Study of the dynamics of Manas-Beki river for assessment of erosion in upper Assam using geospatial techniques

Phuntsho Dorji[1*], Dechen Wangmo[1], Ugyen Tshering[1], Gopal Sharma[2] and P.L.N. Raju[2]
[1]University of Petroleum and Energy Studies (UPES), Dehradun- 248001
[2]North Eastern Space Applications Centre (NESAC), Umian-793103
*Email: dphuntsho69@gmail.com

(Received: April 03, 2020; in final form: Oct 14, 2020)

Abstract: The bank line erosion of Manas-Beki river has become a major problem especially for Barpeta and Baksa districts of Assam as the river is characterized by rapid changes in its morphological dynamics. About 75km stretch of Manas-Beki river starting from the foothills of Bhutan has been studied using geospatial techniques. Digital IRS LISS-III data of time frame 2008-2015 has been analysed in GIS environment for identifying erosional and depositional areas along the bank of Manas-Beki river. Sinuosity index, channel length, channel width and plan form index have been studied to understand the erosion and deposition processes that took place over seven years. It is observed that a total area of 22.57 km^2 was eroded and 10.03 km^2 was deposited, indicating dominance of erosion processes with an average of 3.22 km^2/year. Although heavy rainfall, associated flooding, landslides in upper reaches, excessive siltation and braiding channel are primary causes, another possible reason could be sudden flooding due to water release from Kurichu dam in Bhutan during this period. Results of this study provides important information on river dynamics and erosional activity along the bank of Manas-Beki river, which can be utilised for designing and implementation of drainage development programmes and erosion control schemes.

Keywords: Bank line erosion, river dynamics, IRS, LISS-III, GIS, Manas-Beki River

1. Introduction

River bank erosion associated with channel migration is one of the major geological hazard in north-east India causing loss of adjoining valuable land, which could be either agricultural land, forest land, tea plantations or human settlements or associated infrastructure. It is reported that total land loss per year due to erosion of Brahmaputra river is around 80 km^2 /year and bank erosion has wiped out more than 2500 villages and 18 towns including sites of cultural heritage and tea gardens affecting lives of 500,000 people, who are forced to migrate and relocate themselves and are deprived of their basic livelihood (Phukan et al., 2012; Das et al., 2014). Property worth around Rs. 182.24 Crore was damaged as a result of bank erosion (Das et al., 2014; Sayanangshu Modak and Nirmalya Choudhury, 2017). According to Das et al. (2014) "It is observed that after forced human migration due to bank erosion, displaced people face economic insecurity due to loss of agricultural land and become unemployed. The victims also suffer from social insecurity due to deprivation of civic rights, health insecurity due to lack of basic infrastructure, etc. All these insecurities caused by forced displacement lead to deprivation, destitute, fragility and increased vulnerability of the families". Study of erosion-deposition processes around Majuli island, Assam based on study of Survey of India (SOI) topo sheets and Indian Remote Sensing (IRS) satellite imagery spanning the period from 1966-1975 to 2008 in a Geographical Information System (GIS) environment revealed average annual rate of erosion and deposition to be 8.76 km^2/year and 1.87 km^2/year respectively, indicating significant rate of erosion than the deposition (Dutta et al., 2010). Analysis of temporal Landsat data for time frame 1989 to 2017 of the Subansiri river in its highly dynamic and unstable lower 100 km stretch, lying in Assam revealed that about 103 km^2 land area got eroded with an average of 3.68 km^2/year (Bordoloi et al., 2020). Many other previous studies in north-east region of India and parts of Bangladesh have attempted to study bank line erosion (Goswami et al., 1999; Kotoky et al., 2003; Sankhua et al., 2005; Das et al., 2007; Islam, 2009; Sharma et al., 2010; Sarma and Acharjee, 2012; Sarkar et al., 2012; Sinha and Ghosh, 2012; Talukdar, 2012; Khan, 2012; Gogoi and Goswami, 2013; Gogoi and Goswami, 2014; Chakraborty and Mukhopadhyay, 2015; Deka and Talukdar, 2016; Sarmah and Sarma, 2017).

