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Estimation of Channel Oscillation Pattern of Lower Kopili River Using Geospacial Technology, Assam, India

Shanku Ghosh[1], C Prakasam[1*]

1Department of Geography, School of Earth Sciences, Assam University Diphu Campus, (A Central University), Diphu, Karbi Anglong, Assam 782462, India

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Abstract

This study attempts to study the course change or channel migration of the Lower Kopili River (LKR) between 1980 and 2020. Spatially, the study is mostly focused on the Nagaon district section, where the river is experiencing the highest shifting compared to other parts. The planform, surrounding land use land cover, and channel sinuosity have been measured, and their temporal variation has also been studied. Satellite data from Landsat MSS, TM, and LISS III have been used to generate LULC maps and to extract channel planform for different decades. Channel central lines for all planforms were drawn in GIS, and the channel migration toolbox from the Department of Ecology, State of Washington, was used as the primary tool for measuring the decadal extent of channel migration. Following the channel central lines, cross sections were drawn at-500 meters intervals. To study the land use land cover maps (LULC) dynamics of the study area, five LULC maps were generated across all five decades (1980-2020). The results of the study show that the highest average migration has occurred at 99.16 meters per transect between 1980-1990, followed by 44.58 meters/transect between 1990-2000, and 94.51 and 63.25 meters per transect between 2000-2010 and 2010-2020, respectively. The section-wise sinuosity index reveals that between sections 4 and 7, the river follows a highly meandering path with an average sinuosity index of 2.08. It has been observed that the river frequently changes its flow path through channel avulsion, creating several oxbow lakes.

Keywords: *Channel shifting, Kopili River, LULC, river shifting, meandering.*

1. Introduction

Channel shifting, migration, and avulsion are defined as when the river changes its course or abandons the old one and starts flowing along a new course. This is a common characteristic of meandering streams, where the river flows along a meandering path, generates cut-offs and migrates in the floodplain (Brizga & Finlayson, 1990). Through this process of meandering and floodplain formation, the river channel migrates across its floodplain. Point bar deposition along the inner banks of meander loops increases sheer stress and accelerates erosion on the outer bank (Dietrich et al., 1979; Zhu et al., 2022). Continuous sedimentation on the point bar pushes the channel outward and causes it to migrate laterally across its floodplain (Dietrich & Whiting, 1989; Zhu et al., 2022). A river channel becomes straight or decreases local sinuosity by formingof cut-offs. Cut-offs are mainly of two types: neck cut-offs and chute cut-offs (Howard and Knutson, 1984). Cut-off formation results in the abandonment of the old meander loop, and the river starts to flow through a newly created straight path; simultaneously, the abandoned loop exists as an oxbow lake. In the process of channel avulsion Bank failure is an integral part. River hydraulic erosion develops cantilevered soil blocks through undercutting along the banks, which overhang without any basal support; during high-flow times (floods), increased shear stress and accelerated erosion cause these blocks to collapse (Debnath et al., 2023; Chakraborty and Saha, 2021). River discharge, flow velocity, bank lithology, stratigraphy, channel geometry, and human influence are important factors in river bank failure. Based on the degree, magnitude, intensity and frequency of flood occurrence there are changes in channel width due to bank scouring, sedimentation, etc. (Gupta and Fox, 1974). Stream gradient plays an important role in controlling velocity; a high stream gradient results in a higher flow velocity and increased erosivity. The presence of loose bank material, along with lateral, sequential erosion and deposition, Causes the River channel to shift across its floodplain and adjust its geometry (Debnath et al., 2017). River planforms exist in equilibrium with three fundamental components: energy, sediment supply, and vegetation. Any changes in these components result in channel planform morphological changes, in some cases shifting from one planform to another (Gurnell et al., 2009). Vegetation, sediment supply and river discharge are directly related to the land use land cover (LULC) of the river basin catchment areas as well as downstream channel planform riparian areas. River channels respond differently to watershed LULC change over space and time. Changes in upstream LULC have a direct impact on the downstream channel form and shape, depending on the time lag between upstream LULC change and the downstream channel›s response to it, because it might take a long time to transport coarse bed load to the downstream (Kondolf et al. 2002). The volume of discharge from the river is altered by changing LULC. According to Schilling et al., there has been an increase in Mississippi

