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Role of Channel Migration and Influencing Hydro-Geomorphic Attributes in Dibru River Basin Using Remote Sensing and GIS

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ABSTRACT

The action of the river is dynamic and exhibits morphological changes over time. River channel migration may take place because of sedimentation, geology, soil properties, geomorphic setup, precipitation, land use pattern, natural bank geometry (e.g., channel width, meander length, meander wavelength, amplitude, the radius of curvature, arc angle, and sinuosity), discharges of various frequencies (Brice 1982, MacDonald et al. 1991, Garcia et al. 1994), distribution of riparian vegetation, and vertical and horizontal heterogeneity of floodplain soils (Motta et al. 2012), etc. are some factors for channel migration. The present study is undertaken in the Dibru River Basin, the left-bank tributary of the Brahmaputra River. To identify the Spatio-temporal changes, satellite imagery is used in the GIS environment. The extraction of the river is done from the GIS software (Arc GIS 10.4) by digitizing process and tries to overlay the different time periods of shifting of the river and find out the rate of magnitude and nature of the river course changes. An interval of 10 years is taken to find the rate of magnitude and nature of changes in the river courses from satellite imagery. The time period is taken from 1977-2020 at 10 years intervals. Along with the rate of river course changes, channel avulsion is also shown with the help of satellite imagery. The Dibru Saikhowa National Park falls within the Dibru river basin, where numerous streams are found, within the national park. The Saikhoa river and Ajuka river flow within the national park. The Sursa river is a small channel linked with the Dangori river. With phases of time, the river made a headward erosion and confluence with the Ajuka river and formed a channel. The Saikhoa river flowed till 1987; due to deposition, the river abandoned its original course. In 1988, the Ajuka river and Sursa river merged and flowed northwest direction. The high discharges of the Lohit river diverted towards the Ajuka and Sursa Rivers and took a new channel named the Lower course of Lohit river within the study area. It can be called an avulsion channel because it changed its direction from its original to a new course in 1990. Since 1990, the course of the channel has been tremendously expanding its length and breadth, causing a flood, bank erosion, and deposition nearby human habitats and Dibru Saikhowa National Park. From the multi-temporal satellite imagery, the river courses were studied, and found the year of avulsion took place in the channel. Multi-temporal satellite imagery is used to identify the channel's avulsion. An avulsion is the rapid separation of a river channel to form a new course, which is only possible due to flood, high discharge, soil properties or tectonic activity, etc. that creates instability and causes the channel avulsion..

INTRODUCTION

River morphology is changeable and active in varying environmental landscapes over both spatio-temporal scales. An avulsion is a process by which flow is diverted from the parent channel into a new course in the floodplain. A local avulsion forms a new channel that joins its parent channel downstream (Heller & Paola 1996). Channel diversion mainly occurs within the floodplain region, and bank erosion is held because of lateral shifting of the course. Usually, it is a natural process, but with the ages of time, its terms as semi-natural because of human intervention. Changing channel courses create great havoc on the socio-economic life of the people living in the region. Sometimes, many people lose their homes, agriculture fields, and infrastructure due to channel migration. It is variable; some changes are gradual and some are unnoticeable, while others depend upon the phenomena like extreme floods and droughts. Channel avulsion is a natural process associated with changing channel patterns over space and time. Different channel patterns are identified in the same river course because of the behavior of the river. In foodplains, sinuous to meandering channel patterns are common in the river course.

The Brahmaputra River has been causing severe bank erosion along different parts of its alluvial banks in Assam. Among the localities afflicted by severe bank erosion in Assam (such as Majuli, Moriahola, Kaziranga, Laharighat, Palasbari, Gomi, Mokalmua, and Bogribari), the Rohmoria area has the highest rate of bank erosion in the south bank of the Brahmaputra (Sarma & Phukan 2006). An attempt has been made for the first time to evaluate the role of a neotectonic fault on rapid bankline migration vis-à-vis bank erosion of the Brahmaputra River around Rohmoria locality of Assam (Sarma & Acharjee 2012).

The Dibru River is a left-bank tributary of the Brahmaputra river. The Dibru river is a northward-flowing river system that drains into the Brahmaputra River in the plains region. The Dibru river origin near the village name called Natun Maithang bujiliban and flows northwards to drain into the Brahmaputra river. The Dangori river is a sub-tributary of the Dibru river and confluence at the Raidang wetland. It is just a tributary of the mainstream river but changes its morphological characteristics by expanding its bank over time. Before, it was just a tiny channel or Nala. Now, Dangori is known as the second Brahmaputra by the local people of the study area. The river creates great havoc on the physical and socio-economic landscapes. The 20 m wide small channel of the Dangori river of 1995 has become about 2,000 m wide channel of the Lohit in 2007 causing severe bank erosion, flooding, and loss of life and property (Sarma et al. 2011).

GIS is the most sophisticated tool used for environmental deterministic research studies. Various multi-temporal satellite imagery is used to identify the temporal change of the Dibru river course and the lower course of the Lohit river. The advantage of using advanced tools for geo-referencing, image processing, visualization, overlay, water bodies extraction, and channel migration position over multiple years to a single extensive system. The high-resolution images give accurate and precise data for a particular region and are essential to evaluating the trend of river shifting. This will be helpful for ordinary people for earlier vulnerability to communities living on the flood plains.

OBJECTIVES OF THE STUDY

1. To identify the high-risk point of channel migration of the Dibru river using satellite imagery.
2. To assess the magnitude of channel change of the Dibru river using geospatial tools.
3. To study the hydro-geomorphic indicator of channel migration.

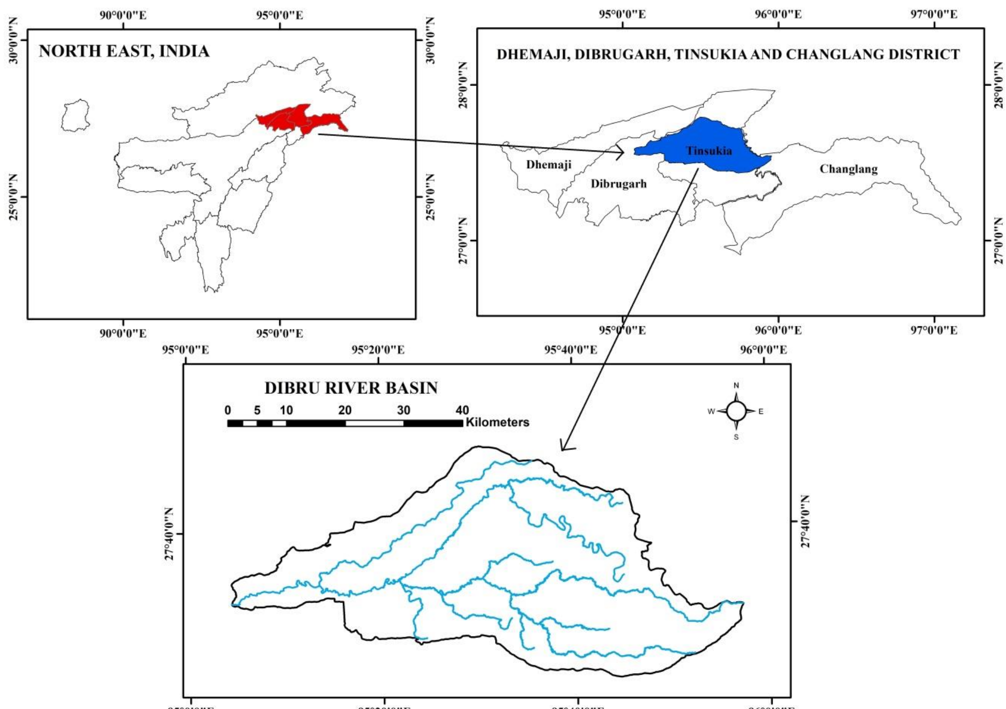


Fig. 1: Location map of the study area.

4. To study the impact on human activities.

STUDY AREA

The Dibru River is a left-bank tributary of the Brahmaputra River. The basin drains into the plain region of Assam experience the great sub-Himalayan terrain and is bounded by the river Brahmaputra and the Lohit in the north, Noa Dihing river in the eastern, and some tributaries of the Burhi Dihing river in the southern and western borders of the basin. Geographically, its latitude and longitudinal extensions are 27º25´30″ N-27º46´30″ N and 95º6´0″ E-95º58´30″ E covering about 1,779 sq. km area of Tinsukia, Dibrugarh, Dhemaji district of Assam and a small part of the Changlang district of Arunachal Pradesh (Fig. 1) with ever-green and semi-deciduous forests and the climatic condition is high humidity and moderate temperature. The slope of the basin varies from a gentle slope to a base-level slope (0^{o}-5^{o}).

The Dibru river origins at an altitude of about 155 m above mean sea level and run up to 132.95 km, where the channel gradient is 0.35 $m.km^{-1}$.

A major portion of the study area is a plain region. The population concentration is very high in the southern part of the basin. The Dibru River Basin consists of four revenue circles viz- Chabua, Doom Dooma, Margherita, and Tinsukia revenue (Fig. 20).

DATABASE

The Dibru River basin is delineated from Survey of India topographical Sheets No: 83M/2, 83M/5, 83M/6, 83M/7, 83M/9, 83M/10, 83M/11, 83M/13, 83M/14, and 83M/15 at 1: 50,000 scale. To understand the dynamic nature of the Dibru River Basin, Multi-temporal Landsat satellite data and LISS III data for the years 1977, 1987, 1997, 2007, and 2020 were used. The details of the satellite images for channel migration are given below in Table 1.

To study the Channel Avulsion satellites imagery details are given in Table 2. To understand the flow characteristics of the river, the fluvial and geomorphic databases are collected from the Flood observatory.colorado.edu website. Along

Table 1: Details of Satellite imagery of changes in the course of the river:

Sensor	Date of acquisition	Bands used	Resolution
MSS	6 February 1977	MTL	60 m
MSS	22 March 1987	2,3,4	30 m
MSS	16 February 1997	2,3,4	30 m
LISS III	1 February 2007	2,3,4	24 m
OLI and TIRS	22 December 2020	3,4,5	30 m

Table 2: Details of the satellite imagery for channel avulsion.

