Morphodynamic changes of Lohit River, NE India: GIS-based study

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The Lohit River is a south bank tributary of the Brahmaputra River. Till 1987, the Lohit River used to meet the Brahmaputra at a place near Bairagi Chapari (27.77°N, 95.44°E). By 1995, the confluence point had shifted about 20 km downstream. One small channel of the Lohit River captured the Dangori River during the 1988 flood. Gradually the Lohit River started flowing along the captured channel. By 1995, it became the trunk channel of the Lohit River and Dibru Saikhowa region became an island. Banklines of Brahmaputra and Lohit rivers have undergone significant changes near their confluence point within the last few decades. By 1987, the south bank of the Brahmaputra near Rohmoria (27.55°N, 95.15°E) shifted about 1.6 km southward from its position in 1973. Interestingly, within the period 1988–90 the south bank shifted about 4.1 km south. This major shifting was the result of capturing of the Dangori River by the Lohit River. However, migration of the rivers towards the south has stopped after 1995. Analysis of SRTM DEM reveals that topographic elevation has played a major role in changing the course of the Lohit River.

Keywords: Banklines, confluence point, morphodynamic changes, topographic elevation, trunk channel.

THE Lohit River is a major tributary of the Brahmaputra River. It originates in Zayal Chu ranges in eastern Tibet and flows about 460 km before meeting the Dibang River. Before entering India, the river flows about 200 km through Tibet. Major thrusts of Mishmi Hills like Lohit Thrust and Tidding Thrust are prominent on the longitudinal profile of the river. However, the Mishmi Thrust is not clearly reflected by the longitudinal profile. The river has a braiding nature along its alluvial segment. The basin area of the river is about 22,418.6 sq. km. During the 1988 floods, the Lohit River captured the Dangori River, flowing southwest from it. By 1995, the captured channel became a perennial channel of the Lohit River and finally became the trunk channel.

Geomorphic and sedimentary responses of alluvial rivers in relation to tectonics have been studied[1–14]. The avulsion properties of rivers have also been well-studied[15–18]. Some attempts have been made to understand the fluvial process–response system of the Brahmaputra River and its tributaries[2,19–25]. There have been significant changes in morphology and planform of the Brahmaputra and its tributaries within the last few decades. The 1897 (12 June) Shillong earthquake and 1950 (15 August) Assam earthquake of magnitude 8.7 and 8.5 respectively caused extensive landslides, liquefaction, sand-vent and ground fissuring in the region[26,27]. The Subansiri River and some of its tributaries changed their courses at places after the 1950 earthquake[27]. Extensive work has been done on fluvial process and bankline migration of the Brahmaputra River in Assam[24,25,28–30]. Lahiri and Sinha[22] have described seismotectonic controls on the Brahmaputra River in the Upper Assam region. Kotoky *et al.*[31] have studied the nature of bank erosion. The present work involves a study of the changing behaviour of the Lohit River within the period 1973–2000 in Assam and some parts of Arunachal Pradesh, India.

Study area

The study area is a part of the alluvial Brahmaputra valley in Assam and Arunachal Pradesh. The area is bounded by 94.84°E–97.89°E long. and 27.20°N–29.70°N lat. Monsoonal rain is predominant in summer with maximum rainfall of 300 cm (as of 2012). During this period, the maximum temperature rises to 37°C. During winter minimum temperature of the region reaches 2°C (as of 2012). Elevation of the study area ranges between 90 and 7200 m from mean sea level (MSL). Brahmaputra is the major river in the region, with many small and large tributaries.

Figure 1 shows the location map of the study area. Seasonal flood caused by monsoonal rainfall is a major natural disaster for the region. Moreover, according to Indian earthquake hazard zoning map, the area is within 'Zone V' with highest risks of earthquake. Earthquake of up to MM intensity IX can be expected in the area. The region has already experienced very high-intensity earthquakes in the past. For example, the Cachar earthquake of *M* 7.5 on 10 January 1869, the Shillong earthquake of *M* 8.7 on 12 June 1897, the Assam earthquake of *M* 8.5 on

