Jiadhal River, Assam, India: An integrated Remote Sensing and GIS approach to study the sorrow of Dhemaji

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ABSTRACT

The Jiadhal River, one of the major rivers of the district is characterized by intense annual flash floods, rapid bank erosion and highly unpredictable channel migration. An integrated approach using Remote Sensing and Geographic Information Systems (GIS) has been used to analyse the dynamics of the river and its impacts within the area. Time series satellite imagery together with toposheets ware used to examine the extensive changes of the river during the period from 1924 to 2026. The analysis reveals random behaviour of the river with a progressive downstream extension of the river debouching point accompanied by increased sediment deposition and significant widening of the channel course. The flashy nature of river flow which is controlled by steep channel gradients, strong seasonal variability in discharge and tectonic influences within the catchment area plays a crucial role in governing the spatio-temporal variability of channel dynamics and sediment dispersal in the area. This dynamic channel behaviour significantly influenced the geomorphology and land use land cover of the area and has profound implications in the socio-economic condition of the state.

Keywords: Fluvial dynamics, Channel migration, Flash flood, Sediment aggradation

INTRODUCTION

Dhemaji District situated on the north bank of the Brahmaputra River is bounded by the Brahmaputra River in the south and Subansiri River in the west and towards the north and east bordered by Arunachal Himalaya. A number of tributaries from north join the Brahmaputra River in this region one after another. The entire river systems are severely disturbed and the area experienced regular annual floods. The intensity of the floods in the area can be well imagined when the water of the Brahmaputra River synchronize with the other tributaries of the area. Some tributaries are seasonal almost dry in the winter but bring high discharge and debris in the monsoon season. Entire area is subjected to flood during the monsoon. The area is characterized by the widespread palaeochannels, swampy land, waterlogged area, natural levees, active and abandoned channel and their vast distribution signifies about the severity and magnitude of the flood problem. The shifting of channels is so abrupt and uncertain that the whole district can be said to be the flood plain area. So, it is almost risky to demarcate as well as classify the land use pattern to be suitable either for cultivation or for human settlement.

Among the tributaries of the Brahmaputra, the Jiadhal River is particularly notorious for its destructive behaviour and is widely known as the “Sorrow of Dhemaji.” Its highly dynamic nature characterized by recurrent flooding, rapid channel migration, bank erosion and sediment deposition causes extensive damage to settlements, agricultural land, transportation networks and other infrastructures of the area. Pegu (2021) described the Jiadhal as an “angry river” highlighting how its unpredictable behaviour has significantly affected the livelihoods of local communities in the district.

The Jiadhal River originates from the West Siang district of Arunachal Pradesh and debouching in the Dhemaji district of Assam. The name Jiadhal is derived from the word “Jia” meaning alive and “Dhal” meaning flash floods due to the rivers tendency of generating flash floods during monsoons (Borgohain et al., 2016). The river before entering the plains flows through a narrow gorge within the mountainous region after which it

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enters the plains near Jiadhalmukh acquiring an aggradational and braided nature. The river is characterized by extensive depositional activity and numerous channel bar formation (Sonowal and Laskar, 2017). Jiadhal is known as the Kumotiya river after receiving Kumotiya but after crossing the railway line up to the Gogamukh - Ghilamara P.W.D road it is known as the Sampara river. Jiadhal River flows through the plains before joining the Brahmaputra Rivers anabranching channel Kherkutia Suti near Kathonigaon at an elevation of 91 metres above mean sea level. The river now connects to the Subansiri River near Ghagarmukh after an embankment was built over the Kherkutia Suti in 1965-66 (Sonowal and Laskar, 2017).

Numerous studies have documented the highly unstable nature of the Jiadhal River which is marked by frequent flooding, channel avulsion, rapid bank erosion and extensive sediment deposition. These processes have repeatedly altered the river course and floodplain morphology of the area. After 1950 earthquake the river has experienced a series of higher frequency floods in Dhemaji, Assam (Das, 2016). In 1969, 1973, 1984, 1988, 1989, 1992, 1994, 1997, 1998, 2002, 2007, 2009, 2011, 2014 and 2017 there were large flood events that caused significant damage throughout the Jiadhal River drainage basin (Hazarika, 2010; Das, 2013a). The river has become very unstable as a result of the frequent floods, causing the river channel to vary often (Kakoty et al., 2018) which has caused the drainage basin system to partially collapse (Das, 2013b). The area experiences severe to very severe bank erosion during high flood events resulting in substantial loss of agricultural land (Bormudoi et al., 2016). Continuous flooding (Buragohain et al., 2014), lateral bank erosion (Gogoi et al., 2013) and heavy sediment deposition (Das, 2015) within the river channel and adjacent areas have significantly changed the morphology of the river which affects socio-economic condition of the area.

The pronounced variability of the Jiadhal River is primarily governed by geological conditions, morphometric characteristics of the basin and high rainfall intensity. These factors collectively contribute to a highly dynamic fluvial system. Geologically the basin comprises mostly of the Siwalik sediments and Quaternary alluvium deposits (Gogoi et al, 2022). There are three stratigraphic units of the Siwaliks, viz., Kimin, Subansiri and Dafla (Karunakaran and Ranga Rao, 1979; Ranga Rao 1983). The Kimin formation composed of alternating sandstones, clay lens, silt and boulders are thrusted over the Quaternary alluvium deposits by the Himalayan Frontal Thrust (HFT) (Sarma et al., 2022). The Subansiri formation overlies the Kimin formation and is composed of sandstone with salt and pepper texture. The Dafla formation comprising of micaceous sandstones with shale and silty clay beds which overlies the Subansiri formation along the Tipi Thrust (Lang et al. 2016). The predominance of weakly consolidated sedimentary formations together with active tectonic structures enhances erosion and sediment supply to the river system promoting channel instability and frequent geomorphic adjustments.

Study Area

The present study focuses on the Jiadhal River in Dhemaji District, one of the major north-bank tributaries of the Brahmaputra River. The study area covers the entire basin of the river from the hilly region at Lower Arunachal Himalaya to the foothill region to the confluence of the Jiadhal River with the Brahmaputra River. The hilly basin of the Jiadhal River lies in the East Siang District of Arunachal Pradesh. The Jiadhal River is formed by the confluence of three rivers: the Siri River, flowing from east to west; the Sika River, flowing from north to south; and the Sido River, flowing from west to east. These three rivers meet at a common confluence point and their combined flow thereafter is known as the Jiadhal River. From this confluence the Jiadhal River flows in a north to south direction towards the Assam plains (Fig.1). After debouching to the plains the river frequently creates severe challenges in the downstream region owing to its high intensity flash floods and highly dynamic flashy nature. Over time the river has exhibited significant vulnerability through frequent channel migration, annual aggradation of new areas during flood events and continuous morphological changes. These recurring alterations in the river course and its transformations highlight the need to understand its morphological characteristics and dynamic behaviour for better assessment of its fluvial processes and impacts.

