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Socio-Ecological Dynamics and Vulnerability of the Kulik River Basin: A Trans-Boundary Perspective on Livelihoods, Hydrology and Agriculture

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Abstract

This study investigates the complex socio-ecological and livelihood dynamics of the Kulik River basin, a trans-boundary system shared by India and Bangladesh. The research analyses the river's changing hydrology and geomorphology, its impact on riparian communities, and the transformation of local livelihoods, particularly in fishing and agriculture. Using a multi-faceted approach, the study documents a significant decline in fish diversity due to pollution and overfishing, alongside a shift in agriculture from traditional cultivars to high-yielding varieties. A comparative economic analysis of key crops paddy, maize, and jute reveals a substantial increase in production costs and profitability, driven by intensified input usage. These findings highlight the increasing environmental stress on the river and the economic pressures on riparian communities.

Keywords: Kulik River Basin, Trans-boundary Hydrology, Socio-Ecological Dynamics, Riparian Livelihoods, Uttar Dinajpur, Standard Use of Fertilizer

1. Introduction

The Kulik River basin, located in Uttar Dinajpur, West Bengal, and extending into Bangladesh, represents a dynamic trans-boundary socio-ecological system. Situated within the mature alluvial landscape of the Indo-Bangladesh Barind tract, the river originates in the Thakurgaon District of Bangladesh and flows for 136.34 km, with 49 km of its course lying within India. Historically, the river's path has been altered by tectonic events, as evidenced by numerous oxbow lakes and paleo-channels, which contribute to its meandering sinuosity. The river and its basin are integral to the region's physical and human geography, serving as a critical resource for local communities. The Kulik joins the Mahananda River basin system via the Nagar River, making it a vital component of the larger North Bengal plains drainage network.

2. Study Area

The Kulik River originates from a marsh in Raipur, located in the Baliadangi Upazila of the Thakurgaon district in Bangladesh. Locally, the river is known as Morar Beel, which translates to "a water body of the dead," and it is also referred to as Kuluk or Kulik-Kokil by local elders. The river flows south from its source, passing through urban areas such as Sadar, Ranishangkoil, and Haripur in Bangladesh. It acts as a boundary between India and Bangladesh for a brief stretch before entering India at Keshabpur, under the Chai Nagar Gram Panchayat, in the Hemtabad block of Uttar Dinajpur district, West Bengal. The river continues southwest through the city of Raiganj before joining the Nagar River, where fishing activities are common.

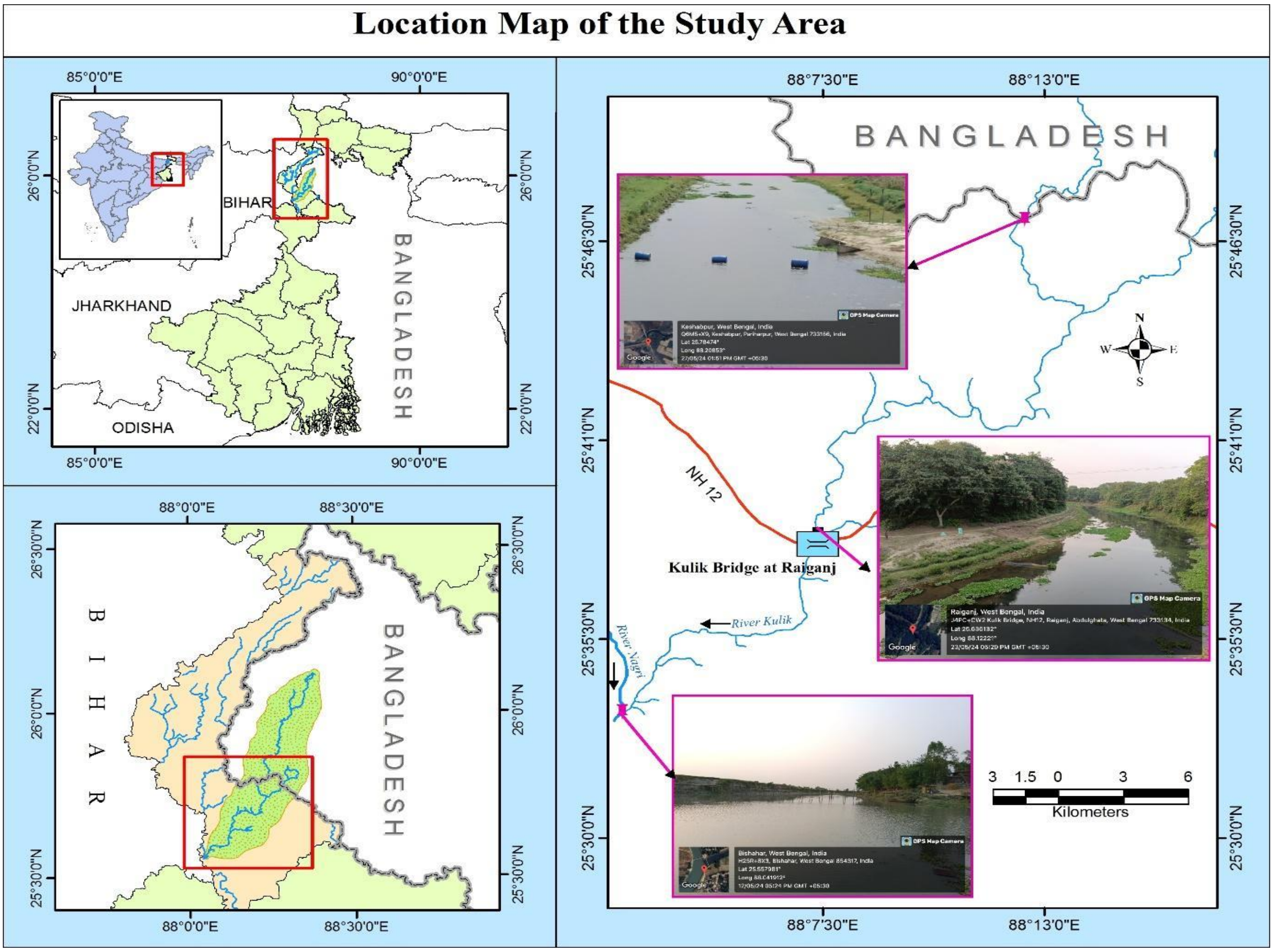

Figure 1 Location Map of the Study Area

The Kulik serves as a natural border between Bangladesh and India for a portion of its course, making it significant for local governance and water management practices. The river supports local irrigation and provides water resources for agriculture and fishing, particularly around Raiganj, where fishing is a regular activity. As a water body, the Kulik River contributes to local biodiversity, supporting various aquatic species and riparian ecosystems. Protecting its ecological health is essential for sustaining these habitats. The river hold cultural significance for local communities, potentially serving as a site for traditional fishing practices and local customs. The Kulik River prone to flooding during the monsoon season, affecting surrounding communities.

3. Objectives

The specific objectives are:

1. To analyze the Kulik River's hydrology, geomorphology, and tectonic impacts on its course and related landforms.
2. To assessing the decline in fish diversity and the changing cost-benefit dynamics of riparian agriculture.
3. To assess infrastructural impacts on basin connectivity and identify key vulnerabilities like flooding and pollution.

4. Methodology

This research is based on a comprehensive analysis of primary data through field survey using questionnaire schedule. The study adopted a stratified purposive sampling technique with equal allocation to ensure balanced and targeted representation from the six selected villages situated along the Kulik River. The villages Bahin Paharpur, Bamuha, Abdulghata, Kotgram, Bhatghara, and Parar Pukhar were selected based on their geographical proximity to the river and their socio-economic dependence on riverine resources, such as agriculture, fishing, and floodplain grazing. Each village represents a distinct stratum with varying levels of exposure to environmental stressors like flooding and erosion. A uniform number of 50 respondents were purposively selected from each village, totalling 300 respondents. Also secondary data was collected from different journals, articles, District Statistical Handbook etc. The study uses information from a variety of sources, including spatial data on the Kulik River basin's dimensions and elevation, tables detailing the river's tributaries, distributaries, and riparian villages, and a list of bridges etc.

