British Journal of Applied Science & Technology
19(3): 1-12, 2017; Article no.BJAST.32073
ISSN: 2231-0843, NLM ID: 101664541

SCIENCEDOMAIN *international*
www.sciencedomain.org

Utility of River Training Structures and Present Status in Patuakhali District Bangladesh

Shaikh Abdullah Al Mamun Hossain[1,2], Wang Lixue[1*], A. K. M. Adham[3], Umme Kulsum Navera[4] and Mir Mohammad Ali[5]

[1]College of Water Conservancy, Shenyang Agricultural University, Shenyang, 110866, China.
[2]Department of Agricultural Engineering, Patuakhali Science and Technology University, Dumki, Patuakhali, 8026, Bangladesh.
[3]Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh, 2202, Bangladesh.
[4]Department of Water Resource Engineering, Bangladesh University of Engineering and Technology, Dhaka, 1000, Bangladesh.
[5]Department of Aquaculture, Patuakhali Science and Technology University, Dumki, Patuakhali, 8026, Bangladesh.

Authors' contributions

This work was carried out in collaboration between all authors. Author SAAMH designed the study, performed statistical analysis, wrote the procedure and first draft of the manuscript. Authors WL, AKMA and UKN managed the analyses of the study and reviewed the manuscript. Author MMA helped in data collection and literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2017/32073
Editor(s):
(1) João Miguel Dias, Habilitation in Department of Physics, CESAM, University of Aveiro, Portugal.
Reviewers:
(1) Suheyla Yerel Kandemir, Bilecik Seyh Edebali University, Turkey.
(2) Jorge Castro Mejia, Universidad Autonoma Metropolitan, Mexico.
Complete Peer review History: http://www.sciencedomain.org/review-history/18183

Original Research Article

Received 6th February 2017
Accepted 6th March 2017
Published 14th March 2017

ABSTRACT

Aims: The focus of this study was to know usefulness of river training structures, controlling hydro-morphological characteristics, socio-economic benefits of inhabitants and current situation of these structures in Patuakhali District.
Study Design: Evaluations were measured on hydro-morphological features of rivers, protection safety based on utility of structures, environmental and social benefits by spot visit, face to face interview and focus group discussion methods.

**Corresponding author: E-mail: wlx1964@163.com;*

Place and Duration of Study: Ten different river side location of Patuakhali District during July-Sep in 2015.
Methodology: Established five groups including eight persons/group in each location to carry out the questioner and evaluations were accomplished based on specific key point issue.
Results: Three categories of river training structure were found at different location of the study area. Revetment with cement concrete (CC) block including 1.75 km bank protection measure from erosion due to high velocity tidal current at Lebukhali point (0.715 km), Patuakhali town protection point 2 (0.62 km) and Khepupara Bandar & town protection (0.42 km). Among them Lebukhali point was found more offensive comparing with others point. The level of risk of all structures was averages under low to medium except Lebukhali point.
Conclusion: The training structures were found moderately stable due to maintenance and effectively acting as qualitative benefit for inhabitants in socio-economic aspect.

Keywords: Usefulness; river training structure; present status; qualitative benefit.

1. INTRODUCTION

Bangladesh is predominantly a low-lying riverine country situated in the South Asian Sub-continent. There are almost 700 rivers including convergence of Ganges (Padma), Brahmaputra (Jamuna), and Meghna and their tributaries were run through country [1]. The physical characteristics, geographical position, climatic condition, and auto-cyclic fluvial courses have produced numbers of big multichannel river following through country with separate channel width of up to 5 km in which scour generated around 50 m depth [2]. The channel width becoming large and depth is reducing over the year due to unfavorable geographical location and river flow control by the countries upstream reaches, that's leading to unexpected erosion-deposition processes along the river. Thus, bank erosion and channel shifting of alluvial rivers are under serious problem in social, economic, and environmental aspect [3]. The alluvial floodplain rivers are always flowing on common geomorphological process which causes of bank erosion. This corresponds to river bank adjustment, variation of channel bed elevation and topography in reaction of modified flow situation, exceptional flooding, and rising intensity of tidal waves [4,5,6,7]. Thus, it's needed to carry out continuous observation and importance to pay attention on geomorphological processes and management situation of the river timely. For example, typical situations of lower part of River Brahmaputra bank protection system, as well hydraulic and morphological consequences, were measured by Zhang et al. [3].

These rivers are always self-regulatory in the way that, they modify their physical appearance or flow pattern in response to any variation of environment. This environmental deviation may occur either naturally by climatic difference, heavy rain, changes in vegetative cover, land slide or maybe the results of human activities such as river training, sand or gravel mining and bridge or highway construction. All these changes destroyed the ordinary quasi-equilibrium of river flow, which need to adjust to new situation by changing its slope, width, roughness. In present constraints, any or combination of these features may adjust as river seeks to maintain balance between its ability to transport and sediment load provided. Therefore, river channel stability is a significant issue to understand overall river steadiness and recognition of present status in many ways, such as: study of bank erosion, lateral instability hazards, construction of structures along the river passageway and develop safe settlement zones [8].

