WATER RESOURCES DEPARTMENT, ASSAM

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HYDRO INFORMATICS UNIT

Building Climate Resilience

Erosion Prediction Modelling for the Brahmaputra River Using Channel Network Analysis.

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IIWW Conference Presentation · 2026

OVERVIEW

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Kumolia–Bagariata, Bhuragaon, Dhakukhana, Guijan, Disang

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1. CONTEXT

A Dynamic, Erosion-Prone Braided System

The Brahmaputra — a river of immense water, sediment and change

One of the world's largest rivers: mean discharge ≈ 19,800 m^3/s (≈4th globally); sediment load ≈ 400–800 Mt/yr
(Goswami, 1985; Islam et al., 1999)

Braided morphology: multiple channels, bedforms, sandbars and chars
(Coleman, 1969; Thorne et al., 1993)

Bar migration and deep inter-bar channels are major contributors to bank erosion
(Thorne et al., 1993)

The 1950 Assam–Tibet earthquake (Mw ≈ 8.6) triggered massive landslides; the sediment surge raised the riverbed and intensified braiding, flooding and bank erosion across Assam
(Goswami, 1985; Goswami & Das, 2002)

WHY IT MATTERS

Bank-erosion prediction directly informs prioritization and site selection for river stabilization works — protecting communities, farmland, and infrastructure along the Brahmaputra.

Two-tier approach:

Satellite-image screening + first-order prediction
(accessible, trainable)

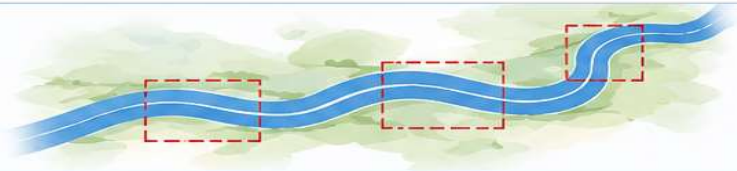
Physics-based modelling for detailed assessment
(Darby & Thorne, 1996)

Empirical Foundations of the CNA Framework

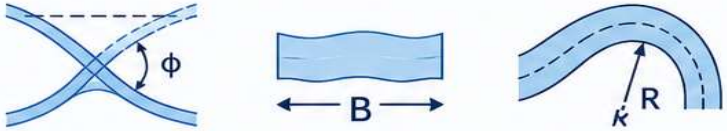
	KEY STUDIES	KEY CONTRIBUTIONS
	**Coleman (1969); Goswami (1985); Sarma (2005)**	Established the Brahmaputra's **channel processes, basin denudation**, and **fluvial morphology.**
	**Klaassen et al. (1993); Mosselman (1993); Jagers (2001, 2003)**	Pioneered **Channel Network Analysis** for braided rivers on the Jamuna (Bangladesh).
	**Hickin & Nanson (1984)**	Lateral migration vs. width-to-curvature ratio (B/R) — max erosion near B/R ≈ **1/2.5.**
	**Donchyts et al. (2016)**	Three decades of **remote-sensed surface-water change** — reliable active-channel mapping.
	**Thorne & Baghirathan (1994); Darby & Thorne (1996)**	Palaeo-channel indicators and analytical **riverbank-stability** frameworks.

What This Study Set Out to Achieve

1. Develop and apply a CNA-based erosion prediction framework for selected Brahmaputra reaches in Assam



2. Assess spatial variability in erosion susceptibility using bifurcation angle (ϕ), channel width (B), and radius of curvature (R)



3. Estimate channel abandonment probabilities and incorporate them into erosion predictions



4. Evaluate the applicability and limitations of CNA in highly dynamic braided systems



5. Support informed decision-making for riverbank protection in data-scarce environments



METHODOLOGY

Channel Network Analysis (CNA) for Braided Rivers using Satellite Imagery

STEP 1

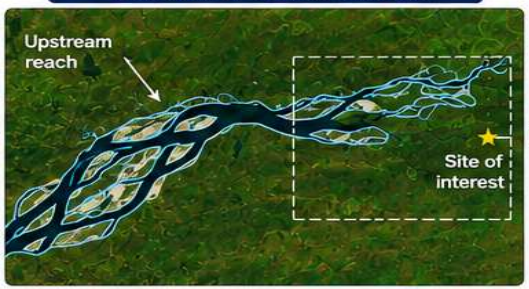
SCHEMATISE NETWORK

- Dry-season satellite images are used to identify the main active channels near the site of interest and in the upstream reach.
- The braided river pattern is simplified into a channel network by selecting only the dominant channels influencing flow towards the site of interest.