* Corresponding author e-mail: cprakasam@gmail.com

River discharge from 1890-2003 due to agricultural activity-induced LULC change in the upper Mississippi River basin (Schilling et al., 2010). Watershed LULC is an important factor that influences watershed hydrology, rainfall, runoff, discharge, and sediment yield. LULC modification or decreased vegetation cover in the watershed influences river channel pattern, response, and results in channel avulsion, bank erosion, and channel migration in the downstream floodplain. This further modifies the channel planform and riparian vegetation (Thakur et al., 2012). Vegetation has significant control over the flow resistance, bank strength, bar formation, log-jam formation and concave bank bench deposition. Lateral stability and channel form of the river are significantly influenced by the root density and soil-binding properties of the bank/channel riparian vegetation (Hickin and Nanson, 1984). Most historical studies addressing the relationship between vegetation cover and channel response conclude that high vegetation cover in fluvial systems results in decreased channel width and form ratio (Turner, 1974; Hickin and Nanson, 1984). The control of bank/channel riparian vegetation on channel form can be seen in the study conducted by Nevins, 1969; where a highly braided pattern channel (Turdnganui River channel in New Zealand) was converted into a meandering pattern through the planned planting of willow shrubs at selected bends (Nevins, 1969). Another Study conducted by Hickin & Nanson on Western Canadian Rivers reveals that, compared to unvegetated alluvial exposed banks, river banks with high vegetation cover and root density offer high resistance to channel migration and lateral erosion (Hickin and Nanson, 1984). Anthropogenic influence in river floodplains is an important agent of river channel change. Human-induced changes in river channels are a longstanding practice, but scientific exploration of such impacts began after 1956 (Gregory, 2006). According to Kesel, to improve and maintain navigation, the lower Mississippi River was channelized and shortened by 245 km (1929-1942), which resulted in the chute cut-off of 15 meandering bands, and the river was additionally shortened by 88 km (between 1939 and 1955) (Kesel, 2003).

In the present era combined impact of climate change and anthropogenic activities making bank erosion and channel widening a mounting issue across the major river systems i.e. Ganga, Brahmaputra, Indus, Amu darya, Irrawaddy, Amazon, Yukon, Lower Mississippi, Middle-Lower Nizer, Lower Congo etc. the Ganga and Brahmaputra are the two major rivers In India, bank erosion in along the Ganga and Brahmaputra and their tributaries are persistent issue (Ghosh & Sahu, 2019; Ghosh, 2022; Ghosh & Sahu, 2023; Rahman et al., 2025; Mosselman, 2025; Bhuyan, et al, 2024) . The Kopili River, one of the major south bank tributaries of the Brahmaputra River follows a highly meandering flow path in the selected location downstream and changes its course over timewhich influences the riparian settlements and agricultural practice. So, it is important to closely examine the river channel-shifting pattern and its controlling factors. With bank erosion, flooding is another significant issue in the study area. Though the flood issue is addressed in some studies (Shivaprasad Sharma and Roy, 2018a; Shivaprasad Sharma and Roy, 2018b), the bank erosion remains untouched. The main objectives of the study are to analyze the channel planform riparian LULC pattern, meandering dynamics, and lateral erosion extent to demarcate LKR planform avulsion-vulnerable locations.