The protecting measures of river bank erosion are very important for sustainable river management. It depends and varies on river morphology, geographical location, social attitudes, knowledge and practices of executing agencies. The amount of bank erosion mostly depends on the hydro-morphological features and circumstances of the river. A major part of the Bengal Delta including all plane land of Bangladesh have been formed from recent sedimentation, which is highly erosion prone by its characteristic except Barind Tracts, Madhupur, Lalmai and Chittagong Hill Tracts [9]. In coastal districts, most of rivers were tidal and navigable throughout the year. Sometimes tidal surge was hugely bump into locality due to low pressure climate. Dronkers [10] stated phenomenon of tides, those are created by attraction of sun and

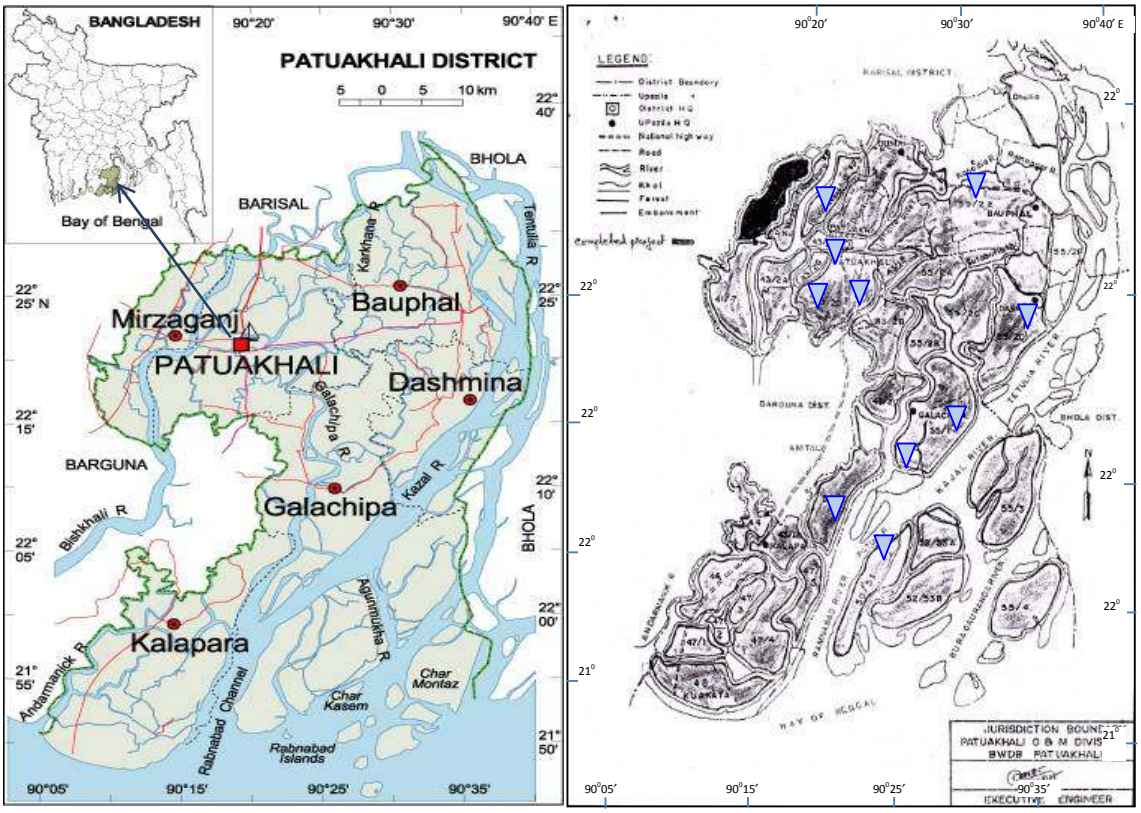
moon with sea water which visible that regular raise and fall of water within a range of several feet. Here rivers were trained to maintain the morphological equilibrium for social, environmental, and economic protection, where buildup numbers of Polder. Though the purposes of this river training structure are noble and credible, but implementation of such training activities without in-depth studies and due to lack of careful consideration about ecological balance would not only aggravate the remaining problems also lead to various unexpected consequences [11]. In Bangladesh river training were practiced from 1960s by Bangladesh Water Development Board (BWDB) [12]. During the later period of 1950s and from mid 1960s river training works started from the west bank of the Jamuna river and extending for some 220 km [3], but development of this training structure was very expensive especially in the coastal reason of Bangladesh. There are varieties of river training structures such as embankments or dikes, spur dikes, groins, revetments, guide bunds, marginal bunds etc. used to maintain channel for river bank protection. Most of them like spur dike, groin, revetment, and embankment are used for river bank protection in Bangladesh. Since 1960's, several earthen embankments were constructed along the major rivers side of the country for protection of rural community, fisheries, livestock's, agricultural lands from tidal flood. In past, several decades, frequent flood and continuous erosion have consumed large areas of floodplains, made thousands of people homeless and destroyed a huge number of infrastructures [3]. From that period, embankments were retired several times due to tidal surge and bank erosion. Then bank protections are repeatedly required during the monsoon and post-monsoon season. In coastal region including research area most of the rivers were trained by establish Water Polder (earthen embankment). A polder is defined as a level area which has originally been subject permanently or seasonally to a high-water level and is separated from the surrounding hydrological regime to be able to control water levels and prevent the intrusion of tidal flood water, where shrimp and paddy culture are practiced [13,14]. Studies were undertaken for effectiveness of these river training structures on protection measure, hydraulic and hydrological concern, and environmental aspect [9]. However, excluding rivers of coastal district. Yet from the construction of these structures, several renovations work accomplished for severe erosion prone bank side, still did not assessed utility based on river process and socio-economic benefit. Shriwastava and Sharmar [15] stated, in present context, it is essential to assess the conventional river training methods practically for respective areas where thousands of kilometers of erosion-affected stream bank-line are waiting for managing action. This paper reported on the usefulness of present river training structures and their perspectives based on hydro-morphology and qualitative socio-economic benefits of inhabitants in Patuakhali District.

