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VULNER ABILITY ASSESSMENT OF PAGLADIYA EMBANKMENTSYSTEMIN NALBARI-BAKSADISTRICTOF ASSAM

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ABSTRACT

The Pagladiya River, a tributary of the Brahmaputrain Assam, is highly dynamicand prone to frequentflooding, causingseverethreatstosettlements, agriculture,andinfrastructure. Thisstudy evaluates the vulnerability of the left bank embankmentbetween Barbhag and Madaltana using satellite imagery from 2015–2025 sourced from Bhuvan portal and USGS Earth Explorer. Bankline migration was analyzed in ArcGIS 10.4.1, while flood behavior was simulated using HEC-RAS 2D modelling. A composite Vulnerability Index based on bankline shifting, bank distance from the embankment,flow velocity, flow direction, and discharge per unit width was developedto identify criticalzonesfor embankmentprotection andfloodmanagement.

KEYWORDS: *Pagladiya River, Embankment Vulnerability, Bankline Migration, Floodplain Modelling, HEC-RAS2D Modelling.*

1. INTRODUCTION

The Pagladiya River isa small yet significant riverinnortheastern Assam, India. Originating in the foothills of Bhutan,it flows through the districts of Baksa and Nalbari before joining the Brahmaputra River.During the monsoon, the riverbecomes highly turbulent and unpredictable, which is reflected in its name, “Pagladiya,” meaning “mad river.” It often causes floods that damage agriculture, settlements, and infrastructure. Its shifting course weakens traditional embankments,increasing flood risk (Khaund et al. 2015, Alam et al.

2007). Most of the embankmentsin Assam were constructed during 1950s and 1960s. Due to lack of continuous monitoringofthehealthoftheseembankments,veryoftentheyfail.Soamethodologyisrequired to identify vulnerable embankmentpoints for prioritization of maintenance requirement under limited fund availability.

Embankmentsaretraditionallyconstructed asatemporary floodmitigation measure. The leftbank ofthe Pagladiya riverisprotected by anexisting embankmentconstructed fewdecades ago.Due to change inrivercourseand wearand tearofthe embankment;the riskforfloodonthe left bank has increased (Barui et al. 2024). A 2-D morphologicalmodel can effectively predict erosion, scour and channel changes (Pareta 2021). A breachin embankmentsignificantly affect bothecologicalbalanceandlocaleconomyofthe regionwithimpacts varyingacrosscommunities (Sarkar2018).Soaembankmentvulnerabilitystudy willbeverymuchhelpful to protectaregion ecologically and economically. Ghosh and Mistri (2020) emphasis the need for integrated management,institutional coordination and activecommunityparticipationto ensure long term embankmentsustainability and disaster resilience.

Talukdar et al.(2017)carriedout a comprehensive study on indexing vulnerability of an embankmentreachagainst breaching using remote sensing and hydrodynamicbasedstudy. The study demonstrates that integrating remote sensing, GIS, and hydrodynamic modelling is an effective approach for identifying embankmentreaches vulnerable to breaching in flood-prone river systems. Analysis of the Nona River showed that channel migration, bank erosion, sedimentation,and changingflowpatterns significantly influenceembankmentstability.

2. STUDYAREA

ForthevulnerabilityassessmentofthePagladiyaembankmentsystem, theleftbankembankment of the Pagladiya Riverhas been considered for detailedstudy. The selected stretch extends from Barbhag in Nalbari District, located at latitude 26°32'16.52"N and longitude 91°31'2.70"E, to Madaltana in Baksa District, locatedat latitude 26°38'37.71"Nand longitude91°30'54.44"E.

During the monsoon, the Pagladiya River carries high discharge from the southern HimalayanfoothillsofBhutan,causingseveredamageinpartsofNalbariandBaksadistricts.The embankment helps in reducing flood impact across the central floodplain and ensures uninterruptedtransportation during the flood season.