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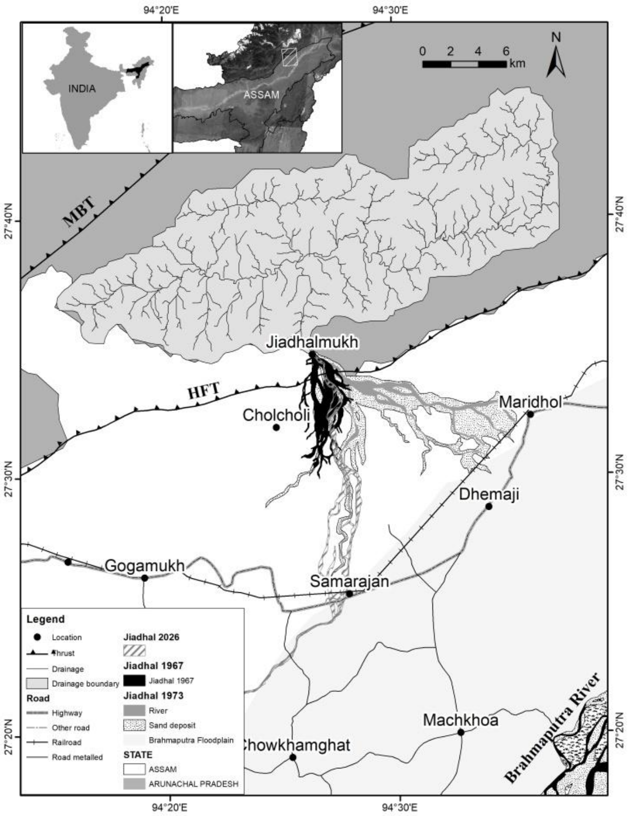

Figure1. Location map of the study area showing the Jiadhal River drainage network and basin boundary in the hilly terrain and three temporal positions of river in 1967, 1973 and 2026 across the Assam plains. (**HFT**- Himalayan Frontal Thrust, **MBT**- Main Frontal Thrust)

Materials and Methods

The variability of the Jiadhal River was analyzed using temporal geospatial datasets spanning more than a century. The study utilised the 1924 and 1967 topographic sheets as the earliest sources of information, followed by a series of multi-temporal satellite images from the LANDSAT satellite missions (Table1). All datasets were pre-processed, georeferenced and standardised to a common coordinate reference system within a Geographic Information System (GIS) environment to ensure spatial consistency and comparability. River channels for different time periods were delineated through visual interpretation and on screen digitisation. The extracted channel datasets were subsequently subjected to overlay analyses to evaluate the spatial and temporal variations in channel morphology, lateral migration and course adjustments through time. Bankline migration and associated erosion-deposition dynamics was quantified using GIS based overlay analysis tool. The Union and Identity overlay functions were applied to successive bankline polygons to delineate spatial changes in the river channel and identify areas of erosion and deposition between different time periods. To facilitate a detailed spatial analysis the river channel was divided into 13 segments and bankline migration was measured independently for each segment for subsequent datasets from1924 to 2026. The areas affected by erosion and deposition were quantified within each segmented reach. This segmented approach enabled a detailed assessment of the spatio-temporal variability of channel migration, bank erosion and sediment deposition along the river course and enabled the identification of erosion and deposition prone reaches over the study period. Digital Elevation Model (DEM) was also employed to characterize the physiographic and geomorphic attributes of the Jiadhal River Basin. Drainage networks were extracted from the DEM in Arc GIS software using spatial analysis tool and various morphometric parameters were computed to understand the basin hydrological and geomorphological behaviour. The integration of temporal river channel data with morphometric analysis provided a comprehensive assessment of the spatio-temporal dynamics and evolutionary trends of the Jiadhal River system.

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Table1. Temporal datasets used for the analysis of spatio-temporal variability and channel dynamics of the Jiadhal River during 1924-2026.

Data	Year	Source	Resolution/scale
Toposheet	1924	University of Texas Libraries	1:100000
Toposheet	1967	Survey of India	1:50000
Landsat MSS	1973	U.S. Geological Survey	79m
Landsat TM	1990		30m
Landsat ETM+	2001, 2006,2010		
Landsat 8-9	2016, 2020,2026		
Digital Elevation Model	2015		30m

RESULT AND DISCUSSION

After traversing a narrow gorge in Arunachal Pradesh the Jiadhal River debouches into the low gradient alluvial plains of Dhemaji district where a sudden reduction in channel gradient and confinement causes the river to exhibit highly dynamic and unpredictable behaviour creating persistent challenges and distress within the surrounding areas. The Jiadhal River has undergone substantial geomorphological transformation over time characterized by an increase in channel length, pronounced lateral migration and extensive sand aggradation across its floodplain.

The temporal variability of the Jiadhal River has been analyzed using multi-temporal datasets spanning from 1924 to 2026. River length was measured for different years to understand channel evolution and geomorphic adjustments over time. River length was measured from the foothill of the river up to its debouche point or merging point with other small streams which finally join the Subansiri River or Brahmaputra River. The observed changes in channel length indicate significant fluctuations. Overall the river shows progression in the length over the time.

Year	Length (km)
1967	10.3
1973	16.2
1990	21.2
2001	22.5
2006	20.1
2010	32.4
2016	32.8
2020	32.0
2026	35.4

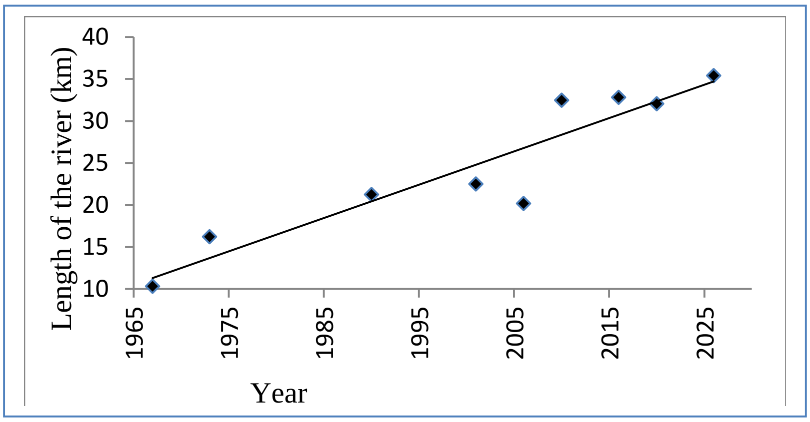

Figure2**.** Length of the Jiadhal river measured within the plains from foothill zone to its debouching point for the period 1967 to 1926 (left). The scatter plot (right) shows the temporal variation in river length showing an overall increasing trend from 1967 to 2026.

The channel length of the Jiadhal River exhibits significant temporal variability from 1967 to 2026, reflecting its highly dynamic fluvial nature. The river length increased from 10.3 km in 1967 to 22.5 km in 2001, indicating progressive channel elongation associated and lateral migration indicating major geomorphic modifications within a relatively short period. A slight reduction in length was observed in 2006 with the river shortened to 20.1 km. A significant increase occurred between 2006 and 2010, when the river length

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expanded from 20.12 km to 32.46 km. The river length remained relatively stable between 2010 and 2020, fluctuating around 32 km, although minor adjustments in channel position continued to occur. By 2026, the river attained its maximum recorded length of 35.4 km, indicating renewed channel progression and increasing sinuosity. The overall trend demonstrates that the Jiadhal River has undergone progressive channel elongation over the years driven by recurrent flooding, high sediment load, channel avulsion and lateral migration processes (Fig.2).

During 1924, the Jiadhal River existed as a comparatively small tributary characterized by a single channel flow pattern. The river exhibited limited energy and maintained a relatively stable course. However, the river underwent remarkable river metamorphosis as observed during the period 1967 transforming from a narrow and stable channel into a highly braided and laterally shifting river system (Fig. 6).Temporal analysis of the Jiadhal River shows that the river has undergone massive geomorphological transformation with repeated unpredictable lateral migration of the river. To understand the magnitude and nature of lateral shifting of the river the measurements were made in 13 segments starting from foothills region to the debouch point of the river (Fig.3).

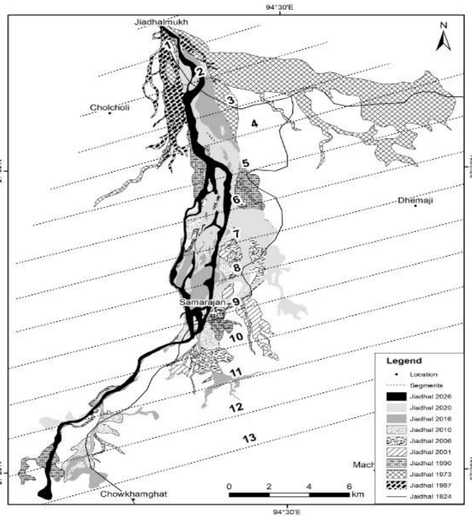

Figure 3. Lateral migration of the Jiadhal River across 13 channel segments between Jiadhalmukh and its downstream debouching point, showing temporal variations in channel position and migration pattern during the period 1924 to 2026.

