ГЛАСНИК Српског географског друштва 106(1) 193-216
BULLETIN OF THE SERBIAN GEOGRAPHICAL SOCIETY 2026

Original scientific paper UDC 556:504.5(541.2)
https://doi.org/to_be_assigned

Received: October 22, 2025
Corrected: December 29, 2025
Accepted: February 2, 2026

Debika Ghosh[1]*, Shreyasee Das Mistry*, Priyanka Pramanik*, Mintu Roy*, Rakhi Bairagya*

**Krishnagar Government College, Krishnagar, Nadia, West Bengal*

PROBLEM OF CHANNEL DECAY OF TROPICAL RIVERS AND ANTHROPOGENIC IMPACT ON RIVERS: A REMOTE SENSING AND GIS BASED STUDY AT WEST BENGAL, INDIA

Abstract: The present research highlights the problem related to channel decay of tropical rivers and the research gives special emphasis on anthropogenic impact on the tropical rivers and again it focuses on the management of the decaying rivers. To satisfy the aims of the present study, four rivers viz, river Kharkhari, river Churni, river Anjana, and river Jalangi have been taken into consideration. The present study has been conducted based on remote sensing (RS) and Geographic information system (GIS). Secondary data have been collected from the trustable sources in form of satellite images, reports etc. Statistical technique has also been used in this study to draw connection between river decay and various anthropogenic activities. The result of the research exhibits that there are drastic reduction in river length and width especially in case of river Kharkhari, Churni, and Anjana. A notable deep anthropogenic impact has been observed in decay of river Channels. Statistical technique shows that growing settlement cover, agricultural uses have negative and significant connection with change in channel geometry. The coverage of areas under the water bodies of river Kharkhari, river Jalangi, river Churni, river Anjana have been decreased from 5.82 percent to 1.94 percent, 9.63 percent to 2.44 percent, 13.51percent 5.5 percent, and 6.87 percent to 4.19 percent respectively from the year 1991 to 2025 within the 2 kilometer buffer area on both sides of the rivers.

Keywords: river Decay, rivers in tropics, human impact, supervised classification

[1] idebikaghosh@gmail.com (corresponding author)
Debika Ghosh (https://orcid.org/0000-0002-2546-4165)
Shreyasee Das Mistry (https://orcid.org/0009-0006-5443-3575
Priyanka Pramanik (https://orcid.org/0009-0008-3443-1024)
Mintu Roy (https://orcid.org/0009-0002-4882-8029)
Rakhi Bairagya (https://orcid.org/0009-0009-8921-1560)

Introduction

Rivers are very important lifeline for the survival of all biotic community. Rivers are very important source of the total potable water in India. The very past history clearly exhibits the development of all human civilization were started along the river banks. World's first civilizations were developed along River Indus, Nile, Huang He, Tigris and Euphrates (Mackline and Lewin, 2015, Wang and He, 2022). Maaß et. al, (2021) stated that from the beginning of the Holocene period, various human activities have been observed at different scales from the river basin area to the channel and human activities have an enhancing impact on fluvial system. There are so many advantages to live along the banks of a river. Rivers are not just body of water but it also acts as a medium of transportation, source of water to the agricultural field, domestic uses, habitat for many species. Therefore, it can be said that river is a lifeline to the organic community for their survival. Humans depend on rivers for various essential needs like drinking water, irrigation, and industrial use, crop irrigation, transportation, food sources, hydroelectric power generation, recreational activities, etc. But unfortunately, various human activities are continuously affecting very badly the entire river system. Various human activities like heavy construction along the river banks, unplanned settlement growth, construction of dams, deforestation, disposal of waste into the river water etc, leads to various problems in river system. Anthropogenic activities play crucial role in destruction of channel, pollution of river water, flow destruction or simply it alters the entire geomorphic processes associated with river. Decay of river is a burning problem in today's world. Belletti et. al, (2020) stated that highest barriers on rivers have been found in densely modified rivers of central Europe and lowest barriers on rivers have been found in the most remote, low populated areas of Europe. Development of human civilizations along the river banks and different anthropogenic activities continuously act as influential factors for decaying river ecosystem (Ekka et.al, 2019, Li et. al, 2022). Rivers are being badly affected by pollutant water in industrial region (Criniet.et. al, 2022, Sekharan et. al, 2022, and Sahu, 2023). Milijašević et. al, (2025) studied Tamiš River in Serbia and they said that the water quality of Tamiš River in Serbia has been affected by anthropogenic pollution. Near about 99 percent of river in the world is affected by various human activities like intensive cultivation, expansion of urban area, use of fertilizer and pesticides and other contaminants (Meter et. al, 2016, and Li et. al, 2022). Dragićević et al. (2017) studied the bank erosion problem of Kolubara River basin in Serbia from 1930 to 2016 and they showed the high rate of bank erosion caused by natural and land use land cover alterations. Langović et al. (2021) studied riverbank erosion and lateral channel migration of major Serbian rivers like Velika Morava, Kolubara etc. and focused on land use land cover change in environmental protection. Manojlović et. al., (2025) studied the dynamics of suspended sediment in the Južna Morava River in Serbia and showed the human impact on it. Spinti et. al., (2023) studied on the rivers of United States and they said that 63 % of longest rivers of the World are not free from barriers. Spinti et. al., (2023) also showed in their study that 48% of river all over the world suffer by the diminished river connectivity due to anthropogenic impact. Maaß et. al, (2021) showed that various human activities like growing urban settlement, deforestation, construction of dam, bridge, embankment, agricultural development, etc. have deep influential impact on river or floodplain in the Western European region since the starting of the Holocene period. Abdelmohson et. al, (2025) studied on the Colorado river basin and they argued that the anthropogenic activities cannot be ignored in continuous water depletion facing by the Colorado river basin area of America. Yang et. al, (2023) showed the flow of river Arkansas has been decreased and it has significant effects on ecological and economic environment of the region. Different anthropogenic activities like urbanization, population growth, future development of hydro power and dam have very much bad affects on rivers and it leads to destroy the water quality (Sidabutar et. al. 2017, Winton et. at., 2021). Spinti et. al., (2023) showed in their study that the fragmentation of rivers in United States is occurring due to construction of dams on rivers. Stoffers et. al, (2024) focused on the protection of deteriorating rivers of Europe and they also comment on freshwater restoration for environmental wellbeing. Rivers have got affected badly by different national water ways (Choudury, 2020). Decay of river denotes the shrinking of river channels mainly caused by various anthropogenic activities. EEA (2021) clearly showed in their reports that construction of dam, culvert or different barriers on rivers are deteriorating the entire river ecosystem in European countries. The prime objective of this research is to study the problem of river decay and the present research also focuses to find out human impacts on the river decay using RS and GIS technique. After disintegration, this research focuses.

- To study the spatio-temporal change of decaying rivers over long period of time
- To find out the change of land use land cover within 2 Kilometer (km) buffer zone of both sides of the decaying rivers over long period of time.
- This study tries to identify connection between decay of channel and anthropogenic activities
- To focus on the management of decaying rivers.

To achieve the objectives of the study, river Kharkhari, river Jalangi, of Murshidabad district, and river Churni, river Anjana and river Jalangi of Nadia district, West Bengal, India, have been taken into consideration. The present study has its importance at local to international levels. This research shows scenario of conversion of living rivers into decaying rivers. This is an attempt to show how various human activities gradually destroyed living rivers. This study has drawn a direct connection between various human activities and the decay of rivers scientifically. This research also has worked on the management of decaying rivers. This study will be definitely fruitful for the management of river decay and at the same time, this study will be beneficial for the society. The preconceived idea has been taken in this research is that "Decay of river is highly caused by various human activities".