2. Study Area:

The Kopili River, after originating from the Barail range (1800 M.) near the Jayantia hills of Meghalaya flows for almost 300 Km across Assam, Meghalaya. ‹ ‹a major south bank tributary of the Brahmaputra River, which contributes approximately 1.47% of the Brahmaputra River›s discharge (Sharma et al., 2019). Major tributaries of the Kopili are Diyung, Jamuna, Borpani, and the Kolong River. The river basin has a total geographical area of 15921.72 Km², covering the Dima Hasao, West Karbi Anglong, Karbi Anglong, Nagaon, and Marigaon districts of Assam. The present study selects a 117.8 km section of the Lower Kopili River, which lies mostly under the Nagaon district (Figure 1). With a total 2287 km² geographical area and drained by 23 large and small rivers Nagaon is majorly dominated by agricultural activity and highest crop producing district of Assam, due to lack of agricultural infrastructure and irrigation facilities fellow agriculture also practiced here, where during the winter seasons croplands are kept as fellow land in some places of the district (Bhuyan & Deka, 2024). The district is located in the floodplain of the Brahmaputra and Kopili River. Kopili is the largest river flowing through the middle of the district. From a Lithological perspective, the district is composed of Quaternary fluvial sediment deposits (Geological Resource Map, 1998) with a gentle gradient towards the Brahmaputra River.

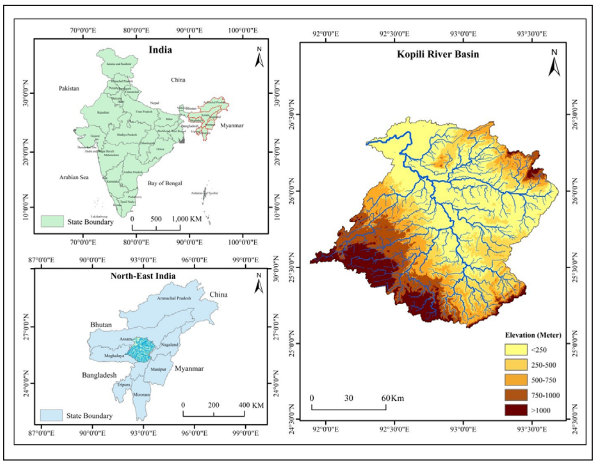

Figure 1. Study area map showing geographical location of the study area.

3. Methodology:

The tools, techniques, and database used in the study are in the methodological flowchart (Figure 2). Different temporal satellite images (Table 1) were collected and preprocessed (layer stacking, noise removal, and haze reduction) for analysis. The four-kilometer buffer area was created on both sides of the channel thalweg along the 117.8 km stretch of the river. Further, the study area was extracted from the satellite images using a buffer. Satellite images were resampled to address differences in spatial resolution. In the next stage, five LULC maps were generated from the resampled images using the Maximum Likelihood supervised classification method. Following the major land use and land cover types, the entire area was classified into six classes (dense vegetation, sparse vegetation, agricultural land, water body, built-up area, and sand bar). The river channel planform shapes were extracted from satellite images for overlay analysis and to study spatiotemporal variation over the five decades. To study the channel planform dynamics the sinuosity index was used. Here, the river study area was divided into nine sections, and the Sinuosity index was calculated for each section. The primary objective of the study is to estimate channel migration and its spatial-temporal variation. The rate of channel shifting was calculated for each successive decade (1980-1990, 1990-2000, 2000-2010, and 2010-2020). The entire reach was divided into cross-sections at 500-meter intervals. The decadal rate and direction (eft bank & right bank) were further plotted in a graph.

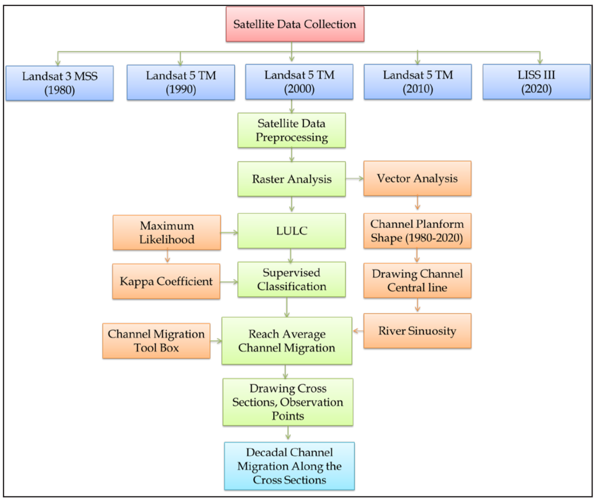

Figure 2. Methodological flowchart showing the tools, techniques, and database used in the study.