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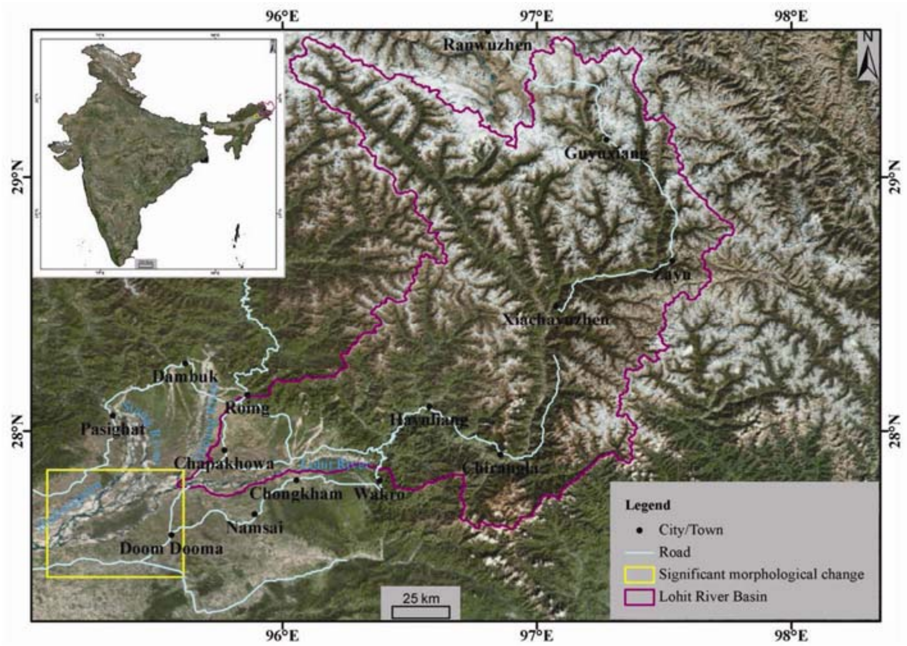

Figure 1. Location map of the study area showing the basin boundary and significant changes that occurred in morphology of the Lohit River.

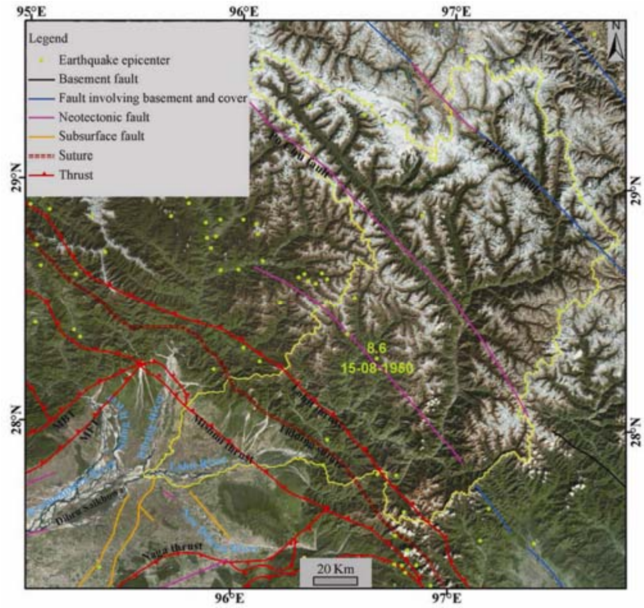

Figure 2. Tectonic map of the study area along with epicentres of instrumental earthquakes. Major thrusts within the study area are MBT (Main Boundary Thrust), MFT (Main Frontal Thrust), Mishmi Thrust, Tidding Suture, Lohit Thrust and Naga Thrust (after Narula *et al.*[33]).

15 August 1950, etc. Smaller earthquakes magnitudes ranging between *M* 3.0 and *M* 5.5 are common in the region.

Database and methodology

The major data used in this study are Landsat image, ESRI World Imagery and SRTM digital elevation model (DEM) with 30 m spatial resolution (vertical error < 4 m)[32]. Landsat-1 image with 60 m spatial resolution and Landsat-5 and 7 with 30 m spatial resolution acquired within the period from 1973 to 2001 were obtained from Earth Resources Observation and Science Center, United States Geological Survey. Geo-Tiff format (UTM, WGS-1984, Zone 47N, 46N) imageries and DEM were collected for the study area. Required bands of the imageries were stacked using ERDAS IMAGINE (version 2011) to make standard false colour composite (FCC). The Brahmaputra River and its tributaries have been delineated from Landsat images. The length of the tributaries has been computed from the attribute tables of the vector layers. All the measurements were done from the attribute tables of the vector files using ArcGIS (version 10.0).