Sensor	Date of Acquisition	Band	Resolution
MSS	22 March 1987	2,3,4	30 m
MSS	27 October 1988	2,3,4	30 m
MSS	12 January 1989	2,3,4	30 m
MSS	18Nov 1990	2,3,4	30 m
MSS	7Dec 1991	2,3,4	30 m
MSS	7 November 1990	2,3,4	30 m
MSS	28 December 1993	2,3,4	30 m
MSS	28 October 1994	2,3,4	30 m

with it, we have also used a secondary database, especially the Soil map prepared by the National Bureau of Soil Survey and Land Use Planning Regional Centre, a Geological map from the Geological Survey of India. Rainfall data had collected from various rainfall gauge site stations within and around the basin for a period of 9 years. A primary survey was carried out within the affected villages' areas by lateral migration and their impact on households, tea gardens, and others activities.

MATERIALS AND METHODS

For the identification of the spatio-temporal migration of the Dibru River, the satellite image is projected at the same coordinate system units, and that is WGS_1984_UTM_Zone_46N. The whole work and the dynamic nature of the Dibru river over different years are digitized and analyzed with ArcGIS 10.4 software. The channel avulsion is carried out from satellite imagery from 1987 to 1994.

The morphometric parameters like long profile, Sinuosity Index and channel gradient, channel slopes, etc., are computed using the Survey of India toposheet at a 1:50,000 scale and contour interval of 20 m. The affected villages are identified by overlaying the layer of the river course of 2020 over the map of the village. In this way, the numbers of affected villages are identified and for the ground truth, a primary survey was carried out with the help of GPS.

RESULTS AND DISCUSSION

Morphological Changes in the Dangori River (Lower Course of Lohit River)

The Dangori river was just a tiny channel or Nala as per the toposheet (SOI), 1966. But with phases of time, the small channel changes its nature and behavior. The Dangori river has small streams like the Sursa river. Many small streams are found within the Dibru Saikhowa National park. This national park is shaped by the erosion and deposition works of the Dibang, Dihang, and Lohit rivers, which bring tremendous siltation from hilltops and are deposited at the foothill of Assam. The Dibru Saikhowa National Park, where numerous streams are found, and the Saikhoa river and Ajuka river flow within the study area. The Sursa river is a small channel linked with the Dangori river. With phases of time, the river made a headward erosion and confluence with the Ajuka river and formed a channel. The Saikhowa river flowed till 1987; due to deposition, the river abandoned its original course. In 1988, the Ajuka river and Sursa river merged and flowed in a northwest direction. The high discharges of the Lohit river diverted towards the Ajuka and Sursa Rivers and took a new channel named the Lower course of Lohit river within the study area. It can be called an avulsion river because it changed its direction from its original to a new course in 1990. Avulsion can result from high peak discharges, sediment accretion, uplift or lateral tilting (tectonic), jamming of the channel through the exogenous process, etc. (Miall 1996, Slingerland & Smith 1998, Jones & Schum 1999). Since 1990, the course of the channel has been tremendously expanding its length and breadth, causing flood, erosion, and deposition nearby human habitats and Dibru Saikhowa National Park.

From the Multi-temporal satellite imagery, the river courses were studied, and fond the year of avulsion took place in the channel (Fig. 2). A multi-temporal satellite imagery is

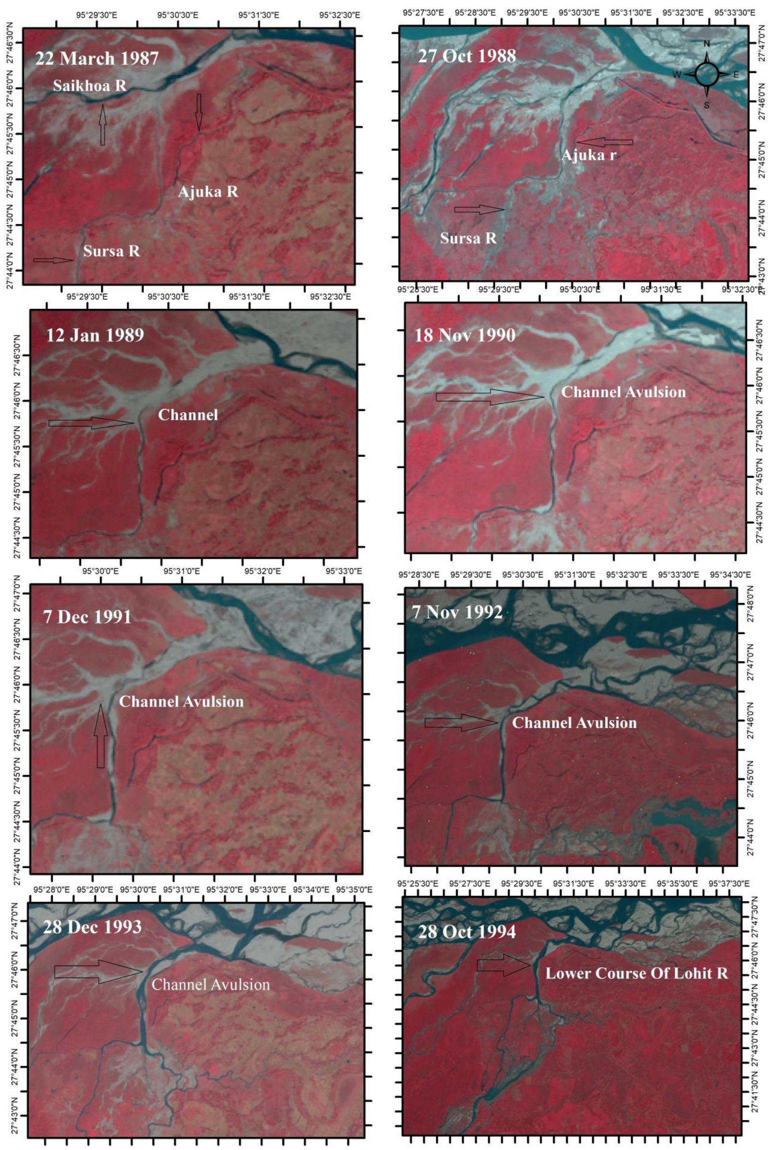


Fig. 2: Morphological changes of Dangori River (Lower Course of Lohit River).

Table 3: Magnitude of changes rate in some selected cross sections:

Cross Section	1977-1987		1987-1997		1997-2007		2007-2020	
	R [km]	L [km]	R [km]	L [km]	R [km]	L [km]	R [km]	L [km]
A-A1	0	0.08	0.82	-	0.54	-	0.07	-
B-B2	0.10	-	-	0.48	-	0.41	0.60	-
C-C3	0.13	-	-	0.37	-	0.48	0.63	-
D-D4	0	0.03	0.22	-	0.02	-	-	0.07
E-E5	0	0.01	-	0.01	-	1.28	0.42	-
F-F5	0	0.04	0.017	-	-	0.83	-	0.83

used to identify the channel's avulsion. An avulsion is the rapid separation of a river channel to form a new course, which is only possible due to flood, high discharge, soil properties or tectonic activity, etc., that creates instability and cause the channel avulsion. A local avulsion forms a new channel that joins its parent channel downstream (Heller & Paola 1996).

Magnitude Changes of Some Selected Cross-Sections Within the Course of the River

Channel Changes (Cross Section AA') during 1977-2020

In 1977, the channel was in a left direction along cross section AA.' In the early age of 1980, the channel shifted towards the left direction with an extent of 0.08 km in the year 1987 again its extent to the right in the year 1997, 2007 and continue till 2020, with a rate of 0.82 km, 0.54 km, and 0.07 km (Table 3). This can occur due to the soil characteristics and high discharge flows (Fig. 3 & 9)

Channel Changes (Cross-Section BB ') during 1977-2020

From 1977-1987 the channel was in the right direction along cross-section BB,' and in the early age of 1990, the channel was shifted towards the left direction with an extent of 0.48 km and 0.41 km in the year 1987-2007 (Table 3). Again from 2007-2020, it shifts towards the right at 0.60 km (Fig. 4 & 10).

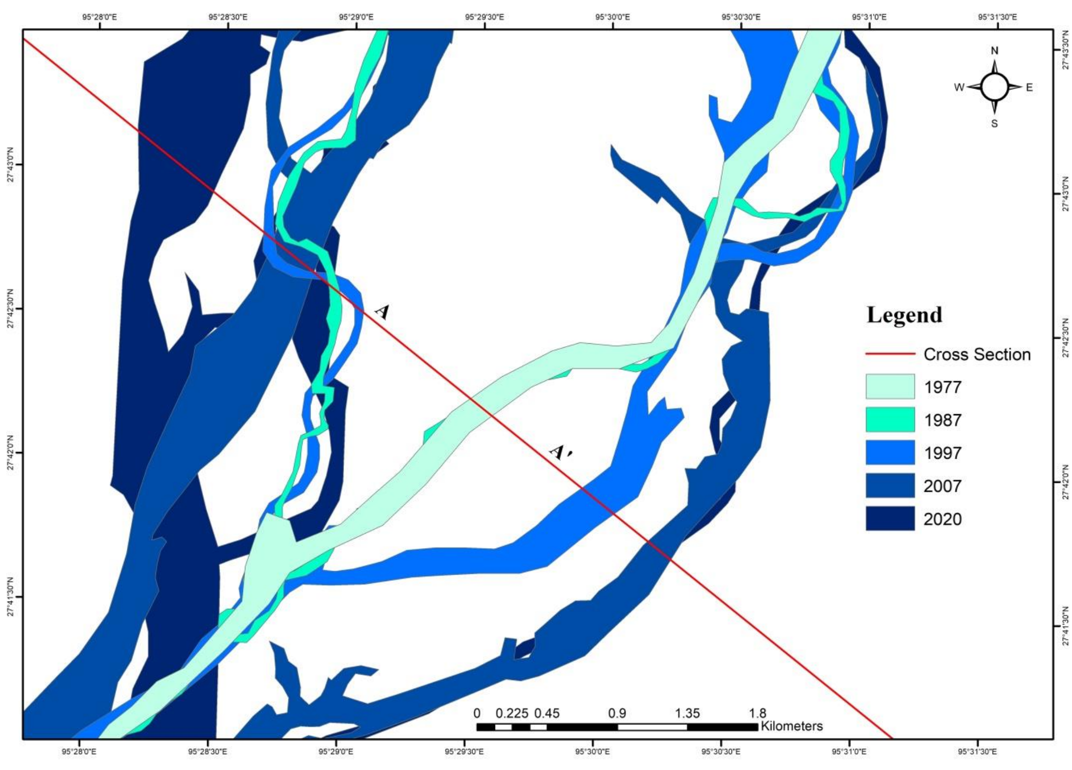


Fig. 3: Cross Section AA'.