2. MATERIALS AND METHODS

The objective of this research was to assess the usefulness of existing river training structure and their status based on hydro-morphology, qualitative and socio-economic benefits of inhabitants.

2.1 Research Area

The research area (Patuakhali district) is situated at 22° 21'15″North latitude and 90° 20' 5″East longitude. The area was surrounded by different main rivers of Patuakhali district lies on southern coastal zone in west Barguna district, North & East surrounded by Barisal and Vola district and in south the Bay of Bengal. The main rivers which pass through the area are Payra, Lohalia, Andharmanik, Lawkati, Kajal, Ramnabad, Tetulia and Agunmukha etc. Most of the rivers are distributary channels originated from the Ganges and drop into the Bay of Bengal. The rivers flow through Patuakhali district are close to the Bay of Bengal which is tidal and navigable all over the year. The tides were influence by attraction of sun and moon with sea water [10]. The rivers were trained to maintain morphological equilibrium for social protection where buildup numbers of Polder by constructing coastal embankment. Three categories of training structure were selected from 10 (ten) different polder and sub project area which was implemented by Bangladesh Water Development Board (BWDB) as shown in Fig. 1 as well as describe in Table 1. Most of the river training structure was practiced for controlling bank erosion for sustainable river management and for socio-economic benefits and environmental ecological aspect. Different categories of bank protection practices were evaluated in context of sustainability, erosion prone and their existing situation of the study area.



Study location = ▽

Fig. 1. A map of Patuakhali District (left side) including the study area showing main rivers and different study location (right side) besides rivers

Source: BWDB, Patuakhali Operation & Management division office's publication (Hard copy) and [http://mapofbangladesh.blogspot.com/2011/09/patuakhali-district.html]

Table 1. Selection of different river training structures at different location of research area

Category of structures	Name of river	Location name
1. Earth embankment	-Payra river -Lawkati river	Maximum Polder and coastal embankment project area, such as: (i) Mirzagonj Rampura project-Payra river, (ii) Subidkhali Madhobkhali coastal Embankment, Muradia kalagachia coastal embankment and Dumki Lawkati embankment, etc.
2. Revetment		
i) with cement concrete (CC) block	-Payra river -Lohalia river, -Andharmanik river	(i) Lebukhali Feri Ghat point, (ii) Patuakhali town protection work 2 (iii) Khepupara Bandar and town protection work.
ii) with Geo-bag/sand-cement bag	-Lawkati river	Patuakhali town protection work 1
iii) with stone	-Lohalia river	Patuakhali town protection work 2
3. Bandals	-Kajal river	Galachipa

Source: Spot visit

2.2 Data Collection

To document and assess the utility of river training structure and its present status in Patuakhali district, data were collected by visiting at 10 (ten) main river bank protection site of different polder located beside the river. A worksheet has been prepared to carry out the questioner survey and social inquiries on particular river training practice and bank protection measures. During study period, we established five groups together with eight peoples per group in each location for measurement of different level of risk of these training structures based on some key point issue such as: spot observation, river flow situation, inhabitant's previous observation based opinion and length of erosion-protection point. The indigenous knowledge of local natives was used and interprets in technical point view that might be a good tool for understanding the river bank erosion risks and effectiveness of these training structures as evaluated effectiveness of watershed management practices by collecting data through semi-structured interview, focus group discussion, field observations and field measurements [16] and severity of flood embankment situation by field visit and questioner survey [17]. Formerly, we had assigned score based on these key points issue for different level of risk such as: low risk level (1.0-2.5), medium risk level (2.6-4.5) and High risk level (4.6-6.0) from individual's opinion. Thus, around 40 inhabitants participated in this group discussion gave their opinion to complete the worksheet in each location. The status and usefulness of all protection structures were measured based on of five points such as (i) stable time after construction and renovation, (ii) number of erosion per year, (iii) number of qualitative benefits due to protection measures, (iv) number of damages due to erosion and (v) spot observation. Similarly, several key components such as historical data, upper storage of water reservoir, flood damage filed survey, flood mitigation option etc. was considered for assess flood damage risk status [18]. The discussion upon these points, decision was taken about the present status of these training structures by assigning score 1 (one) for each point collectively as unstable (<1.0), short time stable (1.0-2.0), stable due to maintenance (>2.0-3.0), moderately stable (>3.0-4.0) and stable (>4.0-5.0).

