Assessing the bridge construction effect on river shifting characteristics through geo-spatial lens: A case study on Dharla River, Bangladesh

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ABSTRACT

The key objective of the bridge structure on a river is to confirm and assist the continual communication. On the other hand, it also has a harmful effect on the hydrological and morphological behavior of the neighboring zone as of the river width contraction. The present study assessed the Bridge construction effect on river shifting characteristics for Dharla River. For doing so, this study followed two steps. First, Landsat imageries for both pre-bridge structure period (1988, 1993 and 1998) and post-bridge structure period (2003, 2008, 2013 and 2017), has been processed and used to determine the thalweg line. Then, geo-spatial environment has been used to assess the thalweg line shifting characteristics and channel width variations. The results revealed a frequent shifting of thalweg line towards both the east and west direction at the upstream side of this Bridge and also the dominating eastwards shifting at the downstream side of the Bridge. After constructing the Dharla Bridge on Dharla River (i.e. post-bridge structure period) the movement of the channel has been changed at a significant level. Particularly, it has been found that the east side shifting is higher than the west side. Thus, the existing of Dharla Bridge has an abundant effect on the shifting characteristics of thalweg line. The study concluded that the shifting of the thalweg lines of Dharla River undergoes a drastic change of study period and the River can be treated as a very dynamic one. The results of this study might supportive for the sustainable and future development of the rivers and adjacent flood plain in Bangladesh.

1. Introduction

The rivers systems play an important role to mobilize the environment and ecological balance of specific regions (Arsenault et al., 2015). The river bank shifting are the main geomorphological process of a fluvial system (Wang et al., 2016). The bank shifting of river can be considered as the result of the change of the water flow of the river and over many years the river is having drastic shifting of its banks (Best et al., 2007). A flowing river is always dynamic and therefore anti-erosion measure can never be stable for a long time (Mitra, 2015). The change of the flow of the river as well as the change of the river bank mostly has drastic effects on the people of the riverside (Bose and Navera, 2017). The river channel migration through time and space is very important considering many river management problems (Pal et al., 2017). River may be shifted for various reasons. The geomorphic shifting of river channel can result from many factors with floods, crustal movement, channelization etc. (Hohenninger et al., 2018). However, the major changes in the river morphology can be seen right after large floods, especially in tropical areas of the world (Saleem et al., 2020). Once more, constructing the structure such as damming or bridges over it can be another way of the shifting river banks as it reduced flood area of water way (Lin, 2011; Biswas, 2010; Madej et al., 1994). In that case the thalweg lines play a great role to shape the direction of river bed. The thalweg lines are the deepest flow path of the main stream of the river. Immovability of the thalweg lines is a collective effect of geological controls (consequence of the geological edifice) in the channel (Falowski et al., 2018). With the continuation of the previous knowledge, our south Asian/third world Country (Bangladesh), the study on River shifting of thalweg line is very important.

Bangladesh is a riverine country and vulnerable to affect with acute inundating as it is located at the confluence of three mighty rivers called the Ganges, Brahmaputra, and Meghna. As a result, river inundating due to flood and bank shifting by erosion are common natural disasters that rigorously affect the land, lives and economy of the country (Hossain et al., 2020; Bose and Navera, 2017; Best et al., 2007). But recently, in Bangladesh Bridge construction has a great effect on the dynamics of

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morphological characteristics of River as an on river bed and width changes, bank shifting, and land use change etc. (Islam et al., 2017; Kauser et al., 2015). As bridge is the man made structure and it has a major effect on the changing characteristic of river morphology (river bank shifting, width changing etc.), much more study is necessary to see its effect analyzing by satellite imagery, experimentally, simulating, and also field measurement (Biswa, 2010; Madej et al., 1994). If we cannot manage bridge construction effect on the river the flow path of the river will be shifted prominently and the river channel will eat into the surrounding flood plain by losing huge amount of civilized and cultivated land (Bose and Navera, 2017). Therefore, the assessing of the pre- and post-bridge construction effect on river shifting characteristics is very important to visualize the actual fact in Bangladesh.

