

ASSESSMENT OF EROSION RISK POTENTIAL IN TERMS OF BANK MATERIAL PARTICLE SIZES AROUND 3KM UPSTREAM AND 3KM DOWNSTREAM OF HAJI SHARIATULLA BRIDGE ALONG ARIAL KHAN RIVER IN BANGLADESH

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Abstract

River bank erosion is a recurring issue at monsoon in Bangladesh. Erosion expedites the river bank failure occurring among many of the river bank failure criteria. So, it is very much important to assess bank erosion of the river prior to the planning of bank protection works. Here an attempt has been made to assess the erosion risk potential at the left and right banks around 6.0 km of Arial Khan River. In this study particle sizes are analyzed and percentage of Clay, Silt and Sand has been found out. From the particle size analysis, it has been seen that the left bank of the Arial Khan River predominantly consists of sand particles, except for Khas Char Bachamara, where silt particles dominate. On the other hand, right bank of Arial Khan River dominates the Silt and Sand particle. The erodibility index is determined through Bouyoucos erodibility index and EI_{ROM} . From the erodibility index result of EI_{ROM} the soil erosion of the bank is categorized and observed that the left bank of Arial Khan River is very high to critical position in risk of erosion except 3.0 m depth of Khas Char Bachamara which layer sometime protects the bank from erosion. On the other hand, the right bank of Arial Khan River is high to critical position in risk of erosion. From this study a design engineer can be aware of the bank materials and predict erosion risk. However, it is recommended that a full geotechnical investigation is needed to prevent river bank erosion.

Keywords: Arial Khan River, Bank materials, Erosion risk potential, Particle sizes.

Introduction

The major part of Bangladesh is on the delta formed by three significant rivers Brahmaputra, Ganges and Meghna. Originating beyond the country's borders, these rivers, along with numerous smaller ones, constitute the Ganges-Brahmaputra-Meghna River system. A wide delta has been formed over the past thousand years due to sediments from these rivers, which have shaped the vast area of Bangladesh and the submerged delta-plain in the Bay of Bengal. 80% of the country's soil is formed by these sedimentary deposits. The remaining 20% of soils, 12% are obtained from Tertiary and Quaternary sediments found in hills, while 8% are uplifted Pleistocene terraces. (Banglapedia, 2021). River bank erosion is a frequent occurrence during monsoon in Bangladesh. Almost every year river banks are facing problems like erosion and failure occurs due to erosion along with other river bank failure criteria (Alom *et al.*, 2020). By this way bank materials play an important role on river bank erosion as well as failure.

The Arial Khan river is a Prominent and highly active river in Bangladesh, creates significant bank erosion which is one of the main reasons for the suffering of the local people (Akter *et al.*, 2013). This river serves as a significant branch of the Padma river's distributary network. It originates from the Padma river at 51.5 km downstream of Goalanda of Rajbari district. The river runs through Faridpur, Madaripur and Barishal districts and maintains meandering channel through its course and is erosion in nature. The river is navigable round the year and has tidal characteristics. Its normal tidal range at Madaripur is 0.32 m. This river covers a total length of 160.0 km (Hossain *et al.*, 2007). Severe river bank erosion have caused destruction of number of settlements in vicinity of bank. Under such circumstances a study has been undertaken in order to assessment of the bank erosion in terms of particle sizes of bank material around 6.0 km of the left bank and right bank of Arial Khan River at

Shibchar Upazilla under Madaripur district of Bangladesh. Watson *et al.* (2006) studied stream bank erosion with a review of processes of bank failure, measurement and assessment techniques and modelling approaches. They stated that stream bank erosion depends mainly on flow pattern, bank material composition, bank geometry, channel geometry, bank soil-moisture conditions, vegetation and man-induced factors. Talukdar (2006) studied the probable causes of erosion, river instability, soil erosion, sediment transport and deposition. He concluded that sediment gets into the river not only from the catchment area but is also contributed by erosion of its banks. He defined that causes of failure of river banks can be directed erosion of the river bank among other probable causes. Roslan *et al.* (2013) worked on river bank erosion erodibility of Langat river of Malaysia and found the Sheet, Rill and Gully three types of soil erosion features commonly seen along Langat river. They found that along the Langat river the soil classifications predominantly consist of sand and silt, commonly referred to as well-graded silty sand, sandy clay of low plasticity and very clayey sand. They stated that soils with a greater proportion of sand show a greater risk of failure which is substantiated and affirmed by the 'ROM' scale equation where most of the soil samples were categorized as very high and critical in the degree level of erosion risk and thus will lead to risk of river bank failure. 'ROM' scale (after the name of the researchers Roslan and Mazidah) is used to ascertain the degree of soil erodibility namely low, moderate, high, very high and critical along the river bank based on the percentage composition of sand, silt and clay. They concluded that the responsible authority could implement proactive measures to prevent adverse incidents along the Langat river at an early stage.