Table 1 Village-wise Area, Population, Household Distribution, and Sampling Coverage in the Study Area

Village Name	Total Area (Hectares)	Population (2011)	Households (2011)	No. of Respondents	Percentage of Respondents	Sample (%) with Respect to Total Households
Bahin Paharpur	235.8	1,257	573	50	16.7%	8.73%
Bamuha	367.7	2,707	579	50	16.7%	8.64%
Abdulghata	63.7	568	134	50	16.7%	37.31%
Kotgram	83.2	3,112	684	50	16.7%	7.31%
Bhatghara	175.1	2,766	608	50	16.7%	8.22%
Parar Pukhar	297.9	948	203	50	16.7%	24.63%
Total	1,223.4	11,358	2,781	300	100%	10.79%

Source: Prepared by Authors

Table 1 presents a village-wise distribution of area, population, households, and sampling coverage for six selected villages situated along the Kulik River in Uttar Dinajpur district. These villages Bahin Paharpur, Bamuha, Abdulghata, Kotgram, Bhatghara, and Parar Pukhar vary significantly in terms of population density, land area, and household numbers. A uniform sample size of 50 respondents per village was maintained to ensure consistency in comparative analysis. This sampling strategy allowed for capturing a broad spectrum of livelihood patterns, challenges, and local resource dependencies. While the number of respondents was the same in each village, the percentage of sampled households varied based on total households ranging from 7.31% in Kotgram to a substantial 37.31% in Abdulghata. Such a structure ensures both statistical representativeness and in-depth insights into smaller, more vulnerable communities.

5. Spatial Dimensions and Drainage Characteristics of the Kulik River Basin

The Kulik River basin lies within the mature alluvial landscape of the Indo-Bangladesh Barind tract (Sarkar & Mondal, 2020), extending from 25°32′00″ N to 26°10′06″ N latitude and 87°60′00″ E to 88°24′56″ E longitude. This trans-boundary river originates in the Thakurgaon District of Bangladesh and flows into Uttar Dinajpur district of West Bengal, India, eventually joining the Nagar River near Bishahar village in the Itahar CD Block in Raiganj subdivision of Uttar Dinajpur district in West Bengal, India. It is situated 15.9 km away from Raiganj. The total length of the river is 136.34 km, of which 49 km falls within Indian Territory, and the river traverses a basin area of 1040.49 sq. km, with 440.59 sq. km lying in India.

The elevation across the basin ranges from a maximum of 71 meters at its source to a minimum of 17 meters at the confluence with the Nagar River. This slight difference of only 54 meters indicates that the Kulik River flows over a broad, flat terrain, typical of mature alluvial plains. The river's meandering pattern is reflected in its sinuosity index of 1.93, showing that it follows a moderately winding course rather than a straight path. The straight-line distance of the river is only 70.454 km, further emphasizing its curvilinear nature.

Historically, based on 1951 USGS topographic maps, the Kulik was a direct tributary of the Mahananda River (Sarkar & Mondal, 2020). However, tectonic disturbances redirected its flow, resulting in its present confluence with the Nagar River. Numerous oxbow lakes and paleo-channels about 281 in number (Sarkar & Mondal, 2020; Sarkar & Pal, 2018) dot the landscape on both banks, serving as geomorphic evidence of the river's historical shifts and dynamic course changes.

Flooding is a major concern within the basin, primarily driven by intense monsoonal rainfall, sediment deposition, and the reduced carrying capacity of the river. Although local flood management efforts like afforestation along riverbanks have been initiated, they remain insufficient. The region's flat topography, combined with low-lying features such as abandoned channels and ponds, increases vulnerability to seasonal inundation, affecting human settlements, agriculture, and infrastructure. Heavy rainfall upstream in Bangladesh also significantly influences the discharge and flood levels in the Indian segment of the basin, especially during the monsoon months.

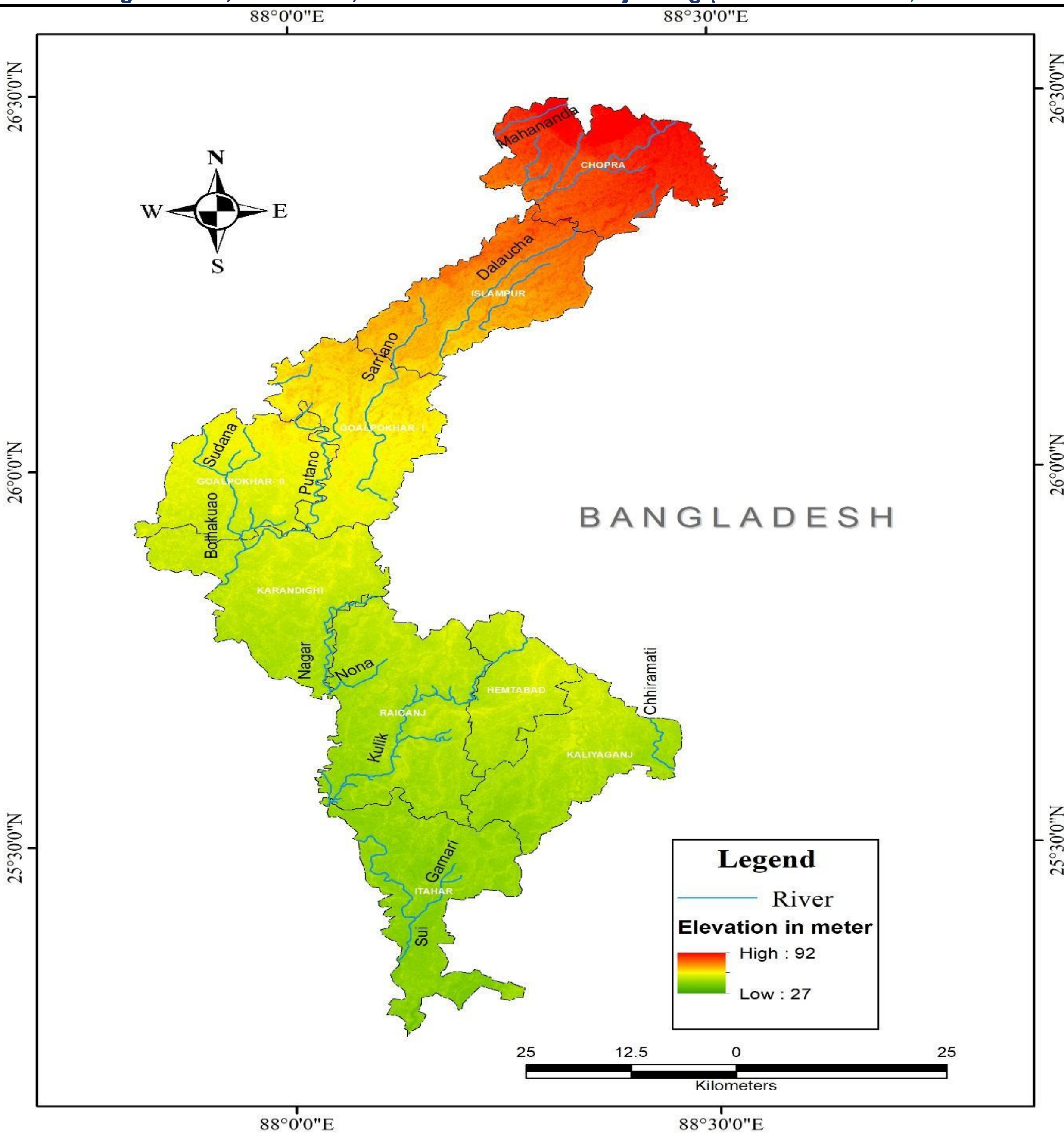

Figure 2 Rivers of Uttar Dinajpur District

Table 2 Geographical and Hydrological Characteristics of the Kulik River and Its Indian Segment

Name of the River	Total Actual Length (km)	Total Straight-Line Length (km)	Actual Length in Indian Territory (km)	Straight-Line Length in Indian Territory (km)	Total Basin Area (sq. km)	Basin Area in Indian Territory (sq. km)
Kulik	136.34	70.454	49	30	1040.49	440.59

Source: Prepared by Authors

Table 2 illustrates the geographical and hydrological profile of the Kulik River, emphasizing its sinuous nature and spatial distribution. The river's total actual length of 136.34 km, nearly double its straight-line length of 70.454 km, reflects significant meandering, which contributes to floodplain development and lateral erosion. In Indian Territory, 49 km of the river flows through a 440.59 sq. km basin area. Overall, the spatial and hydrological features of the Kulik River basin make it an ecologically dynamic but flood-prone landscape requiring integrated cross-border watershed planning and risk mitigation.

