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RESEARCH ARTICLE

A Spatio-Temporal Analysis of River Channel Migration & Erosion-Depositional Pattern of Lower Part of the Dikrong River of Assam by Using Geo-Spatial Technology

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Abstract. Rivers often show different morphological changes in different periods and geographical areas; a river's morphology changes due to erosion, deposition & transportation processes to attain the equilibrium state. The activity of erosion & deposition is highest in the alluvial River as a result of the river channel migration, which affects the land cover and the livelihood of the inhabitants. The Dikrang River is the northern sub-tributary of Brahmaputra, which originates in Arunachal Pradesh and flows through the Brahmaputra valley. As a result of the erosion and deposition, both the river channels have migrated, this changes the equilibrium state of the River's aquatic environment and modifies the land use pattern in the floodplain. The objective of the present study is to identify the River channel migration pattern & the erosion-depositional scenario of the Dikrong River channel from the period of 1973-2022 to identified the responsible factors of the hazard that may helpful for the better management of the River channel. The Survey of India topographical map, LANDSAT satellite images, and geospatial tools have been applied to measure the bank line migration of the Dikrong River. The output of the study represents that the remarkable channel migration occurred in the River due to the vast sedimentation & ongoing erosion activity on both banks of the River. The lower and central parts of the river channel have gradually changed the course of the River both in the direction of the West and East of the Dikrang River channel. The study will be helpful for the planners & geomorphologists in preparing an effective management strategy to solve the problem & proper development of the watershed.

1. Introduction

The changing morphology of an alluvial river channel is a common phenomenon, and several activities are associated with the changing morphology of a river, such as sedimentation, erosion, high discharge, River channel migration, etc. Other natural and anthropogenic factors influence the morphological characteristics of a river. The high discharge of water in a river, changing patterns of rainfall and tectonic activity, and some other anthropogenic activities, including deforestation, land use patterns, and construction of dams and bridges along the River, also impact the morphology of a River channel. The River channel migration is usually a natural geomorphic activity of a River (Maity & Das, 2019).In an alluvial River, river bank erosion generally happens during the monsoon period, and it is the main factor in the migration of the River channels (Haque & Matin,2022). The river bank erosion is demarcated as a natural hazard because it supplies sediment into the River and alters the river bank, affecting the land use pattern and the livelihood of the local inhabitants (Mandal, S., 2017). The anthropogenic activity also alters the River's physical morphology and chemical properties. The different studies have verified that anthropogenic activities are degrading the characteristics of River water worldwide, and it is severe in urban areas (Chen, S.S. et al., 2022). A case study was carried out on the Dwarkeswar River to study the impact of sand mining activity and bridge construction. The study found that the dynamic of the braiding index value and the average bank erosion rate observed near the mining area of the River (Ghosh, B., 2024). Therefore, detecting and managing the river course is necessary for a watershed's conservation and sustainable development.

Many researchers applied numerous models and techniques to determine the dynamic characteristics of a River channel and identified its influence on the land cover in India and outside of the countries. In most of the studies, LANDSAT satellite imagery of different periods was applied to measure the shifting of a river channel. The LANDSAT imagery helps identify the dynamic features of river morphology, soil fertility, and the pattern of the land cover of an area (Singh S. et al., 1988). The bank erosion is the primary factor of the occurrences of the changing pattern of the Mahanadi river course, and the BEHI model applied in the river basin to determine a vulnerable area of erosion on the river bank (Chakraborty & Saha, 2021). The BEHI model was also used to determine the potentiality and the stability of the bank erosion of the Ganga River (Mandal, S., 2017).In Bangladesh, most of the River usually changes course, which disrupts the social as well as the economy of the country. Monitoring the river course is necessary in the country; the GIS tools by using the satellite imagery and ARIMA model have been applied to calculate as well as future prediction for the shifting of the River channel in Padma River in Bangladesh, which will be helpful for the formulation of proper management planning (Naim & Hredoy, 2021). The geospatial tools, by using the satellite imagery and SOI toposheet, provides accurate results for the River channel migration, and this technology is applied to identify the dynamic nature of the Khowai River course and its effect on the pattern of the land use of the watershed (Debnath, J. et al., 2017). The Google Earth images have been applied to measure the changes in the River morphology in the Ayeyawady River, and the SVM method was applied to categorize the different areas of the River based on the features (Aung & Tint, 2019). The migration pattern of the Jamuna River course was determined by applying the different regression models and calculating the rate of bank erosion. The study found that the regression model is one of the effective methods to measure the river bank erosion of a River (Haque & Matin, 2022). The LANDSAT imagery using the DSAS model based on the GIS techniques has been used to determine the migration characteristics of the Brahmaputra River, and the CA-Markov model was applied to predict its current and future effect on the LULC (Debnath, J., 2023). The introduction of new technology, such as remote sensing and GIS tools, helped to determine the changing morphology of a River channel. This technology is more famous for detecting a river channel's temporal changing pattern and for detecting a meandering channel because it provides accurate results within a short interval of time and covers a large area (Nigam, M.K. et al., 2016).