The bank line erosion of Manas-Beki river has become a major problem especially for Barpeta and Baksa districts of Assam as the river is characterized by rapid changes in its morphological dynamics. According to Sayanangshu Modak and Nirmalya Choudhury (2017), "In 2007, alone around 440 hectares of land was eroded and around 76 villages and some 2500 families were affected from the river bank erosion. The total loss of property was around Rs. 33 million". In order to estimate changes subsequent to 2007, the present paper describes the study of Manas-Beki river during the time frame 2008 to 2015. It describes dynamics of river system and channel configuration leading to erosion and deposition. Sinuosity index, channel length, channel width and plan form index have been studied to understand the erosion and deposition processes.

2. Study area

Study area is shown in figure 1. Manas-Beki river (Kurichhu in Bhutan) originates from a Himalayan glacier and the main river and its tributary channels flow south through the plains of Assam (through Baksa and Barpeta districts in north-west, Assam) for about 85km, drain an area of 26,243 square kilometers approximately and meets the Brahmaputra river. Erosion and the recurring floods of characteristically high magnitude by Beki river have been heavily affecting the agricultural lands, crops, cattle and people of Barpeta district of Assam (Deka and Talukdar, 2016). Barpeta district of Assam is mostly affected by erosion and flood, 80 villages are fully affected and some others are partially affected in the district (Khan, 2012). The river channel changes its course due to changes in rainfall pattern, heavy landslide in catchment area causing sudden rise in the silt load, beheading of the one river into another, impact of seismic activity in bed slope etc. Every year very high magnitude flood also causes channel widening, river bank erosion and changes in channel pattern and the changes in the river system bring episodes of changed geomorphic scenario. Temporal change in the behavior of Manas-Beki river system and continuous changing braided behavior of river Brahmaputra cause dynamic changes in the sandbars (Sarmah and Sarma, 2017). Manas-Beki river system dynamics is in terms of bank line, alteration of direction of flow due to neck cut off, widening of channel and progressive shifting of meander bends. Changes in bank line are prevalent throughout the study period but with an increased severity during the last decade (Purkait, 2004).

The river crosses through Barpeta and Baksa districts of north-west Assam in India. The climate is extremely varied, ranging from hot and humid subtropical conditions in the south to cold and dry alpine conditions in the north, heavy rainfall and frequent floods in the region (Goyal, 2014; Jain, 2006).