Seismotectonics

Moderate earthquakes frequently rock the region. Earthquakes exceeding *M* 6 are also common in the area. These earthquakes have brought various changes into the Brahmaputra and Barak valleys. Besides, the whole region is characterized by numerous thrusts, faults and folds.

The Brahmaputra alluvial plain in Upper Assam is bounded by the Himalayan Frontal Thrust (HFT) to the northwest, Mishmi Thrust to the northeast, Naga Thrust to the southeast and Mikir Hills to the west[33]. From this tectonic set-up it is evident that the sediments and rocks of the region have experienced compressive forces from time to time. The region has experienced several high-magnitude earthquakes within a short period. Many of

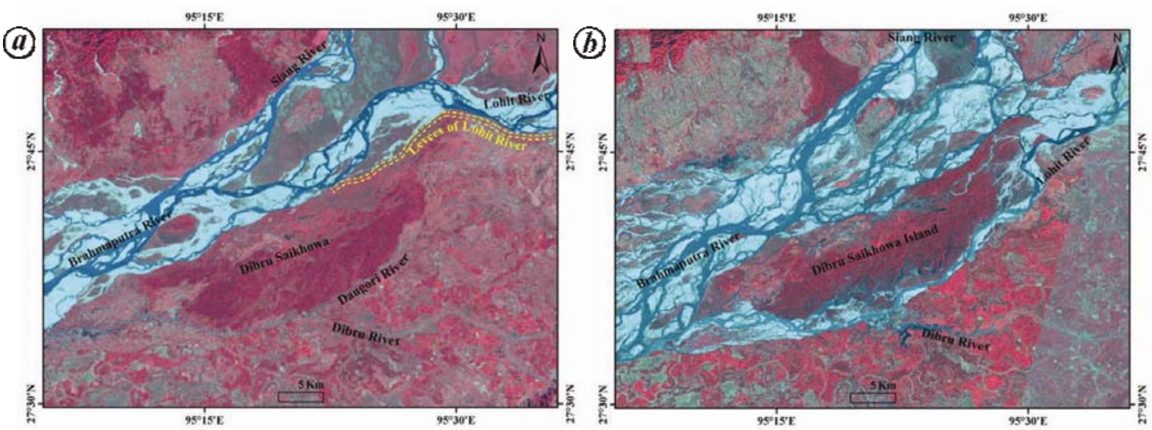

Figure 3. Landsat image over Dibru Saikhowa. ***a***, 15 November 1973; ***b***, 28 November 2000. Levee deposits (yellow dashed lines in ***a***) of the Lohit River acted as a natural embankment till 1988. After erosion of the levees in the 1988 flood, the river started flowing south of the Dibru Saikhowa capturing the Dangori River.