3. RESULTS AND DISCUSSION

3.1 Features of Training Structures

There were three categories of river training structure such as earth embankment, revetment (with CC block, stone, sand-cement, and geo-bag) and Bandals were found in the research area. Most of the river was trained by establishing Polder [13] as like earthen embankment. The details of main rivers of this research area (ten locations) under training including numbers of Polder and name of these locations are described in Table 2.

Table 2. Main rivers of Patuakhali district under trained by constructing numbers of Polder

Name of main River	Polder name/Number	Length of bank protection/embankment/revetment with CC block/ Geo-bag/sand-cement bag (Km)	Name of location
Payra	Itbaria-lebukhali sp.*	0.713	Lebukhali
Payra	Mirzagonj Rampura sp.*	45.60	Mirzagonj Rampura
Lohalia	43/2D	0.625	Patuakhali Town 1
Andharmanik	54/A	0.427	Khepupara Bandar protection
Andharmanik	43/1B, 46	22.77	Kalapara
Lawkati	43/2H	0.842	Patuakhali Town 2
Kajal	55/1	46.16	Galachipa
Ramnabad	50/51	48.00	Baherchar
Tetulia river	55/2 E	70.00	Bauphal
Tetulia river	55/2D	65.60	Dasmina

** sp-sub project, Source: BWDB, Patuakhali operation & management division office publication and [19,20]*

Earth embankment is a ridge or bund built especially by earth, or mixture of earth and rock to confined river and flood water or to construct highway, railway, canal etc. This type of earthen river training embankment constructed and practiced in Bangladesh [12], especially in research area for protecting people's lives, homes, agriculture, and infrastructures from tidal flood. The embankments feature and purposes were depending on nature under a variety of circumstances. This structure was also designed to control or prevent tidal surge, high water flooding. The embankment built to prevent flooding of low-lying land is also called levee or dyke which constructed along the riverbank and maintain certain distance from the river to retain floodwater. Almost flat and low land elevations (from the mean sea level) are interspersed with a dense network of semi-diurnal tidal channels carrying saline water that make the area none-suitable for agricultural production. Firstly, people started constructing Polders by raising the banks of tidal channels thus preventing entry of saline tidal prism on low-lying area and helping inhabitants to cultivate crops. The Polders were formed into a closed area by earthen embankment surrounding the depressions zone (keeping the main tidal channels outside of the Polder) and maintain connection with main channel by constructing sluice gated hydraulic structures on an intersecting point (meeting points of embankment and secondary tidal channels) [12]. Most of the monsoon time, different places of Bangladesh have witnessed of unprecedented distractions and damages of several embankments due to tidal flood, cyclone, tidal surge etc. For that reason, almost two-thirds area of the country went under water every year and thus broken of embankments and relevant distractions were caused massive damages of properties [17]. The earthen embankments of the research area represent the identical role as well as all over the country. Some places of this structures constructed of revetment using cement concrete (CC) block, geo or sand-cement bag, or stone etc. regarding to level of erosion risk. Recently bandals (made by bamboo or relevant wood) were used to construction of groin like structure along the river side to prevent bank erosion which has demonstrated worthy result.

3.2 Structural Failure Mechanism and Risk Measure

In present circumstances, the river management authorities have necessity to understand the mechanism of bank failure. In fluvial systems, there are three ways river bank generally fail such as: (i) hydraulic forces remove erodible bed or bank material, (ii) geotechnical instabilities result in bank failure, and (iii) a combination of hydraulic and geotechnical forces causes failure [21]. Some river side of this research area are becoming vulnerable condition of erosion due to above mention reason and still these areas are under different level of risk though dissimilar protection measure has been taken. The details of bank erosion and protection measures under different level of risk at different location of main rivers of this study area are described in Table 3. According to the individual's opinion we found different locations at different river side were noticed under different level of risk in which constructed the protection measure. The risk level scores ranged from 1 to 6 with an average of 2.71 represented all the training structures under low to medium level of risk except Payra river side at Lbukhali Feri Ghat point. Adjacent to Lebukhali Feri Ghat and several other points including about 1.74 km concrete block revetment was failed due to high flow velocity directly struck on river bank and return flow creates local scouring near bank which caused massive failure as view in photographic Fig. 2 and represented under high level of risk averages 5.22 as shown in Fig. 3a. The high velocity return current reflects by emerging char at opposite bank of Payra river. For that reason, generation of high expulsion around the revetment also causes of failure. The both bank side of Payra River at Lebukhali Feri-Ghat point is more vulnerable as comparing from others points. Cement concrete (CC) block revetment possess this area safe from tidal current temporarily. The revetment with cement concrete (CC) block including around 1.8 km bank protection work from erosion due to moderate velocity tidal current under low risk level at Patuakhali town protection point 2 and Khepupara Bandar & town protection point. Revetments with geo or sand-cement bag at Lawkati river bank side for Patuakhali town protection point 1 are the defensive structure and relaying under medium level of risk. In this section of the river flowing straight and this protection measure can save the bank from straight flow current. The main purpose of these structures was to modify the struck flow velocity on the river bank and protect from erosion. The earthen embankment used as river bank protection structure of Baherchar point, Bauphal point, Dashmina point and Southern Galachipa point was found under low risk level whereas bank protection by bandals at Galachipa point

was found under medium level of risk as shown in Fig. 3a and b. Therefore, although the maximum bank protection structures condition under low to medium risk level however, all are effective in purposes as several researchers evaluated using different techniques. Sarker and Akter [22] evaluated bank protection structure of Jamuna river and stated as effective, minor damage, major damage, minor damage but effective etc. by historical data and experience from several case studies. Revetment with Jute Geotextile was found as effective after three times investigation of river bank protection measure [23].