In Assam, agriculture is the primary livelihood of the local inhabitants, and the process of River shifting due to bank erosion is common, which disrupts the state's economy. The flood occurs annually in nearly all the districts of the state, and during this period, most of the rivers eroded the river bank and deposited the sediments on the other side of the bank. Among all the Rivers of the State, the Jiadhal River is one of them that frequently change the River channel, and it badly affects the agricultural land and the settlement area of the flood plain (Saur & Rathore, 2022). The Subansiri is another dynamic river in the northern plain of Assam, and it often changes the river channel after the great earthquake in 1950. A study was carried out to analyze the migration characteristics of the River from 1828-2011. The lieutt R.Wilcox survey map, the Survey of India toposheet and satellite imagery data from the year of 1828 to 2011 were applied in the study. All the applied data were georeferenced and digitized the bank line of the River channel in GIS platform to identify the shifting pattern of the River by superimposing the different year of the bank line. The authors of the study divided the River channel into 17 number of cross section to identify the changes of the bank line and also measured the changes of the width in 30 different location of the cross section. The output of the study indicates that the River channel migrated westward from the Eastern side (Gogoi & Goswami, 2014). The Barak River of Assam also periodically changed course, and a study was conducted on the River to evaluate the meandering characteristics of the River from 1990 - 2020. The satellite images has been applied in the study and the water bodies identified by measuring the NDWI. The GIS tools used to digitized and conducting the evaluation of the migration pattern of the different cross section of the bank line. The result of the study has shown that the main channel's maximum shifting rate during this period was 602.86 meters, and the upper part of the channel was most vulnerable to River shifting (Nath, A & Ghosh, S., 2022).The dynamic behavior of the drainage River channel mostly observes in the Brahmaputra River and also in its tributaries. The Majuli is the largest River island of the world that experience high erosion and deposition process and its tributaries shows the dynamic changes of the River channel. A changing pattern of the River channel and the erosional features of the River channel of the Majuli Island have been analyzed by applying the satellite imagery from the year of 1973 to 2014 respectively. The sinuosity of the different River of the island viz., Jiadhal, Charikoria and Gainadi has measured in the GIS platform and sinuosity also measured to identified the dynamic pattern of the River channel length of the River. The erosion activities of the island has measure by overlapping the satellite images of the year of 1973 and 2013 that indicates that the west part of the island experienced in the western section the area in the last 50 years.(Das, L.M., 2020). The Dibru River of Assam is another dynamic River which is the important tributary of the Brahmaputra River. A study carried out on the Dibru River to identify the changing channel characteristics by applying the satellite imagery data and the GIS tools. The author selected the satellite data during the time period of 1977 to 2020 and the River channel has extracted by digitized in the GIS platform. The cross section has selected in the different year of the River course to determine the nature of the changing pattern of the River channel. The study conclude that the lower course of the Dibru channel has shown a significant changes in the lower course of the River channel and the soil charcterstics,seisimic activities and the human activities are mainly responsible for the changing pattern of the River course of a River (Sonowal, G,, et al., 2022). The Brahmaputra River is one of the most braided Rivers of the world and temporal changes of the morphological features have observed in the River. A study has conducted in the River to evaluate morphodynamic features of the River as well as the influencing factors of the dynamic features of the River. The remote sensing data and GIS software applied in the study to conduct the entire analysis in the study. The bar development index, width of the River has measured that found a positive relation between them and the number of micro – meso bar has shown an increasing trend from 1976 to 2020. (Hazarika, N., et al., 2024). The identification of the long term changing pattern of the River channel is essential to predict the possibility of the changing direction of a River course as well as it helps to understand the associated erosion and depositional features of a River. The satellite and areal images, toposheet are mostly applied to determine migration pattern and the erosional features of a river channel. The GIS is an effective tool in the study of River dynamic behavior by applying the remote sensing data and there are tools developed for measurement of the long term morphological features of a River course. The author in the study describes the application of an effective toolbox to determine the geomorphic processes of a River. The name of the new toolbox is Sandalone built in the Arc GIS software that provides the output from the single vector polygons. The single polygon represent the River channel and it can detect the River course shifting, erosion, deposition between the two consecutive date (Rusnak, M., et al., 2025).Therefore, a scientific study and proper monitoring of the river channel are necessary to formulate a plan for managing erosion and shifting of the river bank. The aim of the present study is to evaluate the migration of the River channel and the erosion-depositional pattern in the Dikrang River over a specific period.

The Dikrong River is the tributary and northernmost sub-tributary of the Subansiri River and Brahmaputra River. The River originates in the Arunachal Himalaya, flowing through the Papumpare district of Arunachal Pradesh and Lakhimpur district of Assam and it finally joined the Subansiri River (Fig.1). The area of the current study is located between the 26°57′34" N to 27°44′67″ N latitude and 93°49′36″ E to 93°49′36″ E, respectively. The total 113 km distance flows through Arunachal Pradesh and 32 km through the Brahmaputra plain of Assam. The river channel experiences the sub-tropical humid climate where the severe cold type of climate is found in the upper portion, and the humid climate is experienced in the lower part of the catchment area of the river basin. The River experiences maximum rainfall during the monsoon season, with above 1500 mm rainfall annually, an average 37°C temperature in summer, and a minimum of 10°C in winter season in the lower portion of the channel: the alluvial soil and the sedimentary rock found in the Dikrong River basin. The number of sub tributary joins in both the bank of the Dikrong River channel, namely Pachin River, Ranchi River, and Pang River, Keyate River in the upper catchment, and Beguli River, and Kachikata River in the lower catchment area of the basin, respectively. The river catchment area is most vulnerable to soil erosion due to different geomorphic processes, tectonic activity, lithology, and the basin's climatic condition. The northern portion of the basin mainly consists of dense forest, and the southern portion of the Dikrong River basin mainly covers agricultural land.

2. Methods

The LANDSAT imagery and survey of India topographical map (Toposheet no.83I/03, 83I/02) has been applied as an input data in the current study to determine the River course changes in the Dikrong River from 1973 to 2022. The SOI toposheet of the year of 2018 -19 used in the study to prepare the base map of the study area and the mapping has been done in the GIS platform. For extracting the River channel of the different year of 1973, 1990, 2010, and 2022 were digitized from the satellite imagery by applying the GIS tools. The main River channels of the different year were divided into 11 cross sections and the shifting value of the river bank was determined by superimposing the river channel over the two different years viz., 1973-1990, 1990-2010 and 2010-2022 respectively (Fig.2). The LANDSAT satellite imagery from 1973, 1990, 2010, and 2022 were digitized, and all main channels of the River were divided into 11 cross sections by using Geospatial tools. After that, the shifting value of the river bank was determined by superimposing the river channel over different years. The entire area of the unchanged area has been measured for each consecutive two years by using the "intersect tools" in GIS tools to determine the total area of erosion-deposition between the two consecutive years of the river. After that, the total area of erosion and deposition was calculated between the years 1973-1990, 1990-2010, and 2010-2022, respectively.