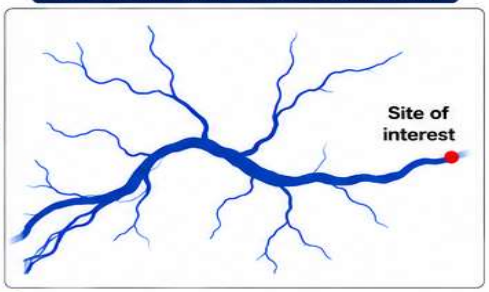
1A. SELECT DRY-SEASON SATELLITE IMAGE



1B. IDENTIFY ACTIVE CHANNELS



1C. SCHEMATISED CHANNEL NETWORK



The braided pattern is schematised by retaining only the dominant channels that control flow distribution. *(Source: Klaassen et al., 1993; Mosselman & Martin, 1993)*

STEP 2

DRAW THALWEGS

- Flow paths are represented using thalweg or channel center-lines in the absence of bathymetric data.

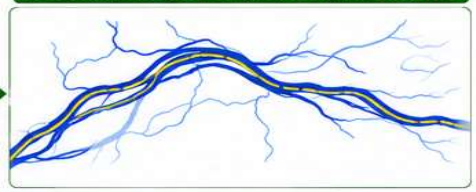
2A. SATELLITE IMAGE (DRY-SEASON)

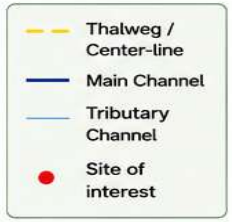


2B. TRACE THALWEG / CENTER-LINES



2C. THALWEG / CENTER-LINES (FLOW PATHS)





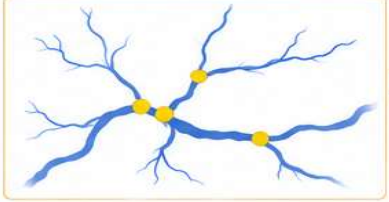
Thalwegs, representing the deepest flow paths, are delineated from satellite imagery or approximated using channel center-lines when bathymetric data are unavailable. *(Source: Klaassen et al., 1993; Mosselman & Martin, 1993)*

STEP 3

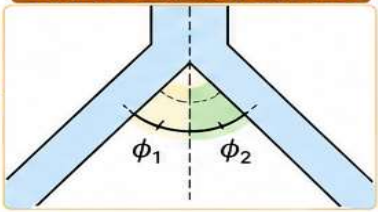
DETERMINE BIFURCATION ANGLES

- Bifurcation angles are measured at channel splitting points to assess the likelihood of channel stability or closure.

3A. IDENTIFY BIFURCATION POINTS



3B. MEASURE BIFURCATION ANGLES

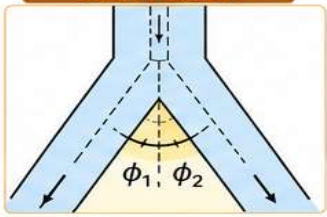


3C. INTERPRETATION (PROBABILITY OF ABANDONMENT)

✓ Large bifurcation angles (e.g., ϕ_1, ϕ_2 > 60°)
→ Lower probability of abandonment
→ More stable channels

✗ Small bifurcation angles (e.g., ϕ_1, ϕ_2 < 30°)
→ Higher probability of abandonment
→ Higher chance of instability or closure

3D. APPLICATION



Bifurcation angle (ϕ) is measured between the upstream channel and downstream branches and is used to estimate the probability of channel abandonment. *(Source: Mosselman, 1993; Jamuna Test Works Consultants, 2001)*
Individual probabilities are combined for serial and parallel channel configurations. *(Source: Jagers, 2003)*

METHODOLOGY: EROSION PREDICTION USING CHANNEL NETWORK ANALYSIS (CNA)

(Based on Mosselman, 1993; Jamuna Test Works Consultants, 2001; Jagers, 2003)

1. BIFURCATION ANGLE (ϕ) AND PROBABILITY OF CHANNEL ABANDONMENT

Bifurcation angle (ϕ)	Probability of abandonment	
	Channel length ≤ 20 km	Channel length > 20 km (major anabranch)
ϕ ≤ 20°	P(A) = 0	P(A) = 0
20° < ϕ ≤ 153°	P(A) = (ϕ − 20°) × 1.1%	P(A) = 0
ϕ ≥ 153°	P(A) = 100%	non existent

Source: Mosselman (1993); Jamuna Test Works Consultants (2001)

2. FUNCTIONS FOR PROBABILITY OF EXCEEDANCE OF LARGEST BANK EROSION RATES

For $B/R \leq 0.4$	For $B/R > 0.4$
$f\left(\frac{B}{R}\right) = 2.5\frac{B}{R}$	$f\left(\frac{B}{R}\right) = \frac{2 - 2\frac{B}{R}}{3\frac{B}{R}}$