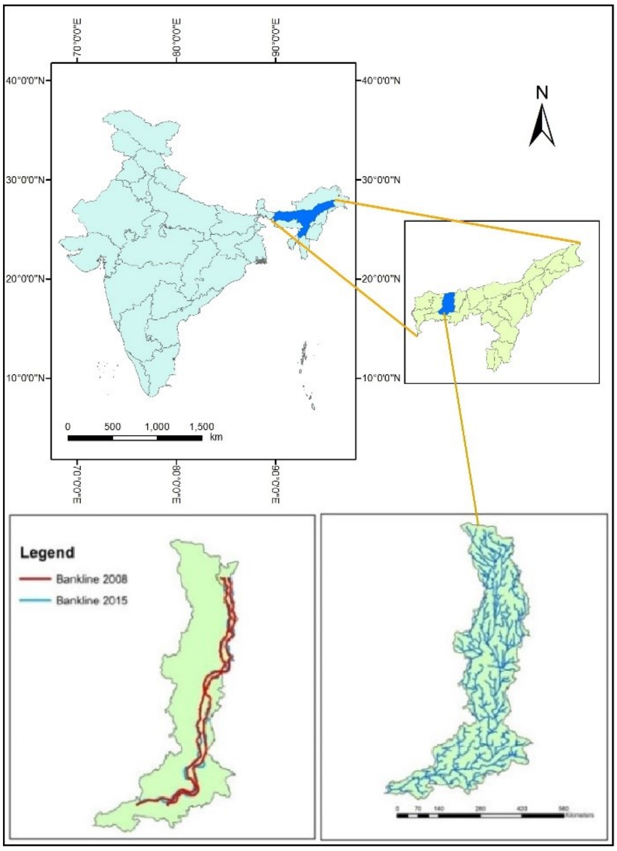

Figure 1: Location map of the study area

3 Material and methods

3.1 Data used

Digital images of the Indian Remote Sensing Satellite (IRS), LISS III sensor, comprising of scenes for the years 2008 (16 October) and 2015 (27 December) were used. The LISS III images are precisely ortho-rectified with the following parameters: Sensor: LISS-III Path: 109 Row: 053 Date of pass: 16Oct08/27Dec15. The other data used in the present study includes Digital Elevation Model (DEM) of Cartosat.

3.2 Bankline erosion

To identify bankline erosion, after due co-registration of LISS-III images, the right and left banks of the river were visually interpreted on screen at 1:25, 000 scale in GIS environment using ERDAS Imagine and ArcMap image processing and GIS software available at NESAC. After overlaying the bank lines of both years, bank lines were visually compared to identify the erosion and deposition sites. To quantitatively calculate the amount of erosion and deposition, the study area was divided into seven reaches. The total area covered by erosion and deposition was calculated using the polygon estimation tool available in GIS, the total area covered by erosion and deposition was calculated. When erosion and deposition occurs, they are accompanied by changes in the width of the channel (Islam, 2009). The shifting of the bank lines indicates the occurrence of erosion and deposition (Clerici and Perego, 2016). The study area was divided into seven equal sections and changes observed along the river banks during the seven years were studied (Figure 2 and Figure 3).

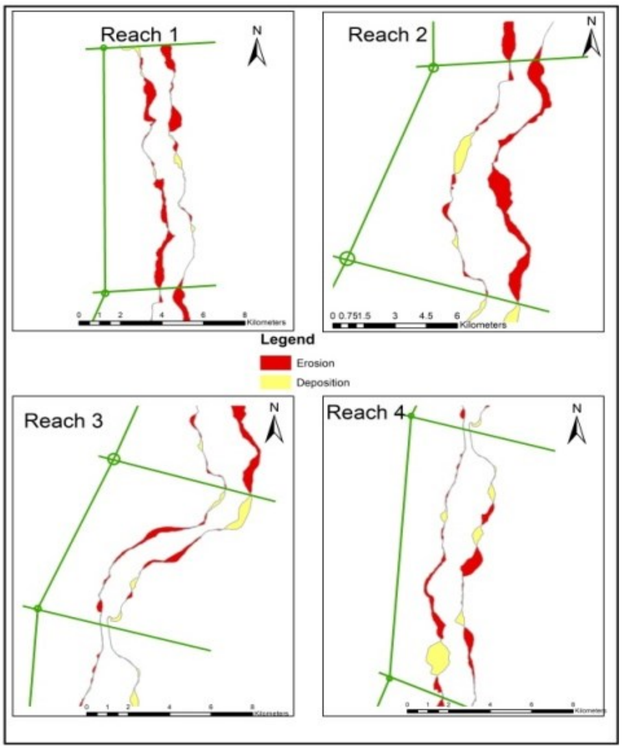

Figure 2: Erosion/deposition (Reach 1 to Reach 4) in various reaches of Manas-Beki River over a period of 7 years (2008-2015)