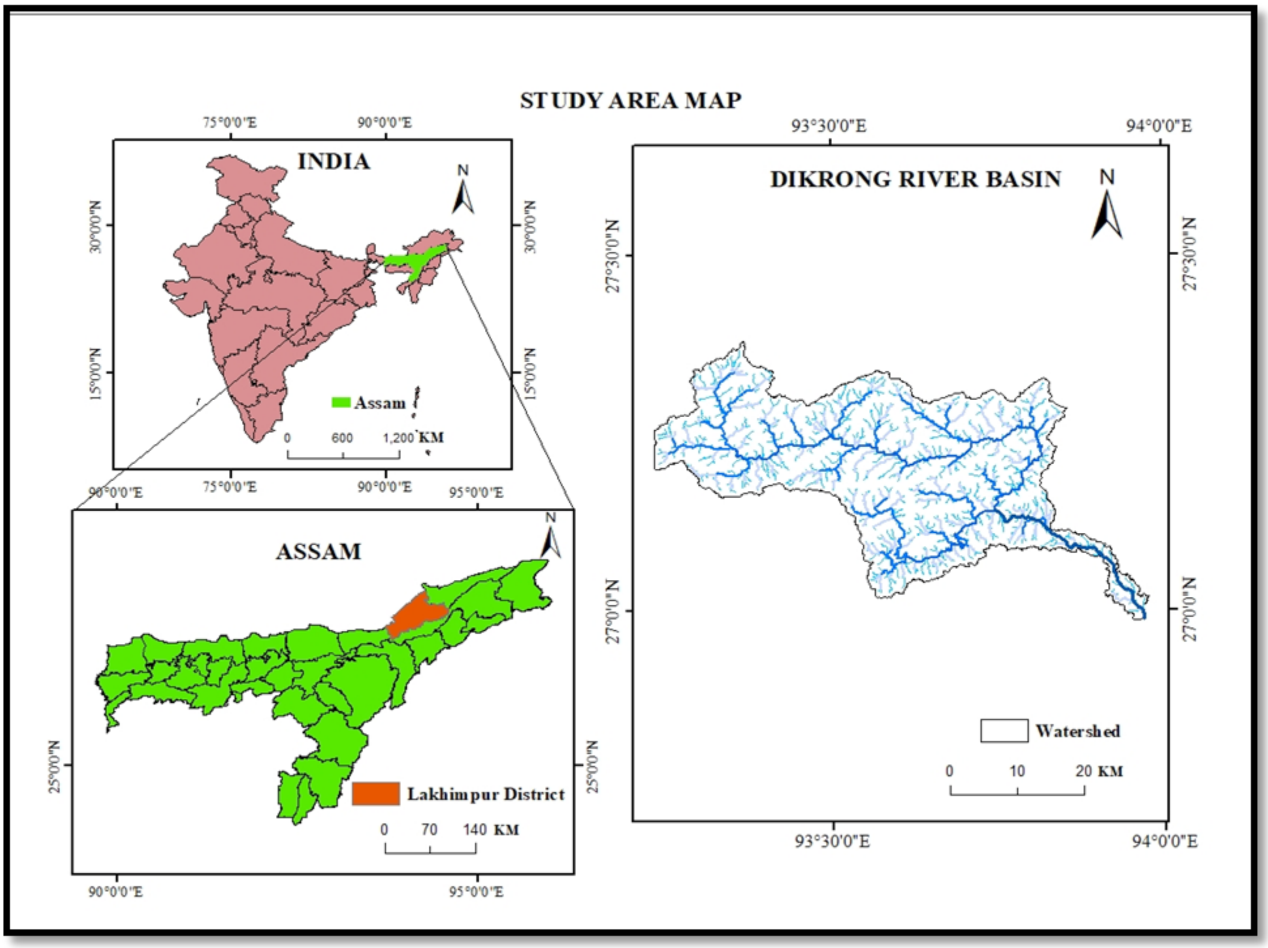

Figure1. Study area map

Table 1. Details of the data used in the study

Data	Year	Date	Resolution/Scale	Sources
SOI Toposheet	1918-19	-	1:50,000	Survey of India
LANDSAT 1 MSS	1973	15.11.1973	60 m	USGS
LANDSAT 5 TM	1990	11.12.1990	30 m	USGS
LANDSAT 5 TM	2010	21.03.2010	30 m	USGS
LANDSAT 8 OLI	2022	06.03.2022	30 m	USGS