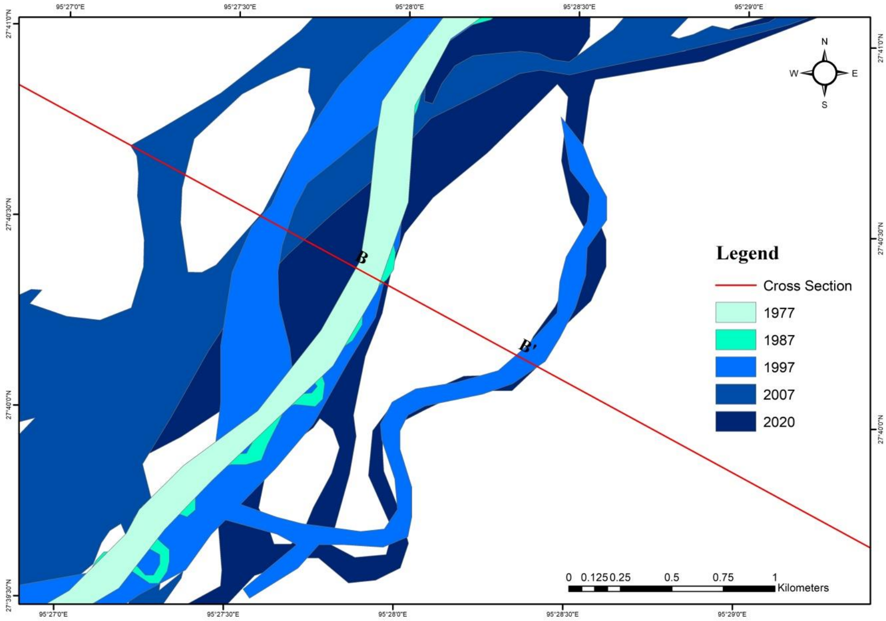


Fig. 4: Cross-section BB'.

Channel Changes (Cross-Section CC', DD' and EE') During 1977-2020

From (Fig. 5 & 10) 1977-1987, CC's cross-section channel was in the right direction and shifted towards the left in 1997 and 2007 at the rate of 0.37 km and 0.48 km, again shifting towards the right in the year 2020 at the rate of 0.63 km (Table 3). From (Fig. 6 & 11, 7 & 11) 1977-1987, cross-section DD' and EE' was in the left direction, cross-section DD' shifted towards the right in the year 1997-2007, and again shifted towards the left direction. And cross-section EE' was a left direction until 1997-2007 and shifted to the right in 2020 (Table 3).

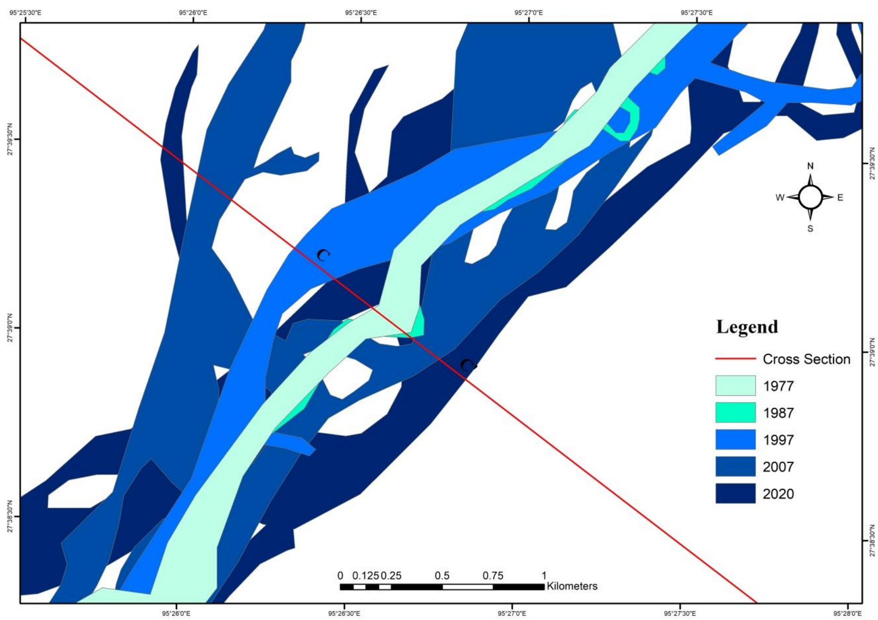


Fig. 5: Cross-section CC'.

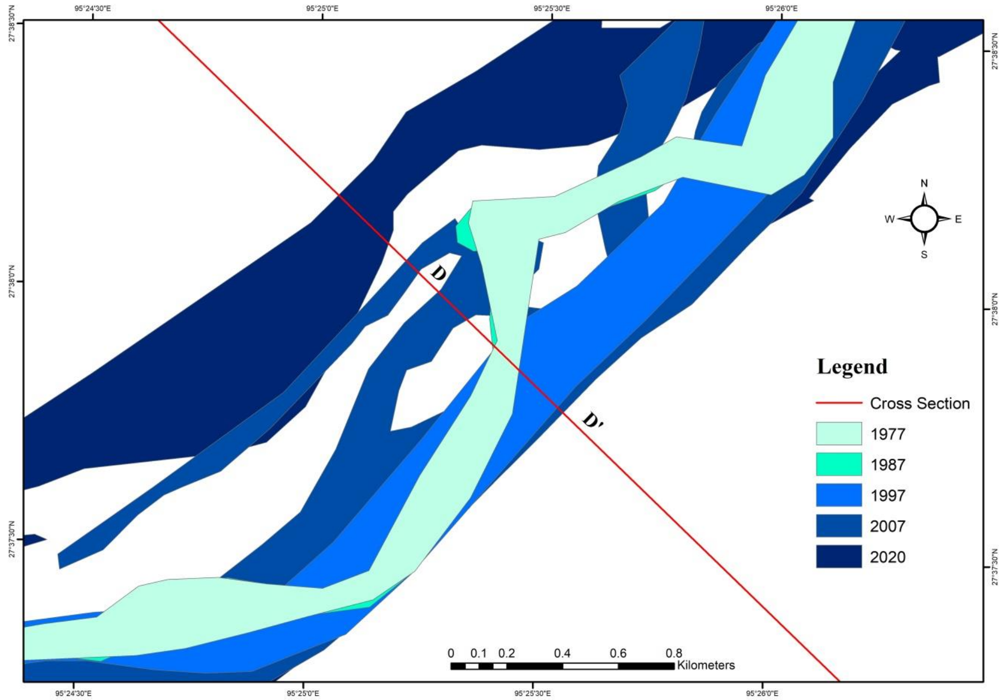


Fig. 6: Cross section DD'.

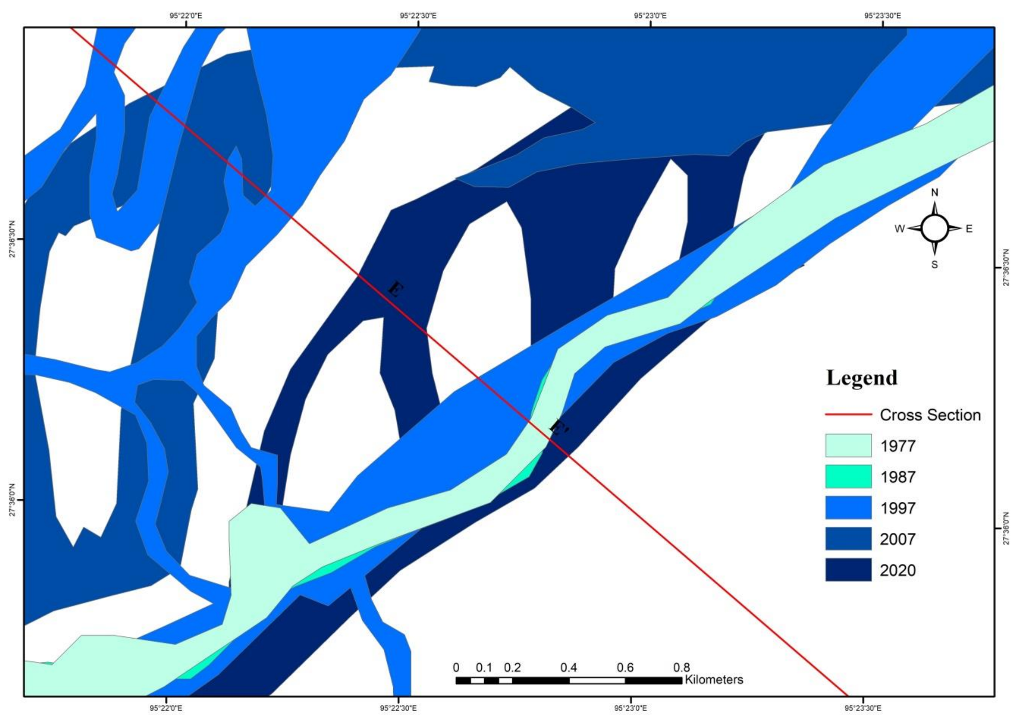


Fig. 7: Cross-section EE'.

Channel Changes (Cross Section FF') During 1977-2020

From 1977-1987, the FF' cross section channel was in the Left direction and shifted towards the right in 1997 at the rate of 0.0.17 km, again shifting towards the left in 2007 and 2020 at the rate of 0.83 km constantly till 2020 (Table 3). In (Fig. 8 & 12), the channel is rapidly progressive in meander formation because of the cliff slope of the channel. The helical flow of the meander bend plays a vital role in sediment transport and deposition (Azpiroz-Zabala et al. 2017).