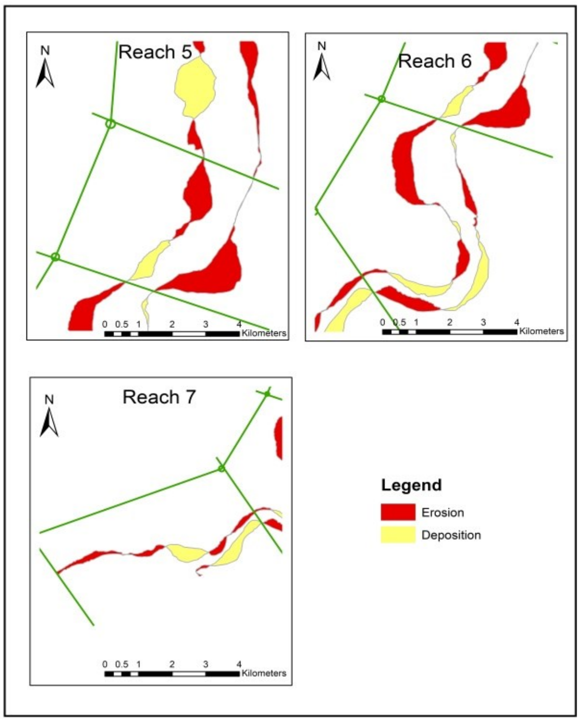

Figure 3: Erosion/deposition (Reach 5 to Reach 7) in various reaches of Manas-Beki River over a period of 7 years (2008-2015)

3.3 Sinuosity index

The curvilinear distance and straight line distance was measured (Sapkale et al., 2016). A python script tool which calculates the ratio between the two was used to find the sinuosity index. Sinuosity index of each reach were calculated and the average indices of the different years (2008 and 2015) were compared.

3.4 Channel Length

The channel lengths were measured using measurement tool available in ARCMAP. Variations observed within the seven years have been quantified.

3.5 Plan Form Index

Plan form index (PFI) reflects the fluvial landform disposition with respect to a given water level and its lower value is indicative of higher degree of braiding was utilized (Figure 4). The expression is formulated as; PFI= (T*100)/(B*N) (Pande and Moharir, 2017). Where, T= Flow top width B= overall width of the river section N= Number of braided channel. For providing a broad range of classification of the braiding phenomenon, the following threshold values for PFI were proposed, highly braided: PFI<4 moderately braided: 19>PFI>4 Low braided: PFI>19

4 Results and discussion

The total amounts of erosion/deposition that took place within seven years in the right and left bank are shown reach wise in table 1. The maximum erosion of 4181050 m^2 took in reach 1 and minimum erosion 1487251m^2 took place in reach 3 as shown in figure 5.

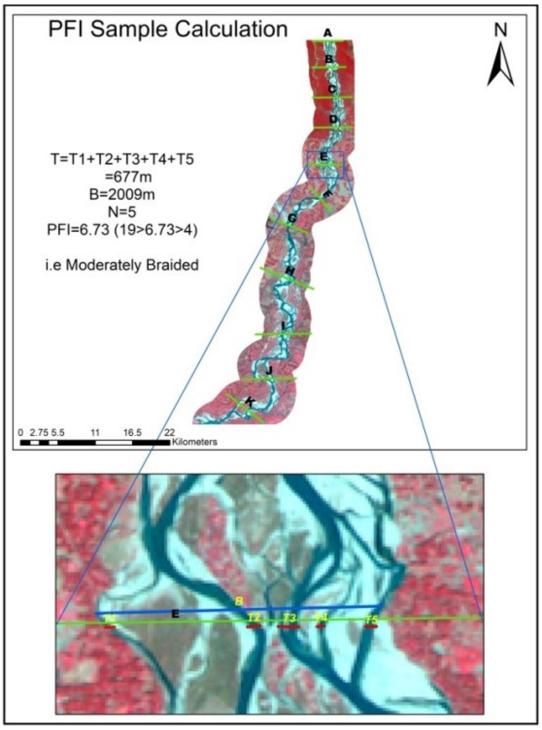

Figure 4: PFI sample calculation

Table 1: Total amount of erosion in left and right bank (2008-2015)

Reach	Left bank erosion(m^2)	Right bank erosion(m^2)	Total Erosion(m^2)
1	2661690	1519360	4181050
2	470142	2957830	3427972
3	918109	569142	1487251
4	1682980	2200210	3883190
5	1156170	1999660	3155830
6	2754500	1360160	4114660
7	2199590	123560	2323150

Likewise, as shown in table 2 maximum deposition of 3139510m^2 took place in reach 7 and minimum deposition of 493815.6 m^2 took place in reach 5. From the year 2008 to 2015 Manas-Beki River has experienced more erosion compared to deposition as clearly seen in figure 5.