Material and methods

Study area

The study area comes under Nadia and Murshidabad district of West Bengal (Figure 1). River Kharkhari, river Jalangi of Murshidabad district and river Churni, river Anjana, river Jalangi of Nadia district are the important streams of West Bengal. River Kharkhari is flowing over Raghunathganj-I and Sagardighi community development (C.D) blocks of Murshidabad district in West Bengal, India. And, river Jalangi of Murshidabad district is flowing over some community development (C.D) blocks of Murshidabad district in West Bengal, India (Census of India, 2011a). Economy of this community development blocks are mainly based on agriculture (Census of India, 2011a-b). River Churni is the created distributary of river Mathabhanga (District Census Hand Book Nadia, 2011). The river Mathabhanga divides into two rivers Ichhamati and Churni near Majhdia at Krishnaganj Community Development (C.D.) block of Nadia district (District census Handbook, Nadia, 2011 and District Survey Report of Nadia District, Government of West Bengal, 2022). It is flowing from the source of river Mathabhanga near Majdia of Krishnaganj Community Development (C.D.) block to its mouth at river Bhagirathi near Shibpur at Ranaghat II C.D. block (District Census Hand Book Nadia, 2011). River Churni passes through krishnaganj, Hashkhali ,Ranaghat I and Ranaghat II C.D. blocks (Fig. 1).

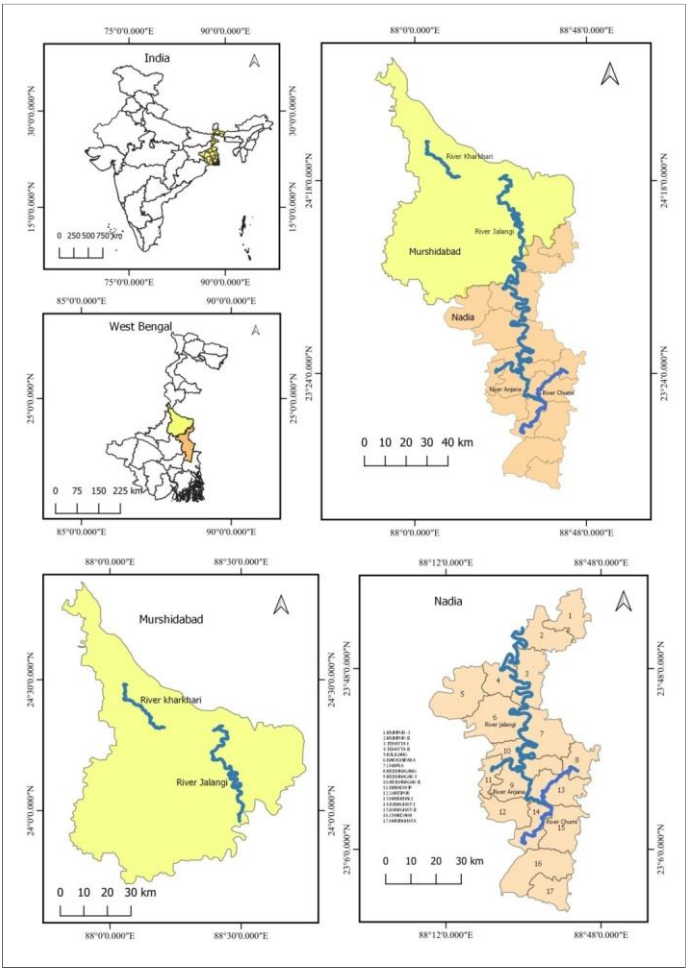

Fig.1. Location map of the study area

The total number of households in the four community development (C.D.) blocks are 289308 where the total number of households are 78432, 56507, 85687, and 68682 in Kaliganj Ranaghat-I, Ranaghat – II, Hanskhali community development (C.D.) blocks respectively (District Census Hand Book Nadia, 2011).After originating from river Jalangi, the river Anjana is flowing through four Community development blocks viz., Krishnagar-I, Krishnagr-II, Santipur, and Ranaghat-II community development blocks of Nadia district. River Jalangi is one of the important river in Nadia district which is passing through eight community development blocks viz., Karimpur, Tehatta-I and II, Nakashipara, Chapra, Krishnagar-I and II, Nabadwip of Nadia district. All the rivers are flowing through populated community development blocks of Nadia and Murshidabad district. Remote sensing and GIS based methodology has been accomplished in this study (Fig. 2).

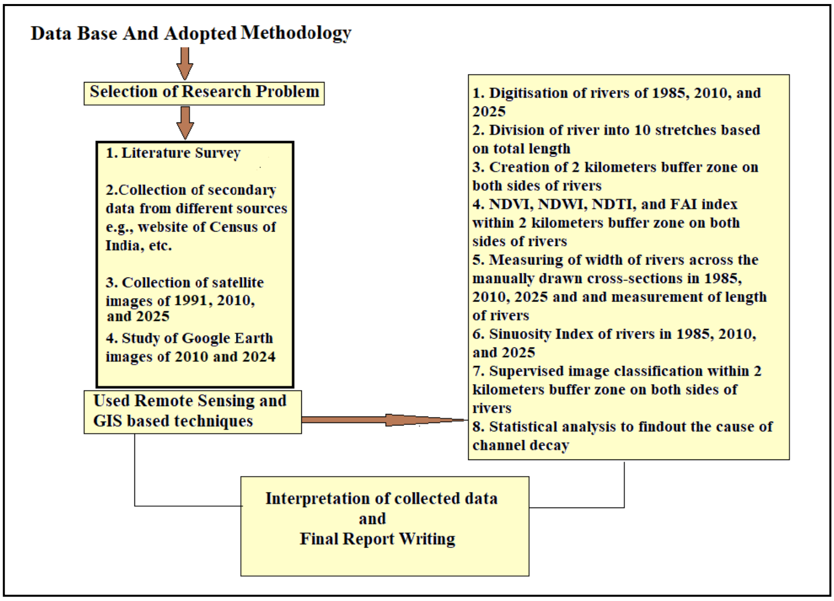

Fig. 2. Data base and adopted methodology used in this research

Data collection

The present work has been done based on satellite images which have been collected from reliable sources (Table 1). Google Earth images of 2010 and 2025 have also been consulted to do the present work.

Table 1. Details of used satellite images

Date of Acquisition Imageries	Path/Row	Data Set	Producer
09.05.1991	138/44	MSS(Landsat-5)	USGS
21.11.1991	139/43	TM	USGS
29.03.2025	138/44	OLI_TIRS(Landsat-8)	USGS
14.06.2025	139/43	OLI_TIRS(Landsat-8)	USGS

Channel Geometry of rivers from the year 2010 to 2025

To calculate the width of the river Kharkhari, river Jalangi of Murshidabad district and river Churni, river Anjana, river Jalangi of Nadia district, all the rivers are divided into ten stretches based on their total length and total six cross sections have been drawn manually in every stretch (total sixty cross sections) across the river Kharkhari of Murshidabad district and river Jalangi of Murshidabad and Nadia district (Fig. 3). And, total fifty cross sections (Five cross sections in every stretch) have been drawn manually across the river Churni and Anjana in Nadia district (Fig. 3) and here, total stretch of rivers have been considered (fragmented part of rivers also included). The name of the cross sections has been given both years by using GIS technique. The length of the rivers has also been measured using GIS technique (Fig. 3).

