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CHANGE OF RIVER CHANNEL AND BANK EROSION OF THE BURHI DIHING RIVER (ASSAM), ASSESSED USING REMOTE SENSING DATA AND GIS

J.N. SARMA@, D. BORAH AND U. GOSWAMI
Department of Applied Geology, Dibrugarh University, Dibrugarh - 786 004, India
@Corresponding author: jnsdu@yahoo.com

ABSTRACT

The Burhi Dihing river flows in a meandering course for about 220 km through alluvial plains of Assam including a short rocky and hilly tract in between. Sequential changes in the position of banklines of the river due to consistent bank erosion have been studied from Survey of India topographic maps of 1934 and 1972, and digital satellite data of 2001 and 2004 using GIS. Two broad kinds of changes have been observed, e.g. alteration of direction of flow due to neck cut-off and progressive gradual change of the meander bends that accounts for translational, lateral, rotational, extensional and other types of movement of the meander bends. Study of bankline shift due to the bank erosion has been carried out for the periods 1934-1972, 1972-2001, 2001-2004 and 1934-2004 at 13 segments spaced at $5'$ longitude interval (average 15 km) as the river course trends nearly east to west. The amounts of the bank area lost due to erosion and gained due to sediment deposition are estimated separately. The total area eroded in both banks during 1934-1972 was more (26.796 km^2) as compared to sediment deposition (19.273 km^2), whereas total sediment deposition was more (34.61 km^2) during 1972-2001 as compared to erosion (23.152 km^2). Erosion was again more in 2001-2004 (7.568 km^2) as compared to sediment deposition (2.493 km^2). During the entire period (1934-2004) of study the overall erosion on the both banks was 31.169 km^2 and overall sediment deposition was 30.101 km^2. The highest annual rates of bank erosion as well as bank building of the river are 21055.47 m^2/km in 2001-2004 and 9665.81 m^2/km in 1972-2001, respectively. Similarly the highest average annual rates of erosion as well as sediment deposition in both banks are observed during 2001-2004 and 1972-2001, respectively. The hard rocks of the hilly tract situated in between result in development of entrenched meandering and this tract has suffered minimum bank erosion.

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Introduction

Remote sensing data taken at certain intervals are very appropriate and ideal for studying and monitoring bankline shifting and river erosion. Some studies in this regard have been carried out in the northeastern India. NRSA (1980) has done the river migration study of the Brahmaputra using airborne scanner survey. Bardhan (1993) studied the channel behaviour of the Barak river using satellite imagery and other data. SAC (Space Application Centre, Ahmedabad) and Brahmaputra Board (1996) and Brahmaputra Board (1997) studied the erosion in Majuli Island. Naik *et al.* (1999) studied the erosion at Kaziranga National Park using remote sensing data. Mani *et al.* (2003) studied the erosion in Majuli island using remote sensing data. Goswami *et al.* (1999) carried out a study on river channel changes of the Subansiri in Assam using information of topographic sheet and satellite data. Sarma and Basumallick (1980) studied on the bankline migration of the Burhi Dihing River using topographic maps and field survey. A comprehensive study of the bank erosion and channel migration of the entire Brahmaputra river in Assam has been carried out by Sarma (2004) using remote sensing data and GIS.

The Burhi Dihing is the largest south-bank tributary of the Brahmaputra in Assam (Fig. 1). The precursor of this river is the Namphuk, which takes its rise in the Patkai Range at the Indo-Myanmar border (27°20′ N : 96°42′ E) and flows through the Patkai Range for about 115 km before coming out into a piedmont alluvial plain where it changes its name for the Burhi Dihing. After flowing for about 70 km through the alluvial plain from east towards west, the river again passes through the outcrops of Tertiary sedimentary rocks exposed on a low hill range in between 95°25′ E to 95°31′ E for about 19 km. Thereafter it again flows through the alluvial plains of Assam for 128 km and falls in the Brahmaputra at Dihingmukh (27°15′ 55″ N: 95°42′ 20″ E in 2004). The river drains a basin of about 6000 km^2 and its width varies from 300 m to 400 m in the