Table 1. Description of the collected satellite images.

SL. No.	Satellite	Sensor	Spatial Resolution	Date of Acquisition	Path and Row
1	Landsat-3	MSS	60M.	01-02-1980	146/042
2	Landsat-5	TM	30M.	08-05-1990	136/042
3	Landsat-5	TM	30M.	27-12-1999	136/042
4	Landsat-5	TM	30M.	10-11-2011	136/042
5	Resourcesat-I	LISS-III	24M.	10-10-2018	111/053

4. Results:

4.1. Land Use Land Cover (LULC):

As defined by the Food and Agricultural Organization (FAO), land cover is the physical feature of the Earth›s surface, and the addition of economic activity and modification of land cover is known as land use. In the present study, channel riparian LULC dynamics (1980-2020) have been analyzed to examine channel migration in the Lower Kopili River. Five LULC maps were prepared for each decade (1980 to 2020). The study area comprises six major LULC types (Figure 3), namely dense vegetation, sparse vegetation or bushes, agricultural land, built-up area, sandbar (channel bars), and water body (pond, lake, river, wetlands). The results of the LULC analysis (table 2) show that throughout the study period (1980-2020), agricultural land occupied the highest proportion (>30%) of the study area. Here, the agricultural land represents both the recent crop lands and current fallow lands. In 1980, agricultural land constituted 40.42›% of the study area among all the decades. In 2010, agricultural land constituted the highest proportion (56.20%), adding an additional 10%. Both the dense and sparse canal riparian vegetation have shown negative growth of 12.54% and 54%, respectively. The dense vegetation covered 56.53 km² in 1980, which reduced to 49.44 km² in 2020; the same trend was observed for sparse vegetation, which reduced from 277.86 km² in 1980 to 127.81 km² in 2020. Water bodies (natural and artificial) and built-up areas (rural and urban) have seen the highest positive growth of 141.48 and 324.37 percent respectively. The area occupied by the water body has grown from 42.7 km² to 103.11 km². Built-up area has seen the highest increase from 52.97 km² to 224.79 km² over the five decades, mainly due to the expansion of areas occupied by sparse and dense vegetation. Sandbar represents channel-bar deposition (mid-channel, point, lateral) and bank-surface sand splay due to sedimentation. This area constitutes approximately 5% of the total study area (1980-2020).

Table 2. Decadal area distribution of each LULC class and their growth rate.

Area (Km²)					
LULC Type	1980	1990	2000	2010	2020
Sand Bar	2.42	5.62	2.57	12.45	2.87
Dense Vegetation	56.53	105.08	113.08	62.33	49.44
Sparse Vegetation	277.86	222.88	178.97	101.52	127.81
Water body	42.7	88.52	96.97	40.77	103.11
Agricultural Land	293.42	233.9	243.65	407.99	217.88
Built Up Area	52.97	69.9	90.66	100.84	224.79
Total Area	725.9	725.9	725.9	725.9	725.9