6. Tributaries, Distributaries, and Canal Connections of the Kulik River

The Kulik River, flowing through the Uttar Dinajpur district of West Bengal, India, and adjacent areas of Bangladesh, has a network of left-bank tributaries, a significant right-bank distributary, and a man-made canal. Among its left-bank tributaries, the Nehara, Dudhiyamoni, and Kahalai rivers are prominent. The Nehara River joins the Kulik near Kalandia village in Bangladesh, while the Dudhiyamoni meets it at Sandharai, also in Bangladesh. The Kahalai River, which originates from a seasonal wetland (beel) in Hajipur area, Pirganj Upazila, Thakurgaon District, Bangladesh, has two key confluences. It first merges with the Julai River near Amtoli Market in Sengaon (Bangladesh), and later flows into the Kulik River at Kastarai village, located in the Hemtabad block of West Bengal, India. Though once a more active stream, the Kahalai is now non-perennial, and its flow has diminished significantly due to sedimentation and reduced rainfall.

Table 3 Tributaries and Distributaries of Kulik River with Confluence Location

Sl. No.	Name of Tributary/Canal	Bank Side	Confluence Location	Latitude	Longitud	Country
1	Nehara River	Left Bank	Near Kalandia Village	26°00.45′ N	88°18.49′ E	Banglades h
2	Dudhiyamoni River	Left Bank	Sandharai	25°54.52′ N	88°16.43′ E	Banglades h
3	Kahalai River (to Kulik)	Left Bank	Kastarai, Hemtabad	25°44.31′ N	88°13.88′ E	India
4	Kahalai River (to Julai)	Left Bank	Amtoli Market, Sengaon	25°47.85′ N	88°18.02′ E	Banglades h
5	Kaich (Kanchan) River	Right Bank	Near Sitgram Village	25°39.78′ N	88°02.92′ E	India
6	Man-made Canal (Start)	Right Bank	Abdulghata, Raiganj	25°38.28′ N	88°07.37′ E	India
7	Man-made Canal (End)	Right Bank	Dakshin Shushihar Bridge	25°38.59′ N	88°10.36′ E	India

Source: Prepared by Authors

On the right bank, the Kulik receives one major distributary Kaich (Kanchan) River, which originates near Dilga Ghat, in Rautnagar, Kathaldangi of Bangladesh. It eventually joins the Nagar River near Sitgram village, West Bengal. This distributary plays a role in local hydrological connectivity and may influence downstream floodplain dynamics. Additionally, a man-made canal diverts water from the Kulik at Abdulghata village, Raiganj, and re-enters near Dakshin Shushihar Bridge in the same region. This canal reflects human intervention for agricultural irrigation and local water regulation. These tributaries, distributaries, and canal systems not only affect the seasonal flow, sediment load, and water availability in the Kulik basin but also demonstrate how trans-boundary water networks connect ecological and livelihood systems across India and Bangladesh.

7. Riparian Villages along the Left and Right Banks of the Kulik River

The Kulik River in Uttar Dinajpur district flows through a diverse landscape supporting numerous settlements on both its left and right banks. These riparian villages exhibit varying land use patterns, population densities, and exposure to fluvial processes. Understanding the spatial extent represented by perimeter and area of villages on both banks is essential for evaluating their vulnerability, resource availability, and development planning.

Table 4 Village-wise Perimeter and Area Distribution of Riparian Settlements along the Left and Right Banks of the Kulik River

Sl. No	Name of Village		Perimeter (km)		Area (sq.km)	
	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank	Left Bank
1	Ekamba	Pirojpur	4.47	11.47	1.13	3.53
2	Soharai	Bamuha	10.37	12.41	3.27	3.29
3	Pariharpur	Sitalpur	9.71	8.72	2.93	1.48
4	Ratanpur	Bahin Paharpur	10.81	10.15	4.06	2.22
5	Parar Pukur	Dhurail	7.37	7.43	2.87	1.55
6	Kokra	Mohishgaon	7.88	9.46	1.69	2.15
7	Daudpur	Keshabpur	5.64	5.41	1.40	1.40
8	Durgapur	Makarhat	4.56	6.33	0.78	1.23
9	Balia	Chandratiya	13.46	5.22	6.14	1.03
10	Barbar	Arazi Bahala	9.93	3.39	3.06	0.50
11	Mukundapur	Kastarai	13.02	5.50	4.93	1.32
12	Serpur	Bolkundi	17.14	7.85	7.11	1.35
13	Lohanda	Mahajambari	13.18	8.79	4.52	3.19
14	Jugiamir	Titihi	9.02	15.86	1.66	4.61
15	Tegra	Kasimpur	8.76	11.41	2.20	4.39
16	Lahujgram	Sonabari	7.39	5.65	2.03	1.22
17	Viti	Gobindapur	3.78	10.01	0.57	3.47
18	Katihar	Bishahar	4.94	6.54	0.99	2.13
19	Maharajpur	Amritakhanda	14.20	8.24	4.27	1.47
20	Bhatghara	Birahimkhanda	7.63	8.30	1.66	1.88
21	Bhattadighi	Rudrakhanda	9.07	7.84	3.74	1.97
22	Abdulghata	Gouri	3.78	14.75	0.53	3.84
23	Kotgram	Tenohari	4.09	9.08	0.79	3.36
24	Nasratpur Katabari (CT)	Avor	8.68	7.56	1.86	1.79
25	Gayas	Kasba (CT)	8.19	13.53	2.44	3.58
26	Rampur	Abdulghata	15.28	3.78	6.23	0.53
27		Raiganj (M)	-	18.04	-	10.32