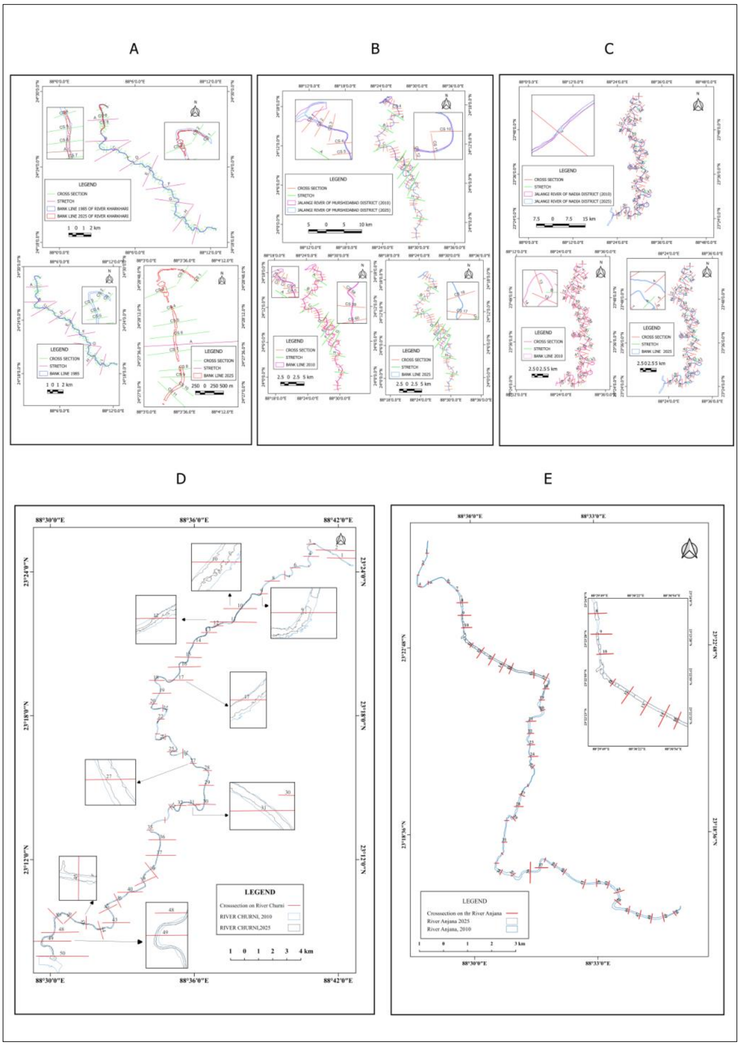

Fig. 3. Changing width of rivers across the cross sections from 2010 to 2025

Sinuosity index (Equation 1) (Fig. 4) of rivers have been measured based on the Sinuosity index proposed by Schumm (1963). Sinuosity is the deviation of channel that is the observed path from its expected path (Charlton, 2008). The formulae for the calculation of Sinuosity index (SI) is as follow:

$$SI=OL/EL \tag{1}$$

Where, SI= Sinuosity index, OL= Observed path / Actual path of the river, EL= expected path of the river. The SI value 1.0 indicates straight channel, SI value 1.0-1.5 indicates sinuous channel and SI value greater than 1.5 indicates meandering channel.

Creation of 2 kilometers buffer zones

Two kilometer buffer zone on the both sides of rivers have been created using GIS technique. NDVI, NDWI, and Supervised Image Classification have been done within the buffer zone which has been created on the both sides of rivers for the identification of changes of different features like vegetation cover, water bodies, settlement areas etc.

Normalized difference vegetation index (NDVI)

In this present research, NDVI (Equation 2) index has been used to detect the condition of vegetation within two kilometer buffer zone from the both side of river Kharkhari, river Jalangi of Nadia and Murshidabad, river Anjana, river Churni in the year 1991 and 2024. Healthy vegetation plays very important role in the maintenance of stream corridor and river health. The formulae of NDVI (Bhatta, 2021) is as follow:

$$NDVI = (NIRRED)/(NIR+RED) \qquad (2)$$

Where, NIR is the reflectance in the near-infrared band (700-1100 nanometers), RED is the reflectance in the red band (600-700 nanometers).

The values of NDVI range from 0.3 to 0.8 indicate a dense and healthy vegetation canopy. Negative values indicate clouds, water, and snow fields. The values of NDVI range from 0.1 to 0.2 indicate soil. The value of NDVI ranges from 0.3 to 0.6 indicates stressed vegetation (Bhatta, 2021).

Normalized difference water index (NDWI)

In this present study, NDWI (Equation 3) has been used to know the change in surface water body within two kilometer buffer zone from the both side of the rivers in the year 1991 and 2025. The formulae of NDWI (Bhatta, 2021) is as follow:

$$NDWI = (NIR-SWIR)/(NIR+SWIR) \qquad (3)$$

Where, NIR stands for the near-infrared band (700-1100 nanometers), SWRI stands for Short-Wave Infrared (900 to 1700 nanometers).

NDWI values ranges from -1 to + 1. Generally, the values of NDWI range from -1.0 to +1.0. The values of NDWI from 0.5 and more than 0.5 indicate water bodies. Negative value (-0.2) of NDWI indicates built up areas. Values of NDWI towards -0.1 indicates water less dry areas.

Land use / land cover change

Supervised image classification has been done using maximum likelihood method using QGIS software for the year 1991 and 2024 within the two kilometer buffer zone on the both sides of rivers to identify the changes in land use and land cover. In the years 1991 and 2025, the features like river / water bodies, agricultural use within the channel and vegetation area have been identified within two kilometer buffer area to find out changes in land use and land cover. The percentage of area under the above selected parameters for land use and land cover change has been calculated using QGIS software. The land use and land cover change within two kilometer buffer area has been done to identify the positive or negative changes in selected parameters for land use and land cover in this study. The changes may help to show various anthropogenic activities on rivers.

Pearson's correlation analysis

Pearson's product moment correlation analysis (Equation 4) is a parametric test. It is used to measure the relationship between variables. This analysis is based on the assumption that both variables come from the normally distributed populations (Gaur et al., 2009 and Ghosh and Sahu, 2019a and Ghosh and Sahu, 2019b). The formula is as follow:

$$r = \frac{\sum XY}{N} - \bar{X}.\bar{Y}/\sigma X.\sigma Y \quad (4)$$

(Gaur et al., 2009, Ghosh and Sahu, 2019a, Ghosh and Sahu, 2019b)
[Where, r= Product moment correlation coefficient, N= Number of data-pair, $\bar{X}$= Mean of X, $\bar{Y}$= Mean of Y, ∑XY= Sum of the products of X and Y, σX= Standard deviation of X, and σY= Standard deviation of Y].

To check correlation among the selected variables like change in area of water bodies from 1991 to 2025, change in area of agricultural use within channel from 1991 to 2025, change in area of agricultural land from 1991 to 2025, change in area of vegetation from 1991 to 2025, change in average width of river from 2010 to 2025, Pearson correlation analysis has been applied. This analysis has been done by using SPSS software.

Results and Discussion

Spatio-temporal changes in rivers channels from the year 2010 to 2025

Drastic changes have been observed in width of all rivers across the drawn cross-sections (Fig. 3, Table 2). Maaß et. al (2021) stated that technological development and growth of population are causing river modification and geometrical changes in rivers. Spinti et. al. (2023) stated that anthropogenic fragmentation of rivers in United States alters and modify the entire river geometry. A dramatic change also observed in the average width of river Kharkhari of Murshidabad district. The average width of river Kharkhari in 10 stretches from stretch A to J (Fig. 3) in the year 1985 (from A to J) across the drawn cross-sections were 91.16 meters (m), 83.83m, 53.83m, 45.66m, 49.33m, 60.66m, 89.66, 60.33m, 81m, and 44.66m respectively. But, it is very strange to say that in 2025 the river only observed in A, B, and D stretches with 59.16m, 56.83m and 77 m width (Table 2). It is very unfortunate to say that the river Kharkhari is a decayed river; it has totally lost its almost entire course. The existing part of river Kharkhari is fragmented into ponds. The length of river Kharkhari in the year 1985 was 35.57 km but now it is only 4.53 km in 2025 due to anthropogenic impact. The river Kharkhari has been obstructed by fencing. The satellite images and field survey are showing that the channel bed of river Kharkhari has been using as built up area and agricultural field. Most of the part of the river has been dried due to barriers, agricultural use, and construction activities. The average width of the Jalangi in 10 stretches from stretch A to J (Fig.3), Murshidabad district were 154.83meters (m) 84.30m, 65.67m, 94.12m, 88m, 47m, 52m, 50.33m, 52.34 m, and 53.33m respectively in 2010 where average width of the river Jalangi in same stretches (A to J) across sections are 36.33m, 23.50m, 29.83m, 21.66m, 23.50m, 26.67m, 34.83m, 37.16m, 37m, 39.83m respectively. It can be said that in every selected stretches the average width of river Jalangi in Murshidabad has been remarkably decreased which is indicating channel decay. The length of river Jalangi in Murshidabad is also decreased it was 76.55 Kilometers during 2010 but in 2025, it is 75.98 kilometers (Km). In 2010, the average width of river Jalangi in Nadia district across the drawn cross-sections in ten stretches (A–J) (Fig. 3) were 60.01m, 57.15m, 76.88m, 59.87m, 85.97m, 108.16m, 93.76m, 109.66m, 128.96m, and 148.05m which are 62.33m, 61.53m, 79.15m, 61.09m, 80.26m, 94.42m, 85.37m, 118.9m, 135.88m and 144.40m in the year 2025. It can be said in E, F, G, and J stretches, the average width of river Jalangi of Nadia district has been notably decreased. The average width of river Anjana across the drawn cross-sections in every stretch (A-J) (Fig. 3) has been drastically changed. The average width of river Anjana across the drawn cross-sections in every stretch in the year 2010 were 33.37m, 46.85m, 80.01m, 60.27m, 37.55m, 41.20m, 47.22m, 49.52m, 70.83m, and 57.04m respectively and in 2025, the river Anjana only exists in B, C and D stretches with average widths are 24.62m, 77.53m and 12.96m respectively. The length of river Anjana was 29.00 kilometers in 2010 which is only 6.124 Kilometers in 2025. The field verification clearly reveals that river Anjana is now converted into a drain with very bad condition. The average width of river Churni across the drawn cross-sections in selected stretches (A to J) (Fig. 3) in the year 2010 were 67.20m, 75.06m, 62.13m, 61.53m, 64.84m, 51.60m, 66.22m, 55.78m, 46.38m, and 70.58m respectively which are observed in the same stretches in the year 2025 as 0 m, 16.81m, 39.87m, 37.82m, 44.79m, 37.51m, 30.81m, 44.98m, 51.33m, and 59.52m respectively. Therefore, it can be said that the river Churni is gradually decaying. The total length of river Churni in 2010 was 63.30 kilometers which is 46.71 Kilometers in 2025.