In 1924, the river debouched as a single channel tributary flowing predominantly in the north-south direction. In Segment 3, the channel exhibited an eastward deflection and subsequently bifurcated into two distributary streams. One branch flowed in a northeast–southwest direction downstream, while the other continued eastward before being joined by additional tributaries.

During the period from 1924 to 1967, the Jiadhal River underwent massive fluvial transformation marked by significant lateral migration, channel widening and development of a braided channel pattern. In 1967, the width of the Jiadhal River was broad and the length was small bifurcating into small streams which ended up into a marshy land. During the period from 1967 to 1973 the river shows huge shift in the river course towards the westward leaving the earlier course of the river.

During 1967 the river flow towards north-south to north to southwest direction and was short in length whereas during 1973 the main course flow direction shifted to north–south east direction with increase in length. Presence of numerous bifurcated channels flows towards the different direction observed on the satellite image of 1967 depicts the eastward sequential migration of the river over the period from 1967 to 1973 by avulsing and abandoning the earlier course of the river (Fig.6). Measurement of magnitude shows maximum shift of approximately 14 km of river course from west to eastward direction at segment 4 (Fig.4) The river covers an areal extent of approximately 15 to 18 km in the segment 4 and 5. The river flows towards the east of the

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Dhemaji town upto the Maridhol where the river merges with small river and flow towards the Brahmaputra River as Kapardhoa Nadi. During 1973 to 1990 the river shifted its course back towards the westward direction attaining the position of the earlier course with progression in river length. The river course shifted maximum of approximately 12 km from east to west. The river course follows the north-south direction upto the segment 7, 8 and then it deflects slightly towards the westward and flows downstream northeast to southwest direction before debouching at the marshy area downstream (Fig4).

From 1990 to 2016, the river generally followed a similar channel pattern exhibiting only minor lateral shifts while maintaining its distributary nature in the downstream reaches. In 2000, the river further widened and extended downward joining a small tributary of the Subansiri River. The river proceeds towards the Brahmaputra River and the river splits up into multiple thalweg. This bifurcating thalweg are identified on the image as dry channel since the satellite image is taken from the dry season. The channel might flow into multi thalweg during the monsoon season when the water discharge is high. In 2006, the river are in the similar condition except the main thalweg of the river shortened then the river during 2001 period and ultimately during the period 2010 the main thalweg shifted towards the west leaving the earlier course and continuing towards the bifurcation channel of the period 2000. In 2010, the river further extended downward and took a slight bend towards the west. The river during 2020 was characterized by significant channel widening and extensive downstream sand aggradation (Fig.5, 6).

In contrast the 2026 Jiadhal river course showed a relatively confined channel with less sediment accumulation and a marked increase in channel length.

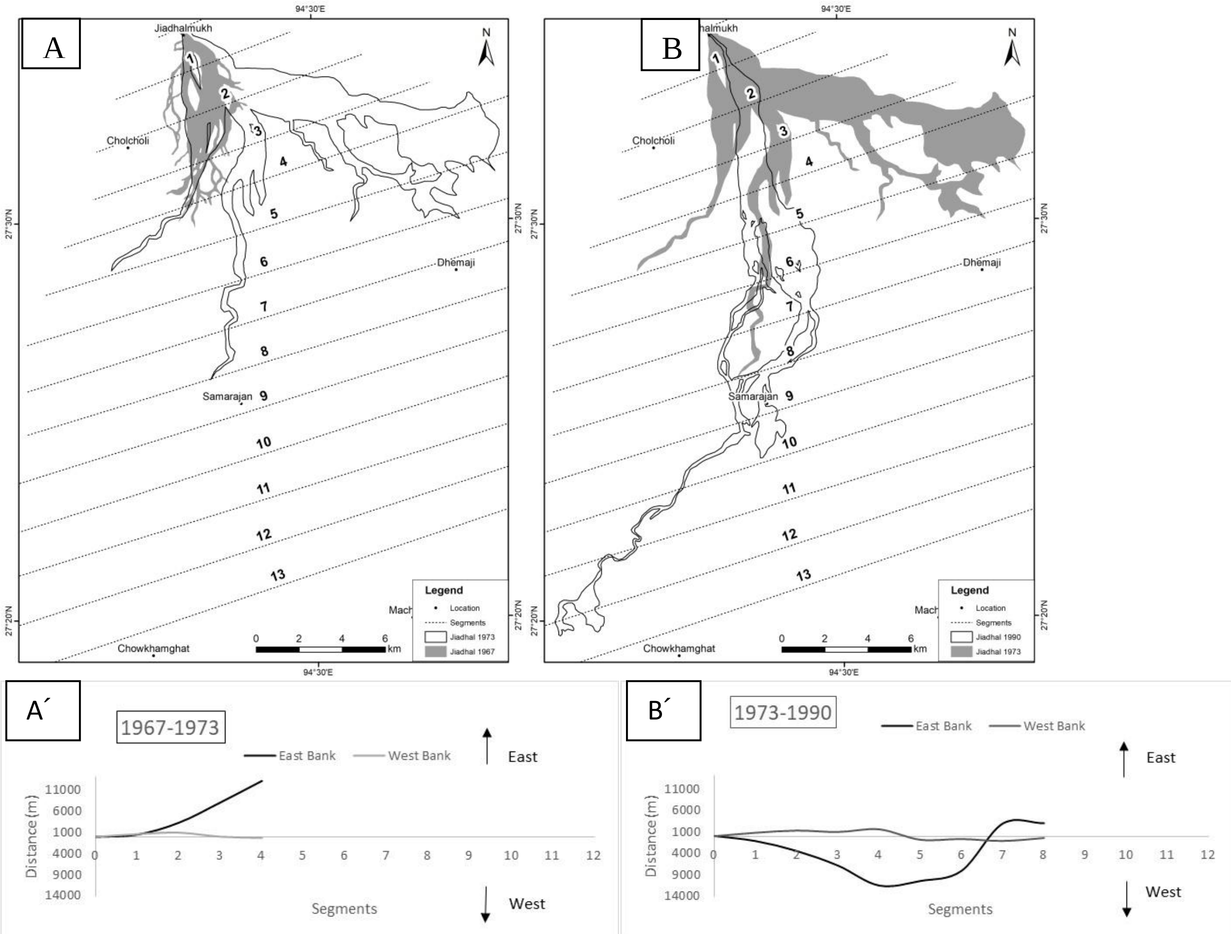

Figure 4. Map showing the bankline positions of the Jiadhal River and bankline changes between 1967 - 1973(A) and 1973 - 1990 (B). Graph showing the magnitude and direction of bankline shift along the eastern and western banks of the Jiadhal River during 1967–1973 (A´) and 1973-1990 (B´).