Hydro-Geomorphic Attributes

Longitudinal River

A long profile is defined as the channel length from source to mouth. It depends on the grade of the slope. Slope declines downwards due to discharge, tectonic activity, geologic structure, sediment transport, flow resistance, width, and depth. From the source to the mouth, the river carries its materials and deposits sediment where it finds the equilibrium point or base level. Displacement along the graded profile would indicate disequilibrium due to tectonic uplift or rock perturbations (Mackin 1948, Leopold & Maddock 1953, Whipple & Tucker 2002, Whittaker et al. 2007). The Dibru river originates at about 155 m above mean sea level and runs up to 132.95 km (Fig. 13). The river is at the mature stage, forming a concave valley. The Dangori river originates at about 145 m above mean sea level and runs to 87.02 km (Fig. 14). The river is at the mature stage, forming a concave valley.

Sinuosity Index (S. I.)

According to Brice (1982) sinuosity index is the ratio of the length of the channel to the length of the meander belt axis. The river has a sinuosity of 1.5, called sinuous or meandering. The Sinuosity Index of the Dibru river and Dangori river were 1.36 and 1.46 in 1966. It shows that the headstream of the Dibru river and Dangori river is sinuous, and in the future, it will be in meandering and braided channels. It is significant in the evolution of landscapes and beneficial for geomorphologists, hydrologists, and Geologists.

Channel Slope

The slope ratio is the ratio between the degree slopes of any given order to the next successive higher order of the basin. It is mathematically expressed as

$$Rs = \frac{Su}{S_{u+1}}$$

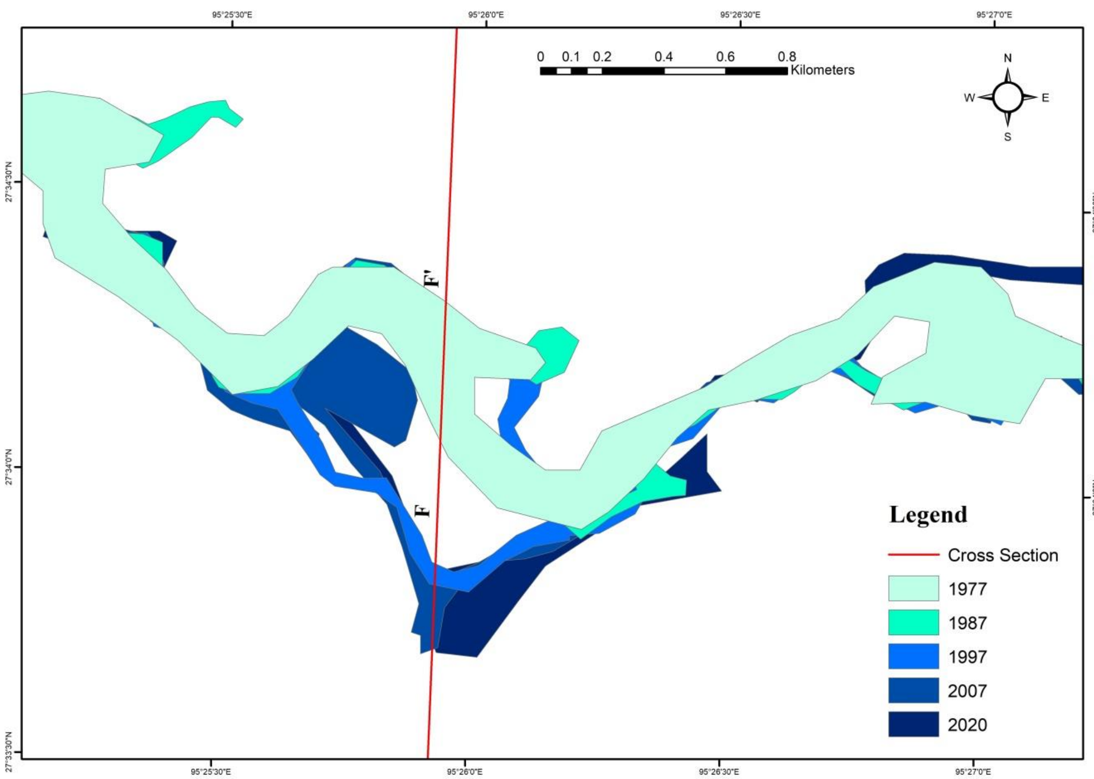


Fig. 8: Cross Section FF'.

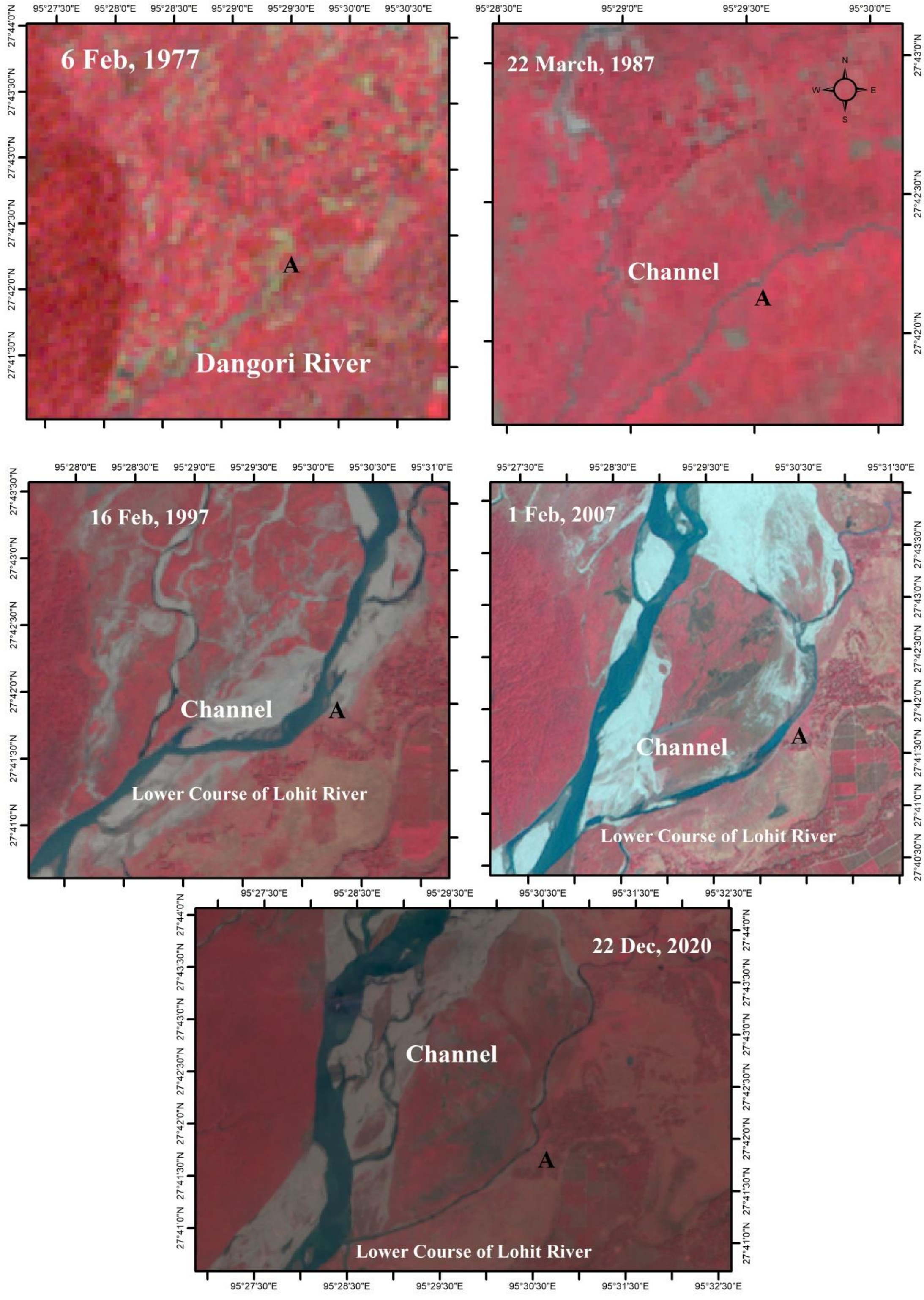


Fig. 9: Satellite imagery of each cross-section.