In Bangladesh, Dharla River, one of the trans-boundary rivers patented in the Himalayas, alongside with Brahmaputra River has a great effect on the recurring inundations and erosion in north-western side. Approximately, in each year, excessive erosion and embankment damages caused by Dharla. It makes thousands of general people become homeless with massive loss of crops, lands and houses etc. Another source of misery is an erosion of banks, which brings in the destruction of lives and properties, damage of engineering works etc. (Mamun and Sobnam, 2021; Winkley et al., 1994; Nagata et al., 2014). It enters Bangladesh through the Lalmonirhat District and maximum depth of the river is 3.7 m and maximum depth is 12 m, in the origin of Kurigram (FFWC, 2012). According to Local Government Engineering Department (LGED), Dharla Bridge (25° 49’ 9.7” N, 89° 40’ 5.2” E) has been started to construction on 24 February 2000 and opened on 21 December 2003.

Dharla River, a trans-boundary river crossing over Kurigram district, is shown in Figure 1. It originates in the Himalayas where it is known as the Jaldhaka River, and then it flows through the Jalpaiguri and Cooch Behar districts of West Bengal, India, one of the seven main rivers to do so. It enters Bangladesh through the Lalmonirhat District and flows as the Dharla River until it empties into the Brahmaputra River near the Kurigram District. The average depth of the river is 3.7 m and maximum depth is 12 m, in the origin of Kurigram (LGED, 2012). According to Local Government Engineering Department (LGED), Dharla Bridge (25° 49’ 9.7” N, 89° 40’ 5.2” E) has been started to construction on 24 February 2000 and opened on 21 December 2003.

Dharla Bridge is located over the Dharla River near Kurigram district town at 3 km of Kurigram-Nagenshwar-Bhurungamari Road. The total length of the bridge is 648 m and width are 10 m. The bridge has 17 spans. The Bridge includes approach roads of length 1.92 km at Kurigram side and 1.4 km at Pateswari side. It has 16 piers. In the general case of the construction of the piers hampers the natural flow of the river, thus situation happens. Such bridge pier alters river shifting process, also increases the supply of silt locally (FFWC, 2012).

### 2. Methodology

#### 2.1. Study area

Dharla River, a trans-boundary river crossing over Kurigram district, is shown in Figure 1. It originates in the Himalayas where it is known as the Jaldhaka River, and then it flows through the Jalpaiguri and Cooch Behar districts of West Bengal, India, one of the seven main rivers to do so. It enters Bangladesh through the Lalmonirhat District and flows as the Dharla River until it empties into the Brahmaputra River near the Kurigram District. The average depth of the river is 3.7 m and maximum depth is 12 m, in the origin of Kurigram (FFWC, 2012). According to Local Government Engineering Department (LGED), Dharla Bridge (25° 49’ 9.7” N, 89° 40’ 5.2” E) has been started to construction on 24 February 2000 and opened on 21 December 2003.

LGED implemented the Dharla Bridge project. The Dharla Bridge is located over the Dharla River near Kurigram district town at 3 km of Kurigram-Nagenshwar-Bhurungamari Road. The total length of the bridge is 648 m and width are 10 m. The bridge has 17 spans. The Bridge includes approach roads of length 1.92 km at Kurigram side and 1.4 km at Pateswari side. It has 16 piers. In the general case of the construction of the piers hampers the natural flow of the river, thus situation happens. Such bridge pier alters river shifting process, also increases the supply of silt locally (FFWC, 2012).

#### 2.2. Data collection

The GIS data are frequently used to form the historical thalweg line shifting map of the river (Falkowski et al., 2018). Several studies have been done for investigates the bank erosion, bank shifting, and deposit of the river by using GIS (Bilah, 2018; Saleem et al., 2020; Best et al., 2007; Pal et al., 2017). To proceed with the research the secondary data such as Landsat imageries of 30 m resolution was collected from USGS Earth-Explorer () and USGS GloVis () for approximate 16 km length of Dharla River. We have used interactive tracing digitization method in GIS for digitization of the images. The highest level of zooming was used and the zooming level was same for every years. The data which include Landsat 7 ETM + for all the selected year’s corresponding to the dry season (January) only. The dry season image data for the seven years, pre-bridge (1988, 1993 and 1998) and post-bridge structure (2003, 2008, 2013 and 2017) were selected because such data were free of cloud cover and topographic seasonal variations (Table 1). Nature of any rivers are always uncertain. Many other parameters can be considered to get better results. But our collected satellite images are acquired in almost same times in dry season (for all years in January). In that way we have fixed the seasonal error issues to get the accurate images.