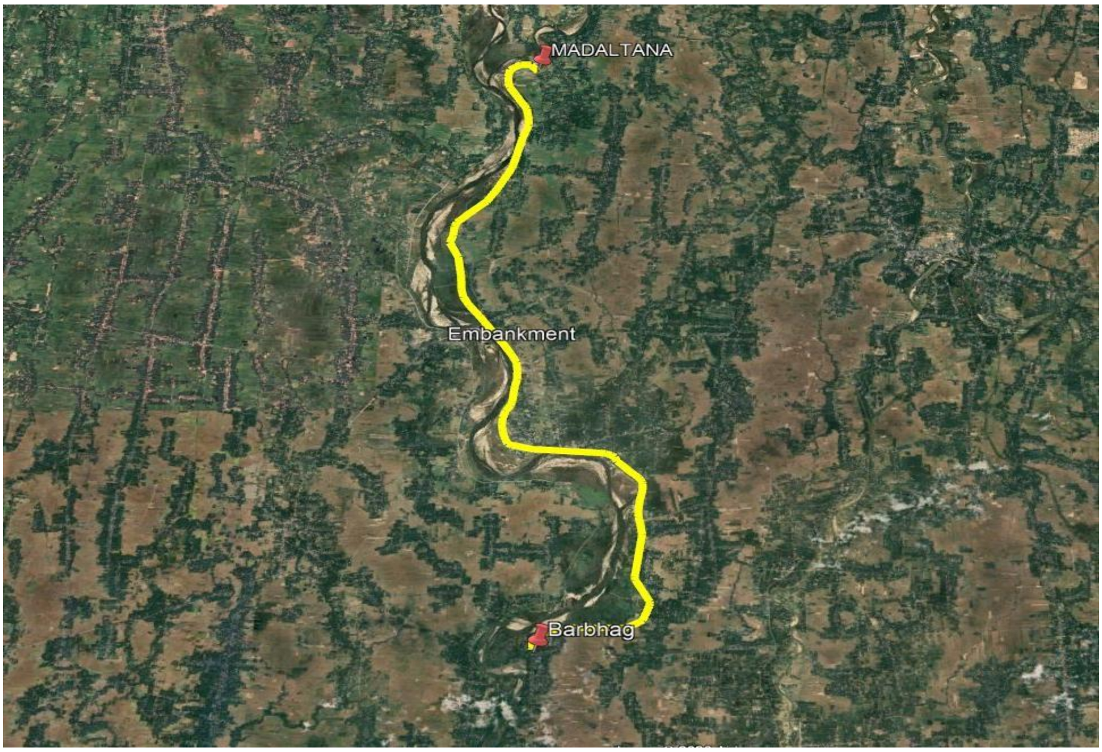

Fig.1:LocationoftheEmbankmentontheleftbankofPagladiyaRiver.

3. METHODOLOGY

Bankline mapping of the Pagladiya Riverwascarriedout using satelliteimageries from Bhuvan portal and USGSEarth Explorer. Non-monsoonimages from 2015–2025 wereselected to avoid flood distortion. ArcGIS 10.4.1wasused for band processing, mosaicking,and preparingannual maps for analysis.

The riverbanklinesofthe Pagladiya Riverweredigitized using GIS polyline toolsforthe periodfrom 2015to 2025.Based on the extracted banklines,polygonshape fileswereprepared in ArcGIS for spatialanalysis. The right and left banks weredividedinto ten points to evaluate erosion and deposition patterns, with erosion assigned positive values and deposition negative values. GIS techniques wereused to study spatialand temporal changes along the riverbanks. In addition, a two-dimensional floodplain model was developedusing HEC-RAS 2D modelling to analyze inundationextent and flow behavior,supporting embankmentvulnerabilityassessment.

VulnerabilityParametersand VulnerabilityIndex

Five major parameters have been considered for the vulnerability assessment of the Pagladiya EmbankmentSystem at selectedpoints. These are:

(i) Distanceoftheembankmentfromthebank

(ii) Rivervelocity

(iii) Directionofflow

(iv) DepthxVelocity

(v) Banklineshifting

Geotechnical propertiesarealsooneimportant parameter for embankmentvulnerability. Poorly graded sandy soil with high silt content, low shear strength,and excessive pore water pressure increasetheriskof failure duringmonsoonconditions (Mondal et al. 2012).

In the present case, the geotechnical properties are found homogenousthroughoutthe embankmentreach. So they contribute equally to the vulnerability index. That is why the soil parameter is ignored.

Each parameter is divided into different classes to ensure proper distribution of vulnerability values. Zero value is assigned to a parameter with highest vulnerability and a maximumvalueof 5isassigned for leastvulnerability.The classificationispresented inTable-1 to Table-5.