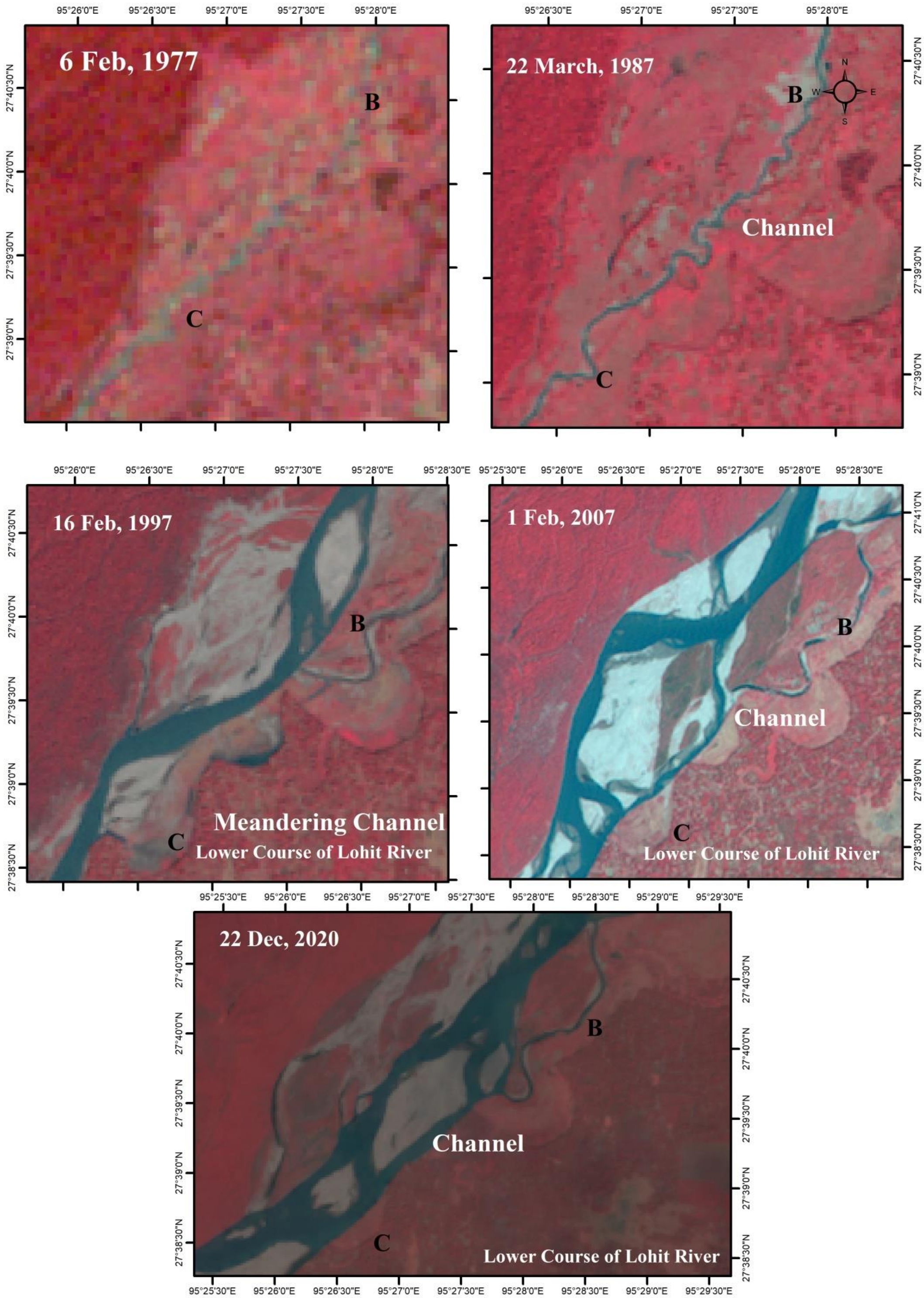


Fig. 10: Satellite imagery of each cross-section.

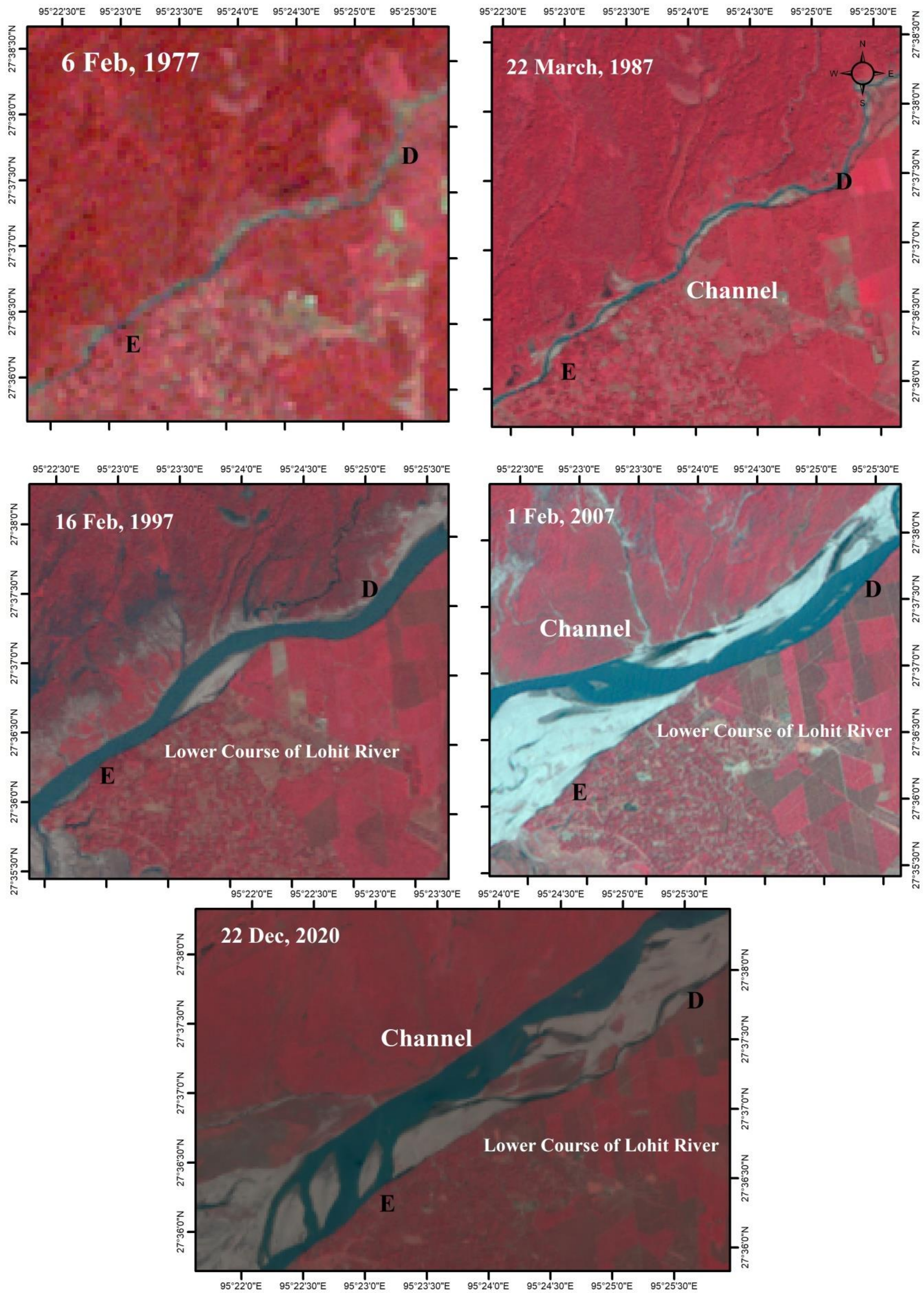


Fig. 11: Satellite imagery of each cross-section.

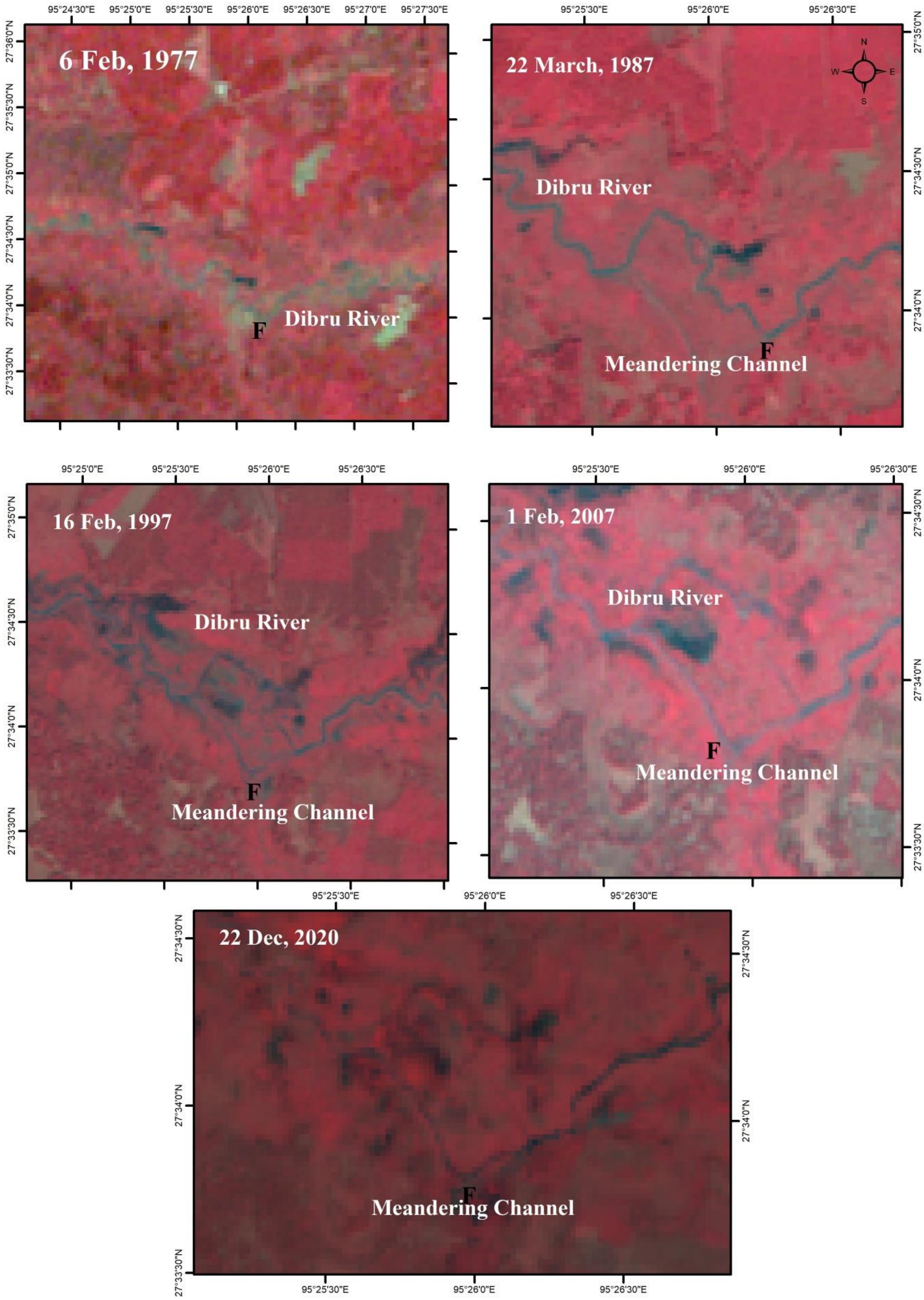


Fig. 12: Satellite imagery of each cross-section.