Where, B = Channel width (m) and R = Radius of bend curvature (m)

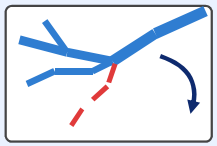
Source: Mosselman (1993)

3. PROBABILITY OF EXCEEDANCE OF BANK EROSION RATES

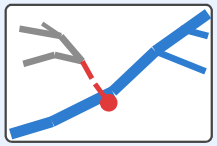
Probability of exceedance, P(E) (%)	Bank erosion rate in direction perpendicular to former channel (m/year) (E)
90	$0.3 \times B \times f(B/R)$
75	$0.5 \times B \times f(B/R)$
50	$0.7 \times B \times f(B/R)$
25	$0.9 \times B \times f(B/R)$
10	$1.1 \times B \times f(B/R)$

Source: Mosselman (1993)

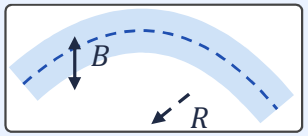
4 Step 4:
Calculate probabilities of channel abandonment for each channel.



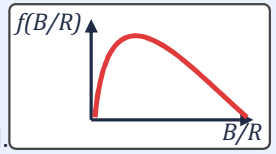
5 Step 5:
Calculate the probability that the channel along the site of interest is abandoned.



6 Step 6:
Determine local channel width (B) and radius of bend curvature (R).



7 Step 7:
Calculate probabilities of exceedance of largest bank erosion rates under the condition that the channel is not abandoned.



8 Step 8:
Correct the bank erosion rates obtained by using the probability of channel abandonement

$$E_{final} = (1 - P(A_{local})) \times (E)$$

Where:
$P(A_{local})$ = probability of local channel abandonment

Note: *The above methodology is adapted from Channel Network Analysis (CNA) approach developed for braided rivers.*

5 · REACH-WISE ANALYSIS

Five Reaches Along the Brahmaputra System

Kumolia–Bagariata

Biswanath district

B/R = 0.23 · Abandonment 18%

Bhuragaon

Morigaon district

B/R = 0.54 · Abandonment 30%

Dhakuakhana

North Lakhimpur district

No Dominant Channel — High Uncertainty

Guijan

Dibrugarh district

B/R = 0.664 · Abandonment 15%

Disang

Sivasagar District

Abandonment 0% — Palaeo-Channel Influence

The application of CNA across these reaches reveals significant spatial variability in erosion dynamics, driven by differing channel morphology and flow behaviour. All four main-river reaches show varying degrees of channel instability and erosion potential; the Disang tributary is assessed separately for avulsion risk.

Kumolia–Bagariata Reach, Biswanath District

The Problem :

Continuous channel shifting and bank erosion **threaten** nearby embankments.

In some locations, erosion has reached **close** to flood protection structures.

Repeated emergency measures provide only **short-term relief.**

Why This Area Is Critical :

Protects **villages, farmland,** and key **infrastructures.**

High erosion rates observed over the last decade.

Immediate need to understand erosion trends to support **planning and protection.**



Empirical Channel Network Analysis

Study Overview

- Braided channel network mapped up to **~20 km** upstream of the site.
- **5** major bifurcation points identified and analysed.
- Bifurcation angles measured to estimate channel abandonment probability.

Key Quantitative Results

- Local probability of channel abandonment influencing the site: **~18%**
- Average channel width at site: **~335 m**
- Radius of curvature: **~1468 m**
- Width-to-curvature ratio (B/R): **~0.23**, indicating active bank erosion potential.