Source: https://onlinemaps.surveyofindia.gov.in/Digital_Product_Show.aspx

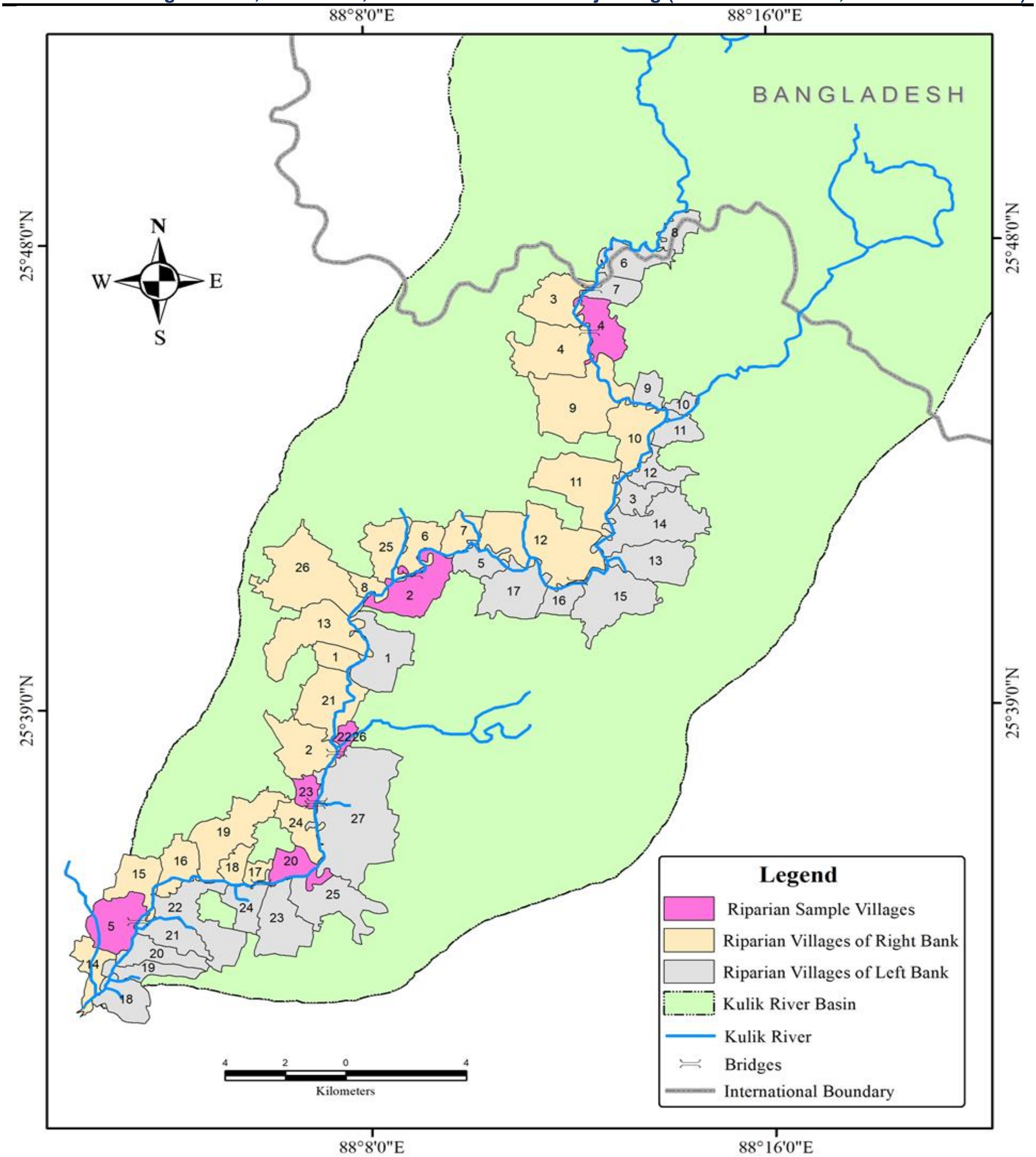

Figure 3 Riparian Villages along Kulik River in Uttar Dinajpur District

The Kulik River's riparian landscape comprises 26 villages on its right bank, including Nasratpur Katabari (CT), and 27 villages on the left bank, including Kasba (CT) and Raiganj (M), the latter being an urban municipality. These 53 villages demonstrate varied areal and perimeter characteristics shaped by river morphology and historical settlement patterns. Among these, six villages were purposively selected for detailed field investigation—three from the right bank: Kotgram, Bhatghara, and Parar Pukhar, and three from the left bank: Bahin Paharpur, Bamuha, and Abdulghata. These villages were chosen to reflect geographical diversity, land-use patterns, and degrees of exposure to riparian dynamics such as flooding, erosion, and sedimentation.

Parar Pukhar (2.87 sq.km) and Bhatghara (1.66 sq.km) exhibit compact land sizes on the right bank, while Kotgram has a relatively small area (0.79 sq.km) but strategic locational significance. On the left bank, Bamuha (3.29 sq.km) presents a balanced profile in terms of perimeter and area, whereas Bahin Paharpur (2.22 sq.km) and Abdulghata (0.53 sq.km) display contrasting land sizes. Interestingly, their paired counterparts (e.g., Abdulghata vs. Gouri) show asymmetry in development space. This selection ensures the representation of varying ecological pressures, livelihood structures, and demographic compositions across the riverbanks.

Table 5 Structural and Locational Details of Bridges over the Kulik River in Relation to Riparian Connectivity and Accessibility

Bridge Name	Location	Lat, Long	Type of Bridge	Connection	Status	Year of Establishment
Keshabpur Pariharpur Bridge	Keshabpur	Lat 25.78474°, Long 88.20853°	Steel Truss	Keshabpur to Pariharpur	Completed	1997
Bahin Paharpur Kulik Bridge	Bahin Pahar, Bindole, West Bengal	Lat 25.77096°, Long 88.206455°	Concrete	Bahin Paharpur to Bindole	Completed	2005
Sherpur Bridge (Sherpur Bagrol Ghat)	Kasimpur, Sherpur	Lat 25.690412°, Long 88.202924°	Girder on RCC Bore Pile Foundation	Thakurbari to Bindole	Completed	2012
Bamuha Bridge	Bamuha	Lat 25.692962°, Long 88.148369°	Girder on Well Foundation	Bamuha to Kokra	Completed	2016
NH12 Kulik bridge	Abdulghata, Raiganj	Lat 25.636132°, Long 88.1222459°	Girder on Well Foundation	Raiganj to Dalkhola	Completed	
Subhasganj Kulik River Railway Bridge	Subhasganj	Lat 25.619903°, Long 88.116162°	Concrete	Raiganj to Barsoi	Completed	
Subhasganj Kulik River Bridge	Subhasganj	Lat 25.619088°, Long 88.115559°	Girder on Well Foundation	Kanchanpally to Subhasganj	Completed	1995
NH12 Bypass Kulik Bridge	Bhiti, Abhor	Lat 25.593777°, Long 88.097485°	Girder on Well Foundation	Bhiti to Abhor	Completed	
Parar Pukhar Bridge	Parar Pukhar	Lat 25.582223°, Long 88.055001°	Girder on Well Foundation	Rudrakhanda to Parar Pukhar	Incomplete	2013