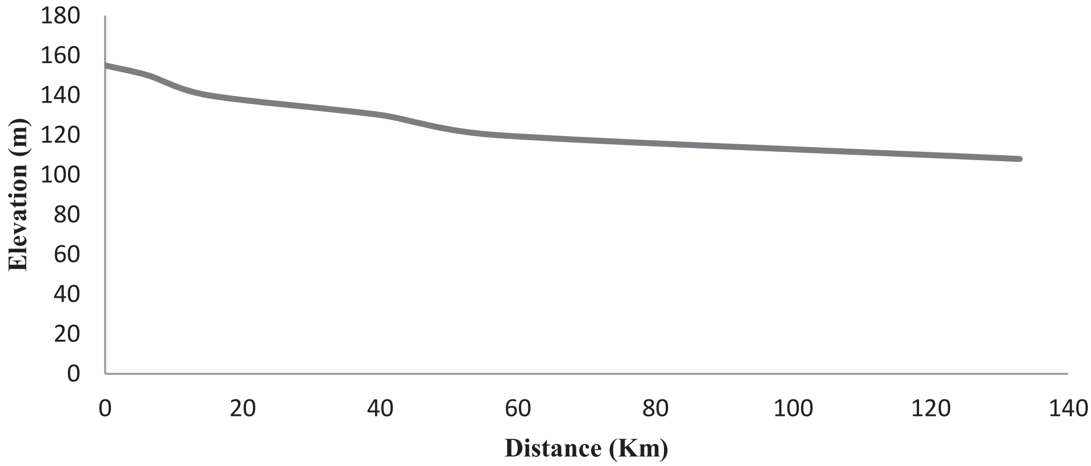


Fig. 13: Longitudinal profile of Dibru river.

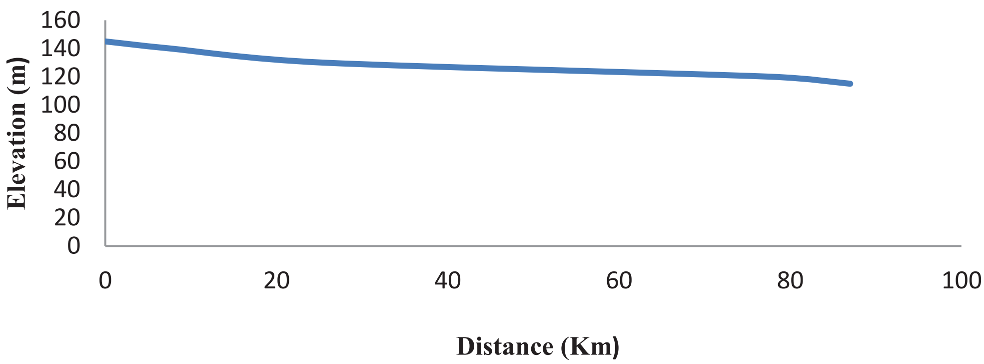


Fig. 14: Longitudinal profile of Dangori river.

Where Su is the slope of a given order, S_{u+1} is the slope of the next higher order

The Law of Channel slope is usually measured from the upper stage of the first-order stream to the lower stage of the last-order stream of the single master stream of the river. Usually, the Law of channel slope is finding out the ratio of vertical drop to increase in a horizontal distance of each order. The mean channel slope of each order is then derived and tabulated (Table 4).

Table 4: order wise slope ratio.

Order	Slope in degree	Slope ratio
1	0º4′26.63″	1.279
2	0º3′28.33″	1.052
3	0º3′18.01″	1.066
4	0º3′5.64″	3.750
5	0º0′49.5″	1.302
6	0º0′38″	-

'The Law of channel slope' as propounded by R.E Horton and applied by M. Morisawa and Leopold and Miller (1956), states that mean channel slope decrease with increasing next order in geometric series with constant slope ratio (Fig. 15). The exponential function is fitted to mean channel slope and stream order.

Flow Characteristics

A flow characteristic is essential to know about the discharge within the channel. Discharge leads to erosion and deposition of material within or outside the bank. Variability of water discharge highly impacts bank erosion, especially in the bank-full stage (Dragicevic et al. 2017).

From (Fig. 16), predictions can be made to know the channel's maximum and minimum peak flow. According to this, planning and management can be done within the study area.

Climatic Indication

Dibru River Basin is situated in the humid sub-tropical belt

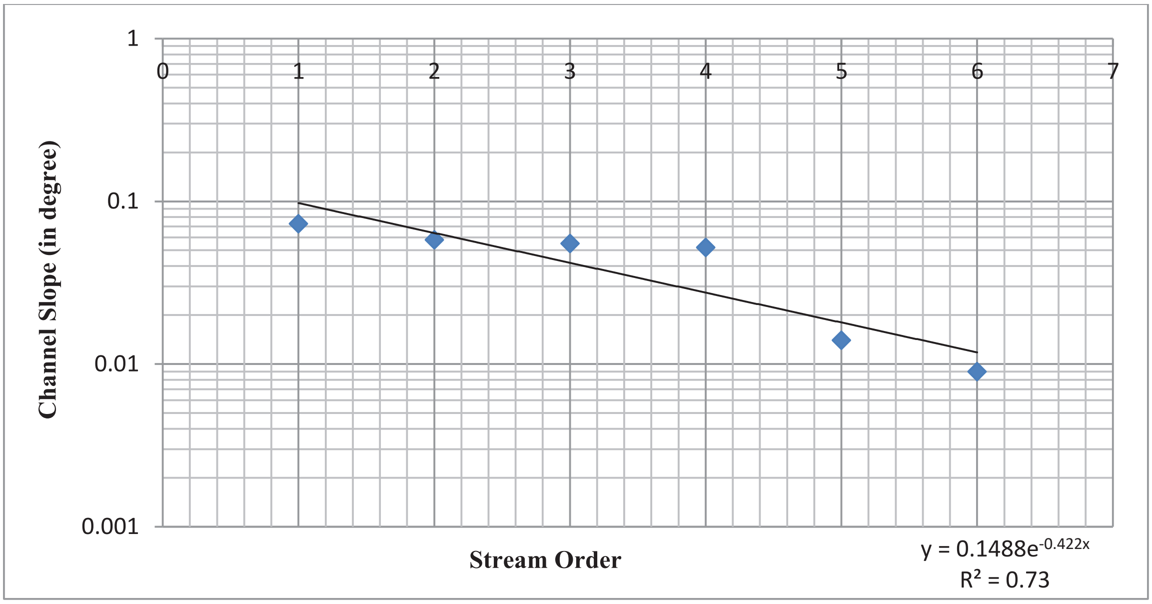


Fig. 15: Channel slope of Dibru River.

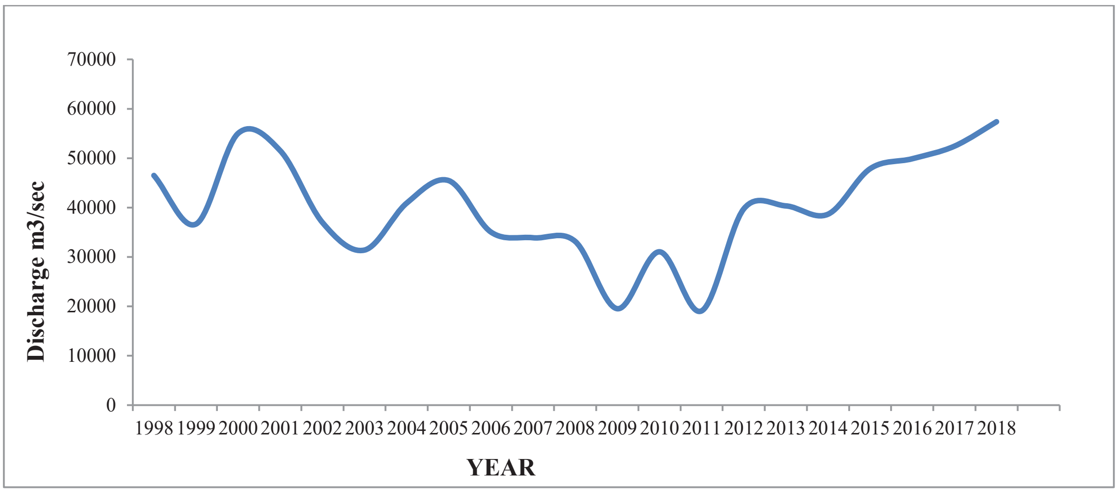
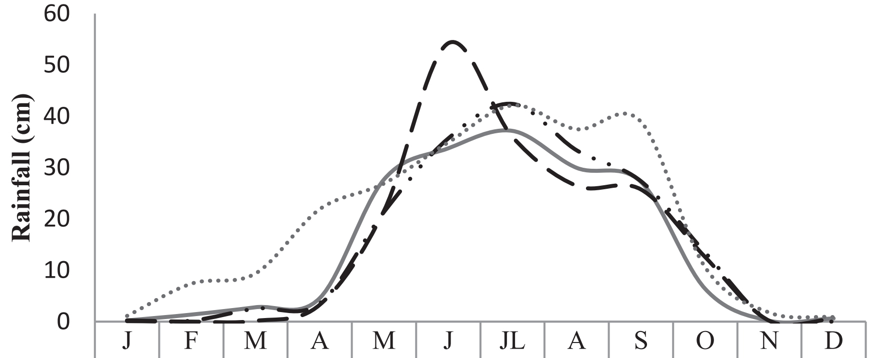


Fig. 16: Annual hydrograph 1998-2019.

within the Brahmaputra River basin. The region experienced a typical subtropical monsoon climate that has some local variations due to its geographic location. In the North and northeast direction of the basin, Arunachal Pradesh and Naga hills develop a sustainable variation in rainfall. The average annual rainfall of the study area is 185.55 cm. The amount of rain received in the Dibru River Basin is not uniform throughout the year. The simplest way of representing the seasonal pattern of variation is the graphical representation of monthly rainfall for different months of the year. The monthly average data for 2011-2019 shows the seasonal variation of rainfall. The monthly averages for the 9 years of record from 2011-2019 are shown in Fig. 17. The ideal graph gives a fairly monthly cycle in a smooth shape. The peak starts from April to September. The maximum amount of rainfall is recorded in July. The rain begins decreasing in October and becomes minimum in December. Maximum precipitation can describe the study area's monthly precipitation patterns during the summer or high sun, insolation at its peak, and a dry season during winter or winter solstice.