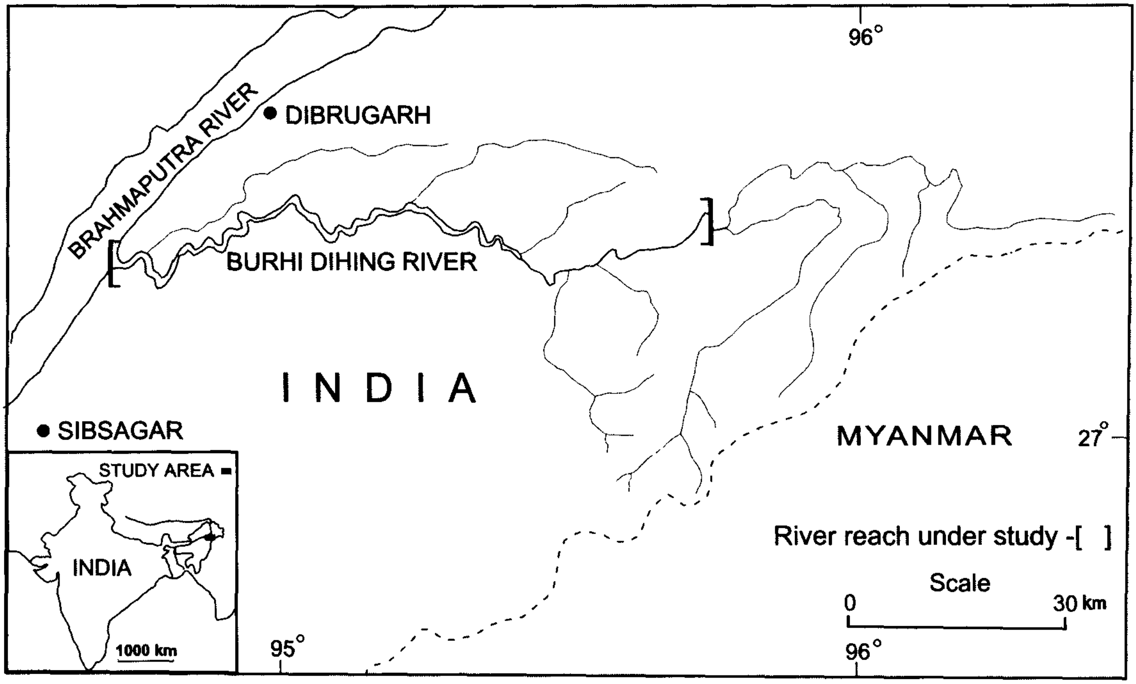

Fig. 1. Location map of the Burhi Dihing river.

plains. But about 250 years ago the Dihing (present Burhi Dihing) flowed westerly through Sibsagar district to meet the Brahmaputra at the extreme western point of Majuli island, which is now nearly 200 km west of present Dihingmukh, i.e. the outfall of the Burhi Dihing (Sarma and Phukan, 2003). But as the Brahmaputra migrated to the south and captured the Dihing near present Dihingmukh, the confluence point of the Dihing with the Brahmaputra had shifted to present Dihingmukh.

The Burhi Dihing is a meandering river of sinuosity 1.6; hence shifting of the banks of the river takes place along its meander bends within the alluvial plain by erosion in one part and deposition in the other. There are local variations of geology and constituent bank materials along the course of the river. Hence, an attempt has been made to study the nature of bankline migration as well as to make a quantitative assessment of the total amount of bank area subjected to erosion at different parts of its course during a period of time from 1934 to 2004. For the present study almost the entire reach of the river flowing through the plains from a place named Ketetang (95°44′ E: 27°20′ N) up to Dihingmukh has been considered.

Source of Information

Although there are some historical data about the river Dihing, it is by no means possible to convert these data into an accurate cartographic map. The earliest available accurate maps showing the details of the banklines and other important topographic features of this area were prepared by the Survey of India (SOI) during the survey of 1934 which was published in 1:63,360 (1 inch = 1 mile) scale. The revised edition of these maps, prepared based on aerial photographs and published in 1:50,000 (2 cm = 1 km) scale in 1972, provides the second set of data regarding changes taking place over a period of 38 years. The third and the fourth sets of data are the LISS III full scene digital data of IRS 1D acquired in December 2001 and IRS P4 LISS III data acquired in January 2004, respectively.