From May 31, 2003, Landsat-7 ETM+ had scan line fault, due to failure of Scan Line corrector (SLC), so the image data type was erroneous. There were some techniques to improve the quality of the images.
In this study, ERDAS IMAGINE-2014 software was used for focal analysis to compensate errors. This method was designed to modify neighboring pixels in a single Landsat 7 SLC-off scene, creating a final aesthetic image.

### 2.3. Setting of reference lines

The downloaded raster images from the USGS EarthExplorer and USGS GloVis were imported in ArcGIS. After that the 8 Reference lines A, B, C, D, E, F, G, and H were drawn over the river which divides it on 8 sections (Figure 2). The setting of reference lines with coordinate were considered with respect to substantially detected critical point by using priority ranking tools for better visualization of the river (Table 2) and also for ease of investigation (Mohammad et al., 2014; Takagi et al., 2007). The approximate distance (in km) between the reference lines A-B, B-C, C-D, D-E, E-F, F-G, and G-H are 2.00, 2.00, 1.65, 1.50, 1.15, and 1 respectively. The position of bridge is between the reference line C and D. Considering the position of the bridge, the reference line A, B and C are in upstream side of the bridge and rest of the reference lines (D, E, F, G, and H) are in downstream side. From the literature review and expert opinion, it was perceived that the morphological changing pattern of a river was larger in the downstream side than the upstream side from river crossing structures (Islam et al., 2017; Kauser et al., 2015). Thus, we have selected three sections at the upstream side and five sections at the downstream side of the river from bridge site.

The approximate distance of upstream reference line of A, B, C from the bridge position are 5 km, 3 km, 1 km respectively and on the other hand the downstream reference line of D, E, F, G, H from the bridge position are 2.5 km, 4 km, 5.15 km, 6.15 km respectively. The section line of right bank and left bank were drawn for the pre-bridge (1988, 1993 and 1998) and post-bridge structure period (2003, 2008, 2013 and 2017). After that central line of 1988 was taken as the main reference line to measure the shifting of the Thalweg lines for rest of the study years. Then, the east bank to west bank river channel widths were calculated by using Cartesian coordinate method in ArcGIS tools with its basic geom-etry (Mohammad et al., 2014; Saleem et al., 2020). The thalweg line of the river has been acquired from the corresponding imageries for the study period by using an external extension on ArcGIS tools called the Polygon to centerline (Mohammad et al., 2014). Then, the geo-spatial environment tools (visualizing platform of the spatial data through GIS and Remote Sensing) were used to see the change of the river shifting behavior easily. All the works on software related was prepared by the third author.

So, the historical bank shifting map was formed for Dharla River. The measured values of shifting were plotted in excel taking the eastward

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**Table 1. Description of secondary data used.**

| Satellite | Satellite Sensor | Spectral Bands | Scale/resolution | Acquisition date | Path/Row | Source |
|-----------|------------------|----------------|------------------|------------------|----------|--------|
| Landsat 7 | Landsat 7 ETM+   | 30 m           | 1/25/1988        | 138/42           | USGS     |
| Landsat 7 | Landsat 7 ETM+   | 30 m           | 1/22/1993        | 138/42           |          |
| Landsat 7 | Landsat 7 ETM+   | 30 m           | 1/20/1998        | 138/42           |          |
| Landsat 7 | Landsat 7 ETM+   | 30 m           | 1/26/2003        | 138/42           |          |
| Landsat 7 | Landsat 7 ETM+   | 30 m           | 1/16/2008        | 138/42           |          |
| Landsat 7 | Landsat 7 ETM+   | 30 m           | 1/5/2013         | 138/42           |          |
| Landsat 7 | Landsat 7 ETM+   | 30 m           | 1/8/2017         | 138/42           |          |

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**Figure 1.** Study area showing Dharla River and Dharla bridge.
throughout the years (Figure 3).

Figure 2. Thalweg line shifting plot for the pre (1988, 1993, 1998), and post (2003, 2008, 2013, 2017) bridge construction period.