Table 2: Total amount of deposition in left and right bank (2008-2015)

Reach	Left bank deposition (m^2)	Right bank deposition (m^2)	Total Deposition (m^2)
1	235573	282409	517982
2	561565	499.676	562064.676
3	153352	837094	990446
4	1783890	867122	2651012
5	490703	3112.6	493815.6
6	747851	932942	1680793
7	1412810	1726700	3139510

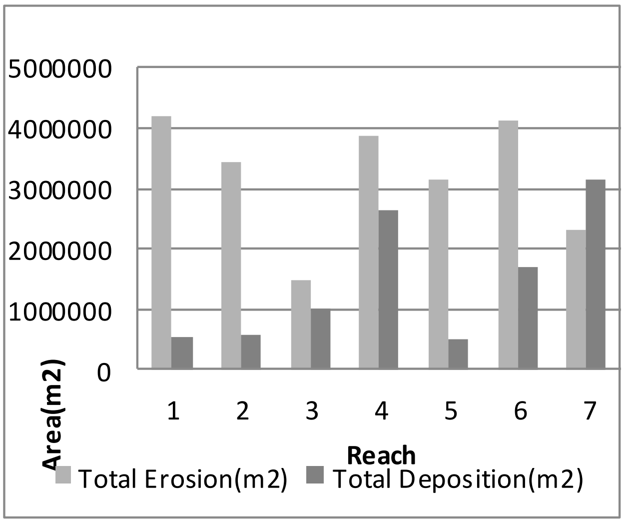

Figure 5: Total erosion and deposition (m^2)

A total area of 22573103m^2 was eroded and 10035623.276m^2 was deposited. The difference given by the erosion and deposition will give the weathered material. Hence, an area of 12537479.724m^2 has been weathered out. Therefore, this amount of weathering has been contributing in flooding in the state of Assam.

Reach one has undergone maximum erosion (table 1) and forested areas. One of the reasons for maximum erosion could be high slope due to which increases velocity of the river flow eroding the material along the river bank (Sarma and Acharjee, 2018). In case of Reach two erosions occurs is found to be higher on right bank as compare to left bank. In this case, the river enters the flat plain from the high elevation, meandering occurs and maximum erosion occurs at the cut bank (Florsheim et al., 2008). Udmari, Jaria and Sawpur are a place which falls in Reach five, here agriculture land and settlement comprising of almost 2 km^2 were eroded within seven years. The River has changed its course after entering this reach, flow direction changed from South to South west. Second highest erosion took place in Reach six, good amount of erosion has occurred in both sides of the bank. The eroded land mostly consists of agricultural land and settlement. Titapani, Bankabhanga and Balikuri N.C are some settlements which are near Reach six. Erosion and deposition is accompanied by variation in the channel width (Sapkale et al., 2016). In the present study area, channel width has increased indicating the occurrence of erosion within seven years. Table 3 shows the variation in the channel width within seven years.

Sinuosity index can be explained as the deviations from a path defined by the direction of maximum downslope (Sapkale et al., 2016). For this reason, bedrock streams that flow directly downslope have a sinuosity index of 1, and meandering streams have a sinuosity index that is greater than 1. Sinuosity index of year 2008 and 2015 is shown in Table 3 as well as the length of the channel. The sinuosity index decreased from 1.178 to 1.169 from 2008 to 2015. Correspondingly the channel length has also been decreased from 71.175km to 70.582km from the 2008 to 2015. This decrease in both the sinuosity index and channel length indicates the occurrence of erosion.