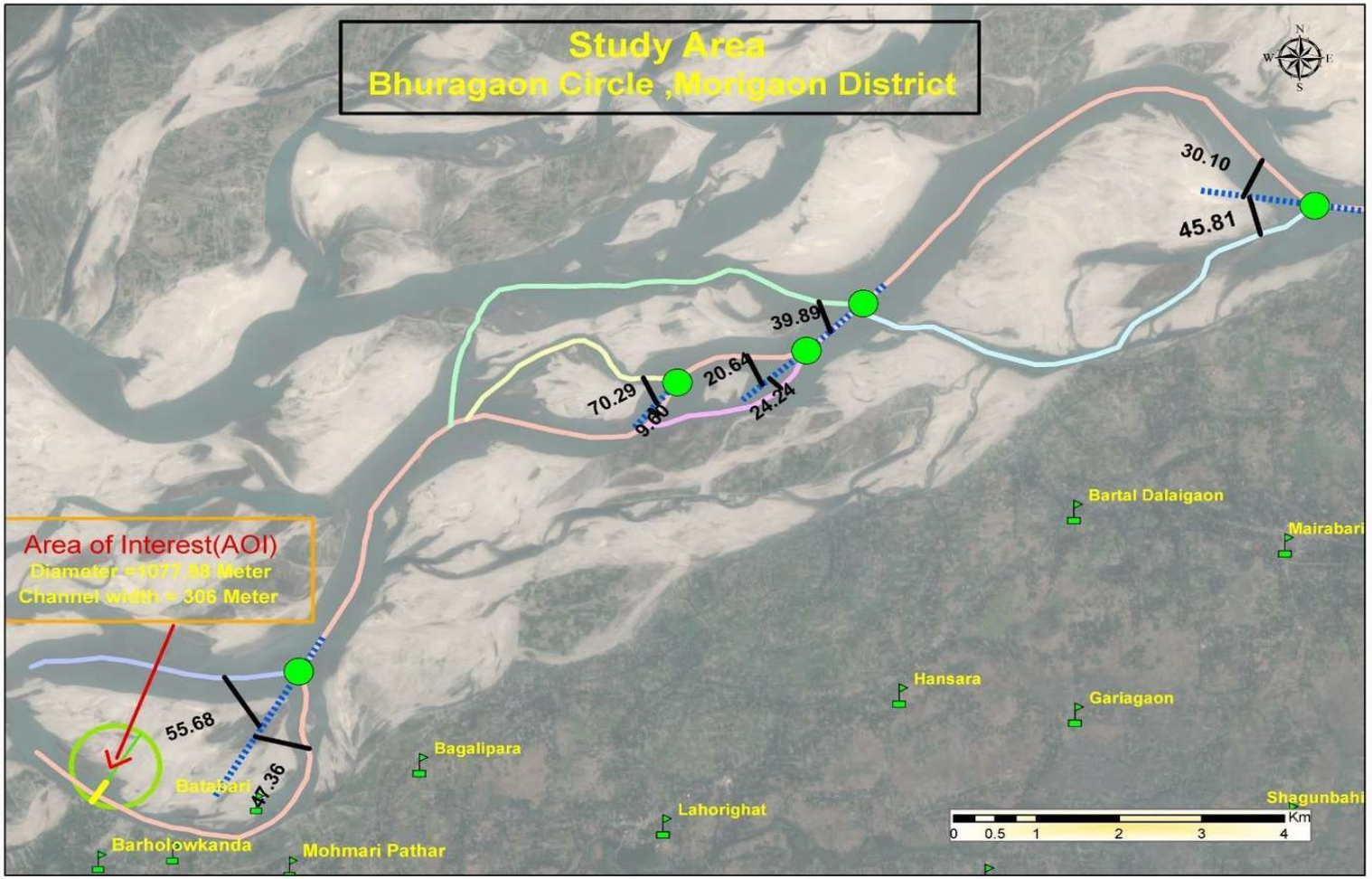
Estimated Bank Erosion (After Correction)

- 90% High probability (90%): **~46 m**
- 50% Moderate probability (50%): **~108 m**
- 10% Low probability (10%): **~170 m**



Probability of Exceedance (%)	Bank Erosion Rate (m/year)	
90	56.3 × 0.82 =	**46.35 m**
75	94.13 × 0.82 =	**77.19 m**
50	131.78 × 0.82 =	**108.05 m**
25	169.443 × 0.82 =	**138.94 m**
10	207.097 × 0.82 =	**169.819 m**

Bhuragaon Reach (Morigaon District)



The Bhuragaon area of Morigaon district of Assam is known for repeated **riverbank erosion** and **riverine flooding.**