Table 2. Year wise average width of rivers across the cross-sections in 10 stretches

10 Stretches	The average width of rivers in meters (year wise)									
	River Kharkhari		River Jalangi of Murshidabad		River Jalangi of Nadia		River Churni		River Anjana	
	1985	2025	2010	2025	2010	2025	2010	2025	2010	2025
A	91.16	59.16	154.83	36.33	60.01	62.33	67.2	0	33.37	NE
B	83.83	56.83	84.3	23.5	57.15	61.53	75.06	16.81	46.85	24.62
C	53.83	NE	65.67	29.83	76.88	79.15	62.13	39.87	80.01	77.53
D	45.66	77	94.12	21.66	59.87	61.09	61.53	37.82	60.27	12.96
E	49.33	NE	88	23.5	85.97	80.26	64.84	44.79	37.55	NE
F	60.66	NE	47	26.67	108.16	94.42	51.6	37.51	41.2	NE
G	89.66	NE	52	34.83	93.76	85.37	66.22	30.81	47.22	NE
H	60.33	NE	50.33	37.16	109.66	118.9	55.78	44.98	49.52	NE
I	81	NE	52.34	37	128.96	135.88	46.38	51.33	70.83	NE
J	44.66	NE	53.33	39.83	148.05	144.4	70.58	59.52	57.04	NE
NE denotes not existed										

Change in the sinuosity of rivers from the year 2010 to 2025

The calculated values of sinuosity index of all rivers show that there is a change in the sinuosity index of river Churni, river Anjana, river Kharkhari from the year 2010 to 2024 (Fig. 4). But river Jalangi is not showing change in SI value. In the year 2010, the values of sinuosity index of river Jalangi in Nadia, river Churni, river Anjana, river Jalangi in Murshidabad, river Kharkhari (in the year 1985) were 2.95, 1.70, 1.58, 1.88, and 1.53 respectively and in the year 2025, the value of sinuosity index of river Jalangi in Nadia, river Churni, river Anjana, river Jalangi in Murshidabad, river Kharkhari are 2.96, 1.51, 1.00, 1.88, highly fragmented river respectively. According to sinuosity value of SI proposed by Schumm (1963), it can be said that path of rivers in the year 2010 was meandering and the path of river Churni is sinuous in the year 2025 and the path of river Anjana is straight in 2025. So, there is a change in channel planform and the anthropogenic activities cannot be ignored. Specially, uses of channel bed for different purposes like agriculture, construction of settlement etc.

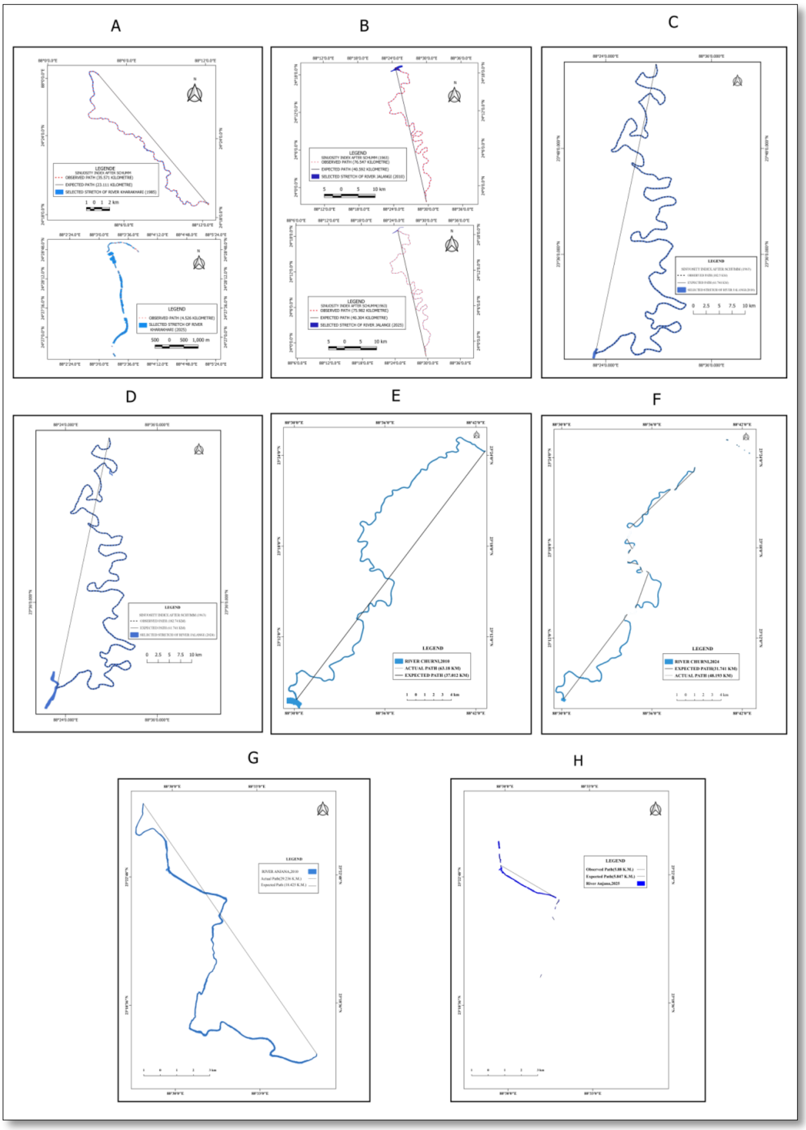

Fig. 4. Change in channel planform of rivers using Sinuosity Index from the year 2010 to 2025

Changes in the vegetation cover from the year 1991 to 2025

The calculated values of NDVI (Fig. 5) clearly exhibits that the existence of healthy vegetation is almost negligible within two kilometers buffer zone on both sides of rivers. In the year 1991, the lowest values of calculated NDVI index (Fig. 5) of river Kharkhari and river Jalangi of Murshidabad district, river Jalangi, river Anjana, and river Churni of Nadia district were -0.923, -0.307, -0.071, -0.054, -0.243 respectively. In the year 1991, the highest values of calculated NDVI index (Fig. 5) of river Kharkhari and river Jalangi of Murshidabad district, river Jalangi, river Anjana, and river Churni of Nadia district were 0.710, 0.477, 0.413, 0.474, and 0.026 respectively. In the year 2025, the lowest values of calculated NDVI index (Fig. 5) of river Kharkhari and river Jalangi of Murshidabad district, river Jalangi, river Anjana, and river Churni of Nadia district are-0.069, -0.056, -0.008, -0.182, and -0.056 respectively. In the year 2025, the highest values of calculated NDVI index (Fig. 5) of river Kharkhari and river Jalangi of Murshidabad district, river Jalangi, river Anjana, and river Churni of Nadia district are 0.519, 0.433, 0.454, 0.026, and 0.466 respectively. Therefore, it can be said that the healthy vegetation cover within 2 kilometers buffer area is deteriorated in case of all rivers.