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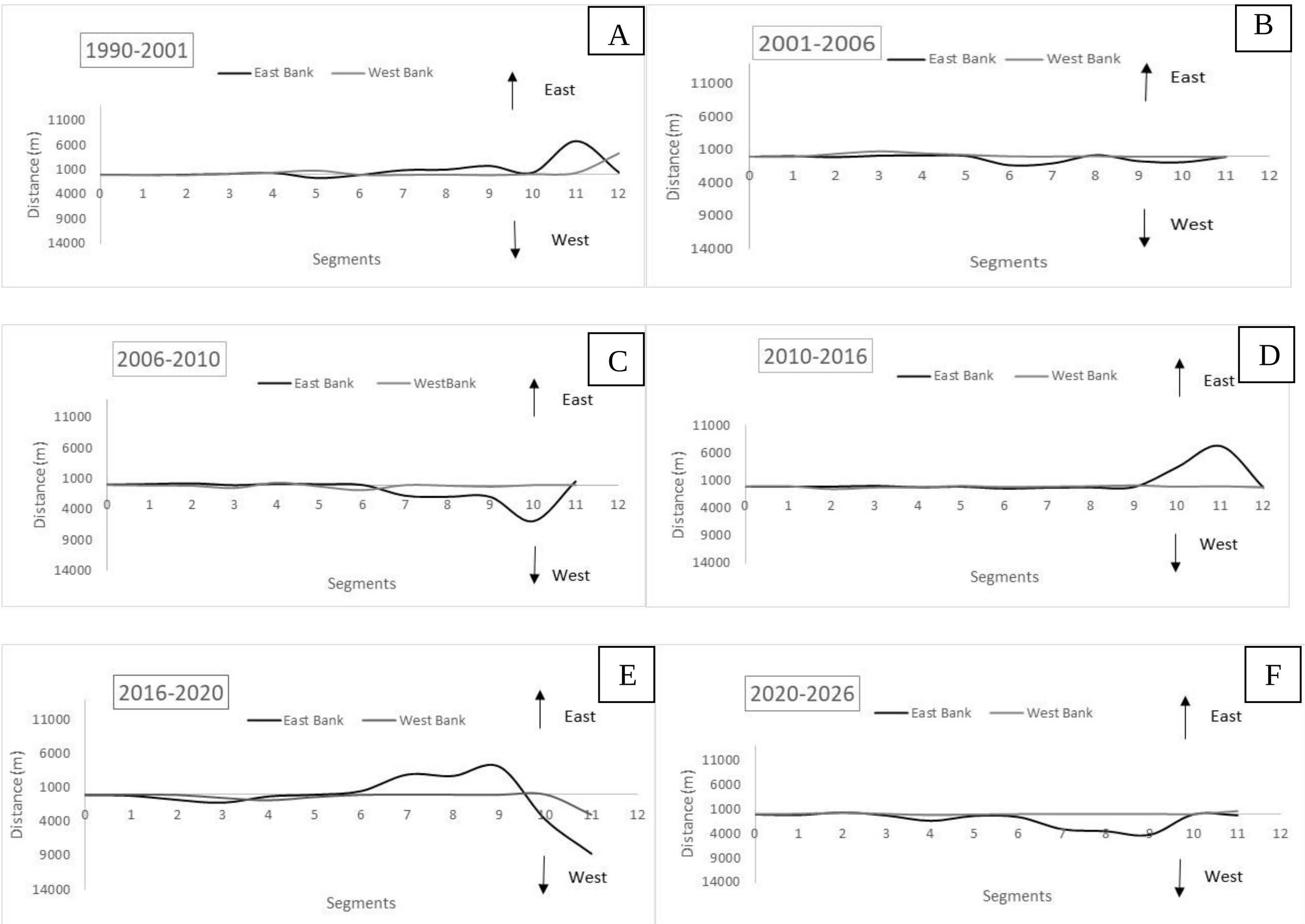

Figure 5. Graph showing the magnitude and direction of bankline shift along the eastern and western banks of the Jiadhal River during 1990-2001 (A), 2001 - 2006(B), 2006 - 2010 (C), 2010-2016 (D), 2016-2020(E) and 2020-2026(F).

Sand aggradation is one of the most prominent geomorphic processes affecting the Jiadhal River basin. In 1924, the river flow remained comparatively stable and did not exhibit sediment deposition or sand bar development within the channel course.

However, by 1967, the river underwent significant geomorphic alteration, and the sand covered area increased to approximately 10.86 sq. km.

During this period, the river remained relatively short, flowing only about 10.3 km from the foothills before dispersing into marshy and low-lying floodplain areas. By 1973, the total area covered by sand deposits increased dramatically to approximately 50.4 sq. km, representing an increase of nearly 17 sq. km compared to 1967.

This substantial expansion of sandy deposits reflects intense channel aggradation and enhanced sediment influx within the river system. During this period, the Jiadhal River exhibited a massive increase in channel width, reaching a maximum width of nearly 13 km in Segment 4 (Fig7).

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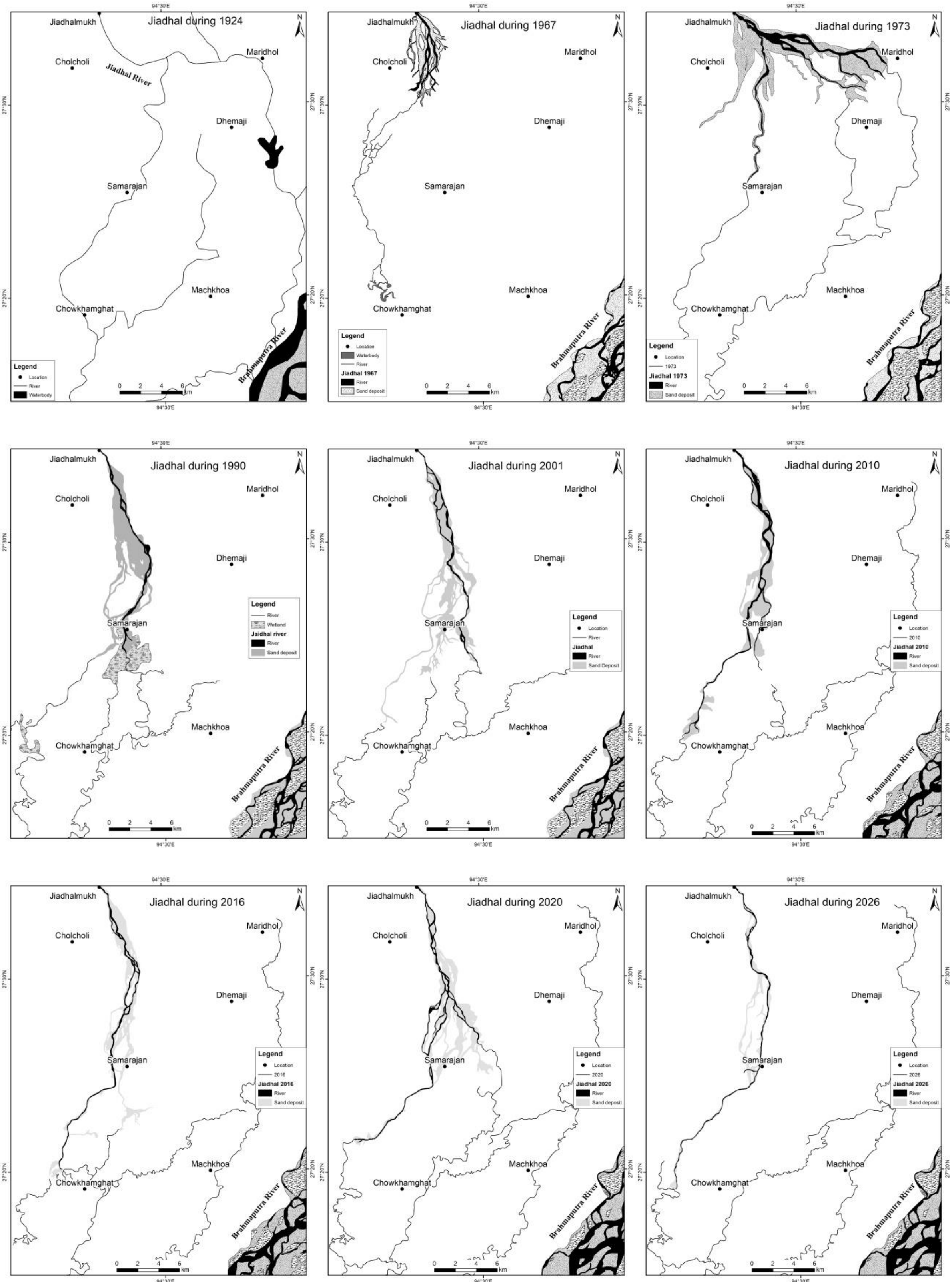

Figure 6. Maps of Jiadhal river ~100 years of time span showing change in position, length, width, lateral migration as well river transformation during the period from 1924 to 2026.