Figure 3 shows the bar diagrams for Thalweg line shifting for different condition thalweg line (1988), the towards the eastward and westward shifting is visible. From this figure it is also revealed that the thalweg line shifting is expanded gradually from the section D to E and then between the section E and F it was great oscillation. Then, it can be concluded that the shifting of the thalweg lines of Dharla River undergoes a drastic change of the corresponding years. From these shifting it is decided in this investigation that Dharla River is a very dynamic one. Alike, as the other research (Bose and Navera, 2017) also reveals that the path of the Dharla river is shifted enormously ever since 1987 to 2017 due to the erosion.

3. Results and discussion

3.1. Development of thalweg line shifting map

The raster images of the Dharla are imported in ArcGIS and the east and west bank lines are drawn. Then the central lines which are the flow lines of the main stream for each year of the river are drawn. These central lines are called the thalweg lines (Falkowski et al., 2018) of the River. The thalweg lines shifting map were drawn for the Dharla River from which are shown by Figure 2 before Dharla Bridge construction since 1988, 1993, and 1998, and then after as 2003, 2008, 2013 and 2017.

From Figure 2, it is revealed that at A westward side shifting was found for the post–bridge construction year (2008, 2013 and 2017), and eastward side shifting was visible for pre-bridge construction period (1993 and 1998). At B eastward side movement was seen but for C it was westward. After the reference line D (i.e. downstream of the Bridge), a large variation of shifting was noticed. On the other hand just before D and upto B (i.e. upstream of the Bridge) the variation is not exhibited so much. The highest shifting towards west bank side was found for the year 2013 at E and F (post-Bridge). The lowest was found for the year 2003 (just opening year of the bridge) at E towards west bank side and at F (towards east bank side) for the year 1993 and 1998 (pre-Bridge). For the all years not so much changes has been observed along the reference line G. Far away from the bridge at H shifting was observed towards the east bank side for the years 2008, 2013 and 2017 but for then year 1998 no changes occurred, and for the 2003 towards the west bank side shifting is visible. From this figure it is also revealed that the thalweg line shifting is expanded gradually from the section D to E and then between the section E and F it was great oscillation. Then, it can be concluded that the shifting of the thalweg lines of Dharla River undergoes a drastic change of the corresponding years. From these shifting it is decided in this investigation that Dharla River is a very dynamic one. Alike, as the other research (Bose and Navera, 2017) also reveals that the path of the Dharla river is shifted enormously ever since 1987 to 2017 due to the erosion.

3.2. Measurement of thalweg line shifting

Measurement of thalweg line shifting has been displayed on Figure 3 and Table 3. The thalweg line for 1988 has been taken as base (i.e., 0) condition for shifting calculation for the rest of the years. From the base condition thalweg line (1988), the towards the eastward and westward side shifting is considered as positive and negative value respectively. Figure 3 shows the bar diagrams for Thalweg line shifting for different sections as (a) reference line A, (b) reference line B, (c) reference line C, (d) reference line D, (e) reference line E, (f) reference line F, (g) reference line G, and (h) reference line H. The bridge location is in between the reference line C and D. Measurement of thalweg line shifting from the constructing map has been completed by using the ArcGIS tools (Table 3). Considering the position of the bridge, the reference line A, B and C are in upstream side of the bridge and rest of the reference lines (D, E, F, G, and H) are in downstream side.

At reference line A, which is approximately 5 km away from the bridge, there a significant transformation of the thalweg line is observed. Before the construction of the Bridge (years. 1988, 1993 and 1998), the thalweg line was moving towards west bank side (410 m and 182 m for the year 1993 and 1998 respectively). The thalweg line was started to shift eastward bank side (a gradual increment of the shifting as an amount 201 m in 2003, 182 m in 2008, 494 m in 2013, and 1147 m in 2017) after the Bridge construction (Figure 3a). On reference line B (Figure 3b) which is 3 km away from the bridge, the thalweg line is observed not steady. The thalweg lines of after the year 1993 (pre-bridge) were shifting in the west direction except 2013. But in the year 1993

Table 2. Setting of reference lines.