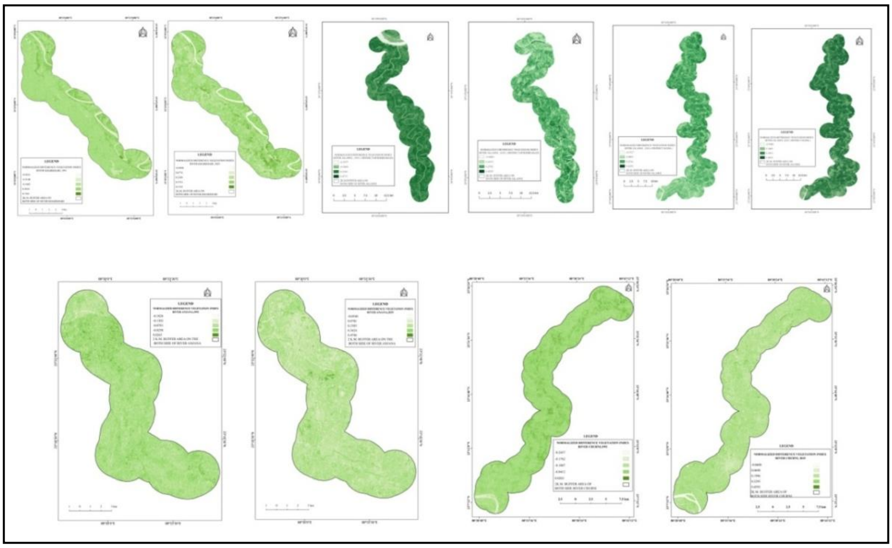

Fig. 5. NDVI of all rivers within 2 kilometers buffer zone on both sides of rivers

Changes in the Water body from in the year 1991 to 2025

The calculated values of NDWI (Fig. 6) clearly exhibits that the existence of healthy water body is almost negligible within two kilometers buffer zone on both sides of rivers. In the year 1991, the lowest values of calculated NDWI index of river Kharkhari and river Jalangi of Murshidabad district, river Jalangi, river Anjana, and river Churni of Nadia district were -0.627, -0.346, -0.379, -0.271, -0.286 respectively. (Fig. 6) In the year 2025, the lowest values of calculated NDWI index (Fig. 6) of river Kharkhari and river Jalangi of Murshidabad district, river Jalangi, river Anjana, and river Churni of Nadia district are -0.470, -0.375, -0.405, -0.431, and -0.421 respectively. In the year 2025, the highest values of calculated NDWI index (Fig. 6) of river Kharkhari and river Jalangi of Murshidabad district, river Jalangi, river Anjana, and river Churni of Nadia district are 0.107, 0.104, 0.042, 0.073, and 0.093 respectively. From the calculated values of NDWI, it can be easily said that healthy water bodies are absence within the buffer area and the water quality has been more declined from the past decades to present year.

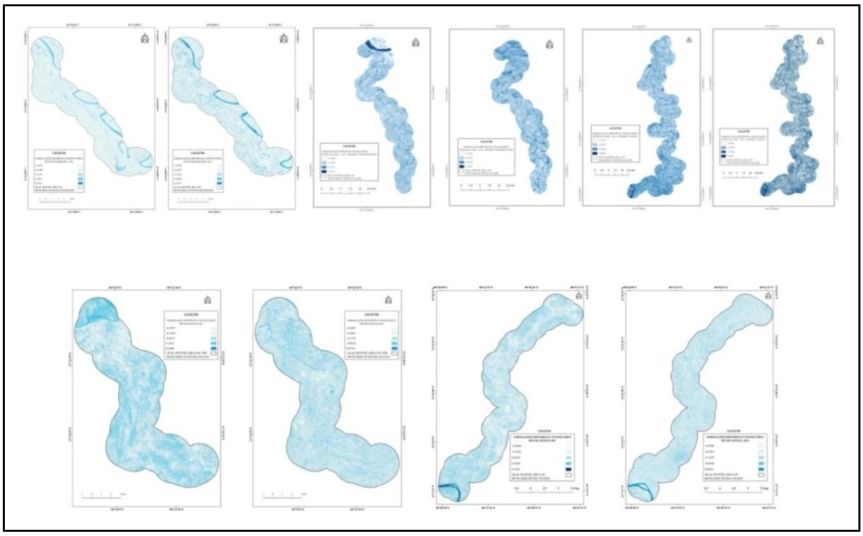

Fig. 6. NDWI of all rivers within 2 kilometers buffer zone on both sides of rivers

Changes in the land use / land cover from the year 1991 to 2025 and anthropogenic impact on rivers

To get clear scenario of land use/land cover alteration within the two-kilometer buffer zone of rivers the total river stretches has been divided into ten zones or sub-stretches. In case of river Kharkhari of Murshidabad district (Fig. 7 and Fig. 8, Table 3), the area under water bodies has been decreased by 3.88 percent.

Table 3. Land use / land cover change within 2 kilometers buffer zones of river Kharkhari, river Jalangi of Murshidabad, river Jalangi, river Churni, and river Anjana of Nadia

LULC Pattern	River Kharkhari in Murshidabad		Change	River Jalangi in Murshidabad		Change	River Jalangi in Nadia		Change	River Churni in Nadia		Change	River Anjana in Nadia		Change
	Area in percentage 1991	Area in percent age 2025		Area in percentage 1991	Area in percent age 2025		Area in percentage 1991	Area in percentage 2025		Area in percentage 1991	Area in percentage 2025		Area in percentage 1991	Area in percentage 2025	
River /water bodies	5.82	1.94	-3.88	4.2	0.68	-3.52	9.63	2.44	-7.19	13.51	5.5	-8.01	6.87	4.19	-2.68
Agricultural use within the channel	9.69	4.89	-4.8	3.71	0.11	-3.6	10.79	41.89	31.1	9.29	21.15	11.86	8.91	28.07	19.16
Settlement	42.73	23.49	-19.24	48.16	33.52	-14.64	40.34	31.66	-8.68	24.63	30.37	5.74	21.2	33.82	12.62
Agricultural land	31.45	54.16	22.71	9.86	50.32	40.46	21.53	6.29	-15.24	29.77	10.29	-19.48	35.11	7.73	-27.38
Vegetation	10.31	15.52	5.21	34.07	15.36	-18.71	17.72	17.73	0.01	22.79	32.69	9.9	27.91	26.19	-1.72

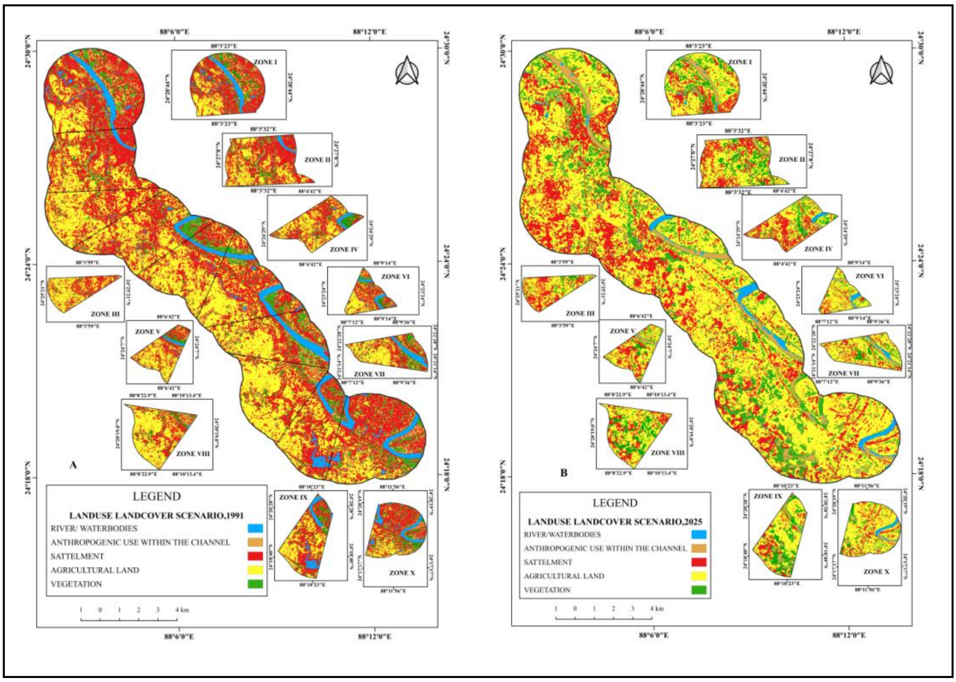

Fig. 7. Land use / Land cover within 2 kilometer buffer zone of river Kharkari in Murshidabad district in 1991 (A) and 2025 (B)