Source: Authors Field Survey

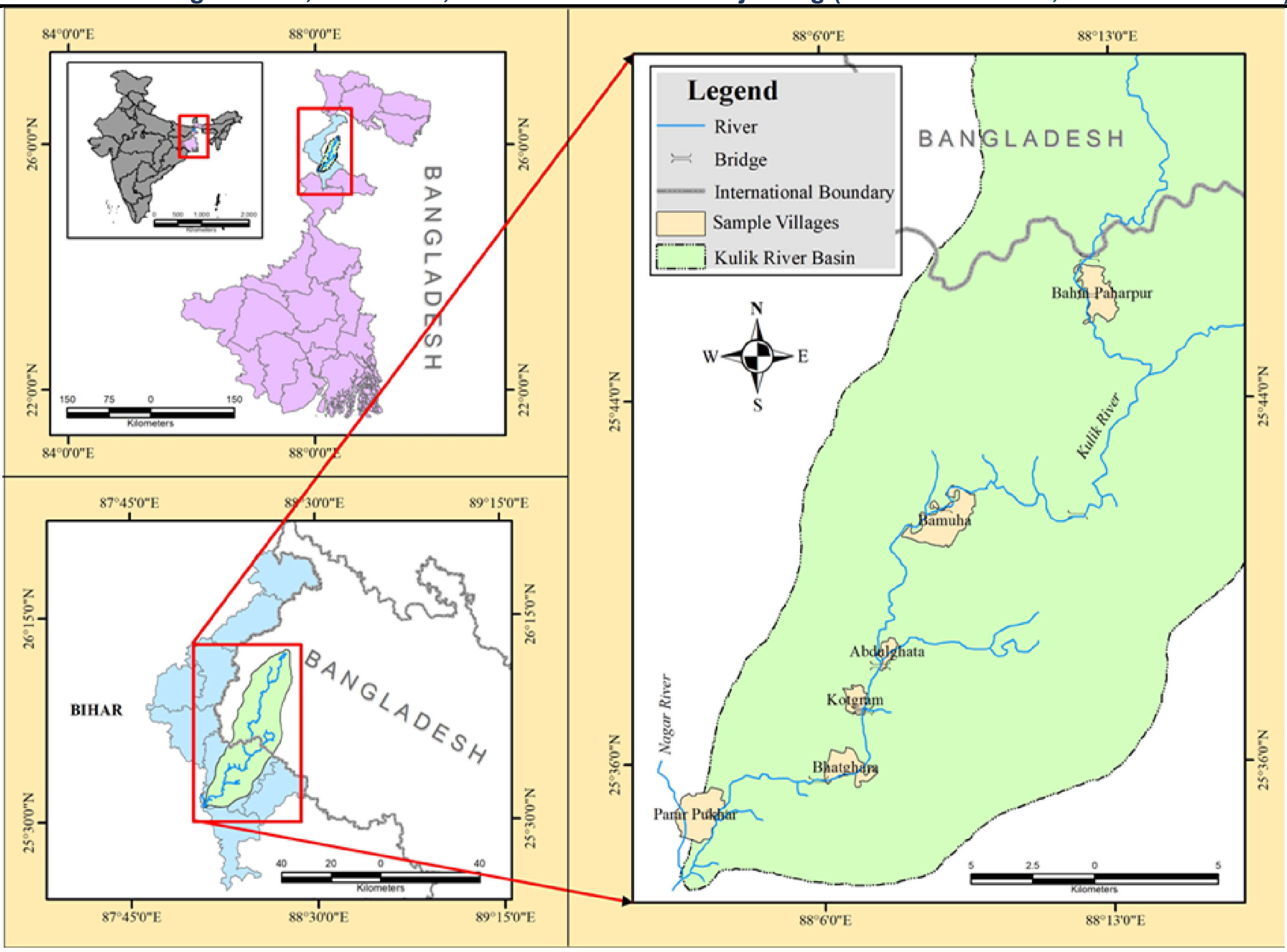

Figure 3 Bridges over the Kulik River

Table 5 presents a detailed overview of bridges constructed over the Kulik River, highlighting their structural types, geographic locations, and status. A total of nine bridges span the river, most of which are completed and serve critical roles in linking rural settlements like Keshabpur, Pariharpur, Bindole, Kokra, Dalkhola, and Barsoi. These bridges, ranging from steel truss to girder foundations, enhance intra- and inter-village mobility, supporting the transportation of goods, access to services, and integration into broader economic circuits. However, the Parar Pukhar Bridge remains incomplete since 2013, reflecting infrastructural disparity that affects the movement and living conditions of residents in that area. The presence of multiple bridges especially on NH12 and near Subhasganj demonstrates significant state-led infrastructural investment. Overall, bridge development across the Kulik River plays a crucial role in improving household infrastructure, reducing isolation, and enhancing the standard of living in riparian communities.

8. Riverine Resources and Fisheries

The River Kulik has long supported a rich diversity of edible fish species that are integral to the diet and livelihoods of riparian communities. However, over the past decade, noticeable changes have occurred in the availability and abundance of these species. Several fish that were once very frequent are now observed only occasionally or have disappeared entirely. These declines can be attributed to factors such as pollution, habitat degradation, and overfishing.

Table 6 Changes in the Availability and Abundance of Edible Fish Species in the River Kulik Over the Last Decade

Sl. No.	Local Name of the Fish	Scientific Name of the Fish	Presence 10 years ago	Presence now
1	Rui	Labeo rohita	VF	O
2	Katla	Catla catla	VF	O
3	Boaal	Wallago attu	VF	F
4	Puti	Puntius ticto	VF	VF
5	Tengra	Mystus tengara	F	F
6	Pabda	Ompok bimaculatus	F	F
7	Nandan	Labeo nandina	F	A
8	Reba or Rewa	Cirrhinus reba	F	A
9	Veda or Vecchi	Nandus nandus	F	O
10	Chela	Chela cachius	F	O
11	Telapia	Oreochromis mossambicus	O	O
12	Bata	Labeo bata	VF	F
13	Sharputi	Puntius sarana sarana	F	F
14	Baim	Mastacembelus armatus Scopoli	VF	O
15	Ayer	Sperata aor	VF	O
16	Gang Koi	Anabas cobojius	VF	O
17	Bighead carp	Hypophthalmichthys nobilis)	O	O
18	Raikhor	Cirrhinus reba	F	O
19	Gochi	Anguilla bengalensis bengalensis	VF	F
20	Calbaus	Labeo calbasu	F	F
21	American Rui	Cyprinus carpio	F	O
22	Baila	Awaous guamensis	VF	F
23	Chitol	Chitala chitala	F	O
24	Kholse	Colisa fasciata	VF	F
25	Moya	Lepidocephalichthys berdmorei	VF	F
26	Darkina	Rasbora daniconius	VF	F
27	Kechhki	Corica soborna	VF	F
28	Gutum	Lepidocephalichthys guntea	F	O
29	Chada	Chanda nama	VF	F
30	Magur	Clarias batrachus	F	O
31	Gulsha	Mystus cavasius	F	O
32	Mirka	Cirrhinus cirrhosus	F	F
33	Shingi	Heteropneustes fossilis	F	F
34	Shol	Channa striata	F	F
35	Silver crap	Hypophthalmichthys molitrix	O	O
36	Sati	Channa punctata	VF	F

37	Chapila	Gudusia chapra		
38	Kholse	Colisa fasciata	VF	F
39	Foli	Notopterus notopterus	F	O
40	Chingri	Macrobrachium malcolmsonii	VF	VF
41	Kakila	Xenentodon cancila	O	A
42	Kakra	Barytelphusa cunicularis	VF	F
43	Geri Gugli	Helix pomatia	VF	VF
44	Jhinuk	Brown Mussel	VF	VF
45	Shamuk	Anastomus oscitans	VF	VF
Very Frequent (VF) – observed in most samples or locations, Frequent (F) – regularly observed, Occasional (O) – observed only sometimes, Absent (A) – not observed during the survey period				

Source: Authors Field Survey

Table 6 provides a comparative overview of the presence of 45 locally consumed fish species in the River Kulik across a ten-year period, highlighting significant ecological and livelihood implications. The data reveals a marked decline in the abundance of many fish species that were once very frequent (VF) or frequently (F) observed. For example, staple species like Rui (Labeo rohita), Katla (Catla catla), and Ayer (Sperata aor) have shifted from "Very Frequent" to "Occasional," while species such as Nandan (Labeo nandina) and Reba (Cirrhinus reba) are now absent. Despite this decline, a few species like Puti (Puntius ticto), Chingri (Macrobrachium malcolmsonii), and Geri Gugli (Helix pomatia) remain consistently abundant.

This decline reflects growing environmental stress on the river ecosystem, likely due to pollution, siltation, overfishing, and reduced water flow. The consequences for riparian households—many of which depend on fishing for income and nutrition—are significant. Diminishing fish diversity and abundance directly impact food security and income levels, thereby lowering overall living standards. The shift also suggests a need for immediate conservation efforts and sustainable fishery management practices to support riparian livelihoods.

9. Agriculture Livelihood Activity Chain in Riparian Zones of Kulik River

The riparian zones along the Kulik River in Uttar Dinajpur District support diverse agricultural practices shaped by soil fertility, water availability, and traditional knowledge. Jute, paddy, and maize are the dominant crops grown in these areas, reflecting seasonal patterns and ecological suitability. The table below outlines critical aspects of cultivation including cropping seasons, fertilizer usage, irrigation practices, mechanization levels, and sustainability indicators like field fertility and residue management. This comparative overview helps identify trends and challenges in local farming systems.

