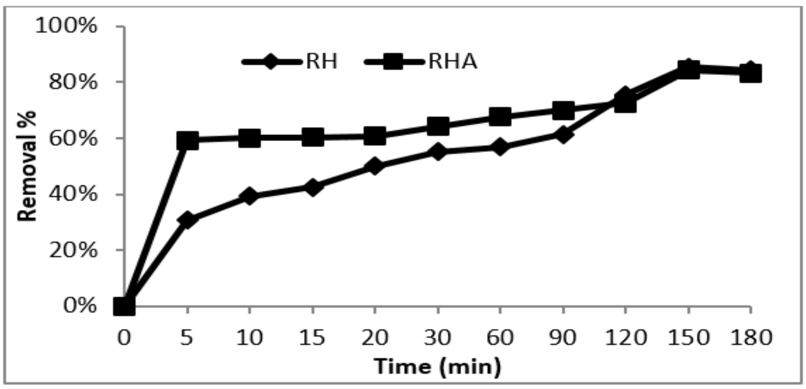

Fig 9: Effect of contact time for removal of Cr(VI) by RH and RHA.
(For RH and RHA dose was 20 g/l, initial concentration 44.8 mg/l).

From [Fig. 9] the results show that the Cr(VI) adsorption increase with an increase of time it may be observed that till the contact time (0-180) min. The [Fig. 9] shows that Cr(VI) removal occur for both RH and RHA when used as adsorbent. Maximum removal of Cr(VI) is 85.49% for RH and 84.38% for RHA when Cr(VI) concentration 44.8 mg/l.

CONCLUSIONS

Rice husk and rice husk ash are interesting alternative adsorbent for heavy metal removal. These are useful for alternative waste management programs and friendly with ecosystems. RH and RHA are performed well in acidic condition. The removal efficiency for RH was 94% and for RHA it was 88.4% when pH 2, contact time 150 min, initial concentration 5 mg/l, adsorbent dose 20 g/l, room temperature and agitation speed 200 rpm. For tannery wastewater initial Cr(VI) concentration was 44.8 mg/l. In batch experiment the removal efficiency for RH was 85.49% and for RHA it was 84.38%.For the application of Langmuir and Freundlich equations, the experimental results show that the Langmuir and Freundlich model was fitted well. From the present study R_L value 0.2466 for RH and 0.1963 for RHA. The value of n at equilibrium is 2.2624 for RH and 3.2744 for RHA suggest that the adsorption is physical. The kinetic data tends to fit very well in the pseudo-first-order and pseudo-second-order kinetics model with high correlation coefficients. Finally the RH and RHA utilization is an alternative waste management or environmental conservation.All adsorption parameters as pH, initial concentration, contact time and adsorbent dose can affect to the Cr(VI) adsorption by RH and RHA.

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A COMPARATIVE STUDY OF POLLUTANT REMOVAL EFFICIENCY BETWEEN CONSTRUCTED HORIZONTAL AND VERTICAL FLOW WETLAND SYSTEM USING SAW DUST AND STONE CHIPS FOR MUNICIPAL WASTEWATER

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ABSTRACT
Constructed wetlands have been used for decades mostly for the treatment of domestic or municipal wastewater. For a small community with limited funds for expanding or updating wastewater treatment plants, constructed wetlands are an attractive option. Constructed wetlands are treatment systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality which are low in energy consumption, requiring minimal maintenance. The overall objective of this study was to assess performance of two subsurface flow constructed wetland to treat municipal wastewater. The specific objectives were comparative study of pollutant removal efficiency between horizontal and vertical flow wetland system using stone chips and saw dust, evaluate the removal performance of pollutants from municipal wastes such as color, pH, alkalinity, BOD_5, COD, E.coli, and fecal coliform, and also analyze removal of pollutants by wetland plants and filter materials. The two systems had identical configuration, each consisted of a subsurface vertical flow (VF) wetland, and a horizontal flow (HF) wetland. The wetlands were planted with *Canna indica* but employed different media, including organic saw dust and stone chips. The results were impressive, Removal efficiency of BOD is more than 90% in stone chips media and more than 75% in saw dust media. Vertical flow constructed wetlands shows 40% removal efficiency in pH and also very efficient in reducing both BOD_5 and COD than horizontal flow systems. Removal efficiency of total suspended solid varies in the range from 30-40%. Vertical flow constructed wetlands are more efficient in removing suspended solids from water. Horizontal flow wetlands provided efficient color removal under predominantly anaerobic condition. The results provided a strong evidence to support widespread research and application of the constructed wetland as a low-cost, energy-efficient, wastewater treatment technology in Bangladesh.

Keywords**:** Wastewater; wetland; stone chips; sawdust; pollutant removal; efficiency.

INTRODUCTION

Constructed treatment wetlands are engineered systems, designed and constructed to utilize the natural functions of wetland vegetation, soils and their microbial populations to treat contaminants in surface water, groundwater or waste streams. As the nation's population continues to grow, development is pushed further into rural areas where septic systems must be used for wastewater treatment (El-Khateeb, 2003). Constructed wetlands for wastewater treatment are an inexpensive, eco-friendly and technologically appropriate solution for wastewater treatment in developing countries (Jayakumar, 2003). Unfortunately, in developing countries, the constructed wetlands had not been found widespread use. This study has been designed to assess the performance of constructed wetlands, used for the treatment of polluted water collected from Babu Bazaar canal. The objectives of this study are many-folds: to evaluate the rates of the removal of nutrients, organics, and coliforms from the polluted surface, to evaluate the difference in removal percentage between two medias, to evaluate the difference in removal percentage between horizontal and vertical flow.The other objective is to inspire the use of natural materials that are locally available for the application of constructed wetlands.

METHODOLOGY

The actual source of water is the municipal waste water from Babu Bazar Khal which comes from Buriganga River. The khal meets Turag at Kamrangirchar, near Hazaribagh so it receives all the waste water from Turag, which flows through Tongi, Savar and Hazaribagh. Sample water was collected from BabubazarKhal at Old Dhaka in 40 sunlight insulation barrel drum which contain 30 liter of municipal wastewater. Then it was transported to Bangladesh University of Engineering and Technology form collection point.

Dosing System & Description of Tanks

At first the outlet was turned on for 1.5-2 minutes to check the whole system and workability of the filtering process. Then wastewater was poured into tanks. Dosing was done 3 times a week. Two rectangular steel tanks were used to replicate the lake on a large scale. A media is used for the growth of microbial community. It was constructed in such a way, so as to facilitate the growth of roots underwater.

Horizontal Tank

The HF had rectangular shape tank. This tank is made with high strength steel materials. The dimension consist depth of 3'11", a width of 1'8", a length of 3'4" shown in Fig 1. The outlet was located at the 1m from the bottom of the reactor. Two-inch valve is used as the outlet of the reactor. Another outlet pipe is used to remove excess water from the tank and to provide a certain level of water for the research.

Vertical Tank

The VF had rectangular shape also made with high strength steel materials. The dimension consist depth of 3'11", a width of 1'8", a length of 1'8" shown in fig 2. The outlet was located at the 1m from the bottom of the reactor. Two-inch valve is used as the outlet of the reactor.

Wetland Vegetation

Constructed wetlands can be planted with a number of adapted, emergent wetland plant species. Wetlands created as part of compensatory mitigation or for wildlife habitat typically include a large number of planted species. Commonly used plants are Phalarisarundinacea (reed canary grass), Typha spp. (cattails), Scirpusspp, (bulrushes) and Glyceria maxima (sweet mannagrass) (Chadde, 2011). However, the most frequently used plant species worldwide is Phragmitesaustralis (common reed) (Robert H. Kadlec, 2008, p. 97). *Canna Indica* is the plant which was used for our experiment.

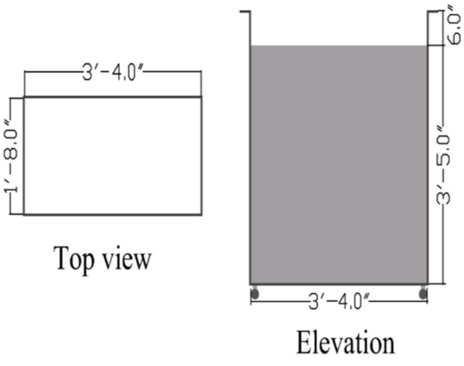

Fig.1**:** Dimension of Horizontal Sub Surface flow

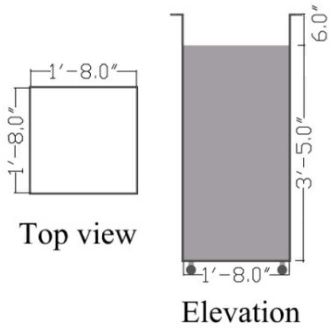

Fig.2**:** Dimension of Vertical Sub Surface flow

Preparation of Media Bed

Crushed stone and saw dust are most accessible natural resources, and are major basic raw material used by construction, agriculture, and other industries. At first we took sufficient amount of media and washed them with clean water to remove other organic and inorganic substances, harmful elements, oils and impurities. Then a thin shit of wooden board is placed under the tank below outlet. After that we put those media into the tank and filled it. For horizontal tank we filled 2'11" and for vertical tank 3'2". The top of the tank is left open and planted Canna Indica plant above the media. After all these we filled the tank with our collected municipal waste water from Babu Bazar canal upto a certain level. This constructed wetland technology is based upon the treatment power of three main mechanism: microorganism, optimizing the system, the physical and chemical properties of the media and finally the plants themselves.

RESULT AND DISCUSSION

Data Analysis of Water Parameters

The removal performances of pH, TSS, BOD and color of vertical and horizontal wetland treatment have been summarized in this section. From fig.3 and fig.4, it is clearly observed that between two media, stone chips shows better removal percentage. For vertical wetland the percentage is almost 18%.

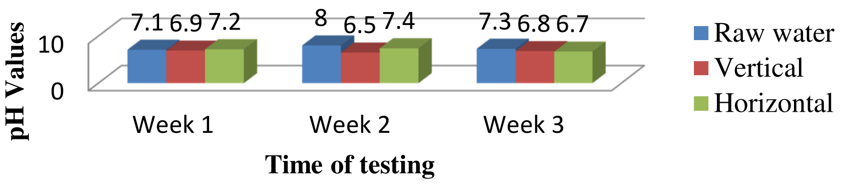

Fig.3: pH value analysis for three weeks' water sample for stone chips media

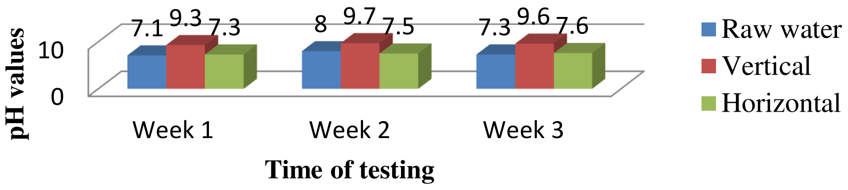

Fig .4: pH value analysis for three weeks' water sample for saw dust media

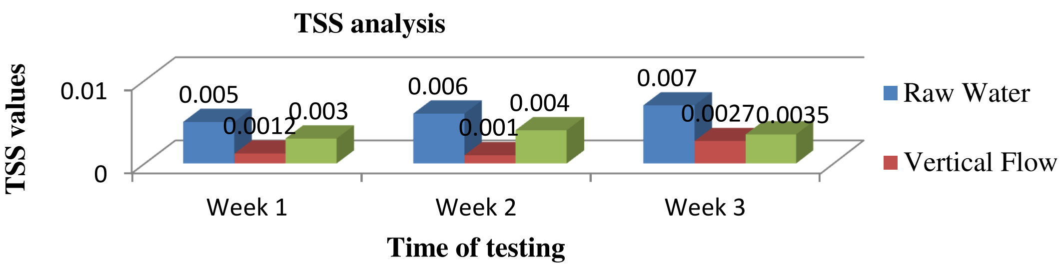

Fig. 5: TSS value analysis for three weeks' water sample for stone chips media

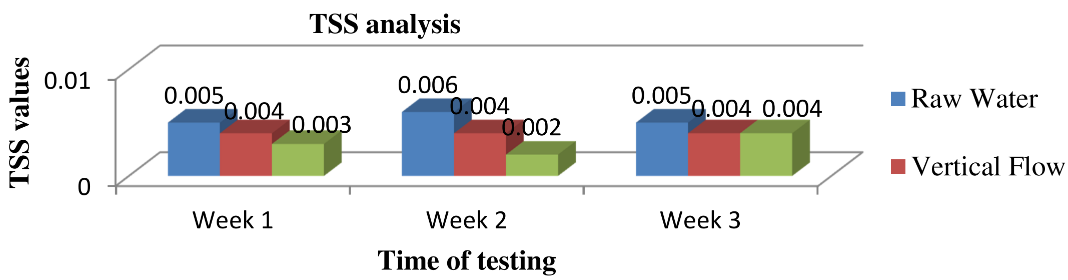

Fig. 6: TSS value analysis for three weeks' water sample for saw dust media

From Fig.5 and Fig.6, clearly indicates that the percentage of removal of TSS is very good in stone media and vertical flow. The percentage is between 30-40% for 1st and 2nd week and for 3rd week approximately 50%. The graphs in fig.7 and fig.8, indicates that color removal efficiency is good in both media. After 3rd week test it showed almost 50% removal efficiency for both media. From fig.9 and fig.10, it is clearly observed that between two media, stone chips shows better removal, almost 90% for first two weeks for vertical flow. For sawdust media the removal percentage is almost 75%.

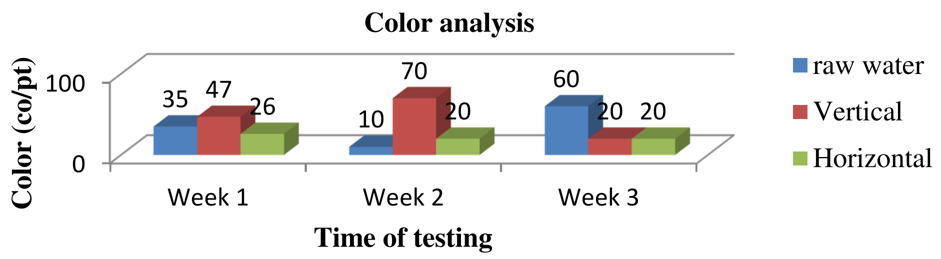

Fig. 7: Color value analysis for three weeks' water sample for stone chips media

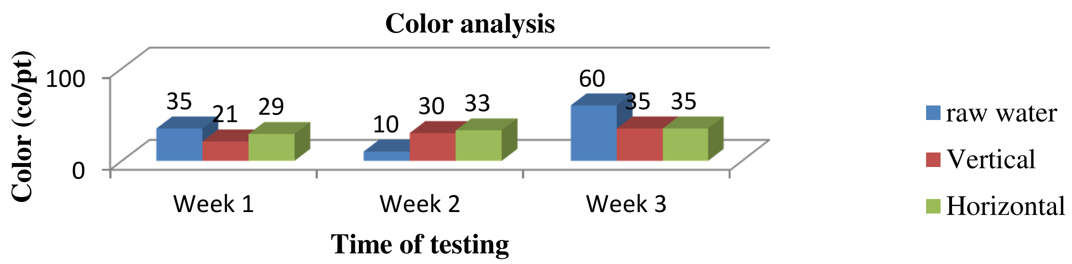

Fig. 8: Color value analysis for three weeks' water sample for saw dust media

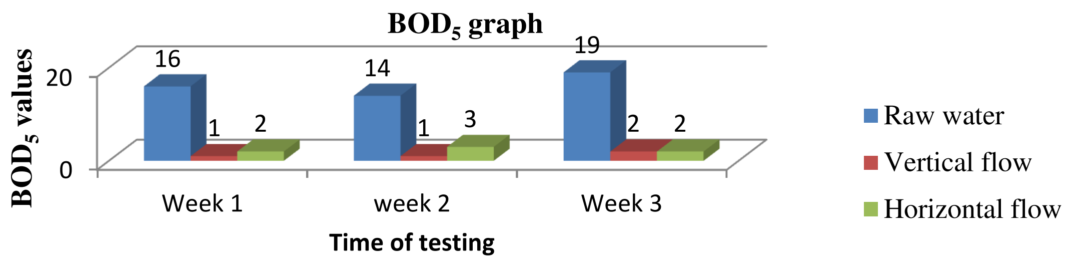

Fig. 9: BOD_5 values analysis for three weeks' water sample for stone media

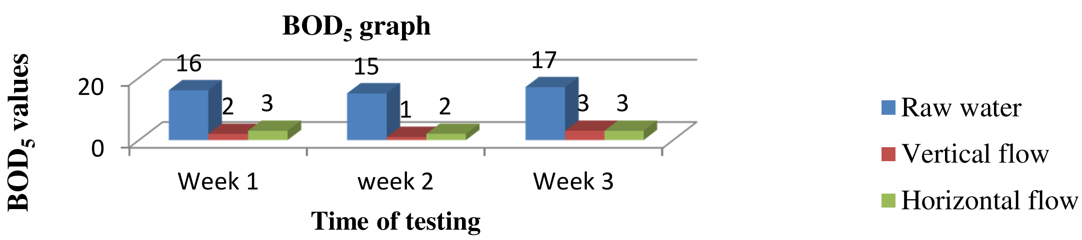

Fig. 10: BOD_5 value analysis for three weeks water sample for saw dust media

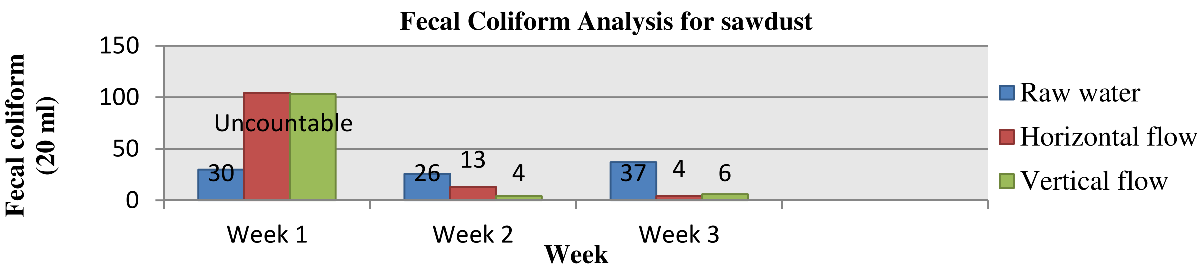

Fig. 11: Fecal coliform values analysis for three weeks water sample for sawdust media

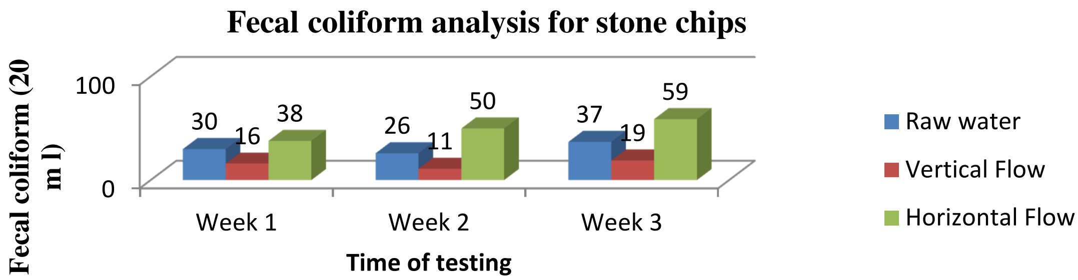

Fig. 12: Fecal coliform values analysis for three weeks water sample for stone media

From Fig. 11 and Fig.12, for stone chips media Horizontal flow cannot remove fecal coliform but increase and the vertical flow shows tremendous efficiency to remove fecal coliform and removes almost 60%. For sawdust media removal efficiency is good for both horizontal and vertical flow.

CONCLUSION

It is observed from the analysis that the vertical flow in both stone and sawdust media using *Cannaindica* plant works better than horizontal flow for pH, turbidity, TSS and BOD_5. But in color removal percentage of horizontal flow is higher than vertical flow. Overall, constructed wetland can provide a green, relatively inexpensive means of treating effluent in order to meet wastewater regulations and decrease impact on the environment.

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WASTEWATER QUALITY ASSESSMENT DISCHARGING TO THE PADMA RIVER IN RAJSHAHI, BANGLADESH

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ABSTRACT

The Rajshahi city stands on the river Padma. The whole drainage system of Rajshahi is disposed to the river after being accumulated from various points of the city. Most of the portion of this wastewater consists of household wastewater and human wastes. The purpose of this study is to monitor the quality of wastewater of four major discharging points to the river. The four major discharging points are located at Barakuthi Mukta Mancha, Padma Garden, Padma Garden Oyaktiya Jame Mosque and Dargapara discharging channels. The wastewater quality parameters to be monitored are pH, Hardness, Turbidity, Temperature, Conductivity, BOD and COD. The samples were collected at noon when the discharge is at its peak condition and the quality of wastewater is at worst state. This study illustrates the present assessment of the water quality parameters of the municipal wastewater of Rajshahi and the deviation from the standard values. The result of the study also indicates the intensity of treatment required for this municipal wastewater before being disposed to the river body.

Keywords: wastewater quality parameters; discharging points; comparison; quality of wastewater.

INTRODUCTION

Rajshahi, one of the major cities of Bangladesh stands on the river Padma. As the river is directed to move towards the Bay of Bengal after being emerged with other large rivers, this is a natural drainage body that is used to transport the treated and untreated wastewater including the domestic, industrial and other effluents, produced from many point of this city. All the drains are disposed to this river resulting in pollution of water day by day and the natural resources as well as the beauty of this river is being degraded gradually. The impact of this wastewater (Ho, et al., 2012; Aktar & Moonajilin, 2017) is catastrophic for the river, public health (Islam, et al., 2016) and also for the environment (Sahu, Katiyar, Tiwari, & Kisku, 2007). As this river plays an important role in living water resources, the wastewater is a direct threat to these living beings (Uqab, Singh, & Mudasir, 2017; Kwadzah & Iorhemen, 2015). Moreover, a quantitative variation between the allowable wastewater quality and the practical quality of the untreated wastewater(Ali, et al., 2017; Aththanyaka, Asanthi, & Maithreepala, 2014) being discharged to the river water(Margaryan, 2016; Mridha, 2011) directly, shows the pollution intensity(N & S., 31 August-2 September,2017; Shivani, Anukool, M.P.S, & .P.K, 2011) due to this wastewater(Saha & Alamgir, 2013; Rahman, Abedin, & Rana, 2013; Sagar & babu, 2016).

METHODOLOGY

There are 12 primary drains in Rajshahi City whose total length is 44.80km (RDA, 2005). 6 samples are collected from each four sites and analysed for this study. The minimum and maximum value of this result are taken for the final assessment of present wastewater of Rajshahi Municipality

STUDY AREA AND SAMPLING SITES

The study area includes Fudkipara, Padma garden and Dargapara of Rajshahi. This area covers the 4 major discharging points as Barakuthi Mukta Mancha (24.3613054, 88.6004632), Padma Garden.

(24.3620754, 88.5988696), Padma Garden Oyaktiya Jame Mosque (24.362020,88.597005) and Dargapara (24.362495, 88.594552). Water samples were collected from four different selected drainage water disposal sites on 22ndJanuary, 2018.

COLLECTION OF WATER SAMPLES

The water samples had been collected in high grade plastic bottles of half litre capacity. Before collection, the plastic bottles were rinsed once with distilled water and then thrice with respective water sample (EPA, 1982). During collection, care was taken to avoid the trapping of air within the bottle by completely immersing the bottle within the respective water sample until the bottle is completely filled in with the water.

Fig. 1: Collection of Wastewater Sample

Fig.2:Site1(Barakuthi Mukta Mancha)

Fig. 3: Site2 (Padma Garden)

Fig. 4: Site3 (Padma Garden Oyaktiya Jame Mosque)

Fig. 5:.Site4 (Dargapara)

PARAMETERS ANALYZED

The samples collected were brought to the laboratory and the parameters pH, Hardness, Turbidity, Temperature, Conductivity, BOD and COD were examined. Standard methods (Rice, Baird, & Eaton, 2017) were adopted for the analysis of water samples.

RESULTS AND DISCUSSIONS

pH value of the collected samples from these sites has been seen in slight variation from the desired value. It has been observed that the pH values are 6.61 in minimum and6.79 in maximum. The test result shows the values of hardness as the concentration of $CaCO_3$ of site1, site2, site3 and site4 having the range of 250-271,355-386,246-261 and 308-318 in mg/L. The highest hard water sample has been collected from site2 and the sample containing lowest value of hardness is site3. Among The turbidity test of the samples from site1, site2, site3 and site4, the highest value of turbidity is found in site3.The test result has been shown in NTU and the observation shows that the quality of waster in these sites is under the permissible limit which is completely satisfactory.

Table 1: Physio-chemical parameters of water samples

Parameters Analysed	Site1		Site2		Site3		Site4		Permissible Limit(Agency, 2018; Mast & Turk, 1999)
	Min	Max	Min	Max	Min	Max	Min	Max	
pH	6.61	6.79	6.26	6.41	6.11	6.23	5.42	5.76	6 - 9
Total hardness as $CaCO_3$ (mg/L)	250	271	355	386	246	261	308	318	150
Turbidity (NTU)	59	61	55	59	68	71	22	27	300
Temperature(^{0}C)	18.1	20.4	17.9	23.2	18.3	21.7	18.2	24.3	45
Conductivity (µS/cm)	2900	3100	1900	2100	2000	2200	1800	2100	1800
BOD (mg/L)	204	256	194	227	197	216	187	201	350
COD (mg/L)	250	279	203	243	216	229	234	276	430

Temperature is another promotor that enhances the rapid growth of unexpected microorganisms and chemical substances. The result of temperature test of the samples shows the satisfactory condition of the wastewater which is much below from the permissible limit. Site1 shows the more conductivity property than the other sites. The deficiency of dissolved oxygen is found in site4 as this shows the lowest BOD which is measured in 5 days test at 20^0 C. Site1 contains the highest chemical demanding water and site2 contains the lowest.

CONCLUSIONS

It is always expected that the wastewater either domestic or industrial must be treated in order to ensure the maximum healthfulness of the surface water bodies. This study has revealed that the wastewater disposed to the river Padma must undergone through required treatment for the preservation of river water from being polluted. This clearly indicates that water resources management is incomplete in the Rajshahi district and needs further introductory development for the wastewater treatment for the final disposal to the river Padma. The pollution levels are strongly recommended to be reduced by strict enforcement of The Bangladesh Environment Conservation (Amendment) Act, 2010 and waste effluent regulations to ensure the physiochemical properties are within the permissible limits.

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A STUDY ON ENVIRONMENTAL FATE OF NEONICOTINOID IN SOIL AND GROUNDWATER AND ITS IMPACT ON HUMAN HEALTH: A REVIEW

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ABSTRACT

Neonicotinoids, a systemic pesticide, have been detected at a considerable amount in various environmental compartments especially in soil and water. The compounds have adverse effects in many targeted or non-targeted species but few studies were performed about the human health effects of exposure. The objective of this systematic review is to summarize environmental fate of neonicotinoids related to soil and groundwater, identify their exposure pathway, risk and toxic behaviour related to human. The residues after the application in the field or from coated seeds can cause soil contamination. Factors particularly application rate, pH, temperature, plant cover, crop rotation control the further movement into the receiving body through soil and water. High water solubility and low adsorption capacity have verified their pollution in groundwater. Leaching has been proved to be the main mechanism responsible for the contamination of groundwater where dinotefuran and clothianidin pose high leaching potential. Lowest mobility has been observed in the soil with highest organic matter content. It has been found that most neonicotinoids pose low toxicity to human beings even in large ingestion although newborn, children and old people are more vulnerable. Dermal route has the greatest potential for exposure, with a minor contribution of the respiratory route (not that volatile) when aerosols or aerial spraying are used. Thiacloprid is found more likely carcinogenic to human than other compounds. Disorientation, sweating, vomiting, agitation, increased heart and respiratory rates are the few side-effects that are confirmed from the long-term exposure of neonicotinoids. Regular monitoring of its usage level in environmental compartments are required to control the concentration

Keywords: Neonicotinoid; Chemical Properties; Environmental fate; Soil and Groundwater Contamination; Human Health Risk.

INTRODUCTION

Innovation in pesticides composition and its different application method ensure sustainable food production. Neonicotinoids are regarded as systemic pesticides due to its special killing technique. The invention of neonicotinoids brought a new era in pest management which have a higher versatility in application system and a high target set for only invertebrates. Today, this new product controls the insecticide market and is listed for use on more than 140 different crops in 120 countries which were first introduced in the late 1980s (Jeschke and Nauen, 2008). Neonicotinoids now cover one third of the market, representing the largest selling product of insecticide and seed treatments (Jeschke et al., 2010). Their actions in pre-defined pests, physicochemical characteristics, and relatively less toxicity than DDT are reasons behind growing popularity in insect control since 1990. By far ten separate neonicotinoid compounds are available; namely imidacloprid, thiacloprid, clothianidin, thiamethoxam, acetamiprid, nitenpyram, dinotefuran, sulfoxaflor, carbendazim, and fenvalerate. They have been designed as a defence products to kill insects which are damaging to crops. They are also practiced as a veterinary drug to control parasites such as fleas, ticks and worms on domestic animals and other non-agricultural pests (Bijleveld et al., 2014). As a result, they create a serious risk on some non-target animals. They have also been found toxic to bat, bees, mammals, birds, and other higher organisms like human. There have been few studies on the side effects of the current use of Neonicotinoids on wildlife, particularly at higher levels of populations, communities and ecosystems (Köhler and Triebskorn, 2013).

Traces of contamination in soil and ground water have been found widely as result of extensive use as a pesticides and through leaching of soil. Factors particularly pH and type of soil, temperature, plant cover, application rate, water solubility, partitioning properties and soil adsorption of the neonicotinoids control their movement through soil to groundwater. The half-lives of neonicotinoids are high and they can be transported vertically into groundwater and get contaminated in absence on light; which lately intake by human or other organisms through various pathway. It affects directly on central nervous system. Long term exposure exacerbates the condition and proves fatal in some cases. There are few studies regarding human exposure pathway and toxicity associated with neonicotinoids. Studies have indicated unsolved relations between a neonicotinoid pesticide and a human health. This may create biasness of the literature (Franco et al., 2014). The objective of this systematic review is to summarize available data on chemical properties, environmental fate of neonicotinoids related to soil and groundwater, and to investigate the exposure pathway and effects within the human body.

METHODOLOGY

Although most of the studies related to neonicotinoids are made on bees but recent evidences of traces in human body made us reviewed different literatures which are available online. Most of the data are collected from scientific journals and authentic websites.

RESULT AND DISCUSSION

Neonicotinoids exhibit chemical properties that enhance environmental persistence and susceptibility to transport through percolation, runoff from application areas.

Chemical Properties and Environmental fate (soil and ground water)

Neonicotinoids are used directly to the plant where they expose or are released from seed coatings into the soil. In such way they are incorporated into plant tissue and available to be taken up by plant roots, other higher organisms like human (Mullins, 1993). Only 2 to 30% of total pesticides are used to kill the insects and rest remain in the soil. Usually the breakdown of plant that contains neonicotinoids can release concentrations back into the soils and cause further soil contamination (Horwood, 2007). It has the capacity to cause adverse effect on soil ecosystem.

Neonicotinoids pose high water solubility, volatility and long half-lives in both soil and water. These shows resistance to hydrolysis at neutral or acidic pH condition in absence of light. It undergoes photo degradation under aerobic condition. Table 1 depicts the chemical properties and environmental fate of neonicotinoids. The average molecular weight ranges from 200 to 292 g/mol. Imidacloprid poses low vapor pressure of 1.0 x 10^{-7} mmHg indicating its non-volatile characteristics. Acetamiprid, dinotefuran, nitenpyram and thiamethoxam have high water solubility. KOC determines the mobility of the concentration into soil; lower the value higher the mobility is. Neonicotinoids can remain present at a concentration that can be measurable after passing a long periods in the soil. These systematic pesticides have a broad range of half-life which ranges between 1 (Nitenpyram) and 1386 (Clothianidin) days. Thiamethoxam has high water solubility and shows most vulnerability to leaching in a wet condition. Thiacloprid has shown class II carcinogenic tendency. There is no information on thiamethoxam and nitenpyram in such matter.

The main mechanism of contamination of groundwater is the leaching of pesticides through soil pore. Soil type, size, pH, temperature, flow rate, pore size, organic content etc. are the core controlling factors responsible for leaching. Organic matter helps to bind complexes to its negative surface. This is why lowest mobility was observed in some studies of contaminated soil with highest organic matter content upto 3.5 %. The presence of hydrophilic bonding on functional groups of the insecticides which may bind to the phenolichydroxyl and carboxylic acidic groups of soil organic matter (J.M. Bonmatin, 2014).Neonicotinoids can remain in the soil for a long time and be transported vertically into groundwater in absence of light and concentrations may reach at soil depths of 105 cm (Felsot et al., 1998).

Table 1: Chemical properties and environmental fate of neonicotinoids (Bonmatin et al. 2014 Gustafson 1989, PPDB. 2012)

Insecticide	Molecular Mass g/mol	Water Solubility (mg/l) @20ºC	Mobility, Koc (days)	Soil Half-life DT50 (days)	GUS	Carcinogenic Tendency
Acetamiid	222.7	2950	132-267	< 1 to 8.2	0.94	Not Likely
Clothianiin	249.7	340	277- 1286	148 - 1155	4.91	Not Likely
Dinotefuran	202.2	39.83	6 -45	81.5 days	4.95	Not Likely
Imidacloprid	255.7	610	156 – 800	48 -190	3.76	Not Likely
Nitenpyram	270.7	590	21	1-15	2.01	-
Thiacloprid	252.7	184	4,700	9-27	1.44	Likely
Thiamethoxam	291.7	4100	68.4	7-72	3.82	-

Various studies has shown its detected concentrations in ground water ranging from 1.93µg/L (imidacloprid) to 8.93 µg/L (thiamethoxam) (Christy et al., 2015). Due to horizontal movement of water, is regarded as percolation, nonicotinoids discharge into nearby surface waters such as lakes, rivers, streams and wetlands. Leachate potential can be measured using Groundwater Ubiquity Score (GUS) by the sorption coefficient (Koc) times the soil halftime (DT50) (Gustafson, 1989). Leaching rate ranges between 0.94 to 4.95 where dinotefuran and clothianidin pose very high leaching potential whereas imidacloprid and thiamethoxam have high leaching potential. The persistence of these contaminants in groundwater depends on light, composition of microorganisms and biota.

After discussion it can be concluded that neonicotinoids have a high potential to leach vertically down the soil profile or laterally through soil flow paths and contaminate groundwater. With an ever-increasing scale of use, impacts on human being can be easily expected from intake of contaminated soil, food or water.

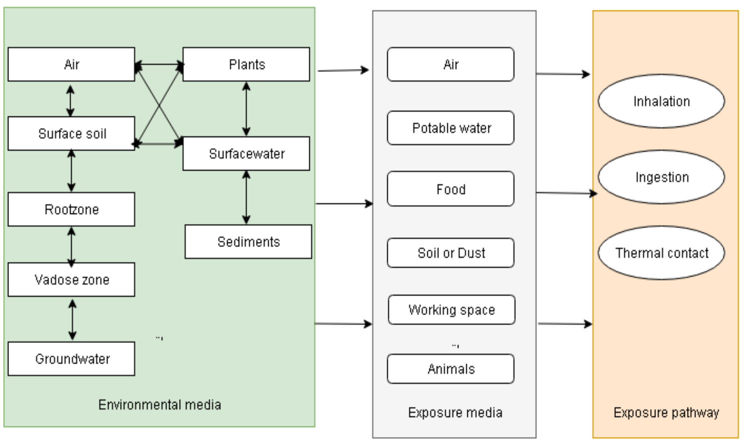

Fig 1: Environmental media, exposure media and pathway of neonicotinoids (Joseph and Thomas, 1998)

Impact on human

Neonicotinoids usually block a target neuron pathway that is copious in insects than mammals and animals (Frederick, 2016). These insecticides showsneuro toxicity to insects than others. However, very few studies regarding human health effects have been done so far. Our review sought to recognize and summarize the impacts on the human.

Traces of neonicotinoids contamination in soil, groundwater and surface-water have been found in various part of the world especially US, India, Japan, UK and Canada. It becomes lethal when organisms are exposed to a sufficient amount of pesticides for a long period of time. The conventional environmental media, exposure media and pathway to human contamination have been shown through Fig. 1. Human especially workers or farmers who are involved in the production, transportation, mixing, loading of pesticides and associated with food production are at highest risk for their long-term exposure. The dermal route has the greatest potential for exposure, with a minor contribution of the respiratory route when aerosols or aerial spraying are used. Usually neonicotinoids are less volatile to atmosphere which make it popular than DDT. Ingestion of contaminated foods like vegetables, fruits and animals, intake of water and inhalation of particulate may cause bioaccumulation in a victim's body. At a low dose, bioaccumulation of imidacloprid was observed in the animal study (Kavvalakis, 2013).

The EPA categorizes neonicotinoids as both toxicity "class II and class III" compounds. They are also labelled with the indicator word "Warning and "Caution". Neonics are especially recognized as its capacity to impact on developing brain especially in central nervous system. Neonics have been found to affect mammalian acetylcholine receptor (nAChRs) in a similar way that nicotine does (Kimura et al., 2012). A unique aspect of neonic toxicity is the ability to bind to the most prominent subtype of nAChRs in mammals. These acetylcholine receptors are mostly found in the thalamus of any warm blooded animal (Chen et al., 2014). It has also been found in PPDB that thiacloprid is more likely carcinogenic to human. According to beyond pesticides blog, imidacloprid and clothianidin are moderately toxic and probably linked to neurotoxic, reproductive and mutagenic effects if exposure for a long term.

Toxicity data shows that imidacloprid is less toxic when absorbed by the skin or when inhaled compared to ingestion. It causes minor eye reddening, but is non-irritating to the skin (Frederick, 2016). However, a study (Alok et al., 2013) from Indian report investigated serious cases of human intoxication with imidacloprid, three of which were fatal. This study reported a case that presented with severe gastrointestinal symptoms along with respiratory distress and neuropsy- chiatric features following accidental inhalation exposure to imidacloprid. Traces have also found in the urine of young kids in Japan but their environmental exposure pathway is still unidentified (Aya et al., 2016). In general, it poses low toxicity to human beings even in large ingestion. No poison-specific treatments are developed and also lack of antidotes. So, it can be concluded from the different study that disorientation, sweating, vomiting, agitation, increased heart and respiratory rates are the side-effects from the long-term exposure of neonicotinoids.

CONCLUSION

Environmental compartments are becoming full with compounds of neonicotinoids widely. The main benefit of this pesticide is its acute toxicity on target insecticides rather than mammals or human. This systematic pesticide causes threat to soil environment, surface and groundwater ecosystem because of its low volatility, high water solubility, low soil adsorption, and longer half-life; act as a better substitute than DDT or others. Leaching of pesticides is the key mechanisms responsible for the contamination of groundwater. There is no carcinogenic information on thiamethoxam and nitenpyram. It is highly ambiguous to draw some decision based on the studies of few cases. Yet, few studies showed that neonicotinoids pose low toxicity to human beings even in large ingestion although new born, children and old are more vulnerable. Few side-effects along with increased heart and respiratory rates have been confirmed from the long-term exposure of neonicotinoids.

Regular monitoring of its level in environmental compartments are required to control the concentration. Besides that, as a result of wide-scale use of neonicotinoids in UK, US, China, and India, further research is recommended to explore the human health effects; if possible in-depth research on diagnosis and treatment of acute noetic exposures.

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A STUDY ON ISO 14001 ENVIRONMENT MANAGEMENT SYSTEM IN BANGLADESH

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ABSTRACT
ISO 14001 is environment management system, a central member of ISO 14000 series. It specifies the requirements for an industry or organization to have a certifiable environmental management system. It not only implies a guidelines to protect & prevent environment but also plays role in sustainable development of balance between industry & eco system. In the world community many advanced countries adopted this EMS for a sustainable growth without misbalancing Mother Nature's law. Behind the pioneer industrial leaders Bangladesh is also marching forward in industrial revolution with very limited resources. So to obtain & sustain in this long run merging our industrial system with global standards is a concurrent demand. Albeit some industries adopted the other standards of ISO, the EMS still in the slow side especially when it is mandatory for small country like ours. Even some of our medium & small enterprises do not have any plan to adopt this standard in future. So this paper here focused on the scopes & necessities of ISO 14001 EMS for organizations to achieve sustainable process in business growth along with environmental balance. Furthermore the EMS brought many advantages for organizations including reduction cost & increasing process efficiency by its continual improvement & prevention of pollution policy. So here recommendation are made for the growing industrial sector of our country to adopt EMS for a better green future of this riverine land.

Keywords: ISO, EMS, Sustainable, ISO standards, Eco system, ISO 14000 series.