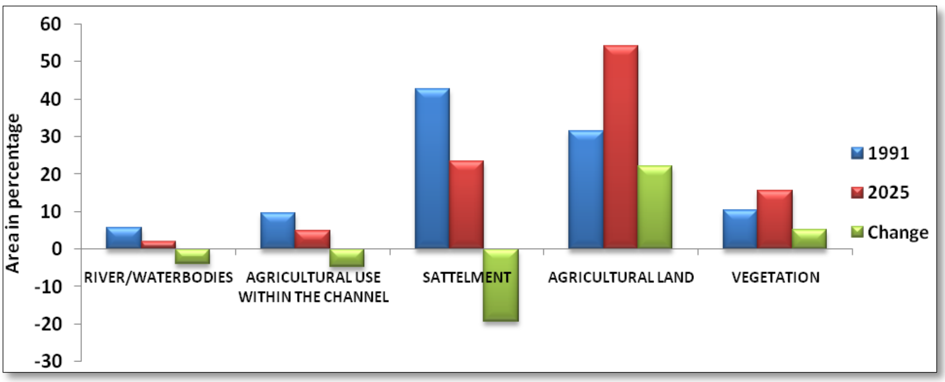

Fig. 8. Land use / land cover alteration within 2 kilometers buffer zone of river Kharkhari from 1991 to 2025

The agricultural land has also been increased by 22.71 percent from the year 1991 to 2025. In case of river Jalangi of Murshidabad district (Fig. 9 and Fig. 10, Table 3), a huge change in land use/land cover has been observed from the year 1991 to 2025. In Zone-I, the percentage of area under river/water body, agricultural use, with in channel, settlement, agricultural land, vegetation was 15.12, 14.35, 41.49, 7.37, and 21.67 respectively in the year 1991, which are 1.29, 0.37, 56.37, 35.22, and 6.75 respectively in the year 2025.Therefore, in zone I, their percentage change of area from 1991 to 2025 are-13.83, -13.98, 14.88, 27.85, -14.92 respectively. In case of river Jalangi of Murshidabad (Fig. 9 and Fig. 10), there are decreased in percentage of area of water body and vegetation in all the ten stretches.

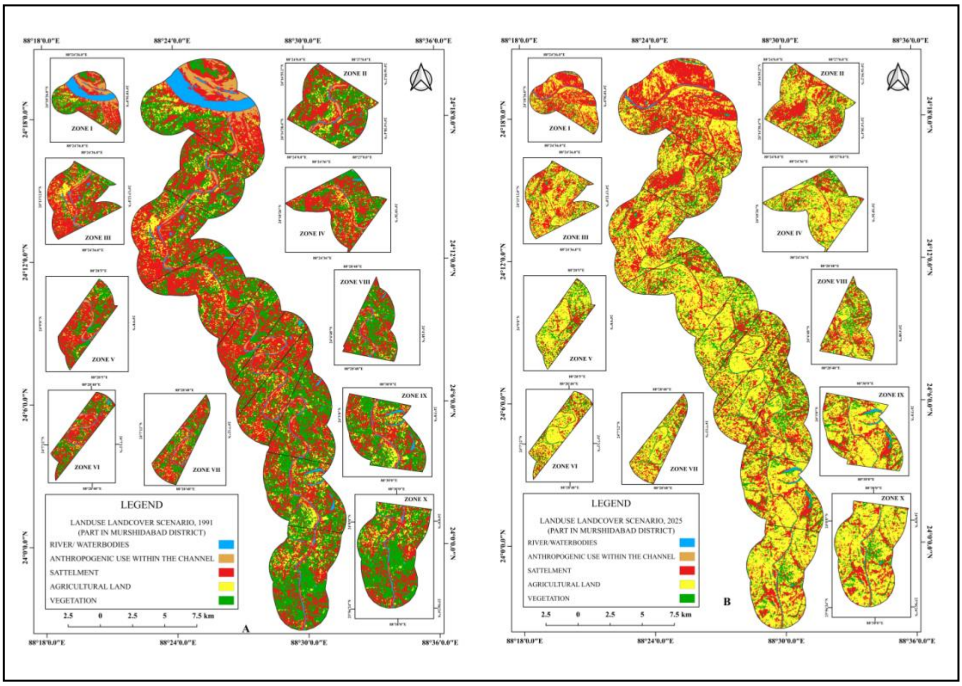

Fig. 9. Land use / Land cover within 2 kilometer buffer zone of river Jalangi in Murshidabad district in 1991 and 2025

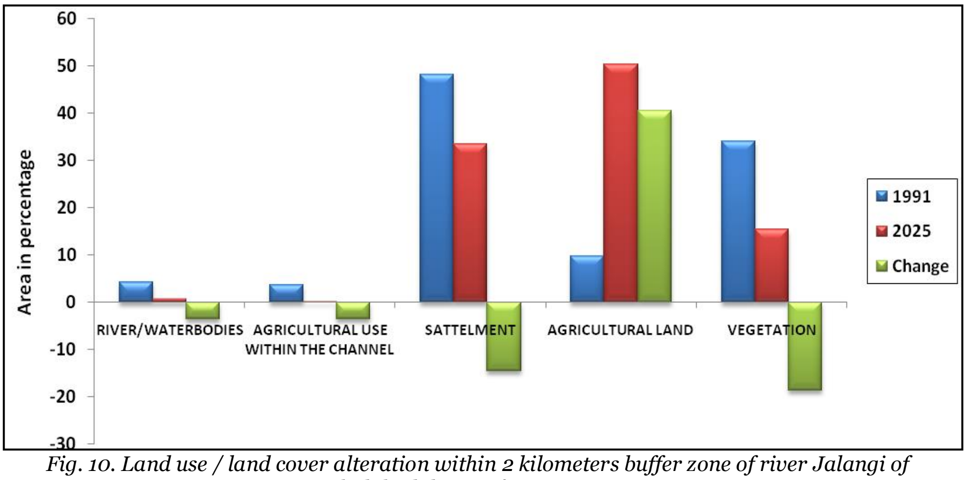

Fig. 10. Land use / land cover alteration within 2 kilometers buffer zone of river Jalangi of Murshidabad district from 1991 to 2025

The overall areas of water bodies have decreased by 3.52 percent and vegetation cover has been decreased by 18.71 percent from the year 1991 to 2025. Area under agriculture has been increased by 40.46 percent. In case of river Jalangi at Nadia district (Fig. 11 and Fig. 12, Table 3), in every zone, the percentage of area under water bodies are decreased from the year 1991 to 2025. But the percentage of area under agricultural use within channel has been increased remarkably.