The soil scientist Bouyoucos invented Eq. (1) for determining the Bouyoucos erodibility index (BEI) on the basis of composition of soil

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$$BEI = \frac{\% \text{ Sand} + \% \text{ Silt}}{\% \text{ Clay}} \quad \text{Eq. (1)}$$

This lack of versatility has led to the development of an advanced and new improved soil erodibility index in the name of EI_{ROM} or ‘ROM’ Scale as in Eq. (2).

$$EI_{ROM} \text{ equation} = \frac{\% \text{ Sand} + \% \text{ Silt}}{2 \times (\% \text{ Clay})} \quad \text{Eq. (2)}$$

This new equation still uses the original principle of Bouyoucos, which is to analyze the soil textural composition of sand, silt and clay. The new equation has effectively demonstrated both the significant value and the threshold for delineating soil erodibility, while also indicating the anticipated erosion characteristics. With the new EI_{ROM} equation outlined in Eq. (2), the more realistic and significant value of soil erodibility index can be used concurrently considering its corresponding risk category as illustrated in **Table 1** to denote the extent of soil erodibility.

Table 1. ‘ROM’ scale with regards to soil erodibility category.

‘ROM’ scale	Soil erodibility category
< 1.5 Low	Low
1.5 -4.0	Moderate
4.0 -8.0	High
8.0 -12.0	Very High
> 12.0 Critical	Critical

(Source: Roslan and Mazidah, 2012)

EI_{ROM} = (% sand + % silt) / 2(% clay) The ‘ROM’ scale was developed solely on the grading characteristics of soil, utilizing the EI_{ROM} equation to derive the soil erodibility index and ascertain the configuration of erosion features. In other words, the ‘ROM’ scale quantifies the degree of soil erodibility by applying the EI_{ROM} equation. This pioneering scale represents the first endeavor to categorize erosion severity based on both the soil erodibility index and erosion features. During the early stages of developing the ‘ROM’ scale, various areas and locations across Peninsular Malaysia experiencing erosion-induced landslides were pinpointed. Physical reconnaissance and observation of soil erosion features, coupled with basic soil classification information, were documented during surveys conducted in the identified areas. The impact of the soil erosion process on the affected areas recognized from the erosion features commonly known as sheet, rill, and gully were critically observed. The identification of the soil textural composition namely sand, silt and clay are crucial in determining the risk of landslides caused by erosion. The EI_{ROM} equation as stated in advance was created to gain an acceptable sound erodibility value

relative to other scale of measurements. Duong *et al.* (2019) studied the processes of river bank failure along the red river bank using three distinct bank soil and by modeling both mass failure and undercutting erosion. They found that there was a close relationship between the content of fine-grained particles and soil erosion. The rate of erosion is lowered by an increase in fineness. Majumdar and Mandal (2021) studied on the estimation of river bank erosion risk potential using mechanical and erodibility analysis of soil on the left bank of the Ganga river near Malda district in West Bengal, India. Their results reveal that the erodibility levels increase from high to moderate along an extended left bank line (middle to lower) and fall relatively low along another line on the upper branch of the line according to the ‘ROM’ scale. They concluded that the nature of soil along left bank is dominantly sandy in which promotes vulnerable condition of river bank sites. They also conclude that basic parameters of soil and its mechanical analysis also reveals that unstable condition exists along river bank line but instability condition is increasing from upper to lower segment of bank line. They recommended that the risk of river bank failure can be measured by determining textural composition of soil. Das and Deka (2020) studied on estimating bank erosion vulnerable areas in Kamrup district, Assam, India using ‘ROM’ scale. They observed that most of the soil categories in the study area have soils that have a higher proportion of sand and thus have greater risk of bank collapse. They found sandy soil is recognized as minimal cohesive force and thus more susceptible to erosion and transportation by stream. They established by the ‘ROM’ scale calculation where maximum number of the soil samples was sorted as very high and critical in the degree level of erosion vulnerability and is susceptible to bank failure. They recommended that suitable mitigating methods can be planned for prevention of bank erosion.