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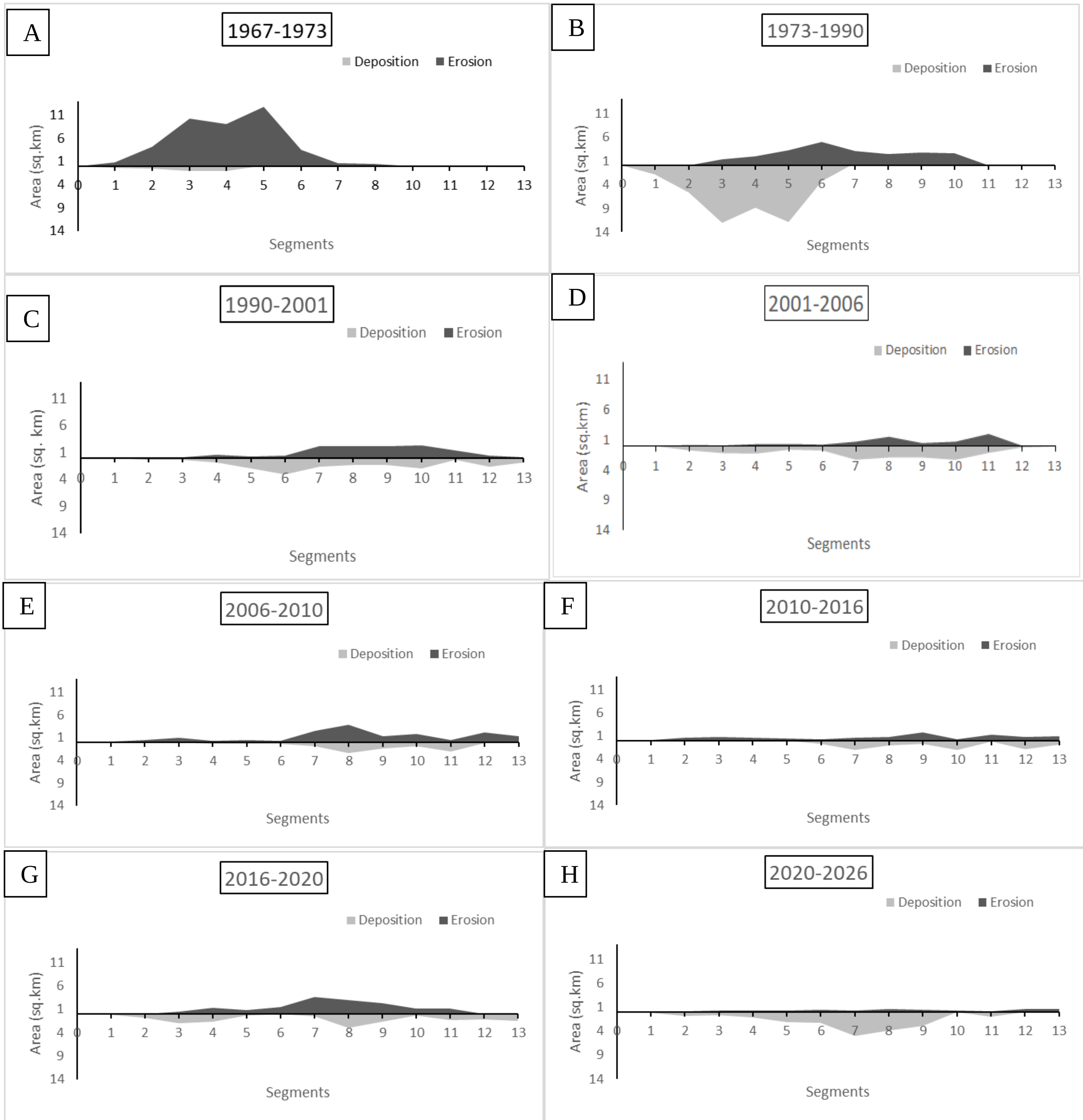

Year	Deposition rate (sq.km/yr)	Erosion rate (sq.km/yr)
1967-1973	0.52	7.00
1973-1990	2.62	1.49
1990-2001	1.46	1.09
2001-2006	2.84	1.38
2006-2010	11.13	6.36
2010-2016	1.59	1.57
2016-2020	3.58	3.92
2020-2026	3.48	0.68

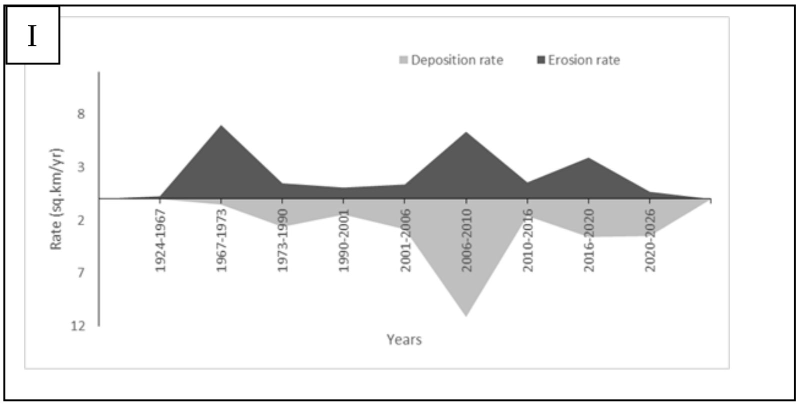

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Figure 7. Graphs showing the areal extent of sand deposition and bank erosion along the Jiadhal River for the different observation periods in 13 segments from 1967 to 2026 (A-H) and temporal variation in the corresponding erosion and deposition rates between consecutive datasets from 1967-2026 (I).

Jiadhal River shows significant temporal variability in its erosional and depositional behaviour. Erosion rates are prominent during 1967-1973, 2006–2010 and 2016–2020**,** indicating phases of relatively intense channel erosion. Whereas deposition is most prominent during 2006 – 2010, followed by relatively lower depositional rates during the other periods. The alternating peaks of erosion and deposition suggest that the river channel has undergone continuous morphological adjustment throughout the 1967–2026 periods (Fig7.)

The river displayed a pronounced distributary from Segment 2 onward where the main channel bifurcated into multiple channels flowing downstream in different directions across the floodplain producing a characteristic triangular pattern of flow. However, most of these distributary channels gradually diminished and terminated by Segment 6 due to sediment choking and reduced flow competence. Only a single prominent distributary channel persisted up to Segment 10, beyond which the remaining distributaries continued as comparatively smaller channels that eventually merged with minor tributaries and local drainage networks of the surrounding area.

During 1990, 2001 and 2006, the lateral areal extent of the river decreased drastically while the river length progressively extended further downstream. The total area affected by sand aggradation was measured approximately 28.058 sq. km, 27.071 sq. km, 19.568 sq.km in 1990, 2001 and 2006 respectively, indicating a reduction in sediment covered area compared to the previous phase. The river flowed predominantly in a north-south direction as a single confined channel up to Segment 5, 6 beyond which it bifurcated into multiple distributary channels in the downstream reaches. Some distributary channels gradually diminished before entering the Brahmaputra floodplain due to sediment choking and reduction in discharge, whereas some active distributaries continued downstream and eventually merged with the Brahmaputra floodplain.

During 2010 and 2016, the river flowed through a comparatively confined channel maintaining an almost north-south course up to segments 4 and 5. Beyond these segments the channel shifted towards a northeast-southwest direction indicating continued lateral adjustment of the river course.

The river bifurcated at segment 7 producing multiple downstream channels across the floodplain. The areal coverage of sand deposits was estimated at approximately 27.54 sq. km in 2010 and 22.80 sq. km in 2016, reflecting a gradual reduction in sediment aggradation and lateral channel expansion during this phase.

However during 2020, the sand aggradation area again increased to nearly 28.76 sq. km due to the re-emergence of multiple channel flows and expansion in the areal extent of the river system. This increase indicates renewed channel instability and sediment redistribution within the floodplain environment.

By 2026, the sand aggradation area decreased drastically to approximately 11.94 sq. km, which is nearly comparable to the condition observed during 1967. During this period, the river flow became largely confined to a single dominant channel characterized by reduced channel width and greater downstream continuity. The river bifurcated into two channels between Segments 4 and 8, however during the dry season only one channel retained active water flow continuing downstream up to Segment 12, while the other channel remained largely inactive or sediment filled.