Methodology

For the assessment of the type of the lateral movement of channels and measurement of shifting of the banklines, the approach involved in the present study is the use of SOI topographic maps of both of 1: 63,360 and 1:50,000 scales, and remote sensing digital data. The SOI topographic maps of 1934 and 1972 are scanned part by part. The scanned topographic maps and the digital images are exported to the format compatible to the PCI Geomatica V 8.1 and SPANS V 7.2 image processing and GIS softwares. All the scanned portion of toposheets and the satellite images are geo-referenced following a standard projection system (Lat-Long) with standard datum (D076-India-Nepal) and ellipsoid (Everst-E006). Some well-known prominent points such as road crossing, bridge, corner of large water tank, airport runway, etc. are considered as the ground control points (GCP) for the georeference. The georeferenced maps are merged together for the entire length of the river under study. Then banklines of both the banks (Fig. 2) for different years are digitized for the study area and the digitized layers of different years are then superimposed using overlay analysis. From the superimposed banklines of different periods the nature of changes of the banklines between two periods are found out. The superimposed line layers are then converted to area layers. From the area layers the area lost due to bank erosion and gained due to sediment deposition are estimated for different periods along different parts of the river during the time elapsed in between two periods of data.

Results

Types of Change in Bankline

The types of bankline change noticed on the river Burhi Dihing within the reach under study during the period 1934-2004 can be broadly grouped into two categories.

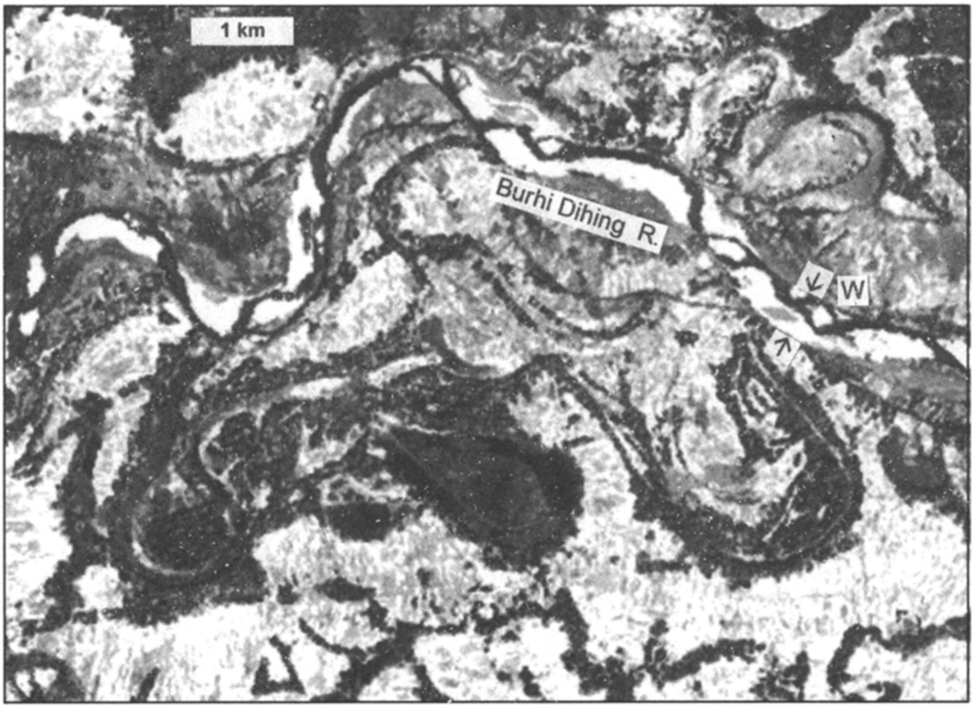

Fig. 2. IRS-1D (LISS III) digital image acquired in December 2001, showing the banklines of a segment of the Burhi Dihing river channel (W= width of the channel).

1. Neck cut-off at the meander loop leading to channel abandonment and straightening.
2. Progressive gradual change in meander bends as well as in straight parts of the channel (without neck cut-off).