| Reference Lines | West side Position (x, y) | East side Position (x, y) |
|-----------------|---------------------------|---------------------------|
| A               | 25.86587N, 89.62853E      | 25.86395N, 89.73567E      |
| B               | 25.84715N, 89.62699E      | 25.84513N, 89.73214E      |
| C               | 25.83085N, 89.61721E      | 25.82975N, 89.74354E      |
| D               | 25.81588N, 89.61720E      | 25.81362N, 89.73965E      |
| E               | 25.79920N, 89.61669E      | 25.79698N, 89.73747E      |
| F               | 25.76655N, 89.61509E      | 25.76454N, 89.73223E      |
| G               | 25.77749N, 89.62803E      | 25.77565N, 89.74202E      |
| H               | 25.76614N, 89.62957E      | 25.76391N, 89.74212E      |

2.4. Procedure for analyzing the shifting characteristics

The assessing of the shifting characteristics of the Dharla River was performed based on the conducts as:

- The degree of shifting of the river for different years: From the historical bank shifting map which was formed by ArcGIS and represented through bar diagram of Dharla River for pre-bridge (1988, 1993 and 1998) and post-bridge construction period (2003, 2008, 2013 and 2017) are used to analyze the point of shifting of the river.
- Changes of river width for different years: The changes in river widths of different years are determined using the ArcGIS tools.
- Changes of river width for different years: The degree of shifting of the river for different years: From the historical bank shifting map which was formed by ArcGIS and represented through bar diagram of Dharla River for pre-bridge (1988, 1993 and 1998) and post-bridge construction period (2003, 2008, 2013 and 2017) are used to analyze the point of shifting of the river.
The high increasing trend of positive shifting (1236 m for the year 1993) to the east bank side was observable. At reference line C (Figure 3d), which is just upstream side of the bridge's position, 1 km away from the Bridge, it is detected that the degree of the shifting of thalweg line is very prominent. The thalweg line was moving towards eastward (maximum 466 m in 1998) before bridge construction. Suddenly, it started to shift westward till post-bridge period 2008 (maximum shifting 323 m) and again eastward for 2013 and 2017 (post-bridge) as a quantity of 111 m and 95 m respectively.

The reference line D is 0.65 km away from the Bridge and it is observed that the thalweg line is shifting toward the left bank side only for all the years (Figure 3d) and the shifting pattern is gradually increasing trend. But at the year 2000, the year of the construction of bridge, the shifting of the thalweg line proceeds an abrupt growing. The maximum thalweg line shifted about 723 m was noticed for the year 2013 (post-bridge). On reference line E (2.5 km away from the bridge) (Figure 3e) the thalweg line shows an utmost growing trend. For all the years the positive shifting of thalweg line (maximum 2603 m at 2017) was seen. Once more, for reference line F (4 km away from the bridge) (Figure 3f), the shifting of the thalweg line becomes significant enough considering the construction of the Bridge. Not only the thalweg line changed its direction but also it underwent a huge increment of shifting to eastward. The maximum positive shifting (i.e. towards east direction) has been found around 2359 m for the year 2013 (post-bridge). On the other hand, before construction of the bridge, the negative shifting (i.e. towards west side bank) was observed (maximum 395 m in 1993). At reference line G (5.15 km away from the bridge) (Figure 3g) the shifting of the thalweg line is positive value for all over the years. The maximum east side shifting was 438 m for the year 2017 (widespread time away after the construction of bridge) and 259 m for the year 1993 (before the construction of bridge). At reference line H (6.15 km away from the bridge) the thalweg line became very significant from the year 1993–2003 moving to east bank direction at a highest increasing rate.

![Figure 3. Bar diagrams for Thalweg line for (a) reference line A, (b) reference line B, (c) reference line C, (d) reference line D, (e) reference line E, (f) reference line F, (g) reference line G, and (h) reference line H.](image-url)
But after the year 2006 it changed its direction rightward (maximum 317 m in the year 2011) suddenly (Figure 3b). Study of channel shifting near Ngawun bridge on Ngawun River (Thu et al., 2018) shows that the river shifted to the westward in upstream and eastward in downstream of the bridge between the years 2001–2016 and the changes of river channel on that year were very dynamic and unstable.