Table 7 Major Cultivation Practices in Riparian Zones of Kulik River

Crop Description	Number of Crops (Rabi/Kharif/ Zaid)	Riparian zone / Midland / Highland	Irrigation (Rainfed / Irrigated)	Name of Fertilizer / Pesticide Application	Use of Equipment (Mechanized / Traditional Types)	Use of Traditional Techniques	Is There Change in Field Fertility	Post-Harvest Crop Residue Burning
Paddy (Oryza sativa)	2–3 (Kharif, Rabi, sometimes Zaid)	Mostly Riparian zones	Mostly Irrigated; some Rainfed	Urea, DAP, MOP; Chlorpyrifos, Carbofuran; organics in some areas	Semi-mechanized (tractors, threshers); traditional tools	Yes (manual transplanting, line sowing, sickle harvesting)	Yes (chemical dependency, overuse)	Rarely (used as fodder or mulch)
Maize (Zea mays)	1 (Mostly Rabi, some Kharif)	Riparian and Midland zones	Rainfed and Irrigated	Urea, DAP, Potash; Carbaryl, Metasystox	Increasing mechanization (seed drillers, ploughs); traditional harvesting	Yes (broadcast sowing, hand weeding)	Yes (but less than paddy)	Sometimes (for fuel or fodder)
Jute (Corchorus spp.)	1 (Kharif)	Riparian and Midland zones	Rainfed (with supplemental irrigation)	Urea, DAP, Potash; Endosulfan, Monocrotophos (restricted use)	Traditional tools; limited mechanization	Yes (line sowing, retting in stagnant water)	Yes (chemical overuse, lack of organics)	No (used as compost or bedding)

Source: Authors Field Survey

10. Rice Cultivation Trends in Uttar Dinajpur: Variety, Yield, and Vulnerability

Rice is the predominant crop in Uttar Dinajpur, cultivated during Aus, Aman, and Boro seasons across sandy-loam to clay-loam soils of the old alluvial Gangetic plain. While traditional varieties like Tulaipanji (GI-tagged) still hold significance, high-yielding varieties (HYVs) dominate constituting 62% of cultivation, with 31% local and 7% hybrid (Ghosh & Dasgupta, 2022). Popular varieties include Swarna, BB 11, Khitish, IR 64, and Arize 6444. A sharp decline in traditional cultivars such as Changa Dhan and Kalirai has been noted due to the widespread adoption of HYVs, impacting genetic diversity and local agro-heritage.

Table 8 Characteristics of Rice Varieties Grown by Farmers (2021–22) in Uttar Dinajpur District, West Bengal

Name Variety	Paddy Type (HYV/Hybrid/ Traditional)	Yield (t/ha)	Duration (Days)	Land (Up, Mid, Low)	Irrigated/Rainfed	Growing Season	Disease Noticed (Blast,BL, B, BPH,FS,PB)	Pest (Noticed SB,LF, BPH, GM, GB)
Begun Bichi	Local	3.5	155	Up-Mid	Irrigated, Rainfed	Kharif	Blast	YSB
Swarna	HYV	4.5	145	Low	Irrigated, Rainfed	Kharif	Blast, BLB, PB	LF, BPH, BLB
Kalirai	Local	3	165	Low	Rainfed, Deep water	Kharif	NA	LF
BB 11	HYV	4.5	125	Up-Mid	Irrigated	Kharif	BLB	YSB, BPH
Maharaja	HYV	4.5	140	Mid	Irrigated	Boro, Kharif	BLB	YSB, LF
Tulaipanji	Local	2.5	155	Up-Mid	Both	Kharif	Highly Sensitive to Blast	YSB
Danga Basful	Local	3	155	Up-Mid	Both	Kharif	Blast, BLB	YSB
GB 2	HYV	4	130	Up-Mid	Both	Boro, Kharif	Blast, BLB	YSB, LF
Zeera	HYV	4.5	135	Up-Mid	Irrigated	Boro, Kharif	Blast, BLB	YSB, LF
Khitish	HYV	4.5	145	Up-Mid	Irrigated	Boro	BLB, Blast, BLB	YSB, LF
Swarna Sub - 1	HYV	4.5	145	Low	Irrigated	Kharif	Blast, BLB, ShB	YSB, LF, BPH
IR 64	HYV	4.5	150	Up-Mid	Irrigated	Boro	BLB, Blast, BLB, ShB	YSB, LF, BPH
Satabdi	HYV	4.5	145	Up-Mid	Irrigated	Boro	Blast, BLB, ShB	YSB, LF, BPH
Sampa	HYV	4	135	Up-Mid	Irrigated, Rainfed	Kharif	Blast, BLB, ShB	YSB, LF, BPH
Josnua	Local	2.5	145	Up-Mid	Irrigated, Rainfed	Both	YSB, LF, BPH	

Arize 6444 Gold	Hybrid	5.5	145	Mid	Both	Both	Blast, BLB, ShB	YSB, LF, BPH
IET 1444	HYV	4	150	Mid	Both	Both	Blast, BLB, ShB	YSB, LF, BPH
Sourab	HYV	4.5	145	Mid	Both	Both	Blast, BLB, ShB	YSB, LF, BPH
Gourab	HYV	4.5	145	Mid-Low	Irrigated	Kharif	Blast, BLB, ShB	YSB, LF, BPH
Yamuna	HYV	4.6	155	Low	Irrigated	Kharif	Blast, BLB, ShB	YSB, LF
Hi-Rise	Hybrid	5.2	135	Mid	Kharif	Good	YSB, BPH	
Ranjit	HYV	4.5	155	Low	Irrigated	Kharif	BLB, ShB	YSB, LF, BPH
Nilanjana	HYV	4.3	145	Mid	Irrigated	Kharif	BLB	YSB
Kalo Nunia	Local	2.5	155	Mid	Rainfed	Kharif	PB	YSB, LF, BPH
Swarna Dheki	Local	3.5	155	Mid	Rainfed	Kharif	NA	YSB, LF, BPH
MTU 1010	Local	4.5	135	Up-Mid	Both	Both	Blast, BLB, ShB	YSB, LF, BPH
Gobindabhog	Local	2.4	145	Up-Mid	Both	Kharif	Blast, BLB, ShB	YSB, LF, BPH
Niranjan	HYV	4.5	145	Mid	Both	Both	Blast, BLB	YSB, LF
Kalabhat	Local	4	160	Low	Rainfed	Kharif	FS	NA

Source: Rice (Oryza sativa L.) Varietal Diversity, Uttar Dinajpur, West Bengal, India (Ghosh & Dasgupta, 2022)

Table 8 provides a comprehensive overview of 29 rice varieties cultivated in Uttar Dinajpur during 2021–22. The varieties encompass high-yielding (HYV), hybrid, and traditional/local types. HYVs dominate the region's cultivation practices, comprising the majority of varieties like Swarna, BB 11, Khitish, IR 64, and Satabdi, which offer higher yield potential (around 4.5 t/ha) with moderate to short duration (145–150 days). Hybrids like Arize 6444 Gold and Hi-Rise achieve even higher yields (up to 5.5 t/ha). Traditional varieties such as Tulaipanji, Gobindabhog, Kalirai, and Kalo Nunia are still valued for their aroma and eating quality, though their yield is relatively lower (2.4–3.5 t/ha). Among these, Tulaipanji stands out with GI recognition and excellent cooking quality, despite its high susceptibility to blast disease.

Land preference varies from upland to lowland, and both irrigated and rainfed practices are observed. Most HYVs are grown in Kharif or Boro seasons, while traditional varieties often adapt to both seasons and diverse land types. Lodging is generally not a significant issue, although a few traditional varieties like Tulaipanji and

Kalabhat show vulnerability. Diseases such as blast, bacterial leaf blight (BLB), and sheath blight (ShB) are widespread among both HYVs and hybrids, while pests like yellow stem borer (YSB), leaf folder (LF), and brown plant hopper (BPH) are common threats across most varieties.

Additional varieties from riparian villages, such as Ranjeet, 1075, 1092, and 1000 Bibi, are HYVs and indicate further diversification toward high-yielding seeds. In addition to rice, riparian areas also grow HYV and traditional maize (Seed: 3355), wheat, and both types of jute (White and Tossa). Overall, the data reflect a shift toward higher-yielding modern varieties, while traditional cultivars are declining due to susceptibility issues, despite their cultural and aromatic value.