Neck cut-off: Neck cut-off occurs when the meander loop becomes either nearly circular or when the two ends of the loop come very close; consequently, the river straightens the course at the neck of the meander bend resulting in abandonment of the meander loop and formation of ox-bow lake. Straightening of channel by neck cut-off along the studied reach is observed at 4 places during the period 1934-1972. However, new meander bends also formed at 2 places during this period. The length of the river channel along this reach was 212 km in 1934, which remained nearly constant with 213 km in 1972. The number of neck cut-off observed during the period 1972-2001 is 9, whereas development of new meander bend is only 3. Greater number of neck cut-offs had resulted in shortening of the channel course, and it is observed that the river course in 2001 (180 km) became shorter by 33 km than that in 1972. During the period 2001-2004 there are neither neck cut-off nor development of new meander bend, and so the length of the river reach also remain nearly constant, i.e. 179 km in 2004. Hence the total number of neck cut-off during the entire study period (1934-2004) is 13 resulting in the shortening of the river course by 33 km.

Progressive gradual change in meander bends: In order to study the nature of change in the bankline the changes that occurred in every individual bend are considered. The amount of change is determined from the position of the superimposed banklines of two sequences of topographic maps and digital data for the three periods, viz. 1934-1972, 1972-2001 and 2001-2004. The frequency of the types of change in individual bend is analyzed by comparison with models of movements. For this purpose the primary elements of movement of Daniel (1971) have been identified and grouped into double and triple combinations following Hooke (1977). The primary elements of movements are translation, extension, rotation, change in wavelength, lateral movement and complex change. Each type of movement can be in one of the two directions, i.e. upstream or downstream, increase or decrease or to the left or right. The double or triple combinations include the domain of any two or three primary modes. However in the present case, in addition to the six types mentioned above, the other types of movements observed are enlargement, extension and translation, widening and narrowing, and development of new meander bend (Fig. 3).