Over all, it can be said that upstream side of bridge (at sections A, B and C) there was a frequent shifting was observed towards both the east and west side for all overs the study period. On the other hand, the downstream side of bridge (at D to H), the dominate east side movement was seen except at section E and H. Further, before construction of Bridge the almost eastside shifting was revealed at the sections B, C, D, E, G, and H, and the west side shifting was seen at A and F. Moreover, after construction of Bridge east ward movement was observed at section A, D, E, F, G, H and west side was seen at B, C, H (Table 3). Also, it is found that the eastward shifting is higher than westward shifting. Thus, it can be concluded that the existing of Dharla Bridge over the Dharla River has an abundant effect for the shifting characteristics of thalweg line. The study (Ch et al., 2017) detected that the negative values represent a shift due to erosion process along the channel Bankline, while the positive values show shifting due to deposition. The previous study on Dharla River (Bose and Navera, 2017) shows that the upstream west bank and east bank has been shifted to the outwards and inwards respectively. The downstream east bank has been shifted outwards resulting erosion and the west bank has been shifted inwards. The middle part of the river has seen to be more stable. Moreover, according to the study on lower part of river Niger (Ibitoye, 2021), the nature of the river channel centerline was not constant both at the left and right flange of the river flow paths throughout the years as the centerline shifted towards the east in the earlier years of study (1990–2002) but migrated greatly in the later years of study (2002–2017) in the westward direction. They also found that the shifting of the bank line was abundant to eastwards at right flange and westwards at the left flange.

### 3.3. Construction of river width changes map

The construction of Dharla River width changes map is shown in Figure 4 and Table 4 (using the shapefiles drawn in ArcGIS by the raster images) for the years (approximately 5 years interval) pre-construction (1988, 1993, 1998) and post-construction (2003, 2008, 2013, 2017) respectively.

From these figures it is demonstrated that for some specific places of the River, the River width is decreasing gradually and those are started immediately after the bridge pier construction. The decreasing of the

![Figure 4. Dharla River width changes map since pre ((a) 1988, (b) 1993, (c) 1998), and post ((d) 2003, (e) 2008, (f) 2013, (g) 2017) bridge construction period.](image-url)
River width is related with the construction of pier as the depth of river has been decreasing. Also, in the years 1993 and 1998 (pre-construction) width was not so much changes except at section B and C. But in the years 2003 and 2008 (post-construction) there was a greater change of width at the downstream side of the bridge. So, it can be said that the construction of the Bridge has some effect for width variation of the Dharla River.

3.4. Measurement of river width changes from the constructing map

The ArcGIS tools has been used for the measurement of the River width changes from the constructing map (Table 4). The bar diagram for Dharla River width changes along the (a) reference line A, (b) reference line B, (c) reference line C, (d) reference line D, (e) reference line E, (f) reference line F, (g) reference line G, (h) and reference line H has been presented on Figure 5.

In the years of pre-construction (1988, 1993, 1998) and post-construction (2003, 2008, 2013, 2017) the river width fluctuates between (153 m–439 m, 87 m–330 m, 121 m–360 m) and (72 m–303 m, 145 m–306 m, 116 m–432 m, and 102 m–334 m) respectively. The total width for all the sections varies from 1444 m in the year 2017–2488 m in the year 1988. So, it can conclude that the width has a reducing shape after construction of Dharla Bridge. For more specific understanding, Table 5 has been prepared by using this table which shows the reducing/increasing of the width for the Dharla River for all-reference lines.

Lengthways the section A (Figure 5a) the river width gradually decreases (varies from 109 m to 330 m), and the more decreasing pattern are seen just after the construction of bridge. Along section B (Figure 5b), there is an abrupt change of width for year 2003 but then it was started to increase and continue to hold around as around equivalent width. The width varies from 72 m (in the year 2003) to 350 m (in the year 2013). On the nearest section of the Bridge at upstream, the section C which is shown in (Figure 5c), the river width is affected badly by the construction of bridge pier as the abrupt change in river width happening just after the construction. The width varies from 102 m (in the year 2003) to 360 m (in the year 1998). At the downstream of the bridge, along the section D (Figure 5d) the changes of river width is significant as it is gradually reducing its width (varies from 265 m (in 2017) to 350 m (in 1998)). Lengthwise the section E which is shown in (Figure 5e) the changes in the River width are not very significant except the abrupt changes seen in the year 2003. The width varies from 132 m (in the year 1993) to 345 m (in the year 1998). Alongside the section F (Figure 5f) the River width changes are not predictable. The width varies between 87 m (in the year 1993) to 432 m (in the year 2013). Along the section G (Figure 5g) the river width change is predictable as it is gradually decreasing (changes from 140 m (in year 2017) to 270 m (in year 1988)). Figure 5h shows that along the section H the river is very stable with respect to its width. The variation of width shows behaviour as like a deteriorating convex curve. The width varies from 150 m (in the year 2017) to 439 m (in the year 1988). The temporal channel width changes exposed small in the years from 1960 to 2000 for the study (Takagi et al., 2007) on the braided-belt channel width of Brahmaputra River, Bangladesh.