11. Changing Cost-Benefit Dynamics of Paddy, Maize, and Jute Cultivation in Riparian Villages in 2024

Agriculture remains the backbone of rural livelihoods in the riparian villages along the Kulik River in Uttar Dinajpur. Among the principal crops, paddy, maize, and jute are widely cultivated due to their adaptability to the region's soil and climatic conditions. Over the years, farming practices have undergone noticeable changes in terms of input usage, cost of cultivation, and profitability. The following analysis highlights the changing expenditure and income patterns before 2015 and in 2024, reflecting broader trends in input intensification, rising production costs, and shifting profit margins across these staple crops.

Table 9 Comparative Expenditure, Income, and Profitability of Paddy, Maize, and Jute Cultivation before 2015 and in 2024 in Riparian Villages

Expenditure (In Rupees)	Paddy Production		Maize Production		Jute Production	
	Before 2015	Present 2024	Before 2015	Present 2024	Before 2015	Present 2024
Seed	200	400	800	2200	400	600
Land Preparation	700	1300	600	1300	500	800
Transplanting	600	1400	200	600	300	400
Application of Organic Manure	200	800			400	1000
Application of Chemical Fertilizers	1000	3000	1500	4000	600	1200
Insecticides, Pesticides	200	700	200	800	100	400
Field Maintenance	600	1400	200	800	800	2000
Irrigation	500	1000	700	1500	300	600
Harvesting	900	1500	1000	1400	2000	3000
Others	100	300	300	1200		
Total Expenditure	5000	11800	5500	13800	5400	10000
Maximum Income	8500	16000	10800	27000	12000	20000
Benefit	3500	4200	5300	13200	6600	10000
Maximum Production (Quintal)	6 Quintal	7 Quintal	10 Quintal	14 Quintal	3 Quintal	3.5 Quintal

Source: Authors Field Survey

Table 9 presents a comparative analysis of input costs, income, and benefits from paddy, maize, and jute cultivation before 2015 and in 2024. Across all three crops, there has been a significant rise in production costs more than doubling in most cases due to increased reliance on chemical fertilizers, pesticides, irrigation, and mechanized transplanting. Despite rising expenses, incomes have also surged, particularly in maize (Rs. 27,000) and jute (Rs. 20,000), leading to higher net benefits in 2024. Maize shows the highest benefit increase (Rs. 13,200), followed by jute (Rs. 10,000), indicating its growing profitability. While paddy remains crucial, its profit margin has increased modestly. These trends reflect a shift toward intensive farming practices for better returns in the riparian agricultural economy.

12. Standard Fertilizer Application Rates (kg per acre) for Major Crops

Standardized fertilizer application rates (in kg per acre) play a crucial role in ensuring balanced nutrient supply for various crops. The use of Di-Ammonium Phosphate (D.A.P.), NPK (10:26:26), and Single Super Phosphate (SSP) fertilizers is common practice to enhance crop productivity by meeting specific nutrient requirements during different growth stages. These fertilizers, often supplemented with Urea and Muriate of Potash (MOP), are applied at key stages such as sowing, early growth, and mid-season to support optimal root development, flowering, and yield. The recommended dosages vary by crop type and are essential for maintaining soil fertility and sustainable farming.

Table 10 Standard D.A.P. Fertilizer Application Rate (kg per acre)

Crops NPK (kg per acre)	Total Fertilizer (kg per acre)			Sowing / Transplanting Time (kg per acre)		Chapan Fertilizer, 2nd Application (kg per acre)	
	DAP	Urea	Potash	DAP	Potash	Urea (1st)	Urea (2nd)
Kharif Crops Aus & Aman Paddy, High Yielding 28:14:14	30	49	23	30	23	33	16
Boro Paddy 52:26:26	56	91	43	56	43	61	30
Jute (Tossa) 20:10:10	22	35	17	22	17	23	12
Jute (Deshi) 16:8:16	17	28	27	17	27	19	9
Vegetables Pumpkin, Ridge Gourd, Bottle Gourd, Cucumber, Pointed Gourd or Parwal 56:28:28	61	98	46	61	46	65	33
Brinjal or Eggplant, Taro Root 60:40:40	87	96	66	87	66	64	32
Ladies Finger or Okra,Tomato 72:36:36	78	126	60	78	60	84	42
Cauliflower, Cabbage 80:40:40	87	140	66	87	66	93	47
Pulses Lentil, Chickpea, Mung Bean, Mash Kalai or Biuli 12:24:24	52	6	40	52	40	4	2

Oilseeds Mustard 40:20:20	43	70	33	43	33	47	23
Rai 48:24:24	52	84	40	52	40	56	28
Potato 80:60:60	130	123	100	130	100	82	41
Wheat, Chilli 48:24:24	52	84	40	52	40	56	28
Hybrid Maize 56:28:28	61	98	46	61	46	65	33

Source: INDO RAMA, IRC Agrochemicals Private Limited, Emerald House, 4th Floor, 1B, Old Post Office Street, Kolkata, West Bengal, India, Pin-700 001

Based on the data provided in Table 10, the standard D.A.P. (Di-Ammonium Phosphate) fertilizer application rates vary significantly across different crop types depending on their nutrient requirements, particularly for nitrogen (N), phosphorus (P), and potassium (K). For Kharif crops like Aus & Aman paddy (HYV) and Boro paddy, the fertilizer requirements are higher due to their long growth periods and intensive cultivation. Boro paddy has the highest total fertilizer requirement among paddy types, requiring 56 kg D.A.P., 91 kg urea, and 43 kg potash per acre, indicating its high nutrient demand. Among vegetables, crops like Cauliflower, Cabbage, and Brinjal demand significantly higher nutrient inputs, especially urea (nitrogen), reflecting their rapid biomass accumulation and long growing season. For example, Cauliflower requires 87 kg D.A.P., 140 kg urea, and 66 kg potash per acre, with the second urea application going up to 47 kg—the highest among all listed crops. In contrast, pulses such as Lentil, Chickpea, and Mung bean need much lower fertilizer inputs. Their ability to fix atmospheric nitrogen explains the minimal urea requirement only 6 kg urea per acre, supplemented with 52 kg D.A.P. and 40 kg potash, which supports early root development and pod formation. Similarly, oilseeds like Mustard and Rai also have moderate fertilizer requirements. Mustard requires 43 kg D.A.P., 70 kg urea, and 33 kg potash, while Rai needs slightly more, indicating crop-specific variation even within the same category. Hybrid maize and potato are among the most input-intensive crops, reflecting their high yield potential. Potato shows the highest total fertilizer use, requiring 130 kg D.A.P., 123 kg urea, and 100 kg potash per acre.

Table 11 Standard 10:26:26 Fertilizer Application Rate (kg per acre)

Crops NPK (kg per acre)	Total Fertilizer (kg per acre)			Sowing / Transplanting Time (kg per acre)			Chapan Fertilizer, 2nd Application (kg per acre)	
	10:26:26	Urea	Potash	10:26:26	Urea	Potash	Urea (1st)	Urea (2nd)
Kharif Crops Aus & Aman Paddy, High Yielding 28:14:14	54	50	0	54	0	0	34	16
Boro Paddy 52:26:26	100	91	0	100	0	0	61	30
Jute (Tossa) 20:10:10	38	35	0	38	0	0	18	17
Jute (Deshi) 16:8:16	31	28	13	31	0	13	14	14
Vegetables Pumpkin, Ridge Gourd, Bottle Gourd, Cucumber, Pointed Gourd or Parwal 56:28:28	108	98	0	108	38	0	30	30
Brinjal or Eggplant, Taro Root 60:40:40	154	97	0	154	33	0	32	32
Ladies Finger or Okra,Tomato 72:36:36	138	126	0	138	32	0	62	32
Cauliflower, Cabbage 80:40:40	154	140	0	154	54	0	43	43
Pulses Lentil, Chickpea, Mung Bean, Mash Kalai or Biuli 12:24:24	92	6	0	92	0	0	6	0
Oilseeds Mustard 40:20:20	77	70	0	77	35	0	35	0
Rai 48:24:24	92	84	0	92	32	0	52	0
Potato 80:60:60	230	124	0	230	30	0	64	30
Wheat, Chilli 48:24:24	92	84	0	92	21	0	42	21
Hybrid Maize 56:28:28	108	98	0	108	38	0	30	30