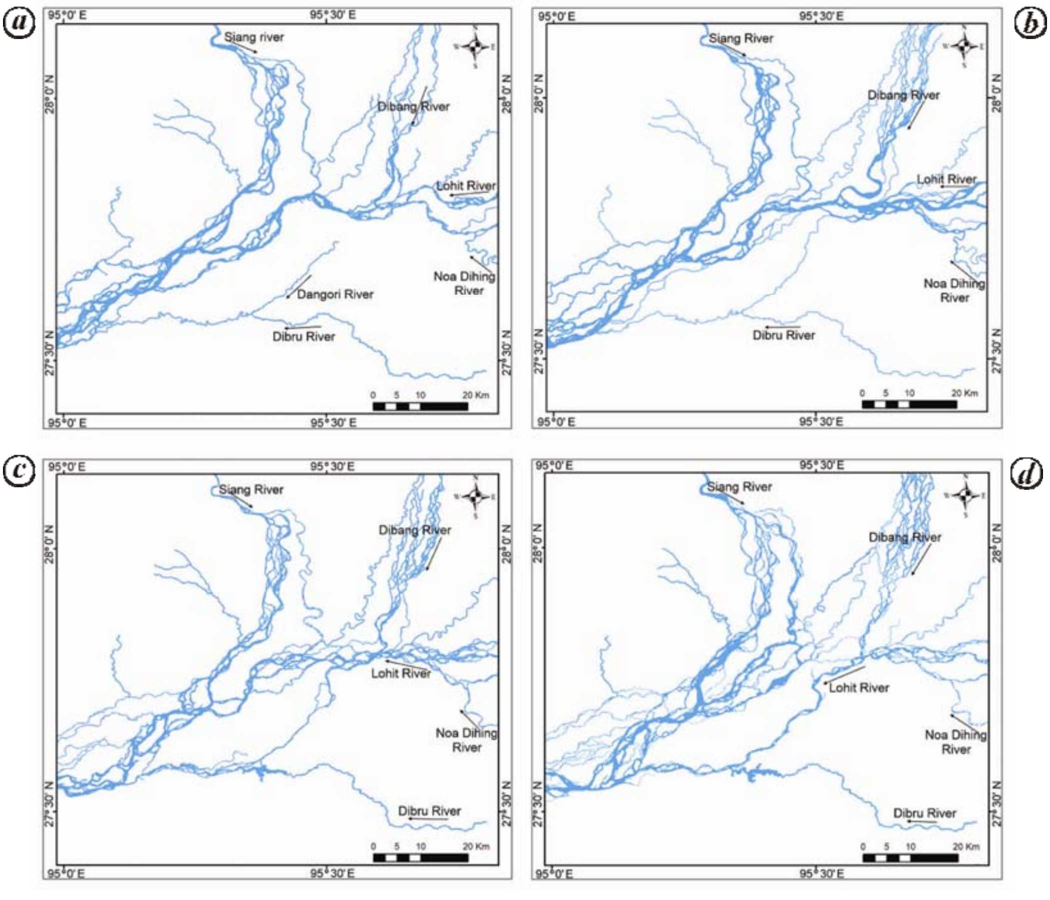

Figure 4. Trunk channels of Siang, Dibang and Lohit rivers near Dibru Saikhowa. ***a***, November 1973; ***b***, October 1988; ***c***, November 1995; ***d***, November 2000.

these earthquakes have genetic relationship with the thrusts and faults in the region. The distribution of earthquake epicentres shows that the Mikir Hills and Indo-Burma thrusts are much more active than the Naga–Patkai ranges of thrusts. Figure 2 shows tectonic features of the study area along with the epicentres of earthquakes.

River course dynamics

Till 1987, the confluence point of Lohit and Brahmaputra rivers was at a location near Bairagi Chapari (27.77°N, 95.44°E). During the 1988 floods, the Lohit River overflowed its banks and captured the Dangori River, flowing southwest from it. By 1995, the captured channel became a perennial channel of the Lohit River and finally became the trunk channel (Figures 3 and 4).

The banklines of the Brahmaputra and Lohit rivers have undergone significant migration near the confluence point within the last few decades (Figure 5). The south bank of the Brahmaputra near Rohmoria (27.55°N, 95.15°E) shifted about 1.6 km southward by November 1987 from its position in 1973. Interestingly, within 1988–90 the southbank shifted about 4.1 km south. This major shifting was the result of erosion by the new channel of the Lohit River. After this, southward migration of the southbank was limited to only 0.14 km till November 2000. The Kundil River originates in the Mishmi Hills and is a tributary of the Lohit River. In 1973, the river had overall sinuosity 1.81 along its alluvial part. The sinuosity decreased to 1.42 till 2000. Comparison of Landsat images acquired in 1973 and 1988 shows that a new tributary has joined the river and its morphology has changed significantly (Figure 6).

Discussion

The Lohit River is characterized by highly braiding nature in its alluvial part. Monsoonal flood is the major natural disaster in the downstream region of the river. The flood level in 1988 was high in the study area. On 20 August the flood level at Dibrugarh (near the study area) reached 106.38 m, which was the highest recorded till then. Landsat image acquired on 27 October 1988 shows that a small braid branch of the Lohit River got connected with the Dangori River after the 1988 floods. This channel of the Lohit River showed dramatic changes in the later years. The river started to flow along the captured channel to meet the Dangori River, abandoning its older course. By November 1995, the Lohit River totally changed its course and the Dangori River became the trunk channel of the Lohit River (Figure 4).