Fig. 2. Photographic view showed the severe erosion prone area at Lebukhali point of Payra River

3.3 River Morphology and Status of Protection Measure

River morphology is the variations of river shape in cross-section and changes of flow direction and pattern due to sediment deposition and transportation processes, which can be segmented into different branches that are often interrelated to each other. The areas of morphology are including overland flow, channel flow, channel network distribution and diversion, stream channels with flow characteristics, stream stages, stream discharge, drainage systems, horizontal profiling and profile development, stream erosion and transportation etc. [24]. It affects on river width, depth, slope, flow velocity, discharge, flow resistance, sediment size and sediment load [25]. Maximum of the floodplains including the research area of Bangladesh have been formed by the settlement of sediment that's carried by rivers. Zhang et al. [26] make a comparison study with conventional revetments and spur dykes. The flow structure and bed morphology around the Sirajganj Hardpoint and Betil/Enayetpur spur dykes of Jamuna River, found much more complex due to the complex flow and bed conditions. In this study area, tidal flow carry high sediment load and recent formation of bed load in high velocity. For that reason, rivers of this area are highly dynamic in nature. Hydrological and climatic parameters also would make the rivers more vulnerable as well as unpredictable. Morphology of these rivers was being subsequent impacts on floodplain dwellers [27], which were likewise under observation during study period. The status and usefulness of all protection structure were measured by fixing criteria as designated method as shown in Fig. 4 and described with consequences in Table 4. All the protection structures were found from moderately stable to stable due to maintenance though morphological changes of river is different at different location. The tidal flow velocity and depth of bottom scouring in all rivers are very high. Payra River is more vulnerable due to erosion prone because of river flows directly hit on this bank, reflect the current and producing meandering channel. Though revetment with CC block is moderately stable structure according to the outcome, however after construction of this revetment, this area is free from short time risk. The revetments with geo-bag and sand-cement bag at Patuakhali town protection bank are defending strongly form high velocity flow hit. As per local people

Table 3. Persons perception showed present status of river bank under different level of risk

Name of river	Bank failure	Location name	Level of risk
Payra,	Sever	Lebukhali Feri Ghat point	High
Payra,	Moderate	Mirzagonj Rampura point	Medium-Low
Lohalia,	Moderate	Patuakhali town protection 1	Medium
Andharmanik,	Moderate	Khepupara Bandar protection	Low
Lawkati	Moderate	Patuakhali town protection 2	Low
Kajal,	Moderate	Galachipa point	Medium
Ramnabad,	Moderate	Baherchar point	Low
Tetulia river	Moderate	Bauphal point	Low
Tetulia river	Moderate	Dashmina point	Low
Agunmukha	Moderate	Southern Galachipa point	Low