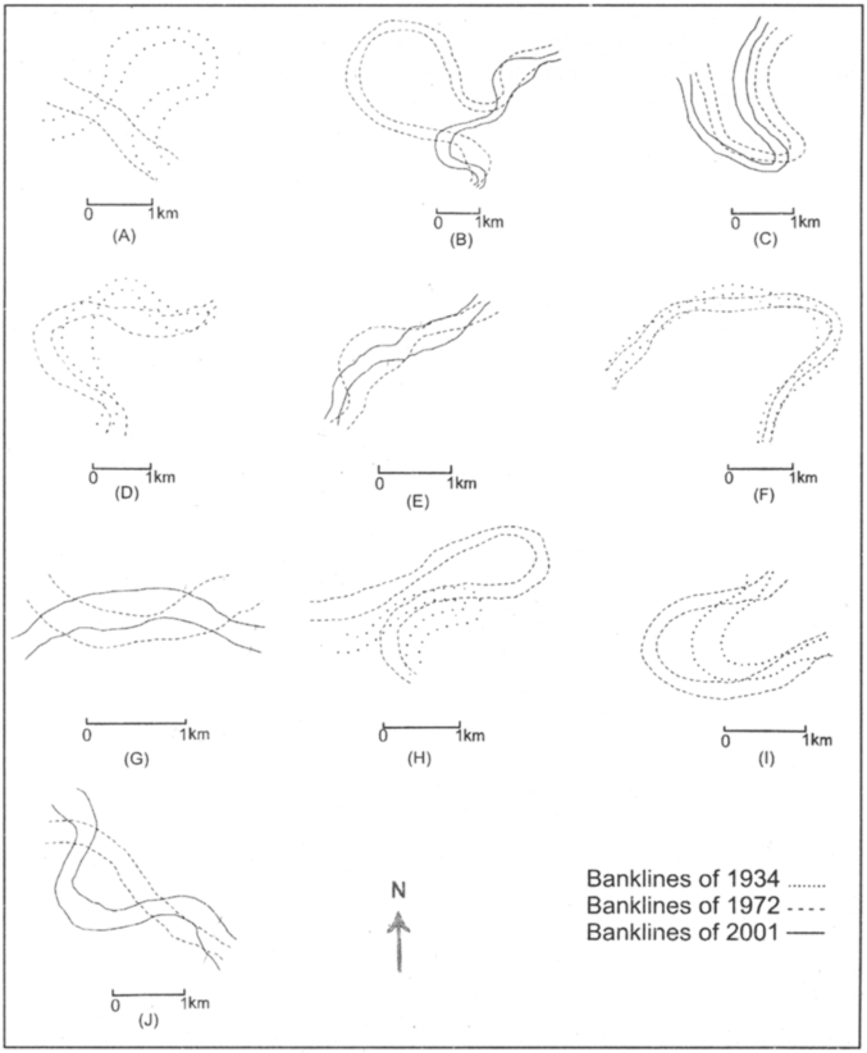

Fig. 3. Common types of movements of the meander bends of Burhi Dihing river: (A) Neck cut-off, (B) Neck cut-off and development of new meander bend, (B) Translation, (D) Rotation, (E) Narrowing/widening, (F) Complex change, (G) Lateral movement, (H) Extension and Translation, (I) Extension, and (J) Development of new meander bend

The number of neck cut-offs and other types of changes of the banklines during the three periods of study are given in Table 1. Out of the ten types of progressive changes the maximum number of change observed is translation (23.4%), followed by lateral movement (20.8%). Among the three periods of study the number of changes is maximum during 1972-2001, which amounts to 46.75% of the total changes. The factors responsible for this large-scale change during this period may be either climatic or anthropogenic. Two extreme floods occurred in the river during 1980 and 1988, which resulted in the development of a number of neck cut-offs. Moreover, there is a sharp increase in opencast coal mining area and a very large-scale dumping of loose mine overburden debris on the bank of the river along Margherita-Ledo coal mine region since 1985, which contributed suddenly huge amounts of sediment to the river. The small reach of the river within the low hill range remained conservative and no conspicuous change could be noticed in the meander bends.

Amount of Bank Erosion

It has been observed in the present study that due to shifting of the banklines the bank areas are subjected to erosion and the earlier channels get filled-up by sediment deposition. Hence the bank area lost due to erosion and gained due to sediment deposition are measured from the area layers separately both for the right (north) and the left (south) banks of the river.

In order to have an idea about the amounts of erosion and sediment deposition during different periods of time from 1934 to 2004, the entire duration of study is divided into four periods, i.e. first (1934-1972), second (1972-2001), third (2001-2004) and entire (1934-2004). Since materials comprising the banks of the river at different parts of its course are not uniform, the assessment is carried out for different segments of the river separately by dividing the nearly east-west trending Burhi Dihing river course into 13 small segments at 5′ longitude intervals (average length= 15 km). The amount of erosion in km^2 in the first, second, third and entire periods were, respectively, 13.405, 13.400, 2.888 and 17.367 in the left bank, while 13.391, 9.752, 4.680 and 13.802 in the right bank. Similarly the area of sediment deposition in km^2 in the first, second, third and entire periods were, respectively, 7.545, 19.448, 1.626 and 15.410 in the left bank, while 11.728, 15.162, 0.867 and 14.791 in the right bank. The data reveal that the amount of erosion was more than sediment deposition in both the first and third periods. On the contrary, the area of sediment deposition was more than erosion in the second period. The overall change during the entire period of study (1934-2004) reveals an amount erosion of

Table 1: Frequency of types of movement in meander bends of the Burhi Dihing River in different periods.

Period	Neck cut-off	Extension	Translation	Rotation	Enlargement	Lateral movement	Complex change	Extension & Translation	Rotation & Increase in wave length	Widening & Narrowing of Channel	Development of new meander bend
1934-1972	4	3	4	6	1	7	2	4	1	0	2
1972-2001	9	1	10	1	0	6	1	4	0	1	3
2001-2004	0	0	4	0	0	3	0	0	0	0	0

1.957 km^2 in the left bank and sediment deposition of only 0.4 km^2 in the right bank. The hilly reach of the river between Nagaghat (95°25′ E) and Direkmukh (95°31′ E), although meandering in nature, showed the least amount of change during all the periods (Fig. 4). Within the outcrops of hard rocks of this reach the river develops entrenched meanders, which inhibit shifting of the banks to a great extent.