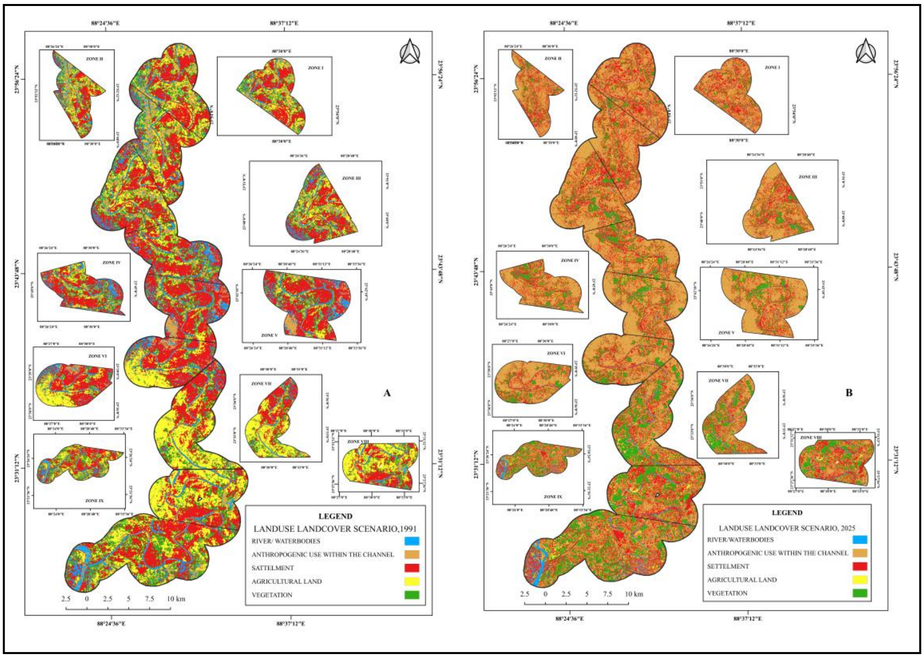

Fig.11. Land use / Land cover within 2 kilometer buffer zone of river Jalangi in Nadia district in 1991 (A) and 2025 (B)

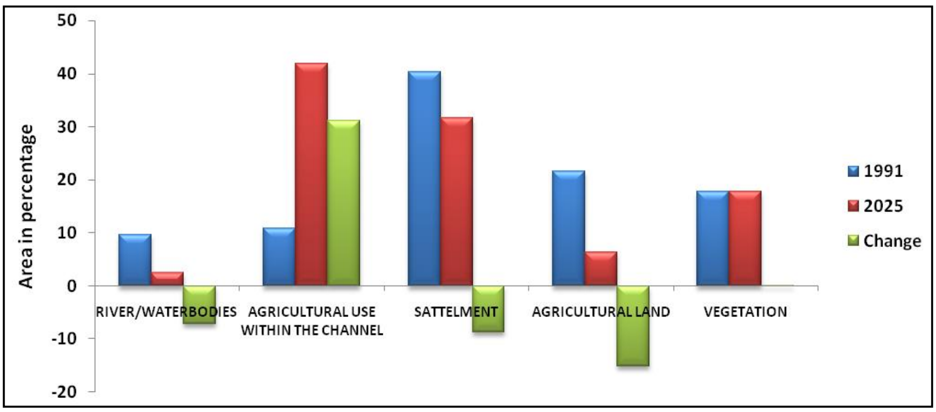

Fig. 12. Land use / land cover alteration within 2 kilometers buffer zone of river Jalangi of Nadia district from 1991 to 2025

Overall, the area under water bodies has been decreased from 1991 to 2025 by 7.19 percent. And, 31.1 percent area of land under agricultural use within channel has been increased from 1991 to 2025. In case of river Churni of Nadia district (Fig. 13 and Fig. 14, Table 3), in every zone, the percentage of area under water bodies are decreased from the year 1991 to 2025. But the percentage of area under agricultural use within channel has been increased remarkably.

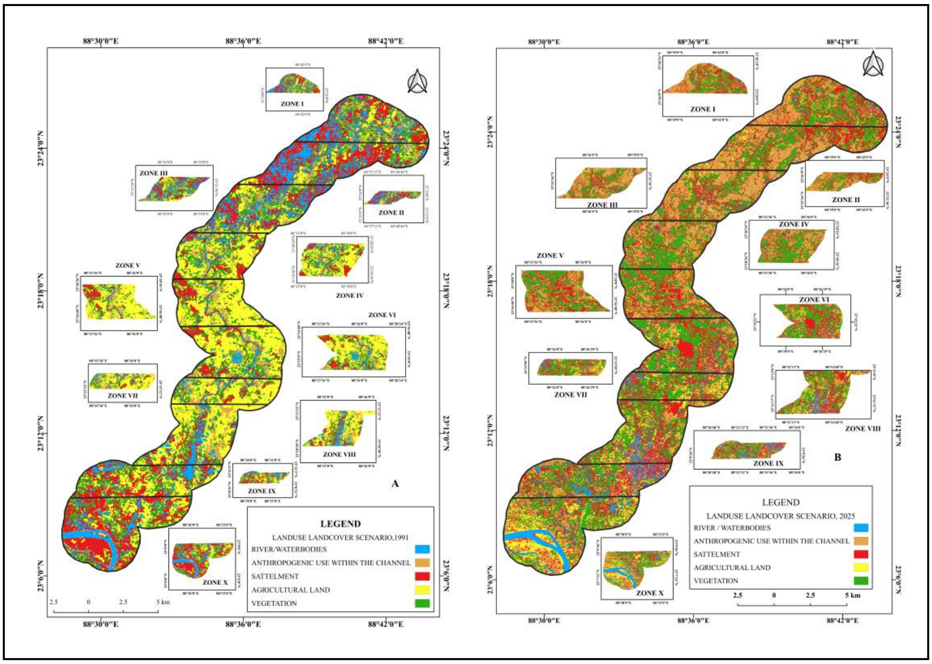

Fig. 13. Land use / Land cover within 2 kilometer buffer zone of river Churni in Nadia district in 1991 (A) and 2025 (B)

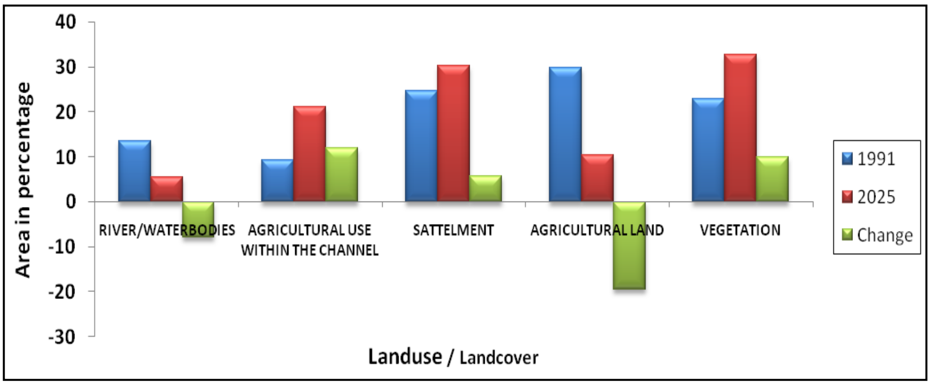

Fig. 14. Land use / land cover alteration within 2 kilometers buffer zone of river Churni of Nadia district from 1991 to 2025

Overall, the area under water bodies has been decreased from 1991 to 2025 by 8.01 percent. And, 11.86 percent area of land under agricultural use within channel has been increased from 1991 to 2025. 5.74 percent area of land under settlement has been increased from 1991 to 2025. In case of river Anjana of Nadia district (Fig. 15 and Fig. 16, Table 3), in every zone, the percentage of area under water bodies are decreased from the year 1991 to 2025. But the percentage of area under agricultural use within channel has been increased remarkably. Overall, the area under water bodies has been decreased from 1991 to 2025 by 2.68 percent. And, 19.16 percent area of land under agricultural use within channel has been increased from 1991 to 2025. 12.61 percent area of land under settlement has been increased from 1991 to 2025.From the foregoing discussion, it is cleared that drastic changes in the percentage of areas under various land use / land cover have been observed, specially, decreased in area of water bodies, increased in area of agricultural land, increased in area of agriculture within river channel, increased in settlement area, have been identified in most of cases. Various human impacts cannot be ignored in decaying of rivers and deteriorating the quality of water of the decaying rivers. In the present study, decreasing area of rivers / water bodies, increasing area under agricultural use within channel, increasing area under agriculture, decreasing area under vegetation cover, increasing area under settlement cover have been clearly observed from the year 1991 to 2025.