INTRODUCTION
Industrial revolution is a wind which already embraced the developed countries of this world. Changes came in those countries economy rapidly & with this flash of development they had climbed the top of success in technology. This leaders of economy made their nations marched forward with a systematic approach with adjacent framework. This frameworks were the monitory pathways which helped the 1st world countries keeping ahead a light year than the poor nations. However with time now this frameworks are available internationally to guide the industries for betterment. ISO (International Organization for Standardization) has become the worldwide federation of international standard bodies which sole purpose is to prepare standards through involving ISO technical committees. Achieving balance between the environment, society & the economy is considered essential to meet the needs of the present without compromising the ability of future generations to meet their needs. The purpose of ISO 14001 standards is to provide organizations with a frame work to protect the environment & respond to changing conditions in balance with socio economic needs. It specifies requirements that enable an organization to achieve the intend outcomes it sets for healthy environmental management system. Like others Bangladesh is also in the wave of development in industrial sector & technology but we have a very few natural resources. Despite of the capricious climate condition & over dense population along with indigence we have to move on to keep the pace with world economy. ISO 14001 EMS could be a very effective tool to save the environment & concurrently get maximum utilization of natural resources for betterment of industrial growth.

METHODOLOGY
This proposed paper focused on the importance and limitations of EMS for organization in Bangladesh. For this purpose site visit was made and data collected on one process plant of Bangladesh. However after

collecting data and studying them it is found that industries using EMS for their management processes are getting good environmental and business outputs. Furthermore this paper identified the scopes that local companies have to emphasize for adopting EMS and get sustainable benefits. Success factors of proper implementation of EMS with management tools also discussed considering the limitations of this countries organizations. Thus this case study will provide a path way for local companies to adopt international environmental standard by following the world leaders. In this paper we will observe Aim and scope of EMS in industries of Bangladesh, Success factors, PDCA cycle, and limitations of EMS in Bangladesh and Data analysis of local industries for EMS

Aim and scope of EMS in industries of Bangladesh

The abbreviation of EMS is environmental management system which has been using as a standardization process for industries environmental impacts all over the world from last few decades. With rapid industrial revolution & economic growth the countries started marching forward with a light speed. Through the economy needs energy to boost up its process but our nature has its own limitations. Water is the purest substance on earth which is not only the raw material of many industrial processes but also the washing medium. Last few decades witnessed the rapid industrial revolution & also the adulteration of our finest element on earth. So ISO 14001 EMS is particularly designed to maintain & handle the industrial waste up to a level for its reuse and to release back to environment with minimizing harmful effects. Industrial impact on environment occurs in various aspects, depending on the type of industries of our country. We are in an initial stage of industrial growth & without achieving sustainability further development is quite unobtainable. For Bangladesh this sustainable developments evolved with some factors such as growing pressure of population on environment, transparency & sustainability of stringent legislation, inefficient use of resources, improper waste management system etc. The impacts of this are climate change, degradation of ecosystem, loss of biodiversity & above all scarcity of available energy. To reduce this environmental effects at the same time with the rapid increase in the industrial economy organizations of Bangladesh need to adopt a systematic approach to environmental management by implementing EMS with the aim of contributing to the environmental pillar of sustainability. The standard framework is design in such a skeleton form to protect the environment & concurrently respond to the changing environmental aspects in balance with socio economic needs. It specifies requirements that enables an organization to achieve the intended outcomes it sets for its EMS. The aim of EMS should be such that it will provide an organization to build success over the long term sustainable development to save the surrounding natural resources & reduce impacts by:

- Protecting the surrounding environment by preventing adverse industrial impacts.
- Mitigating the potential adverse effect of environmental conditions on the organization
- Assisting the organization to fulfill their compliance obligations.
- Controlling the way of organization’s products & services designing, manufacturing, distribution, consumption & disposal by using a life cycle perspective that can prevent environmental impacts.
- Proper communication of environmental impact to interested parties.

Success Factors

The success of environmental management system depends on commitment from all levels and functions of the organization led by top management. Organization can leverage opportunities to prevent or mitigate adverse environmental impacts with strategic and competitive implications. Top management can effectively address the risk and opportunities by integrating environmental management into organization’s business, process and aligning environmental governance into its overall management system. Demonstration of successful implementation of this ISO 14001 can be used to assure interested parties that an effective environmental management system is in place.

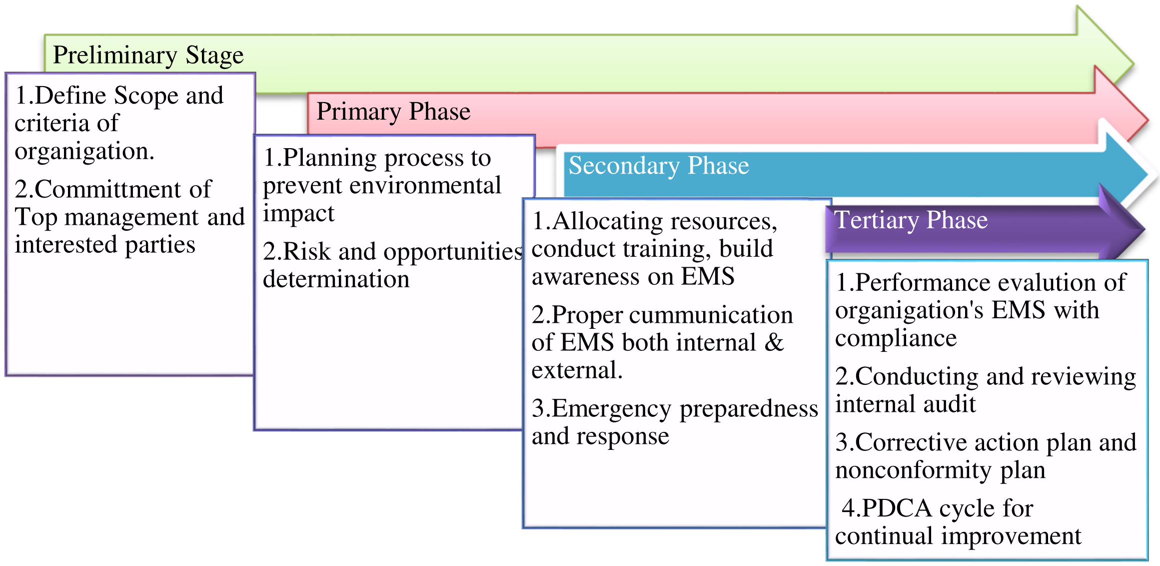

Fig.1: Flow diagram of success factors for adopting and implementation of EMS

Preliminary Stage

Adopting international standard of EMS will not in itself guarantee optimal outcome to reduce environmental impacts. Application of this standard can differ from one organization to another due to the extent and context of organization. Two organization can carry out similar activities but can have different compliance obligators, commitments in the environmental policy. So preliminary stage is to define the scope of organisations and its boundary so that the impact on environment could be identified. Top management along with all interested parties have to understand the facts of environmental impacts related to their business processes. Top management should indicate the environmental objectives, fulfil compliance obligator and enhance environmental performance by continual development.

Primary Stage

The surroundings in which an organization operates its processes is called environment which includes air, water, land, natural resources, flora, fauna, humans and their interrelationships with surroundings. Surroundings can be extended from within an organization to the local, regional and global system. Biodiversity, ecosystem, climate and other characteristics can be also described as surroundings. Element of an organization's activities or products or services that interact with the environment could be referred as environmental aspects. Environmental aspects can cause environmental impacts. Proper planning for available environment condition need to be characterised within certain points. Have to set objective for obtaining environmental goals. So objective have to be strategic and measurable. An objective can be expressed in other ways, e.g. as an intended outcomes, a purpose, an operational criterion or a goal. Environmental policy have to be considered during setting the objectives of an organization. Prevention of pollution can include source reduction, process or product change, efficient use of available resources, material and energy substitution. Reuse, recovery, recycling or treatment could also mitigate environmental impacts. Organization should consider the compliance obligations related to EMS and analyse the effect of uncertainty or risk.

Secondary Phase

To adopt and implement EMS in an organization the basic requirements are proper knowledge and adequate resources. Leadership of top management could boost up this process as their direct involvement in the EMS adopting process will help them to utilize the hindrances of organization process. Competence is another sever factor as only a competence person can be a good resource. Hence organization have to determine necessary competence of persons involving in work under its control that affects its environmental performance and its ability to fulfil its compliance obligations. Ensuring the competence of the involved personal on the basis of appropriate education, training and experience. The organization have to circulate the EMS policy for proper awareness and the significant environmental aspects related actual or potential environmental impacts associated with their work. Evaluating people's contribution to the effectiveness of EMS, including the benefits of environmental performance is another important criteria for maintaining EMS in an organization.

Tertiary Phase

This phase includes compliance indicators and their evaluation of meeting, internal audit programs for continual improvement, action plans for both corrective and nonconforming outputs etc.

PDCA CYCLE

This is a management tool for maintain EMS for any organization and thus developing the business process by continual improvement. This cycle consist of plan, do, check and act phase. An organisation that starts to implement ISO 14001 may be a company, corporation, firm or enterprise. It can be incorporated or not, public or private and has its own function and administration. But PDCA cycle is equally essential for all entities. Planning includes identifying environmental problems, establishing goals, aims and environmental policy. Do refer to implementation and operation. An organisation must establish various elements necessary for the implementation and operation of the plan. Checking includes monitoring, measurements, and EMS auditing. This part of the standard should define how the performance of the EMS is checked and weaknesses strengthened. Act includes management reviews. Top management and appropriate staff must periodically review the management system once a year based on information from measurements, monitoring and audits. Where needed, the programme is renewed; new objectives and aspects are established and policy is changed etc.

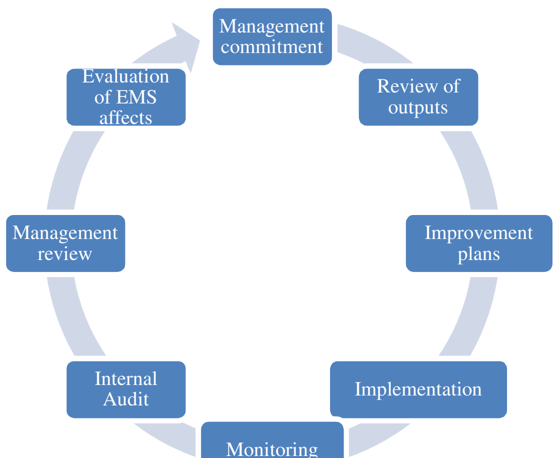

Fig.2: EMS Implementation and improvement circle

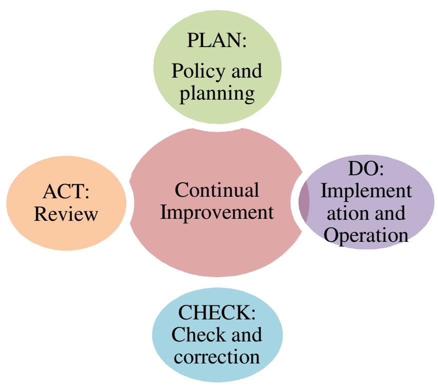

Fig.3: "Plan, Do, Check, Act" model.

LIMITATIONS FOR INDUSTRIES IN BANGLADESH TO ADOPT EMS

Bangladesh is a small country with her dense population. Industrial revolution had touched this country's economy to such an extent that Bangladesh not only fulfilling its own demand but also exporting goods to international market. Though this country has a very limited source of natural resources, proper utilization of resources can help this boom of economy in upcoming future. Hence we have to put emphasize on proper prevention from pollution of these limited natural resources. In today's world fast growing industries are marching towards eco-friendly business process to keep the environment safe and protected whereas in Bangladesh things have been running at opposite direction. Over population, poverty, low quality of livelihood and above all limitations of resources made industrial growth cuffed, thus to keep pace with international community people exploiting natural resources like rivers, channels etc. As industry needs proper and cheaper transportation, so maximum industry grew up near the river banks and continuously discharging their waste in rivers without prior treatment and destroying available water sources. Furthermore high cost of waste disposal also influencing the easy discharging into the river. It is high time to think twice before further exploiting the natural resources thus EMS for every organization is required. EMS will provide the guidelines to mitigate the adverse effect for industrial processes. Industries of this country have to consider the EMS as the helping tool which would made their business not only eco-friendly but also profitable.

DATA ANALYSIS OF AN INDUSTRY IN BANGLADESH

Table 1: EMS criteria and action taken by EMS certified organization (BPBL). (Collected on site)

Sr. No.	Criteria	Environmental Impact	Action taken	Annual Generation	Annual Treated	Before EMS Implementation	After EMS Implementation
1	Emission	Air pollution	Dissolve in water	16-18Ton/yr	13-15Ton/yr	20%	83.3%
2	Sewage water	Water Pollution	ETP	135 KLD	108 KLD	12%	80%
3	Chemical Disposal	Surrounding pollution	Incinerator	25-28Ton/yr	20-22Ton/yr	10%	78.5%
4	Hot works	Fire hazard	Fire Hydrant	8-8.5Ton/yr	7-8Ton/yr	25%	95%
5	Metal Disposal	Soil pollution	Incinerator	11-13Ton/yr	8-10Ton/yr	15%	76.9%
6	Earthing	Lightening impact	Earth Pit	N/A	N/A	56%	93%
7	Noise level	Sound pollution	Maintain dB level	98 dB/day	81 dB/day	45%	82.6%
8	CFC level	Greenhouse effect	CFC free Compressor	N/A	N/A	8%	12%
9	Process Dust	Air pollution	Dust collector	25-26Ton/yr	20-22Ton/yr	26%	84.6%

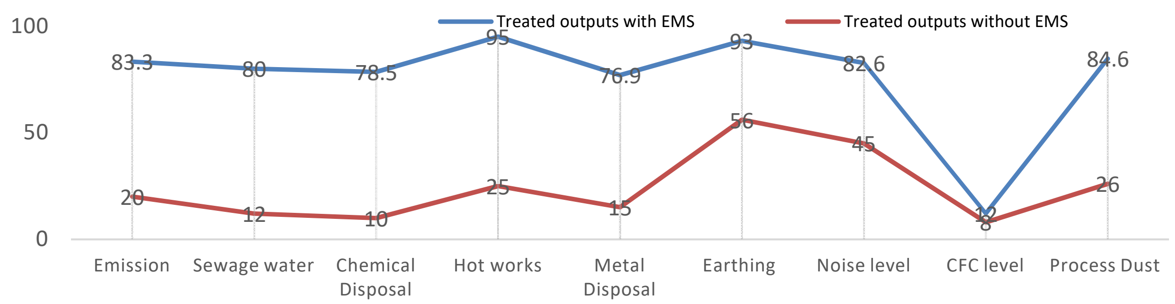

Fig.4: Treated pollutant outputs before and after environment management system implementation.

Mathematical expression for oil recovery percentage calculation

$$\frac{\textit{Annual pollutent treated}}{\textit{Annual Pollutent generated}} = \% \frac{\textit{Annual treated output}}{100} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

RESULTS AND DISCUSSIONS

According to Table 1 and using Eq. 1 percentage of annual treated output or annual performance indicator from Berger paints Bangladesh limited found increased 3-4 times after proper implementation and utilization of EMS. For furnace emission the amount of treated pollutant before discharging to environment was 20% whereas after taking ISO 14001 it increases to 83.3%. Also the sewage water and noise level treatment percentage showed same sort of change after taking EMS which is above 80%. In case of CFC level proper monitoring with EMS tools has increased up to 4% than previous. Unlike the other pollutant adjustment hot works, chemical disposal and metal disposal shown same characteristics. For process dust after EMS implementation the annual treated pollutant rate increased to 84.6% than only 26%. So proper utilization of this international standard could help to mitigate the overall pollutant impacts on environment caused by an organisation by its process and business outputs.

CONCLUSIONS

In this paper, the study represents the importance of EMS to mitigate pollution. With proposed environmental management system an organization can understand the effects of its environmental threat. This paper tried to focus on necessity of ISO 14001 EMS to adopt and implement for both environmental and economic beneficiary thus sustainability can be achieved for an organization. Developing countries like Bangladesh where the usage of renewable energy is so low due to costly investment, adopting environmental management system could be a remarkable achievement to save further damage to the existing natural resources. Moreover some leading organizations of Bangladesh also adopted this standard leaving a track for the local organizations for both implementation and gain sustainability. In densely populated country like ours where air pollution, noise pollution and water scarcity is a curse we have to create some breathing space under these immense pressure of population growth & industrialization. This could only be done if an organization meet both the requirement of effective environment management approach and economically beneficial results. If the benefits of this international standard are properly understood then it will be a matter of time that many local organizations will march forward along with government aid to adopt this standard & make the world green again.

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USE OF MEMBRANE BIOREACTOR FOR THE TREATMENT OF WASTE WATER

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ABSTRACT

Bangladesh is among the countries with the lowest level of wastewater treatment in the Asia Pacific region. The country treats only 17 present of its wastewater says the United Nations World Water Development Report 2017 released on 22nd March, 2017. On water management system in Dhaka, the report said only two present of its water was safely managed. It also stressed the need for improving the efficiency of wastewater treatment and management systems in order to increase the proportion of wastewater that is safely managed. Membrane bio reactor (MBR) is one of the novel and green approach for the treatment of waste water. Membrane bioreactor (MBR) is the combination of a membrane process like microfiltration or ultrafiltration with a biological wastewater treatment process, the activated sludge process. It is now widely used for municipal and industrial wastewater treatment. This system is cost effective compare to other treatment process since it does simplify the complexities of waste water treatment. It can effectively reduce almost 97% of BOD from the municipal waste water. This paper will provide information about how the membrane bioreactor can be used to treat waste water in Bangladesh. This paper will also discuss about fouling which is considered as one of the most significant drawback in MBR system and suggest some anti-fouling measure.

Keywords: Waste water; Treatment of waste water; Membrane Bioreactor; Air pollution treatment; Biological treatment

INTRODUCTION

MBRs are being increasingly used for wastewater treatment that requires excellent effluent quality, e.g., water reuse or water recycling (Judd, 2006, 2008; Liao et al., 2006; Yang et al., 2006; Wang et al., 2008a). MBRs allow high concentrations of mixed liquor suspended solids (MLSS) and low production of excess sludge, enable high removal efficiency of biological oxygen demand (BOD) and chemical oxygen demand (COD), and water reclamation. However, membrane fouling is a major obstacle to the wide application of MBRs. Additionally, large-scale use of MBRs in wastewater treatment will require a significant decrease in price of the membranes. The current MBR market has been estimated to value around US$216 million in 2006 and to rise to US$363 million by 2010 (S. Atkinson ,2006). MBR is needed if waste-water is discharged into sensitive waters especially those designated for contact water-sports and recreation. MBR is the combination of a membrane process like microfiltration or ultrafiltration with a biological wastewater treatment process, the activated sludge process. It is now widely used for municipal and industrial wastewater treatment (S. Judd, 2006). MBR when used with domestic wastewater, the processes can produce effluent of high quality enough to be discharged to coastal, surface or brackish waterways or to be reclaimed for urban irrigation. Other advantages of MBRs over conventional processes include small footprint, easy retrofit and upgrade of old wastewater treatment plants. It is possible to operate MBR processes at higher mixed liquor suspended solids (MLSS) concentrations compared to conventional settlement separation systems, thus reducing the reactor volume to achieve the same loading rate. Recent technical innovation and significant membrane cost reduction have enabled MBRs to become an established process option to treat wastewaters (S. Judd, 2006). As a result, the MBR process has now become an attractive option for the treatment and reuse of industrial and municipal wastewaters, as evidenced by their constantly rising numbers and capacity.

The objective of this paper is to: Discuss about the significance of membrane bioreactor (including its types, process of work, its benefits and drawbacks) for the treatment of industrial waste water; and The paper will also discuss some counter measure to control the fouling process in MBR which is considered as one of the most important drawback in MBR system.

MEMBRANE BIOREACOR

Types of membrane bioreactor

Broadly membrane bioreactor can be categorized in to two types such as, 1. Internal or submerged MBR, and 2. External or side stream MBR. The breakthrough for the MBR came in 1989 with Yamamoto and co-workers idea of submerging the membranes in the bioreactor. Until then, MBRs were designed with the separation device located external to the reactor (side stream MBR) and relied on high transmembrane pressure (TMP) to maintain filtration. Both the categories are briefly explained below.

Internal/submerged MBR

The filtration element is installed in either the main bioreactor vessel or in a separate tank. The membranes can be flat sheet or tubular or combination of both, and can incorporate an online backwash system which reduces membrane surface fouling by pumping membrane permeate back through the membrane. In systems where the membranes are in a separate tank to the bioreactor, individual trains of membranes can be isolated to undertake cleaning regimes incorporating membrane soaks, however the biomass must be continuously pumped back to the main reactor to limit MLSS concentration increase. Additional aeration is also required to provide air scour to reduce fouling. Where the membranes are installed in the main reactor, membrane modules are removed from the vessel and transferred to an offline cleaning tank (Wang et al., 2008).

External/side stream MBR

The filtration elements are installed externally to the reactor, often in a plant room. The biomass is either pumped directly through a number of membrane modules in series and back to the bioreactor, or the biomass is pumped to a bank of modules, from which a second pump circulates the biomass through the modules in series. Cleaning and soaking of the membranes can be undertaken in place with use of an installed cleaning tank, pump and pipework (Wang et al., 2008).

Process of membrane bioreactor

When used with domestic wastewater, MBR processes could produce effluent of high quality enough to be discharged to coastal, surface or brackish waterways or to be reclaimed for urban irrigation.

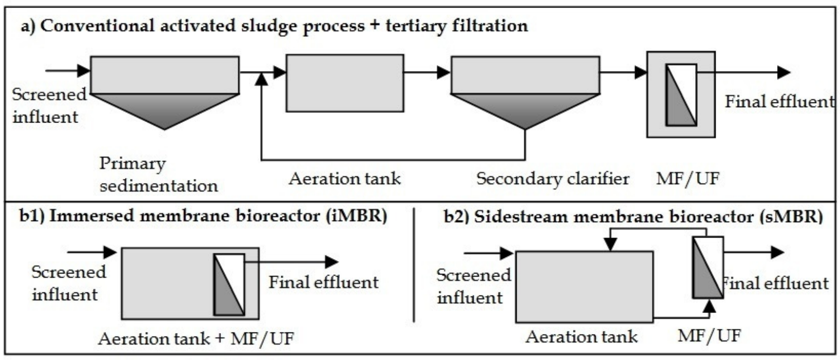

Fig 1: (a) Schematic of conventional activated sludge process (b1) internal (immersed) membrane bioreactor (b2) external (side stream) membrane bioreactor

Other advantages of MBRs over conventional processes include small footprint, easy retrofit and upgrade of old wastewater treatment plants. It is possible to operate MBR processes at higher Mixed Liquor

Suspended Solids (MLSS) concentrations compared to conventional settlement separation systems, thus reducing the reactor volume to achieve the same loading rate.

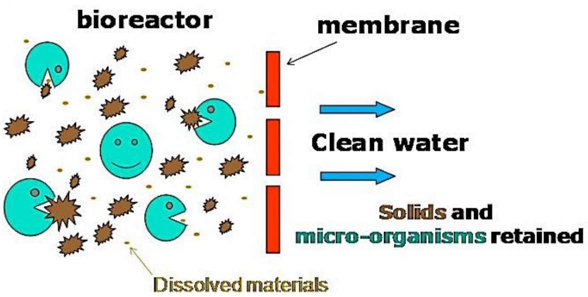

Fig 2: Simple schematic describing the MBR process

The wastewater is first screened and then fed to a bioreactor as shown in [Fig. 1 and Fig. 2]. The bioreactor is a tank made of steel, concrete etc. In the bioreactor the organic content of the waste water is reduced considerably by the presence of microorganisms. There is a pipe at the bottom through which air is blown to provide the necessary aerobic conditions. In the anoxic zone de-nitrification results. The nitrates, nitrites etc. is reduced to nitrogen gas. Now the mixed liquor is passed through a membrane module (UF or MF). The effluent is sucked with the help of vacuum created by a vacuum pump. The sludge is returned back to the bioreactor with occasional purging. The effluent after disinfection can be utilized for feed water to the reverse osmosis plant.

BENEFITS AND DRAWBACK OF MEMBRANE BIOREACTOR

The benefits of MBR can be explained by the following points.

1) The first advantage of this technology is considered to be the compactness, as the clarifier, where the separation of the sludge from the treated effluent occurs traditionally by gravity, is replaced by a membrane filtration which can be implemented directly in the aerated biological reactor.
2) Moreover, the membrane system can be operated with sludge concentration in the biological reactor up to 20 or 25g TS (total solids)/L, unlike the conventional technology which is limited to max 5g/L in order to ensure good sludge sedimentation.
3) Furthermore, unlike the conventional technology the MBR plants can be operated with a broader range of operation conditions such as sludge concentration, sludge age, organic load etc., and are more robust to load variations.
4) Another specificity is the broad range of operative sludge concentration, which enables to decouple the hydraulic residence time (HRT) from the mean cell residence time (MCRT), or sludge age. This renders the technology especially interesting for areas with important seasonal or daily variations, such as in tourist or decentralised districts.
5) In addition, the modularity of the technology facilitates the use and planning in areas with quick population growth (i.e. developing countries or new settlements), where the amount of water to be treated is difficult to predict beyond few years.
6) Last but not least, the MBR technology stands out for the excellent and constant treatment quality that is achieved: particle free and disinfected effluent whatever the incoming raw water or pollutant load, and notwithstanding usual problematic issues in conventional plants such as filamentous bacteria, bulking or floating sludge, pinpoint flocs, etc. This makes the MBR treated water particularly relevant when high treatment standards are required, such as to comply with bathing water directives and or unrestricted water reuse. Due to the advanced quality of the MBR permeate, devoid of particles, bacteria but also colloids, the MBR technology is also an excellent pre-treatment before Nano-filtration or reverse osmosis.

The drawbacks of membrane bioreactor are given below:

1) The main drawback of the membrane bioreactor technology still remains the capital and operation costs due to use of the membrane filtration aggregates (first sets and replacements), and the high energy requirement resulting from module aeration.
2) Quick membrane fouling and inefficient membrane cleaning after fouling impact also significantly operation and membrane replacement costs through reduced lifespan of membrane modules, and loss of permeate during filtration breaks and back flush.
3) It is also a "high-tech system" requiring qualified and committed staff, clear operational guidelines, and quick reaction in case of any process or system disturbance.

CONSTRAINT OF MBR SYSTEM: MEMBRANE FOULING

Characteristics of membrane fouling and its importance in MBRs

Membrane fouling is a major obstacle that hinders faster commercialisation of MBRs. As shown in [Fig. 3], membrane fouling in MBRs can be attributed to both membrane pore clogging and sludge cake deposition on membranes which is usually the predominant fouling component (Lee et al., 2001).

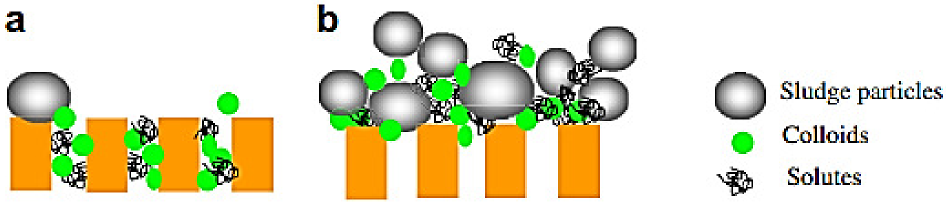

Fig 3: Membrane fouling of MBR: (a) pore blocking and (b) cake layer

With respect to MBRs, membrane fouling occurs due to the following mechanisms: (1) adsorption of solutes or colloids within/on membranes; (2) deposition of sludge flocs onto the membrane surface; (3) formation of a cake layer on the membrane surface; (4) detachment of foulants attributed mainly to shear forces; (5) the spatial and temporal changes of the foulant composition during the long-term operation (e.g., the change of bacteria community and biopolymer components in the cake layer). In other words, the membrane fouling can be defined as the undesirable deposition and accumulation of microorganisms, colloids, solutes, and cell debris within/on membranes (Cho and Fane, 2002; Zhang et al., 2006a).

Anti-fouling strategies that can be applied to MBR

Many other anti-fouling strategies can be applied to MBR applications. They comprise, for example:

1. Intermittent permeation or relaxation, where the filtration is stopped at regular time interval before being resumed. Particles deposited on the membrane surface tend to diffuse back to the reactor; this phenomenon being increased by the continuous aeration applied during this resting period.
2. Membrane backwashing, where permeate water is pumped back to the membrane, and flow through the pores to the feed channel, dislodging internal and external foulants.
3. Air backwashing, where pressurized air in the permeate side of the membrane build up and release a significant pressure within a very short period of time. Membrane modules therefore need to be in a pressurised vessel coupled to a vent system. Air usually does not go through the membrane. If it did, the air would dry the membrane and a rewet step would be necessary, by pressurizing the feed side of the membrane.
4. Proprietary anti-fouling products, such as Nalco's Membrane Performance Enhancer Technology (Nalco, 2008)

In addition, different types/intensities of chemical cleaning may also be recommended:

1. Chemically enhanced backwash (daily);
2. Maintenance cleaning with higher chemical concentration (weekly);
3. Intensive chemical cleaning (once or twice a year).

CONCLUSION

Both the research and commercial application of membrane bioreactor technology are growing rapidly around the world for both municipal and industrial waste water treatment. Also, It is one of the most cost effective and environment friendly approach towards waste water treatment. Bangladesh should consider this method due to its cost efficiency and also conduct research on MBR since it has a promising future in context to existing treatment methods of Bangladesh.

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THE EFFECTIVENESS OF LOCALLY AVAILABLE CHARCOAL IN REMOVING DYE FROM INDUSTRIAL WASTE WATER

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ABSTRACT

The treatment of industrial effluent has received great attention in the past few years due to increasing environmental awareness and the implementation of ever stricter environmental rules. Adsorption is one of the techniques used for the effective treatment of dyes. However, the efficiency of the adsorption process depends on the choice of a suitable adsorbent. Because of the high cost of some conventional adsorbents, this research has been conducted for seeking alternatives, such as locally available charcoal. To fulfill this aim waste water were collected from Beximco Textile Industry and then experiments were carried out in their laboratory. To remove the dye five doses (20 mg, 40 mg, 60 mg, 80 mg and 100 mg) of charcoal of five different particle size (1-1.8 mm, 0.6-1mm, 0.3-0.6 mm, 0.15-0.3 mm and0.075-0.3 mm) along with five different centrifuging time (3, 6, 9, 12 and 15 minutes at 4000 rpm) are used. From this experiment it is seen that charcoal is very much effective in removing dyes from colored waste water as around 88-100% of color can be removed and 100% efficiency is achieved using 60 mg charcoal in 100 ml sample having particle size 0.3-0.6 mm which was centrifuged for 15 minutes at 4000 rpm.

Keywords: Effluent; Dye; Adsorbent; Charcoal; Environment.

INTRODUCTION

Water is the most vital element among the natural resources which directly contributes to food production and economic development and also critical for the survival of all living organisms including human. In modern world, there are many cities facing an acute shortage of water and nearly 40 percent of the world's food supply is grown under irrigation (FAO, 2011). Having a wide variety of industrial processes depending on water and the world-wide high level of production and use of dyes which generates colored wastewaters depicts the future with more severe shortage of usable water.

It is a very fact for a developing country like Bangladesh where the production rate is growing at a faster pace of 11.04 % per year to meet the ever-increasing demand of fabrics and food for the rapid expanding population. Textile industry is a complicated manufacturing industry which generally requires 100 liters to 1200 liters water for dyeing per square yards of clothes of most of that comes out as wastewater (Hossain *et. al*., 2007) and in case of dying industry, above 30-60 liters of water is consumed by per kg of cloth dyed (Sivraj,*et al*., 2001) and about 16% of the total water consumed are released during process as effluent. (Namasivayam, *et al*., 1994). Matter of fact that nearly 10-15% of the synthetic textile dyes are lost to waste streams and about 20% of these losses enter the environment per year (Sivraj*et. al*., 2001).

This colored waste water from fabric, textile and dying mills is a serious pollution problem because it is high in color and organic content, temperature, suspended solid content and also high in biological oxygen demand (BOD) and chemical oxygen demand (COD) (Sivraj, *et al*., 2001, Dhas,2008). Now a days, there are more than 10,000 dyes available commercially (Nigam, *et al*., 2000), most of which are not easy to biodegrade because of their stability toward light and oxidation; also these dyes are resistant to aerobic digestion (Gupta *et al*., 2004) due to their complex aromatic molecular structure and synthetic origin (Seshdari *et. al*., 1994). Except changing the quality of the water these dyes cut transmission of sunlight into streams and thereby reduces photosynthetic activity (Namasivayam *et. al*., 2001) and aquatic bio-diversity (Dhas, 2008) with causing allergic dermatitis and skin irritation. Some of dyes are carcinogen or may be transformed into carcinogen (Lee *et. al*., 1999; Pappic *et. al*., 2000). These pollutants also affect ground water system due to leaching (Namasivayam and Sumithra, 2005). The primary concern about effluent color is not only its toxicity but also its undesirable aesthetic impact on receiving waters.

The conventional methods of sewage treatment, such as primary and secondary treatment systems are not suitable for the treatment of effluents from textile companies, dye manufacturing industries, paper and pulp mills, tanneries, electroplating factories, distilleries food companies (Amin *et al*., 2008) containing dye molecules because their very complex nature and stability to heat and light. The methods of color removal from industrial effluents include biological treatment, coagulation, adsorption, oxidation and hyper filtration. Among adsorption is an effective method of lowering the concentration of dissolved dyes in the effluent resulting in color treatment and also due to its sludge free clean operation and complete treatment of dyes and activated carbon is the best option because of its extended surface area, micro pores structure, high adsorption capacity and high degree of reactivity though (Malik, 2003). However, commercially available activated carbons are very expensive for developing countries (Malik, 2003). As a result a wide variety of low cost materials such as agricultural by product (Kadirvelu *et al.*, 2000), waste coir pith (Namasivayam *et al.*, 2001), Indian rosewood sawdust (Garg *et al.*, 2004), pine sawdust (Özacar and Şengil, 2005), banana pith (Namasivayam *et al.*, 1998), rice husk (Lee, *et al.*, 1999), orange peel (Namasivayam *et al.*, 1996) are used as adsorbent. But these materials are not always easily available in Bangladesh. Therefore development of low cost alternative adsorbent which is available in all season has been the focus of this research.

The present study investigates the efficiency to remove color or dyes from effluent using cheaper source of adsorbent, namely charcoal, which is locally available in Bangladesh along with its efficiency under different conditions. The aim of this study is to examine color reduction efficiency in selected wastewater by locally available charcoal. Specific objectives include:to investigate the efficiency of charcoal in the removal of dyes present in textile effluents and to determine the removal performance at different experimental conditions.

METHODOLOGY

Charcoal, a final black odorless and tasteless substance made from wood or other materials that have been exposed to very high temperature in an airless environment is very available and cheap in Bangladesh and was collected from Karwan Bazaar (local market).Wastewater samples were collected from three sites (dyeing Section, printing section and finishing section) in the Beximco textile industry according to the instructions of APHA, 1998. After that laboratory test was conducted on five different sample of 100 ml wastewater added with 20 mg, 40mg, 60mg, 80mg and 100mg charcoal. To achieve the highest efficiency three variables were taken into consideration such as quantity of charcoal, centrifugation time and particle size of charcoal (1-1.8 mm, 0.6-1mm, 0.3-0.6 mm, 0.15-0.3 mm, 0.075-0.3 mm). After resting for 24 hours each of these samples were centrifuged for 3, 6, 9, 12 and 15 minutes respectively at 4000 rpm and then filtered by using filter paper (Whatman no. 1). The filtered water samples were experimented with the help of color test kit (HACH, USA) to assess the removal of color.

RESULTS AND DISCUSSION

The effluents from textile or dying industries contain small proportions of dyes which is degrading water quality as well as lowering the aesthetic value. That is why the removal of color from wastewater is often more important than the removal of soluble colorless organic contaminants. Therefore the outcomes of the present experiment are discussed under following subtitles.

Removing Color from Waste Water

Charcoal of five different particle sizes was used as adsorbent of wastewater for aqueous solution. The doses of each charcoal sample were varied as 20 mg, 40 mg, 60 mg, 80 mg and 100 mg each for 100 ml of waste water solution each of which was centrifuged for 3, 6, 9, 12 and 15 minutes. The color removal result in terms of percentage is presented in Table1.

Table1: Color treatment efficiency (percentage) under different conditions.

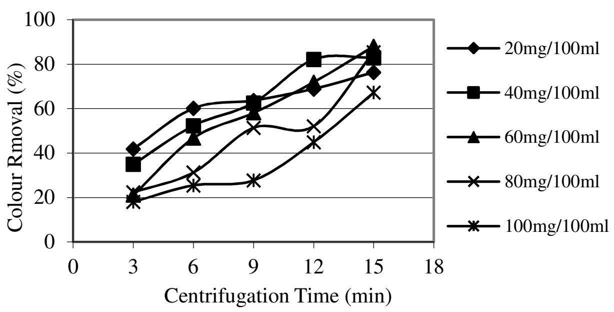
Sample	Centrifugation time (min)	Charcoal Dose (mg/100 ml)				
		20	40	**60**	80	100
Sample-1 (1-1.8 mm)	3	42	35	21	22	18
	6	60	52	47	31	26
	9	64	63	58	51	28
	12	69	82	72	52	45
	15	76	83	88	85	67
Sample-2 (0.6-1mm)	3	15	11	27	21	21
	6	34	20	28	23	43
	9	40	20	63	56	54
	12	47	64	65	57	68
	15	66	65	74	57	81
Sample-3 (0.3-0.6 mm)	3	92	88	93	95	95
	6	93	91	98	97	96
	9	94	94	98	98	98
	12	94	98	99	98	98
	15	99	99	**100**	98	98
Sample-4 (0.15-0.3 mm)	3	68	63	65	64	47
	6	78	64	65	69	48
	9	78	68	67	75	59
	12	72	72	74	76	66
	15	99	72	91	80	73
Sample-5 (0.075-0.15 mm)	3	51	54	47	32	36
	6	52	56	52	56	48
	9	65	57	56	67	64
	12	70	63	82	72	66
	15	76	88	89	73	84

Effect of Centrifugation time

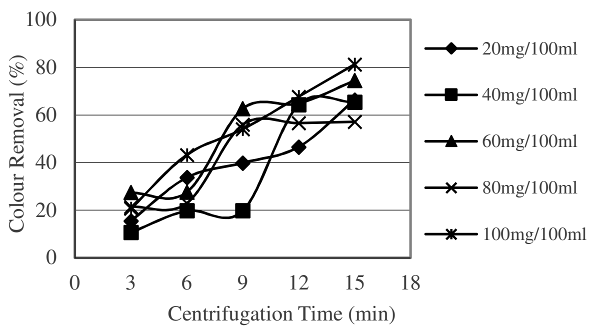
The effect of centrifugation time on color treatment with five charcoal samples of different particle sizes was examined and the results of color treatment are presented in Fig.1. These show a similar trend of color removal with respect to centrifugation time. The fractions of removal increased with the increasing time of centrifugation. The highest frequency of removal for all the samples was achieved at 15 minutes centrifugation time and for sample-3 the success rate is 100%.

Effect of Charcoal Particle Size

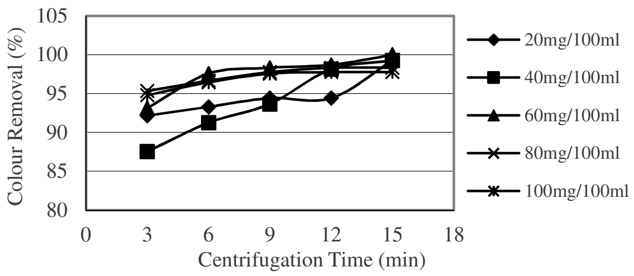
Five charcoal particle sizes; Sample-1(1 to 1.8 mm), Sample-2 (0.6 to 1 mm) Sample-3(0.3 to 0.6 mm) Sample-4(0.15 to 0.3 mm) and sample-5(0.075 to 0.15 mm) were used as adsorbent of five various doses.