The primary peak appearing in April is associated mainly with the pre-monsoon rainstorm caused by the convective activity of ground heating. During the pre-monsoon season, a severe thunderstorm over northeast India generally gives rise



	J	F	M	A	M	J	JL	A	S	O	N	D
Dibrugarh	0.23	1.37	2.8	4.58	27.7	33.8	37.2	30	27.2	6.39	0.17	0.63
Namsai	0.25	0	0.15	3.29	21.6	54.2	36	26.5	25.8	12.6	0.16	0.51
Marghetia	0.1	0.2	2.54	3.57	21.4	35.7	42.4	33.4	27.4	13.5	0.2	0
Dholla	1.11	7.39	9.38	21.9	26.9	34.9	42.1	37.5	38.9	10.6	1.76	0.88

Fig. 17: Rainfall graph of Dibru river basin.

to intense precipitation, leading to the formation of precipitation peaks from April. The maximum rainfall that occurs in July is the effect of the onset of the southwest monsoon.

From August, there is a decline in rainfall due to the effect of a break in monsoon or retreat monsoon taken in September. The deviation of mean monthly rainfall from averages of mean monthly rainfall is observed from October to March. It is found that a highly negative deviation occurs from December to January due to low rain**.**

Geology

The geological map also gives us an idea about geological conditions in particular areas, including rock units and structures. The geological map is prepared by the Geological Survey of India with a scale of 1:50,000 and the map is arranged according to the Age of the formation of the rock layer from the Pleistocene-Holocene to the Meghalayan Age (Fig. 18).

1. Pleistocene-Holocene
2. Holocene
3. Meghalayan

Geologically, the Dibru River Basin was formed during the Pleistocene-Holocene to Meghalaya Age. Pleistocene-Holocene Age covered significant parts of the basin and belonged to older alluvium and consists of rocks oxidized to feebly oxidized sand, silt and clay. Western parts of the basin consist of the Meghalaya Age with newer alluvium and white to greyish sand, silt, pebble, and clay.

The Geological map of the study area is classified into three categories along with their characteristics, and they are mentioned below (Table 5).

Soil

Soil is a naturally complex mixture of inorganic and organic materials. It is a product of a continuing process of evolution in a parent material through physical and chemical weathering processes. It is influenced by the activity and accumulated residues of numerous microscopic and macroscopic plants and animals (Hillel 1998). Soil is one of the pivotal factors in landform development and modification.

Table 5: Geology of Dibru River Basin.

Age	Group_Name	Formation	Lithologic
Pleistocene-Holocene	Older Alluvium	Sorbhog	Oxidized to feebly oxidized sand, silt, and clay
Holocene	Newer Alluvium	Hauli	Established and unoxidized sand, silt, and clay
Meghalayan	Newer Alluvium	Barpeta-I	White to greyish sand, silt, pebble, and clay

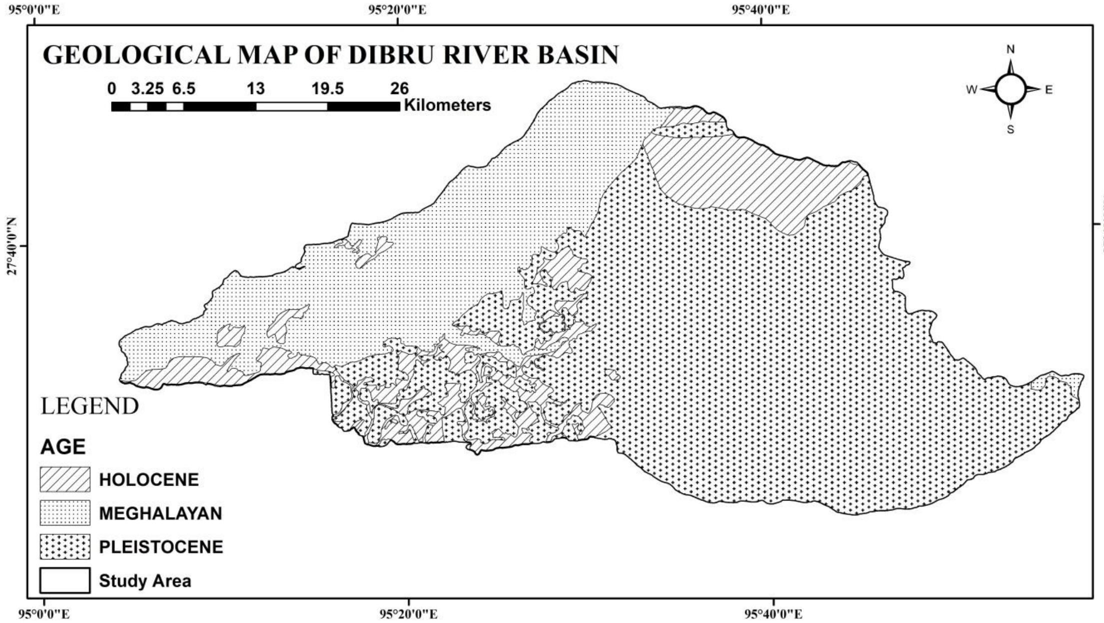


Fig. 18: Geology map.

Thus, it reflects the topographic, geomorphic, hydrologic, and environmental dynamics and impacts the domain of fluvio-geomorphology.

There is a number of factors that have contributed to the processes of soil formation in the Dibru River Basin. Among these factors, the most significant role is played by climate and lithology. Heavy rainfall has contributed to the leaching and lateralization process. Similarly, the diurnal and seasonal temperature variation has contributed to the occurrence of rocks' mechanical disintegration.

The topography and climate have played an essential role in the process of soil formation in the Dibru River Basin. The influence of these two features is more predominant in the rate of surface runoff and erosion. Further, biological features like decayed parts of plants and microorganisms play an essential role in soil formation. The sub-tropical vegetation of the Dibru River Basin the decayed parts and decayed parts of micro-organisms have accelerated the process of soil formation.

The soil of the Dibru River Basin can be classified as Fine-loamy, Coarse-loamy, Fine-Silty, and Sandy. The Soils of the Dibru River Basin have been broadly classified on the published soil map of the Dibru River Basin prepared by the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) Regional Centre Jorhat, Assam, India (Fig. 19). The soil of the Dibru River Basin can be classified into the following categories based on Soil Taxonomy. The different Soil Taxonomy is mentioned in Table 6.

Earthquake

Earthquakes are one of the most destructive natural hazards in Assam. Assam experienced several devastating events that led to many deaths and severe property damage in Assam. Geo-morphologically, Assam falls within the earthquake-prone zone of the Indian Sub-continent. Much of Assam lies in the Brahmaputra valley, except for a few in southern districts. Northern and Eastern valleys are bounded by Himalayan frontal thrust. Himalayan is a result of a continent-

Table 6: Soil Description of Dibru River Basin.

Soil Taxonomy	Description
Fine-clayey	Very deep, well-drained, clayey soils occur on the undulating plain with slight erosion
Fine-loamy	Very deep, well-drained, fine loamy soil occurring on undulating upland having a loamy surface with slight erosion
Coarse-loamy	Very deep, well-drained, coarse loamy soil occurring on undulating upland having a sandy surface with moderate erosion
Fine silty	Very Deep, poorly drained, fine silty soil occurring on very gently sloping flood plain having a loamy surface with moderate erosion
Sandy	Deep, well-drained, sandy soil occurring on the level to nearly level active flood plain having a loamy surface and severe flooding

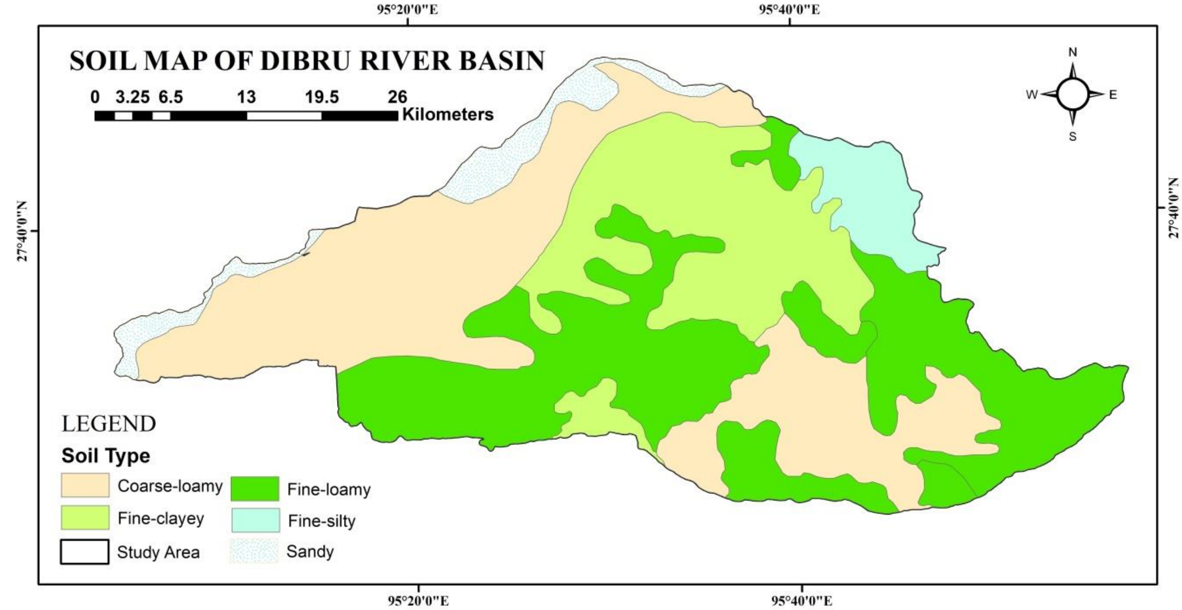


Fig. 19: Soil map.

continent collision with Eurasian plates. In the eastern part, there is Lohit and Naga thrust. In 1897 and 1950, large earthquake events occurred in Assam, and their magnitude was 8.7. According to some documents, these earthquakes were so intense that rivers changed their courses, and ground elevations were immensely affected. Sliced between two tectonic plate collision boundaries, the Himalayan in the north and the Indo-Burman in the east, the northeastern region is the seismically most active region of the world.