Table 3: Channel width section

Section	Width (m) 2008	Width (m) 2015
A	1920	1565
B	639	1399
C	666	921
D	650	1177
E	1912	2253
F	391	463
G	870	913
H	1221	2032
I	1443	1857
J	1587	2517
K	638	474

After applying the expression formulated by Sharma et al. (2010), the calculated PFI value of each section for the year 2008 and 2015 were shown in Table 4(a) and Table 4(b). Section 1,2,3,5 and 6 falls under moderately braided class(19>PFI>4) and section 4, 7 and 8 falls under low braided class(PFI>19) in the year 2008. Section 1,2,3,5 and 6 falls under moderately braided class(19>PFI>4) and section 4,7 and 8 falls under low braided class((PFI>19) in the year 2015.

Table 4(a). Plan Form Index (2008)

PFI of 2008				
Section	*N(m)*	*B(m)*	*T(m)*	*PFI(08)*
1	3	1172	365	10.38111
2	2	673	217	16.12184
3	6	1325	495	6.226415
4	4	882	704	19.95465
5	4	1969	843	10.7034
6	2	1236	466	18.85113
7	2	962	520	27.02703
8	3	806	694	28.70141

Table 4(b). Plan Form Index (2015)

PFI of 2015				
Section	*N(m)*	*B(m)*	*T(m)*	*PFI(15)*
1	4	1502	344	5.725699
2	4	1034	219	5.294971
3	3	1025	288	9.365854
4	3	1116	841	25.11947
5	4	2009	677	8.424589
6	2	1279	276	10.78968
7	2	979	691	35.29111
8	2	571	541	47.37303

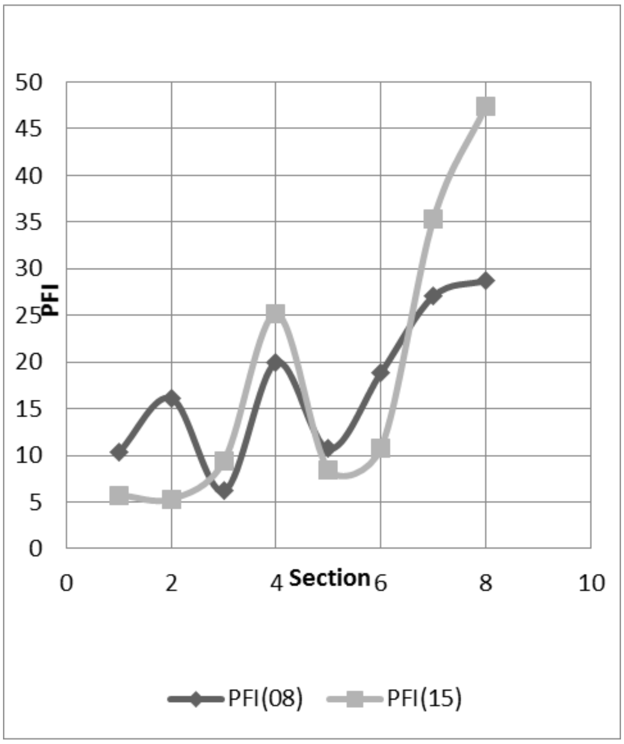

Figure 6: PFI comparison plot

Figure 6 shows how the PFI value has varied between 2008 and 2015. PFI value in section 1 and 2 has deceased tremendously from 2008 to 2015 indicating highly braided and increased in the PFI value in section 7 and 8 indicating low braided. The PFI value has varied throughout the sections indicating the occurrence of erosion and deposition (Sharma et al., 2010).

5 Conclusion

The present study of using the integrated approach of remote sensing and geographic information system has revealed the amount of erosion and deposition within seven years (2008-2015) along with the change in the river morphology. It is observed that the river has experienced erosional activity more in both banks than depositional activity. The change in the channel width, decrease in the sinuosity index and channel length all indicates the occurrence of erosional activities (Elliott, 2011).