Source: INDO RAMA, IRC Agrochemicals Private Limited, Emerald House, 4th Floor, 1B, Old Post Office Street, Kolkata, West Bengal, India, Pin-700 001

The Table 11 presents standard fertilizer application rates for a variety of crops using NPK 10:26:26, urea, and potash, measured in kilograms per acre. Kharif crops like Aus and Aman paddy (high-yielding) require 54 kg of NPK and 50 kg of urea at the time of sowing, followed by two applications of urea (34 kg and 16 kg). Boro paddy needs a higher dosage 100 kg of NPK and 91 kg of urea, with 61 kg and 30 kg of urea applied in two later stages. Jute (Tossa and Deshi) requires lower doses compared to paddy, with Deshi needing additional potash. Vegetables such as pumpkin, ridge gourd, bottle gourd, and cucumber require moderate to high inputs (108 kg NPK and 98 kg urea), while brinjal and taro root demand even higher quantities (154 kg NPK and 97 kg urea). Crops like okra and tomato also need substantial urea applications during the second stage (62 kg). Leafy vegetables such as cauliflower and cabbage require some of the highest input levels: 154 kg of NPK and 140 kg of urea with significant urea top dressing in two phases (43 kg each). Pulses like Lentil and Mung bean require minimal urea (only 6 kg), indicating their nitrogen-fixing ability. Oilseeds such as mustard and Rai show moderate fertilizer needs. Potato is the most input-intensive crop here, requiring 230 kg of NPK and 124 kg of urea. Wheat, chilli, and hybrid maize have moderate fertilizer requirements.

Table 12 Standard SSP (Single Super Phosphate) Fertilizer Application Rate (kg per acre)

Crops NPK (kg per acre)	Total Fertilizer (kg per acre)			Sowing / Transplanting Time (kg per acre)			Chapan Fertilizer, 2nd Application (kg per acre)	
	SSP	Urea	MOP	SSP	Urea	MOP	Urea (1st)	Urea (2nd)
Kharif Crops Aus & Aman Paddy, High Yielding 28:14:14	88	60	23	88	15	23	30	15
Boro Paddy 52:26:26	163	112	43	163	28	43	56	28
Jute (Tossa) 20:10:10	63	44	17	63	11	17	22	11
Jute (Deshi) 16:8:16	50	35	27	50	9	27	17	9
Vegetables Pumpkin, Ridge Gourd, Bottle Gourd, Cucumber, Pointed Gourd or Parwal 56:28:28	175	122	46	175	30	46	62	30
Brinjal or Eggplant, Taro Root 60:40:40	250	130	66	250	33	66	64	33
Ladies Finger or Okra,Tomato 72:36:36	225	156	60	225	39	60	78	39
Cauliflower, Cabbage 80:40:40	250	174	66	250	43	66	88	43

Pulses Lentil, Chickpea, Mung Bean, Mash Kalai or Biuli 12:24:24	150	26	40	150	7	40	12	7
Oilseeds Mustard 40:20:20	125	87	33	125	22	33	43	22
Rai 48:24:24	150	104	40	150	26	40	52	26
Potato 80:60:60	375	174	100	375	43	100	88	43
Wheat, Chilli 48:24:24	150	104	40	150	26	40	52	26
Hybrid Maize 56:28:28	175	122	46	175	30	46	62	30

Source: INDO RAMA, IRC Agrochemicals Private Limited, Emerald House, 4th Floor, 1B, Old Post Office Street, Kolkata, West Bengal, India, Pin-700 001

The Table 12 outlines standardized SSP, Urea, and MOP fertilizer application rates (in kg/acre) for various Kharif and Rabi crops, highlighting nutrient distribution across three stages: sowing/transplanting, Chapan (first Urea application), and the second Urea dose. Among cereals, Boro paddy shows the highest total fertilizer demand (318 kg/acre), especially for SSP (163 kg) and Urea (112 kg), indicating its intensive cultivation nature. Aus and Aman paddy follow, with moderate inputs (171 kg/acre total), showing balanced nutrient needs for high-yielding varieties. Vegetables such as cauliflower, cabbage, brinjal, and tomato exhibit the highest fertilizer demands (above 400 kg/acre for some), reflecting their nutrient-intensive growth. For instance, cauliflower and cabbage require 250 kg SSP, 174 kg Urea, and 66 kg MOP. This high input supports their fast growth and heavy nutrient uptake. Pulses like lentil, Mung bean, and chickpea demand relatively lower Urea due to their nitrogen-fixing ability, requiring only 26 kg Urea and 150 kg SSP per acre. This shows efficient nutrient use. Oilseeds like mustard and Rai show moderate needs, particularly in SSP (125–150 kg) and Urea (87–104 kg). Potato has one of the highest total inputs (649 kg/acre), justifying its high market value and yield potential. Across crops, SSP usage is consistent and often higher than Urea, indicating a strong emphasis on phosphorus application. MOP (Potash) is also used widely, reflecting its role in root development and yield quality. This standardized application ensures balanced soil nutrition and crop productivity.

13. Findings

The Kulik River basin exhibits the characteristics of a mature alluvial plain, with a slight elevation difference of 54 meters over its 136.34 km length and a sinuosity index of 1.93, indicating a meandering course. Tectonic shifts have redirected the river's flow, as evidenced by the presence of 281 oxbow lakes and paleo-channels. The basin's riparian villages are vulnerable to monsoonal flooding due to flat topography and low-lying features. A critical finding is the significant decline in fish diversity and abundance over the last decade; staple species like Rui and Katla have become occasional finds, while others like Nandan are now absent. This reflects increasing environmental stress from pollution and overfishing. Economically, while agricultural costs for paddy, maize, and jute have more than doubled since 2015, the profitability has also increased significantly, especially for maize and jute, showing a clear shift toward input-intensive, high-yield farming. The adoption of high-yielding rice varieties (HYVs) dominates cultivation, impacting the genetic diversity of traditional cultivars like Tulaipanji.

14. Recommendations

To address the documented socio-ecological challenges, a multi-faceted approach is recommended. First, implement a trans-boundary watershed management plan between India and Bangladesh to coordinate flood mitigation and pollution control. This should include regulations on urban and agricultural runoff and investment in waste treatment facilities along the river's course. Second, promote sustainable agricultural practices by encouraging the use of bio-fertilizers and integrated pest management (IPM) to reduce reliance on chemical inputs, which are driving up costs and contributing to pollution. Third, support local livelihoods and biodiversity through community-based conservation initiatives. Establishing protected fishing zones and promoting sustainable aquaculture can help restore fish populations. Additionally, farmers should be encouraged to cultivate traditional rice varieties alongside HYVs to preserve agro-heritage and genetic diversity, possibly through market incentives or GI-tagging programs. Finally, a complete the Parar Pukhar Bridge project to improve connectivity and reduce the isolation of local communities.

15. Conclusions

The Kulik River basin is a dynamic and vulnerable trans-boundary landscape where human activities and natural processes intersect. The study reveals a worrying trend of ecological degradation, marked by the severe decline in fish populations and the increasing prevalence of input-intensive agriculture. While modern farming has boosted profitability, it has also raised environmental concerns and led to the neglect of traditional, climate-resilient crop varieties. The infrastructural development, though beneficial for connectivity, has not yet fully addressed the area's vulnerabilities, as seen by the unfinished Parar Pukhar Bridge and persistent flooding issues. The findings underscore the urgent need for a shift from fragmented management to an integrated, cross-border approach. Without coordinated conservation efforts, policy reform, and community-led sustainable practices, the river's ecological health will continue to decline, jeopardizing the livelihoods and food security of the riparian communities that depend on it. This study serves as a call to action for stakeholders to protect this vital resource.

Some Glimpses of Livelihoods, Hydrology, and Agriculture

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