Source: Spot visit & group discussion

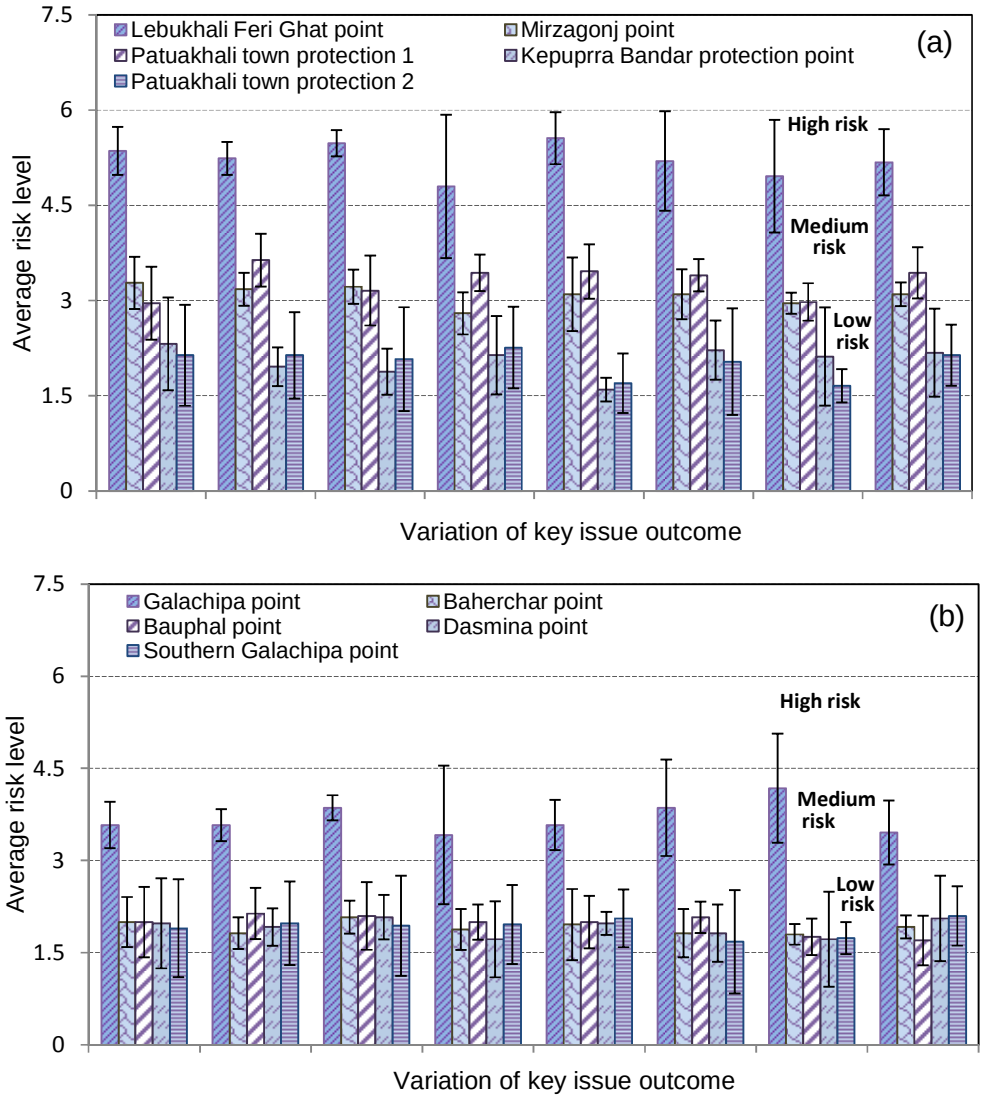


Fig. 3a and b. Variation of different level of risk in groups at 10 (ten) different location of bank protection practices

perception, the Bandalling (made by wood) savings temporarily their valuable agricultural land form erosion at Kajal river side, Galachipa. This structure is a simple alternative low cost conventional structure made by bamboo or wood. Bandal structures are physically considered as combined structures of permeable spur dykes and pile dykes [26]. The bandals are positioned at an angle with main flow. When surface flow forced on the face of structure, it reduced velocity due to obstacle and flow through the bottom direction [28]. These are the characteristics of this structure are for the control velocity of water and sediment flow [29]. Thus, sand bar or char land were formed along the river bank side due to sedimentation as shown in Fig. 5. However, the structures are required to keep under continuous observation and renovation timely necessarily in any situation.

3.4 Benefit of Protection Structures

These river training structures is expected to lead to increase of benefits and development for stakeholders as well as for locality of the research area. Benefits of human lives saved are impossible to quantify and are not included in the economic analysis. However, it is estimated that

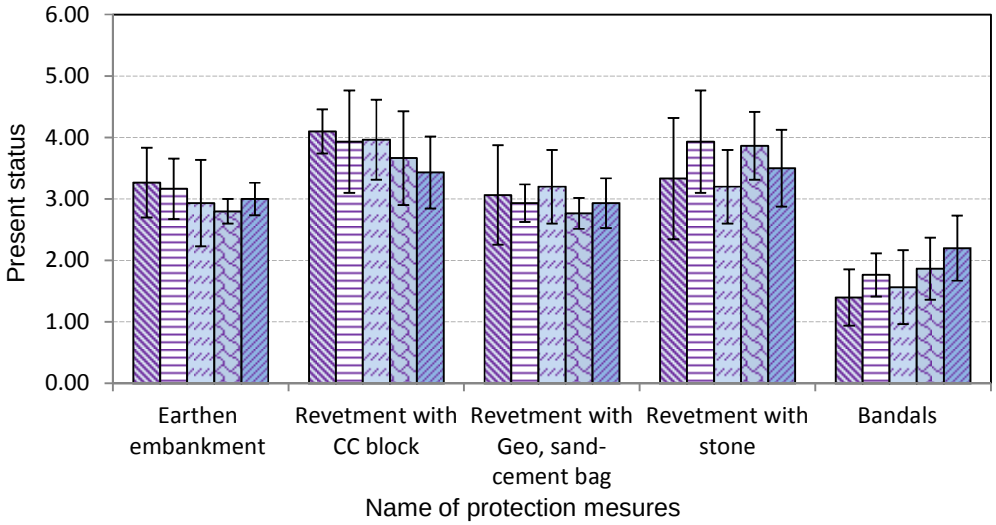


Fig. 4. Present status of protection measures found at different location based on stable = >4.0-5.0, moderate stable = >3.0-4.0, stable due to maintenance = >2.0-3.0 and short time stable = 1.0-2.0)