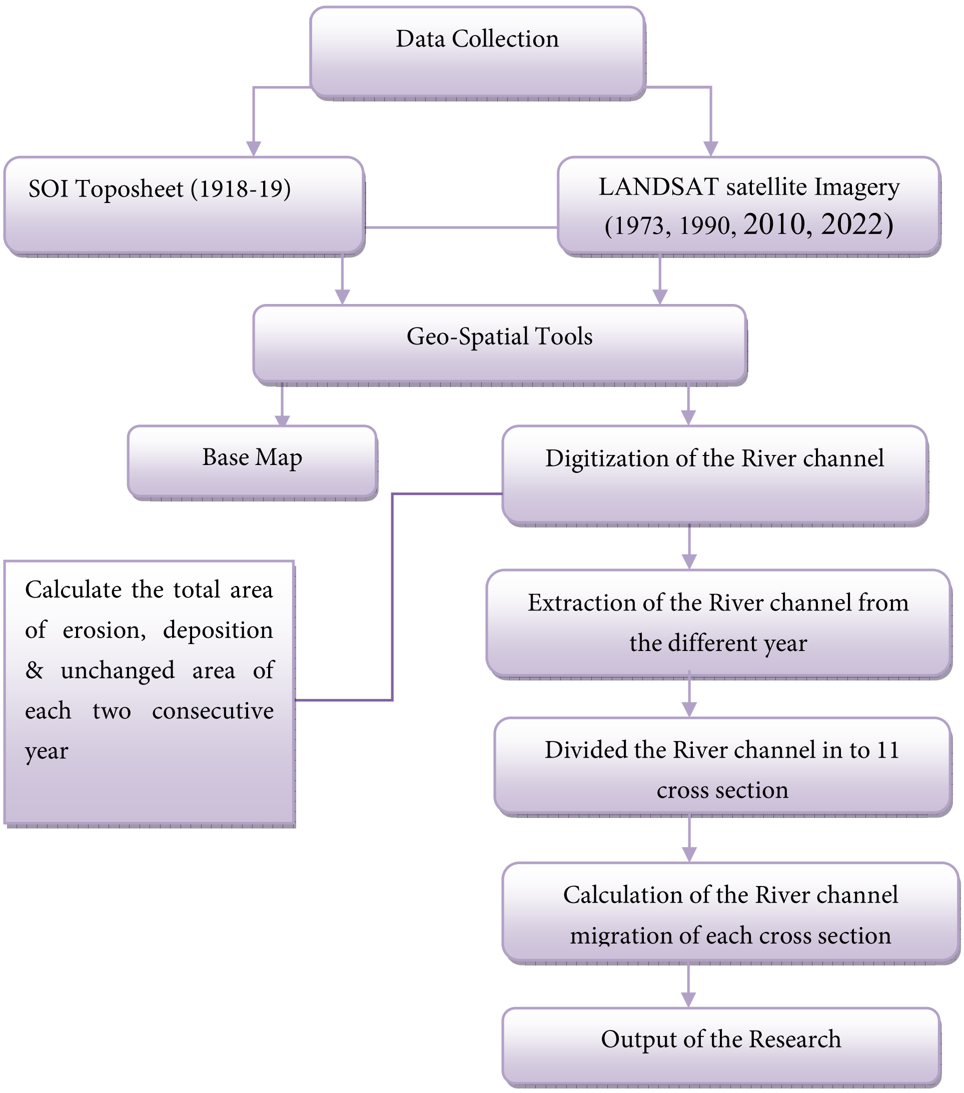

Figure 2. Flow diagram of the methodology applied in the present study.

3. Result & Discussion

The Dikrong River flows from the high mountain areas of Arunachal Pradesh towards the northern plain of the Brahmaputra River of Assam. It is an alluvial River that changes course due to the continuous severe bank erosion and deposition occurring in the River. The river course migration from 1973 to 2022 has been calculated and identified as the major and minor variation of the Dikorng River. After that, the total eroded area and deposition area were measured between the years 1973-1990, 1990-2010, and 2010-2022, respectively. The central and lower parts of the Dikrong River have been extracted, and it is divided into 11 cross sections to measure the magnitude of the channel changes in the River.

4.1 River Channel migration of the Dikrong River from 1973-2022

From 1973 to 1990, migration of the River channel occurred both in the right and left banks of the River (Fig.3, Fig.6, and Table 2). The maximum changes of the river course occurred in the middle portion of the river in the D cross-section, which is 1431.14 meters towards the western direction. The minimum variation of the river bank occurred in the lower part in the cross-section of H, which is 72.61 meters towards the eastern direction (Fig.6). The average variation of the river channel found in the cross-section of J, which is 2648.17 meter to the Eastern direction and lowest rate of channel shifting found in the 89.68 meters in the cross-section of J towards the Eastern direction from 1990 to 2010 (Fig.6). Similarly, the