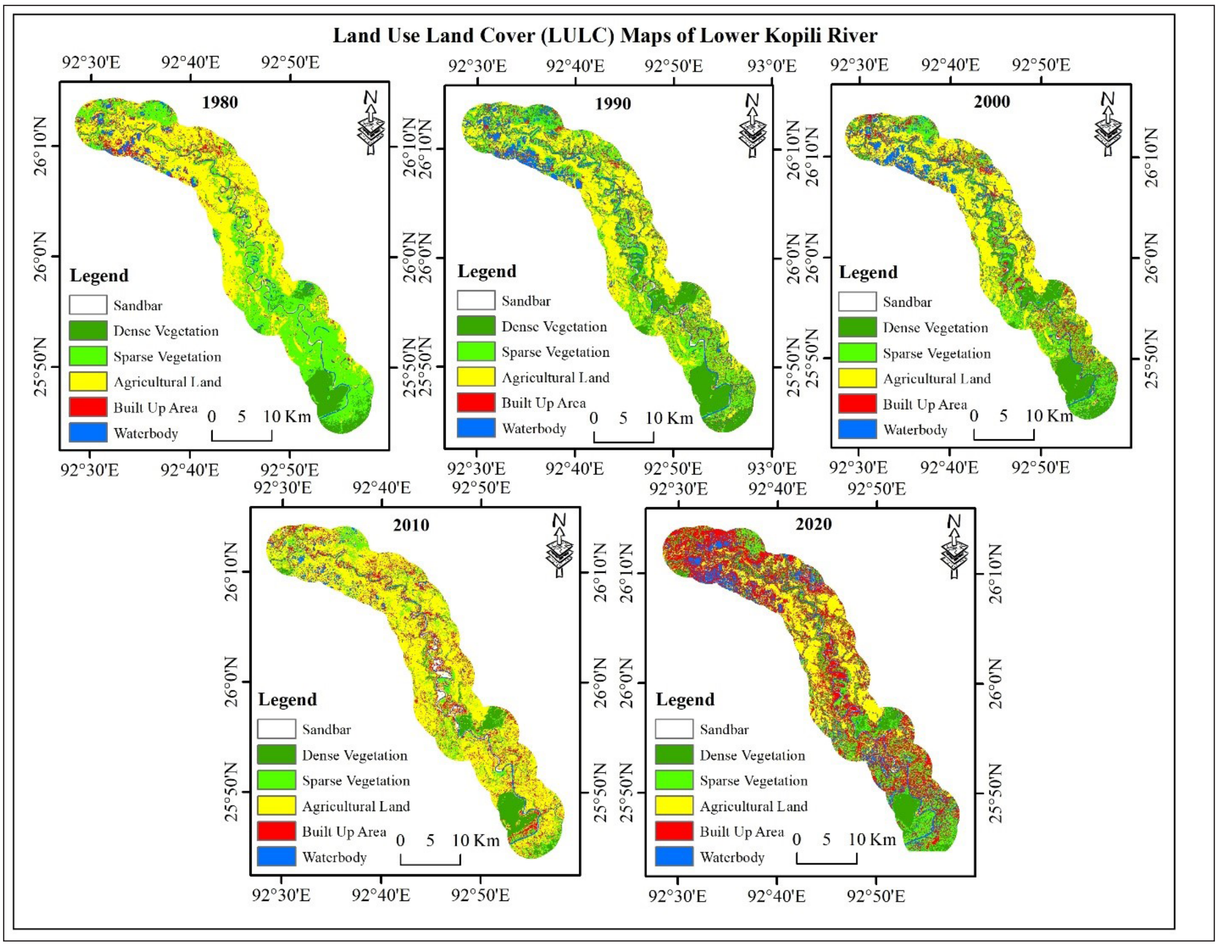

Figure 3. LULC maps, showing decadal LULC dynamics in the study area.

4.2. Channel Meandering:

The sinuosity index (SI) is a measure of how much river channels deviate from a straight line path; ‹ ‹it›s an important parameter of measuring river channel stability, while a high sinuosity value indicates a meandering channel, a tendency of more channel widening through bank erosion and course change. Since the present study concerns channel sifting of the LKR, the sinuosity index was considered an important parameter for analysis. The total stretch of the river has been classified into nine sections to identify areas with dynamic meandering adjustment and migration. As mentioned in Table 3 & Figure 4, the LKR sinuosity index varies from the lowest 1.29 to the highest 3.19, while the river carries an overall SI of 1.78, which confirms a high channel meandering nature. Among the nine created sections, significant spatio-temporal variation has been noticed. sections 4, 5, and 6 demarcate the zone of high sinuosity and dynamic channel adjustments. The channel flows with an average SI of 2.16 through this zone, and across the remaining section, the channel contains a relatively lower SI of 1.58. Section 6 has the highest sinuosity index of 2.56, followed by section 4 with 2.05 sinuosity index and section 5 (1.88). A lower SI value along the channel stretch of sections 1, 2, 3, 7, 8, and 9 indicates channel stability and less dynamic sifting, and vice versa.