Table 5 shows the tabular form of difference in channel width changes between the years 1988–93, 1993–98, 1998–2003, 2003–08, 2008–13, 2013–17, and 1988–2017 along all reference lines. From the table the following results have been found. In 1988–1993 at all sections the percentage reduction of channel width observed (maximum reduction was 10.21% at F and minimum 0.40% at A). The maximum width reduction 8.43% at A and minimum (0.97%) at G, where maximum increase was observed at E (12.14%) and minimum 1.14% at D for the year 1993–98. For the years 1998–2003 almost at all sections the reduction of
width (maximum 10.61% at C and minimum (1.15%) at G) was visible except F (increased by 5.28%). The maximum width increased 15.55% at B and minimum 0.93% at A for the time period 2003–08 and also in this period a nominal width decrease was observed at D, E, G and H. For the year 2008–2013 the width was increased by 6.94% at F and decreased at D by 0.22%. In 2013–2017 at all sections the percentage reduction of channel width detected (maximum reduction was 12.93% at F and minimum 0. 36% at A). In the last row of table for the whole years from 1988–2017, it observed that almost at all sections the decrease of width (maximum 17.87% at H and minimum 5.33% at D) was noticeable except at B and E (increased by 5.61% and 0.48%). Over all, it can be said that a maximum of width changes 10.21% was observed for 1993–98 (before construction of the Bridge) at F and increase of 12.14% at E, and the reduction of width changes was not significant for the year 2003–08 (after construction of the Bridge) but increasing of 15.55% at B was observed. According to the study on lower part of river Niger (Ibitoye, 2021), the river channel width was showed diverse reduction and growth at various indicated sections of the channel reach.

4. Discussions

The current study assesses the Bridge construction effect on river shifting characteristics for Dharla River by using Landsat imageries for both pre (1988, 1993 and 1998) and post-bridge construction stage (2003, 2008, 2013 and 2017). The geo-spatial tools have been used to accomplish the study. The goal of this study was executed based on the techniques as per: i. development of thalweg line shifting map and then measure the shifting, and ii. construction of river width changes map and them estimate the width changes for perilously mentioned years. The main outcomes of this study work are as:

On 3 km, 1 km from upstream side of bridge, and 0.65 km, 2.5 km, 5.15 km, and 6.15 km from downstream side of bridge the eastside shifting was revealed, and westward shifting at 5 km upstream side and 4 km downstream side of the bridge for pre-Bridge construction period. The eastward movement was observed at 3 km from upstream side of bridge, and 0.65 km, 2.5 km, 4 km, 5.15 km, and 6.15 km from downstream side of bridge, and west side at 3 km, 1 km from upstream side afterward post-Bridge construction period.

The greater thalweg line shifting was observed on the sections at 2.5 km and 4 km away from the downstream site of the bridge a maximum amount of 2603 m and 2359 m respectively. Subsequently, major protective action should take by the authority on that critical section from further longtime land loses from the shifting the river which will stimulus on social life and economic life on the river side peoples. Thus, the thalweg line shifting of Dharla River undergoes an extreme amendment in the post-bridge construction period and it is obvious that Dharla River is a very dynamic one. The study on Dharla River (Bose and Naveen, 2017) shows that the upstream west bank and east bank has been shifted vastly to the outwards and inwards respectively. But their study did not consider the bridge construction influence over the river.

In the pre-bridge construction years 1993 and 1998 the width was remained almost unchanged. But in the post-bridge construction years 2003 and 2008 there was a big change has been found on width at the downstream side of the bridge. The width varies from 150 m (in the year 2017) to 439 m (in the year 1988). Thus, the construction of the Bridge has serious effects on width variation of the Dharla River. The decrease of the river width is interrelated with the construction of bridge pier (Biswa, 2010). The variation of width shows behaviour as like a deteriorating convex curve.