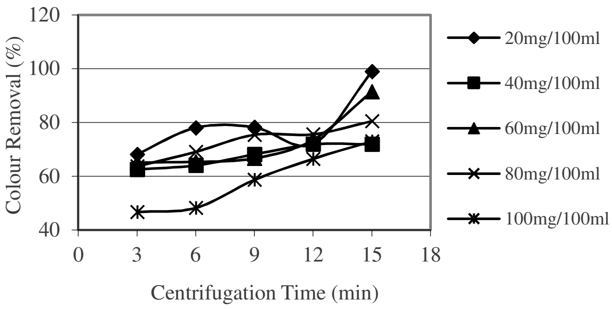
a) Sample 1



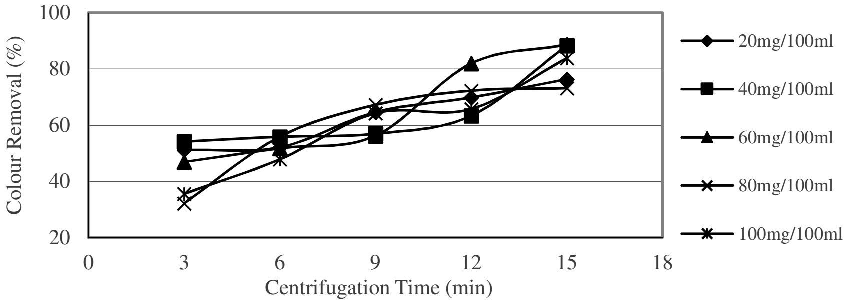
b) Sample 2



c) Sample 3



d) Sample 4



e) Sample 5

Fig. 1: Efficiency of Color Removal with Different Doses of Charcoal with Different Centrifugation Time

As maximum treatment was obtained at the centrifugation time of 15 minutes, the effect of particle size of charcoal on color removal is presented only for that duration in Fig. 2. The highest removal of color was obtained for the Sample-3 (0.3 to 0.6 mm sized charcoal powder).

Effect of Adsorbent Dose

The highest removal from wastewater solution was obtained against the charcoal dose of 60 mg/100 ml for all samples except Sample-2. The highest percentage of removal was obtained for Sample-3 in any doses of charcoal compared to the other samples.

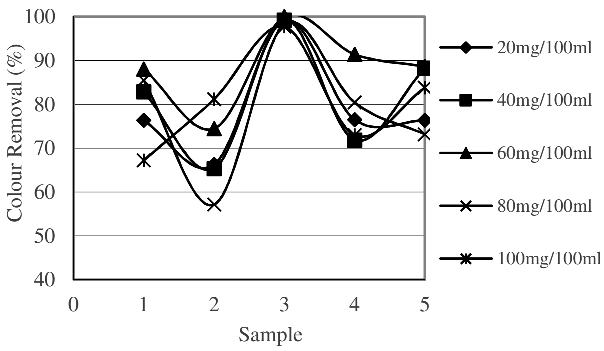


Fig. 2: The Effect of particle size of Charcoal on Color Removal

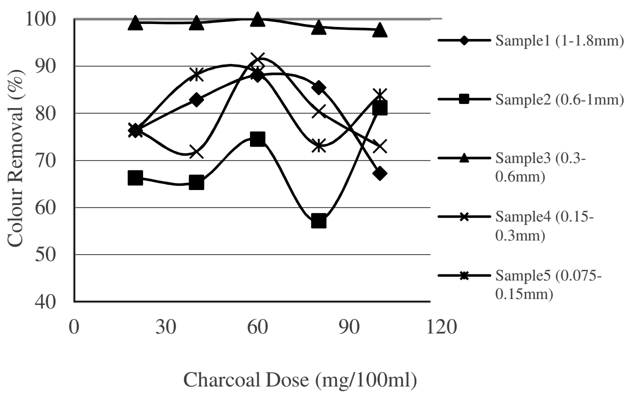


Figure 3: The Effect of dosage of Charcoal on Color Removal

CONCLUSION

The conflict between the development and environment is one of the greatest concern in today's world and this is gaining more attention due to the need for more production to meet the ever-increasing demand of the rapidly increasing population, basically in developing countries. Hence to ensure sustainable development, it is a matter of concern that the effluents from the production industries especially fabric and textile contain dye which changes the temperature, pH, COD and BOD values of the water bodies. But the authority is not interested to run ETP regularly due to high cost. Therefore, it is an urgent call to go for a cheaper source of adsorbent to get relief of dyes. With this aim, this work has found that locally available charcoal is very efficient since 100% efficiency is achieved with the use of 60 mg dose of charcoal per 100 ml waste water, grounded at particle size of 0.3-0.6 mm along with centrifugation for 15 minutes at 4000 rpm. Therefore if the charcoals can also work to standardize the pH, BOD and COD of the effluents, it will encourage the authority to run the ETP on a regular basis due to its low cost and round the year availability which in turn will ensure safer and greener environment for the coming future.

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EVALUATION OF A WATER TREATMENT PLANT IN CHITTAGONG CITY, BANGLADESH

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ABSTRACT

Water is one of the most vital element for mankind's survival. So, ensuring better quality of drinking water is of the utmost importance. Chittagong, the port city of Bangladesh is having issues due to increasing demand of drinking water. In order to satisfy the demands of people, Chittagong Water Supply and Sewerage Authority (CWASA) of Bangladesh has undertaken the project 'Chittagong Water Supply Improvement and Sanitation Project (CWSISP)'. The primary purpose of this project is to construct a surface water treatment plant at Modunaghat, Chittagong. The project cost is about 170.0 million USD and is funded by the World Bank. The aim of this study is to work on the treatment process of Modunaghat Water Treatment Plant (MWTP). Halda River will be used as the source of raw water for the plant. Everyday about 100 Million Liter per Day (MLD) water will be drawn from the river. About 90 MLD will be ready to be distributed among the people and the Remaining 10 MLD will be used for backwashing and chlorine mixing. The drawn water will be treated through several processes i.e. Collection of water, Removing Screenings, Chemical Dosing, Coagulation, Flocculation, Sedimentation, Filtration, Chlorination, Distribution. Several chambers and filters will be used for the treatment processes. Modunaghat Water Treatment plant will use Chlorine as disinfectant as it can kill certain bacteria and other microbes in water. Chlorine is also much cheaper compared to the other disinfectants. Other methods like ultraviolet and ozonation are not as cheap and effective as chlorination. So, Chlorine is a better option for the treatment process.

Keywords: Chlorination; Chemical Dosing; Raw Water; MWTP; Surface Water Treatment.

INTRODUCTION

As the population of Chittagong city has increased, so the demand for safe drinkable water has increased simultaneously. To meet up that excessive demand for drinkable water MWTP will play an excellent role. This study deals with the evaluation of treatment process of the MWTP which is using chlorine as its main disinfectant. The plant is situated at Modunaghat which is at the verge of main city.

MWTP will treat the surface water collected from Halda River using physical and chemical methods. Chemical treatment systems are necessary for disinfecting the water. Among various disinfection methods such as chlorination, ozonation, UV radiation, chloramination; water chlorination is most common. Water chlorination is the process in which chlorine (Cl_2) is being added to water. For inactivating or destroying bacterias, dissolved chlorine is very much effective. Chlorination is done in two phases as prechlorination and post chlorination. Prechlorination includes odor, corrosion control, reduction of BOD load and to aid in coagulation and setting. In the postchlorination process chlorine will be used to remove microorganisms. Water chlorination is also preferable for having the characteristic of being residual content for an extended period of time. This property helps to maintain the water contamination free after the treatment has been completed. This also allows chlorine to travel through the water supply system, effectively controlling pathogenic backflow contamination. In large distribution system, chlorine is boosted at points for maintaining residual chlorines. Chemicals such as chlorine and alum are added to the influent water and it goes through the process of coagulation, sedimentation, filtration and disinfection for postchlorination (Lee et al., 2016). Several researchers including (Chauhan et al., 2015), (Sorlini et al., 2015), (Farhaudi et al., 2016) have evaluated the drinking water treatment process for different municipal areas. Objectives of this study includes, a) to evaluate the treatment process of Modunaghat water treatment plant, as it will be using chlorine for chemical disinfection, b) To provide the knowledge of efficiency of this treatment plant, and c) To assess the stages that will be used in both physical and chemical methods.

METHODOLOGY

The study is conducted in Modunaghat Water Treatment Plant, which is being constructed by the bank of Halda River. The treatment plant is situated at Modunaghat in Hathazari Upazila. The plant is located at 22°25'56.57"N longitude and 91°52'20.48"E longitude. The elevation of the study area is 20ft above mean sea level.

Fig. 1: Study Area

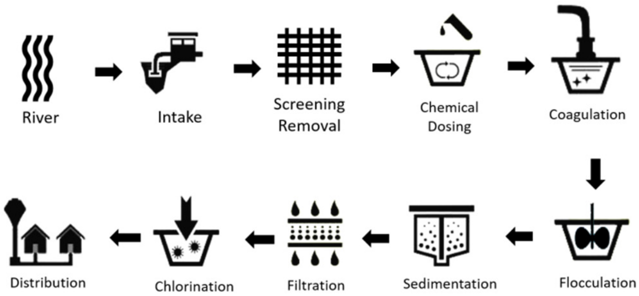

Fig. 2: Treatment Process flow diagram

Collection of Water

The treatment process will be initiated by drawing raw water through the intake. The intake consists of two inlet channels. The water from the river will enter the intake through the inlet channels. Daily about 100 MLD water will be collected from the river.

Removing Screenings

Raw water flows through a primary screen of 100 mm opening, which will remove the large floating substances like leaves, fishes, weeds etc. Sand pump will be used to remove sediments from the raw water. Then raw water will flow through a fine screen of 20 mm opening that constitutes a travelling mesh. It will remove the debris from raw water. Then raw water flows into the wet pump wells and the pumps discharge the water into the receiving well.

Chemical Dosing

The water from intake facility flows into the receiving well through raw water pipelines. Chlorine will be discharged into the raw water for pre-chlorination. Alum and lime will be mixed in the dissolving tank and dosed in the receiving well. Polymers may also be used during periods of high turbidity. Once the chemical dosing is complete the water will flow into the Rapid Mixing Chamber. Then flocculation and pre-chlorination will take place after mixing the chemical.

Table 1: Chemical dosage ratio (Source: CWASA, 2014)

For 100 Mld Flow Rate	Alum Dosing Rate	Lime Dosing Rate	Chlorine Dosing Rate	Polymer Dosing Rate
Material condition	Alum crystal $Al_2(SO_4)_3.16H_2O$	Powder	Cl_2 gas	Powder
Material quality	16% at Al_2O_3	68% at $Ca(OH)_2$	-	Polymer
Solution concentration	10%	10%	-	0.2%
Dosage ratio	Minimum=10 mg/L Average= 20 mg/L Maximum= 60 mg/L	Minimum= 3 mg/L Average= 5 mg/L Maximum=15 mg/L	Minimum=1.5 mg/L Average= 3 mg/L Maximum= 5 mg/L	0.02 mg/L

Coagulation

It is the process of destabilizing the colloidal particles in the water by adding coagulants. They neutralize the suspended charged turbid particles to form flocs. MWTP will use alum ($Al_2(SO_4)_3.18H_2O$) as coagulant. It will react with calcium bicarbonate present in water to form floc as follows:

$$Al_2(SO_4)_3.18H_2O + 3Ca(HCO_3)_2 \rightarrow 3CaSO_4 + 2Al(OH)_3 \downarrow + 6CO_2 + 18H_2O$$

The reaction requires suitable alkalinity, if the water doesn't contain suitable alkalinity lime (CaO) will be added in addition to alum to get proper floc formation. Here lime provides the suitable alkaline environment.

Flocculation

Flocculation is a physical process when coagulating chemicals are added to water containing turbidity, flocculant precipitates are formed to bring about removal of the floc particles. Rapid mixing will be followed by a 20-30-minute period of gentle flocculation. This gentle mixing causes small particles to collide and form fewer larger particles. Because of their size and density these large particles can be removed by gravity settling. Flocculation intensity is measured in terms of velocity gradient G. The G-values ranges from 10 to 75 s^{-1}.

Sedimentation

It is a physical process to separate clumps. After flocculation, raw water flows to the sedimentation tank where flocculated solids settle down which is called sludge. The flocculated sludge settles on the bottom which will be removed by means of sludge collectors. The sludge is then withdrawn using pneumatic valves and conveyed to the drainage tank.

Filtration

After sedimentation, water flows to filters to remove particles which are still present. Here rapid sand filter will be used which is a gravity type filter consisting of sand and gravels. Rapid sand filter occupies less space and it can remove bacteria, turbidity and unwanted color from the water. It will be able to filtrate about 148 m/day. Chlorine will be added with the filtered water for post-chlorination. Then 90MLD clean water will be discharged into the clean well and 10MLD will be used for Backwashing and chlorine mixing purpose.

Chlorination (Disinfection)

It is the final step of water treatment process. A small amount of Chlorine will be used here for disinfection and control algae growth, biological growth, removal of irons, and manganese from the water.

$$Cl_2 + H_2O \rightarrow HOCl + OCl^- + H^+$$

Chlorine gas reacts with water and produce hypochlorous acid, hydrogen ions and hypochlorite ions. The combination of these two products makes free chlorine which has a capability to react another compound readily. The presence hydrogen ion decreases water P^H. Dosage ratio for post chlorination is 0.02-2 mg/L.

Distribution

Clear well is the reservoir for treated water. Clear well pump station will deliver the treated water to CWASA's water transmission and distribution system. Then 90 MLD clean water will be distributed at several points of the Chittagong Metropolitan City. A booster station at Patenga is also being constructed for better maintenance.

RESULTS AND DISCUSSIONS

Assessment of present raw water quality

In this study, it has been assessed the present condition of water for Halda River. The raw water quality shown in the Table 2, signifies that the turbidity of the raw water is comparatively high which is not suitable for drinking water. So, to ensure the water quality for drinking, treatment is mandatory. The other parameters are comparatively acceptable as they are close to standard values.

Table 2: Raw water quality of Halda River (Source: CWASA, 2014)

SL	Parameters	Unit	Raw water quality
01	Turbidity	NTU	80~170
02	pH	No unit	7.07~7.031
03	Nitrate (NO_3)	mg/l	2.8
04	Chloride(Cl^-)	mg/l	8~60
05	BOD_5 at 20° c	mg/l	1.0~1.2
06	COD	mg/l	16~18
07	TDS	mg/l	50~70
08	PO_4-P	mg/l	0.46
09	C_r(Total)	mg/l	0.004
10	SO_4-S	mg/l	18~20

Expected final water requirements

As the treatment plant is not running in this current period, the final quality is not possible to be assessed. But we have collected the data of expected water quality after treatment process and have compared them with the ECR standards for drinking water after disinfection.

Table 3: Final water requirements of MWTP (Source: CWASA, 2014)

SL	Parameters	Unit	Allowable Limit for Drinking Water (ECR standards)	Maximum Permissible Level (CWASA)
01.	Total coliforms	mL	0 per 100 mL	0 per 100 mL sample
02.	turbidity	NTU	10	10 (WHO: 5NTU, JWWA: Less than 2NTU)
03.	pH	No unit	6.5-8.5	6.5~8.5
04.	Arsenics (As)	mg/l	0.05	0.05
05.	Cadmium (Cd)	mg/l	0.005	0.003
06.	Chromium (Cr)	mg/l	0.05	0.05
07.	Cyanide (CN)	mg/l	0.1	0.07
08.	Fluoride(F)	mg/l	1.0	1.5
09.	Lead(Pb)	mg/l	0.05	0.01
10.	Mercury (Hg)	mg/l	0.001	0.001
11.	Iron (Fe)	mg/l	0.3-1.0	1.0
12.	Manganese(Mn)	mg/l	0.1	0.1
13.	Copper (Cu)	mg/l	1.0	1.0
14.	Zinc (Zn)	mg/l	5	3.0
15.	Nitrate (NO_3)	mg/l	10	44
16.	Nitrite (NO_2)	mg/l	<1	3.0
17.	Chloride(Cl)	mg/l	150-600	600

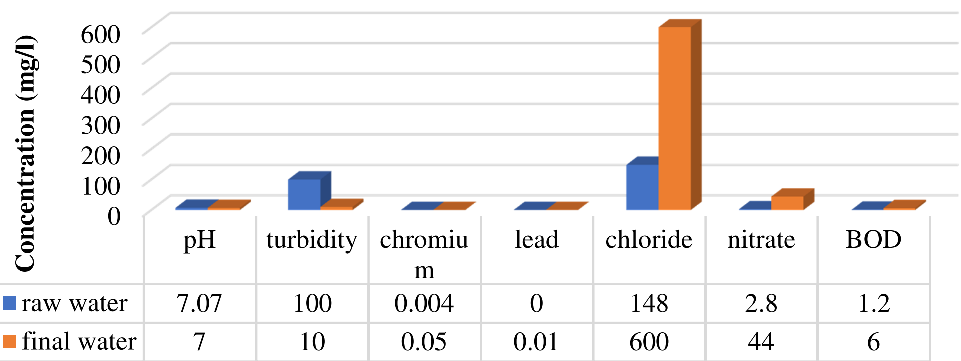

Fig. 3: Bar chart comparison of raw water and final water (Source: CWASA, 2014)

The chart represents comparison between the parameters of raw water and final water quantity. The amount of chlorine present in the final water is quite high but it presents the residual content of chlorine which will protect water from further contamination while distribution. Except that the other parameters satisfy the ECR, 1997 standards. The odor and taste of final water will be unobjectionable. The sludge produced during the treatment process will be prepared and transported in the cake yard.

CONCLUSIONS AND RECOMMENDATIONS

Chlorine is a strong oxidant and acts strongly with various organic materials. In MWTP chlorine gas is permitted to be used as disinfectant as it is cost effective and includes by definition 100% chlorine. As we know what ever the source of chlorine is, when it is added to water it becomes hypochlorous acid (HOCl) and at higher pH losses proton and becomes hypochlorite (OCl^-). At pH 7.54 these two free chlorine present in equal amount, at higher pH hypochlorite dominates, at lower pH hypochlorous acid dominates. Hypochlorous acid is much stronger disinfectant than hypochlorite that is why it is recommended that water should always have a pH less than eight when chlorination is being applied. As chlorine is highly reactive, when added to water, it will react with natural elements in the water. So, the dose has to big enough to meet both the chlorine demand of the water and to produce a residual that is strong enough to kill targeted pathogens. As Bangladesh is free from protozoa in water infection, so the CT_{99} value up to 40 min-mgL^{-1} is enough to totally disinfect the water from virus and bacteria. At the Modunaghat WTP to attain required CT_{99} value, 30 min contact time has been permitted with 2 mgL^{-1} concentration of chlorine. Chlorine doesn't pose any health risk itself, though it has some odor and taste consequences. The byproducts produced during chlorination are trihalomethanes(THMs) and haloacetic acids(HAAs). The byproducts are harmless but may cause problems to human body when used in high doses. The WHO has permitted the use of chlorine saying, "The risks to health from these by-products are extremely small in comparison with the risks associated with inadequate disinfection".

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AN EXPERIMENTAL STUDY ON THE INDUSTRIAL EFFLUENT TREATMENT PLANTS WITH OIL SEPERATION TECHNIQUE

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ABSTRACT
Bangladesh is one of the developing countries which made immense progress in industrial revolution in the last few decades with limited natural resources. Water is not only the basic raw material for most of the process of an industry but also the inevitable part of production and cooling system for its physical characteristics & availability in nature. Though abundant water resources flowing over Bangladesh, we need to treat this before discharging it into nature. Effluent treatment plants are introduced in our industries and textiles to treat the used process water up to a nominal level before discharging it. Due to high investment and running cost second world country like ours still using regular ETP system whereas advance ETP system implicit many other features to treat the water to a satisfactory level. So in this study an attempt is made to focus the basic drawbacks of the present ETP system and find a suitable cost effective solution to overcome present situations with resource limitations. This study paper also implies a simple sustainable solution to remove and recover oil particles from ETPs using oil separator before discharging into the river. Recommendations are also made to adopt proposed technique over the conventional effluent treatment process to save this land of rivers.

Keywords: Resources; Raw material; Effluent; ETP; Oil separator.

INTRODUCTION
From the last few decades, the amount of wastes generated by human population became insignificant due to population densities coupled with the fact that there are very high exploitation in natural resources. Along with ground breaking development in science & technologies the cost effective man made materials replaced the natural woods and carbon materials for regular usage. Furthermore those natural materials could be easily biodegrade where currently using plastic and others not even mixed with soil. Notwithstanding the rising quality of life and high rates of resource consumption patterns have an unintended and negative impact on the urban environment. As a fact cities are grappling with the problems of high volumes of waste as well as the impact of waste on the local and global environment. The reason is that the important sector like public health has been left alone when major upgrading projects improved the water supply systems in many countries and provinces. Two reasons appear to be the major cause firstly, wastewater collection and treatment is costly and their benefit often hard to show; and secondly, even if low-cost solutions are being implemented many projects fail to deliver the expected outcome. Here either the technology was not appropriate, so the beneficiary was not involved or the responsibilities within government were not resolved to ensure the necessary support. In a second world country like Bangladesh it is expected that small scale wastewater treatment system with certain conditions are the solution for these problems. So here this project aimed to introduce an effective small scale treatment process with oil separation technique, which will be less complex, cost effective, technology appropriate and the beneficiary involved under certain circumstances. While it is hard to resolve the problem of government responsibilities for practitioners in the sanitation engineering field, the problem of non-delivery may be relieved through ensuring beneficiary project planning and implementation.

METHODOLOGY

In this proposed paper technology, an attempt was made to focus on the existing industrial effluent treatment plant, with their basic working principles and outputs. For this purpose field visit was made for two different process plant of Bangladesh and sample collected from their effluent treatment plant. During the study location selection, one of the criteria was no suitable oil separator or other process should be present to separate the oil before discharging into natural source. As oil has different density than water it never get mixed with water rather floats on water surface. So for both industries process effluent water treating by ETP but no waste oil treatment stage found as it remains on the surface of treated water. So here the proposed technology supposed to separate the surface oil from effluent considering the cost effectiveness. This oil recovery process could be helpful not only for treating effluent by separating oil but could be a major source of reusable oil source after certain distillation. Data analysis with bar chart was done here for counting the effectiveness of this oil recovery system in line with conventional ETP for Bangladesh. Thus instead of a large investment of high technology, small cost effective sustainable technology will help us to get the desire result. This research comprises of Introduction of ETP, Conventional ETP system, Our Industries & limitations of ETP, Oil separator process, Data analysis of oil separation technique, Mathematical expressions.

Introduction of ETP

The abbreviation of ETP is effluent treatment plant which has been using as a secondary water treatment plant all over the world from last few decades. With rapid industrial revolution and economic growth the countries started marching forward with a tremendous speed. Through the economy needs energy to boost up its process but our nature has its own limitations. Water is the purest substance on earth which is not only the raw material of many industrial processes but also the washing medium. Last few decades witnessed the rapid industrial revolution and also the adulteration of our finest element on earth. So Effluent Treatment Plant or ETP is one type of waste water treatment method which is particularly designed to purify industrial waste water for its reuse and its aim is to release safe water to environment from the harmful effect caused by the effluent. Industrial effluents contain various materials, depending on the industry. Some effluents contain oils and grease, and some contain toxic materials (e.g. cyanide). Effluents from food and beverage factories contain degradable organic pollutants. Since industrial waste water contains a diversity of impurities and therefore specific treatment technology called ETP is required. There are enormous benefits of using ETP in an industry but some majors are:

- To clean industry effluent and recycle it for further use.
- To preserve natural environment against pollution.
- To reduce expenditure on water acquisition.
- To get a sustainable energy recovery system & avoid government penalties.

Conventional ETP System

The implementation of suitable methods for the disposal of wastewater dates back to the times of Roman civilization. However, it was only in the later part of the 19th century that a spurt of activity in the realm of wastewater treatment took place. The growth of the human population, urbanization and industrialization necessitated the treatment of wastewater. It became evident that the untreated wastewater which was discharged directly into water bodies caused pollution and posed health hazards. A lot of research followed in the late 19th century and led to the development of the ETP. Now a days this system developed to such an extent that it almost capable of treating all the waste process water of an industry before draining it into the natural sources. But third world countries like Bangladesh still using the conventional type ETPs for treating water because of the risk of high costly investment and adoption of advanced technologies. Here the conventional system compose of the major stages. Primary, secondary & tertiary treatment. The three phases includes some steps as primary filtration, cooling and mixing, Neutralization tank, Coagulant bath, settling tank, filters & drain to the natural source.

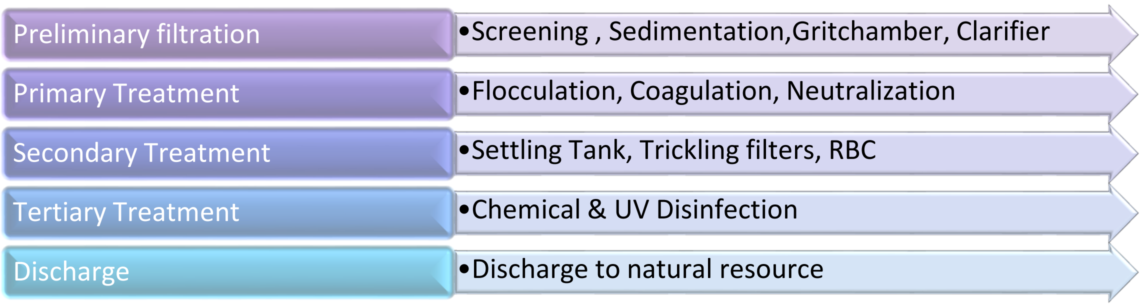

Fig.1: Flow diagram of conventional ETP process.

Preliminary Filtration is the initial process where floating large particles being separated by using of screening method. Then the sediment separated from sedimentation tank and passes through grit chamber. Clarifier are introduced at end process to separate the remaining small particles. *Primary Treatment comprises of* effluent with dissolved particles flows through the flocculation tank. Coagulation refers to collecting the minute solid particles dispersed in a liquid into a larger mass. Chemical coagulants like A_{l2} $(SO4)_3$ (also called alum) or Fe_2 $(SO_4)_3$ are added to wastewater to improve the attraction among fine particles so that they come together and form larger particles called flocks. A chemical flocculent (usually a polyelectrolyte) enhances the flocculation process by bringing together particles to form larger flocks, which settle out more quickly. Flocculation is aided by gentle mixing which causes the particles to collide. Then in the neutralization tank the effluent is mixed & settled down, pH correction of water is done here. *Secondary Treatment* is used for treating industrial waste water using air and a biological flock composed of bacteria. Trickling filters, also known as sprinkling filters, are commonly used for the biological treatment of domestic sewage and industrial waste water. The RBC is rotating biological contractor where aerobic process is used to break off the dissolved chemical into nature friendly element with the help of sunlight and air. *Tertiary Treatment* is to provide a final treatment stage to raise the effluent quality to the desired level before it is reused, recycled or discharged to the environment. Chlorine and UV pond disinfection considered as an ideal disinfectant for industrial waste water. It leaves no residual disinfectant in the water by ensuring the water quality. It does not produce any disinfection by-products.

Our Industries & limitations of ETP

With industrial growth we setup our industries beside the river banks for available cheap water resources and this was done well until some people dumped their sewage directly into the rivers thus destroying them. Through the industries adopted and installed the effluent treatment system for treating the process water but suitability of those ETP at stack. Because the effluent produced from different manufacturing industries like textiles, ternaries, chemical industries & pharmaceuticals are vary from each other's due to their mixing agents while same type of cheap technology to treat them. Two major factors playing a vital role here, one is the high cost of major investment and another is the technical adoptability. We have economic and social barriers to overcome these two major hindrance for adopting suitable ETP systems industry wise. So here discharging effluent only by removing some of the basic compounds from it but not the rest. Waste oil is such a type whose treating process is totally absent in our existing ETP system for pharmaceutical & chemical industries (Table 1).

Oil Separator

It is a unique advance idea of separating extra floating oil particles to a nominal level by using the principle of force draft mechanism. Here an impeller is introduced with a submergible motor in a separator tank at a standard level. When the water surface reached the impeller level, the impeller start to rotate with a fixed rpm. The rpm varies with the density of processes water. As due to chemical property oil and water never get mixed together so oil always float at the water surface. So when the impeller rotates it splash the upper surface of sewage water with floating oils. A collector shell collects the water mixed oil and store it for further separation. Thus after refining a good amount of oil can be restored from waste one for reuse. As the upper level separated with floating oil and grease particles now the remaining water is good to go for further treatment.

Table 1: Existing industrial ETP & oil separation process in Bangladesh (10/09/2017-13/09/2017).

Name of Industry	Product	Raw water usage (Ton/hr)	ETP Type	Oil mass in per litre effluent	Oil Removal Process	Discharge medium
Samuda Chemical complex Limited	NaOH, HCL, $CaCo_3$	1.6	ETP	346 gm	Absent	To river
Berger Paints Bangladesh Limited	Industrial & domestic Paints	2.8	CETP	220 gm	Absent	Recirculate in process

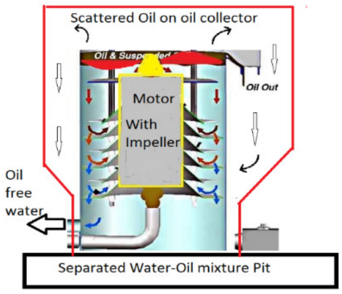

Fig.2: Schematic diagram of water-oil separator

Fig.3: Model of proposed water-oil separator

Data analysis of oil separation technique

Table 2: Separated oil mass vs. rpm of impeller vs water density with inlet water velocity at 30 °C.

Experiment	**Separated Oil mass(gm)**	**Impeller rpm**	**Inlet Water velocity (m/s)**	**Water Density ρ (kg/m³)**
1	175	2200	0.2165	998
2	222	1500	0.2165	998
3	231	1800	0.2165	998
4	155	1200	0.2165	998
5	181	2200	0.2430	994
6	228	1500	0.2430	994
7	236	1800	0.2430	994
8	159	1200	0.2430	994
9	183	2200	0.2875	992.5
10	230	1500	0.2875	992.5
11	238	1800	0.2875	992.5
12	161	1200	0.2875	992.5
13	184	2200	0.3150	992
14	232	1500	0.3150	992
15	240	1800	0.3150	992
16	162	1200	0.3150	992

From the Table 2, it is visible that the amount of reusable oil recovered from sewage water accordingly 184gm, 232gm, 240gm and 161 gm where the volume of inlet raw sewage is 2500 gram at different density.

Here it seems that when the impeller speed is minimum the amount of separated oil is less. At same impeller diameter with increasing speed the amount of separated oil particle also increased. But above a certain speed the amount of oil decrease. This speed depends on the density of fluid & inlet velocity. Amount of separated oil is maximum when density of sewage is minimum. This stage is energy recovery process where the waste oil is separated & recovered for further use as energy source. This separated oil could be reused in industrial sectors after proper heat treatment & distillation.

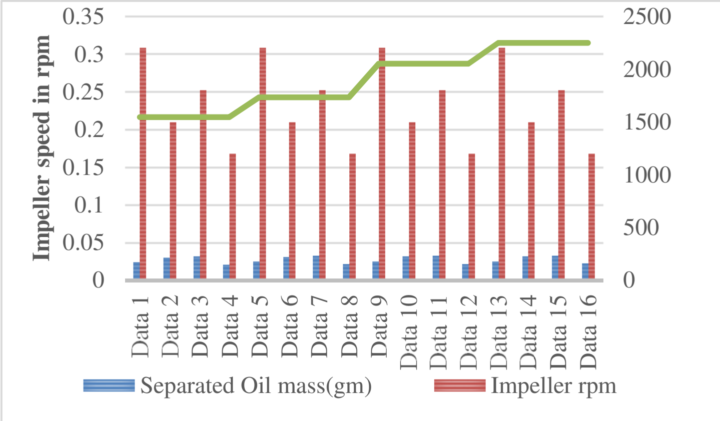

Fig. 3: Separated oil mass vs. rpm of impeller vs water density with inlet water velocity at 30 °C.

So this process not only separates the oil from waste water to treat it but also generate a great scope to recover a part of waste energy for economically beneficial interest. Mathematical expression for oil recovery percentage calculation

$$\frac{\textit{Mass of Oil separated}}{\textit{Mass of inlet waste water}} = \% \frac{\textit{Oil recover from sewage}}{100} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

According to Table1 amount of reusable oil recovered from sewage water accordingly 184gm, 232gm, 240gm and 161 gm where the volume of inlet raw sewage is 2500 gram at different density. By using Eq.1, we get the oil recovery percentage is 7.36%, 9.28%, 9.6% & 6.5% accordingly. Oil recovery is maximum when the influent concentration is less & impeller speed is in moderate range (1500-1800rpm). At a high or lower impeller speed as 2200 or 1200 rpm the rate of oil removal decreases for same density of waste water. So, before oil separation stage it is necessary to separate the small dissolved or floating particle to lower the sewage density so to get the maximum oil recovery.

RESULTS AND DISCUSSIONS

From above outcome it is clearly visible that approximate 9.6gm oil have been recovered from 100gm of waste water from ETP. So oil free treated effluent could get to discharge into the natural source and save the purest element of earth from adulteration. On the other hand grade of oil changes after its usage in industry, so this recovered oil could be a good source with some refining and grade adjustment treatment. With this oil recovery stage not only we are getting a reusable energy source but also treating the waste water from industrial oil. By further treatment and distillation of these recovered oil in oil refineries a good amount of energy could be restored. Moreover this recover energy source could be a part of turning table of nation's economy.

CONCLUSIONS

In this paper, the effect on disposal of residual waste liquid from household & factory with proposed treatment plant was studied and examined the influence of some process variables. The proposed oil separator can achieve up to 9.60% oil recovery from waste oil at ambient temperature of 28°C to 32°C where impeller speed & water density are major factors. Proposed technology reduces oil percentage significantly which is advantageous on traditional ETP treatments. Compared with ETP treatment method or traditional other methods, proposed oil separator could significantly decrease treatment cost for its less space requirement, less time consumption & technical suitability. Developing countries like ours where the usage of renewable energy is so low due to costly investment, proposed type of plant with oil recovery system could be a remarkable achievement as energy source. Moreover the separated biomass from primary stage also be a good source to produce biogas in small plants where space & cost are major concern. In densely populated country like ours where water scarcity is a curse we have to create some breathing space under these immense pressure of population growth & industrialization. This could only be done if a plant meet both the requirement of effective treatment and economically beneficial requirements. Thus in recent future many other private farms will also march forward along with government aid to setup such efficient plants & make the world green again.

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ABLUTION WATER MANAGEMENT THROUGH MOTIVATION

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ABSTRACT
Water has distinct importance in Islamic perspectives especially for ablution, a ritual that has to be performed by the Muslims before prayer. This study assessed the effectiveness of motivation in water consumption during ablution in three residential gents' halls of Khulna University, Bangladesh. Data was collected through questionnaire survey in January 2017 and consequent water measurement before and after motivation. The study found that currently, a student use 3.64 L water in an ablution. Doing ablution unconsciously in speedily flowing tap and keeping the tap running while not in use was the major reason of water wastage. However, after motivation water consumption in ablution was significantly ($p<0.05$) reduced to 1.93 L. This study suggests that raising awareness along with providing Islamic knowledge and practicing Islamic guidelines properly can be effective in minimizing water wastage in ablution without compromising comfortability. Our findings will influence water managers to introduce awareness program and sensor technology to save water in daily life.

Keywords: Ablution; Water Wastage; Awareness; Islamic Guideline; Comfortability

INTRODUCTION
Water is the most important natural resource as it is the lifeblood. Despite water covers 70% of the globe but quantity of usable fresh water is limited. The amount of water available for use on the planet is finite (Athens and Ferguson, 1996) and out of the available water, only 3% is potable, 2% of which is frozen in glaciers and polar ice caps, which leaves only 1 percent as useable water (Varghese, 2007). Thus, water that everyone can take advantage of them do not exceed 0.01% of the total available water. Providing the safe drinking water to the growing population would be the greatest challenge of the century. If water resources are not managed properly, there will be a water crisis in the future.

According to UNESCO, increase in population growth causes increasing water demand which become an alarming issue to the living world. Despite groundwater plays a very significant role in the supply of water for human activities, in most parts of the developing world, rapid expansion of groundwater exploitation depleting groundwater level (UNWWAP, 2003). So, we are going to face tremendous challenge in terms of availability of potable water without which any development activities and even life is impossible. In an effort to secure urban water supply into the future, demand-side management has emerged as an essential component of a total water cycle management approach, and a complement of more traditional supply side approaches to the management of fresh water (Russell and Fielding, 2010). However, there is a clear research gaps about demand management of water consumption in Bangladesh though developed world emphasizing on that aspects.

Water is important in Islamic perspectives that has been mentioned many places in the Holy Quran. Water not only serves for household uses but also essential for religious purposes as it is the media of purification. Purification through ablution (locally known as 'wudhu') is an obligatory component of the Islamic prayer ritual and Muslim worshippers carry out this process before each of the five times daily prayers. In addition, Muslims must need water in obligatory shower. In Bangladesh, most ablution system consists simply of a row of water taps with drainage through to carry the greywater to main drains. As the tap is usually left running during the idle time of ablution, much water is wasted in the process. The ablution ritual usually takes up several minutes at a running water facility, allowing a considerable amount of water to go to waste when only handfuls of water are collected and used at each step of the ritual. No study has been conducted to measure how much water is wasted during ablution despite its massive importance in suggesting water reduction strategies. Statistic has shown that Muslim population is increasing at 1.84%/ y into the total Muslim population of 2.1 Billion in 2012 (islamicpopulation.net). Increasing Muslims will waste much water while purifying themselves if are not aware in advance. As quoted in the Hadith, Prophet Muhammad reminded Muslims to avoid wastage, even when performing the cleansing ritual or ablution prior to prayer. The Prophet Muhammad (peace be upon him) urged moderation when using water during ablution. He, Himself used a minimal amount of water (625 ml) when carrying out Wudu and about 3 L in shower. Prophet Muhammad (S) used to aware his followers (R) in different aspects of Islam and that is fruitful for them. In Holy Quran Allah Subhanahu Taala mentions that “Advice! Surely, it is helpful for the true believers”. Hence, this study attempted to identify the impact of awareness building through motivation in reducing ablution water wastage.

METHODOLOGY

Study Area

Three residential gents halls of Khulna University (Khan Jahan Ali hall, Khan Bahadur Ahsanullah hall, Bangabandhu Sheikh Mujibur Rahman hall), Bangladesh are considered as the study area. A total of 1100 students with 850 Muslim students live in these gents’ halls. Considering the ease of access and potential environment for communication with the respondents this site is considered.

Data Collection

Data was collected through questionnaire survey from the respondents, practical observation while performing ablution and measuring ablution water before and after motivation.

Questionnaire Preparation

Draft questionnaire was prepared through literature review, personal thinking and consulting with my thesis supervisor. After a series of correction the questionnaire was finalized with a subsection of motivation after first ablution. The questionnaire is included in the Appendix A.

Sampling Unit and Sample Size

In the present study students of three residential halls were the sampling unit. Out of 850 Muslim students a total of 60 students were selected for this study. Sample size was determined using online software which is supported by the formula as used by others (Kothari, 2004).

Sampling procedure

Purposive random sampling technique was adopted to select respondents came for performing ablution. The ablution performers were requested for assistance in fulfilling the questionnaire after a brief introduction about myself and research project. We also let them know that we need time from him to perform ablution once again after prayer as of our need. The students who agreed the terms and conditions are considered for surveying. Thus, a total of 60 students were surveyed to fulfill the task as 20 from each hall.

Water measuring technique

The water consumption in ablution was measured by practical observation. Before doing the task, permission was taken from the respondent. To catch water used in ablution, a container was used under the tap before the respondent started ablution. A measured water pot was used to determine water consumption. To estimate the time consumption in every step of ablution, stop watch was used during ablution. After motivation, the respondent was again requested to do the task in the same way. After measuring the water consumption in ablution (after motivation), the difference in water use was declared to respondents for further motivation.

Data Processing and Analysis

Data were recorded on Microsoft Office Excel spreadsheets. None of the data sets failed to meet the assumptions of the normal distribution hence Mann-Whitney U test was performed to assess the significant level. Statistical analyses were conducted using Statistical Package for Social Science (SPSS) version 20.0.

The mean, standard deviation, standard error, percentages were calculated. Some measurements were calculated using calculator.

RESULTS AND DISCUSSION

Existing water consumption in ablution

Across the hall, daily average water consumption and wastage (due to keeping tap open while not in use) by a person during ablution was 18.2 L and 3.9 L respectively. Water consumption in ablution and wastage varied among the halls as the highest consumption (4.2 L / person/ prayer) and wastage (2.2 L/ person/ prayer) of water was found in Khan Jahan Ali hall followed by Khan Bahadur Ahsanullah Hall and Bangabandhu Hall respectively. The highest quantity of ablution water used in washing feet (1L/ person/ prayer) followed by washing until elbows (0.67L/ person/ prayer), washing face (0.65 L), gurgle, swabbing head, washing hands, and washing nose respectively [Fig.1].