The present work using multi-temporal spatio satellite data has exhibit a useful application of remote sensing and Geographic information system, allowing the synoptic viewing of the large regions, assessing the river dynamics and erosional/depositional activity. The information generated from this study can be in cooperated with other studies like climate change, flood control measures and can be helpful to take flood/erosion protection measures in Manas-Beki River.
From the present study, it can be concluded that more erosion has occurred where the river course is more prominent. A total area of 22573103m^2 was eroded and 10035623.276m^2 was deposited. Also reach one proved to be the most critical area having erosion of 4181050m^2 which is also evidently shown in the PFI plot.12537479.724m^2 of materials are weathered at the downstream area of Assam during the study period (2008-2015). Planning and extension of settlement and agricultural activities around this area should be avoided. River enhancement protection structures and methods should be given first priority around the areas where change in course is more drastic (Basiago, 1998).

One of the reasons for erosion in Manas-Beki River is due to the sudden water release from Kurichu dam in Bhutan, which affected thousands of people in Barpeta District and Baksa District. Kurichu is a 60MW hydropower project involving a 55m high concrete gravity and discharge capacity of 12,200m^3/second which can have massive downstream impacts if the downstream area is already facing rainfall and floods (Mahanta, 2010). Central water commission's flood forecasting site reported on oct14,2014 that Beki River at Beki NHC crossing was flowing at 45.25m, above the warning level of 44.1m, danger level of 45.1m (Purkait, 2004). Bhutan must inform central warning system about the release of water from the dam and avoid releasing the water without any information.

Acknowledgements

Authors are thankful to Department of Space, Government of India for providing necessary facilities at North Eastern Space Application Centre, Umiam Meghalaya to carry out the work. Authors also thank anonymous reviewers for their valuable suggestions and comments which improved the present study many fold.

References

Basiago, A.D. (1998). Economic, social, and environmental sustainability in development theory and urban planning practice, Environmentalist, 19(2), 145-161.

Bordoloi, K., B.R. Nikam, S.K. Srivastav and D. Sahaariah (2020). Assessment of riverbank erosion and erosion probability using geospatial approach: a case study of the Subansiri River, Assam, India, Applied Geomatics, https://doi.org/10.1007/s12518-019-00296-1.

Chakraborty, S. and S. Mukhopadhyay (2015). River bank erosion and channel width adjustments across a meandering channel of North Bengal, India, Earth Science India, 8(3).

Clerici, A. and S. Perego (2016). A set of GRASS GIS-based Shell scripts for the calculation and graphical display of the main morphometric parameters of a river channel, International Journal of Geosciences, 7(2), 135-143.

Das, J.D., T. Dutta and A.K. Saraf (2007). Remote sensing and GIS application in change detectionof the Barak river channel, N.E. India, Journal of Indian Society of Remote Sensing, 35(4), 301-312.

Das, T.K., S.K. Haldar, I.D. Gupta and Sayanti Sen (2014). River bank erosion induced human displacement and its consequences, Living Rev. Landscape Res. 8, 3.

http://www.livingreviews.org/lrlr-2014-3, doi:10.12942/lrlr-2014-3.

Deka, M. and B. Talukdar (2016). A study of an erosion-affected reach of the River Beki using mathematical modeling, World Environmental and Water Resources Congress, 334-342.

Dutta, M.K., S. Barman and S.P. Aggarwal (2010). A study of erosion-deposition processes around Majuli island, Assam, Earth Science India, 3(4), 206-216.

Florsheim, J.L., J.F. Mount and A. Chin (2008). Bank erosion as a desirable attribute of rivers, BioScience, 58(6), 519-529.

Gogoi, C. and D.C. Goswami (2013). A study on bank erosion and bank line migration pattern of the Subansiri River in Assam using remote sensing and GIS technology, The International Journal of Engineering and Science, 2(9), 1-6.

Gogoi, C. and D.C. Goswami (2014). A study on channel migration pattern of the Subansiri River in Assam using remote sensing and GIS technology, Current Science, 106(8), 113-1120.