The main objective of this study is to categorize the erosion risk potential in terms of particle sizes of bank material.

Methodology

A total of 30 soil samples data has been collected from 6 holes within 6.0 km reach of the left and right bank of Arial Khan River of Bangladesh. The coordinates of the holes of the left bank and right bank have been shown in **Table 2**. The study area and boring layout have been shown in **Fig. 1** and **Fig. 2** respectively. The soil samples have been collected along the holes up to the depth 7.50 m. Here the soil data have been considered up to the depth 7.50 m as the lowest water level near the depth of soil layer. The lowest water level in Arial khan river is (0.13-1.16) mPWD. Particle sizes are analyzed through Laser Diffraction Particle Size Analyzer (Mastersizer 3000). In this study erodibility index has been determined using the $BEI = \frac{\% \text{ Sand} + \% \text{ Silt}}{\% \text{ Clay}}$ and $EI_{ROM} \text{ equation} = \frac{\% \text{ Sand} + \% \text{ Silt}}{2 \times (\% \text{ Clay})}$. Soil erodibility has been categorized using ‘ROM’ scale.

Table 2. Showing the coordinates of boring points along the left and right bank of Arial Khan River.

Left bank	Coordinate (UTM Zone 45N)		Right bank	Coordinate (UTM Zone 45N)	
	Easting(m)	Northing(m)		Easting(m)	Northing(m)
Khas Char Bachamara	204966.44	2589225.30	Sannyasir Char	204142.34	2590445.94
Char Arial Khan	203086.31	2591543.68	Khankandi	205064.15	2587333.27
Bajehar Char	205717.15	2585987.13	UttarcharTajpur	205419.62	2584340.73