Changes in water consumption after motivation

This study found that majority of the people (58%) used to use 2.1-4 L water in an ablution followed by 4.1 to 6 liter water per ablution while the highest consumption was 8.5 L/ ablution [Fig. 2]. In contrary, after motivation the amount was decreased to <2 L for the majority (63%) of the respondents [Fig. 2]. Significant change has been observed in using ablution water after motivation. On an average, the water consumption was reduced by 47% after motivation. In every step of ablution, water consumption was reduced significantly after motivation with the highest saving of approximately 0.5 L/ ablution in washing feet [Fig. 2]. Considering the average ablution water savings after motivation this study identified that it is possible to save 1029 L water everyday for surveyed students (120 students) at 3 students halls in Khulna University while doing their 5 times ablution. 100% respondents were agreed that they waste water in ablution, however, all of them believe that they can save water if they grow consciousness during ablution as we found that after motivation ablution water consumption was reduced significantly to 1.925 L /person/ ablution. This study identified that before motivation people were not watchful that water is wasting while performing ablution. Motivation through religious knowledge and to follow Islamic ideologies were identified as the tool that help to motivate respondents in significantly reducing ablution water. As the relatively excess use of water in ablution was mainly due to unconsciousness of people, growing awareness among Muslims can save ablution water as this study found and addressed in literature (Johari et. al, 2013).

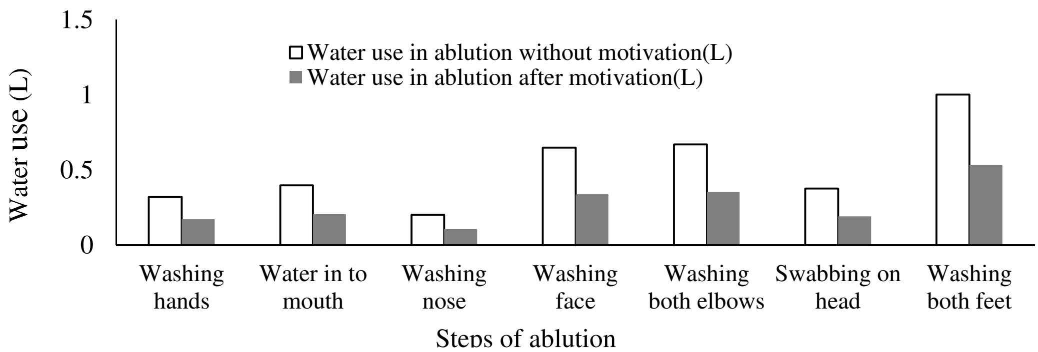

Fig. 1: Water consumption in every step of ablution before and after motivation

Reasons of water wastage and options to save water in ablution

The relatively excess use of water in ablution was mainly due to unconsciousness (67%) of people while free water, tap system and high speed of tap were also identified though less extent (37% combined) [Fig.3]. People think that keeping the tap close when not in use and reduction of tap speed can save ablution water substantially [Fig 4]. Badna and sensor took a less percentage (15% combined) as options to reduce water wastage in ablution [Fig.4]. However, when saving strategy mixed up with comfortability majority of the people (80%) chose tap system to perform ablution.

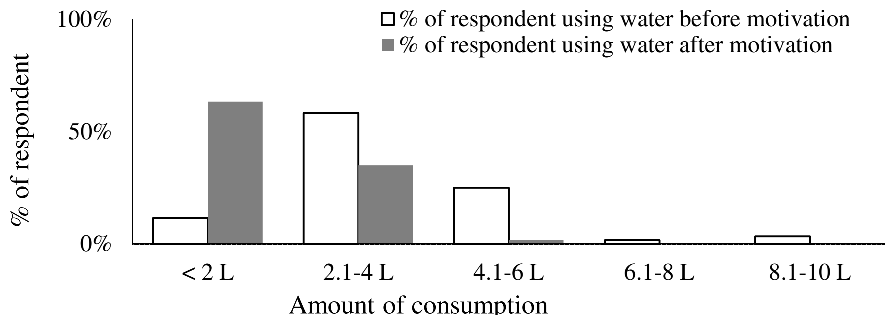

Fig. 2: Average water consumption and wastage in ablution per person per prayer

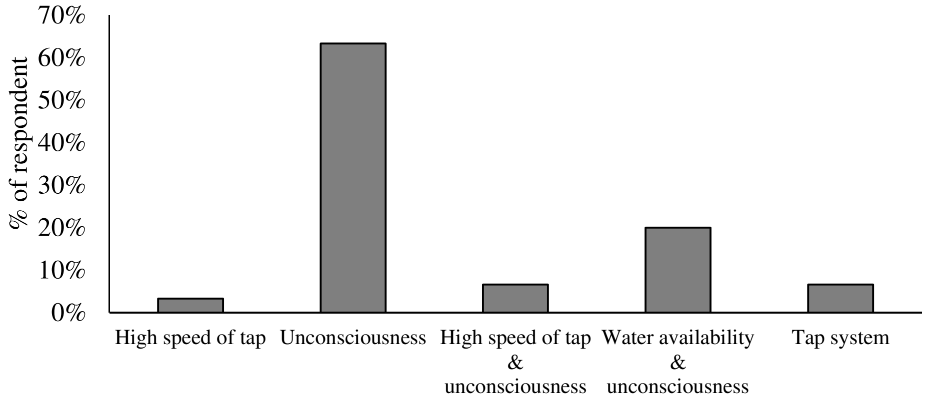

Fig. 3: Reasons of using much water in ablution

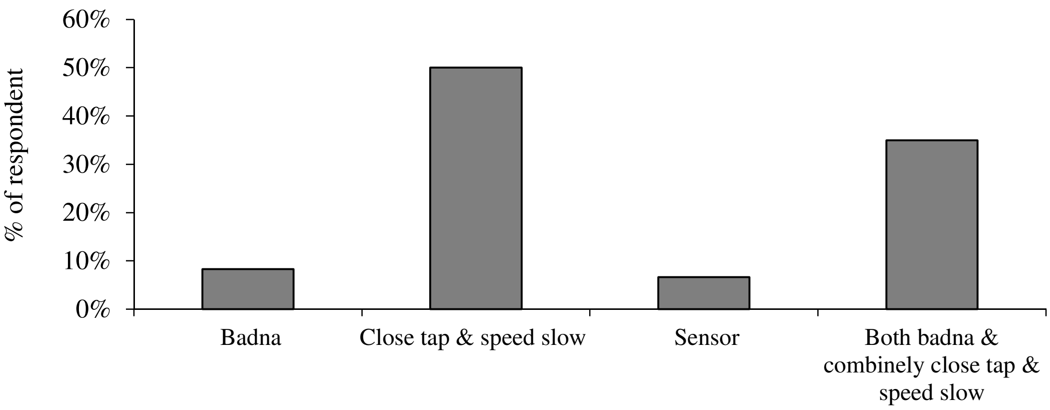

Fig. 4: Options to reduce water wastages in ablution

The wastage of water is mainly due to lack of consciousness and lack of habit. Our findings demonstrated that during ablution in tap water around 50% water is wasted. Despite pot or badna system in ablution save huge water in ablution, most of the people suggest 'awareness building' among the Muslims as the best option in saving water as tap system is common in all the mosques and comfortable. Motivation may help to reduce tap speed and to stop while not in use leading to save ablution water significantly as suggested by our study and also demand of Islam (Faruqui et. al, 2001). Using sensor can also save water as wastage is mainly due to keeping tap running while not in use. Sensor as water saving technology has been using and approved by literature (Besari et al., 2009). Some study marked 'badna' or 'pot' for performing ablution in avoiding wastage of water. (Mohamed et al., 2016) assumed that ablution water wastage can be avoided by using water from a container or pail. In ablution process, the tap is usually left running even while not in use resulting wastage of huge water in the process as we found during survey and suggested by (Suratkon et al., 2014). Disgustingly, about half of the tap water flows directly to the drain without any contamination (Mamun et al., 2014).

CONCLUSION

This study found huge water wastage in ablution while slight motivation reduced water consumption for performing ablution. On an average, the existing water consumption in ablution was 3.64 L per person per prayer. Most of the respondents performed ablution without closing the tap during the whole session and a certain amount of water ran from tap without any use. Such unconscious use of water in ablution along with performing ablution in speedy tap resulting wastage of massive volume of water. The study found that, before motivation, there was no concern on saving water among the respondents. However, after motivation, the water consumption in ablution was reduced significantly to 1.93 L. Awareness through Islamic knowledge was able to motivate water users to reduce water consumption in ablution as Islam suggests. Calculated results showed that, on an average, 50% of the ablution water to a total of more than 1000 L water can be saved in the gents Hall of Khulna University. In a word, the changing of behavioral pattern through raising awareness can be a way to reduce the water wastage while doing the ablution. However, further study covering various residential, slum and commercial areas can conclude these findings more robustly.

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IMPACTS OF SALINITY IN DRINKING WATER ON HUMAN HEALTH IN COASTAL ZONE OF BANGLADESH

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ABSTRACT
In coastal Bangladesh natural drinking water sources have become contaminated by salinity due to saltwater intrusion from rising sea levels, cyclone, floods, storm surges, shrimp farming and upstream withdrawal of freshwater according to Talukder, 2016. Now-a-days salinity is deemed as a disaster in South West part of Bangladesh. Majority of people in coastal areas are susceptible to freshwater salinization. The evidence for health effects of consuming high salinity water is increasing day by day. Through this study existing salinity condition of Holdibunia, Chila villages from Chila union and Kapalir meth village from Burirdanga union of Mongla Upazila were investigated by salinity concentration map and the effects of public health due to salinity were observed by using disease profile of hospitals. Questionnaire survey and FGD were conducted to establish relation between salinity and human health. Disease profile was collected from hospitals for the comparison of disease profile among coastal and non-coastal areas and vulnerability assessment was conducted to determine vulnerable area and vulnerable groups. The people of these areas are mainly affected by high pressure (59%), cardiovascular disease (36%) and water borne disease (78%) etc. The major finding of this study is that female members are affected by hypertension 2.53 times more than the male members. However people are not aware of this for lack of proper education and awareness. Therefore, salinity intrusion is increasing as well as increasing health problems.

Keywords: Salinity; Drinking water; Human health; Arc GIS; Coastal Zone; Bangladesh.

INTRODUCTION

Salinity intrusion becomes exacerbated particularly in the dry season when rainfall is inadequate and incapable of lowering the concentration of salinity on surface water and leaching out salt from soil (Mohammed et al. 2015). It is estimated that 884 million people do not have access to clean drinking water in the world (Vineiset al. 2011). More than 35 million people in coastal Bangladesh are vulnerable to increasing freshwater salinization (Talukder et al. 2016).About 53% of the coastal areas are affected by salinity (Rasel et al. 2013).Lately Bangladesh Medical Research Council carried out a study titled as "Drinking Water Salinity and Maternal Health in Coastal Bangladesh: Implications of Climate Change". Women who drank shallow tube-well water were more likely to have urine sodium > 100 m mol/day than women who drank rainwater [odds ratio (OR) = 2.05; 95% confidence interval (CI), 1.11–3.80]. The annual hospital prevalence of hypertension in pregnancy was higher in the dry season (OR = 12.2%; 95% CI, 9.5–14.8) than in the rainy season (OR = 5.1%; 95% CI, 2.91–7.26) (Khan et al, 2011). Mongla is located in the south western coastal part of Khulna. Rivers of Khulna are already affected by salinity intrusion, and the sea level rise caused by climate change is expected to exacerbate the problem of salinity intrusion (ADB, 2012). In Mongla, public health is severely affected due to salinity intrusion in surface water. As a result it is important to investigate the existing condition of salinity and to identify the extent of salinity as well as the negative impacts on human health, which can assist the decision makers in taking necessary policies to reduce the rate of salinity rise. As the level of salinity is increasing tremendously, the habitats of this region are suffering a lot of problems such as health hazard, scarcity of safe drinking water and so on. In this context it is very essential to investigate the present situation of salinity of Mongla Upazila.

METHODOLOGY

The research was based on primary and secondary sources of data. Primary data was collected through Field survey and questionnaire survey. Field Survey focuses on the measurement of salinity in water sample of different sources and for measuring salinity Electrical Conductivity (EC) Meter was used. Human health survey was conducted through questionnaire survey and 150 households were interviewed. Secondary data such as disease profile from hospitals, salinity data form Center for Environmental Geographical Information System (CEGIS), Satellite image from Google Earth were collected. The collected data was analyzed through different software such as SPSS, GIS and Excel. Using salinity data and by the help of GIS software the map of drinking water salinity concentration for surface water source was prepared which showed the spatial variation of salinity concentration at different level of the study area. With the help of household survey data the most used drinking water sources were identified. In addition, disease map was prepared showing the area affected by different diseases due to salinity by using GIS software with the help of disease profile of hospitals. In the same way, the most vulnerable group who are affected by high salinity and different diseases caused by salinity were identified by disease mapping and disease profile of hospitals. Eventually, the most vulnerable area which are affected by high salinity was identified by three major elements of vulnerability concept as exposure, susceptibility and capacity. Vulnerability index was developed based on three sub-indices such as exposure sub-index (ESI), susceptibility sub index (SSI), and capacity sub-index (CSI) for this research. In this Study, Vulnerability Index to Salinity Intrusion was calculated subtracting CSI from the summation of ESI and SSI.

RESULTS AND DISCUSSIONS

Sources of water and related cost

In Chila 95% people, 96% of Holdibunia and 56% of Kapalir meth are using pond water for drinking purpose. About 40 % people of Kapalir meth are using deep tube well water and a very few amount of people are using rain water. As there is scarcity of drinking water in dry season, people have to buy water for drinking purpose and have to spend a certain amount of money of their income. The survey also shows that the water cost for each jar is estimated 10-20 Tk. according to distance in the study area.

Existing salinity level

The salinity level of different sources were measured by EC Meter in the study area (Table 1). The salinity level of water of available sources those are used by the people for their drinking purpose.

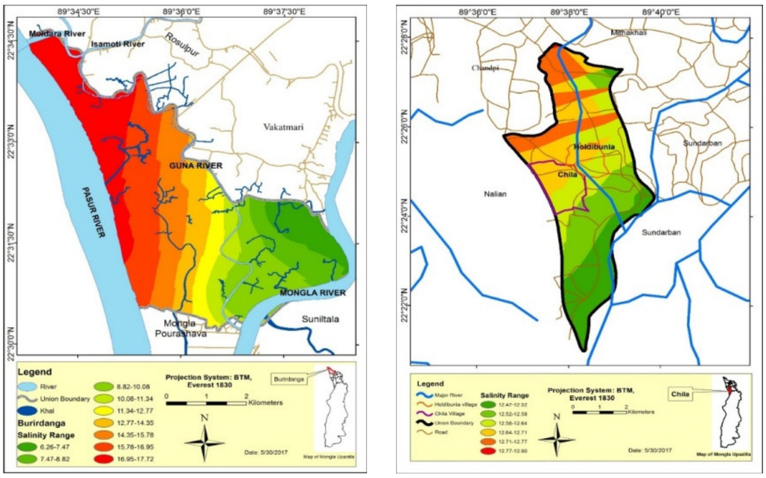
Table 1: Salinity level measured by EC Meter in different sources of water

Source	**Salinity Level** (micro Siemens/cm)	**Source**	**Salinity Level** (micro Siemens/cm)
Rainwater	21	Pond of Chila	153
Deep tube well	116	Pond of Kapalir meth	33
Pond of Holdibunia	130	-	-

From Table 1, it is found that the salinity levels are higher in pond of Chila and pond of Holdibunia which are 153 and 130 micro siemens/cm respectively. Whereas, the lowest salinity level was found in rainwater and it was 21 micro siemens/cm. For this study, salinity concentration map was prepared by using salinity data of surface water of 2002 and the map shows the extent of salinity in the Burirdanga and Chila unions [Fig 1].

Disease Profile and costs for treatment

Different kinds of diseases like hypertension, cardiovascular disease, water borne disease such as diarrhea, cholera etc. are caused for the high salinity. Table 2 shows the summery of diseases in the study areas. According to household survey, age 25-50 years or above 50 years are mostly affected by hypertension. Female are more affected than male by hypertension and cardiovascular disease (CVD). In Chila 68% people are affected by hypertension and 44% are affected by CVD. Because the salinity level of drinking water is comparatively higher than two other villages. This results in heart attack and heart failure which is serious threat for the people. In Chila and Holdibunia most of the people are affected by water borne disease such as diarrhea, cholera, dysentery etc. because they directly drink the pond water without any purification.



(a) (b)

Fig.1: Salinity Concentration map (a) Burirdanga Union and (b) Chila Union

Table 2: Diseases due to high level of salinity in Chila, Holdibunia and Kapalir meth

Name of The Villages	Diseases due to Salinity		
	Hypertension	**Cardiovascular Disease**	**Water Borne Disease**
Chila	68%	44%	100%
Holdibunia	60%	40%	84%
Kapalir meth	50%	26%	50%

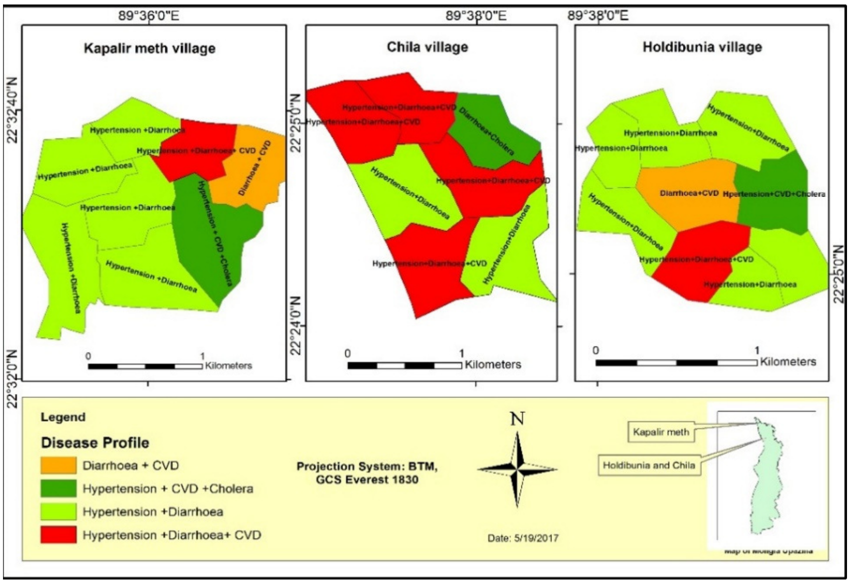
In the coastal areas people use to drink the water which contain certain amount of salt and use salt in cooking. So that they are consuming more amount of salt than the people of non-saline areas. Therefore the total effect of salinity on health in coastal areas is comparatively higher than non-coastal areas. According to disease profile from hospital and household survey data, disease map was prepared by using GIS software for the study area [Fig 2]. The disease map shows the most affected diseases in these three villages. For Kapalir meth and Holdibunia hypertension and diarrhoea are occurring most. But in Chila, hypertension, diarrhoea and cardiovascular disease are occurring most. About 62% and 52% people of Chila and Holdibunia have cost for diseases less than 500 Tk. as they go to Govt. Hospital for treatment. In Kapalir meth most of the people (48%) have health cost ranging from 500-1000 Tk.

Comparison of disease profile of coastal and non-coastal areas

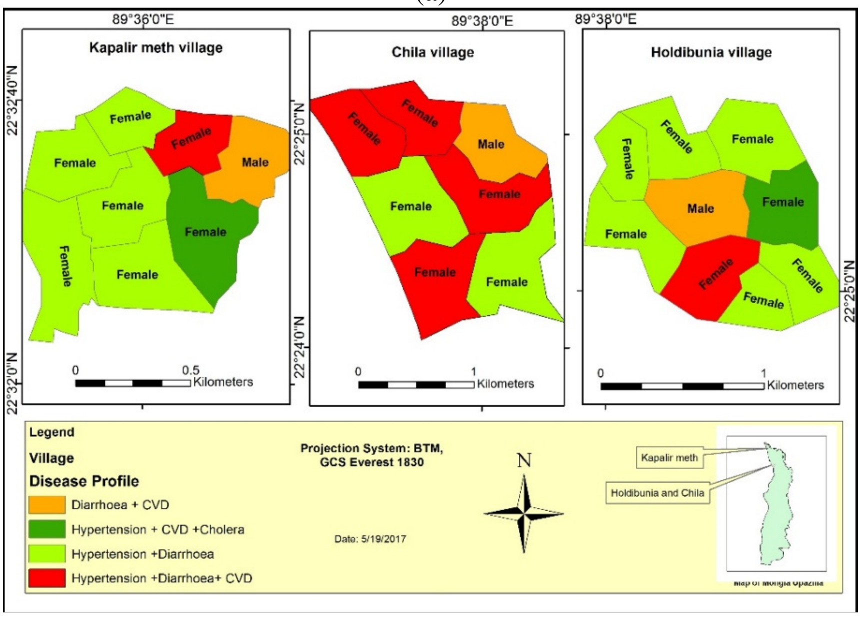
A relative comparison of the diseases due to salinity among coastal and non-coastal Upazilas of Bangladesh, Mongla, Satkhira, Lohagara and Bagharpara are conducted (Table 3). In addition, Table 3 shows that in Mongla and Satkhira the diseases like hypertension, CVD and water borne diseases are occurring more because of high salinity content in drinking water. However, in non-coastal areas this diseases are occurring relatively low in number. Because the people of Jessore and Narail are not consuming extra amount of salt in drinking water. So, it is clear that in coastal areas the people are highly affected by the diseases than the non-coastal areas.

Determination of Vulnerable area by Vulnerability Index

In this research the salinity intrusion vulnerability index was developed based on the following indicators. After calculating the sub-indices, village Kapalir meth had the vulnerability index 0.0904, Holdibunia 0.373 and Chila 0.5672. Using this index value, a rank was fixed for these three villages. On the basis of ranking, Chila was ranked as no. 1 vulnerable area whereas Holdibunia and Kapalir meth were rankedas 2 and 3 respectively.



(a)



(b)

Fig 2: Disease map of Kapalir meth, Holdibunia and Chila: (a) Type of disease, (b) Affected group

Table 3: Disease profile of Health Complexes of coastal and non-coastal areas of January, 2017

Disease	Upazila Health Complex, Mongla			Upazila Health Complex, Debhata, Satkhira			Bagharpara Health Complex, Jessore			Lohagara Health Complex, Narail		
	M	**F**	**T**	**M**	**F**	**T**	**M**	**F**	**T**	**M**	**F**	**T**
Hypertension	52	132	**184**	128	165	**293**	2	7	**9**	8	10	**18**
Diarrhoea	127	100	**227**	58	77	**135**	23	23	**46**	100	76	**176**
Cholera	9	9	**18**	-	-	**-**	6	12	**18**	2	3	**5**
CVD	16	19	**35**	31	16	**47**	2	2	**4**	2	0	**2**

Note: M = Male; F = Female, and T = Total

Table 4: Indicators of Vulnerability Index (Binh, 2015)

Sub Index	Indicators	Types of Vulnerability	Relation to vulnerability
Exposure Sub Index	Effects of salinity intrusion	Environmental	Increase
Susceptibility Sub Index	Health cost income ratio	Social	Increase
	Dependency ratio	Social	Increase
	Illiteracy ratio	Social	Increase
Capacity Sub Index	Income per capita	Economic	Reduce
	Saving per capita	Economic	Reduce
	Number of income sources	Economic	Reduce
	Health insurance ratio	Economic	Reduce
	Number of water sources	Social	Reduce
	Total land areas	Economic	Reduce

Determination of Vulnerable Group

From the comparison of patients from Table 4, it is shown that women patients are more than male patients in Mongla. Only for the combination of Diarrhoea and CVD, male patients are more than female patient. Female patients are greater in number in Hypertension (2.53 times than male) and CVD (1.18 times than male). The reasons behind this are overweight, unhealthy food, drinking more amount of salt, stress and high blood pressure in pregnancy. So, women are the vulnerable group male in three villages.

CONCLUSIONS

The three villages Chila, Holdibunia and Kapalir meth are victims of different natural disasters and by which salinity intrusion occurs more rapidly. Moreover, most of the people of Chila and Holdibunia are not economically solvent so that they can not buy supply water which comes from nearest town Khulna. For this they use pond water for drinking where salinity level is comparatively low than the other surface water without any purification which is not actually safe for health. Long term rainwater harvesting tank, Pond Sand Filter (PSF) technology, deep tube-well etc. should be introduced by Government, NGOs and CBOs to solve this problem.

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DRINKING WATER QUALITY STATUS AND TREATMENT FOR SAFE WATER SUPPLY IN JESSORE MUNICIPALITY, BANGLADESH

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ABSTRACT

Groundwater is the main source of drinking water in Bangladesh. Contamination of groundwater and its supply line is a major problem for creating health hazards. This study investigates the physical (pH, turbidity, salinity, electrical conductivity and total dissolved solids); chemical (ammonia, nitrate and phosphate) and microbiological (total coliform and fecal coliform) quality of shallow tube well, deep tube well and pipeline supply water use for drinking in the municipal area at Jessore district in Bangladesh. Assessment of risk score by "Sanitary Inspection Form" of tube well water and supply water are also evaluated. The quality of groundwater in this municipality is comply with WHO and Bangladesh drinking water standard for both the physical and chemical parameters tested and additional treatment is recommended for the shallow tube well and pipeline supply water due to frequent detection of microbial contamination. According to the results, more than 100 CFU/100 ml of total coliform is observed in supply water. Chlorine dose of 2mg/L for supply water and 1.2 mg/L for shallow tube well water was effective to remove 100% of total coliform within six hour of contact time and residual chlorine was 0.04-0.80 mg/L which is the acceptable by WHO drinking water standard.

Keywords: Drinking water; Fecal coliform; Total coliform; Risk scoring; Microbial quality.

INTRODUCTION

Ground water is the major and preferred source for drinking all over the world even though its contribution is very less (i.e. only 0.6%) to the total water resources on earth (Meenakshi and Maheswari, 2006).People around the world have used groundwater as a source of drinking water, and even today more than half the world population depends on groundwater for survival. Hence, there is always a need for and concern over the protection and management of groundwater quality (UNESCO, 1992).Bacterial contamination of drinking water is a major contributor to water-borne diseases such as diarrhoea, nausea, gastroenteritis, typhoid dysentery and other health-related problems, especially in children and persons with weak immune systems (Patil et al., 2001). Sources of total and fecal coli form in groundwater can include infiltration of domestic or wild animal fecal matter, effluent from leaking septic systems or sewage discharges and agricultural runoff(Azizullah et al., 2011).According to the WHO standard for public drinking water, total coliforms and fecal coliforms in 100 ml of water must both be below detectable levels (Cool, 2010).Among 50 diseases prevalent in Bangladesh, 40 of them including diarrhoea, dysentery, typhoid, parasitic worm infection etc. are related to the contaminated food and water (WHO, 1993). Access to safe drinking water has been an important national goal in Bangladesh and in other developing countries. While Bangladesh has almost achieved accepted bacteriological drinking water standards for water supply, high rates of diarrheal disease morbidity indicate that pathogen transmission continues through the water supply chain and other modes (Miller, 1985). The objectives of the study are conducted as to evaluate the physical, chemical and biological quality of drinking water, to determine the microbial quality of drinking water (tube well water and supply water), to identify the possibility of fecal contamination sources by risk scoring and possible chlorine doses are investigated to disinfect the drinking water in Jessore municipality and to evaluate public health risk.

METHODOLOGY

Study area selection and sample collection

The study was conducted in Jessore Municipality (14.72sq km) under Jessore districts. The municipality located between 21°45ˈ to 23° 45ˈ North latitude and 89°15ˈ to 89°55ˈ East longitude. The water samples were collected 23 separate shallow tube well (STW), deep tube well (DTW) and supply water (SW) system in Jessore Municipality. The GPS Meter (Model- eXplorist®310, ver01.08) was used for collecting the adduct location of sampling site these are pointed out in Fig. 1:

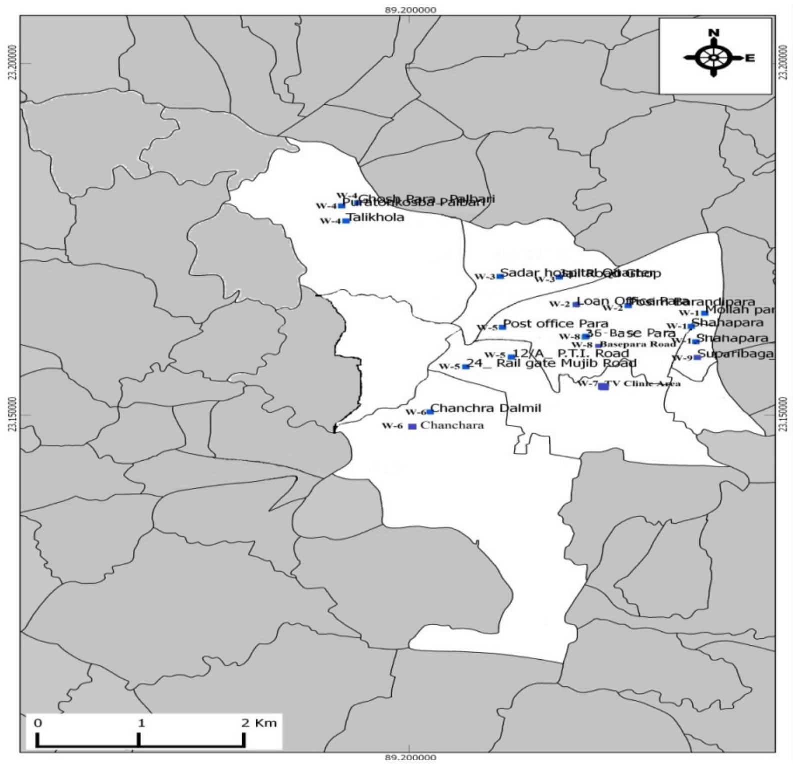

Fig. 1: Sampling points of Jessore Municipality

Table 1: The list of selected parameters and used methods

Parameters/ Units	Methods
pH	Membrane electrode
EC (μS/cm)	Conductivity
TDS (mg/L)	Conductivity
Salinity (mg/L)	Conductivity
Turbidity (NTU)	Photometric
Ammonia (mg/L)	USEPA Nessler Method (8038).
Nitrate (mg/L)	Chromotropic Acid Method (10020).
Phosphate (mg/L)	PhosVer3 with Acid Persulfate Digestion Method (8190).
Chlorine dose(mg/L)	USEPA DPD,Method 8021.
Total coliform count (CFU/100ml)	Membrane Filtration Technique.
Fecal coliform count (CFU/100ml)	Membrane Filtration Technique.

Chlorination

In shallow tube well water the chlorine dose was given 1.2mg/L. Only for supply water the doses 2 mg/L and 4.8 mg/L were applied. Then Residual free chlorine was measured at the initial interval of 1 hour and 6 hour. Chlorine is present in most disinfected drinking water at concentrations of (0.2–1) mg/L (WHO, 2006).Then at the initial, interval of 1 hour and 6 hour the coliform were also measured.

Risk scoring analysis and Data analysis

According to "Sanitary Inspection Forms" the risk scoring of fecal colifrom (FC) is held on spot. All data were put in Microsoft Excel 2007 and statistical analysis was held.

RESULTS AND DISCUSSION

Physical quality of drinking water

It is found that the turbidity range the samples were(0.0 -17.60) NTU in tube well water and supply water. About 13.04% (n=3) sample cross the limit of Bangladesh drinking water standard (10 NTU) and 17.39% (n=4) exceeded from WHO standard (5 NTU).The test result of EC, TDS and salinity are presented by the [Fig. 2]. It is observed that the EC levels are among the range of (452-1177)µS/cm of all the samples of water and 100% (n=23) is in the limit of Bangladesh drinking water standard (2000 µS/cm). According to WHO guideline (700µS/cm) about 86.96% (n=20) samples are exceeded from the limit. The TDS and salinity levels were among the range of (292-765)mg/L and (215-585)mg/L respectively, which is acceptable.

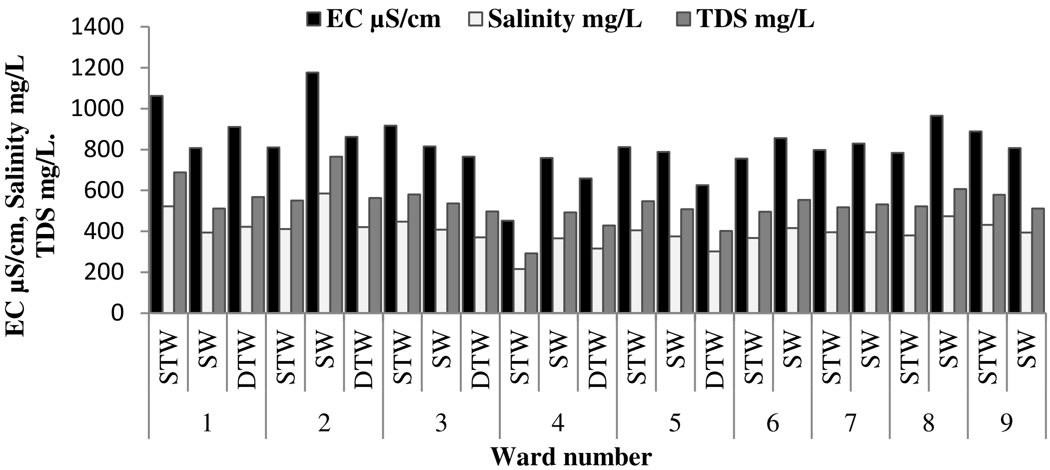

Fig. 2: Results of EC, TDS and salinity (STW-Shallow tube well,SW-Supply water and DTW-Deep tube well).

Chemical quality of drinking water

It is observed that the pH level is between the values of 7.77-8.40 which is slightly alkaline. For Bangladesh drinking water standard pH level is 6.5-8.5 and for WHO 6.5-9.2. So it is within the limit of both Bangladesh and also WHO drinking water standard. The test result of ammonia, nitrate and phosphate for supply water and shallow tube well water are presented [Fig. 3]. It is observed that the concentration of ammonia is exceeded about 11.11% (n=1) sample in shallow tube well water from WHO standard (1.50mg/L). In Bangladesh, the value of ammonia for drinking water standard is 0.5mg/L and about 21.74% (n=5) samples cross the limit of Bangladesh standard. It is observed that the nitrate and phosphate concentration level are between the ranges of (0.4 - 9.6) mg/L and (0.05 - 0.97) mg/L respectively. In Bangladesh the value of nitrate for drinking water standard is 10 mg/L and WHO standard is 50mg/L. So the 100% (n=23) water of shallow, deep tube well and supply water is not exceeded from the WHO and Bangladesh standard.

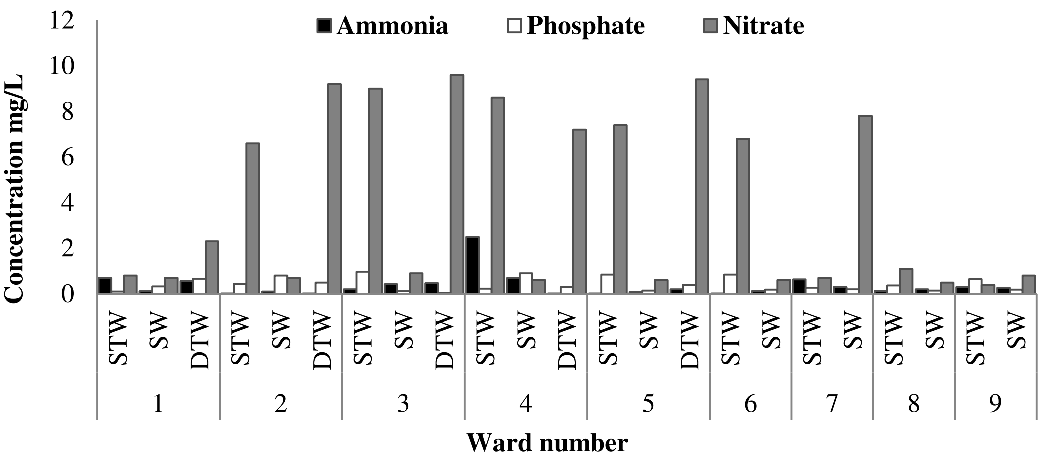

Fig. 3: Results of ammonia, nitrate and phosphate (STW-Shallow tube well water and SW- Supply water)

Risk score analysis with microbial contamination

It is observed that with the increasing of risk score the contamination of fecal coliform is also increased. The supply water sources are highly contaminated by fecal coliform and risk score is also very high. About 86.96% (n=20) sources were contaminated by total coliform. It was observed that the supply water contain(5-500) CFU/100ml and fecal coliform (1-400) CFU/100ml. The highly contaminated water can cause waterborne diseases.The sources of deep tube well were the lower risk of coliform contamination and also the average concentration coliform is <1CFU/100ml.It is observed that the condition of deep tube well is quite good than the shallow tube well and supply water.

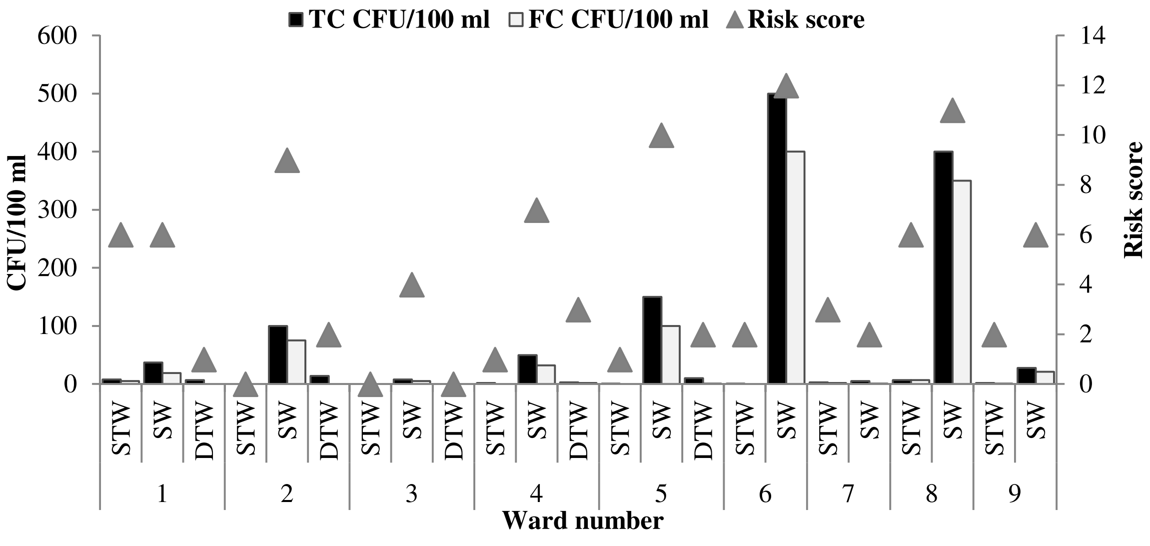

Fig. 4: Risk scoring with the contamination of total coliform (TC) and fecal coliform(FC); (STW-Shallow tube well water and SW- Supply water).

Treatment to remove coliform bacteria

Chlorination doses were applied for considering tube well and supply water as for drinking purpose. For effective disinfection, there should be a residual concentration of free chlorine of 0.5 mg/L after at least 30 min contact time at pH<8.0.For stock solution 4.8mg/L the residual free chlorine was remaining 3mg/L after 6 hour. The concentration of solution 2mg/L and 1.2mg/L were remaining residual free chlorine 0.5mg/L and 0.30mg/L respectively.The removal percentages of coliform bacteria at different doses [Fig.5].

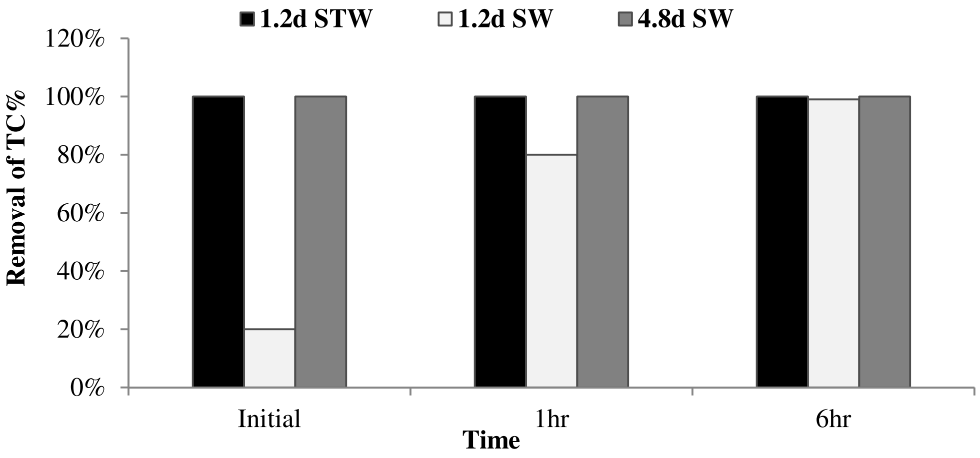

Fig. 5: Removal of total coliform (TC) by applying different chlorine doses; (STW-Shallow tube well water and SW- Supply water)

By chlorination 100% coliform bacteria was removed after six hour. It is observed that in shallow tube well water at first hour 100% total coliform was removed in dose 1.2mg/L. In supply water initially 20%, after 1hour 80% and after 6hours 99% total coliform was removed at the dose 2mg/L. At the dose 4.8mg/L in supply water the total coliform was removed 100%. But this treated water is not safe at 1 hour interval because the residual chlorine is high. So at six hour interval the water is safe for drinking. It is observed that at six hour interval the residual chlorine is in the limit of (0.2-2.0)mg/L, it is in the WHO drinking water standard. Fig. 6, are shown for the chlorine demand at time interval for different chlorine doses that was applied to disinfect the contaminated water as treatment procedure.