The Jiadhal River exhibited a typical meandering single channel pattern during 1924. By 1967, the river had shifted considerably towards the western side and developed a highly metamorphosed braided channel pattern. During 1973, the river again migrated eastward with a pronounced lateral shift towards the eastern side of the study area, inundating extensive areas through flooding and sediment deposition. Subsequently, during 1990 the river shifted back towards the western side and continued its westward migration with minor oscillatory swings in the lower downstream reaches.

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The repeated lateral migration of the river in a triangular zone represents a large alluvial fan deposit of the Jiadhal River (Borgohain et al , 2016.). Within this fan zone, the river swings repeatedly in different directions with highly unpredictable courses during the monsoon season (Fig.9). The river exhibits the characteristic behaviour of an alluvial fan system where the channel bifurcates downstream after emerging from the confined mountainous terrain onto the plains.

Year	Sand cover area (sq.km)
1967	10.86
1973	50.42
1990	28.05
2001	27.07
2006	19.56
2010	27.54
2016	22.80
2020	28.76
2026	11.94

A

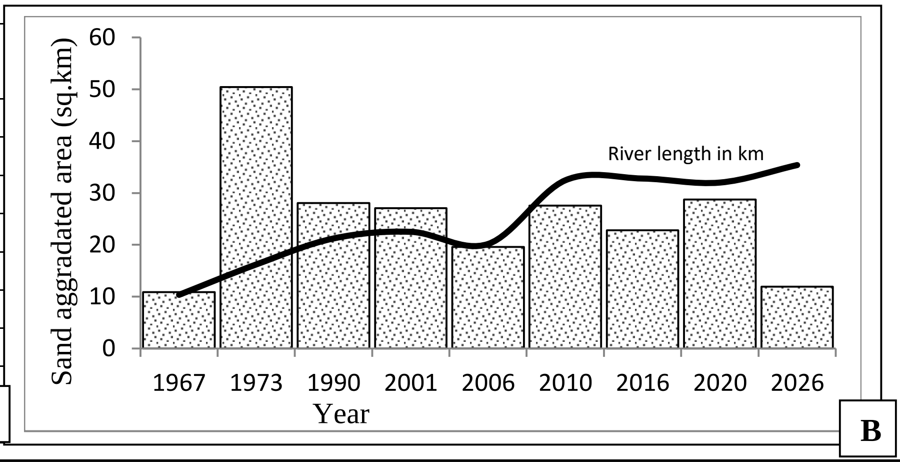

Figure 8. A) Table showing the areal extent of sand cover in Jiadhal river basin from 1967 to 2026. B) Bar graph showing the temporal variation in sand-covered area together with a line graph showing changes in river length during the period 1967–2026.

The distributary nature of the river represents a typical geomorphic characteristic of active alluvial fan where channels divide into multiple branches while flowing downstream. This distributary pattern develops due to excessive sediment aggradation and the gradual loss of stream competence as the river debouches from the steep mountainous catchment to the low-gradient plains. Continuous in-channel aggradation forces the river to undergo frequent avulsions thereby developing braided and distributary flow patterns that are diagnostic geomorphic features of active alluvial fan environments (Blair et al, 1994;   Harvey et al, 2005).

Thus, it can be concluded that the Jiadhal River has undergone gradual downstream extension while exhibiting significant lateral migration. The channel follows a triangular oscillatory pattern, shifting alternately from east to west and back towards the east through successive periods. Such alternating eastward and westward channel migration suggest the rivers geomorphic instability and dynamic behaviour within the alluvial fan environment.

The topographic profiles along sections A-A′, B-B′ and C–C′ across the lateral migration of the river reveal a distinct topographic high in the central part of the migration zone, confirming the presence of an alluvial fan deposit. These elevated surfaces represent zones of significant sediment accumulation resulting from the depositional processes. In contrast, section D-D′ does not exhibit a pronounced topographic high because the profile is located in the distal part of the basin, beyond the extent of the alluvial fan (Fig. 10). The relatively subdued topography along this section reflects the transition from the fan surface to the adjoining floodplain environment where sediment deposition is more evenly distributed and relief is considerably lower. The concentration of river migration within this elevated depositional surface provide strong evidence that the evolution and migration pattern of the Jiadhal River is strongly influenced by alluvial fan geomorphology.

Thus, the river migration zone is largely confined within the alluvial fan region of the Jiadhal River accompanied by significant temporal variations in channel length. The highly dynamic and unpredictable nature of the river has caused numerous adverse impacts within the surrounding areas including recurrent flooding, extensive sand aggradation, bank erosion and repeated damage agricultural land and infrastructures.

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The National Highway 52 and the railway line traverse the distal part of the alluvial fan (Borhohain et al, 2016) making these infrastructures highly vulnerable to annual flood events. During the monsoon season excessive discharge and heavy sediment load frequently lead to channel shifting, overbank flooding and deposition of large volumes of sand over agricultural land and settlements. As a result roads, railways and embankments are repeatedly breached or damaged almost every year which are severely affecting transportation, communication and the socio-economic condition of the region.

The geomorphic transformation of the Jiadhal River into a high sediment influx, highly braided system may be associated with the geomorphic impacts of the great 1950 Assam–Tibet earthquake. The earthquake triggered extensive landslides throughout the eastern Himalayas, generating enormous volumes of sediment that were subsequently transported into the Brahmaputra river system and its tributaries. The sudden increase in sediment supply altered channel morphology, enhanced aggradation, promoted channel instability and accelerated lateral migration processes (Coleman,1969). After the earthquake, the Jiadhal River experienced recurring floods of high intensity (Das, 2016; Gogoi, 2024) due to which the channel became highly unstable and the river morphology frequently kept changing due to lateral bank erosion, sediment deposition and channel avulsion (Buragohain and Bhuyan, 2014; Gogoi et al., 2013; Das 2016). Due to constant dumping of sediments as well as frequent changes in the river flow, the morphometry of the river catchment area keeps changing after every flood event (Kakoty et al., 2018; Gogoi et al., 2022). The rivers braided nature is due to its increase in sediment load (Wang et al., 2016) exceeding the sediment carrying capacity (Baki et al., 2012). The braided channel (Maibangsa et al., 2015) intensifies lateral erosion and channel widening resulting in bankline migration (Saur et al., 2022) of the river.