Table 4. Status, consequences and usefulness of protection measures

Category of structures	Present Status	Consequences and usefulness of protection measure
Earthen embankment	Stable due to maintenance	By construction of earthen embankment protect tidal flow from entering into locality and reduced erosion due to minimized velocity of struck. Save agricultural land. The embankment established as local road for good communication.
Revetment with cement concrete (CC) block	Moderately stable	Flow hits on revetment and divert it to channel center. It reduces erosion due to turbulence flow can protest at the base of the structure and reflect slide down.
Revetment with Geo-bag/sand-cement bag	Stable due to maintenance	Flow diverted due to protection measure and resistance grows from erosion.
Revetment with stone	Moderately stable	Flow diverted into multi-angle (zikzak) stone reduced energy and erosion.
Bandals	Short time stable	Velocity of water reduced and flow diverted. Sand bar formed near bank finally reduce erosion.

about 140,000 people were died in the coastal district of Bangladesh including the study area during the 1991 cyclone [30]. The cyclone devastation with tidal surge struck, destroyed the river bank and sea water enter into locality with several meters' height that caused of huge death. After construction and renovation of these river training structures, it was helped to save lives and properties and bringing social benefits by reduction of devastating damages as stated by Heidari [30]. According to focus group discussion some qualitative benefits were evaluated as described in Table 5.

Fig. 5. Photographic view of bandaling structure used for controlling bank erosion at Kajal river side in Galacipa

Table 5. Qualitative benefits after construction of river training structure

Category	Post-Observations and Qualitative benefits
Human lives	Fewer human lives lost during cyclones, storm surges and tidal surges.
Property and protection	Less property destroyed during cyclones, storm surges, tidal surges that complementary work improve drainage leading to increased agricultural production.
Production	Embankments would protect a gross area from cyclone and tidal surge leading to increased agriculture and fish production.
Afforestation	Afforestation for cyclone protection and embankment maintenance would have ancillary benefits.
Employment	Embankment would generate additional employment during construction and through increased agricultural production.
Damage reduction	Construction of river training structures reduced the damages due to adverse erosion by tidal surges as the benefits.
Others	River training work would give unquantified benefits like, savings on emergency relief, environmental benefits etc.

Source: Spot visit, interview & focus group discussion

4. CONCLUSION

Most of the rivers in Patuakhali District were trained with developing Polder by constructing coastal embankment. The flow velocity with tidal surge creates turbulence in all major rivers results in scour occurs at the bank that getting at risk especially during high tidal current. The structures could protect the bank erosion provisionally while a percentage of bank materials are moderately fragile. All the structures are technically suitable based on local circumstances and moderately stable due to maintenance. The embankment materials of research area are primarily consisting of clay with a small amount of silt and sand. The clay particles of these embankment materials are stickier which can tolerate tidal struck. In the view of environmental ecological and social context of the study area the bandal structure is novel invention and can contribute in coastal embankment protection. The structures has good social acceptance which can makes it further development and renovation and also need to do continuous management for its sustainability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Banglapedia. National Encyclopedia. The People Republic of Bangladesh; 2012a.
Available:http://en.banglapedia.org/index.php?title=River
(Accessed 05 August 2016)

2. Best JL, Ashworth PJ, Sarker MH, Roden JE. The Brahmaputra-Jamuna River Bangladesh. In Large rivers: Geomorphology and management. Wiley & Sons Ltd, Chichester. 2007;395-430.
Available:http://onlinelibrary.wiley.com/doi/10.1002/9780470723722.ch19/summary

3. Zhang H, Nakagawa H, Baba Y, Kawaike K, Rahman MM, Uddin MN. Hydraulic and morphological consequences of bank protection measures along the Jamuna River, Bangladesh. Annuals of Disas. Prev. Res. Inst. Kyoto Univ. 2011;54 B:477-496.
Available:https://www.researchgate.net/publication/266353225

4. Chowdhury RK, Maruf BU, Chowdhury AI. Climate change would intensify river erosion in Bangladesh. Impact of Climate Change in Bangladesh, Dhaka; 2007.
Available:http://www.equitybd.org/newsletter/issue/02/5.pdf

5. Lane EW. The importance of fluvial morphology in hydraulic engineering. American Society of Civil Engineers. US; 1955.

6. Madej MA, Weaver WE, Hagans DK. Analysis of bank erosion on the Merced River: Yosemite Valley, Yosemite National Park, California, USA, Environment Management. 1994;18(2):235-250.
DOI: 10.1007/BF02393764

7. PieÂgay H, Bravard JP. The reactions of a mediterranean riparian forest to a major hydrological event, the 1 in 400 year in the OuveÁze River, DroÃme-Vaucluse, France. Earth Surface Processes and Landforms. 1997;22(1):31-43.