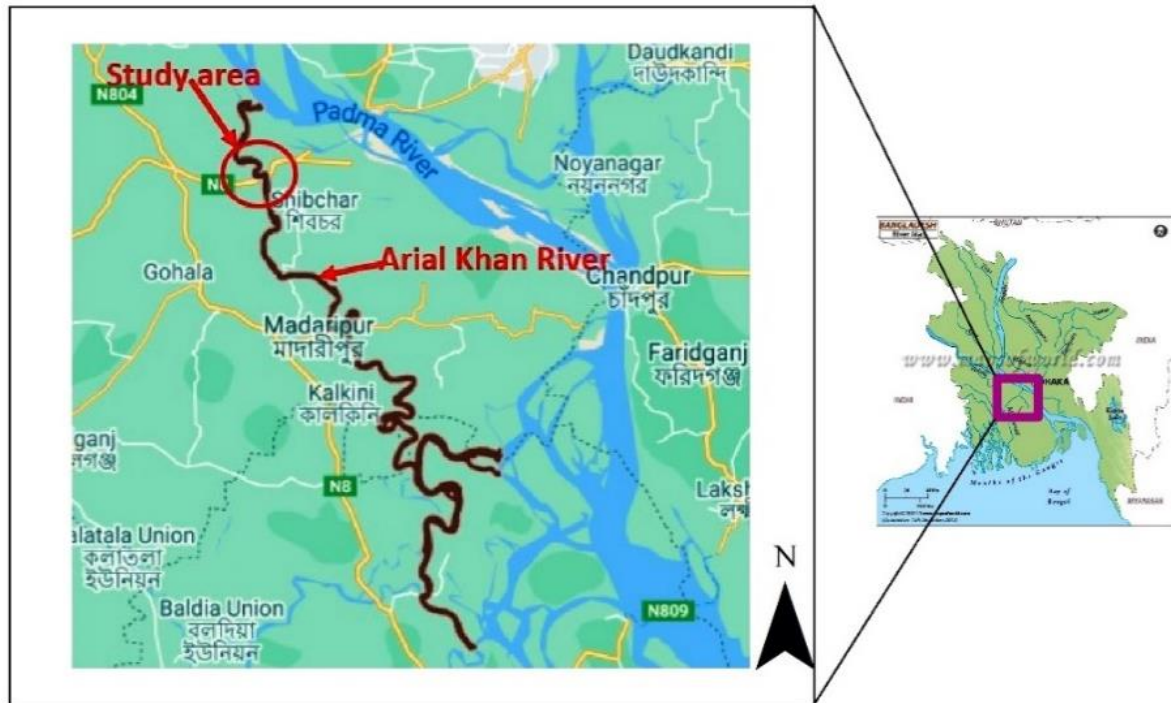


Fig. 1. Study area at and around the Hajji Shariotullah bridge.

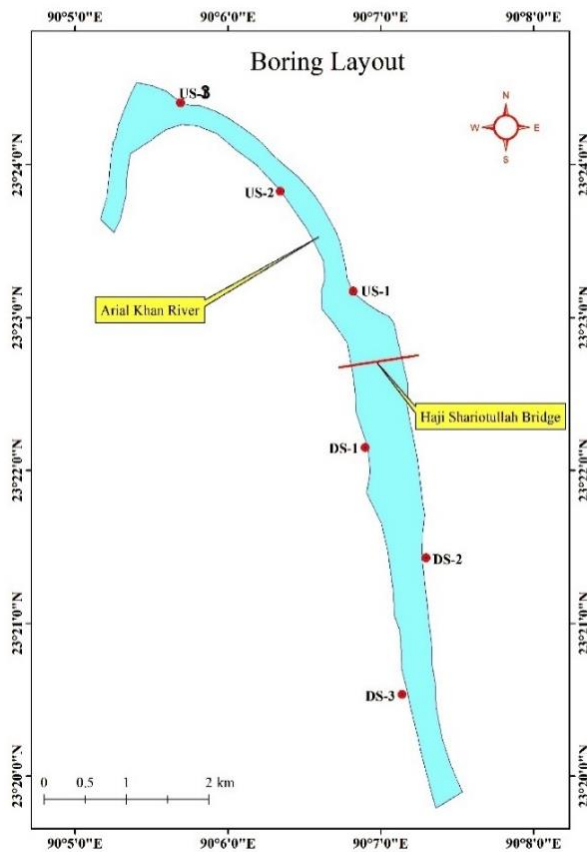


Fig. 2. Boring Layout of the study area.

Results and Discussions

The particle sizes of the soil samples, Bouyoucos erodibility index (BEI) and EI_{ROM} of the left bank of Arial Khan River have been shown in **Table 3**.

Table 3. Showing the percentage of Particle sizes, BEI and EI_{ROM} of the left bank of Arial Khan River.

Left bank of Arial Khan River	Coordinate (UTM Zone 45N)		Depth in m	Particle sizes Analysis			Bouyoucos Erodibility Index (BEI)	EI _{ROM}
	Easting	Northing		Clay in (%)	Silt in (%)	Sand in (%)		
Khas Char Bachamara	204966.44	2589225.30	1.50	5	65	30	19.00	9.50
			3.00	16	82	2	5.25	2.63
			4.50	4	87	9	24.00	12.00
			6.00	4	84	12	24.00	12.00
			7.50	1	27	72	99.00	49.50
Char Arial Khan	203086.31	2591543.68	1.50	4	66	30	24.00	12.00
			3.00	0	26	74	infinity	infinity
			4.50	0	23	77	infinity	infinity
			6.00	0	24	76	infinity	infinity
			7.50	1	35	64	99.00	49.50
Bajehar Char	205717.15	2585987.13	1.50	2	61	37	49.00	24.50
			3.00	1	30	69	9900	49.50
			4.50	0	9	91	infinity	infinity
			6.00	0	24	76	infinity	infinity
			7.50	0	21	79	infinity	infinity