Table 3. Section-wise decadal sinuosity index of Lower Kopili River.

Section	1980	1990	2000	2010	2020	Sum
1	1.8	1.79	1.8	1.76	1.76	1.78
2	1.38	1.31	1.31	1.29	1.3	1.32
3	1.66	1.65	1.67	1.64	1.64	1.65
4	2.18	2.06	2.03	2.02	1.97	2.05
5	1.81	1.85	1.94	1.76	2.05	1.88
6	2.21	2.38	2.51	3.19	2.55	2.57
7	2.05	1.85	1.9	1.78	1.52	1.82
8	1.44	1.45	1.51	1.3	1.58	1.46
9	1.52	1.49	1.48	1.49	1.52	1.50
Sum	1.78	1.76	1.79	1.80	1.77	1.78

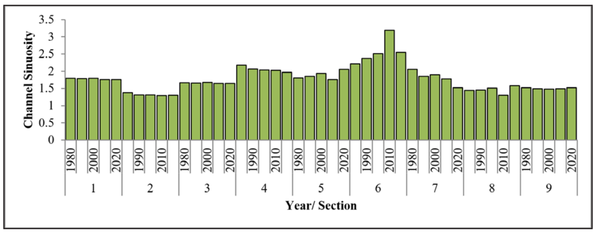

Figure 4. Bar diagram showing the section wise sinuosity index graph.

4.3. Channel Migration & Channel Avulsion:

As mentioned in the methodology, to estimate the extent of channel migration, multiple cross-sections were drawn along the valley central line with 500 meters spacing. Following the extent of the meander loops, the length of the cross-sections was kept at 5000 meters. To measure the extent and direction of channel migration for all five decades (1980-1990, 1990-2000, 2000-2010 & 2010-2020), channel planforms were extracted from satellite images (Table 1), and the valley central line was drawn using the planform shapefile. Specifically, the channel migration extent was measured in both the left- and right-bank directions, as shown in the graph (figure 5). Between 1980 and 1990, the highest right-bank migration was observed at 989 meters along the 132nd cross section and 834 meters along the 120th cross section towards the left bank. Between 1990 to 2020, the channel migrated 470.15 meters along the 69th cross section towards the right bank and 353 meters along the 132nd cross section towards the left bank. Between 2000-2010, the channel migrated 1077.26 meters (121st cross section) towards the left bank and 598 meters (102nd cross section) along the right bank, and between 2010-2020, 715.31 meters migrated following the 102nd cross section and 308.99 meters migrated along the 76th cross section towards the right and left bank respectively. The overall highest average migration of 99.16 meters was observed between 1980 and 1990, followed by 94.51 meters between 2000 and 2010, 63.26 meters/transect between 2010 and 2020, and the lowest of 44.58 meters/transect between 1990 and 2000. As per the direction (left and right) of channel migration, over all decades, nearly the same number of transects have seen migration on both sides of the valley central line. The graph (Figure 6) representing overall channel migration (1980-2020) indicates that, along the studied reach, the highest channel migration has occurred between the 65th and 70th cross sections and the 100th to 140th cross sections; these zones are highly vulnerable to channel migration.