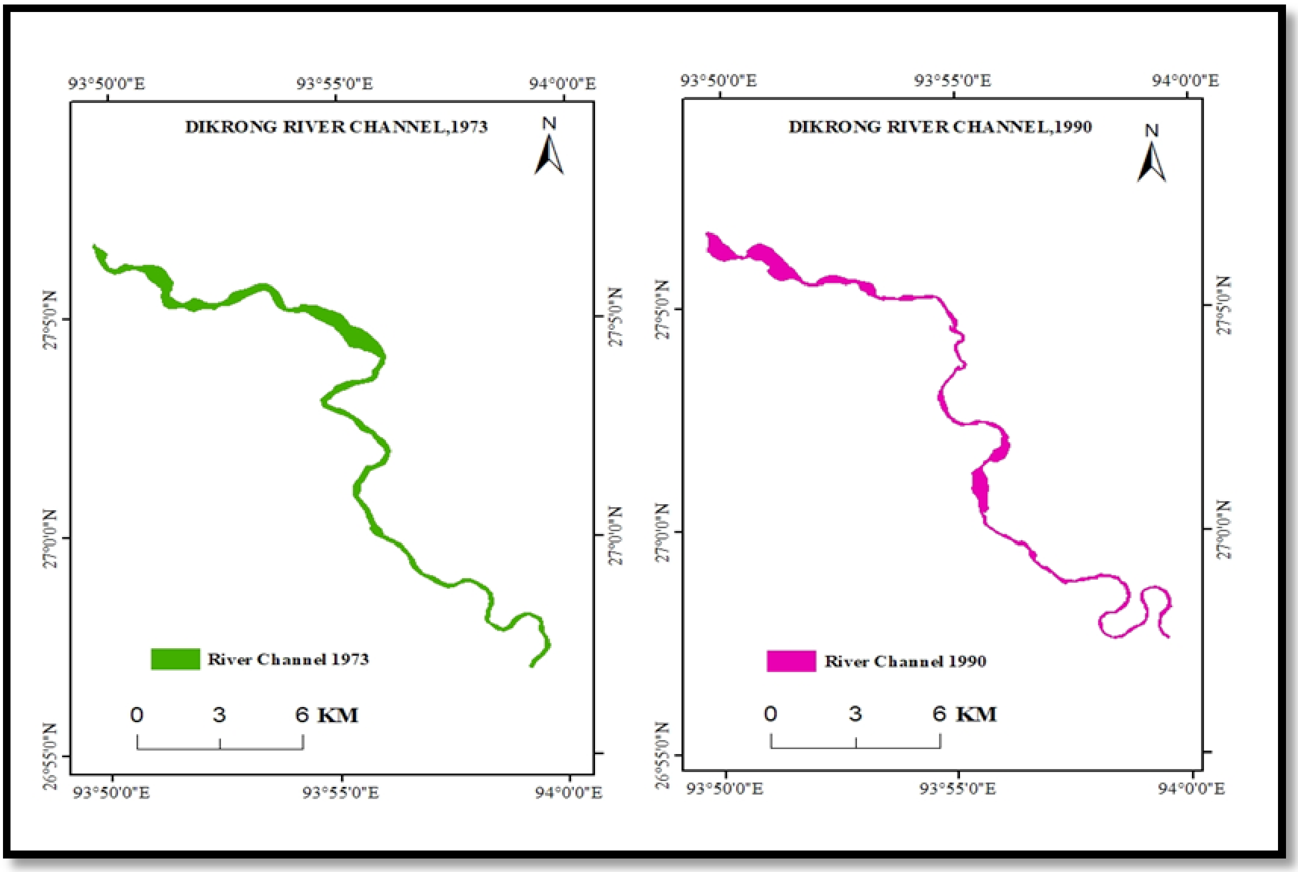

Figure 3. The River channel of the Dikrong River in 1973 & 1990

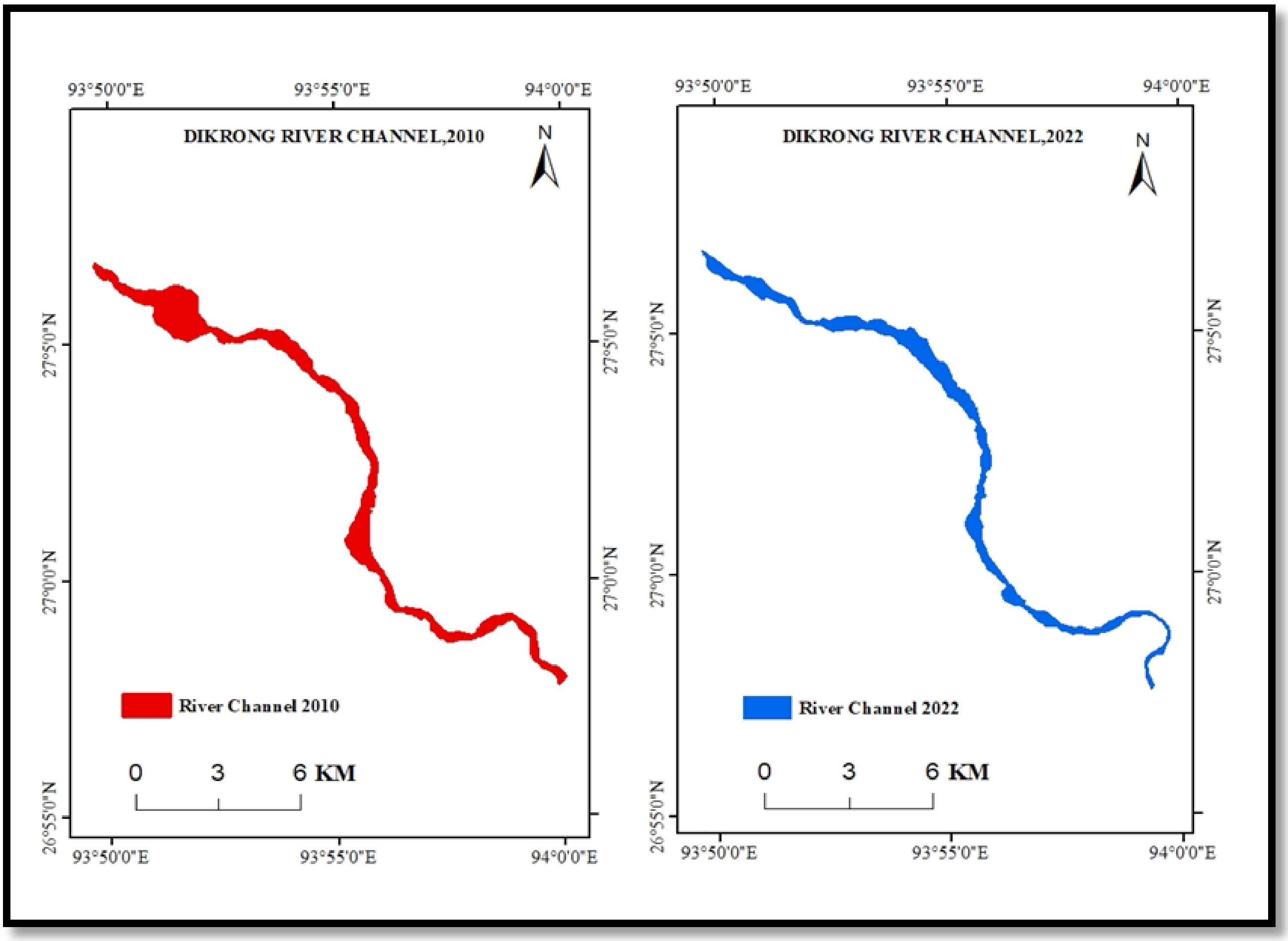

Figure 4. River channel of the Dikrong River in 2010 & 2022.