Goswami, U., J.N. Sarma and A.D. Patgiri (1999). River channel changes of the Subansiri in Assam, India, Geomorphology, 30(3), 227-244.

Goyal, M. K. (2014). Statistical analysis of long term trends of rainfall during 1901–2002 at Assam, India, Water Resources Management, 28(6), 1501-1515.

Islam, M. T. (2009). Bank erosion and movement of river channel: A study of Padma and Jamuna Rivers in Bangladesh using remote sensing and GIS. Division of Geoinformatics, Royal Institute of Technology, Stockholm, Sweden.

Jain, S. K., A.K. Saraf, A. Goswami and T. Ahmad (2006). Flood inundation mapping using NOAA AVHRR data. Water Resources Management, 20(6), 949-959.

Khan, M. H. (2012). River erosion and its socio-economic impact in Barpeta District with special reference to Mandia Dev. Block of Assam. International Journal of Engineering and Science, 1(2), 177-183.

Kotaky, P., D. Bezbaruah, J. Baruah and J. Sarma (2003). Erosion activity in Majuli –The largest river island in the world, Current Science, 84(7), 929-932.

Mahanta, A. (2010). The Case of Kurichu in the Indo-Bhutan Context – Transboundary Hydropower Projects and Downstream Flooding. indiawaterportal.org/ sites/indiawaterportal.org/files/kurichu.pdf

Pande, C.B. and K. Moharir (2017). GIS based quantitative morphometric analysis and its consequences: a case study from Shanur river basin, Maharashtra, India, Applied Water Science, 7(2), 861-871.

Phukan, A., R. Goswami, D. Borah, A. Nath and C. Mohanta (2012). River bank erosion and Restoration in the Brahmaputra River in India, Clarion, 1(1), http://clarion.ind.in/index.php/clarion/article/view/17.

Purkait, B. (2004). Hydrometeorology, In The Brahmaputra Basin Water Resources, Springer, Dordrecht, 24-34.

Sayanangshu Modak and Nirmalya Choudhury (2017). villagesquare.in/2017/09/06/river bank-erosion-no-less-disaster-assam-floods/

Sankhua, R.N., N. Sharma, P.K. Garg and A.D. Pandey (2005). Use of remote sensing and ANN in assessing of erosion activities in Majuli, the world’s largest river island, International Journal of Remote Sensing, 26(20), 4445-4454.

Sapkale, J.B., Y.U. Kadam, I.A., Jadhav and S.S. Kamble (2016). River in planform and variation in sinuosity index: A study of Dhamni River, Kolhapur (Maharashtra), India, Int. J. Sci. Eng. Res, 7, 863-867.

Sarma, J.N. and S. Acharjee (2012). A GIS based study on bank erosion by the river Brahmaputra around Kaziranga National Park, Assam, India, Earth System Dynamics Discussions, 3(2), 1085-1106.

Sarkar, A., R.D. Garg and N. Sharma (2012). RS-GIS based assessment of river dynamics of Brahmaputra river in India, J. Water Resour. Prot., 04(02), 63-72.

Sarma, J.N. and S. Acharjee (2018). A study on variation in channel width and braiding intensity of the Brahmaputra River in Assam, India. Geosciences, 8(9), 343.

Sarmah, R.K. and U. Sarma (2017). Temporal changes of fluvio-morphological scenario and its impact on settlement: A GIS based study for Mandia block, Barpeta District, Assam, ADBU Journal of Engineering Technology, 6(2).

Sharma, N., Amoako Johnson, F., W Hutton, C., & Clark, M. (2010). Hazard, vulnerability and risk on the Brahmaputra basin: a case study of river bank erosion. The Open Hydrology Journal, 4(1).

Sinha, R. and S. Ghosh (2012). Understanding dynamics of large rivers aided by satellite remote sensing: a case study from Lower Ganga plains, India, Geocarto International, 27(3), 207-219.

Talukdar, B. (2012). “River Bank Erosion – A Perspective, Conference Paper. http://www.iitg.ernet.in/coeiitg/31.pdf.