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1973 to 1990

1990 to 2026

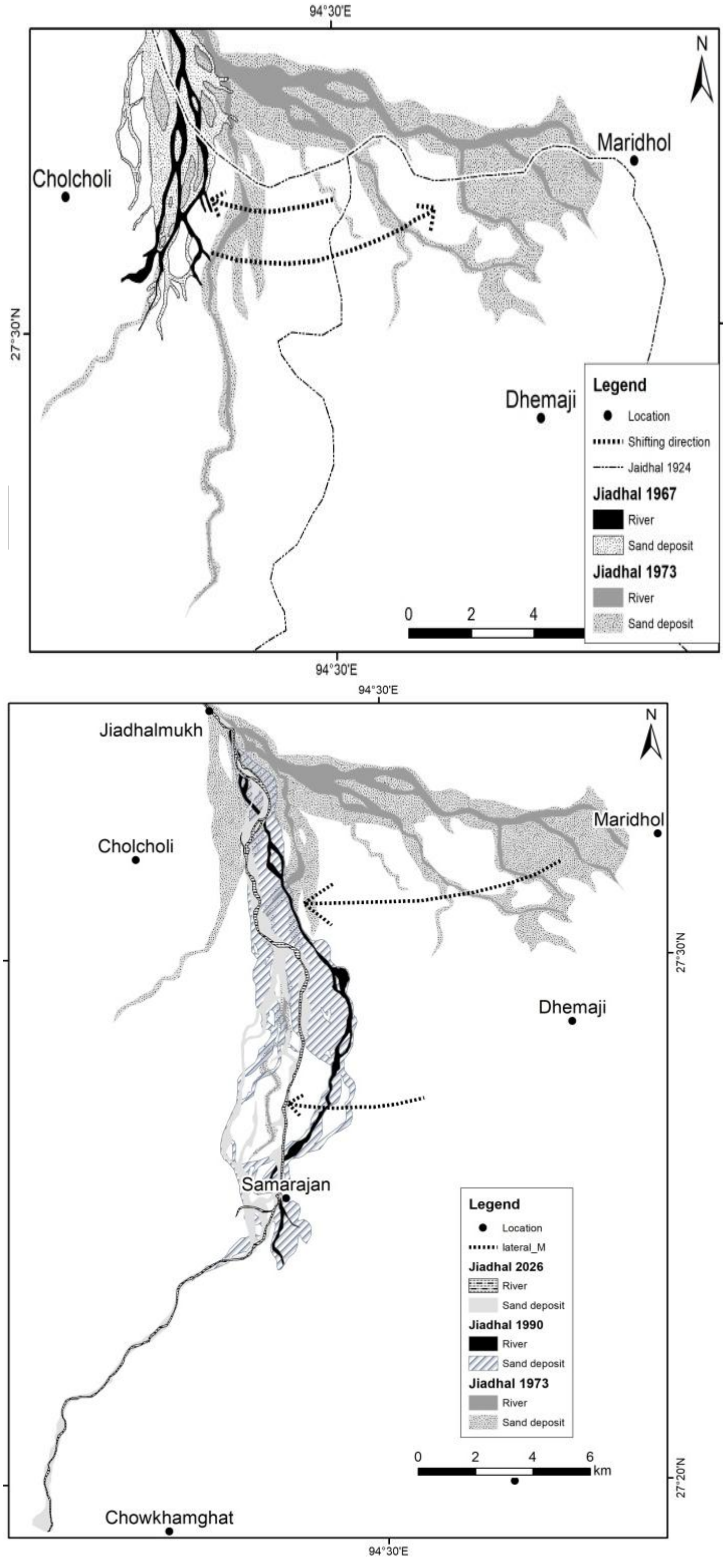

Figure 9. Direction of lateral channel migration of the Jiadhal River during 1924–1973 (A) and 1973–2026 (B), which shows the oscillatory eastward and westward shifting of the river within a triangular migration zone of the Jiadhal alluvial fan.

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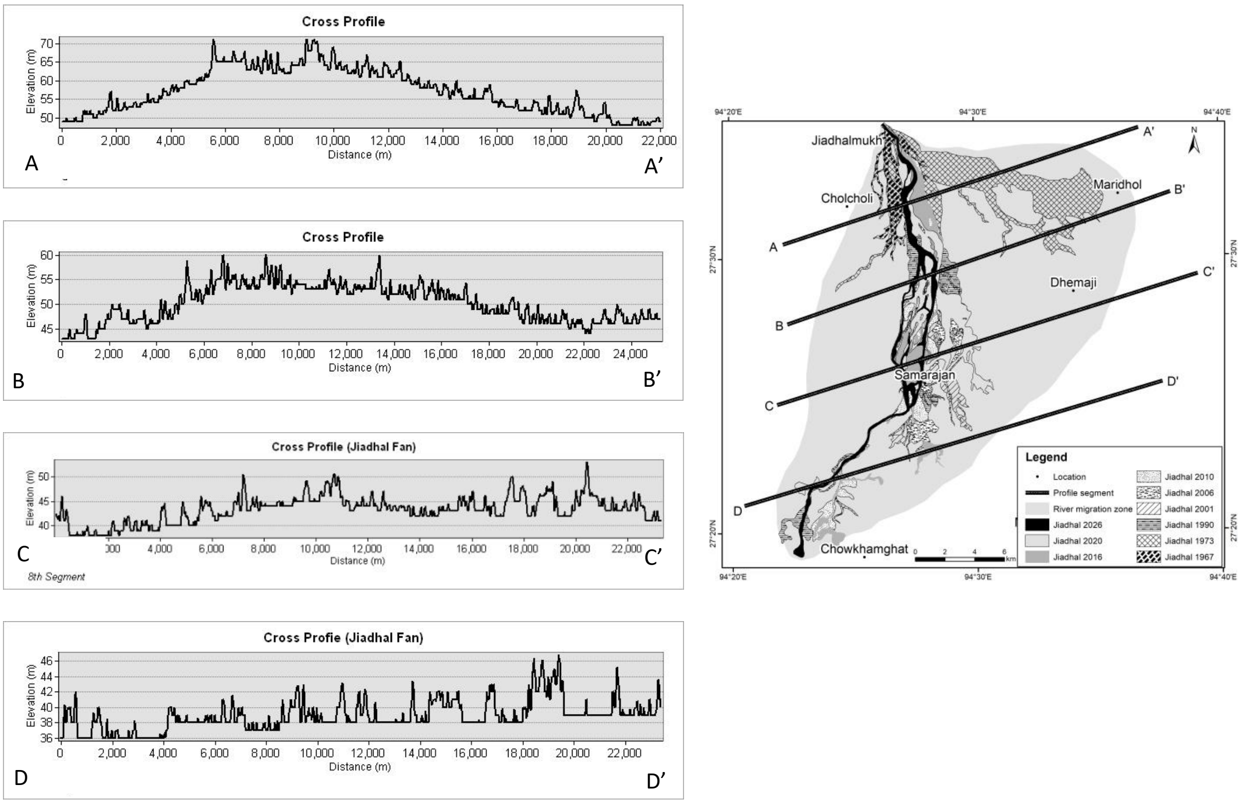

Figure 10. Migration zone of the Jiadhal River showing the locations of cross-sectional profiles A-A', B-B′, C-C′ and D-D′ (right). The corresponding topographic profiles along these sections (left) revealing a pronounced topographic high in the central part of the migration zone, indicating the presence of an alluvial fan deposit.

In the Jiadhal basin, there are a total of 308 streams which spreads over an area of ~396 sq.km and a perimeter of ~118 km. According to the stream order estimation by Strahler, 238 streams were identified as 1^{st} order streams, 56 streams as 2^{nd} order streams, 10 streams as 3^{rd} order streams, 3 streams as 4^{th} order streams and 1 stream was identified as the 5^{th} order streams. The high value of lower order streams suggest that the basin is in youthful to early mature stage of landscape evolution The drainage pattern in the river basin is organised in a dendritic, trellis, rectangular and parallel to sub parallel drainage pattern, indicating a strong lithological and structural influence on drainage development. The average bifurcation ratio is relatively high with a value of 4.04, signifying that the basin has a mature topography with strong runoff and poor recharge.

A drainage frequency of 0.77 and drainage density of 1.06 km/km^2, reflects moderate relief and permeability indicating a balance between runoff and infiltration. The drainage texture ratio of the basin is 0.81 indicating coarse drainage texture suggesting resistant lithology, vegetation cover and low dissection. The basin's circulatory ratio of 0.33 indicates that the basin is very elongated in shape resulting in a low peak flow of longer duration. As a result the flood flow of this type of basin is much more difficult to manage than that of a circular basin.

The mountain front sinuosity of 1.45 indicates a moderately active tectonic regime which reflects a balance between erosional processes and tectonic uplift suggesting that the mountain front is undergoing continuous modification under the influence of fluvial erosion and uplift. Asymmetric factor of 80.02 of the river basin implies a pronounced tilting towards the right side of the main river channel. High asymmetric value indicates that major concentration of drainage area is on the right side and is more developed suggesting that the basin is undergoing geomorphic adjustment.