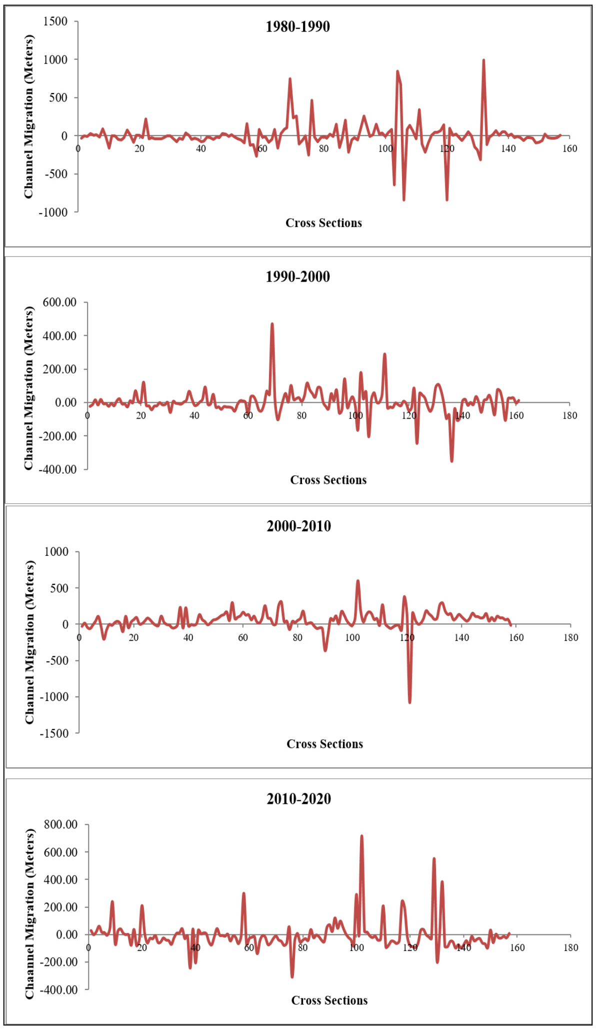

Figure 5. Channel migration graph showing the extent of channel migration

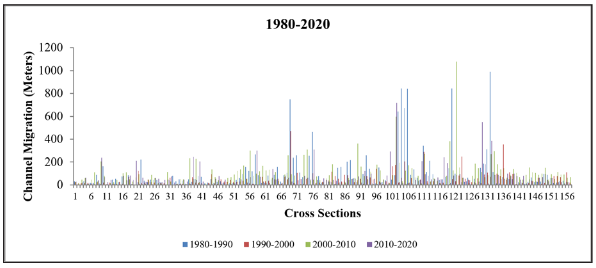

Figure 6. Combined channel migration graph (1980-2020).

5. Discussion:

The above discussion focuses on the derived results, including the analyses of channel riparian land use and land cover (LULC) patterns and their dynamic changes, channel sinuosity, and measurements of channel migration and avulsion. The LULC analysis is focused on the created buffer area (4 km) on both sides of the channel›s central line. The Kopili River channel and surrounding area are covered by agricultural land, which occupies the highest proportion of the area. Both dense forests and sparse vegetation areas have seen significant decreases over the decades. Riparian vegetation cover is a crucial factor in maintaining channel stability, which increases the strength of bank materials, and deforestation reduces root density and canopy cover, promotes greater runoff generation, elevates sediment supply, and increases infiltration loss (Yu et al., 2015; Loch, 2000). As discussed earlier, the second-highest average channel migration occurred between 2000 and 2010, at 94.51 meters per transect. Notably, this period also witnessed the greatest reduction in both dense and sparse vegetation cover, as shown in Table 2. In the following decade (2010–2020), the average migration rate declined to 63.26 meters per transect, while the area covered by sparse vegetation increased, as indicated in the table.

The section-wise channel sinuosity index indicates significant variation in channel sinuosity across specific segments—particularly sections 4, 5, 6, and 7—where the river exhibits extreme meandering patterns (sinuosity > 1.8). In these areas, the channel continuously adjusts its flow path, and a notable meander cutoff occurred between 1990 and 2000 at coordinates 25°55›13»N, 92°50›41»E (Figure 7). The channel migration graph (Figure 6) shows that lateral migration is not uniform across the study area. There is considerable variation in the extent of migration. Certain cross sections—specifically the 65th, 70th, and 100th to 140th—experience high decadal migration, while others show low to very low migration rates. It has been observed that cross sections experiencing high accretion are located within zones of elevated channel sinuosity. This result suggests a direct relationship between the sinuosity index and channel migration. Overall, the analysis of channel meandering and migration indicates that localized channel migration has been occurring consistently throughout the study period in the Lower Kopili River.