5. Conclusions

This study assesses the Dharla Bridge construction effect on river shifting characteristics for Dharla River in north-western side of Bangladesh for past 29 years for both pre (1988, 1993 and 1998) and post-bridge construction phase (2003, 2008, 2013 and 2017). The Landsat imageries were used to assess the thalweg line shifting characteristics and channel width variations (at the eight reference lines) by using ArcGIS software. A frequent shifting of thalweg line towards both the east and west direction at the upstream side of the Bridge and the dominating eastwards shifting at the downstream side of the Bridge were observed for all over the study periods. The greater thalweg line shifting was observed on the sections at 2.5 km and 4 km away from the downstream site of the bridge maximum amount of 2603 m and 2359 m respectively. Therefore, major protecting act ought to take by the authority on that critical section from further longtime land loses from the shifting the river and the impact on social life on river side people will be abated. Additionally, the east side shifting was seen higher than west side and the existing of Dharla Bridge has an abundant effect on the shifting characteristics of thalweg line. The study also revealed that a maximum decrease width change (10.21%) was before construction of the Bridge at 4 km from downstream side of bridge and increase (12.14%) at from downstream side of bridge, and the reduction of width changes was not significant after construction of the Bridge, but increasing (15.55%) at from upstream side of bridge.

The study can be useful for taking needed actions to improve and sustain the embankment to minimize erosion loses in upcoming period. The recommendation goes that the proper dredging should be done in the Dharla River for proper maintenance of the river especially downstream of the bridge the river as the shifting behavior is very high. For the regions with low dynamic nature, vegetation process can be applied to stabilize the river shifting. The study can be more accurate if shifting
characteristics of all the points can be investigated. For further study, field survey for more practical data and flood data are recommended to be analyzed.

Declarations

Author contribution statement

Md. Jahir Uddin: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.
Md. Nazmul Haque: Analyzed and interpreted the data; Wrote the paper.
Md. Atik Fayshal: Performed the experiments; Contributed reagents, materials, analysis tools or data.
Dipto Daku: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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References

Arsenault, M.P., Azam, M.N., Ahmad, S., 2015. Riverbank erosion and migration in Bangladesh’s Char lands. In: Mallick, B., Etzold, B. (Eds.), Environment, Migration and Adaptation: Evidence and Politics of Climate Change in Bangladesh, first ed., pp. 41-62.

Best, J.L., Ashworth, P.J., Sarker, M.H., Roden, J.E., 2007. The Brahmaputra-Jamuna River, Bangladesh. In: Gupta, A. (Ed.), Large Rivers: Geomorphology and Management, pp. 395-430.

Bhalak, L., Dubey, B., Sarma, A.K., 2005. Estimation of bank erosion in the river Brahmaputra near Agaythuri by using geographic information system. J. Ind. Soc. Rem. Sens. 33 (1), 81-84.

Billah, M.M., 2018. Mapping and monitoring erosion-accrretion in an alluvial river using satellite imagery—the river bank changes of the Padma River in Bangladesh. Geograph. Quest. 37 (3), 87-95.

Biswas, S.K., 2010. Effect of bridge pier on waterways constriction: a case study using 2-D mathematical modelling. In: IABSE-JSCE Joint Conference on Advances in Bridge Engineering II, pp. 369-376.

Boothroyd, R.J., Williams, R.D., Hoye, T.B., Barret, B., Prasojio, O.A., 2021. Applications of Google Earth engine in fluvial geomorphology for detecting river channel change. Wiley Interdiscip. Rev. Water 8 (1), e2496.

Bose, J., Naveen, U.K., 2017. Flood maps and bank shifting of Dhariana River in Bangladesh. J. Geosci. Environ. Protect. 5 (9), 109-122.

Ch, M.H., Ashraf, M., Hamid, Q., Sarwar, S.M., Saqib, Z.A., 2017. Geospatial techniques for assessment of bank erosion and accretion in the Marala Alexander reach of the River Chenab, Pakis. Sains Malays. 46 (3), 413-420.

Chakraborty, S., Datta, K., 2013. Causes and consequences of channel changes-a spatio-temporal analysis using remote sensing and GIS Jalabaha-Diana River system (Lower course), Jalpaiguri (Diuars), West Bengal, India. J. Geogr. Nat. Disasters 3 (1), 1-15.