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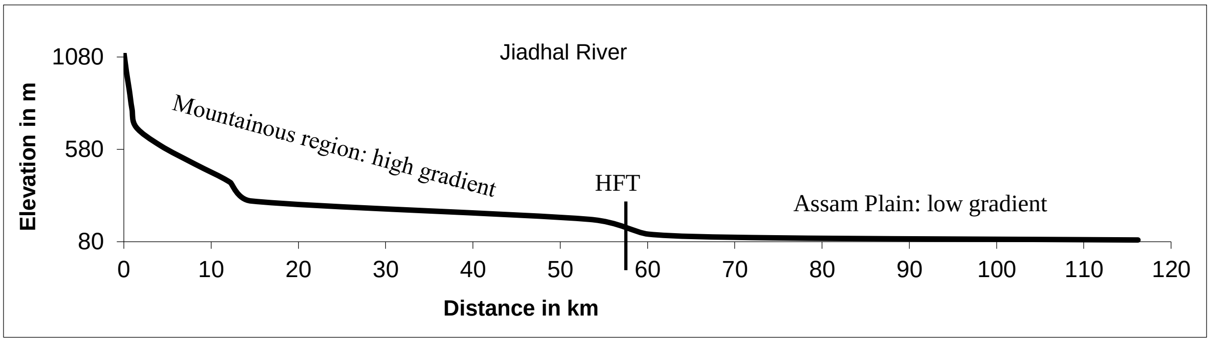

Figure 11. Longitudinal profile of the Jiadhal River from its source in the Arunachal Himalaya to its confluence with the Brahmaputra floodplain, showing a steep upstream gradient and a progressively gentler slope towards the downstream alluvial plains.

The longitudinal profile of the Jiadhal River clearly demonstrates a sharp decline in elevation within the upper reaches followed by a gradual reduction in slope towards the downstream plains. In the mountainous section the river flows through a steep gradient terrain resulting in high stream velocity and strong erosional capability. However, after emerging from the confined hilly terrain towards the downstream the river enters the low gradient alluvial plains where the slope becomes unusually gentle (Fig.11).

Open source rainfall data are collected from a cloud base app (Dry & Wet Spell Explorer) for the period from 1950 to 2025 (Fig.12). The Jiadhal basin experiences consistently high rainfall throughout the study period, generally ranging between 2500 mm/year to 4300 mm/year. Although inter annual fluctuations are evident no significant long-term declining trend is observed. Peak rainfall years occurred during the 1965, late 1977 and around 1990, whereas comparatively lower rainfall was recorded during the early 2000 and around 2020. The persistently high rainfall reflects the strong monsoonal influence on the basin and constitutes a major controlling factor for runoff, flooding, sediment transport and channel instability in the Jiadhal River.

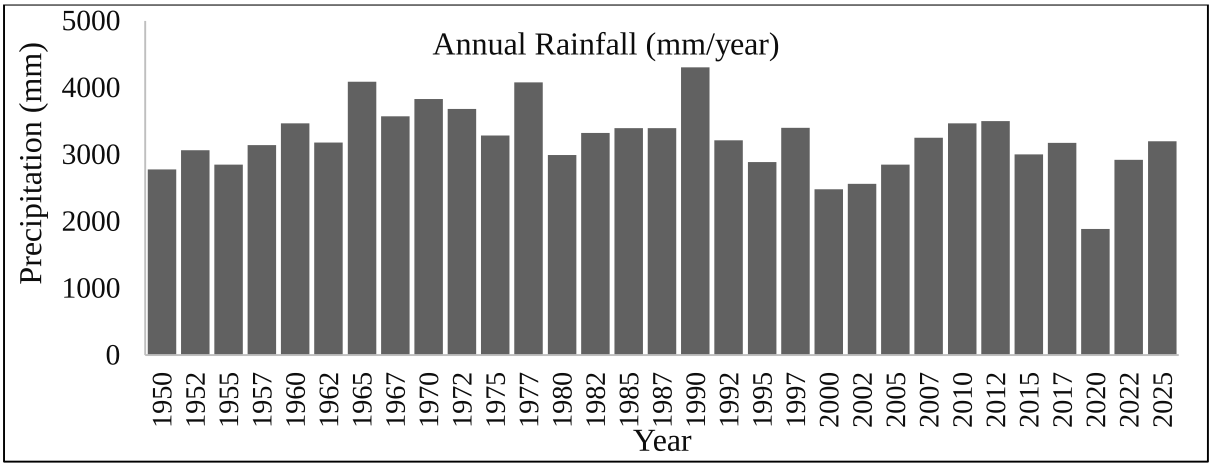

Figure 12. Annual rainfall (mm/year) in the Jiadhal River Basin during 1950 - 2025, showing consistently high rainfall throughout the study period with moderate inter annual fluctuations. (Source: Dry & Wet Spell Explorer, A Cloud-based App)

The findings of the present study reveal that the Jiadhal River is a highly dynamic river characterized by rapid channel migration, recurrent avulsions, high sediment load, extensive aggradation and frequent flash floods. An integrated and sustainable river management approach is required to reduce flood hazards and enhance community resilience.

- Lateral channel migration within the alluvial fan: The study identifies the Jiadhal alluvial fan as the principal zone of channel instability where maximum lateral migration has occurred over the last century. This area should be demarcated as a River Migration Zone (RMZ) and incorporated into regional land use planning.

- Frequent Flash Flood: The flashy nature of Jiadhal River floods requires the establishment of a real time flood forecasting and early warning system. Integrated rainfall monitoring and community based warning networks can provide timely alerts and reduce disaster related losses in downstream settlements.

- Extensive sediment aggradation and sand sheet deposition: The increasing sediment load and downstream aggradation observed in the study indicate the necessity for sediment management at the basin scale.

- Infrastructure damage: Transportation networks such as roads, bridges, railway lines and embankments should be designed considering the historical channel migration pattern of the river. Hazard vulnerability maps using GIS and remote sensing can provide planners in identifying active migration zones.

- Dynamic and unpredictable channel behaviour: Required continuous monitoring of the river through GIS and remote sensing along with hydrological, geological and climatic understanding to comprehend the influences of rainfall, tectonics and human activities on river behaviour. Integrated effort among government agencies, researchers, disaster management authorities and local communities is vital for developing sustainable and long term solutions. Local communities should be actively involved in flood risk management through awareness programmes and participatory monitoring initiatives.

CONCLUSIONS

The present study highlights the spatio-temporal variability of the Jiadhal River and demonstrates its highly dynamic and unpredictable behaviour over the period 1924-2026. The analysis reveals that the river does not follow a consistent pattern of channel migration instead it undergoes continuous adjustments in response to fluvial, geomorphic and tectonic controls. A progressive downstream extension of the river debouching point was observed throughout the study period accompanied by substantial channel widening and sediment deposition in the downstream reaches. The oscillatory lateral migration of the river is characterized by alternating eastward and westward shifts which indicates the typical behaviour of rivers adjustment across an alluvial fan environment. The maximum channel migration was confined within the Jiadhal alluvial fans which specify this region as the primary zone of river instability and vulnerability. Analysis of channel changes over the last century indicates that the river has repeatedly occupied different positions within the fan resulting in extensive bank erosion, channel avulsion and the development of distributary channels. The unpredictable shifting of the river course together with its distributary nature the river has caused significant impacts in the region. Frequent riverbank breaches, extensive sand aggradation and recurrent flash floods during the monsoon season have repeatedly affected the settlements, agricultural lands, transportation networks and other infrastructure. The flashy nature of floods, strong seasonal discharge, high sediment load and the presence of easily erodible bank materials contribute to unstable behaviour of the river. The transformation of the Jiadhal River from a relatively confined channel to a highly braided and sediment loaded system may be linked to the geomorphic consequences of the 1950 Assam-Tibet earthquake and the subsequent small earthquakes over the time as the study area falls under the earthquake Zone V. High monsoon rain fall variability, catchment tectonics and geomorphic setting are perceived to be the major controlling factors governing the behaviour of the Jiadhal River. Overall, the dynamic channel adjustments of the river have significantly influenced the geomorphology, land use patterns and socio-economic conditions of the region. This highlights the necessity for effective river management, sustainable land-use planning and comprehensive flood mitigation strategies to address the challenges posed by the highly vulnerable fluvial landscape.

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Author's contributions: Dr. Ratamali Machahary conceptualized and designed the study, interpreted the temporal datasets and prepared the manuscript. Ms. Parismita Borah contributed to data generation, data analysis and assisted in the preparation of the manuscript. Both authors reviewed and approved the final version of the manuscript

Declaration: The authors declare that there is no conflict of interest regarding the publication of this manuscript. The authors used artificial intelligence (AI) assisted tools solely for language editing, grammar checking and improving the readability of the manuscript.

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