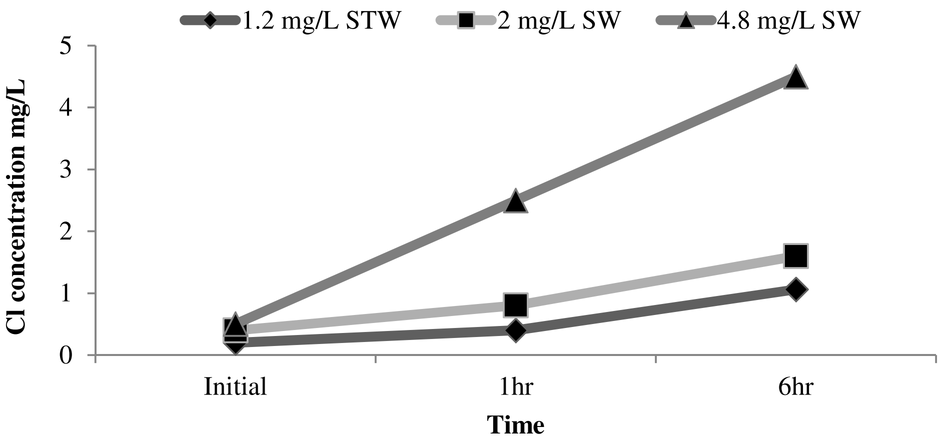

Fig. 6: Chlorine demand at time interval for different chlorine doses.

Strategies to safeguard water quality and public health

Fig. 7 shows a sanitary inspection risk assessment framework for prioritizing control/remedial actions of household roof water harvesting systems based on a grading system of laboratory analytical results (fecal coliform counts) and sanitary inspection risk score (WHO, 2006). It presents a risk assessment framework on how the laboratory analytical results (fecal coliform counts) for a roof water harvesting system can be used to plan and prioritize a control program when water fails to meet WHO drinking water guidelines.

The higher the score was found, the higher possibilities of was presenting fecal coliform. Effective mitigation of roof water contamination and protection of public health will entail using a combination of measures available to users. Understanding the factors controlling water quality and contamination pathways is critical for minimization of water contamination and safeguarding public health. There are strategies required to further safeguard public health risks associated with consumption of water. Combined with laboratory analytical results, sanitary inspection form enables prioritization/targeting of mitigation/control measures.

Indicator Organism		Sanitary Inspection Risk Score			
		Low risk (0-3)	Medium risk (4-6)	High risk (7-9)	Very high risk (10-12)
Fecal Coliform CFU/100ml	<1-3				
	4-14				
	15-75				
	100- >400				

Key	Low Risk(0-3): No actionrequired	Intermediate risk (4-6): Low action priority	High Risk (7-9): High action priority	Very High Risk (10-12): Urgent action required

Fig. 7: Strategies framework to safeguard water quality and public health.

CONCLUSION

The provision of safe drinking water remains a challenge, particularly in impoverished areas with poor infrastructure. Monitoring of groundwater in Jessore, Bangladesh, has determined that the underlying aquifer is not grossly contaminated but the level of bacterial fecal indicators (thermos tolerant coliforms) is positively related with sanitary risk. A correlation of water quality analysis and risks identified in the vicinity allowed a prioritization of interventions. The approach adopted by this study shows that a structured approach to water quality monitoring, with targeted observations, is important to programs in order to identify the priority interventions to be undertaken.

ACKNOWLEDGEMENT

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A STUDY ON RAINWATER HARVESTING IN HILLY AREAS OF BANGLADESH

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ABSTRACT
One of the most basic problems that the inhabitants of hilly districts of Bangladesh face is scarcity of fresh drinking water. Being at an elevated place they are not capable of using groundwater, only surface water being their sole supplier of water demand during dry season. But during rainy season rainwater also comes in handy. This research surveys a standard hilly area (Kukimara andRangamati) to estimate the amount of rainwater the area gets throughout a year by studying the average rainfall for that area. Then it compared with the amount of water demand . In the study area there are near about 819 inhabitants. All of them depend upon on ground water for drinking. But the drinking water quality in this area is below the standard level mostly because of excess quantity of dissolved iron in the groundwater. The annual average rainfall in the study area is approximately 2233.1 mm and having an estimated 3363.02 sqm.of rooftop catchment area which can presumable to meet the daily necessities of those people. The research also finds the procedure for establishment of effective rainwater harvesting tank design for that area. Finally, it is found that Rain Harvesting Water (RHW) can be better and cheaper alternative for drinking purposes as well as domestic purposes in compare to present water quality, location, peoples' perception, environmental issues, and cost.

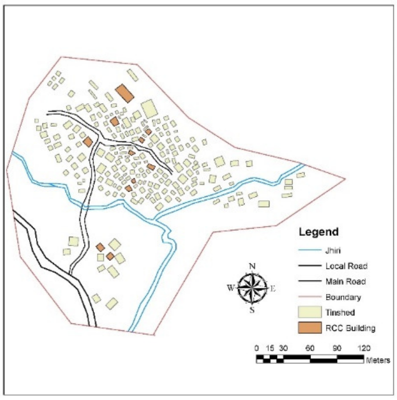
Keywords: RWH; Hilly area; Water; Rainfall.

INTRODUCTION

The Rainwater harvesting is the simple collection or storing of water through scientific techniques from the areas where the rain falls. It is especially beneficial in the areas, which faces the scarcity of water (Yadav et al, 2015). The Chittagong Hill Tracts (CHT) is located in south-eastern of Bangladesh, bordering India and Myanmar. The total area of the Chittagong Hill Tract (CHT) is estimated at around 13,237 sq.km., which is about one tenth of the country (MOCHTA, 2017). According to the census of 1991, the population was 974,447, of which 501,114 were tribal peoples. Rangamati is the largest district of CHT. Its area is 6116.13 sq. km (BBS, 2001). There are about 29 tribes in Bangladesh. Among them 12 tribes live in Rangamati (IWGIA, 2013). Major sources of drinking water in hilly areas are wells, spring, river and stream. A dependable water supply system all throughout the country is offset by two factors: (a) high salinity in surface plus groundwater in coastal areas; (b) want of suitable groundwater aquifers in hilly areas and the high cost of setting up tube-wells due to deep underground water table and stony layers (Alam et al., 2012). The thickness of the main aquifer in the Chittagong hilly areas is highly variable ranging from few tens of meters to more than 100 meters (MPO, 1987). The subsurface stratigraphy of the hills proves to be formidable for ground water extraction at individual household level due to uncertain, deeper and unfavourable aquifer condition and high initial cost of drilling and tubewell installation. Since the aquifer is confined, multiple, or semi- confined in nature, its recharge and groundwater storage are also uncertain. Many cases of drying and disappearance of the springs fed from groundwater sources are already reported. Groundwater piezo metric levels also show some scattered evidences of groundwater mining. There are also iron and manganese problems in groundwater (Field survey, 2017). The northern/north-eastern hilly region has limited DTW and STW development potential and the area is considered unfavourable for extensive groundwater development (Mondal, 2015). Therefore, rainwater harvesting can become effective technology for uplifting the socio-economic conditions of the hilly population.

Study Area

Rangamati is a part of the Chittagong division. It is the largest district of the country. The area of the district is 6116.11 square km of which 4824.63 square km is land. It is bordered by Tripura state of India to north, Bandarban district to south, Mizoram stateof India and Chin state of Myanmar to the east.



(A)

(B)

Fig. 1: (A) Study area, (B) Tara pump available in the study area

The study was conducted at a distant village named 'Kukimara' of Rangamati district. It is in the south of Bangladesh from 22^{0}34'16" to 22^{0}34'6" north latitude and from 92^{0}06'38" to 92^{0}0651" east longitude. As the area is in the hilly region, water collection by deep tube wells is not an efficient option as the aquifer layer goes somewhat 300-400 feet underground. The previous water collection system wasby using dam from the lake. It was almost 1 km far from the area. Unfortunately that supply system was totally damaged by recent landslide in 2017. There was a deep tube well in 2012 and the depth of the tube well was about 120 ft. Water was supplied from that source. Due to lowering of water table whole system was totally stopped. As for present they use 4 tara pumps installed by UNICEF and a tributary (locally called 'Jhiri'). The water collected from the pumps contain iron in an amount larger than BECR standard in the study area (Field survey, 2017). The tributary contains surface contamination in an alarming scale. Also during rainy season water overflows in the tributary containing huge amount of contamination from upstream making the water impossible to use. The aquifer of the area is discontinuous. The depth of the water table is about 90m to 120m Recently a deep tube well is about to install but up to 400 feet , concern authority didn't find any water table and the project subjected to be stopped. There founds a hard soil strata at a depth of 12m and that's why shallow tube well can't be introduced (Field survey, 2017).

METHODOLOGY

A strategy including some qualitative and quantitative methods and analysis was taken to complete the study. Primary and detailed field investigation was done through questionnaire survey to identify socioeconomic constraints, challenges and opportunities that could determine the adoption of rainwater harvesting technology. Land area, major occupation of the people were collected by field survey. The information of monthly and annual rainfall, rainfall pattern, climate conditions were collected from Bangladesh Metrological Department (BMD) and World Weather Information Service (WWI). Water demand-supply has been calculated using Indian Manual for Rainwater Harvesting & Conservation and BNBC-2015code. Stored rainwater samples were collected from May, 2017 to November, 2017 and laboratory tests were performed in Environment Engineering Laboratory to identify the water quality parameters of the rainwater.

Rainfall Analysis

Rangamati has a tropical monsoonal climate with a dry season and a heavy monsoon the rest of year. A 8 year rainfall pattern based on the mean intensity for the period 2009 to 2016 is shown in Fig 2. This region gets hold on average 2233.1 mm of rainfall per year. Heavy rains start in May and it decreases as the winter season comes closer.

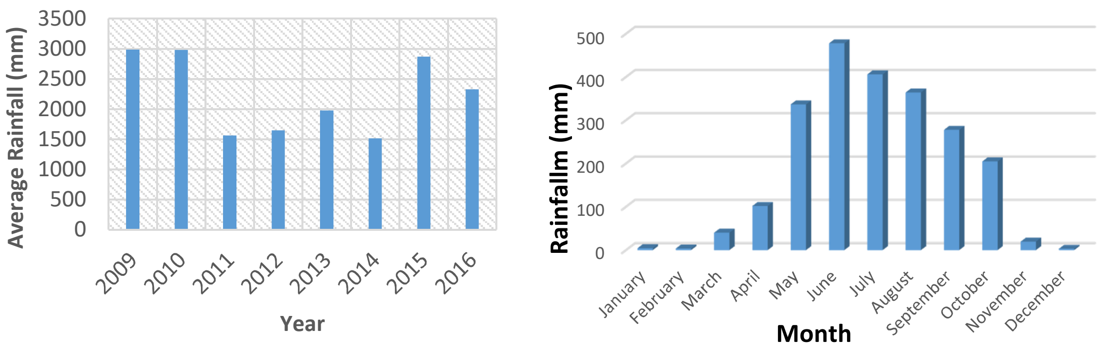


Fig. 2: Variation of Monthly and annual rainfall (WWI, 2017)

In Fig.2, the heavy rainfall only occurs from May to October. Adequate rainfall occurs and the surplus rain from these months would be stored to cover the shortage in dry period. June has the highest average rainfall for all time and rains up to 406 mm. So, comparatively, most of the rain water can be collected in this month. After winter is over, the rainfall starts increasing from the month of May and it lasts up to October.

RESULTS AND DISCUSSIONS

In the study area, there is about 196 tin shed building and 9 RCC building and total 3363.02 sq. meters rooftop area was estimated. It was observed that most of the rooftop are suitable for installing rainwater harvesting system. The calculation was conducted as per "Rain Water Harvesting and Conservation" manual and Bangladesh national Building Code (BNBC-2015). The equation used for calculation is:

$$Y = (A \times R \times f)/1000 \quad (1)$$

$$D = (P \times LPCD \times T) \quad (2)$$

Where,

Y= RWH potential (Volume of rainfall over the plot) $(m^3/year)$, A = Catchment Area (m^2), R = Average annual Rainfall (mm), f = Runoff coefficient taken as 0.75 concrete roof and 0.9 for tin shed,

D = Annual demand $(m^3/year)$, P = Population (nos.), T = Days required in a year (Days), LPCD = Liter per capita demand (as per BNBC)

From Fig. 3, it was found that during June to August rain water supply is beyond the demand line. The annual demand for the study area was found about 40356.23 cum. and the potentiality supply of rainwater is 21557.085 cum. Thus 46 % of total water demand can be fulfilled by the supply water which will reduce the dependence on ground water effectively.

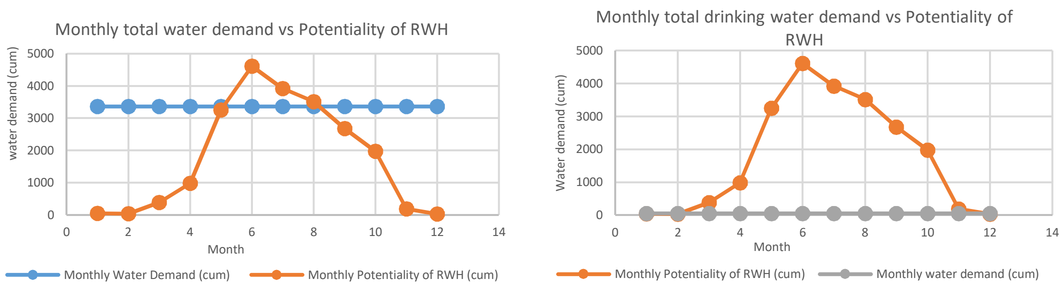


Fig. 3: Demand analysis of the study area.

Per capital consumption of drinking water was taken as 2 liter/capita/day. The monthly drinking water demand is very low comparing to the potential supply of RWH. From Fig.3, it was found that the annual drinking water demand for the study was found about 589.68 cum. Only and the potentiality of rainwater harvesting is 21557 cum. The collection of rain water can be distributed adequately throughout the year.

Assessment of Water Quality Parameters

Various laboratory tests were performed for the sample directly collected from roof. Water quality of the "Tara Pump"and the "Jhiri" also performed. The summary of the test result of water quality parameters are presented in Table 1.

Table 1: Analysis of water quality parameters

Water Quality Parameters	Tin-Shed Building Roof	RCC Building Roof	Tara Pump	Tributary (Jhiri)	Unit	Environmental Conservation Rules
pH	7.25	8.1	6.85	7.35	Value	6.5 – 8.5
Turbidity	10.12	8.54	82.3	11.23	NTU	10
Color	25	30	25	40	Pt-co	15
Odor	-	-	-	-	TON	odorless
Hardness	45.3	31.2	675	360	mg/l	200 - 500
TDS	178	167	1495	810	mg/l	1000
Alkanity	25	30	955	225	mg/l	130-150
BOD	0.49	0.35	-	-	mg/l	-
COD	75	0.62	-	-	mg/l	-
E. Coli	1	1	-	28	N/100mL	-
Fe	-	-	4.49	-	mg/l	0.3 - 1

Almost all the result values collected from roof top were within the range of Bangladesh Standards for Drinking purposes (ECR, 1997). pH value in concrete was found larger. The concrete properties might affect the result. The values ofColor, Turbidity, Alkanityexceeds the limits of standards values for tributary also presence of *E. Coli* also identified. Almost every values for "Tara Pump" exceeds the standard values. The causes of exceedance might be due to higher amount of Iron, suspended and dissolved particles and so on. Pre-treatment is required for using them.

Socio- Economic Survey

Income is an important indicator of socio-economic condition of a community. A community with higher income level can meet their basic needs and enjoy their livelihoods. In the study area 71 % of men are employed, compared to 72 %t of women without any existent variation between urban and rural areas. The percentage of total employee is 71 percent whereas only 29 %t are unemployed. It is also found about 23% people's income level was below 5000Tk.The people whose income level is 5000Tk to 20000Tk lies in middle income and their percentage was about 66% of total population. Last it is found 11% people whose income level was over 20000Tk.

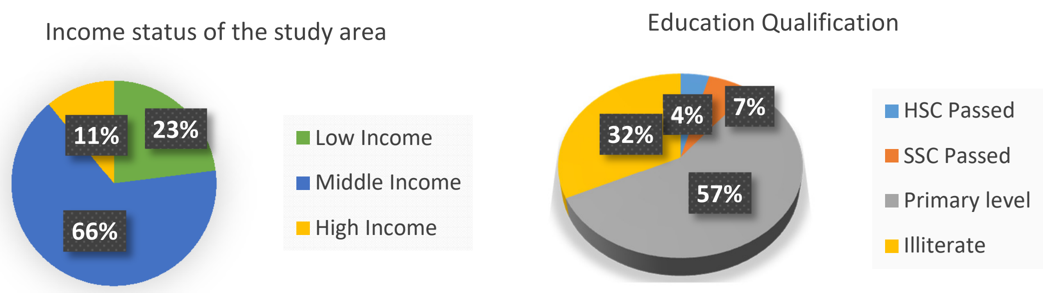


Fig. 4: Socio-economic condition of the study area

The educational situation in hilly area of Rangamati is not very praiseworthy. Only 4% people were found who have completed HSC level. 57% of total population remains in Primary Level and it's a matter of great convulsion that about 32% people are illiterate.

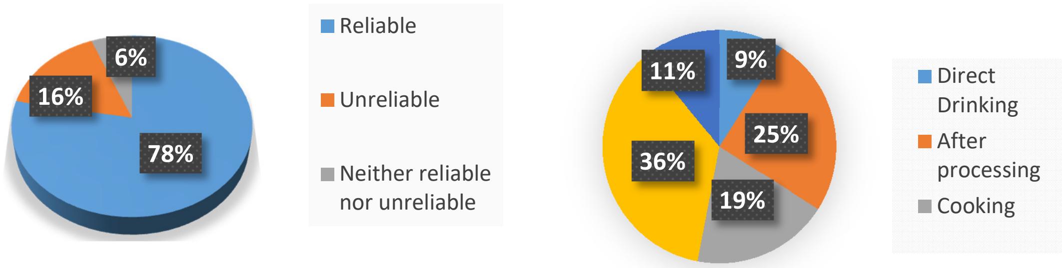


Fig. 5: Users Options regarding Rainwater harvesting

78% of the people showed their reliability on RWH system. About 16% people doesn't think this would work out and other 6% gave their opinion somewhere in between reliable and unreliable.Only 1% people gave their verdict on drinking the harvested rain water directly. 25% think that it needs to be treated before any use. 35% people want to utilize this water in toilet and bathing purposes and in this case the water doesn't need much of treatment; only filtration will do. Another 9% people suggested that it should be used for washing purpose. But the majority, which goes about 30%, wants to use this water for cooking and only filtration can breaks all the barriers that stand before utilizing this water in this purpose.

Design and Cost of Rain Water Harvesting System

During literature survey different proven model of household has been identified which are practiced by different organization in Bangladesh and also in the abroad countries. Construction material of these types is locally available. The modes are Cement/Morter Jar, Ferro-Cement Tank, R.C.C. Ring Tank. Typical tank design for RWHS is shown in Fig. 6 and cost analysis for 3 models is shown in Table 2.

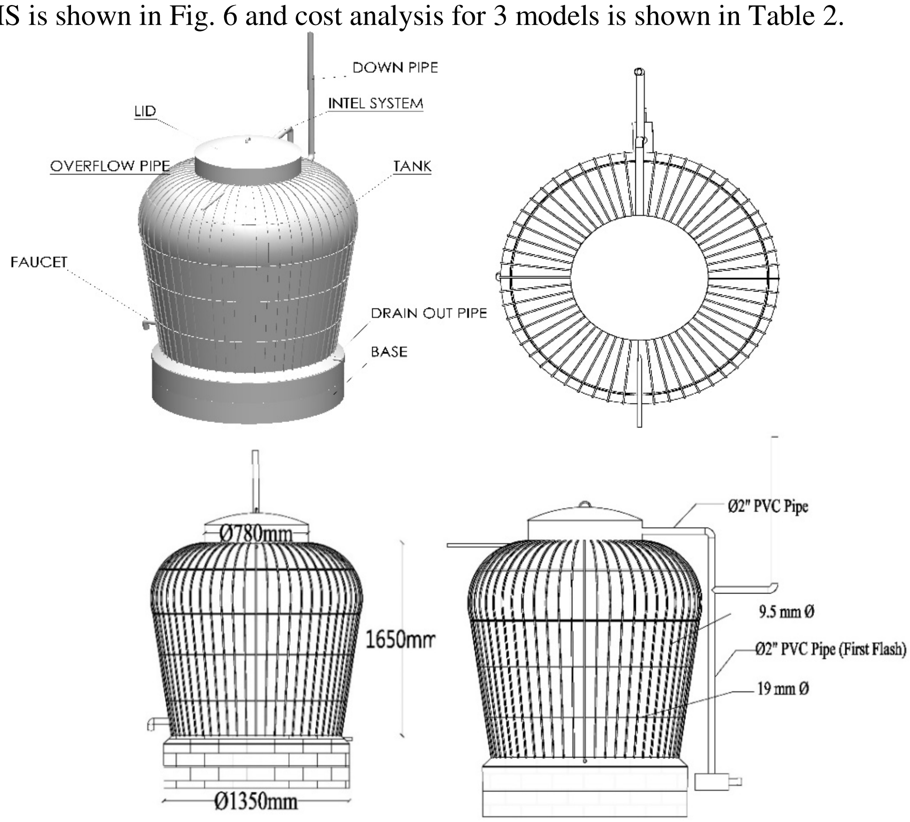


Fig. 6: Tank design (Isometric view, top view, Back view & Side View)

Table 2: Comparative cost analysis.

Cement/Mortar Jar		Ferro - Cement Tank		RCC Ring Tank	
Capacity (Litres)	Cost (Tk)	Capacity (Litres)	Cost (Tk)	Capacity (Litres)	Cost (Tk)
1000	3526	2500	8400	1000	4725
2000	6364	3200	11375	2000	7000
2500	7740	3800	13650	2500	8400
3000	9460	4600	16275		

CONCLUSIONS

Living in the distant part of Bangladesh it is clear that the inhabitants face difficulties collecting water as there is no water supply, the aquifer is too deep to establish wells and the local tributaries contain contaminations which often cause diseases. After conducting the questionnaire survey it is clear that most of the locals want RWH as an alternative to their water collection system. In rainy season the scarcity becomes more severe as the tributary brings more contaminated water than usual. The pumps at present used by the locals collects water which does not satisfy BECR standard for drinking water. As most of the inhabitants are of low income and also there is no chance for regular water supply to be served in this place in near future, RWH is the most feasible measure that can be taken by the locals to eradicate their problem concerning water supply. Also as the whole system is sustainable and is manageable at a small scale, this system is more suitable than others for these sort of hilly area.

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ASSESSMENT OF WATER QUALITY AND WATER SUPPLY SYSTEM OF RAJSHAHI WASA IN BANGLADESH

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ABSTRACT

Safe drinking water access is a basic human right for development issue. Water quality assessment at scale formed to ensure drinkable water requires valuation of measurement of water quality parameter and investigation of water pollution and the recognition of main pollution factors. In Rajshahi city, RWASA (Rajshahi Water Supply & Sewerage Authority) supplies water to meet the need of the water demand through a distribution network in Rajshahi City Corporation (RCC) area. But according to the people's perception, the quality is deteriorated due to some circumstances. The study aimed to assess the water quality parameters (i.e. physical and chemical parameter) and the supply system of RWASA. Water quality parameters collected from different consumers against their sources (WASA point) were tested in the laboratory. These parameters include P^H, turbidity, iron (Fe), hardness and odour. According to the study, around 65-70% people are not using RWASA supply water for drinking purpose. The rest i.e.30-35%people use the supplied water by boiling for a certain period and purifying by filters. This paper will also review the existing water supply scenario of Rajshahi City and the roles of different service providers and stakeholders. The questioner survey conducted by the responses from a random sample of 40 households in this study. The results indicate that P^H of water in the selected areas was within an allowable limit, but however, in few wards, turbidity, iron, hardness and odour deviated from their standard values. These conclusions may provide useful and effective for rising the awareness of water quality improvement and water supply management.

Keywords: RWASA; Water Supply; Water Distribution Network; Water Quality, Physical and Chemical Parameter.

INTRODUCTION

Good drinking water quality is one of the most important elements. A man can survive longer without food than without water. This fact apparently accounts for why water is regarded as one of the essential substances in life (Etim et al., 2013). Water use has been rising due to increasing populations. Rajshahi WASA was established in 2013 to fulfil the water crisis. But, RWASA could not provide good quality water. So, the peoples of this city suffer many water borne diseases. Furthermore, consumers complain about water quality. Even during the literature review there are no studies were found on physicochemical parameters of supplied water quality in Rajshahi city.

Possible causes of supplied water pollution in Rajshahi city may be widespread application of PVC pipe, locally available metals like iron, manganese. On the other hand supplied water may also pollute during transfer, treatment, distribution or storage (Fernández-Navarro et al., 2017). To find out different water quality problems a questionnaire was made to interview the people from selected wards. 40 RWASA samples (consumers and sources) were collected from 10 wards in this city. Then samples were analysed by lab test for some important water quality parameters. Selected parameters were turbidity, iron, hardness, p^H, and odour. But in some wards concentration of iron and hardness was deviated WHO standards and

Bangladesh drinking water standard (BDS). Odour problems find almost all water samples. P^H values fell within allowable range recommended by WHO and BDS. Elevated concentration of iron may cause severe health problems (Memon et al., 2011). This study represents the maximum and minimum values of selected parameters. The main purpose of this study is to investigate water quality with respect to locations where problems have been appeared and to perform lab analysis about which of water quality parameters of defective locations deviate from their standard values. Furthermore, attempt has also been made to concern and help Rajshahi City Corporation (RCC) and RWASA by delivering noticeable information about the present condition of water quality in RCC.

METHODOLOGY

Rajshahi City-corporation is one of the six city-corporations located in the north-west part of Bangladesh. It lies between $24^{0}21^{/}$ and $24^{0}26^{/}$ north latitudes and between $88^{0}28^{/}$ and $88^{0}37^{/}$east longitudes. The city is bounded on the east, north and west by Papa Thana and on the south by the Padma River and the shape of the city is as like an inverted "T" with an area of about 47.78 sq. km (RCC)(Rahman, 2004). The overall methodology can be described by a flow chart.

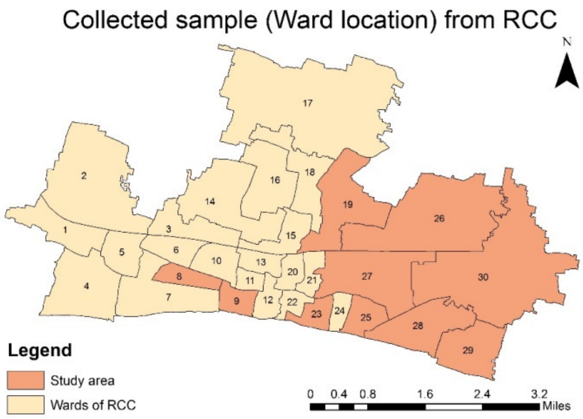

Fig.1: Study area

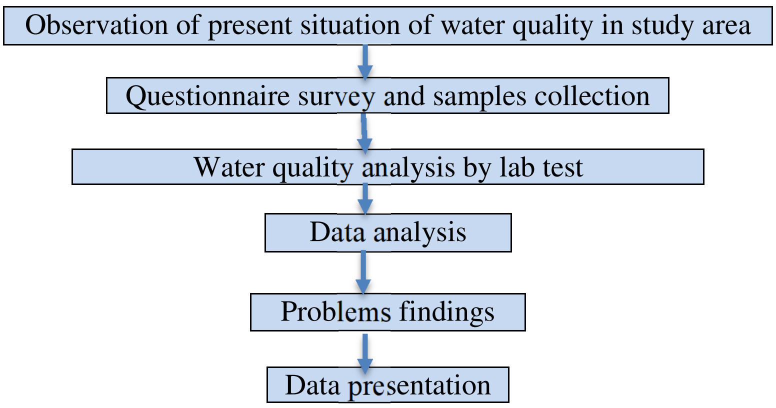

Fig. 3: Flow chart of methodology

Sample collection

Out of 30 wards of RCC, 10 wards were selected for the present study based on public problems. According to public objectives, 3 user's (S1, S2 and S3) points were selected for each source. A total 40 samples were collected and analysed to evaluate important water quality parameters. Water samples were collected from tap of different residential area in1-litre polyethylene (PE) bottles and pre heated by washing with dilute HCl and later rinsed with distilled water (Etim et al., 2013). Collected samples were carried in public health lab of RUET safely.

Lab analysis

Some important physical parameters like P^H and turbidity were determined possible sooner after collection. Otherwise accurate value was impossible to obtain. Almost all these important water quality parameters were measured within four hours of collection (Fahmida et al., 2013). The recommended order for calibration of the individual probes on a multipara meter is pH and turbidity (WHO, 2008).

Table 1: Experimental methods and allowable limit

Selected parameters	Experimental methods	BDS	WHO
P^H	P^H meter	6.5-8.5	6.5-8.5
turbidity	Turbidity meter	10	5
Iron	Titration method	.3-1	.3
odour	Threshold odor number (TON).	odorless	odorless
Hardness	Soda reagent method	200-500	500

RESULTS AND DISCUSSIONS

Questioner survey report, analysis of p^H, hardness, iron, odour and comparison between sources and consumers problems are described in this section. Every parameters are compared to BDS and WHO standards. Furthermore, health effect of poor quality water is described.

Table 2: Questioner Survey Report

Reasonable questions	**Percentage of investigated problems**					
What kind of water used	RWASA			Non RWASA		
	40%			**60%**		
Present condition of water supply system	RWASA			Non RWASA		
	Good	Excellent	Bad	Good	Excellent	Bad
	10%	**5%**	**85%**	**40%**	**20%**	**40%**
Do you drink supplied water from RWASA directly?	yes			no		
	60%			**40%**		
Water supply interruption	evening			1-2 hours		
	yes	no		yes	no	
	25%	**75%**		**30%**	**70%**	
Which time water quality is worse?	morning		evening		night	
	80%		**5%**		**15%**	
Found black water	yes			no		
	70%			**30%**		
Iron problem	yes			no		
	90%			**10%**		
Odour problem	yes			no		
	95%			**5%**		
Water supply problem in summer season	yes			no		
	5%			**95%**		
What process follow to purify supply water	filter		boiling		medicine	
	17%		**58%**		**25%**	
Suffered from water borne diseases	yes			no		
	55%			**45%**		
What type diseases?	Diarrhoea		cholera		others	
	45%		**25%**		**30%**	

According to public interview 40% community use RWASA's water and 60% use non RWASA water. Present condition of water supply system by RWASA is not good. Blackish water, odour and iron problems are 70%, 95%, and 90% respectively. At morning public receive worse quality of water. 45%, 25% people suffer from diarrhoea and cholera respectively. The supplied water in RWASA and Non-RWASA is ranked from bad to excellent. Basically, supplied water from RWASA is bad compare to non RWASA water. About 85% RWASA water was bad. Only 10% was good [Fig. 3]

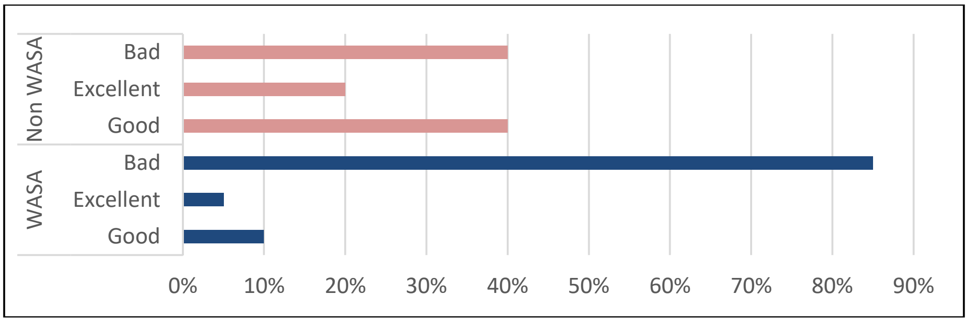

Fig.3: Water supply system and quality of RWASA and Non- RWASA

P^H value indicates to the acidity or alkalinity of the water (Rahmanian et al., 2015). The pH also specifies the degree of acidity or alkalinity of water (Guettaf et al., 2014). Samples collected from RWASA and their consumers had p^H 6.4 to 7.5. All samples satisfied WHO standards and BDS ranges 6.5-8.5 [Fig.4].

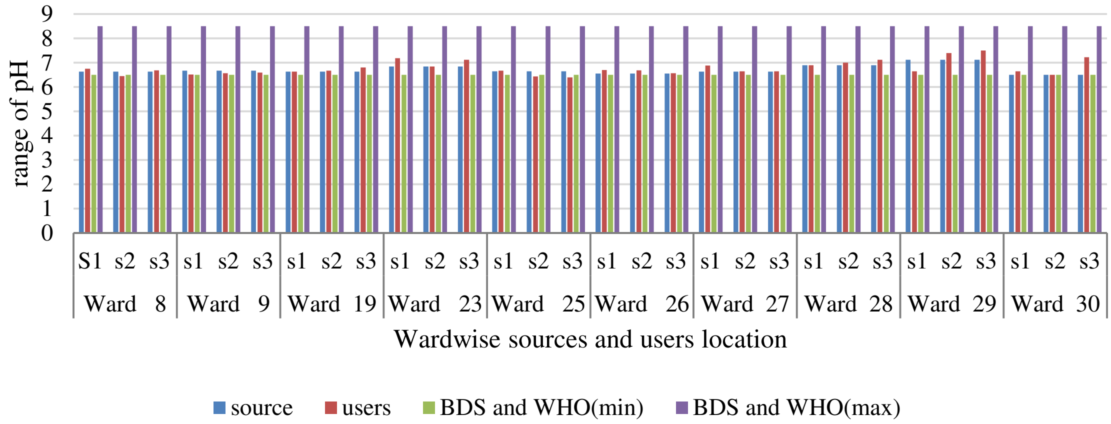

Fig.4: p^H of all samples

Out of 40 samples collected in the study area, the majority of the users about 90% had objectionable odour. Rest of the water samples collected from sources contained free from odour.

Turbidity indicates the presence of suspended material such as clay, silt, finely divided organic material, and other inorganic material. Higher turbidity may create possible bacterial contamination(Rajon and Bari, 2014). According to WHO & BDS guideline the allowable turbidity for drinking water are 5 NTU and 10 NTU respectively.Out of 40 samples, 20 samples of users had turbidity higher than WHO standards. In ward 25 contained maximum value 25.22NTU which is the 5 times of WHO standard and 7.5 times of BDS. Ward 25, 27, 29 and 30 exceeded BDS value. Turbidity ranged 0.52-25.22NTU [Fig. 5].

Water can be classified as soft (<75 mg/L), moderately hard (75-150 mg/L), hard (150-300 mg/L) and very hard (>300 mg/L) according to the concentration of calcium and magnesium (Alam et al., 2017). In targeted study area hardness ranged from 35-530mg/l. 11, 14, 10 samples collected from sources and consumers fell within soft ranges 35-72mg/l, moderately hard ranged from 75-148mg/l, hard ranged from 150-248mg/l, rest of the samples found very hard respectively. 3 samples exceed BDS limit 200-500mg/l [Fig.6].

Comparison between Sources and consumers problems

Turbidity deviate from its standard value 25% at sources but when water reaches to the consumers house the problem increase 3 times of sources that means 75%. Hardness, odor, iron problem was 22%, 21%, and 27% at sources but this problems rise up to 78%, 79% and 73% at household water samples respectively. Possible causes of this ecological imbalance may be due to treatment process which include

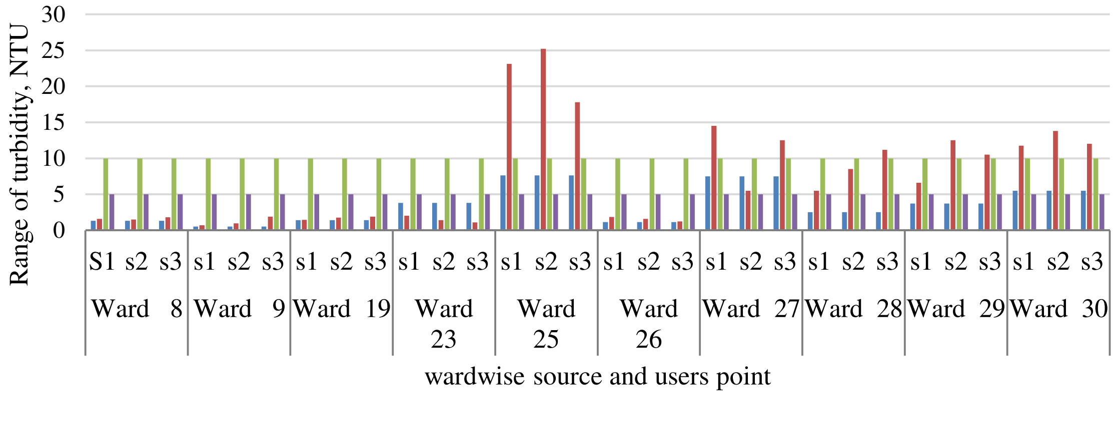

Fig.5: Representation of turbidity of all samples

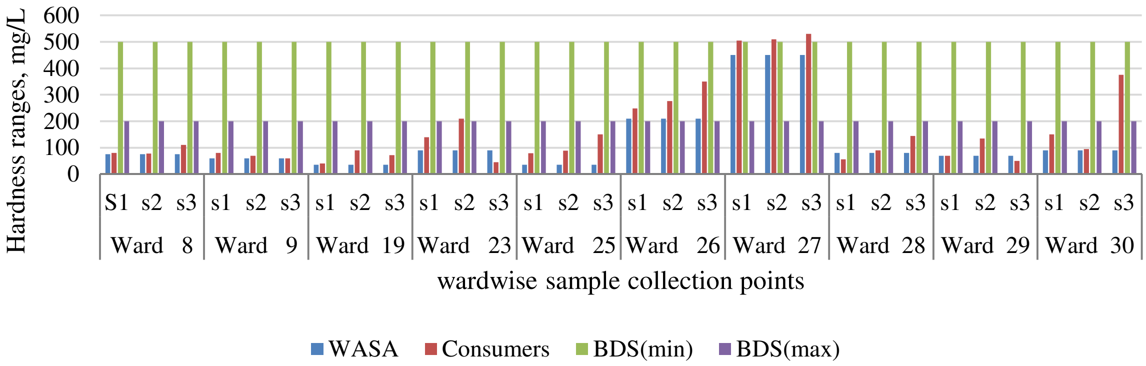

Fig.6: Hardness of all samples

coagulation-flocculation, disinfection, filtration, adsorption, and sedimentation among others. Contaminants produce from such processes and incorporate with water. Another contaminants may be incorporated during water distribution and storage (Fernández-Navarro et al., 2017) [Fig.7].

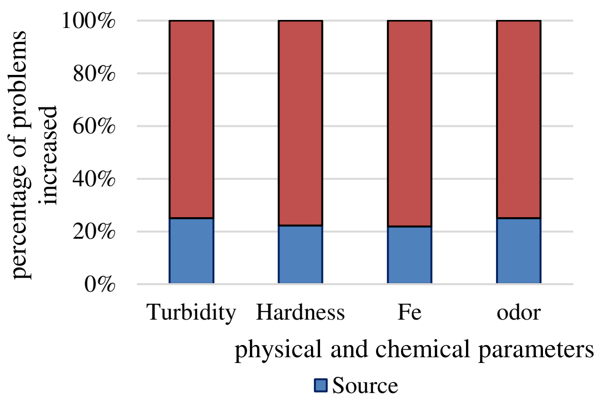

Fig.7: percentage of problems increased from source to consumers

Health Effect

If iron levels are too high, serious health effects like iron overload can develop. Water with excessive amounts iron can have negative effects on skin. It can damage healthy skin cells, which can lead to wrinkles. Iron leaves residue on anything it touches (Etim et al., 2013). Due to unpleasant odor of water, possible health effect gastrointestinal illnesses (diarrhea, vomiting, and cramps) may occur. When People smell strong odors, it may get headaches or feel dizzy or nauseous(ATSDR, 2017). Water having hardness below 300mg/L is considered portable, but beyond this limits cause gastro-intestinal irritation (Alam et al., 2017). Turbidity can provide food and shelter for pathogens (Perlman, 2016). If not removed, turbidity can promote regrowth of pathogens in the distribution system, leading to waterborne disease("Color ,taste and odor problems in drinking water," 2011)

CONCLUSIONS

By performing lab test and analysing all data it revealed that majority of samples contained high concentration of iron. About 90% samples had Odour problems. Few samples had extreme level of turbidity and hardness. All samples had reasonable P^H value 6.5-8.5. From public opinion and lab test it can be concluded that Rajshahi WASA cannot provide water at satisfactory level to the consumers. So Rajshahi WASA authority should take necessary steps to mitigate such problems.