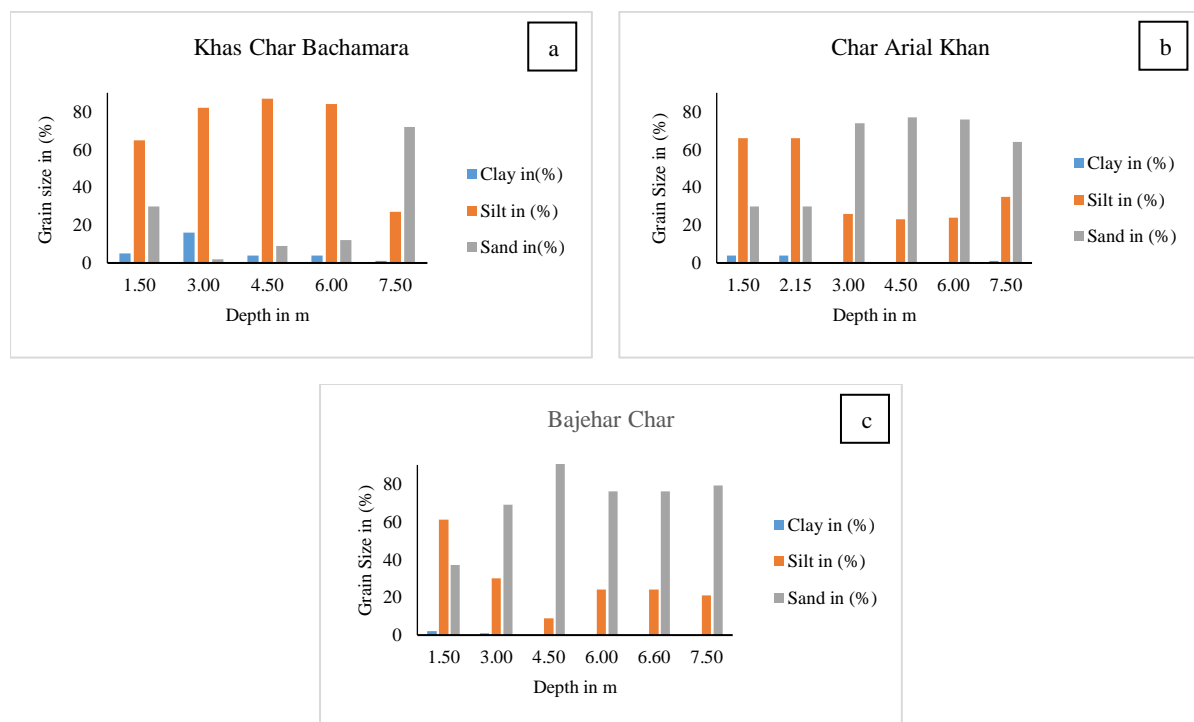


Fig. 3. Showing the Particle Size analysis (a) at Khas Char Bachamara (b) at Char Arial Khan (c) at Bajehar Char.

From **Table 3** and **Fig. 3**, it has been observed that Silt particles dominate at Khas Char Bachamara up to the depth of about 6.0 m and then it consists of Sand layer. On the other hand the layer up to the depth 1.5 m of Char Arial Khan

consists of silt layer and then it consists of Sand layer. However, sand particles dominate at Bajehar Char up to the depth of about 7.5 m except upper layer of depth 1.5 m.

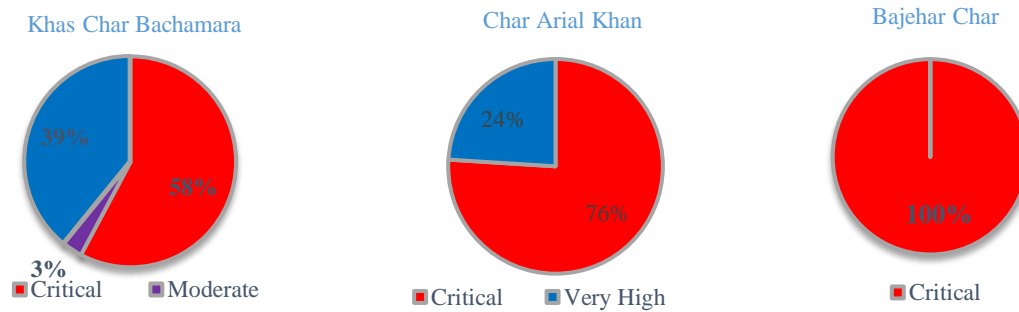


Fig. 4. Illustration of soil erodibility category at Khas Char Bachamara, Char Arial Khan and Bajehar Char.