Three topographic profiles extracted from SRTM DEM (Figures 7 and 8) near the confluence point of Siang, Dibang and Lohit rivers show that average topographic elevation near the new channel of the Lohit rivers is less than that of the older channel. Moreover, the channel flowing south of the Dibru Saikhowa Island shows a slight depression in its longitudinal profile in comparison to the northern channel after the divergence point *P* (Figures 7 and 9). These profiles clearly show that topographic elevation along and near the new channel is 0.5–1.0 m lower than that of the older channel (after the divergence point *P*, Figures 7 and 9). This variation in gradient between the channels is the major factor in changing the course of the Lohit River. Avulsion is a common geomorphic process associated with the river. 'Normal' hydrological floods are the most common triggers of avulsion if the river is close to the avulsion threshold[16]. The abnormal high flood level of 1988 (highest recorded till then) might have crossed the avulsion threshold of the

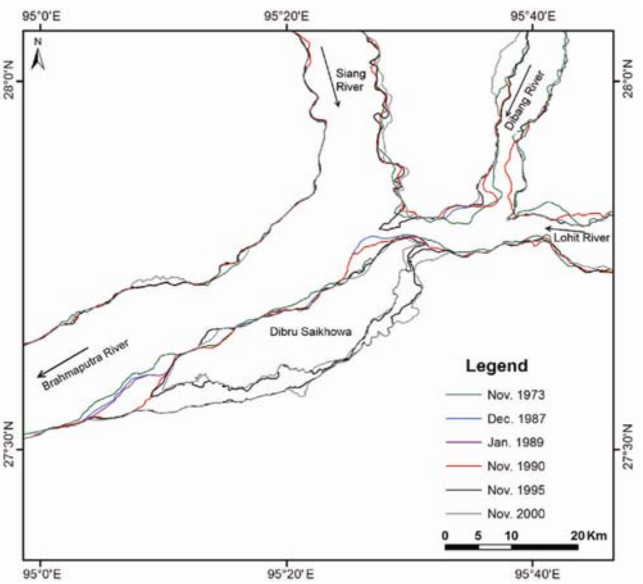

Figure 5. Banklines of Brahmaputra, Siang, Dibang and Lohit rivers near Dibru Saikhowa for six different years.

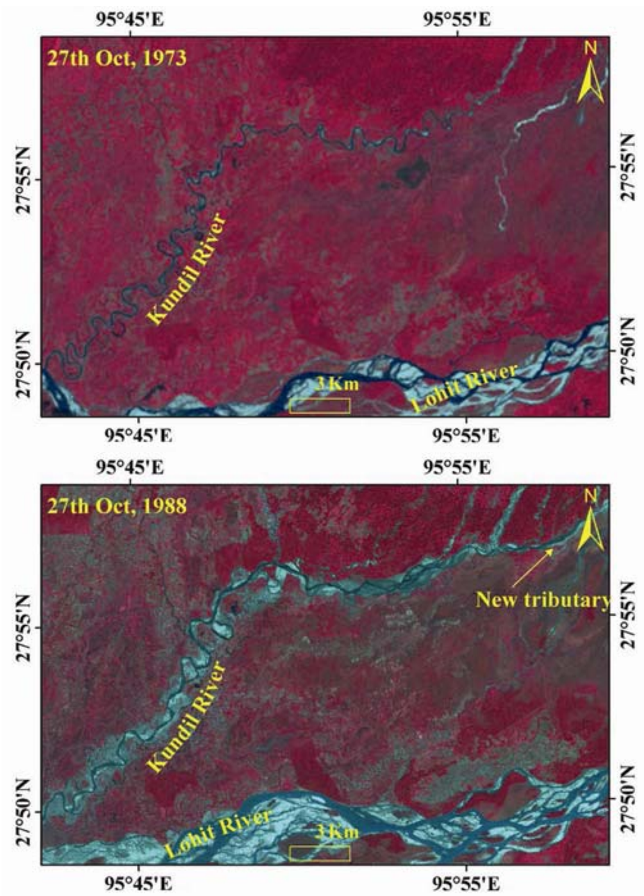

Figure 6. Landsat image over Kundil River. The sinuosity of the river has changed from 1.81 to 1.42 due to joining of a new tributary. The new tributary has increased discharge and sediment load of the river.