Table-1:Classificationofvaluesbasedonproximity,i.e.,distance of embankmentfrom the bank (m)

Distance	0-50	51-100	101-250	251-500	501-1000	>1000
Value	0	1	2	3	4	5

Table-2:Classificationofvaluesbasedonflowvelocity.(m/s)

Velocity	>5	>4	>3	>2	>1	0-1
Value	0	1	2	3	4	5

Table-3:Classificationofvalues basedonflowdirection.

Direction	TowardstheBank	ParalleltoBank	AwayfromtheBank
Value	0	3	5

Table-4: Classificationof valuesbasedondischargeperunitwidth,q(depth×velocity)inm^2/s

q	0-10	10-20	20-30	30-40	40-50	>50
Value	5	4	3	2	1	0

Table-5:ClassificationofvaluesbasedonBanklineShifting.

Erosion/ Deposition	**Erosion**					**Deposition**
	>500m	250-500m	100-250m	50-100m	0-50m	
Value	0	1	2	3	4	5

The Vulnerability Index at allthe points isdeveloped by adding the obtained values for each parameters. The table-6 shows the final vulnerability index based on all these summedup values.

Table-6:VulnerabilityIndexfordifferentlocations.

Category	Sumofall Parameters
LowVulnerable	21-25
ModeratelyVulnerable	16-20
Vulnerable	11-15
HighlyVulnerable	6-10
VeryHighlyVulnerable	0-5

4. RESULTSANDDISCUSSION

BanklineMigrationStudy

A datum lineisdrawnonthe right bank ofPagladiya river.Tenpoints areselectedasA,B, C,D, E, F, G, H, I and J at equal intervals and perpendicular lines are drawnfrom these points to the riverbank. These distances aremeasured and erosion/depositionalong the banks areevaluated at these points. Table-7 and Table-8shows the calculated erosion-depositionat left bank and right bankrespectively;wherenegativevaluesindicateerosionandpositivevalues indicate deposition.

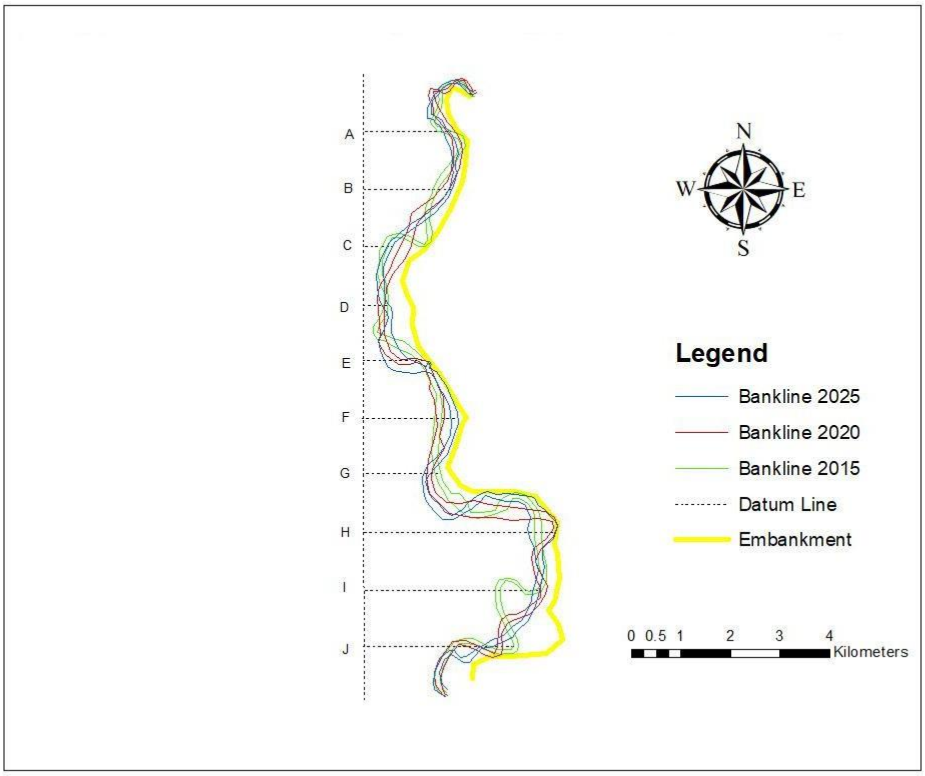

Fig-2: BanklineShiftofPagladiyariverbetweenBarbhagandMadaltana.

Table-7:Migrationattheleftbank during 2015to2025(m).