From **Table 3** and **Fig. 4**, it has been observed that the erodibility index at the bank of Khas Char Bachamara at depth 1.5 m is 9.5 is very high and moderate at depth 3.0 m. However, the erodibility index is moderate to critical at the left bank of Arial Khan River along the bore hole. The erodibility index at the bank of Char Arial Khan is very high to critical at the left bank of Arial Khan River along the bore hole and the erodibility index at the bank of Bajehar Char is

critical along the bore hole. In brief, the left bank of Arial Khan River is very high to critical position in risk of erosion except 3.0 m depth of Khas Char Bachamara which protects the bank from failure for little time. The soil erodibility category in terms of particle sizes has been shown in pie graph in **Fig. 4**. The particle sizes of the soil samples, Bouyoucos erodibility index and EI_{ROM} of the right bank of Arial Khan River have been shown in **Table 4**.

Table 4. Showing the percentage of Particle sizes, Bouyoucos erodibility index and EI_{ROM} of the right bank of Arial Khan River.

Right bank of Arial Khan River	Coordinate (UTM Zone 45N)		Depth in m	Particle Sizes Analysis			Bouyoucos Erodibility Index (BEI)	EI_{ROM}
	Easting	Northing		Clay in (%)	Silt in (%)	Sand in (%)		
Sannyasir Char	204142.34	2590445.94	1.50	4	74	22	24.00	12.00
			3.00	5	65	30	19.00	9.50
			4.50	0	37	63	infinity	infinity
			6.00	0	40	60	infinity	infinity
			7.50	0	34	66	infinity	infinity
Khankandi	205064.15	2587333.27	1.50	0	11	89	infinity	infinity
			3.00	1	70	29	99.00	49.00
			4.50	0	39	61	infinity	infinity
			6.00	0	46	54	infinity	infinity
			7.50	0	30	70	infinity	infinity
Uttarchar Tajpur	205419.62	2584340.74	1.50	1	44	55	99.00	49.50
			3.00	6	86	8	15.67	7.83
			4.50	5	81	14	19.50	9.50
			6.00	3	84	13	32.33	16.17
			7.50	5	81	14	19.00	9.50