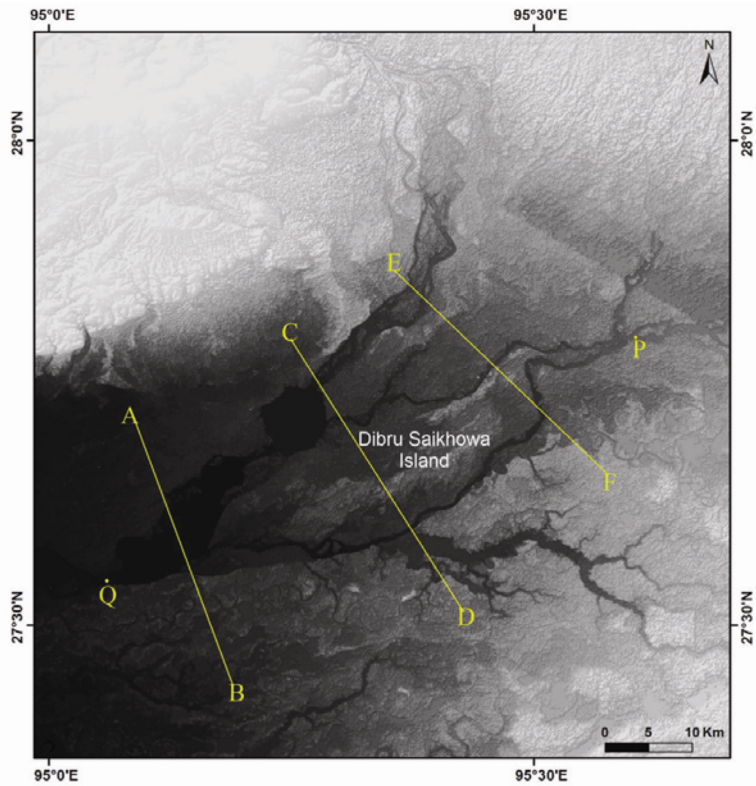

Figure 7. DEM (SRTM, Hillshade) showing the confluence point of Siang, Lohit and Dibang rivers. Transverse elevation profiles have been obtained along *A–B*, *C–D* and *E–F* sections. Longitudinal profiles have been obtained along *P–Q* segment of the Lohit River, both northern and southern channels of the Dibru Saikhowa Island.

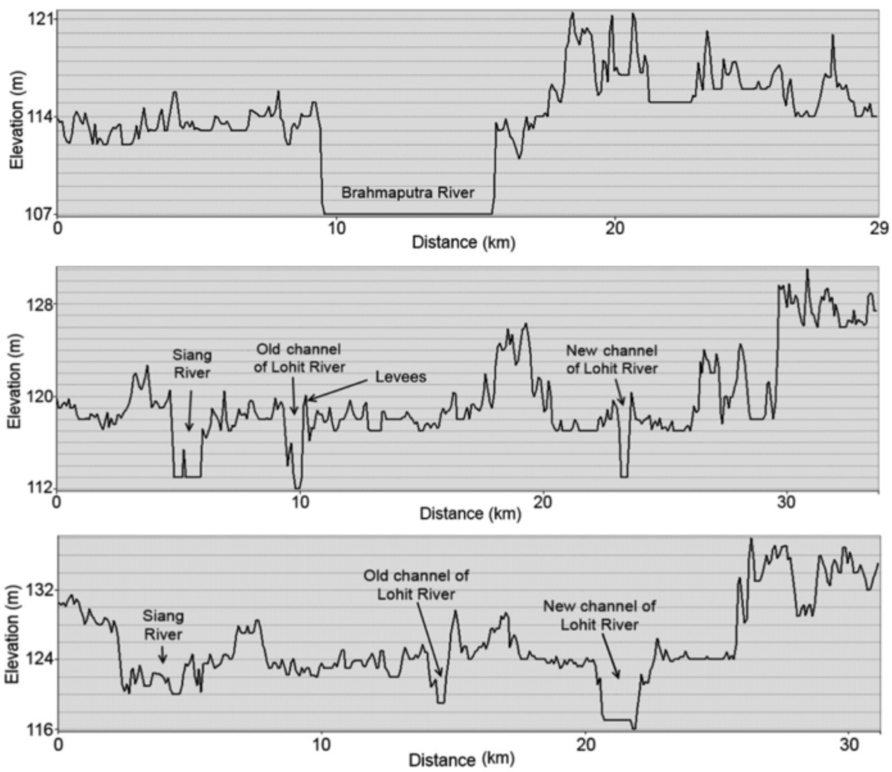

Figure 8. Topographic profiles extracted from SRTM DEM (vertical error < 4 m)[32] along the selected sections (*A–B*, *C–D* and *E–F* in Figure 7) near the confluence point of Siang, Dibang and Lohit rivers. In the *E–F* section, the topographic elevation is lower along and near the new channel compared to the old channel of the Lohit River.