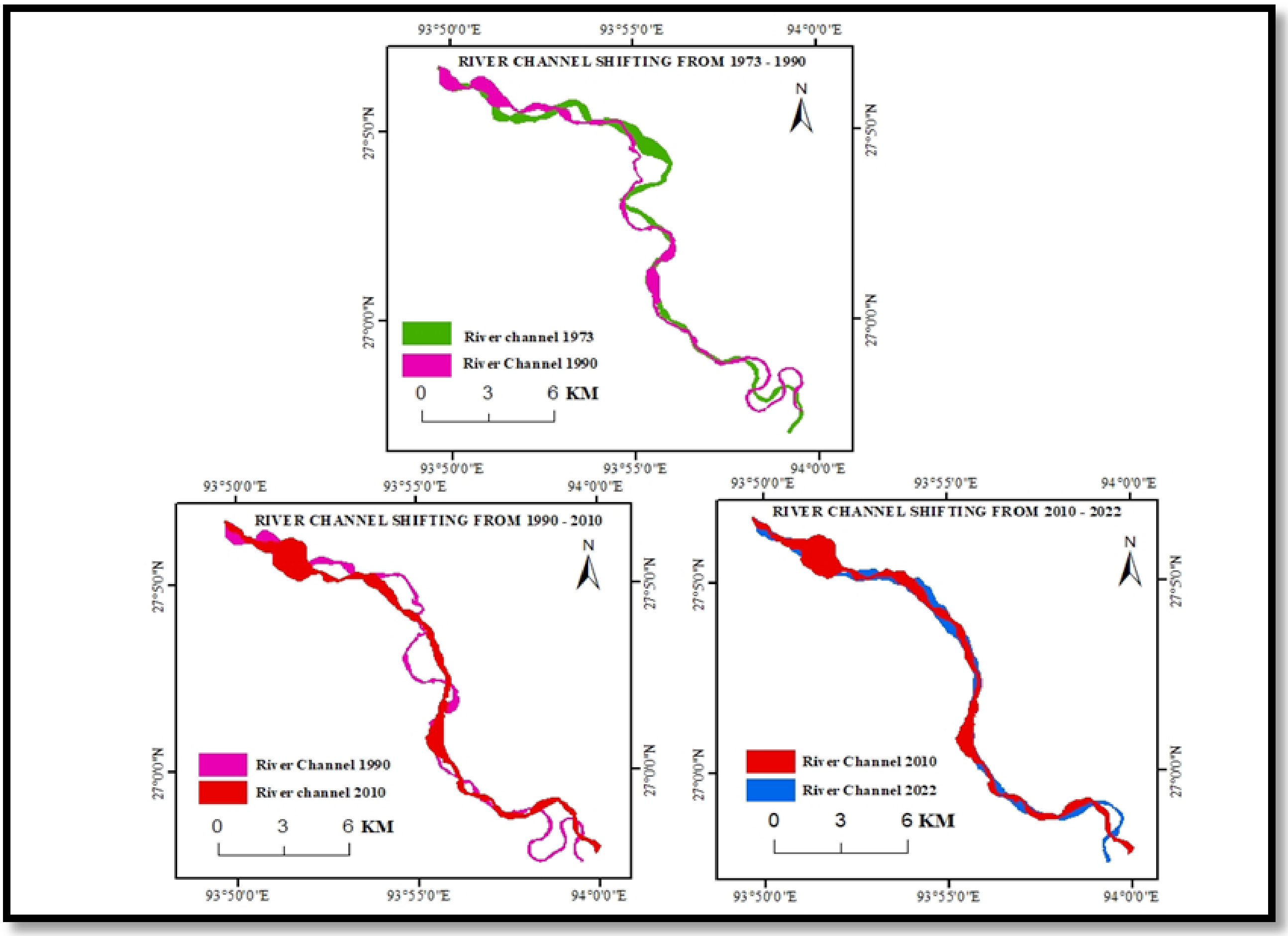

Figure 5. River channel shifting during the period 1973-1990, 1990-2010 and 2010- 2022.

migration rate of the river bank between the periods of 2010-2022 has been measured and the maximum value of migration seen in the cross-section of K which is 908.47 meter towards the Eastern side of the River course. The minimum rate of shifting is found in the cross-section of C, which is 84.68 meters to the Western direction of the river course (Fig.6).

From the result of the overall River channel migration of the Dikrong River for 49 years between the periods of 1973-2022, a remarkable bank line migration has been observed on both the river bank and it is indicated that the width of the channel is not permanent which is changing with different period (Fig.6). Comparing the value of the river channel migration between the three periods, the minimum river channel shifting occurred between the year of 2010-22 and average migration found from 1990 to 2010. The highest westward shifting occurred in the middle course of the channel at the cross-section of E, F, and G as a result of the experience of severe erosion on the right side of the River bank. The lower section of the cross-section of k shows the maximum eastward migration due to the occurrence of deposition in the right bank of the River channel between 1973- 1990. In fig.8 shows that the E, J, and K cross-sections record the average eastward migration due to the happening of erosion in the left bank line, and maximum westward shifting occurred in the cross-section of D due to the occurrence of deposition in the left bank of the main channel from 1990 to 2010. The bank line of the River course during the time of 2010-22 was more stable compared to the period of 1990-2010 and 1973-1990 (Fig.6). During this period, the highest bank line migration occurred in East and westward directions at the cross-section of J & k as result of the occurrence of erosion & deposition of the right & left side of the main channel. The overall River bank migration of the Dikrong River channel from the year of 1973 to 2022 depicted in the graph (Fig.7) that shown a significant changes in the both bank of the River. The resulted graph of the River channel migration of the Dikrong River has shown that the maximum variation of River channel migration occurred in the lower section of the River channel due to the occurrence of maximum deposition (Fig.7).

There are different factors are responsible for the shifting of the Dikrong River and it can be categorized into types mainly natural and anthropogenic factors. The River course shifting happen due to the River flow pattern, sediment materials, water discharge, slope of the channel, erosion and depositional rate, tectonic activities, climate change, deforestation and the changing land use pattern etc (Debnath, J., 2023). In the Dikrong River, the erosion and deposition is the major contributing factors of the River course migration because the River channel Receive maximum rain water during monsoon period that increases the discharge rate and sedimentation into the River. As a result the River eroded the bank and gradually the River changes its course in other direction. The Dikrong River is located in the high earthquake risk zone and the tectonic factors also influenced the shifting behavior of the River channel. Apart from the natural factors, the human activities plays a major contributing factors of the River channel shifting of the Dikrong River particularly the construction of embankment, development of bridge across the River ,changing land use pattern, deforestation in the upper catchment areas influenced the rate of bank erosion and changes the natural morphological properties of the River. Therefore, a proper scientific study is essential to evaluate the dynamic characteristics of the River channel pattern and the rate of River bank erosion to mitigate the occurrence of natural hazard in future and sustainable management of the watershed.

Cross Section	**Year**		
	2010-22	**1990-2010**	**1973-90**
A	319.27 (W)	581.53(E)	334.07 (E)
B	233.1 (W)	560 (W)	893.54 (E)
C	84.68(W)	530 (W)	426.81 (E)
D	380.5 (E)	816.52 (W)	395.09 (E)
E	272.48 (E)	1220.82 (E)	673.45 (W)
F	434.53 (W)	258.14 (W)	1431.14 (W)
G	144.56 (E)	339.81 (E)	664.94 (W)
H	155.67 (W)	359.70 (W)	72.61 (E)
I	277.72 (E)	89.68 (W)	415.60 (E)
J	466.11(E)	2648.17 (E)	510.40 (W)
K	908.47 (W)	845.21 (E)	768.85 (E)

Table 2. The River Channel shifting of the Dikrong River during the time period of 1973-90, 1990-10 2010 –22 towards west (W) and East (E) direction in meter