Empirical Channel Network Analysis

Study Overview

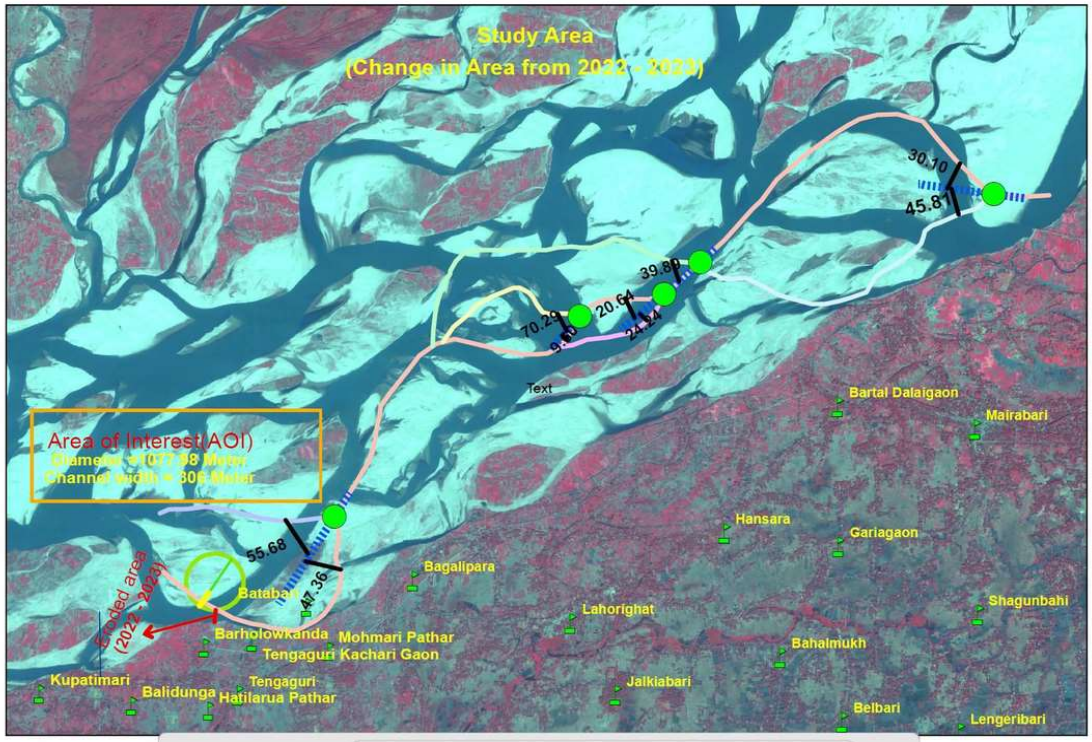
- Braided channel network mapped up to **~20 km** upstream of the site
- Major bifurcation points identified and **analysed**
- Bifurcation angles measured to estimate channel abandonment probability

Key Quantitative Results

- Local probability of channel abandonment influencing the site: **~30.09%**
- Average channel width at site: **~301 m**
- Radius of curvature: **~539 m**
- Width-to-curvature ratio (B/R): **~0.54**, indicating active bank erosion potential

Estimated Bank Erosion (After Correction)

90%	High probability (90%): **~33.64 m**
50%	Moderate probability (50%): **~80.48 m**
10%	Low probability (10%): **~126.47 m**



The analysis reveals a **30.09%** probability of channel abandonment at the site, suggesting a **moderate erosion risk.** The predicted erosion rates, particularly under extreme hydrological conditions, necessitate targeted monitoring and protection efforts.

DHAKUAKHANA REACH (NORTH LAKHIMPUR DISTRICT)