8. Tamrakar NK, Bajrachrya R, Sapkota S, Thapa I, Paudel PN, Tamang NB. Riverbank erosion potential and channel stability status of the Kodku River, southern Kathmandu Basin, Central Nepal. Bulletin of the Department of Geology, Tribhuvan University, Kathmandu, Nepal. 2014;17:1–41.
Available:https://www.researchgate.net/publication/279209423
9. Rahman MM, Arifur RM, Munsur R. Effectiveness of river training structures in Bangladesh. ICSE6 Paris - August 27-31. 2012;935–940.
Available:http://scour-and-erosion.baw.de/icse6-cd/data/articles/000066.pdf
10. Dronkers JJ. Tidal computation in rivers and coastal waters. North-Holland Publishing Company, Amsterdam. 1964;381.
Available:http://www.jstor.org/stable/40605488
11. Imran J. Can river training benefit us? The daily Star, The National Newspaper in Bangladesh. Published Saturday, September 4, 2009.
Available:http://www.thedailystar.net/news-detail-104402
(Accessed, 05 August 2016)
12. Banglapedia. National Encyclopedia. The People Republic of Bangladesh; 2012b.
Available:http://en.banglapedia.org/index.php?title=Embankment
(Accessed, 05 August 2016)
13. Polder of the World. Final report. International Symposium. The Netherlands. 1983;15-23.
14. Segeren WA, Schultz E, Van-Giersbergen WJM, Leemhuis-Stout JM, Luijendijk J, Wolters W. Polders of the world: Papers international symposium. Lelystad, the Netherlands; 1982.
15. Shriwastava A, Sharmar N. Investigation of RCC Jack Jetty as a cost effective river training structure. International Conference on Agricultural, Environmental and Biological Sciences, AEBS-2014. Phuket, Thailand. 2014;42-46.
Available:https://www.researchgate.net/publication/269694387
16. Tiki L, Kewessa G, Wudneh A. Effectiveness of watershed management interventions in Goba district, southeastern Ethiopia. Int. J. Agric. Sci. 2016;6(9):1133-1140.
17. Hossain MZ, Sakai T. Severity of flood embankments in Bangladesh and its remedial approach. Agricultural Engineering International: The CIGR E-Journal. 2008;10. Manuscript LW 08 004.
Available:http://cigrjournal.org/index.php/Ejounral/article/viewFile/1229/1086
18. Heidari A. Structural master plan of flood mitigation measures. Nat. Hazards Earth Syst. Sci. 2009;9:61-75.
Available:http://www.nat-hazards-earth-syst-sci.net/9/61/2009/
19. BWDB (Bangladesh Water Development Board). Final Report. Ministry of Water Resources. The People's Republic of. Bangladesh. Printed and Published by BWDB. Oct. 2010: 1-134.
http://www.bwdb.gov.bd/archive/pdf/249.pdf
20. BWDB (Bangladesh Water Development Board). Final Report. Coastal Embankment Improvement Project, Phase-I (CEIP-I). Ministry of Water Resources. The People's Republic of. Bangladesh. Printed and Published by BWDB. 2013;1(Main Report): 1-164.
Available:http://www.bwdb.gov.bd/archive/pdf/364.pdf
21. Fischenich JC. Channel erosion analysis and control. In: Woessmer and Potts (eds.) Proceedings Headwaters Hydrology. Montana Section, American Water Resources Association, Bethesda, Maryland. 1989;101-103.
22. Sarker MH, Akter J. River bank protection measures in the Brahmaputra-Jamuna River: Bangladesh experience. International Seminar on 'River, Society and Sustainable Development, Dibrugarh University, India; 2011.
23. Islam MS, Khan AJ, Sddique A, Kabir R, Nasrin S. Performance evaluation of river bank protection using jute geotextiles. National Seminar on Jute Geo-textiles, Organized by Jute Diversification Promotion Centre (JDPC), Dhaka, Bangladesh; 2014.
24. Schumm SA. The fluvial system. A Book of classic geomorphology literature. John Wiley & Sons Inc. The Blackburn Press. New York. Geol. J. 1977;13:3.
Available:http://www.blackburnpress.com/fluvialsystem.html
25. Leopold LB, Wolman MG, Miller JP. Fluvial processes in geomorphology, A book of W.

H. Freeman and Company, San Francisco, California; 1964.

26. Zhang H, Nakagawa H, Baba Y, Kawaike K, Teraguchi H. Three-dimensional flow around Bandal-like structure. Annual Journal of Hydraulic Engineering, JSCE. 2010;54:175-180. Available:http://www.cc.kochi-u.ac.jp/~zhang/pdf/J-2010AJHE.pdf
27. Hossain S, Rahman M, Nusrat F, Rahman R, Anisha NF. Effects of climate change on river morphology in Bangladesh and a morphological assessment of Sitalakhya River. Journal of River Research Institute (RRI). 2014;1-13. Available:https://www.researchgate.net/search.Search.html?query=river%20morphology%20bangladesh&type=publication
28. Rahman MM, Nakagawa H, Ishigaki T, Khaleduzzaman ATM. Channel stabilization using bandalling. A published article of Annuals of Disaster Prevention Research Institute, Kyoto University. 2003;46B:613-618. Available:http://repository.kulib.kyoto-u.ac.jp/dspace/bitstream/2433/129127/1/a46b0t55.pdf
29. Rahman MM, Nakagawa H, Khaleduzzaman ATM, Ishigaki T, Muto Y. One the formation of stable river course. A Published Article of Annuals of Disaster Prevention Research Institute, Kyoto University. 2004;47B:601-616. Available:https://www.researchgate.net/publication/47528186
30. The World Bank (WB). Coastal embankment rehabilitation project. Staff Appraisal Report. Bangladesh. Report No. 15039-BD. 1995;43. Available:http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/1995/10/16/000009265_3961008063725/Rendered/PDF/multi0page.pdf

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/18183