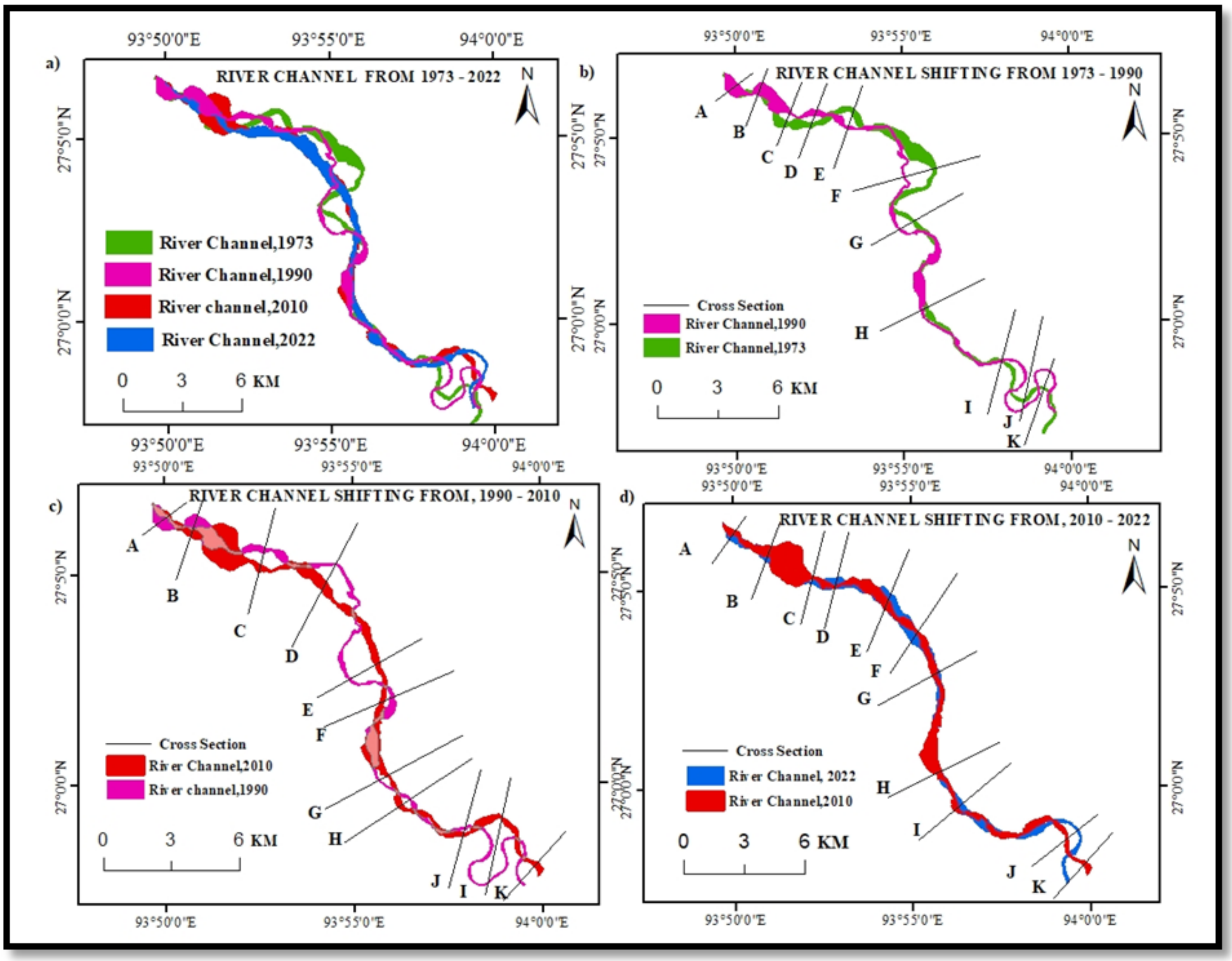

Figure 6. The River channel migration of the Dikrong River from a) 1973 – 2022 b) 1973 -1990 c) 1990 – 2010 d) 2010 - 2022

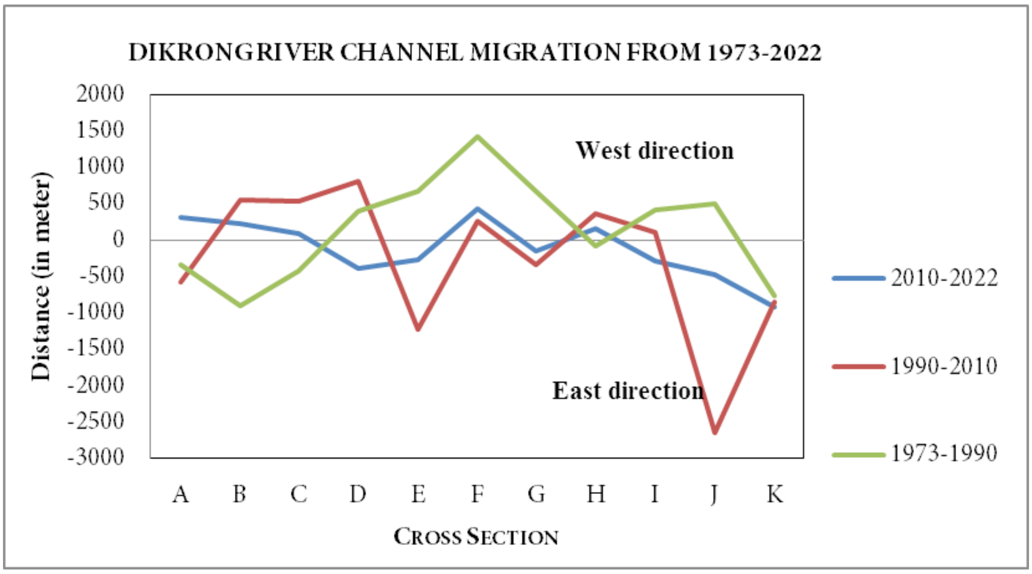

Figure 7. Graph of the Dikrong River channel migration from 1973-2022

4.2 Measurement of the erosion & deposition area of the Dikrong River from 1973-2022

The Dikrong River has been constantly affected by erosion-deposition activity on both channel banks during the monsoon season. The erosion deposition process mainly occurs in the Dikrong River due to the region's hydraulic, geomorphic, climatic, and tectonic activity. The current study selected the lower portion of the River channel to determine the erosion-depositional scenario from 1973 to 2022 (Table 3). During 1973- 1990, the total area of erosion, deposition, and unchanged has been measured, which are 3.90 sq. km, 6.22 sq. km, and 2.45 sq. km, respectively. During this period, the erosion activity was more on the right bank, and deposition occurred on the left bank of the River. As a result, the River channel shifted towards the west direction (Fig.8). The total area of erosion, deposition, and the unchanged area between 1990-2010 are 7.73, 4.04, and 2.31 sq. km, respectively. The erosion-deposition process is not uniform, and both the right and the left bank of the River face severe erosion as well as deposition activity between the periods of 1990-2010 (Fig.8). From 2010 – 2022, the total area of erosion, deposition & unchanged area are 3.86 sq. km, 4.61 & 5.43 sq. km respectively. From 2010 to 2022, the maximum erosion occurred on the right bank of the lower part of the basin, and as a result, the River channel shifted towards the Eastern direction (Fig.8). In the lower portion of the River channel, the westward shifting also observed due to the occurrence of maximum deposition in the left bank of the River.