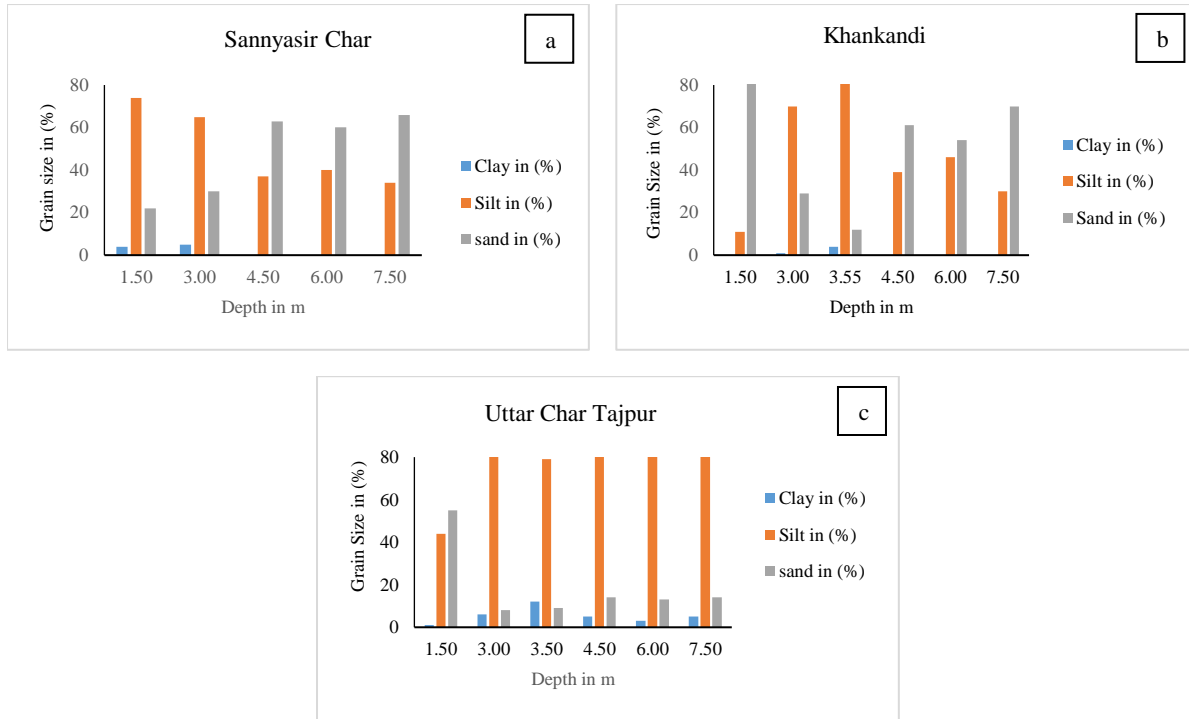


Fig. 5. Showing the Particle Size Analysis (a) at Sannyasir Char (b) at Khankandi (c) at Uttar Char Tajpur.

From Table 4 and Fig. 5, it has been observed that Silt and Sand particles dominate at Sannyasir Char and Khankandi up to the depth of exploration. whereas Silt particle dominates at

Uttar Char Tajpur except the upper layer of about 1.5 m which consists of Silt and Sand layer.

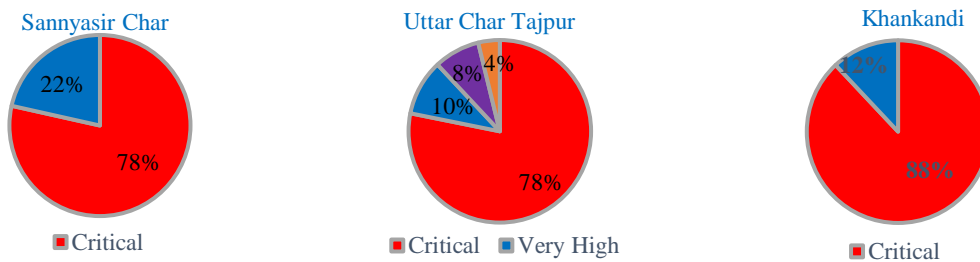


Fig. 6. Illustration of soil erodibility category at Sannyasir Char, Khankandi & Uttar Char Tajpur.

From Table 4 and Fig. 6, it has been observed that the erodibility index at the bank of Sannyasir Char is very high to critical at the right bank of Arial Khan River along the bore hole. The erodibility index at the bank of Khankandi is critical at the right bank of Arial Khan River along the bore hole and the erodibility index at the bank of Uttar Char Tajpur is high to critical along the bore hole. In brief, the right bank of Arial Khan River is high to critical position in risk of erosion.

Conclusions

It has been observed from the left bank of Arial Khan River that Silt particle dominates at Khas Char Bachamara up to the depth of about 6.0 m and then it consists of Sand layer. On the other hand the layer up to the depth 1.5 m of Char Arial Khan consists of Silt layer and then it consists of Sand layer. However, Sand particle dominates at Bajehar Char up to the depth of about 7.5 m except upper layer of depth 1.5 m.

The erodibility index has been observed at the bank of Khas Char Bachamara at depth 7.5 m is critical and moderate at depth 3.0 m. However, the erodibility index is moderate to critical at the left bank of Arial Khan River along the bore hole. The erodibility index at the bank of Char Arial Khan very high to critical at the left bank of Arial Khan River along the bore hole and the erodibility index at the bank of Bajehar Char is critical along the bore hole. In brief, the left bank of Arial Khan River is very high to critical position in risk of erosion except 3.0 m depth of Khas Char Bachamara which protects the bank from failure for little time.

It has been observed from the right bank of Arial Khan River that Silt and Sand particle dominate at Sannyasir Char and Khankandi up to the depth of exploration whereas Silt particle dominates at Uttar Char Tajpur except the upper layer of about 1.5 m which consists of Silt and Sand layer. The erodibility index has been observed at the bank of Sannyasir Char is very high to critical at the right bank of

Arial Khan River along the bore hole. The erodibility index at the bank of Khankandi is critical at the right bank of Arial Khan River along the bore hole and the erodibility index at the bank of Uttar Char Tajpur is high to critical along the bore hole. In brief, the right bank of Arial Khan River is high to critical position in risk of erosion. The study result can help a design Engineer. However, it is recommended here that full geotechnical investigation is needed to prevent the erosion of the river banks.

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