REACH OVERVIEW

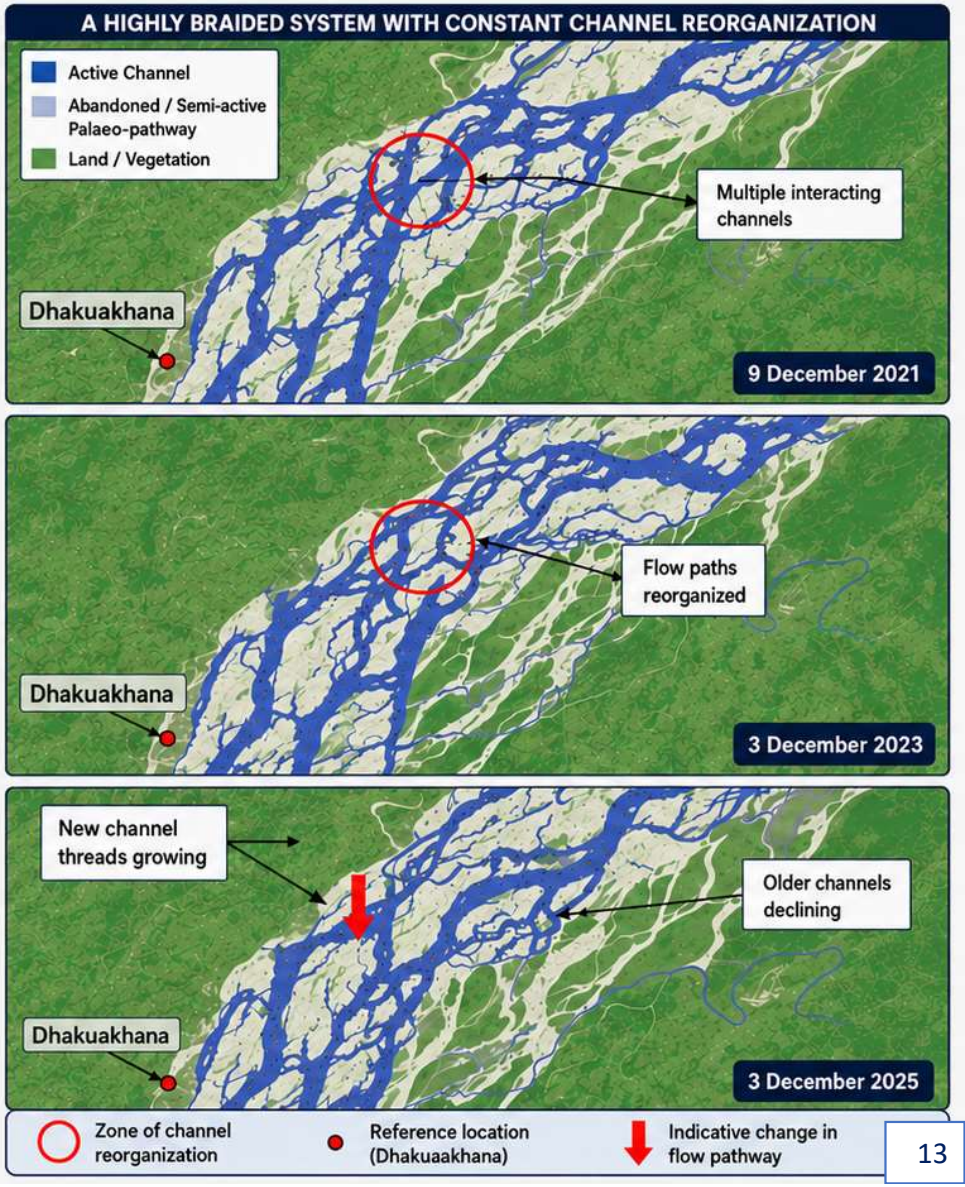
- A highly braided reach of the Brahmaputra with numerous parallel and intersecting channels
- Repeated reorganization of flow paths over short spatial and temporal scales
- No single dominant channel thread persisting through time
- Active interaction between present channels and abandoned or semi-active palaeo-pathways

WHY EMPIRICAL CHANNEL NETWORK ANALYSIS FALLS SHORT HERE

- ✕ **Empirical methods** rely on clearly defined upstream connectivity and dominant channels
- ✕ **Assumptions of stable bifurcation** hierarchy break down in this reach
- ✕ **Channel abandonment probabilities** become ambiguous when all branches reconnect
- ✕ The method cannot distinguish which thread will evolve into the future main channel

IMPLICATIONS FOR EROSION PREDICTION

- Bank erosion risk is governed by **evolving flow pathways,** not past bankline trends alone
- Empirical predictions carry **high uncertainty** in such multi-thread, re-organizing systems
- Results should be interpreted as **indicative, not deterministic**



GUIJAN REACH (DIBRUGARH DISTRICT)