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HEALTH RISK ANALYSIS OF HEAVY METALS IN SURFACE AND GROUNDWATER FROM NEARBY WASTE LANDFILL IN KHULNA

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ABSTRACT

Waste landfill site produces leachate which contaminates underlying groundwater, soil layer and surrounding water bodies as well as possesses public health risk. In addition, heavy metal releases from waste disposal site contains extensive ranges of toxicological chemical compounds that signify a potential risk to public health. The present research aims to evaluate the health risk associated with heavy metals release from surface water and ground water of waste disposal site. To these attempts, fifteen surface and groundwater samples were collected from distinct locations in and around of waste landfill site at Rajbandh, Khulna, Bangladesh. In the laboratory, concentration of heavy metals of As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Pb and Zn in surface and groundwater samples were measured according to standard test methods. In this study, for evaluating health risk from waste disposal site, different environmental media such as water-dermal contact and water ingestion as well as the inhabitants were categorized as adult and child according to US.EPA guideline (1989). The chronic daily index (CDI), hazard quotient (HQ) and hazard index (HI) were evaluated. Results indicated that the values of HQ and HI were found to be higher for child than that of adult as well as reasonable maximum exposure (RME) displayed higher values of HI than that of central tendency exposure (CTE). Result reveals that the heavy metals of Pb, Hg, As and Cd in water were the mainly contributed for non- carcinogenic risk for child's and adults. The concentration of heavy metals, CDI, HQ and HI was distributed spatially using ArcGIS. The uncertainty of exposure and risk parameters was analysed using 1-D Monte Carlo Simulation @risk 7.5 with 10000 iterations. The result of MCS was given in the form of a probability distribution of risk.

Keywords: Waste Landfill; Hazard Quotient; Hazard Index Non-Carcinogens Health Risk, Pearson's Correlation, Monte Carlo Simulation, Spatial Distribution.

INTRODUCTION

Municipals solid waste (MSW) generation in Khulna city, Bangladesh is estimated to roughly 450 t/d in 2016 (Alam and Hassan, 2013).Municipal solid waste (MSW) is dumped in waste disposal site as the cheapest means of MSW management system. The waste dumping site in this process causes various aesthetic and public health problems and also attracts insects, rodents and various disease vectors (Aderemi et al., 2011; Sizirici and Tansel, 2010). The MSW in the dumping process undergoes slow, anaerobic decomposition over a period of 30-50 years and generate substantial amount of leachate with decomposition products, heavy metals and a variety of carcinogens and non-carcinogens chemicals which may seep from the waste disposal site into underground aquifers and thus polluting much needed urban water resources (Shenbagarani, 2013). There are also possibilities of surface runoff and/or overflow of the leachate to the surrounding agricultural lands, ponds, canals and rivers causing surface water quality deterioration (Lee and Jones-Lee, 1994). However, due to the generating huge amount of MSW, most of the developing countries have dumped their MSW in the open disposal sites which possess serious impacts to the surrounding area. In addition, contamination of underlying ground water is one of the major problems regarding open dumping sites (Butt and Oduyemi, 2003; Butt et al., 2008). Surface and ground water is the main source for pure quality of water which is important for human being.

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To date, in the developing countries due to lack of proper design of waste disposal site, leachate is runoff into the surface bodies as well as infiltrated easily through the underlying soil layer and hence pollutant the groundwater which is the most important concern of the human being. To these attempts, it is essential to examine the contamination level of waste disposal site via (soil, leachate, surface and groundwater). The main focused of this study, to evaluate human health and environmental risk from surface and ground water from a selected waste disposal site. For the fulfilment of desired objectives, fifteen surface and ground water samples were collected from distinct locations within a waste disposal site at Rajbandh, Khulna, Bangladesh. The latitude and departure of all the sampling locations was recorded using GPS device. To evaluate health risk assessment from contaminated surface and ground water, ingestion and dermal contact were considered according to US.EPA guideline (1989). Then chronic daily index (CDI), Hazard Quotient (HQ) and Hazard Index (HI) via ingestion and dermal contact route were evaluated. Health risk assessment procedure provides a clear and systematic form of quantitative (or semi-quantitative) description of health and environmental risk. A promising tool for the assessment of risk which provides a means of describing the sensitivity with respect to different exposure factors and evaluating different intervention scenarios is the technique of Monte Carlo simulation (MCS). In this study, to check uncertainty of exposure parameters and risk values, MCS was used. In addition, ordinary kriging (OK) through ArcGIS was performed to distribute CDI, HQ and HI spatially. Here, it can be noted that this study will help in making precise management strategies to avoid or decline of heavy-metal contamination as well as finally environmental and health risk of inhabitants in and around of the selected waste disposal site.

METHODOLOGY

Sample collection

Surface water samples were collected for surface water quality analysis from fifteen distinct locations of the waste disposal site shown in Fig.1. In addition, groundwater sample was collected from a hand tube-wells/production wells located near the waste disposal site [Fig.1]. Water samples were collected in 500 mL HDPE bottle.

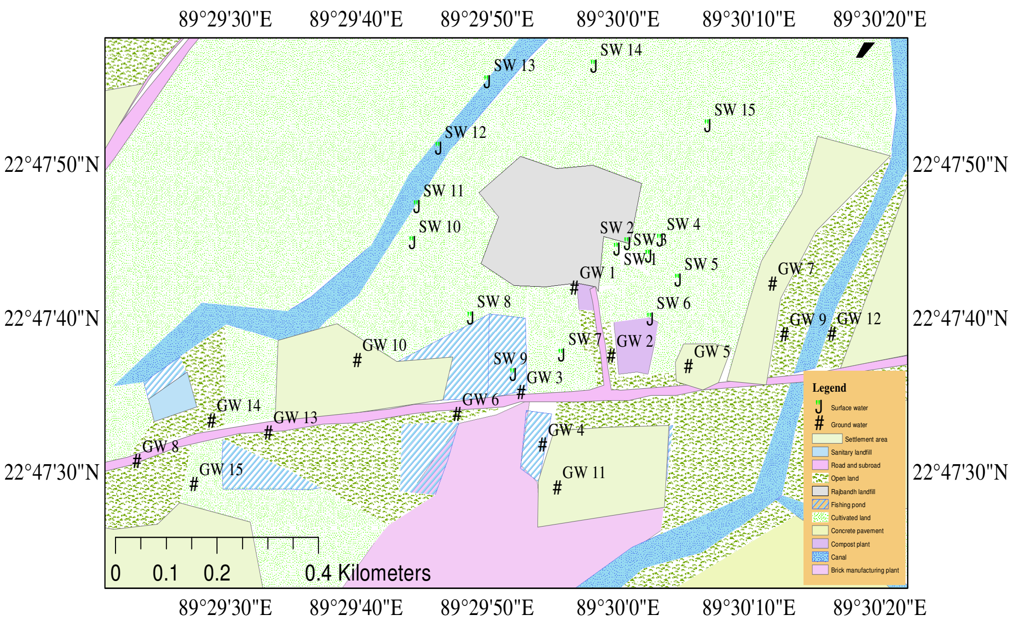

Fig.1: Surface and ground water sampling locations of waste disposal site.

Risk assessment methodology

The health risk associated from heavy metal contaminated site are presented and hence discussed in the following articles.

Exposure assessment

In addition, chronic daily intake (CDI) (mg/kg/day) in case of non-carcinogen risk for ingestion and dermal for water samples were computed using Equation 1 and 2, respectively, was taken from exhibit 6-18 in the Risk Assessment Guidance for Superfund. Volume I, Human Health Evaluation Manual (Part A): Interim Final (RAGS) (US.EPA, 1989). In this study, the values of individual factors (ingestion rate, body weight, body surface area, etc.), or parameters (time weighted factors such as contact frequency, contact duration or lifetime exposure) for different groups of inhabitants with various exposure pathways for central tendanct exposure (CTE) and resonable maximum exposure (RME) were followed from RAGS (US.EPA, 1989).

$$CDI_{ing} = \frac{C_W \times CR \times ABS_S \times EF \times ED}{BW \times AT} \quad (1)$$

$$CDI_{der} = \frac{C_S \times SA \times CF \times PC \times ABS_S \times ET \times EF \times ED}{BW \times AT} \quad (2)$$

Where $CDI_{ing/der}$ = chronic dialy intake through ingestion/dermal contact with heavy metal concentration (Cw) in Water.

In the above exposure models, the exposure parameters stands the meaning of IR= average soil ingestion rate (mg soil/day), CF = conversion factor (10^{-6} kg/mg), FI= fraction ingested from contaminated source (unit less), ABSs=absorption factor (%), SA=skin surface area available for contact (cm^2), AF= solid material to skin adherence factor (mg/cm^2), SM= factor for solid materials matrix (%), PEF=particles emission factor (m^3/kg), ET= exposure time (hrs./event), EF=exposure frequency (days/year), ED=exposure duration (years), BW=body weight (kg), AT=averaging time (period over which exposure is averaged-days). AT=EDx365 days/year, for non-carcinogens effects of human exposure and LTx365 days/year for carcinogens effects of human exposure, considering an average lifetime, LT of 70 years.

Health Risk Assessment

$$\boldsymbol{HQ_{ing/derm}} = \frac{\boldsymbol{CDI_{ing/derm}}}{\boldsymbol{RfD_{ing/derm}}} \quad (3)$$

Where HQing/derm/inh is hazard quotient via ingestion, dermal contact and inhalation (unitless) and Rf*D*ing/derm/inh is oral/dermal/inhalation reference dose (mg/kg-day). The Rf*D*ing, Rf*D*derm and Rf*D*inh values were obtained from the literature elsewhere (Li and Zhang, 2010; US.EPA, 1989; Wu et al., 2009; Liang et al., 2011).

$$HI_{ing/derm} = \sum_{i=1}^{n} HQ_{ing/derm} \quad (4)$$

Where HIing/derm/inh is hazard index via ingestion, dermal or inhalation (unitless).

RESULT AND DISCUSSION

Risk Assessment Observations for Surface water

The values of CDI, HQ and HI for both the CTE and RME condition for child for exposure pathways for surface water sampling point 1(SW1) are provided in Table 1. From Table1 it was found that for child via ingestion pathway the heavy metal of Zn contains the highest value CDI in CTE condition. The sequence of CDI values for child via exposure pathway of ingestion inCTE condition was found Zn> Cu>Fe>Mn>Cd>Ni>As>Pb>Cr (Table 1).

The variation of HQ values of selected heavy metals for adult in CTE condition through ingestion and dermal pathways of surface water sample 1 (SW1) are represented in Fig.2. Figure 2 reveals that Cd showed the higest value of HQ both the igestion and dermal pathways. Fig.2 also showed that in case of ingestion pathway the heavy metal of Cd, As and Fe contains higer values of HQ than that of other heavy metals. In addition, Cd displays the higest value of HQ through the exposure pathway of dermal. Here it cam be noted that Cd was the main contributor to non-cancer risk for adult via ingestion and dermal pathways.

Table 1: Summary of health risk assessment for selected heavy metals in SW1 for CTE condition.

Metals	Child(CDI)		HQ Child		Total (HI)
	Ingestion	Dermal	Ingestion	Dermal	
Fe	5.10E-04	5.24E-05	5.67E-02	7.49E-05	5.67E-02
Mn	3.97E-04	4.08E-05	8.64E-03	2.22E-02	3.08E-02
Cr	9.49E-06	1.95E-06	3.16E-03	3.25E-02	3.57E-02
Cu	8.54E-04	8.78E-05	2.13E-02	7.32E-03	2.87E-02
Pb	2.37E-05	2.44E-07	1.69E-02	4.64E-03	2.16E-02
Zn	2.02E-03	1.24E-04	6.72E-03	2.07E-03	8.79E-03
Ni	3.91E-05	8.05E-07	1.96E-03	1.49E-04	2.11E-03
Cd	1.30E-04	1.34E-05	1.30E-01	1.34E+00	1.47E+00
As	3.56E-05	3.66E-06	1.19E-01	2.97E-02	1.48E-01

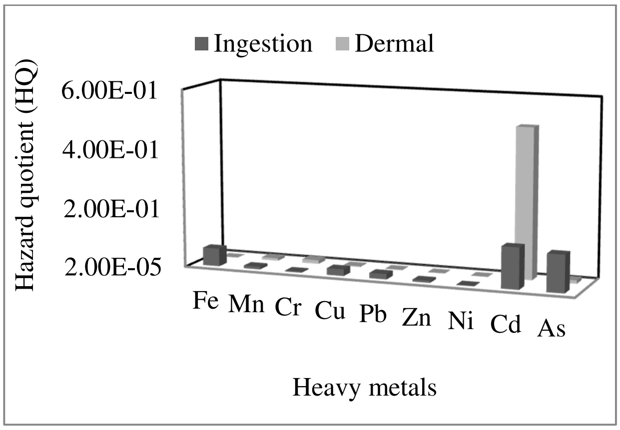

Fig.2: Hazard quotient through different pathways of adult for surface water sample 1 for adult during dry season (CTE).

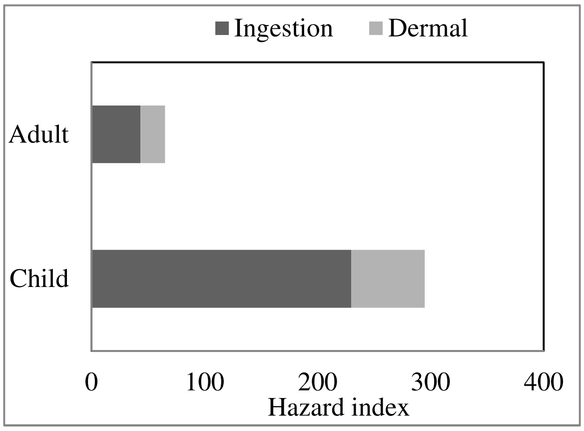

Fig. 3: HI for inhabitants in different pathways for surface water in RME condition

The variation of HI for child and adult for entire surface water samples in RME condition for various pathways is represented in Fig. 3. Fig. 3 depicts that for both the child and adult, the exposure pathway of ingestion was the main dominant pathway for contributing non-cancer risk for inhabitants. Moreover, Fig. 3 also illustrates that the HI value for child was comparatively higher than that of adult for all exposure pathways considered in this study. It indicated that the child's were more vulnerable to health risk than that of adults of the selected disposal site.

Risk Assessment Observations for Ground water

Non-carcinogenic health risk assessment summary for the selected heavy metals in the collected ground water samples in case of CTE condition for Adults via eposure pathways of ingestion and dermal for ground water sample 1 (GW1) is represented in Table 2. From table 2 it was found that for adult via dermal pathway the heavy metal of Zn contains the highest value of CDI in both the CTE and RME condition. The values of CDI for adult via exposure pathway of dermal in CTE condition was found in the sequence of Zn> Cu>Fe>Mn>Cr>As>Ni> Pb>Cd (Table 2). Moreover, the same order of CDI value was also observed in RME condition.Fig. 4 represents the variation of HQ values of selected heavy metals for child in RME condition through exposure pathways of ingestion and dermal of surface water sample 1 (SW1) during dry season.Fig. 4 reveals that As showed the higest value of HQ in ingestion pathway. In addition, Cr showed the highest value of HQ in dermal pathway. Fig. 4 also represents that almost all selected metals such as As, Fe, Pb, Cu, Cr, Mn showed higher value of HQ in ingestion pathway in comparision with dermal pathway. While Cd and Cr showed higher value of HQ in dermal pathway than that of ingestion pathway. It can be noted that As, Fe and Pb are mainly contributed to non-carcinogenic health risk for the inhabitants of selected landfill site.

Table 2: Summary of health risk assessment for selected heavy metals in GW1 for CTE condition

Metal	Adult(CDI)		HQ Adult		Total (HI)
	Ingestion	Dermal	Ingestion	Dermal	
Fe	8.95E-05	1.63E-05	9.94E-03	2.33E-05	9.96E-03
Mn	7.13E-05	1.30E-05	1.55E-03	7.06E-03	8.61E-03
Cr	6.71E-06	2.44E-06	2.24E-03	4.07E-02	4.29E-02
Cu	1.61E-04	2.93E-05	4.03E-03	2.44E-03	6.47E-03
Pb	8.95E-06	1.63E-07	6.39E-03	3.10E-03	9.49E-03
Zn	3.13E-04	3.42E-05	1.04E-03	5.70E-04	1.61E-03
Ni	9.62E-06	3.50E-07	4.81E-04	6.48E-05	5.46E-04
Cd	2.91E-07	5.29E-08	2.91E-04	5.29E-03	5.58E-03
As	4.47E-06	8.14E-07	1.49E-02	6.62E-03	2.15E-02

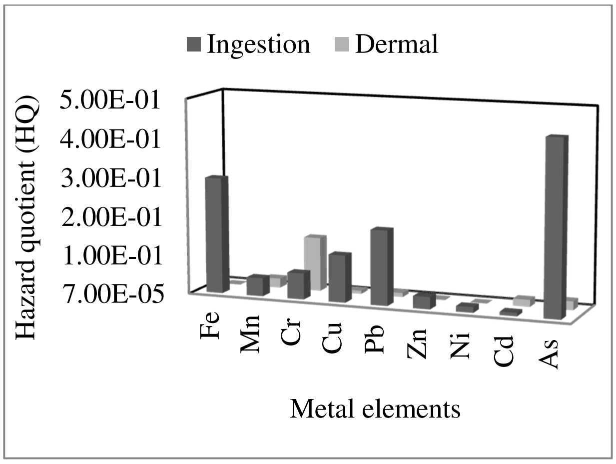

Fig.4: Hazard quotient through different pathways of child for ground water sample 1 in RME condition.

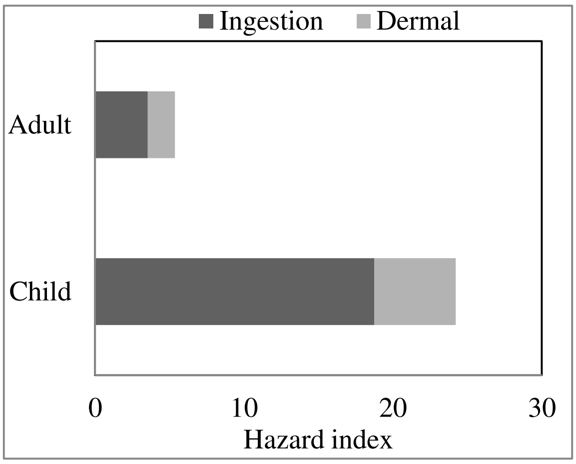

Fig. 5: HI for inhabitants in different pathways for ground water in CTE condition.

Fig.5 depicts the variation of HI for child and adult for entire ground water samples in CTE condition for various pathways. Fig.5 reveals that for both child and adult, the exposure pathway of ingestion was the main dominant pathway for contributing non-cancer risk for inhabitants. Moreover, Fig.5 also illustrates that the HI value for child was comparatively higher than that of adult for all exposure pathways considered in this study. It indicated that the Childs were more vulnerable to health risk than that of adults of the selected disposal site.

The spatial distribution of HI of Zn for child in CTE condition during dry season was illustrated in Fig. 6. The red area in Fig 6 represents the highest value of HI for child in CTE condition during dry season. The red area ranges from 0.00539 to 0.00649. The red area indicates the possible maximum distribution of HI values from the surface water sampling points around the area. It can be summarised that the child near the sampling points covered by the red colour possess to extreme health risk.

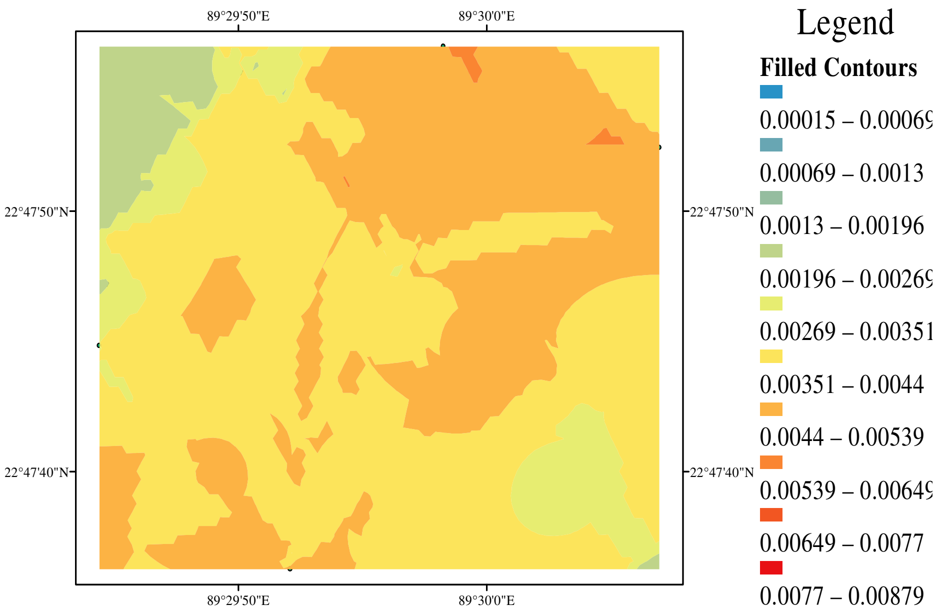

Fig. 6: spatial distribution of HI of Zn for child in CTE condition

CONCLUSIONS

The HQ values for ingestion route were comparatively higher than that of dermal for almost all heavy metals. On the basis of HI, metals hazardous sequel should be like as Cd> Cr>Pb>Mn> Cu> As> Fe> Ni> Zn in groundwater. Furthermore, results reveal that the values of HQ in case of ingestion route for surface water were found to be higher than that of dermal condition. In addition, RME showed the higher values of HQ in compare to CTE. Results of Pearson's correlation and PCA indicated that Fe, Mn and Cu were generated from anthropogenic sources, while, Cd, Cr, Ni, Pb and As from natural sources.

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RAINWATER HARVESTING IN COASTAL AREAS OF BANGLADESH

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ABSTRACT

Rainwater harvesting is a process adopted for collecting and storing rainwater for later use. Rooftop harvesting is one of its kind and it is safe, best as well as cheapest alternate to the traditional water supply system. Due to climate change and sea level rise, the salinity of coastal area is increasing day by day. Moreover city like Chittagong where groundwater and supply water contains so much harmful ingredients like arsenic and iron which is below the standard level of drinking water quality. Water logging is the serious issues in Chittagong city where during rainy season heavy rainfall may cause the flood in several areas. So, if the rainwater harvesting method can be introduced then the total problem can be solved. detailed field survey on the coastal part specifically at CDA Residential Area in Agrabad, Chittagong in Bangladesh was conducted. The value of Turbidity, Color, Hardness, TDS and Fe content of the available water exceeds the standards values. On the contrary the rainwater collected from rooftop found satisfactory although there is existing of microorganisms. The methodology used here are development office to face structured questionnaires to understand the problems of the people and the study contains which contains building analysis, population in the area, use opinion, education qualification. The preference and acceptance of rainwater harvesting found to be great to the people of that region.

Keywords: RWH; Coastal; Salinity

INTRODUCTION

Water is the most mysteries element in the environment. One of the basic necessities of life is water. Water health in coastal area is not good specially drinking water. Bangladesh has very long coastlines and coastal area covers 20,000 km ^{2} area. In the coastal areas, aquifer conditions are not suitable for shallow tube-well and high salinity in both surface and groundwater are the main constraints for the development of a dependable water supply system (Ahmed, 1999). Bangladesh is a tropical country located between 20°34′ and 26°38′ N latitude and 88°01′ to 92°41′ E longitudes. Being located in the Asian monsoon belt, the country experiences a heavy rainfall during monsoon, generally between 1,500 and 3,500 mm (Islam et al., 2014). The mean annual rainfall in Bangladesh is about 2320 mm while that in Chittagong district is about 2785mm (BMD, 2017). Theoretically 20% of the total rainfall might satisfy almost the whole of Dhaka city's demand, collected during the monsoon (Kabir and Faisal, 1999). Institute of Water Modelling (IWM) recently estimated that around 149,160 million litters of water can be harvested during monsoon in the region with the current rate of rainfall. Urban and rural water supply in Bangladesh is mainly based on groundwater, which is free from pathogenic microorganisms and available in adequate quantity in shallow aquifers. The people of south-western coastal region of Bangladesh are suffering from acute shortage of freshwater for domestic purposes due to salinity intrusion, arsenic contamination of groundwater, etc. mainly caused by excessive use of groundwater, upstream withdrawal of freshwater, development activities like shrimp cultivation, etc. Water that covers about 70% of earth's surface is an essential substance for the nature and the ecosystem of the world (Biswas and Mandal, 2014). About 97.5% of all water on earth is salt water, leaving only 2.5% as fresh water, which can be found in various forms such as glaciers and permafrost and groundwater and surface as well as atmospheric water (Shittu et al., 2012). In the above context, search for a new potable water supply source is essential for Khulna division. Rainwater is the only source, which is easy to collect individually with a minimum cost. Rainwater harvesting system requires a collection basin or catchment, usually the roof of the house to harvest rainwater, a piping arrangement and a container to store it. The collected rainwater can be utilized to reduce the shortage of water for safe drinking, cooking and dishwashing purposes (Islam, 2010). The main objective of the study is to develop a sustainable rainwater harvesting system along the coastal region of Bangladesh.

SALINITY ISSUES IN COASTAL AREAS

The coastal area of Bangladesh consists of 19 Districts with an area of approximately 46,271 Km^2. This is around 31 percent of the country's total area. The coastal zone covers an area from the shore of 37 to 195 km, whereas the exposed coast is limited to a distance of 37 to 57 km (Islam et al., 2006). The coastal population is projected to grow to about 43.9 million in 2015 and 60.8 million by 2050 (Ahmad, 2005). A higher value of salinity up to1000 mg/Lfor problematic areas including coastal belt is considered (DPHE 2006) for drinking. Arsenic is found in shallow groundwater in almost all the coastal regions beyond the Bangladesh drinking water quality standards. There are 17 towns located in the coastal region which are relatively in high risk of salinity in groundwater due to high salinity penetration in the upstream area. Table 1 shows the severely affected coastal towns in southern Bangladesh.

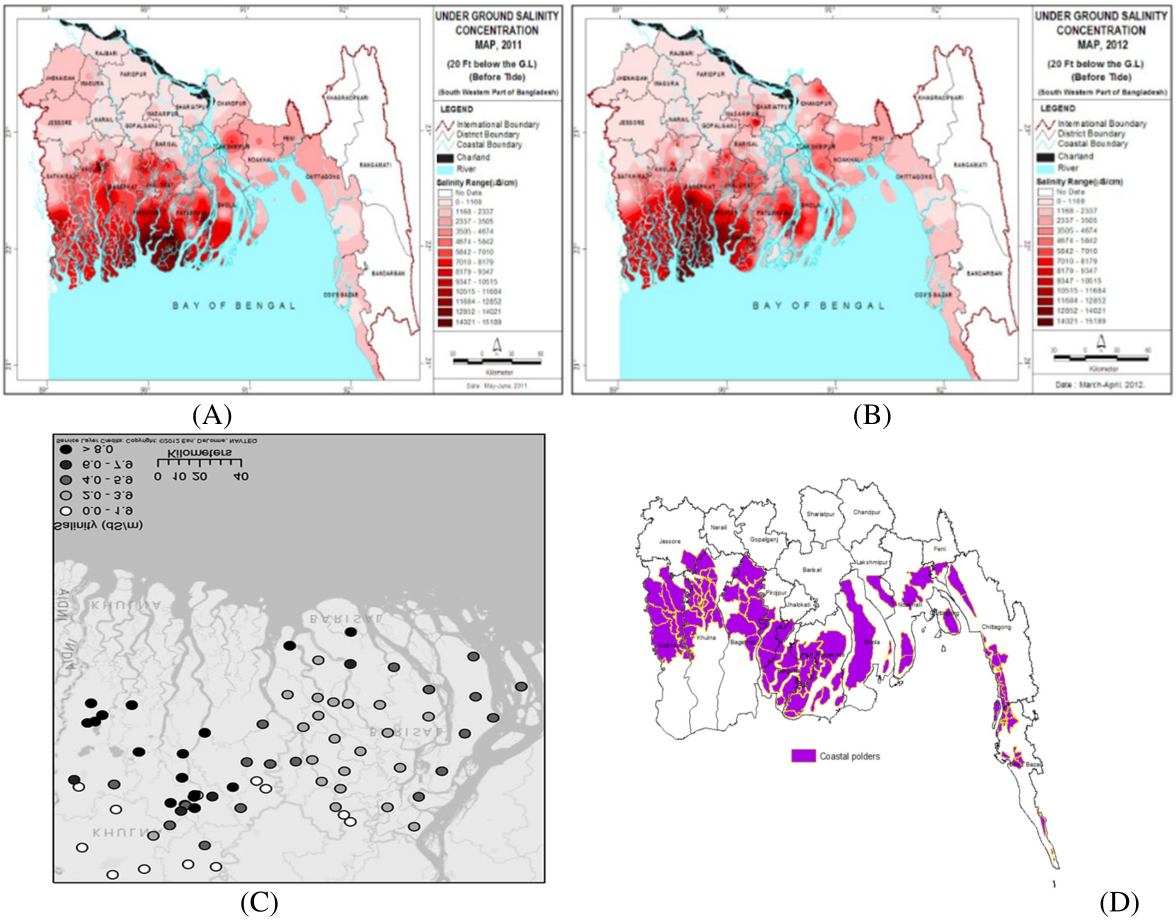

Fig. 1: (A)Variation of Salinity in 2011(BADC-2013) (B) Variation of Salinity in 2012(BADC-2013) (C) Projections of future 2050 river water salinities based on (Dasgupta et al., 2014) (D) Salinity affected area in Bangladesh (Ahmad, 2005).

When groundwater levels in aquifers are depleted faster than they can recharge this is directly related to the position of the interface and determines the amount of saltwater that can intrude into the freshwater aquifer system. Since saltwater intrusion is directly related to the recharge rate of the groundwater, this allows for the other factor that may contribute to the encroachment of seawater into the freshwater aquifers.

STUDY AREA

Chittagong is a major coastal seaport area in Bangladesh. It is the second largest city in Bangladesh. It is located in south-eastern Bangladesh at N 22° 19' 56" and E 91° 47' 51". It is about 5,282.92 sq km. Its population is about 7,616,352. The city is located on the banks of the Karnaphuli River. It is near the Bay of Bengal. So there is a great impact of salinity in this area. The study area was in Agrabad under Chittagong district which is a great coastal zone. The area is located at 22°19'19.34"N and 91°48'01.89'. It is near the Potenga sea beach.

Fig. 2: Study Area

METHODOLOGY

This survey was performed agrabaad in Chittagong city which was started at the central mosque CDA in agrabaad. The methodology of this study starts with the water needs for the community on which the rainwater harvesting is applied is needed to be estimated. The content of this survey is to calculate the catchment area and population in the area therefore estimating the water demand. The information of annual rainfall, rainfall pattern, climate conditions, land use etc. were collected from different secondary sources. Detailed field investigation was done to identify the technical and social problem of existing drinking water supply. A structured questionnaire survey consisting of group discussion and individual questionnaire was conducted to the people from school, college, university and different classes. They were asked about some basic questions regarding the existing water supply system, problem in supply water, about RWH, its advantages, disadvantages and many more. Samples from different drinking water sources along with rainwater from different roof top were collected and tested in the Environment Engineering Laboratory, CUET. Finally study was concluded with underground tank design with cost analysis.

Rainfall Analysis

Chittagong has a tropical monsoonal climate with a dry season and a heavy monsoon the rest of year. A 7 years rainfall pattern based on the mean intensity for the period 2009 to 2016 is shown in Table 1. This region gets hold on average 2785.07 mm of rainfall per year. Heavy rains start in May and it decreases as the winter season comes closer.

The heavy rainfall only occurs from May to October. Adequate rainfall occurs and the surplus rain from these months would be stored to cover the shortage in dry period. July has the highest average rainfall for all time and rains up to 631.7857 mm.

RESULTS AND DISCUSSIONS

In the study area, about 55 residential buildings were analysed and total 10388.883 m^2 rooftop area was estimated. It was observed that most of the rooftop are suitable for installing rainwater harvesting system. The potential for rooftops (catchment) to collect rainwater is dependent on the area of the interception surface, the intensity of the rain and the nature of the catchment material. For this study, a family consisting of six members having water demand of 2 L/capita/day for only drinking and 135 L/capita/day for total water demand was considered. The available rainwater was estimated by the equation (Rahman, 2000).

Table 1: Average Monthly Rainfall (World Weather Information Service-2017)

Monthly Rainfall (mm) from 2009 to 2016								
Month	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**Average**
January	0	5.5	3.4	0	0	23	0.3	4.6
February	3.6	0.6	0.7	0	17.8	0	4.2	3.84
March	72.9	94.4	25.5	4	7.1	2.6	29.2	33.67
April	104.9	93.7	110	104.3	7.9	46.9	57.2	74.98
May	692.8	297.6	102.5	1034.6	178	63.8	283.4	378.95
June	1086.3	500.1	516.8	403.2	623.4	514.9	187.7	547.48
July	846.8	463.1	634.6	384.3	481.3	1081	531.4	631.78
August	589.59	421.5	314.9	378.2	598.7	610.8	430.6	477.75
September	656	384.3	200.7	355.2	227.5	397	207	346.81
October	402.7	291.6	279.3	311.7	100.8	152	221.5	251.37
November	55.7	0	31.8	0.8	7.7	34	96.4	32.34
December	0	8.1	0	0	1.3	0.8	0	1.45
Total Annual Rainfall	4511.29	2560.5	2220.2	2976.3	2251.5	2926.8	2048.9	2785.07
Average	375.9408	213.375	185.0167	248.025	187.625	243.9	170.7417	232.08

$$Y = \frac{f \times A \times R}{1000} m^3 \quad (1)$$

Where, Y is the amount of water yielded per month, f is the catchment's efficiency or coefficient of available runoff (0.70 for RCC rooftop and 0.90 for tin shed rooftop) , R is monthly rainfall (mm) and A is the catchment area in square meters. The minimum catchment area A required for the collection of rainwater for N number of people supplied with q liters per capita per day (lpcd) for the intensity of rain fall I, it can be deduced from the equation (Rahman, 2000).

$$A = \frac{0.365 \times q \times N}{f \times I} m^2 \quad (2)$$

About 25% of the rainwater should be presumed to be lost by evaporation and for washing the catchment area using first rain that produces inferior quality rainwater.

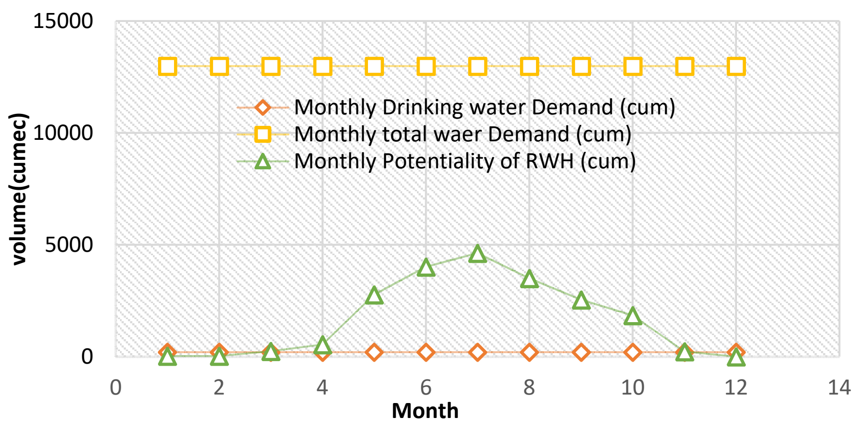

Fig. 3: Monthly Demand vs. Potentiality of RWH

From Fig. 3, it was found that during May to October rain water supply is beyond the drinking water demand line. Total demand was found too higher than the rainwater supply for every month. The annual total demand and drinking water demand for the study area was found about 150842.25 $m^3$and 2234.7 m^3 the potentiality supply of rainwater is 20427.044m^3. Thus 13.54 % of total water demand and full drinking water demand can be fulfilled by the supply water which will reduce the dependence on ground water effectively. The minimum catchment area required for the collection of rainwater for drinking purposes was found 1287.34m^2 and 86895.71m^2 was found for total water demand respectively.

Assessment of Water Quality Parameters

Laboratory tests were performed for the sample directly collected from different types of roofs. Water quality supplied by CWSA and the water from "Karnafuli" river also analysed. The summary of the test result of water quality parameters are presented in Table 2.

Table 2: Analysis of water quality parameters

Water Quality Parameters	Tin-Shed Building Roof	RCC Building Roof	CWASA water	Karnafuli River water	Unit	Environmental Conservation Rules
1.pH	7.25	8.1	6.85	7.35	Value	6.5 – 8.5
2.Turbidity	10.12	8.54	82.3	11.23	NTU	10
3.Color	25	30	25	40	Pt-co	15
4.Odor	-	-	-	-	TON	odorless
5.Hardness	45.3	31.2	675	360	mg/l	200 - 500
6.TDS	178	167	1495	810	mg/l	1000
7.Alkanity	25	30	955	225	mg/l	130-150
8. BOD	0.49	0.35	-	-	mg/l	-
9. COD	75	0.62	-	-	mg/l	-
10. E. Coli	1	1	-	28	N/100mL	-
11. Fe	-	-	4.49	-	mg/l	0.3 - 1

Socio- Economic and Opinion Survey

In this section, the results found from the analysis of the questionnaire survey and field base survey is discussed. The educational qualifications of those surveyed people are shown in Fig. 4. Among those people 5% are illiterate, 21% have passed primary level education, and 15% have passed S.S.C level, 37% have completed their H.S.C level, 13% is in undergraduate and 5% people have completed their graduation.

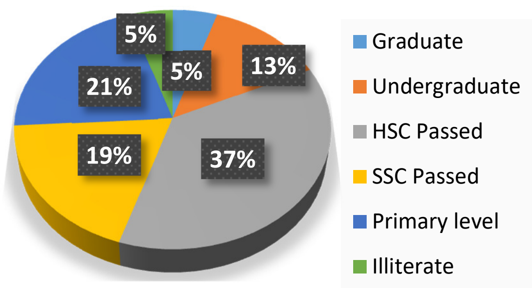

Fig. 4: Education qualification of the study area

The people in Agrabad have great trouble for drinking water. They have to collect water from different place. For that they have to suffer a lot. They use saline water for washing clothes, bathing purpose, washing utensils, toilet purposes etc. Almost most of the people are eager to take benefit of rainwater. Approximately 74% people expressed that they had always like the rainwater harvesting process. They think that the rainwater will fulfil their demand. 17% people think that rainwater will not fulfil their demand and 9% have no opinion. The result found from the building analysis shows that most of the buildings (63.46%) are 2-4 storied and 26.92% of houses were found 5-7 storied. The percentage above 8 storied building is 7.69.

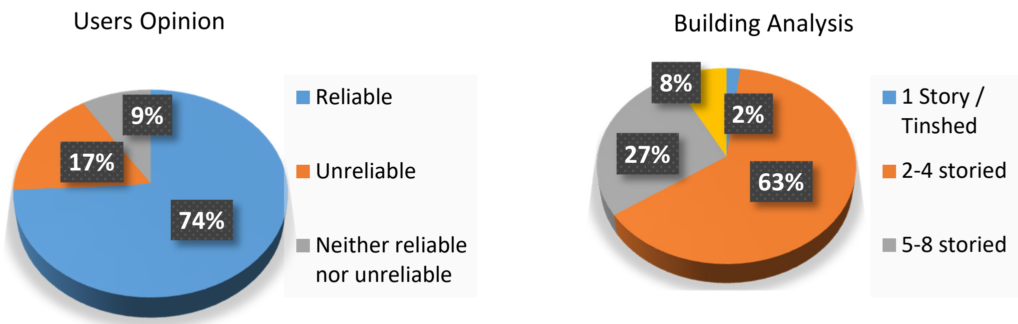

Fig. 5: User's Opinion and building analysis

CONCLUSIONS

It is found that the potential rainwater supply can be accomplished for drinking purposes during May to October and surplus water can be preserved for dry season. Moreover, about 74% people living here are well aware of the necessity of rainwater harvesting. But they do not have personal rainwater collection tank. Very few of them collect rainwater occasionally in buckets or pots. Then don't even filter this water as they use it for such kind job which doesn't require much pure water. Only 17% people doesn't rely on rainwater. Either they are confused about if it can meet up the monthly requirement or not or they are simply don't think that the source is safe enough. But apart from all that, the laboratory test and other research proves the sustainability of this project in this particular area.