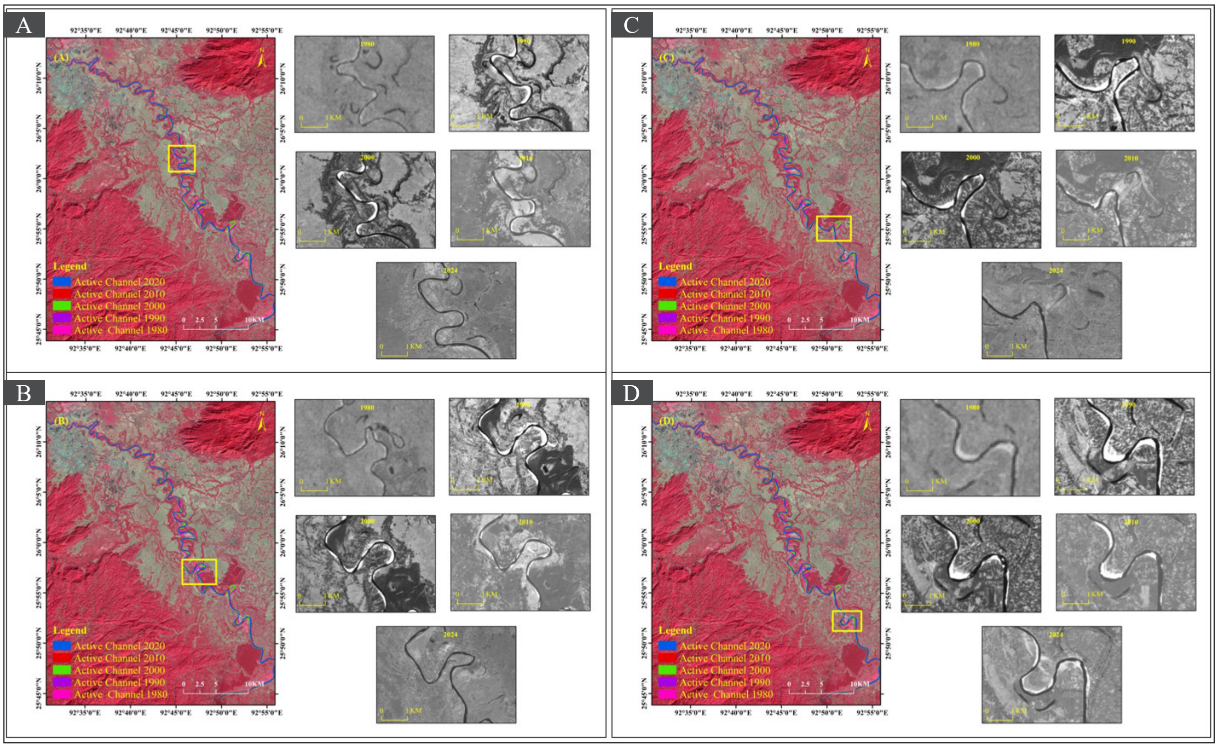

Figure 7. (A), (B), (C), (D): channel migration/avulsion vulnerable zones.

6. Conclusion:

The present study investigates channel shifting in the Lower Kopili River. It includes an analysis of Land Use and Land Cover (LULC), channel sinuosity, and decadal-scale channel migration. The findings reveal that channel shifting is occurring in specific locations that are significantly more vulnerable than other areas along the river. In these zones, the river continuously adjusts its meandering loops, and several oxbow lakes have formed over time. Riparian LULC analysis indicates a rapid decline in vegetation cover surrounding the channel, which has been replaced by settlements, agricultural land, and water bodies. This shift in channel planform has direct implications for land use and the livelihoods of riparian communities. These vulnerable areas require targeted attention and mitigation strategies to address the ongoing channel migration. The current study is based entirely on satellite imagery; however, future research should incorporate field-based investigations, including assessments of soil characteristics, lithology, and geological conditions, to gain deeper insights into the dynamics of channel shifting in these regions.

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