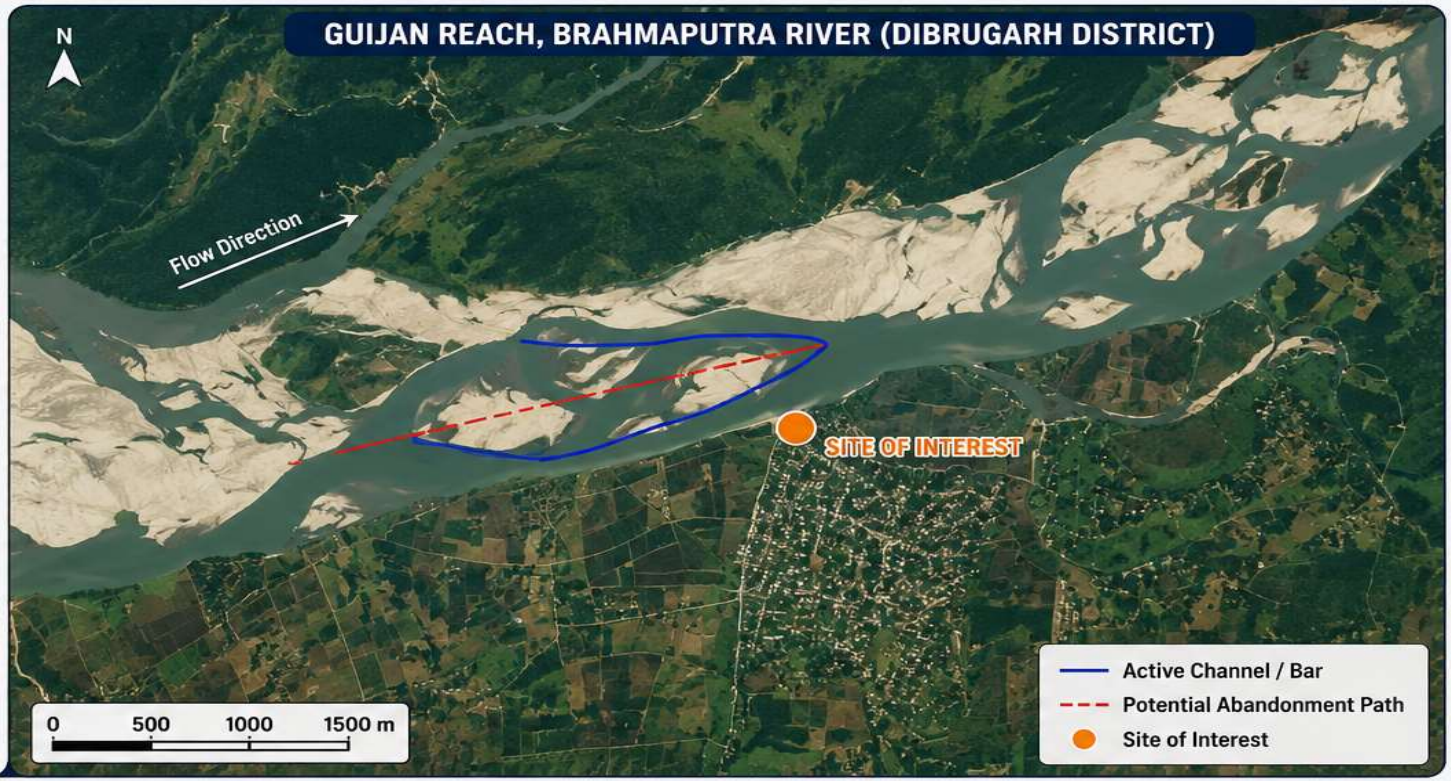
KEY QUANTITATIVE RESULTS

Local probability of channel abandonment influencing the site:
~15.09%

Average channel width at site:
~594 m

Radius of curvature:
~890 m

Width-to-curvature ratio (B/R):
~0.664,
indicating active bank erosion potential



ESTIMATED BANK EROSION (AFTER CORRECTION)

High probability (90%)	Moderate probability (50%)	Low probability (10%)
~40.4 m	~120.48 m	~176.47 m

The width-to-curvature ratio (B/R) of ~0.664 indicates a dynamic bend with active bank erosion potential at the site.

DISANG REACH (SIVASAGAR DISTRICT)

STUDY AREA :
Lower Disang River and adjoining Brahmaputra reach near Disangmukh, Sivasagar District, Assam.

- The Brahmaputra shows persistent eastward channel migration in this reach.
- The lower Disang River follows an old Brahmaputra palaeo-channel.
- Concern that future Brahmaputra outflanking could re-activate the lower Disang reach, altering flow paths and erosion patterns.

KEY OBSERVATIONS

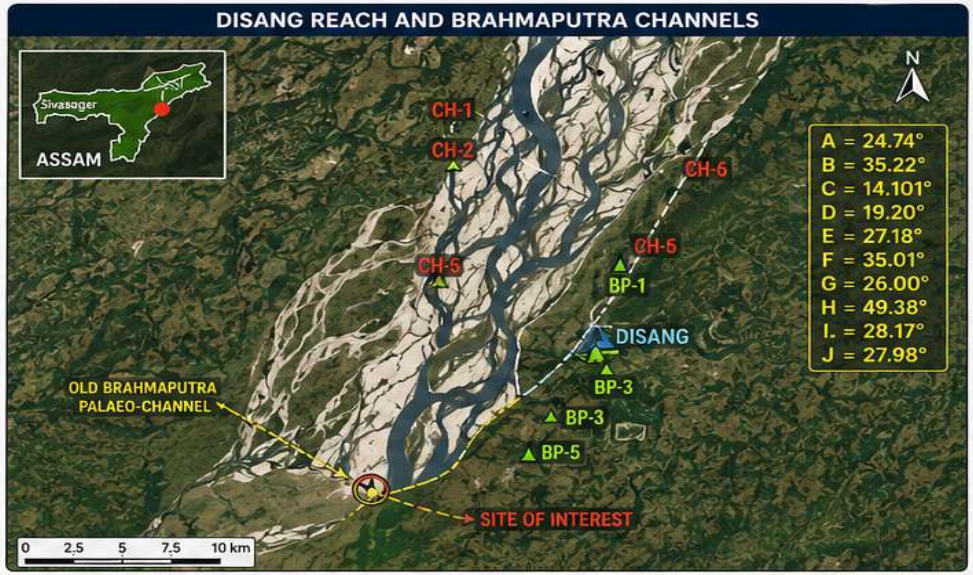
- All bifurcated Brahmaputra channels upstream rejoin before the site of interest.
- Probability of abandonment of the main channel at the site is 0%.
- The lower ~3 km of the Disang River lies across accreted land and aligns with a former Brahmaputra channel.
- Time - series imagery (2016–2025) shows a progressively migrating Brahmaputra channel moving closer to the Disang alignment.
- This creates a potential future capture pathway, rather than an immediate channel shift.