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RAINWATER HARVESTING POTENTIALITIES TO REDUCE OVEREXTRACTION OF GROUNDWATER IN CHITTAGONG CITY

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ABSTRACT
Harvested rainwater has become an inseparable part of sustainable development a long before term ‘sustainability’ appeared. In countries like Bangladesh, where annual rainfall is high, rainwater could meet a significant amount of total demand. Due to maladaptation to the paradigm of extraction of groundwater without considering the sustainability, people in Chittagong and other urban areas in Bangladesh are still reluctant to use this abundant source. This paradigm has been pushing the water supply scenario of Chittagong city closer to a condition where the city might face permanent water crisis, once the underground aquifers goes down below the pumping level or the aquifers become dry. In addition, the surface water condition of peripheral rivers of Chittagong city is in poor condition, which does not encourage increasing use of surface water in Chittagong city. As an alternative of these options, rainwater harvesting has been considered though majority of the users are not fully aware of its potential to become a source of water. Analysis of the catchment availability and size of storage tanks are needed to find the potential of rainwater harvesting in the building and the capacity of buildings to store rainwater and use it. Four selected buildings of Chittagong area are taken in the purpose of case study. To check the technical feasibility and potentiality of rainwater as alternative water source, ARC method is taken to measure the maximum capacity of storable water and size of storage tanks are determined by both Sizing Formula and Ac-Vc relation method. With respect to available storable water, demand satisfaction is also measured to check feasibility of the system.

Keywords: Groundwater; Aquifer; Rainwater Harvesting; Technical Feasibility; Demand Satisfaction

INTRODUCTION
The groundwater table in Chittagong City is at present in a position from where it is difficult to pump groundwater by shallow tube well. Profound tube well is required practically in each place to locate the fresh water from the ground. For the most part, the area, profundity, size, and piece of aquifers are dictated by seasonal rainfall intensity. Some areas in Chittagong experience a great depletion of groundwater level which is shown in [Fig. 1] (Mirdad & Palit, 2017).Being a tropical nation, which gets overwhelming precipitation due to north-easterly breezes amid the stormy season, water can be a potential wellspring of option water supply in numerous zones of Bangladesh (Papon et. al.,2017). Organization of Water Modeling (IWM) as of late evaluated that with the present measure of precipitation, around 149,160 million liters of water can be reaped amid monsoon. The average yearly precipitation in Bangladesh fluctuates from 2200 to 2800 mm, 75% of which happens amongst June and October. The high precipitation power gives a great chance to rainwater harvesting(Yeasmin et al., 2013).Despite the fact that Bangladesh has six seasons (each season comprises of two months) eventually those are covered with each other. Bangladesh gets substantial precipitation amid the stormy season, which stretches out from May to September, with the pinnacle of precipitation occurring amid June, July and August. Rain more often than not falls as showers that can keep going for couple of minutes to a few hours. The normal yearly precipitation under the typical climatic conditions is around 2320mm in Bangladesh while that in Chittagong locale is around 1800 mm. Precipitation information for a time of 20 years (from 1989 to 2008) are introduced in [Fig. 2].

Such information demonstrates that there is a lot of water that can be harvested in the rainy season. On the premise of this precipitation RWH framework can be viably actualized for family unit use. (Water Aid, 2012). Objective s of this study is to determine the maximum storable volume of water and optimum volume size of tank for various size of rooftop catchment area; and alsoto determine the feasibility of rainwater harvesting system for selected buildings.

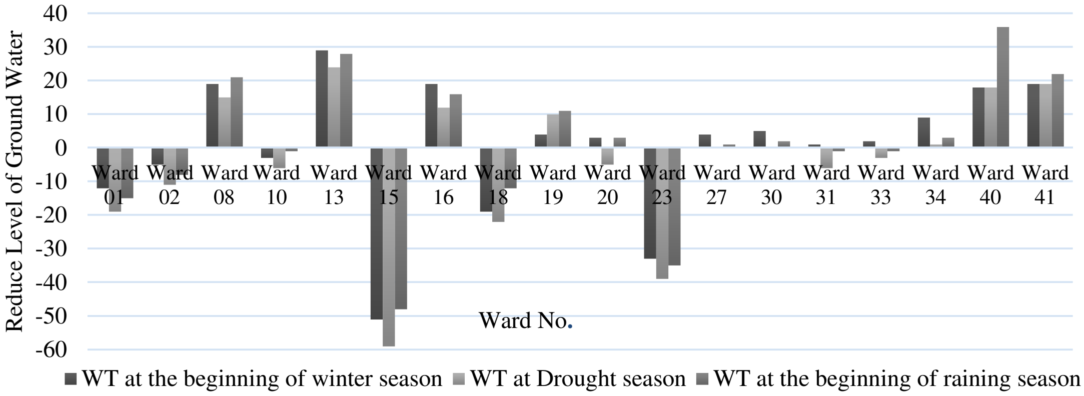

Fig. 1: Seasonal Fluctuation of Groundwater Table (Mirdad & Palit, 2017)

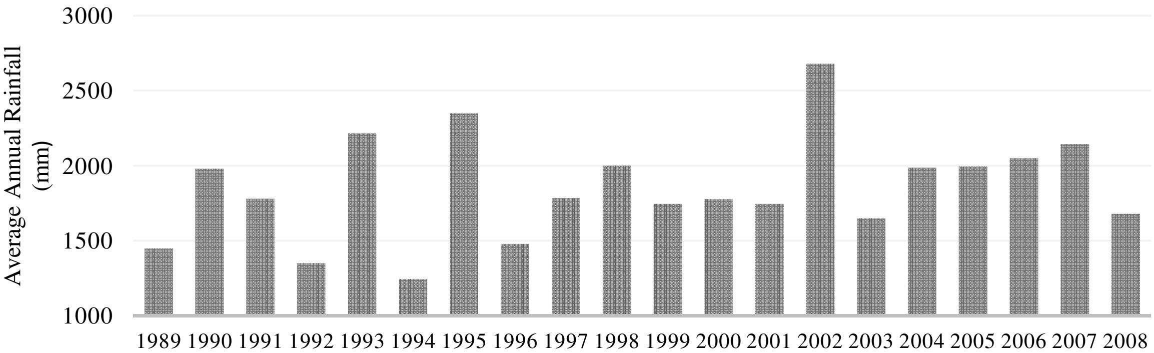

Fig 2: Average yearly rainfall data in Chittagong district from 1989 to 2008 (Water Aid, 2012)

MEASURING WATER DEMAND

Water demand per household is very important to measure the storage tank capacity. The water demand for specific purposes like cooking, drinking, showering, flushing of the households havebeen collected by a direct questionnaire survey

MAXIMUM STORABLE VOLUME OF WATER

The quantity of water that runs off a roof into gutter system in this study is calculated by using Eq. 1 according to the study "Roof water Harvesting: A Handbook for Practitioners" done by Thomas & Martinson in 2007 known as ARC method.

$$\boldsymbol{Q} = \boldsymbol{A} \times \boldsymbol{R} \times \boldsymbol{C} (1)$$

Where Q is the quantity of water that runs off, C is the runoff coefficient, R is the total rainfall (mm/y), and A is the roof area or the catchment area (m^2). A Runoff coefficient of 0.8 was embraced in this study for the count of potential water collected from the catchment range which are made of tiles.

SIZE OF STORAGE TANKS

Sizing Formula

These variables were considered and calculated to determine the best tank sizes; D: (m^3) Daily water demand for a household, T: (m^3) Tank volume, S_t: (m^3) Daily storage, calculated by adding the initial stored water and the rain volume and then subtracting the daily supply, S_{t-1}: (m^3) Initial stored water, from previous day, the first valued was assumed as 0. For the next days, S_{t-1} is equal to the previous daily storage (S_t), S_p: (m^3) Supply. For each day, the value of supply will be the smallest value from comparing the demand and the available rainwater volume that can be stored. (Smaller of D and S_{t-1}).

$$\boldsymbol{S_t = S_{t-1} + R_V - Q} \quad (2)$$

Area consumed (AC) – Volume Consumed (VC) Relation

According to Schiller (1990) the volume of storage tank can be determined using the Area consumed (Ac) - volume consumed (Vc) relation method. In this method critical catchment area per person (m2/capita) and minimum storage volume provided per person serviced (m3/capita) is determined based on the following equations which has been multiplied by the total number inhabitants of a building to find the optimum volume.

$$\boldsymbol{A_{min} = C \times 12 \div f \times R_{min}} \quad (3)$$

Where, $\boldsymbol{A_{min}}$= Minimum Catchment Area, m^2/capita, $\boldsymbol{C}$=Monthly demand per capita, litres/month, $\boldsymbol{f}$ =Runoff coefficient=0.08, $\boldsymbol{R_{min}}$ =Lowest annual rainfall over the observed period, mm/year

$$\boldsymbol{V_{min} = D_{min} \div [1 - \{1 \div (LC \times 0.5 \times NC)}} \quad (4)$$

Where, $\boldsymbol{V_{min}}$=Minimum Volume of Storage Tank,

$\boldsymbol{D_{min} = (f \times A_{min} \times R_{Avg} \times NC - \sum R_i) \div 1000}$= Minimum Depth of Storage Tank (5)

$\boldsymbol{R_{Avg} = C \div (f \times A_{min})}$=Minimum Depth of Storage Tank (6)

And$\boldsymbol{\sum R_i}$=Rainfall in the dry period

DEMAND SATISFACTION

Demand satisfaction is calculated by the total water demand of a building with respect of its maximum available water to storage in the calculated volume of storage tank and presented in graph.

RESULTS ANDDISCUSSIONS

Building No: 1 in high level road (two storied building with single unit in a floor)

Catchment area of 18 m^2 makes the available storable water 24.18 m^3. According to sizing formula the size of storage tank is 7.952 m^3 and according to Ac-Vc relation the size of storage tank is 10.02 m^3. Monthly demand satisfaction with respect to supply has been shown in [Fig. 3].

Building no: 2 in west Khulshi r/a (six storied building with dual units in a floor)

Catchment area of 61.6 m^2 makes the available storable water 82.75 m^3. According to sizing formula the size of storage tank is 18.744 m^3 and according to Ac-Vc relation the size of storage tank is 20.53 m^3. Monthly demand satisfaction with respect to supply has been shown in [Fig. 4].

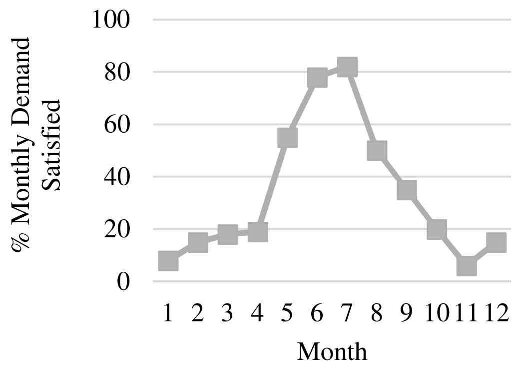

Fig. 3: Monthly demand satisfaction of two storied building with single unit in a floor

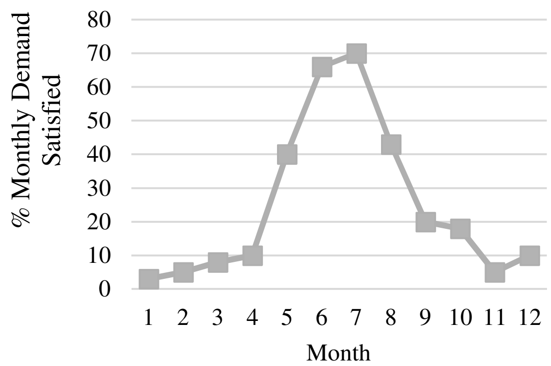

Fig 4: Monthly Demand Satisfaction of six storied building with dual units in a floor

Building no: 3 in Amirbag r/a (four storied building with four units in a floor)
Catchment area of 324 m^2 makes the available storable water 435.12 m^3. According to sizing formula the size of storage tank is 45.44 m^3 and according to Ac-Vc relation the size of storage tank is 49.657 m^3. Monthly demand satisfaction with respect to supply has been shown in [Fig. 5].

Building no: 4 in Dewanhat (one storied semi-pacca building with four units in a floor)
Catchment area of 144 m^2 makes the available storable water 217.6 m^3. According to sizing formula the size of storage tank is 11.36 m^3 and according to Ac-Vc relation the size of storage tank is 15.97 m^3. Monthly demand satisfaction with respect to supply has been shown in [Fig. 6].

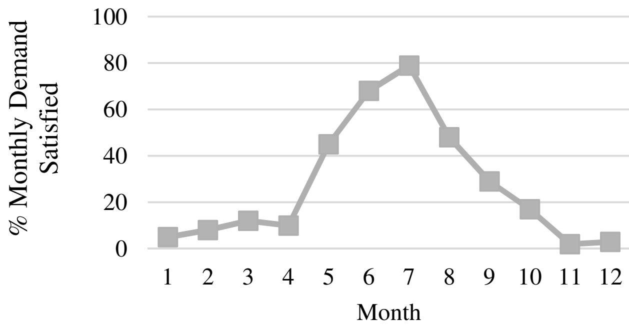

Fig 5: Monthly Demand Satisfaction of four storied building with four units in a floor

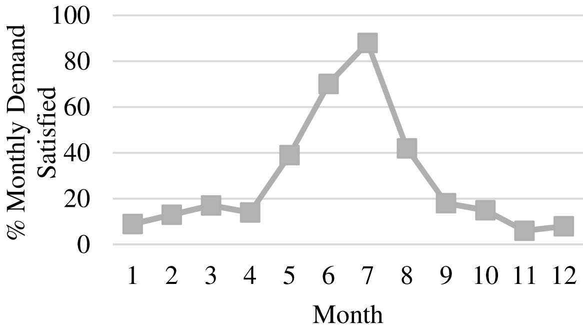

Fig 6: Monthly Demand Satisfaction of one storied building with four units in a floor

CONCLUSIONS

From results and discussions, it is observed that during rainy seasons (Jun-Jul) due to heavy rainfall by harvesting rainwater maximum percentage of demand satisfaction can be gained. Though the system cannot serve well in other seasons but as it will be beneficial to the inhabitants during rainy season to cope with the existing water crisis it can be a very good alternative to have. It served exceptionally well for the one storied with four units building and two storied single unit building as they had comparatively large catchment area with respect of number of inhabitants of building than others.

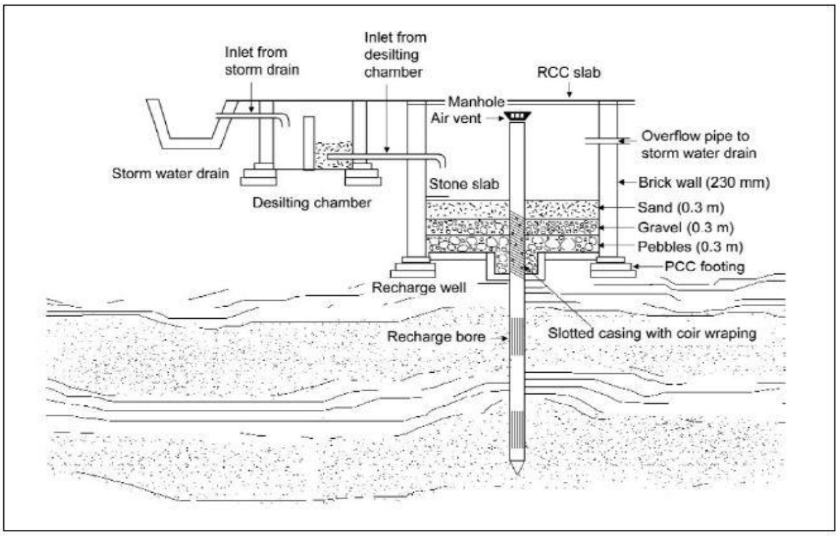

Fig. 7: Cross section of recharge well with desilting chamber (Kalam, 2011)

But according to the analysis rainwater harvesting system can only serve well in the month Jun-Jul. For the rest of the months still Chittagong has to be dependent on groundwater. But, over extraction of groundwater resulting in depletion of ground water table. This has become so severe that in some areas deep tube wells going down over 300 ft under the ground are unable to extract water. There remains no alternative of groundwater recharging to solve this problem. Recharge to deep aquifers can be under taken in a number of areas across the city – from roads to green areas to airports. The storm water drain network is the most suitable for this purpose, as rainwater from the entire city is tapped for recharge. The simplest way to do recharge would be to tap the storm water drain network. Structures can be built next to the storm water drain by tapping the water from it and using the rain water to recharge the aquifer after proper filtration. Recharge structure must be shallower than the ground water table so that the water from the recharge structure is able to permeate through layers of soil, thus undergoing further filtration, before it joins the water table. [Fig. 7] shows the model situation on how the recharge of rain water can be made.

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WATER SUPPLY AND SANITATION SCARCITY ASSESSMENT OF URBAN SLUM: A COMPREHENSIVE CASE STUDY FOR MIRPUR

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ABSTRACT
Slums have regularly been understood as the regions of concentrated deprivation in Bangladesh. The basic concerns inherent in urban slums are health hazards, so this study specially focused on water supply and sanitation condition of slums. Five slums –Kurmitola Balurmath camp - 1, Kurmitola Balurmath camp - 2, Millat camp, Wapda camp, and Rahmat camp - from Mirpur were chosen as the study area. Total sample size was 150 households comprising 30 families from each cluster. An organized investigation was regulated from July to October 2013. Overall sanitation condition in the slums portrayed a depressing image that was established with the aid of various facts, like slum condition, accessible water sources, sanitary facilities, drainage and water logging, waste management and disposal practices etc. The survey found that from 5 to over 72 families in the study area shared one deep tube-well, which is unimaginable for well-being. Water sellers offer water per household at TK 100-150 per month and the buyers get exceptionally less sum of water in spite of the fact that they are paying higher. Dwellers were using unhygienic open pit latrine or hanging pit latrine, as sanitary toilet facilities were inadequate, not even of least standard. Around 25 to 33% people mentioned about discarding their waste in front of the dwelling and 17 to 44% claimed to dispose in a fixed place.

Keywords: Urban slum; Water supply facility; Sanitation circumstances; Health risks; Drainage condition.

INTRODUCTION
Cities of the developing world are witnessing the most unprecedented growth rates in their history where 54 per cent of the world's population lives in urban areas and it is expected to increase to 66 per cent by 2050 (UN, 2014). Presently, 700 million urban dwellers lack adequate sanitation and the problem is particularly acute in south-central Asia, where 43% of the urban populations live in slums (Scott, 2015).Bangladesh being one of the developing countries does not have a comprehensive policy on urbanization and urban poverty. There are between 16 and 40 different bodies involved in one way or another in urban matters in its capital city Dhaka, with insufficient coordination and planning (World Bank, 2007). With a population growth of 4.2% per year, Dhaka will become a home of 25 million people by the year 2025(Asian Metropolis, 2014).The Greater Dhaka Area has a population of over 18 million as of 2016, while the city itself has a population estimated at about 8.5 million (BBS and WPR, 2017). It is estimated that around4 million people live in slum settlements in Dhaka, which could be 9 million by 2020 (Akbar et al., 2007). Lack of job opportunity in villages, landlessness in villages, higher chance of getting job in city, and river erosion are identified as the major reasons for people to migrate from villages to the city (IHE, 2015).
The slum settlements did not develop in the central part of the city like Mothijheel, Kotoali, Sutrapur or Lalbagh Thanas. They mostly developed in the peripheral thanas of Mirpur, Mohammadpur and Demra (Hossain, 2008). Due to an acute demand and high land prices, the slums communities have moved or are moving towards the city's peripheries for cheap shelter (Mahbub et al., 1991). Hence, the predominant survey area was mainly the slum area of Pallabi, Mirpur; Ward Number 2 and 6. The five major slums which were considered for this assessment are –Kurmitola Balurmath camp- 1, Kurmitola Balurmath camp - 2, Millat camp, WAPDA camp, and Rahmat camp.

Dhaka City is dependent on grants from donor agencies and hence has to work within limits set by the conditions of such grants. This kind of control adversely affects the quality of urban services provided to the urban poor. In addition, lack of accountability and transparency of Dhaka City's urban government makes it corrupted and inefficient (Islam et al., 2000). Therefore, it was an instantaneous concern to study the scenario and approaches related to water supply and sanitation conveniences among the urban poor in this city.

METHODOLOGY

The methodology of this survey consisted of practical surveillance and field based data collection through structured and non-structured questionnaire interviews. The survey was undertaken to explore the slum status, sources of potable water, drainage facilities, waste management practices and disposal patterns etc. The collected records were at first scrutinized and then evaluated to address the present situation in urban slums. The sequence of workswas organized under following phases:
Phase-1 (Inspection for primary information and research about individual slum settlement)
*Phase-2 (*Analysis and evaluation of responses to project the prevailing status)
Some chief parameters were also taken into consideration based on the socio-economic conditions of the dwellers like - income and educational competency, which led to a better understanding of dwellers' satisfaction in response to that.

RESULTS AND DISCUSSIONS

For attaining aims of the study, responses from the interviews were categorized and summarizedbysome Tabular and graphical representation. This information was used to illustrate the quantitative information regarding the research according to their significance during the analysis.

Preliminary and Socio-economic Information

The study made its way to the goals through some essential reconnaissance survey along the clusters about the land where it stood, the ownership, population distribution, household condition as well as all the social services available. The considered slums are located in Dhaka City Corporation (North) within the Ward No 2 except WAPDA Camp, which is situated in Ward No 6. Bangladesh Government owns these slum clusters, and these fall under the service of Pallabi Thana in Mirpur.

Table 1: The summary table of elementary information

Slums	Area (acres)	Total Households	Previous residence	Schools	Other services
KurmitolaBalurmat Camp-1	1.5	2000 aprx	Barisal, Mymenshing, Bhola, Faridpur	1	Delivery Center – 1 Mosque - 1
KurmitolaBalurmat Camp-2	1.7	1800 aprx	Barisal, Mymenshing, Bhola, Faridpur	1	Mosques - 2
Millat Camp	3.5	2500 aprx	Bihar, Pakistan	1	Delivery Center – 1 Mosques - 2
WAPDA Camp	1.5	210 aprx	Faridpur, Barisal, Bhola	None	None
Rahmat Camp	0.5	300 aprx	Kishorgang, Barishal, Mymensing	2	Mosque - 1

The comprehensive information about the whole settings in all the clusters are assembled in Table 1, which upholds the basic information like area, household size and other essential services. Individuals or their former peers living there are migrated majorly from the southwestern part of Bangladesh mainly except for the Millat camp. The educational institutions and other social services in each slum are very few against the respective house holds' size.

An enhanced notion about the population distribution, their profession and household expense can be met from Table 2. It was observed that, male and female individuals equally shared both the total populations as well as the household income, and most of them were day laborers. Very few of them had somewhat secure wages but mostly make it in daily basis. The average wage was around BDT 6000, although the Millat camp dwellers earned more for sharing a joint business interest.

Table 2: Population, Profession and House Area of the slums

Slums	KurmitolaBalurmat Camp-1	KurmitolaBalurmat Camp-2	Millat Camp	WAPDA Camp	Rahmat Camp
Total Populace	9000 Male – 4000 Female - 5000	10000 Male – 4500 Female - 5500	12000 Male – 5000 Female - 7000	945 Male – 472 Female - 473	1350 Male – 675 Female - 675
Major Profession Male	Rickshaw & van puller, Day labourer, Small traders	Small traders, Rickshaw & van puller, day labourer	Motomechanic, Benarashi Business, Iindustrial labourer	Rickshaw puller, driver, labourer	Vegetable vendor, Labor, Garments worker
Major Profession Female	Garments worker, Maid	Garments worker, Maid	Benarashi business, Garments worker, Maid	Maid, Garments worker, Laborer	Garments worker, Tailor, Maid
Income (BDT) avg.	4000-5000	4500-6000	7000-8000	6000-7000	4000-5000
House Area (sft) avg	100-150	100-160	150-200	150-250	120-150
House Rent (BDT) avg.	500-600	500-800	800-1200	1200-1300	500-800

The average area used by the single household ranged from 100 sft to 250 sft and the rent escalates with the sizes. The WAPDA camp dwellers pay higher house rent with an average of 1200-1300 BDT compared to other four slums which represents why the total people residing there is fewer. More evidently, the large portions are living in cheaper wings of slums.

People of different age have different responsibilities and perception about the facilities they require and avail for themselves. Among all 150 respondents most of the dwellers' ages fell in the groups 21-30 and 31-40, and this scenario was quite similar everywhere [Fig. 1], ranging from 25 to 35 percent. The number of persons dropped sharply after 40 years group. More than 50 percent people were under the age of 21-40, and the number of children is markedly lesser compared to these people, which certainly indicates a high mortality ratio among inferiors and seniors.

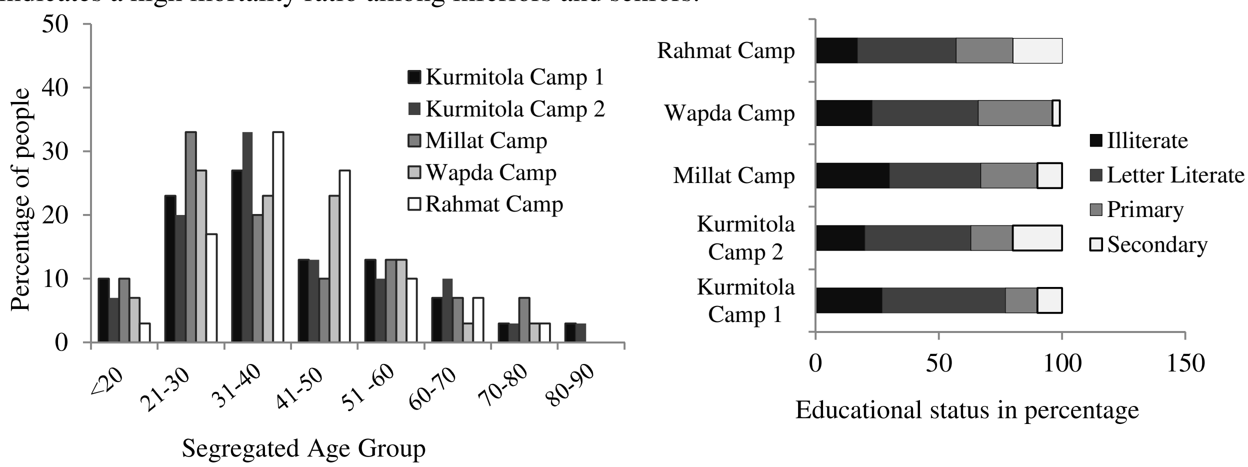

Fig.1:Population Distribution according to age groups and education statuses

As the literacy grows the sense of cleanliness among people, slum populaces lack all the perceptions about their poor hygiene and less water-sanitation facilities being illiterate. When individuals had been asked, the level of education in all slums was observed very low. From the graphical evaluation [Fig. 1], average illiteracy rate was found to be around 23.4% and almost 43% (nearly half of all the slum dwellers) were only letter literate in these entire five slums. However, very few of total inhabitants attained any schooling. As an average, 12.6% people entered in the secondary level and 21.2% attained primary schooling, which is rather inspiring in the context of Bangladeshi slum.

Access towards potable water

Dhaka Water Supply and Sewerage Authority (DWASA) is the only government official that supplies water for drinking and sanitation to the residents. Slum dwellers cannot be entitled for this supply for not owning any postal address. They obtain water through intermediary groups (water vendors) or entities residing beside the slum or the slum welfare committee. These vendors supply water illegally to the slum poor at a rate higher than the actual price.

Table-3: Primary and strategic sources of water and availability

Name of the slums	KurmitolaBalurmat Camp-1	KurmitolaBalurmat Camp-2	Millat Camp	WAPDA Camp	Rahmat Camp
Water Supplier	DWASA	DWASA	DWASA	DWASA	None
Chief Water Sources	Illegal Local Vendor, Nearby Bihari Camp	Illegal points, Water Vendor	Local Vendor	Illegal submersible pump	Illegal submersible pump, Nearby Jhill
Monthly Water Expense/HH	BDT 100- 50	BDT 100	BDT 100	BDT 100-150	BDT 150
Sources of water	Wasa	Deep tube well	Deep tube well	Deep tube well	Deep tube well
Drinking water outside house	Filter water	Shop	Shop	Filter water	Filter water
Households sharing one source	5	6	55	15	72
Average distance from household	20 m	20 m	500 m	100 m	650 m

In the study areas, the sources of water included hand pump tube-wells, WASA pumps, municipal piped water, water vendors and water supplied by some other specific places, such as mosques. Detail information on suppliers and the chief water sources including the monthly expenses carried by households to avail themselves potable water is summarized in Table 3. Water sellers offer water per HH at TK 100-150 per month and the buyers get exceptionally less sum of water in spite of the fact that they are paying higher. Most of the time there is no water in their supply line and they collect drinking water from adjacent mosque or other sources. A few tenants of Kurmitola Balurmat Camp-2 collect water from the adjacent Bihari Camp and Rahmat Camp tenants collect water from the adjacent filthy Jhill for other family reason like cleaning, washing etc. The distances of the water sources from the dwellings varied from 20 to 650 meter, while the time taken to reach them was from 2 to10 minutes. Despite the existence of various available sources of water, their number is insufficient for these large slum populaces. The survey found that from 5 to over 72 families in the study area shared one deep tube-well, which is unimaginable for well-being.

Drainage, Footpath, and Waste Management

The existing floor height was noticed to be lower than the drainage arrangement and drains were not covered or kept clear. In the rainy season it becomes very muddy and slippery as there was no concrete footpath system. Dwellers were using unhygienic open pit latrine or hanging pit latrine, as sanitary toilet facilities were not adequate, not even of minimum standard. Some people of Kurmitola Balurmat Camp-1 use latrine in nearby Bihari camp (Table 4). People face huge problem in night especially the women. No proper knowledge and practices were found for washing hands or hygiene issues and over all living environmental condition of the slum is very poor. Millat Camp and Rahmat Camp slum dwellers were using hanging pit latrines, which are associated with the adjacent Jhill. Individuals require sanitation knowledge as they are utilizing exceptionally poor toilets.

Table 4: Management of Drainage, Footpath, and Waste Disposal

Name of the slums	KurmitolaBalurm at Camp-1	KurmitolaBalurm at Camp-2	Millat Camp	WAPDA Camp	Rahmat Camp
Latrine Set-up	Very poor	Traditional pit latrine	Hanging pit latrins connected to jhil	Open pit latrine	Hanging pit latrins connected to jhil
Drainage System	Raw	Raw	Raw, high from floor	Raw	None
Footpath	No concrete footpath	No concrete footpath	Unanimous and poorly built concrete	Muddy, slippery	Muddy
Waste Disposal	No particular site	Scattered everywhere	No particular site	Nearby Jhil	No particular site
Water logging	3-6 days	3-5 days	1-3 days	1-3 days	1-3 days

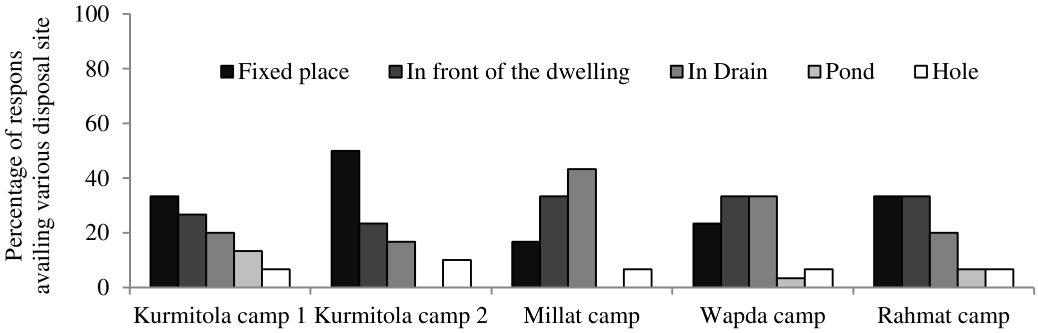

Fig. 2: Various waste disposal practice in percentage

Water logging likewise turned into another obligation for the locals of the chosen clusters. Slum occupants expressed that even a precipitation occasion of 2-3 hours causes water logging in there surrounding. The dormant water turned into a reproducing spots for illness vectors (Mosquitoes) and produces foul smell. There was no specific dumping site for waste disposal so wastes were thrown here and there. [Fig. 2] shows the garbage disposal practices in the selected slums studied. Around 25 to 33% people mentioned about discarding their waste in front of the dwelling and 17 to 44% people claimed to dispose waste in a fixed place though the situation was denoting a contradictory reference. Even if there was a fixed place for disposal, they preferred these bare spaces, as it was easy. They were heedless about the consequences of being exposed to the trash. Like sanitation, solid waste disposal had been appeared to be one of the major environmental problems in these slums. There was practically no steps taken for improving the life style of the slum dwellers specially who all are living in the urban

CONCLUSION

This study helped us to comprehend life status of slum people in Dhaka City including wellbeing and other essential conveniences accessible for them. It will be useful to find different designing cures with respect to these issues.The fundamental issue characteristics in slums are health risks. Absence of essential services like safe drinking water, legitimate accommodation, and waste and excreta transfer administrations make the populace defenseless against contaminations. The capacity of local government institutions are concerned only to deal with public health without considering the slum dwellers, which needs to be improved. Dwellers could have legitimate water supplies with DWASA association in less cost with greater amount of water if there were an approved and authorized planning for these areas. Internal drainage network within the slums should be cleaned regularly. In addition, there is a necessity of regular spray to control mosquito in the territory. Finally, it is of extreme significance to guarantee the appropriate water and sanitation amenities for these mounting numbers of deprived city dwellers.

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AN ASSESSMENT OF AQUIFER POTENTIAL IN AND AROUND PROPOSED WELL FIELD AREA NEAR MADUNAGHAT, CHITTAGONG USING ISOTOPE TECHNIQUES

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ABSTRACT
The study has provided a scientific basis for understanding the potential of deep aquifers as a source of safe drinking water and for assessing the status of groundwater near Madunaghat area, Chittagong, especially the salinity, interconnectivity of the shallow and deep aquifer, mixing of groundwater with the adjacent Halda river, recharge condition and groundwater age. The isotopic features suggest that most of the groundwaters results from a mixing between recent recharge and an older component recharge under climatic conditions cooler than at present. The interconnectivity between shallow aquifers and river waters are mostly found in the line wells installed particularly in shallow depth (16 m) close to Halda River as evidenced from the similar tritium values of sampled line well water with the Halda river water. The groundwater in Madunaghat well field area is not affected by salinity, as it is evidenced by higher values of Na/Cl ratio of the groundwater samples compared to the sea water fresh water mixing line. The geochemistry of intermediate and deep groundwater is dominated by Na-Mg-HCO_3 and Na-HCO_3 type waters. Even the relationship between chloride and oxygen-18 (Cl-$\delta^{18}O$) depicts that the waters from the deep, intermediate and shallow wells do not fall on the seawater mixing line. The Carbon-14 contents of intermediate to deep groundwater samples vary from 16.2 to 59.3 pMC focusing the residence time in the range of 4,300 to 15,000 years BP, i.e., the sourced water recharged the aquifers a long time ago. The intermediate and deep wells have water with arsenic concentrations less than the detection limit 3.0 µg/L. Only a few shallow wells have arsenic concentrations greater than the detection limit varying from 13.7 – 47.4 µg/L, which is less than the DoE permissible limit (50 µg/L) implying that the groundwater at Madunaghat area is not affected by Arsenic contamination.

Keywords: Stable isotope; tritium; carbon-14; salinity; Arsenic; recharge; residence time.

INTRODUCTION
Chittagong is the second largest city in Bangladesh having main sea port of the country. The total area of Chittagong and sub-urban areas is around 550 km^2. The industrialized city of Chittagong is growing rapidly and the population in the City Corporation area is estimated to be about 3.8 million. At present the demand for water supply within the city area is about 500 MLD. But Chittagong Water Supply & Sewerage Authority (CWASA) can supply about 210 MLD through its transmission and distribution pipelines. CWASA is embarking on construction of a water treatment plant (WTP) at Madunaghat for production of 90 MLD treated water. Moreover, during the dry season (i.e. November to May), the salinity of Halda water sometimes crosses the 500 ppm limit which is usually considered the typical limit for drinking water. However, this dry period is likely to increase in the future due to combined impact of lower river flow, climate change and sea level rise. It may, therefore, be necessary to augment the water intake from Halda with lower salinity water for the proposed WTP during high salinity periods to maintain the salinity within the prescribed limits. Having considered the various options for this, the augmentation with low salinity groundwater may be the most cost effective approach if sustainable low salinity groundwater supply is available. Subsequently, CWASA had decided to investigate the potentials of groundwater in the deeper

depth and the sustainability of groundwater aquifer system near the proposed Madunaghat Water Treatment Plant with an aim to study the possibility of using groundwater to augment the water intake of Madunaghat WTP to lower the salinity level of raw water from Halda river during high salinity periods to maintain the salinity within the prescribed limits. Isotope hydrology techniques can be used to identify the safe aquifer systems as a source of clean drinking water as well as to know the recharge mechanism in the deep aquifers, groundwater age and the possible connectivity between different aquifer systems, such as shallow and deep aquifers in and around the proposed well field area and also the mixing status between river (Halda) water and shallow aquifer system. A systematic environmental isotope (stable isotope δ^2H, $\delta^{18}O$ & $\delta^{13}C$, and radioactive isotope ^3H & ^{14}C) including geochemical study was carried out by Bangladesh Atomic Energy Commission (BAEC) on March–April 2015 to understand the groundwater flow system, sources of aquifer recharge and possible hydraulic interconnection between aquifers and surface waters of the study areas.

Study Area and Climate

The study area is located at the south eastern part of Bangladesh, Chittagong (Fig. 1). The city is situated on the bank of Karnaphuli River. The study area covers almost 15 sq.km. This area has been proposed for well field construction because the area located in a synclinal flat areas are guided by two long high hill ranges. The Chittagong region lies in the path of heavily moisture-laden monsoon winds. The rainy season extends from June through September and about 80% of the annual rainfall in concentrated in this season. The average annual rainfall in the area is estimated at 2200 - 3600 mm. The hot spell continues from April to July and mean monthly temperature ranges from 30˚C to 40˚C. Minimum recorded temperature ranges from 8.9˚ C to 12.8˚C. Although the humidity is 35% - 45% from November through March, it becomes 80% or even higher during the rainy season. Wind is generally considered to be mild except during strong thunderstorms and cyclones. The maximum wind velocity recorded is 60 m/s. Such winds occur generally in May through October.

METHODOLOGY

Hydrochemical and Isotopic Sampling

The lengths covered for sample collection in east-west and north-south direction are approximately 6 km and 11 km respectively in the Madunaghat well field area. A total of 40 groundwater samples were collected from different categories of wells, such as, line wells of shallow depth, deep monitoring wells, CWASA production wells, deep wells installed by DPHE and local shallow hand tubewells in and around the study area. Six surface water samples were collected from upstream to downstream of Halda River. Sampling locations are portrayed in a topo map as displayed in figure 1. On-site measurement of physico-chemical properties (such as pH, eH, EC, TDS, Temp. and DO) of water samples was done using an in-line flow-cell. Alkalinity (HCO_3^-) was determined on-site by point inflection method using Digital Titrator of HACH International, USA. The water samples for different kind of laboratory analysis were collected in different HDPE plastic bottles following the USGS protocol. The wells are categorized in three group with respect to depth, namely, shallow well (15–50m depth), intermediate well (60 – 75m depth) and deep well (150–270m depth).

Laboratory Analysis

The major anions (Cl^-, NO_3^- and SO_4^{2-}) of filtered water samples were analyzed by an Ion Chromatograph. The major cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) and trace elements (Fe and Mn) of filtered and acidified samples were analyzed by Atomic Absorption Spectrometer (AAS). The arsenic was measured in AAS using hydride generation technique. The anion analyses were performed in the Isotope Hydrology Laboratory, Institute of Nuclear Science & Technology, Atomic Energy Research Establishment, Savar, Dhaka. The cation and trace elements analyses were performed in the Analytical Chemistry Laboratory, Atomic Energy Centre, Dhaka. The stable isotope of precipitation and groundwater samples were analysed in Division of Isotope Application, PINSTECH, Pakistan using Isotope Ratio Mass Spectrometer (IRMS). Tritium determinations were performed with a Low Level Liquid Scintillation Counter (LSC) after electrolytic enrichment. Carbon-14 (^{14}C) activities and $^{13}C/^{12}C$ ratio were analysed on dissolved organic carbon precipitated from 60 litre water samples as $SrCO_3$. The ^{14}C was determined using the direct absorption technique and analysed on a low level liquid scintillation counter (LSC) in Isotope Hydrology Laboratory, IAEA, Vienna and Austria.