Anthropogenic Indication

The role of Anthropogenic in channel migration can be analyzed in terms of changes in the land use pattern. The alteration of the land surface, where the topsoil and vegetation lose their holding capacity of the soil, can lead to changes in the landscapes.

Table 7: Details of Flood-affected villages by lateral migration, Revenue Circle wise.

Parameters	Revenue Circle		
	Doom Dooma	Tinsukia	Chabua
Total village	317	108	19
Total households	48644	22827	1570
Total population	248835	113094	7853
Field surveyed village	04	01	03
Surveyed household	176	15	76
Surveyed population	3312	330	1261
Affected village	32	06	10
Recorded wiped-out villages	23	05	09
Recorded wiped-out household	757	77	426
Recorded the Population shift from wiped-out villages	7664	316	1261
Total village area lost **(hectares)**	4964.51	772.87	1954.85
Total no. of Tea Garden lost	03	02	01
Total no. of Tea Gardens on the urge of the trend of erosion	02	-	-
The total area of the Tea Garden lost (hectares)	522.25	401.83	28.0

Source: Village Map (Census 2011) and Field Survey

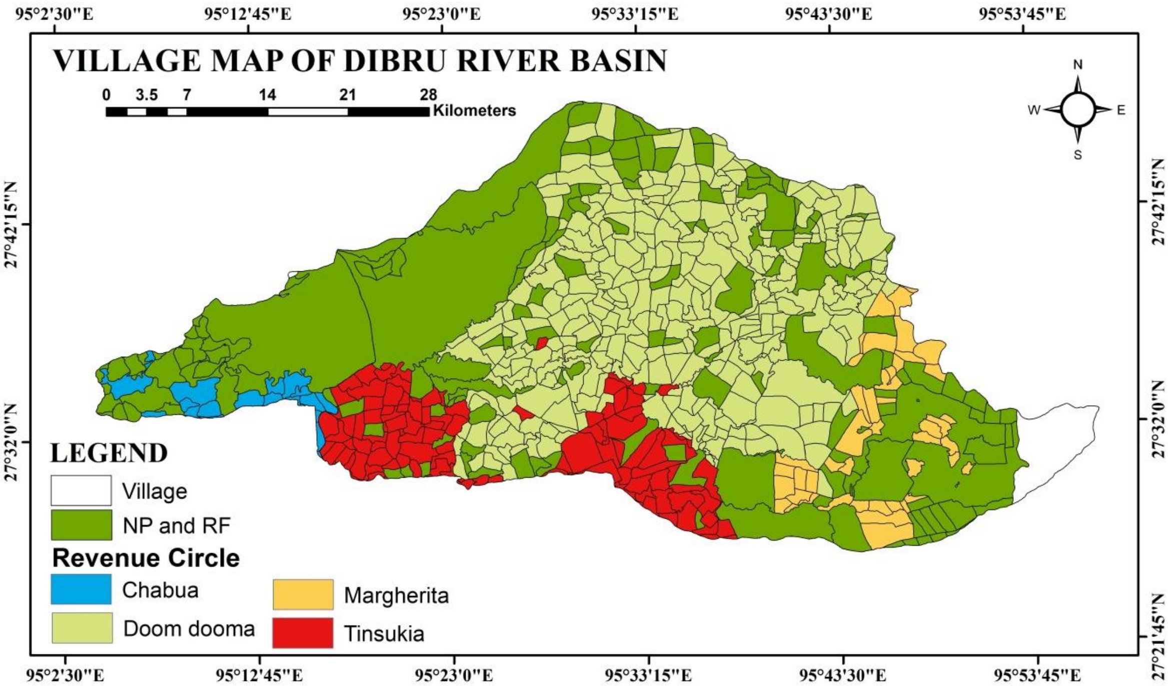


Fig. 20: Village map.

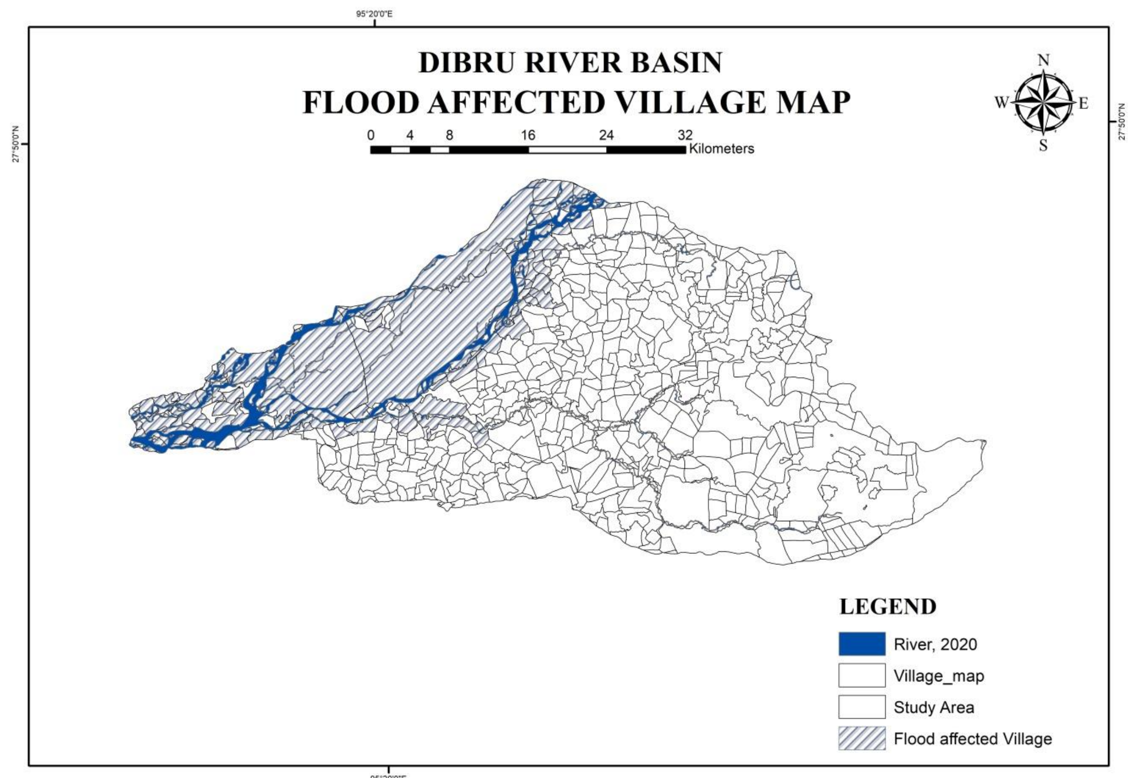


Fig. 21: Flood-affected map.

Consequences of Lateral Migration

Channel migration leads to many changes in the landscapes. They can erode the surface where many villages, tea gardens, households, horticulture, and poultry can lose their life and property. It is a natural process and is usually found in the lower course of each river in the plains region of Assam. Table 7 shows the details of flood-affected villages by the Lower course of the Lohit river, 2020. Since 1966, the river has expanded its wings in recent times and will continue in the future if we don't go for some preventive measures within the study area.

CONCLUSION

The study of the channel migration of the Lower Course of the Lohit river (Dangori) and the Dibru river concludes by using the application of GIS and remote sensing techniques, which helps us to give a glimpse of the channel migration and the nature of the channel. It is difficult to predict the nature of channel migration because of the nature and behavior of the river. Still, we can study the past 54 years of the behavior of the river course and the channel migration from the SOI toposheet and satellite imagery. Using multi-temporal satellite images of the Landsat sensor and LISS sensor of the resolution, we can detect the nature of their shifting and its consequences on the physical and cultural landscapes. Soil properties, Geology structure, tectonic activities, high discharge, precipitation, and the influence of human activities are the leading causes of the channel migration of the Lower Course of the Lohit river (Dangori) and the Dibru river. If we look at the hydro-geomorphic attributes, the profile of the dibru and dangori rivers is in the mature stage, and the river is in a sinuous pattern. This basic help in the shifting and migration of the channel and the channel slope is almost 0° which generally occurs in the plain region. Channel migration is also linked with the climatic indication and soil properties, as the soil of the study area falls in coarse-loamy and fine loamy. The region experiences a great variation of rainfall within and around the basin. The flow characteristic of the river mainly drives the channel migration because of high discharge. If we look at the graph (Fig.16), the discharge rate increased from 2011 to 2018, and the geology structure of the river falls in newer alluvium, as alluvium is linked with floodplain morphology. The most important significance of channel migration is to help to maintain the riparian ecosystem. Riparian ecosystem means the wetlands, ox-bow land, bills, etc. This riparian ecosystem is the home of many species and sustenance the livelihoods of the local people.

The avulsion process is observed within the study area's upper part. Due to this, the Sursa river and Ajuka river merged which led to the flow of the Lohit river within the study area and gave birth to a new channel course as the Lower Course of Lohit river in Dibru River Basin, Tinsukia District.

The rapid expansion of the lower course of the Lohit river led to flood, bank erosion, shifting, and deposition within the study area. In 1966, the channel is expanding its wing and caused much great havoc in physical and cultural landscapes. With the increase in population, the physical landscapes is been converted to cultural landscapes, and alter the changes in land use and land cover of the study area. The region is also fond of the seismic zone. The channel migration erodes many villages, households, and tea gardens near the bank of the river. A total of 37 villages had been wiped out because of channel migration, and 48 are almost affected due to flood and bank erosion problems (Fig. 21). People shifted from their original homeland to new land. Because of channel migration, 5 tea gardens had been wiped out and 2 are on the urge of the trend of erosion. If these problems continue with time, in the coming days many villages, tea gardens, and crop land will be under water. With the help of geospatial tools, we can analyze the rate of shifting and prepare a risk management map to bring awareness to the communities and government to look at these issues and try to mitigate the hazards.

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