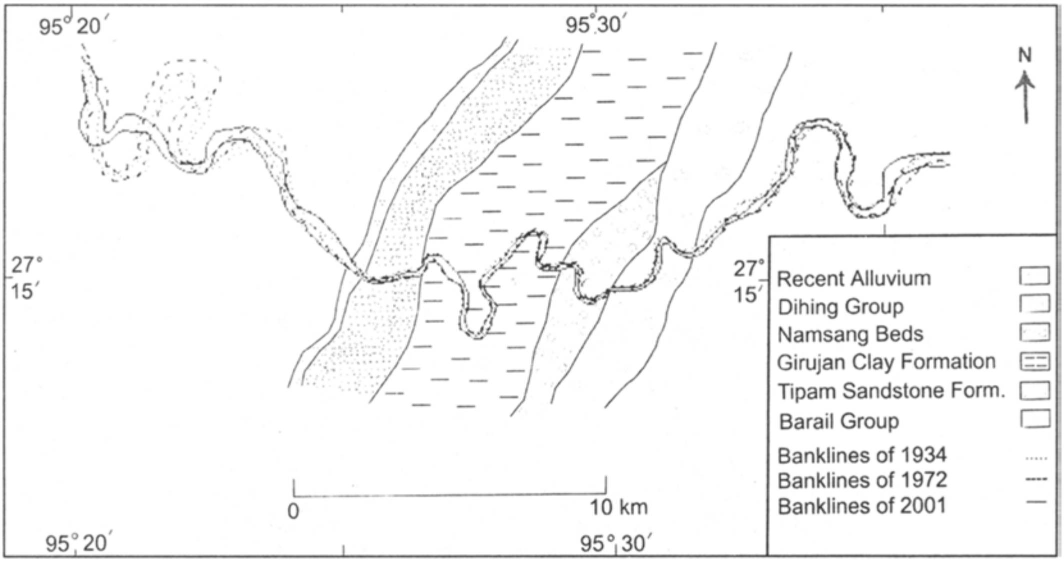

Fig. 4. A part of the course of the Burhi Dihing river across the outcrops of the Tertiary rocks in the hilly reach and through the alluvial plains, showing respective positions of the banklines in the years 1934,1972 and 2001.

Rates of Bank Erosion and Sediment Deposition

Since the periods for which assessment of erosion or sediment deposition is carried out are not uniform, the annual rate of erosion or sediment deposition can be found out by diving the respective amount by the number of years elapsed during each period. Moreover, the rates are divided by the respective lengths of the channel in each segment to derive the annual rate of erosion or sediment deposition per km length of the river reach. Accordingly the annual rates of erosion as well as sediment deposition per km in both the left as well as the right banks are calculated in m^2 for the four periods mentioned earlier. It is observed that the annual maximum rate of erosion per km length of the river for the left bank is 21055.47 m^2 in the segment 95°15′-95°20′ during the period 2001-2004; while for the right bank it is 15344.38 m^2 in the segment 94°55′-95°00′ for the same period. The annual maximum rate of sediment deposition for the left bank is 9665.81m^2 observed within the segment 95°05′-95°10′ for the period 1972-2001 and the same for the right bank is 8240.41 m^2 within the segment 95°20′-95°25′ also for the same period. Considering all the four periods the overall annual average rate of erosion of the river was highest in both banks during 2001-2004 and that of sediment deposition was highest in both banks during 1972-2001.

Conclusion

The Burhi Dihing river shifts its banklines gradually in various manners and sometimes leads to abandonment of the loops by neck cut-off. The gradual changes occurring frequently on the meander bends are mainly translation of the bends and lateral movement of the course due to erosion in one of its banks and concomitant sediment deposition in the opposite bank. The rate of erosion as well as fill-up by sediment deposition in each segment is not uniform in space and time. From the study it can be concluded that a significant amount of area was gained due to sediment deposition on the both banks within the period 1972-2001. It might be due to an increase in frequency of neck cut-off and fill-up of the abandoned loops, resulted due to either climatic or anthropogenic causes. But the riverbanks have been subjected to pronounced erosion in the subsequent period 2001-2004. The small reach of the river through Tertiary sedimentary rocks develops entranced meanders, which remained almost conservative during the entire period of study. The entranced meanders developed across the strike of the rock outcrops of this reach may also infer their origin either similar to a superposed river or due to slow upliftment.

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