5. CONCLUSION

River often changes the pattern with the occurrence of the different geomrphological processes and the changing climate. The River channel shifting and the erosion – deposition activities of a River is mostly observe in the flood plain areas like Brahmaputra River, Barak River and the Ganga River flood plain areas etc.. The Dikrong River is flow through the flood plain areas of the Brahmaputra plain and the channel migration as well as the erosion activities is common phenomenon in the River channel. The present study examined the temporal and spatial migration patterns and the erosion and deposition scenario of the Dikrong River channel from 1973 to 2022 by applying GIS tools and the satellite imagery. After detail evaluation of the study, it is observe that the satellite images able to provide the effective result in the historical morphological dynamic pattern of a River channel. The study's results indicate that a remarkable bank line variation of the Dikrong River occurred during the 49 years due to the continuous erosional activity and sedimentation during the monsoon period. Due to this process, bank erosion and deposition increases, disrupting the aquatic habitat and the livelihood of the local inhabitants of floodplain areas of the basin. The analysis indicates that the right and left banks face heavy erosion and deposition processes. As a result, the river channel migration is seen in both the east and west directions along the River channel. The maximum River channel migration happened during the period of 1990-2010, and average shifting occurred in the East direction of the channel in the cross-section of J a result of the process of the river cutting on the left side of the River channel. The minimum channel variation is seen from 2010 to 2022, and during this period, the lower course, mainly the cross-section J & K, shows the highest bank line variation of the River channel. The output of the analysis from the three different periods of the Dikrong River channel indicate that the central and lower portions of the River channel are more

Year	Area (In Km2)		
	Erosion	Deposition	Unchanged
1973-1990	3.90	6.22	2.45
1990-2010	7.73	4.04	2.31
2010-2022	3.86	4.61	5.43

Table 3. The total area of Erosion, deposition and unchanged area during the year of 1973-1990, 1990 – 2010 & 2010 – 2022.

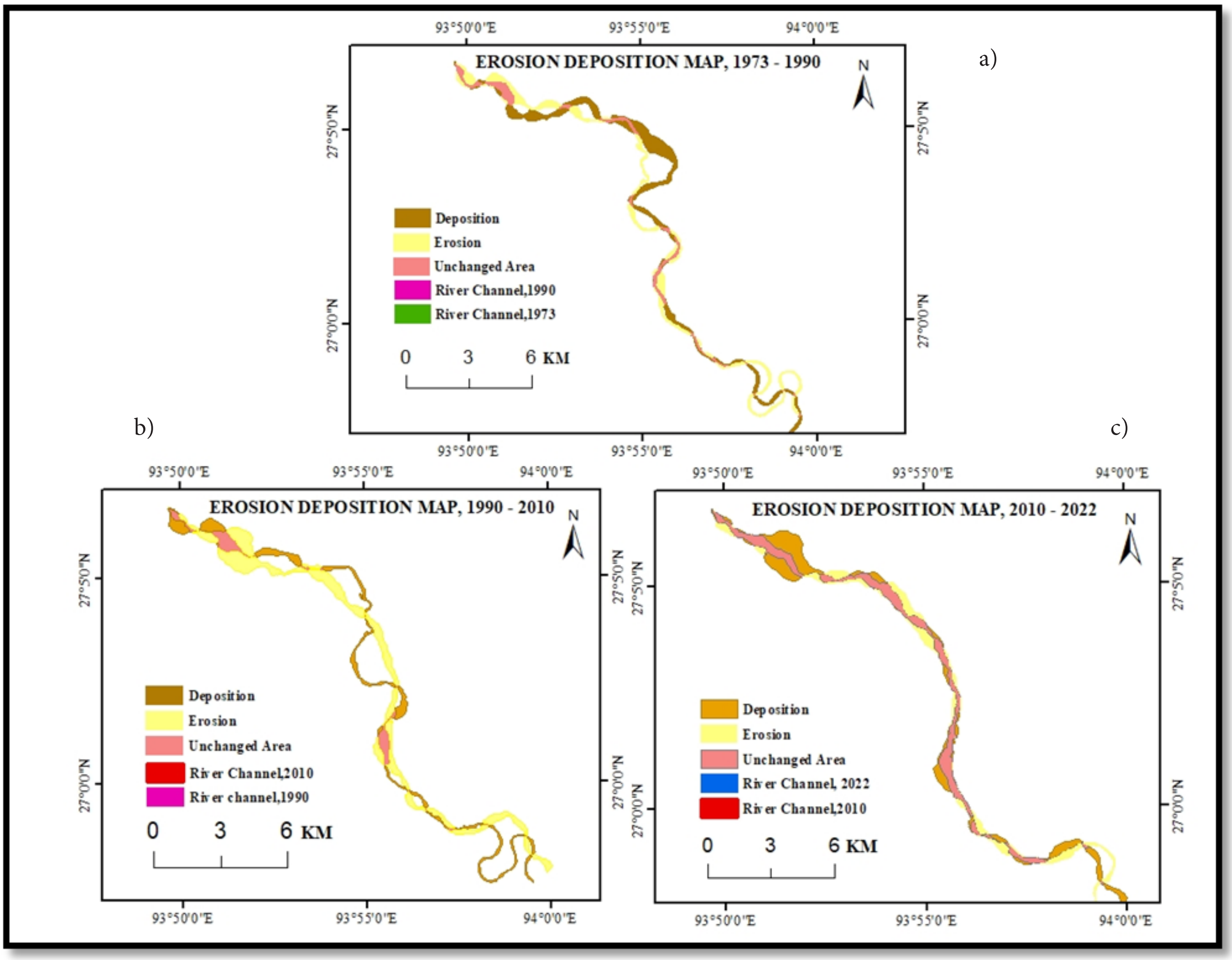

Fig.8: Erosion – Deposition Map of the Dikrong River from a) 1973 – 1990 b) 1990 – 2010 c) 2010 - 2022

unstable, which gradually changes its channel in both the west and east directions. The present analysis can also identified the area of the River channel which are highly affected by the River bank erosion and deposition and it will be help to developed the erosion control measures in the affected areas of the River bank.The findings of the studies will help evaluate the present scenario of the geomorphological changing pattern of the river channel and implement the controlling measurement initiative of river channel migration of the Dikrong River.

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