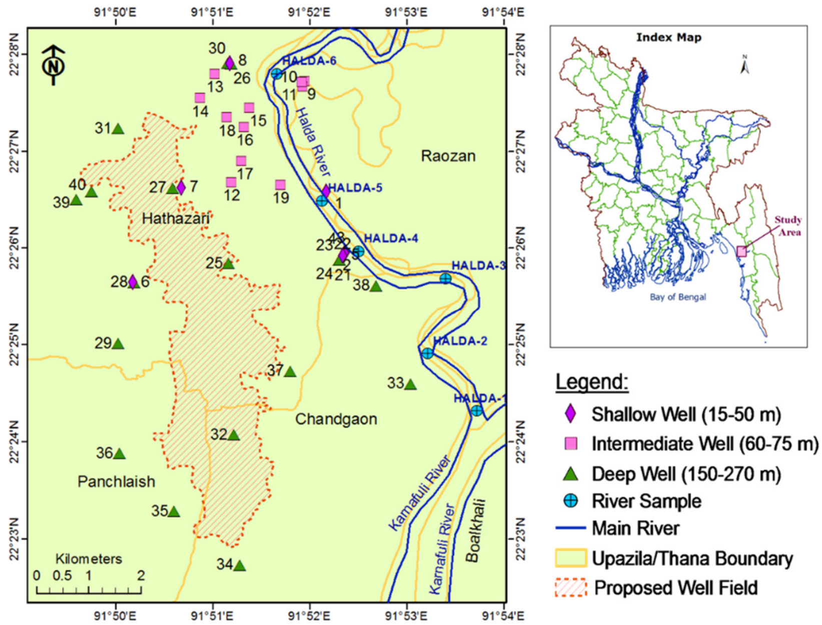

Fig. 1. Location map of sampling of groundwater and Halda river water near Madunaghat area, Chittagong (The numbers indicate the sampling stations).

RESULTS AND DISCUSSION

Hydrochemical Compositions

The average Chloride (Cl^-) concentrations of shallow, intermediate and deep groundwater are 22.08, 8.78 and 45.49 mg/L respectively. The highest value (821.78 mg/L) was recorded in the deep monitoring well (S-28) at Khondokia, Chikandandi, Upazila: Hathazari; that is not potable water. High concentration of Cl^- in deep groundwater suggests they are brackish water. These brackish waters are probably results from relict seawater entrapped in the sediments during the Holocene transgression. Besides, Sikdar et al. (2001) observed similar type brackish connate water pockets in the western site of Bengal Delta. The Na^+ concentrations in shallow, intermediate and deep groundwater of Madunaghat area vary from 25.61-85.53, 17.83-67.93 and 19.61-42.33 mg/L with average values of 40.36, 34.98 and 28.18 mg/L respectively. Mean sodium versus chloride concentration for 40 wells representing all aquifers have been shown in figure 2. None of the groundwater samples fall on or near the dilution line of seawater and dissolution line of halite. Most samples are enriched in sodium, presumably as a result of water-rock interaction. It is seen that the Na/Cl ratio for most of the water samples is higher than that of sea water fresh water mixing and majority of them fall in the field of freshening.

The Piper plot presented in figure 3 reveals three classes of combinations in groundwater. The position of the groundwater in the anions triangle indicates dominance of HCO_3^-, but the absence of sulfate in the groundwater. HCO_3 is the dominant anion and its concentration is mainly attributed to weathering as well as organic matter degradation. Na+ and HCO_3^- concentrations come mainly from weathering of alkali-feldspars related with the recharge areas. Na-HCO_3 represents 'Fresh Type' water in the aquifer. The other two types of 'Blended Water' are found as Mg-Na-HCO_3 in the shallow groundwater of Line Wells at Madunaghat BWDB compound and as Na-Mg-HCO_3 in a few intermediate wells of mid-Holocene aquifer at North Madarsha. This blended type water is low mineralized water indicating the initial source of water recharging into the aquifer systems. The slightly increase in Na^+ exchange for Mg^{2+} suggest softening process, which may indicate much more water-rock interactions along the flow paths. The water type for Halda River is of Mg-Ca-Na-HCO_3 type.

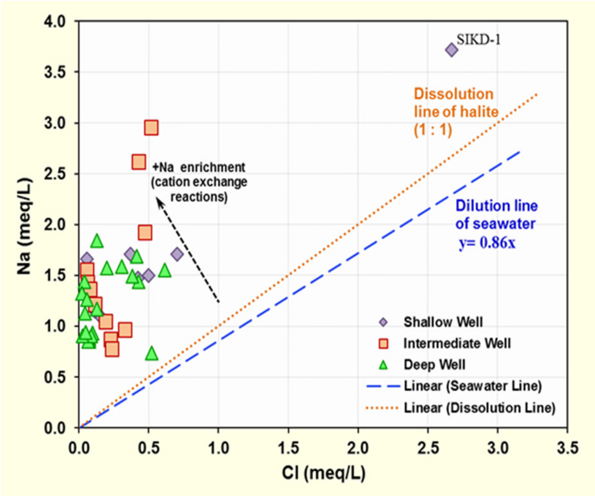

Fig. 2. Sodium versus Chloride concentration for 40 wells at different depths of aquifers.

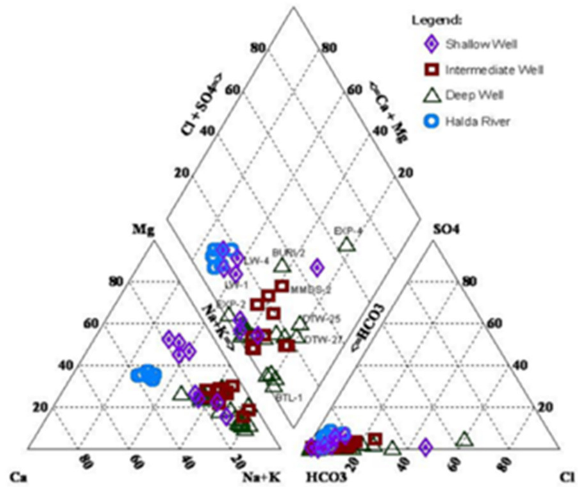

Fig. 3. Piper Trilinear plot showing the percent composition of major ions in groundwater and river water samples from Madunaghat area.

Stable Isotope Compositions

Most of the groundwater samples fall close to and sub-parallel to the global meteoric water line (GMWL), $\delta^2H = 8 \cdot \delta^{18}O + 10$ (Craig, 1961) as in figure 4. This indicates that groundwater recharge is mainly sourced from precipitation and/or flood water, and is weakly affected by evaporation. Mostly, the δ^2H vs. $\delta^{18}O$ fields of deep, intermediate and shallow groundwater are overlapping. Deep groundwater has $\delta^{18}O$ –3.98‰ to –6.17‰; intermediate groundwater has $\delta^{18}O$ –5.02‰ to –5.28‰; and shallow groundwater has $\delta^{18}O$ –5.00‰ to –5.41‰. These isotopic features suggest that most of the groundwater results from a mixing between recent recharge and an older component recharge under climatic conditions cooler than at present. Overlap of some of the data from shallow groundwater samples and data points from deeper aquifer sources suggests a degree of commonality of source for some sites (Smith & Guitjens, 1998). Both shallow and deep groundwater data sets have trends that diverge from the local meteoric water line (LMWL) and GMWL by a shallower slope suggestive of an evaporative component to the water. Some isotope compositions of the deep groundwater (S-34, S-35, S-38, S-39, S-20, S-23) samples with only depleted oxygen isotope values fall above the GMWL and LMWL. This indicates the effect of non-equilibrium fractionation of atmospheric vapour before infiltration. For the stable isotope composition of the Halda river running course, the mean values of $\delta^{18}O$ increase along the river course during high tide. The $\delta^{18}O$ values for the Halda River samples ranged from -4.52‰ to -3.78‰. The river samples fall below the meteoric water line showing the evaporation effect.

Radioactive Isotopes in Sampled Water

The tritium content of shallow, intermediate and deep groundwater in the study area range from 0.28 to 3.10 TU, 0.04 to 0.20 TU and 0.00 to 0.18 TU respectively. Meanwhile, the Halda river water tritium values range from 1.80 to 2.70 TU. The shallow groundwater samples have higher tritium values, it indicates that the aquifers are nourished by active recharge. The qualitative interpretation of observed groundwater samples show that the shallow groundwater is recharged within the aquifers before 1990 and the waters with the absence of ^3H are recharged before 1960s. In the depth versus ^3H plot (Fig. 5), wide range (0.28 – 3.10 TU) of tritium values are observed up to the depth 50 m and the groundwater below 50 m depth shows ^3H content <1.0 TU. Thus, groundwater having depth less than 50 m and tritium value less than 1.0 TU indicate recharge to the greater depths. The deep monitoring well (S-28) has positive tritium value (0.18 TU) indicating the mixing with modern to sub-modern recharge. The Halda river water has tritium content from 1.95 to 6.49 TU. The tritium contents of line well (shallow groundwater) are consistent with recharge from local rain and floodwaters.

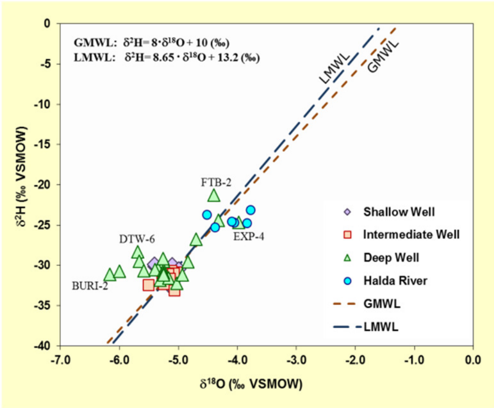

Fig. 4. Plots of δD versus δ^{18}O along with GMWL and LMWLs

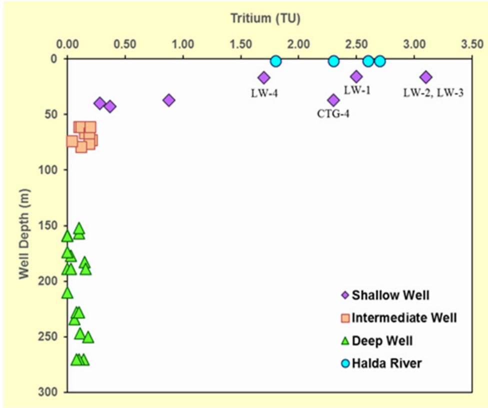

Fig. 5. Depth versus Tritium (TU) plot of all groundwater samples.

^{14}C activity of the analyzed groundwater samples varies from 59.3 to 16.2 pMC in intermediate to deep aquifers. The groundwater ages in and around Madunaghat well field area range from 4,300 to 15,000 years BP. The higher apparent DIC ages indicate confinement of the aquifer in the western boundary. If mixing occurs with younger groundwater, measured ages may be underestimated. Tritium values would indicate the presence of a 'young' component to the groundwater. Notwithstanding these limitations the ages measured indicate that the deeper water-bearing units have very long residence times due to very long flow paths from recharge areas, slow velocities or a combination of the two. Samples with almost no tritium have lower C-14 values of 16.2 to 30.8 pMC. The deep monitoring well (S-28) has higher carbon-14 value (58.5 pMC) indicating mixing with some modern to sub-modern groundwater.

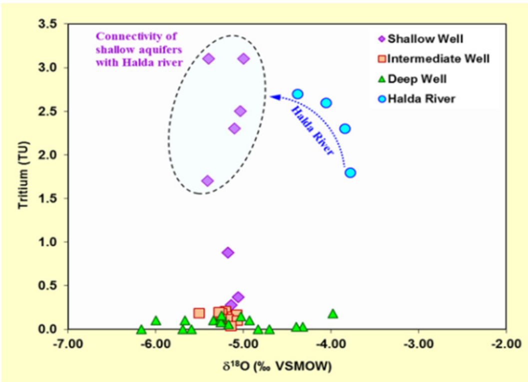

Fig. 6. Relationship between δ^{18}O and Tritium shows the connectivity between Halda river and adjacent shallow aquifer.

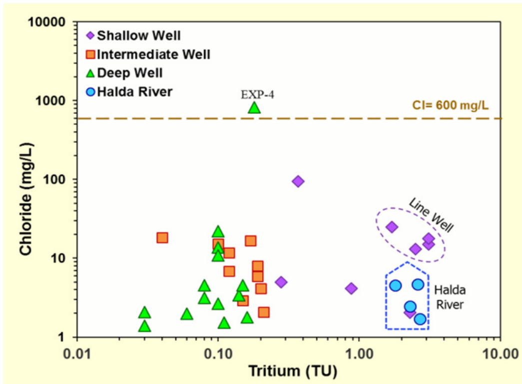

Fig. 7. High tritium values of Halda river and line wells indicate the mixing between river water and shallow aquifer.

Isotopic Evidence of Mixing of River Water with Shallow Groundwater

The plot of oxygen-18 vs. tritium (Fig. 6) of groundwater at Madunaghat area deciphers the connectivity of Halda river water with the shallow groundwater system. The higher tritium values (1.7 to 3.1 TU) are derived from the line wells installed particularly in shallow depth (16 m) close to Halda river which has similar tritium values (1.8 to 2.8 TU). On the other hand, the tritium content vs. chloride of the groundwater and Halda river water samples are plotted to see the evidence of mixing condition (Fig. 7). The plot indicates that the Halda River is feeding to the shallow line wells progressively as its tritium values are closer to each other, suggesting that gradual dissolution or reaction with shallow aquifer materials is the dominant mechanism. The chloride contents in the line wells vary from 13.06 to 25.0 mg/L, which are less than the DoE permissible limit (600 mg/L). As observed, the groundwater is not affected by salinity.

Investigating Salinity in the Groundwater System

In the Cl-$\delta^{18}O$ diagram in the Fig. 8, the mixing line between values of rainwater and seawater are plotted with the measured chemical and isotopic data. The isotopic data from the end member is the weighted mean of Oxygen-18 derived from the rainfall of Chittagong station nearing to the study area. Sea water is defined by $\delta^{18}O$=0‰ and Cl^-=19,000 ppm (Falkenmark & Chapman, 1989). The waters from the deep, intermediate and shallow wells do not fall on the mixing line, which confirms that the enrichment of the heavy oxygen isotope in these samples is due to evaporation effects (Rozansky & Fröhlich, 2001) This relationship between chloride and oxygen-18 (Cl-$\delta^{18}O$) confirms that there is no effect of salinity in the present aquifer system of study area.

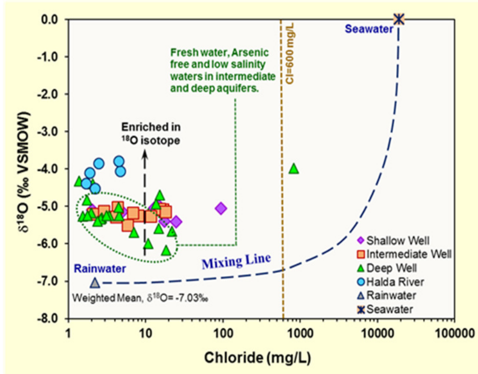

Fig.8. Oxygen-18 and Chloride in the groundwater samples

CONCLUSIONS

This study provided a better understanding on the hydrologic, geochemical and isotopic conditions in the aquifer system of Madunaghat well field area. The stable isotopic features suggest that most of the ground waters results from a mixing between recent recharge and an older component recharge under climatic conditions cooler than at present. The Halda river samples fall below the meteoric water line showing the evaporation effect. The interconnectivity between shallow aquifers and river waters are mostly found in the line wells installed in shallow depth (16 m) close to Halda river as evidenced from the similar tritium values of sampled line well water with the Halda river water. The geochemistry of intermediate and deep groundwater is dominated by Na-Mg-HCO_3 and Na-HCO_3 type waters. The relationship between chloride and oxygen-18 (Cl-$\delta^{18}O$) depicts that the waters from the deep, intermediate and shallow wells do not fall on the seawater mixing line. Hence it is confirmed that there is no effect of salinity in the present aquifer system in the study area. The Carbon-14 contents of intermediate to deep groundwater samples vary from 16.2 to 59.3 pMC focusing the residence time in the range of 4,300 to 15,000 years BP, i.e., the sourced water recharged the aquifers a long time ago.

ACKNOWLEDGEMENTS

The study was carried out under the framework of IAEA TC project BGD/7/007. The support for environmental stable and radioactive isotope analyses provided by IAEA, Vienna, Austria is greatly acknowledged. The cooperation of local DPHE office, CWASA officials and also the field supervisors during field sampling are warmly recognized. Finally, we acknowledge Institute of Water Modelling (IWM) for providing some financial and logistic support for carrying out field sampling activities through a MoU signing between BAEC and IWM.

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AN ANALYSIS OF WATER DEMAND AND AVAILABILITY IN DIFFERENT HOUSING CONDITIONS: A CASE STUDY ON RAJSHAHI CITY

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ABSTRACT
A good water supply is a pre-condition to providing a well-facilitated living place. But the surface water (both ponds and river water) of Rajshahi City is not suitable for drinking and cooking purposes and Rajshahi WASA can serve maximum 67% of dwellers and the rest use ground water. The main objective of the study is to know the availability of ground water sources and water demands of the respondents as well as the health risk of using this water. A questionnaire survey was conducted with 200 random samples from different wards of Rajshahi city to collect the present information of their water use, difficulties and requirements. The collected and categorized data, based on the household and housing material, were analysed through Statistical Package for the Social Sciences (SPSS; version 21). Statistical analysis shows that more than 40% of the poor household don't have any tube well or pipeline connection and almost 60% of them collect water from more than 50m distance. More than 90% family use different water for drinking and cooking than the other daily uses. The major possible remedies from their suffering condition, according to the respondents, are to supply water from Rajshahi WASA, to install deep tube well by the government, to supply water by grouping the houses, rainwater use, etc. This study helps to find out the sufferings of people for water (especially the poor people) and ways to mitigate their sufferings. Furthermore, the study argues a national problem statistically which will make a framework from where concerned authority should be careful and also the analysed data will be a resource for further planning.

Keywords: Availability; Water Demand; Health Risk; Statistical Analysis; Further Planning.

INTRODUCTION
Rajshahi is the fourth largest city of Bangladesh and a major urban, commercial, and educational centre of North Bengal. It is the administrative seat of Rajshahi Division and Rajshahi District (Wikipedia, 2017). So, the city is of great importance and attracts people from nearby northern areas of Bangladesh. These people need a well facilitated living place and good water supply is a pre-condition to that. In Rajshahi City, Rajshahi WASA is able to serve only 67% of the city dwellers with water supply and the rest 33% of the population doesn't have access to safe drinking water as yet (The Independent, 2018). Moreover, surface water (both ponds and river water) of Rajshahi City is not suitable for drinking and cooking purposes, and the dwellers of this city have to depend on arsenic free tube-well water as source of safe and potable water (Rahman, 2005). The Bangladesh Arsenic Mitigation Water Supply Project analysed 25 deep tube wells water under the management of Rajshahi City Corporation and found that 15 out of those deep tube wells were contaminated with arsenic level above the WHO guide line value (0.01 ppm), of which 4 exceeded the Bangladesh standard (0.05 ppm) and the concentration of iron, manganese and total hardness in tube well water of the study area were very high. So, water from any source, either groundwater or surface water, must be treated before use (Rasul; Jahan, 2010). The major causes of the non-usage of water with excessive iron are bad taste and odour; stickiness of hair and roughness of skin and also it makes the teeth and nail black and weak (Hossin; Huda, 1997). Comparing the quality of ground water with the Padma water it was found that the river water is more suitable for use as potable water after proper treatment (Rasul; Jahan, 2010). The present water availability and quality can be analysed to know the water supply condition in Rajshahi city.

The main objective of the study is to know the availability of ground water sources and water demands of the respondents as well as the health risk for using this water.

STUDY AREA PROFILE

Rajshahi City-corporation (RCC) is one of the six city-corporations located in the north-west part of the country. It lies between $24^0 21^/$ and $24^0 26^/$ north latitudes and between $88^0 28^/$ and $88^0 37^/$ east longitudes (Fig. 1) The city is bounded on the east, north and west by Paba thana and on the south by the Padma river and the shape of the city is as like an inverted "T" with an area of about 47.78 sq. km (RCC). The maximum length along east-west direction is about 13 km and along north-south is 8 km (Rahman, 2005).

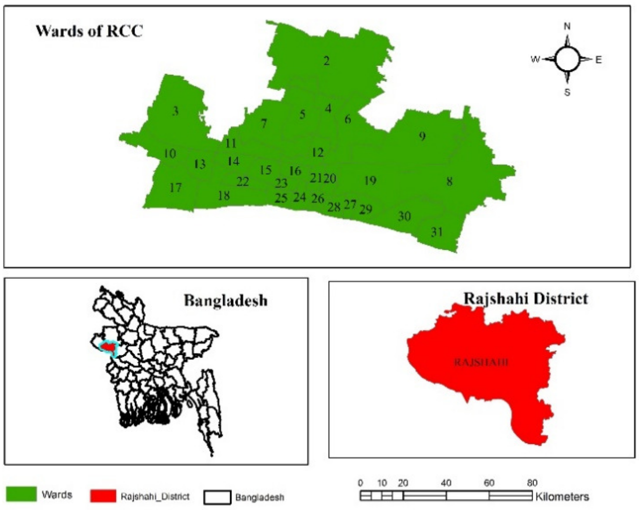

Fig. 1: Study area

METHODOLOGY

The study focuses on the water availability and water quality of Rajshahi city. The study also analyses that if the people use different source of water for drinking water than their daily use and what problem they face regarding water and what they recommend for better facility. A questionnaire survey has been conducted regarding this. The total Rajshahi city of 30 wards has been covered with 200 random samples. A semi-structured questionnaire has been modified after pilot survey and finally the data has been collected with the modified questionnaire. The collected data has been categorized based on the housing material and household and analysed using Microsoft excel and Statistical Package for the Social Sciences (SPSS; version 21). The statistical analysis represents the water condition in the city. The study also illustrates the level of satisfaction with uses of water and these data are collected from the survey.

RESULTS AND DISCUSSIONS

The sources of water are Rajshahi WASA (Rajshahi Water Supply and Swerage Authority), Tube well, and other sources like motorized deep pump. The analysis shows that, 66% area of the city get pipeline connections from Rajshahi WASA, 26% collect water from tube well and the rest 8% from other sources like individual deep pump (*Fig. 2*). The respondents are from different backgrounds. They are categorized according to their household (*Fig. 3*) and their housing materials (*Fig. 4*).

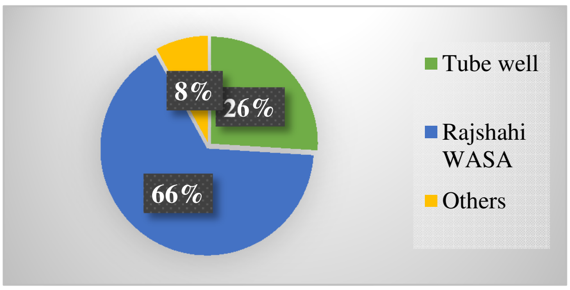

Fig. 2: Source of Water

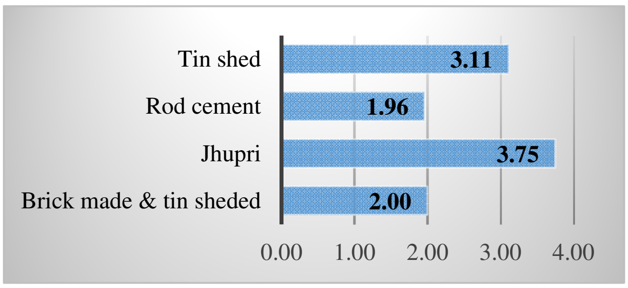

Fig.3: Average Person per Room

Fig. 4 illustrates that maximum housing materials are made by Rod and Cement (48%) which is called pucca houses. Mainly lower class people are living in jhupri made houses and perentage of household living in Jhupri is 8%. Fig. 5 shows that maximum rich people are served with Rajshahi WASA. Among the 52% poor respondents 30% are getting connections from Rajshahi WASA, 20% use tube well water and the rest 2% use water from other sources.

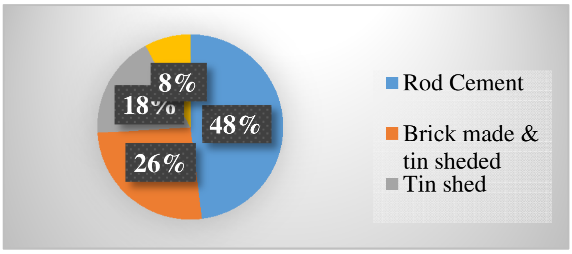

Fig.4: Housing Materials

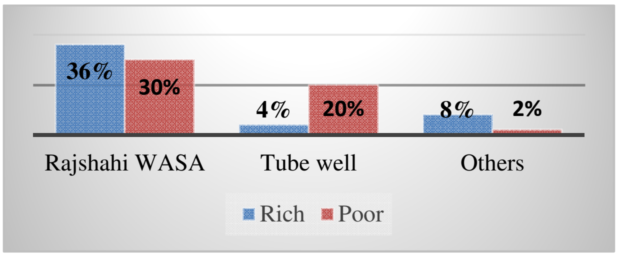

Fig.5: Sources of water

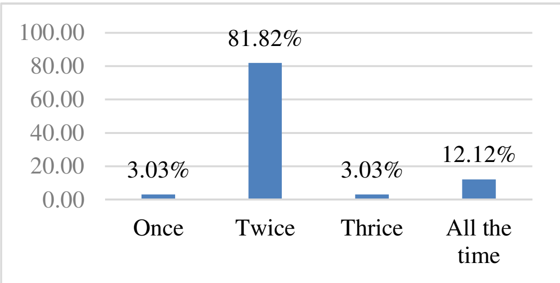

Fig. 6: Availability of Rajshahi WASA

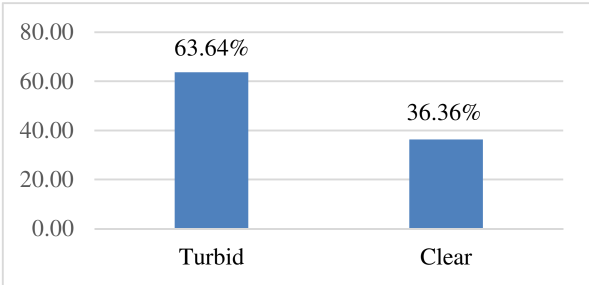

Fig. 7: Quality of water of Rajshahi WASA

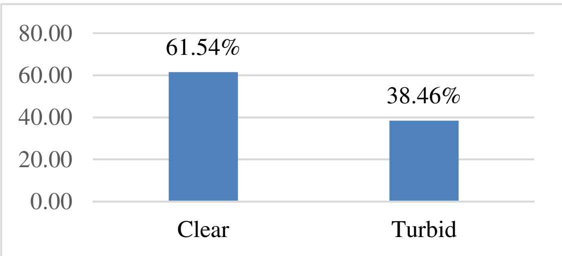

Fig. 8: Quality of Tube well water

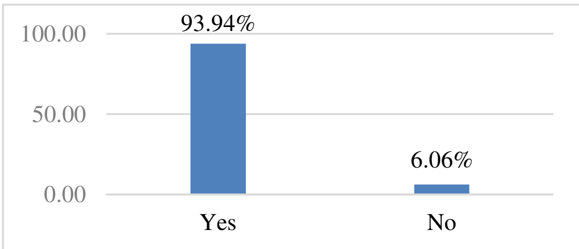

Fig. 9: Separate Drinking Source rather than Rajshahi WASA

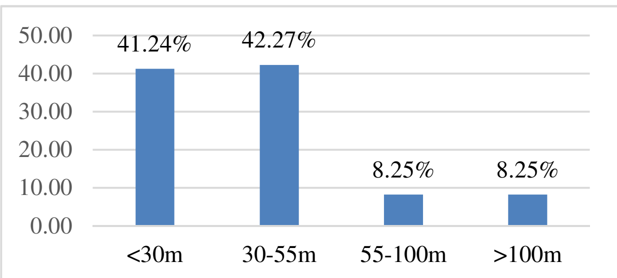

Fig. 10: Percentage of Distance to Drinking Source

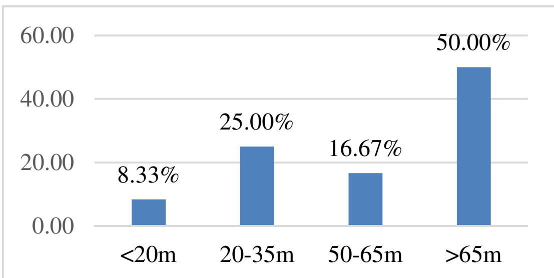

Fig. 11: Distance to Tube Well

So, a portion of the respondents use water from Rajshahi WASA and maximum of the responds said that they get supply only twice in a day [Fig. 5]. The average time is 10am-1pm and 3pm-6pm when they get supply water and the rest of the time they don't get supply water especially at the hours of night. They face intolerable problem due to absence of supply water at night specially who hasn't personal storage of storing water. They also complained regarding the water quality. More than 60% people regarded the water as a turbid one [Fig. 6] where in case of tube well water more than 60% are clear water [Fig. 8].Fig. 9 shows that more than 90% of the respondents use different source for drinking purpose in stead of Rajshahi WASA. This is a major noticable fact in this study. In other cities of Bangladesh, the authors notice that to purify or boiling of water for drinking purpose but not using a different source. In Rajshahi, the source for drinking water is tube well. Some people have tube well for their own and some share with others and sometimes they collect water from even a distance of 200m.

As more than 90% WASA user uses separate source of drinking water, therefore they have to collect drinking water from tube well from distant place. Average distance of drinking water source is not more than 55m [Fig. 10]. On the other hand, the household where WASA water cannot supply water, have to collect tube well water from far away. Fig. 11 shows that 50% of household have to collect water more than 65m.

Table 1: Percentage of shared tube well according to housing materials

Housing type of the poor	Number of respondents	Number of shared tube well user	Percentage of shared tube well user among the poor
Tin shed	36	24	23.08 %
Brick made & tin sheded	52	4	3.85 %
Jhupri	16	16	15.38 %
Total	104	44	42.31 %

Maximum tube well users set up tube well by sharing. Table 1 shows a statistical data of percentage of shared tube well users among the poor. To set up and maintenance cost of tube well for poor people is huge. The table also shows that more than 40% of the poor don't have pipe line connection from Rajshahi WASA or have tube well of their own and as a consequence they share with others' tube well. Again Fig. 11 shows that more than 60% of the respondents collect their daily use water from more than 50m distance.

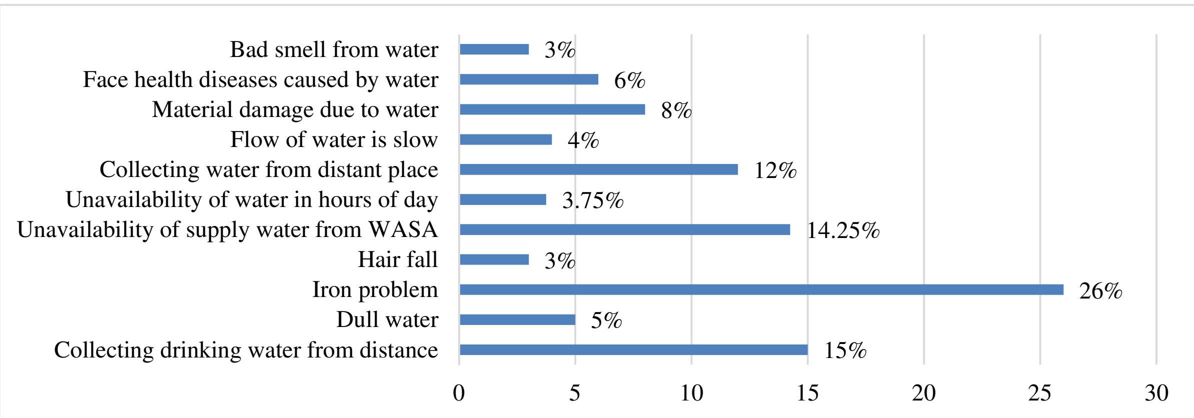

Fig. 12: Problems facing due to water

Overall the respondents said that they face problems like Collecting drinking water from distance, Dull water, Iron problem, Hair fall, Material damage due to water, Face health diseases caused by water, Bad smell from water, Unavailability of supply water from WASA, Unavailability of water in hours of day, Collecting water from distant place, Slow flow of water, etc. The poor, who don't get supply water connection, told that not getting supply water is a problem. The respondents who get supply water connection told about its unavailability at night and morning hours and slow flow of water. They also talked about the iron content in the water and problem regarding this like health diseases, hair fall, and material damage like damage of bathroom fittings and cooking materials. Some face problem of bad smell and dull water quality especially in the initial moment of the supply. To collect their drinking water every day from a distance is also a major problem they face. So overall they face many problems in their daily life regarding water. Fig. 11 shows the percentage of problems that respondents are facing continuously. Among these, in Rajshahi District maximum water is contained with iron and respondents also face same problem mostly. Having WASA connection but collecting drinking water from distance, is really intolerable problem because of poor quality of water. Respondent of 15% claimed that, collecting drinking water from tube well is like extra burden for them.

They recommend some way to remedy and improve their water condition from their own perspective. A major demand is to maintain and clean the water supply connections regularly. They think that the iron content block the pipeline connections and as a consequence they get dull and slow flow water connection with iron contamination causing their problem. The poor, can't manage to get supply water, demand for supply connection. As tube well is the main source of drinking water and the respondents need to collect water from distant tube well. That's why they want that the government care regarding this. It has become a trend to use tube well water for drinking and cooking purpose; so they want government to install deep tube well, if not in every house by making the house group so that they need not collect it from distant part (*Fig. 12*).

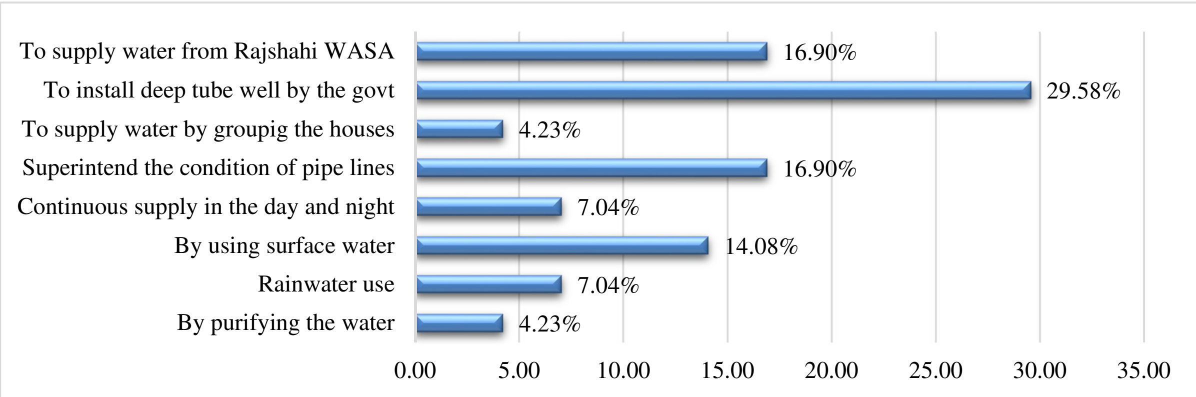

Fig. 13: Possible remedies recommended by the respondents to solve water problems

Table 2: Average satisfaction level in different water source

Source of water	Average Satisfaction (%)
Tube Well	49.2
Rajshahi WASA	63.9
Others	63.9

Table 3: Correlation between source of water and satisfaction level

Correlations			
		Source of Water	Average satisfaction with water
Source of Water	Pearson Correlation	1	.866
	Sig. (2-tailed)		.333
	N	3	3
Average satisfaction with water	Pearson Correlation	.866	1
	Sig. (2-tailed)	.333	
	N	3	3

The Table 2 shows the satisfaction of the respondents in different water sources. Using Rajshahi WASA, Rajshahi citizens are moderately satisfied and the percentage of satisfiction level is 63.9% which is simillar to other water source users. The correlation analysis shows a value of pearson correlation of .866 which indicates a strong correlation among the source of water and their satisfaction (Table 3). It indicates that source of water is positively correlated with the respondents's satisfiction.

CONCLUSIONS

The study shows that the dwellers of Rajshahi city face problem in their daily life regarding water. The Rajshahi WASA can't serve the whole city, even who get the facility of supply of water are not satisfied with water quality. As a result, more than 90% people use tube well water for drinking purpose but they need to collect this water from distance. The poor people face more problem in collecting their daily use water and they are very unsatisfied with their present water facility condition. As deep pumpimg system is not popular in Rajshahi so, this is a great advantange to control ground water table. The government should improve the quality and facilities of WASA to make users satisfied and thus will discourages to set up deep pumping for personal uses. The study also suggests some recommendations from the respondents to improve the present water facility system and more satisfaction of the dwellers.

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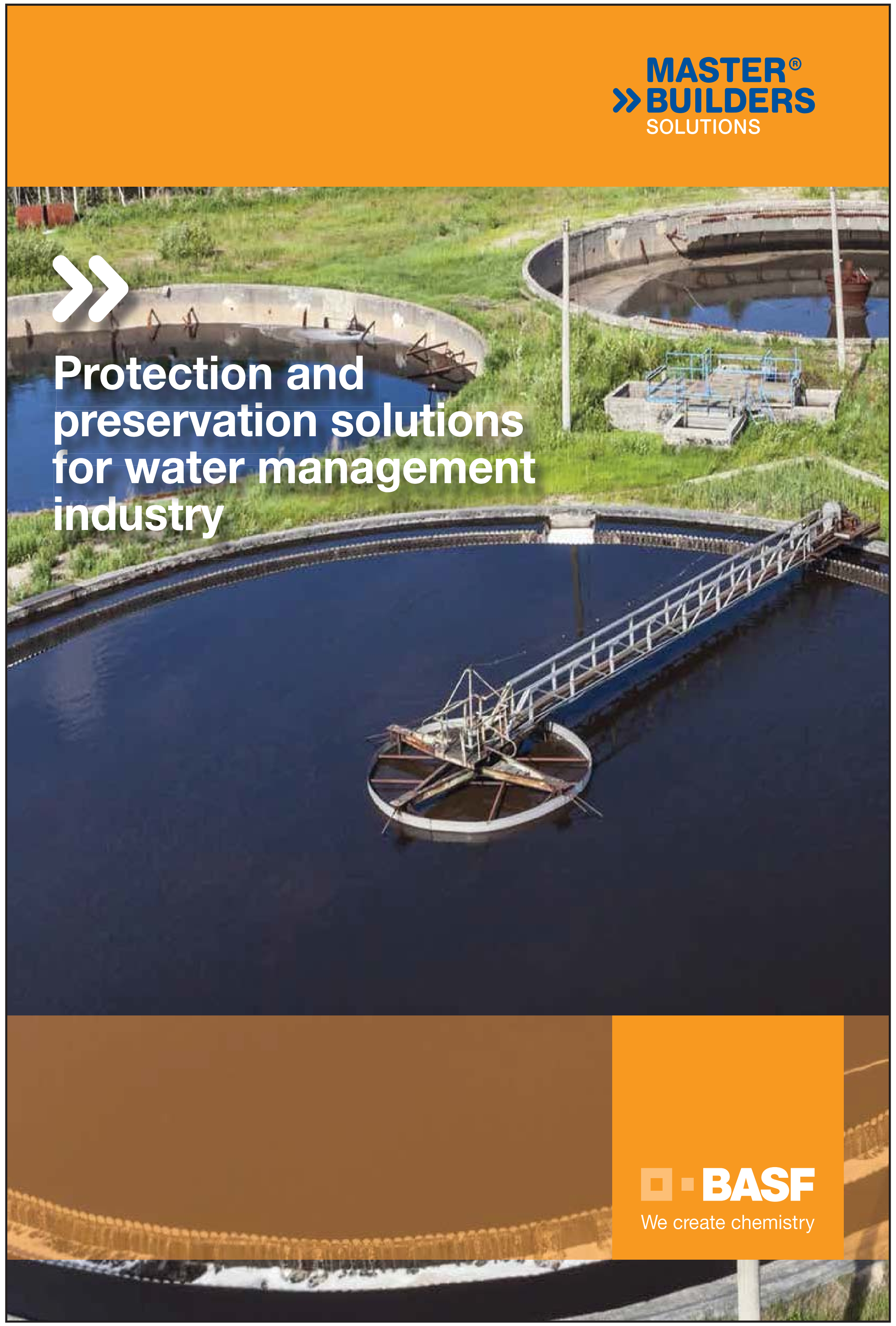
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