TIME–SERIES MIGRATION (2016–2025)

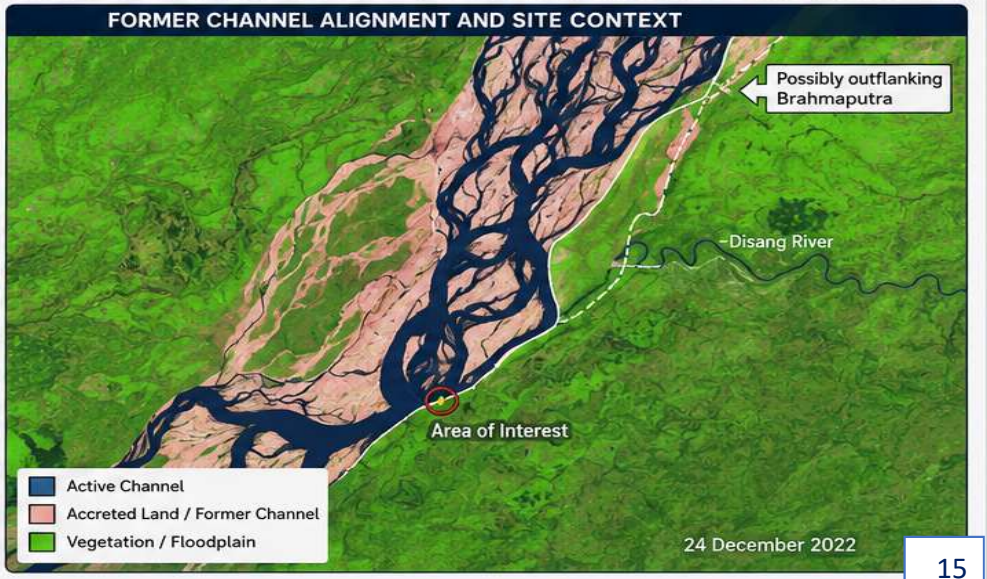


Progressive eastward migration of Brahmaputra channel towards Disang alignment

DISANG REACH AND BRAHMAPUTRA CHANNELS



FORMER CHANNEL ALIGNMENT AND SITE CONTEXT



Bank Erosion Estimation per Plot Site

Erosion Prediction Modelling

Preliminary results

Bank erosion probability (%)	Bank erosion estimation per plot site (in metres)		
	Kumolia–Bagariata Reach (Biswanath District) Year 2023	Bhuragaon Reach (Morigaon District) Year 2022	Guijan Reach (Dibrugarh District) Year 2023
90% High (90%)	46 m	33.64 m	40.4 m
50% Moderate (50%)	108 m	80.48 m	120.48 m
10% Low (10%)	170 m	128.47 m	176.47 m
Observed Erosion From Image (Post-Monsoon)	42 m (Year 2024)	208 m (Year 2023)	22 m (Year 2024)

Fig 4. Bank erosion estimation per plot site

6 · CONCLUSIONS

What the CNA Assessment Demonstrates

✓ CNA is useful for preliminary assessment

The study demonstrates that Channel Network Analysis can provide a practical, low-data first-order assessment of erosion susceptibility in braided river reaches.

✓ Morphology provides a meaningful erosion signal

B/R and channel-abandonment probability help distinguish reaches with stronger lateral erosion potential and describe spatial variability along the study reaches.

✓ Observed erosion supports the broad model signal

At Bhuragaon, CNA indicated substantial instability before comparison with observations. The 208 m observed erosion confirms the reach's strong erosion activity, although its magnitude was underestimated.

✓ Complex reaches require caution

Dhakukhana shows the key limitation: where no dominant channel exists, bifurcation hierarchy and abandonment probabilities become uncertain and predictions should be treated as indicative.

» Way Forward

1 Multi-year validation

Use longer time series and more observations.

2 Local calibration

Tune CNA parameters for Brahmaputra reaches.

3 Integrated modelling

Combine CNA with 1D/2D models and field data.

Overall: CNA is a screening and decision-support tool — not a deterministic forecast

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Thank You

Questions and discussions are welcome.

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