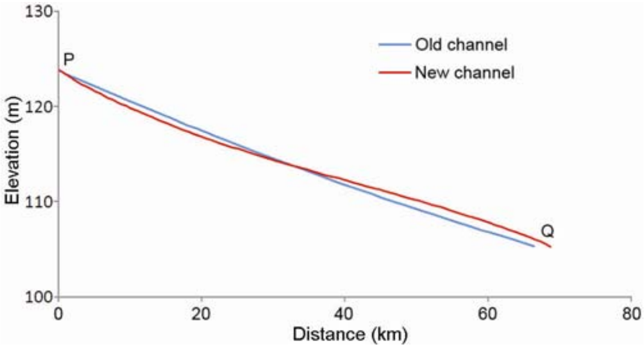

Figure 9. Longitudinal profile of a segment of Lohit River (*P–Q* in Figure 7) obtained from SRTM DEM. The blue curve is for the old channel flowing north of the Dibru Saikhowa Island, and the red curve is for the new channel south of the Dibru Saikhowa Island. The depression in the red curve (new channel) after the divergence point *P* reveals that the new channel is deeper than the old course of the Lohit River. This is the major triggering factor in changing the course of the Lohit River.

river and triggered avulsion resulting in the removal of some parts of the levees along the left bank. After removal of the levees, difference in gradient between the channels led to course change of the Lohit River. Although topographic elevation along and near Dangori River (south of Dibru Saikhowa Island) was lower than that of the older channel (north of Dibru Saikhowa) of Lohit River, the levee deposits of the Lohit River prevented it to flow along the Dangori River before the 1988 floods. The levee deposits acted as a natural embankment. Once the embankment was eroded, the river started to follow the deeper channel, i.e. along the Dangori River. Similar avulsion processes of the Baghmati and Kosi rivers have been studied by Jain and Sinha[15], and Sinha *et al.*[18] respectively. The Baghmati River in North Bihar showed eight major and several smaller avulsions within the period from 1770 to 2000. Extreme hydrological variations and sedimentological adjustments have been attributed for avulsive behaviour of the Baghmati River[15]. On the other hand, the August 2008 avulsion of the Kosi River was triggered by a normal hydrological flow. Sinha *et al.*[18] suggested that aggradation of channel belt after construction of embankments and planform dynamics led to avulsion of the Kosi River.

Landsat image acquired on 27 October 1988 showed that the Kundil River had developed numerous bars (point and mid channel) after joining the new tributary (Figure 6). It can be interpreted that discharge of the river did not increase sufficiently to transport the increased sediment load after joining the new tributary. This resulted in channel deposition of the sediments and decrease in sinuosity of the river. Moreover, a river needs steeper slope to carry higher amount of sediment flux. This can be achieved by reducing sinuosity.

A few subsurface and neotectonic faults have been identified by GSI within the study area[33]. Major thrusts of the Himalaya (MBT, MFT), Mishmi Hills (Mishmi Thrust, Lohit Thrust) and Naga–Patkai (Naga Thrust) ranges are also present near the study area. However, the role of these faults could not be linked directly with the present morphodynamic changes of the Lohit River. Several palaeo-channels and older alluviums are noticed on the southern side of the Dibru Saikhowa region, implying that the topography of the area has remained relatively stable with gentle slope for a long period. This may indicate that the subsurface faults in this part have not caused any change on the surface for last few decades. However, it may be noticed that the Brahmaputra River exhibits northward shifting near Dibrugarh. This may be caused by landform and terrain slope changes, probably affected by the activities along the MFT.

Conclusion

It is evident from the present study and interpretations that the rivers in the study area are changing their morphological behaviour. Topographic elevation has played a major role in changing the course of the Lohit River. Avulsion is a common geomorphic process associated with many rivers of the Ganga–Brahmaputra plain. Some rivers of the Ganga plain like Baghmati and Kosi have also shown significant avulsion in the last few decades[15,18]. Capturing of the Dangori River by the Lohit River was triggered by the abnormal high flood level in 1988, and difference in gradient between the channels led to course change of the Lohit River. SRTM DEMs are used to compare the old as well as new course of the Lohit River, which might have maximum vertical error of 4 m (ref. 32). However, for both the cases the same DEMs are used; hence error becomes common for both the channel areas and comparison will not be affected. By 1995, the Dibru Saikhowa region became an island. After 1995, there has been no significant southward migration of the Brahmaputra and Lohit rivers within the study area.

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