Points	Dist.ofpoint from datum line in 2015 (m)	Dist.ofpoint from datum	Shiftingatthe left bank during	Dist.ofpoint from datum	Shiftingatthe left bank during
A	1859.31	1889.13	-29.82	1761.09	98.22
B	1513.85	1746.26	-232.41	1811.87	-298.02
C	487.68	962.03	-474.35	609.60	-121.92
D	1261.54	441.34	820.20	508.70	752.84
E	1583.29	1238.25	345.04	952.29	631.00
F	1566.34	1625.60	-59.27	1904.39	-338.06
G	1555.75	1388.56	167.19	1354.60	201.15
H	3621.11	3867.16	-246.05	3916.08	-294.97
I	3598.35	3708.41	-110.06	3553.97	44.38
J	3132.62	2800.37	332.25	2638.28	494.34

Table-8:Shiftingattherightbankduring2015-2025(m).

Points	Dist.ofpoint from datum line in 2015	Dist.ofpoint from datum line in 2020	Shiftingat the right bankduring	Dist.ofpoint from datum line in 2025	Shiftingat the right bankduring
A	1615.17	1714.50	99.33	1634.09	18.92
B	1417.33	1561.04	143.71	1735.67	318.34
C	386.11	755.66	369.55	474.20	88.09
D	1066.80	295.29	-771.51	372.63	-694.17
E	1447.80	603.28	-844.52	415.75	-1032.05
F	1456.29	1479.57	23.28	1743.46	287.17
G	1428.79	1261.56	-167.23	1220.50	-208.30
H	3460.12	3765.56	305.44	3326.09	-134.03
I	2656.44	3581.41	924.97	3406.45	750.01
J	1746.29	2705.11	958.82	2387.34	641.06

DeterminationofVulnerabilityParameters

Thedistancesofthe banklinefromthe embankmentatselectedpoints fromAtoJweremeasured using Google Earth Pro. Flow velocity, depth, flow direction, and discharge per unit width for these points were obtained from HEC-RAS 2D modelling where 50 years return period design discharge is considered.The collecteddata is presented inTable 9.

Table-9:Parameters atdifferentpoints onEmbankment.

Vulnerable Points	Dist.From Embankment (m)	Velocity (m/s)	Depth (m)	FlowDirection	Dischargeper unit width (m^2/s)
A	150	1.7	27.56	TowardsTheBank	46.852
B	60	1.88	25.43	AwayfromtheBank	47.8084
C	610	1.03	24.11	TowardsTheBank	24.8333
D	430	1.36	22.33	TowardsTheBank	30.3688
E	310	1.62	21.51	TowardsTheBank	34.8462
F	30	0.93	20.29	ParalleltoBank	18.8697
G	390	1.39	19.62	TowardsTheBank	27.2718
H	20	0.88	18.82	TowardsTheBank	16.5616
I	280	1.45	17.72	ParalleltoBank	25.694
J	1280	0.94	16.54	AwayfromtheBank	15.5476

VulnerabilityAssessment

The Vulnerability Index matrix waspreparedfor allten selectedpoints to identify the most and leastvulnerablesectionsoftheembankment.Scoreswerecalculatedoutof25,wherevaluescloser to 25 indicate lower vulnerability, while values farther from 25 represent higher vulnerability levels.

Table-10:VulnerabilityIndexmatrixfor alltenselectedvulnerablepoints.

Vulnerable	Bankline	Dist.From	Velocity(m/s)	FlowDirection	Dischargeper	Total
A	5	2	4	0	1	12
B	1	1	4	5	1	12
C	2	4	4	0	3	13
D	5	3	4	0	2	14
E	5	3	4	0	2	14
F	1	0	5	3	4	13
G	5	3	4	0	3	15
H	1	0	5	0	4	10
I	5	3	4	3	3	18
J	5	5	5	5	4	24

Based on the Vulnerability Index assessment of the embankment;Point J isclassifiedas low vulnerable. Point Iis classifiedas moderately vulnerable. Points A, B, C, D, E,F and G fall underthe vulnerable category.Point H isclassifiedasHighly Vulnerable.

5. CONCLUSION

Thevulnerabilityassessment carriedout inthis study followsamethodologythat integrates GIS-based analysis, two-dimensional river modelling and bank soil investigation. This combined approachprovidesapracticalframeworkforassessingembankmentvulnerabilityinriversystems flowing throughalluvial soil regions.

Populationdensitymaybeincludedasanadditionalparametertoachieveamore comprehensive vulnerability assessment.

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