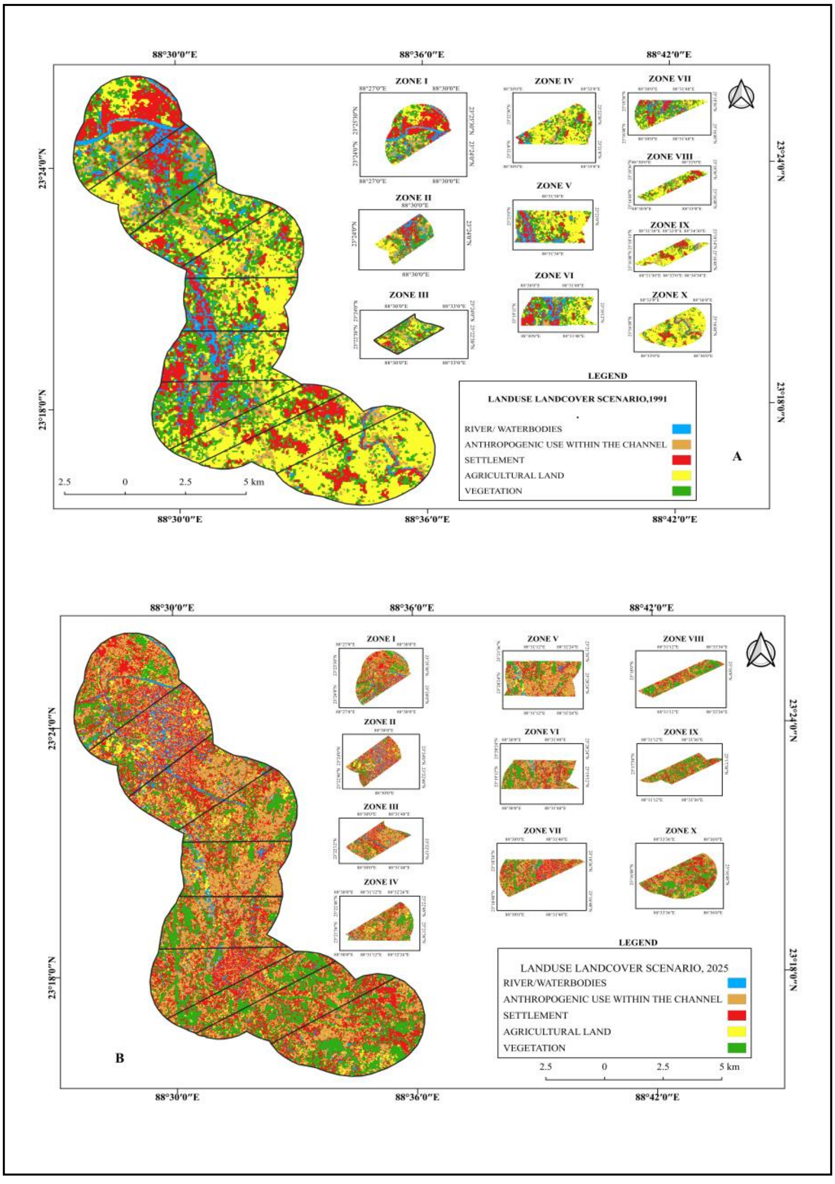

Fig. 15. Land use / Land cover within 2 kilometer buffer zone of river Anjana in Nadia district in 1991 (A) and 2025 (B)

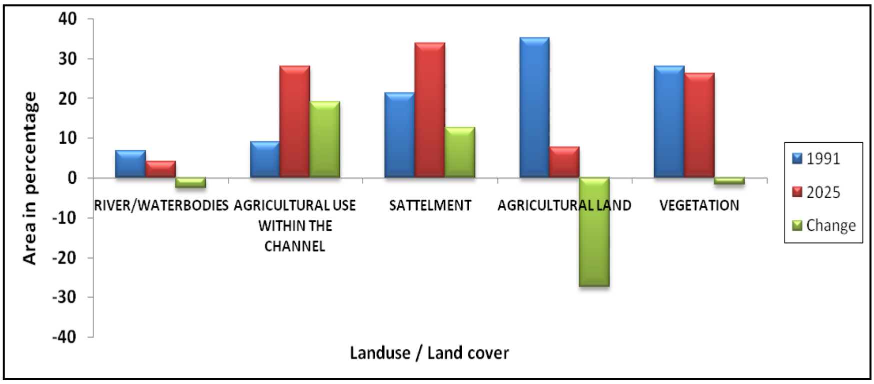

Fig.16.Land use / land cover alteration within 2 kilometers buffer zone of river Anjana of Nadia district from 1991 to 2025

Table 4. Correlation among the selected variables

		Change in area of water bodies	Change in area of agricultural use within channel	Change in area of settlement	Change in area of agricultural land	Change in area of vegetation	Change in average width of rivers
Change in area of water bodies	Pearson Correlation	1	-.592(**)	.098	.021	-.113	.112
	Sig. (2-tailed)		.005	.505	.884	.438	.443
	N	49	49	49	49	49	49
Change in area of agricultural use within channel	Pearson Correlation	-.592(**)	1	.180	-.578(**)	.057	.508(**)
	Sig. (2-tailed)	.005		.216	.000	.697	.000
	N	49	49	49	49	49	49
Change in area of settlement	Pearson Correlation	.098	.180	1	-.790(**)	.260	.039
	Sig. (2-tailed)	.505	.216		.000	.071	.792
	N	49	49	49	49	49	49
Change in area of agricultural land	Pearson Correlation	.021	-.578(**)	-.790(**)	1	-.589(**)	-.252
	Sig. (2-tailed)	.884	.000	.000		.000	.080
	N	49	49	49	49	49	49
Change in area of vegetation	Pearson Correlation	-.113	.057	.260	-.589(**)	1	-.125
	Sig. (2-tailed)	.438	.697	.071	.000		.392
	N	49	49	49	49	49	49
Change in average width of rivers	Pearson Correlation	.112	.508(**)	.039	-.252	-.125	1
	Sig. (2-tailed)	.443	.000	.792	.080	.392	
	N	49	49	49	49	49	49

** Correlation is significant at the 0.01 level (2-tailed).

The result of Pearson correlation analysis (Table 4) shows that a negative and significant change has been observed between 'the change in area of water bodies' and 'the change in area of agricultural use within channel'. The correlation value of person correlation (r) is -0.592. It denotes in most of the cases, people are converting channel bed into agricultural land. The detail field visit reveals that specifically the channel bed of river Anjana, river Churni, river Kharkhari have using for agricultural purposes. A negative and significant change has been observed between 'the change in area of settlement' and 'the change in area of agricultural land'. The correlation value of person correlation (r) is -0.790 (Table 4). A negative and significant change has been observed between 'the change in area of vegetation' and 'the change in area of agricultural land'. The correlation value of person correlation (r) is -0.589 (Table 4). Therefore, it can be easily said that people are converting agricultural land and vegetation cover into buildup area. The areas under water bodies have been continuously converting into agricultural areas and buildup areas by the people to fulfill the ever growing demands of human beings at a cost of natural environment. People are using river and its catchment area as dustbin or waste dumping ground (Fig. 17). Maaß et. al, (2021) stated that human activities like alteration in land use and land cover of flood plain area affects the river channels.

Management and Conclusion

From the foregoing discussion, it is cleared that people are converting areas under natural vegetation, water bodies into agricultural land, built up areas etc. at a cost of natural environment through various activities like deforestation, construction of human structures, expansion of agricultural land etc. The decreasing values of NDVI and NDWI within 2 kilometers buffer zones of both sides of rivers show that the existence of healthy vegetation and healthy water bodies are almost absent there from the year 1991 and 2025. The supervised image classifications in 1991 and 2025 also support drastic alteration in land use / land cover within 2 kilometers buffer zones of both sides of rivers. Various anthropogenic activities not only deteriorating the water quality of rivers (as per less values of NDWI) but at the same time the human activities are encroaching the river channels. To take prompt management strategies for the survival of decaying rivers (Fig. 17) become very necessary because the existence of all biotic communities very much depends on water bodies. If proper management strategies can be implemented then the problem of river decay can be handled well (Fig. 18) and it will be very much essential and beneficial for the human society.

Fig. 17 (a-d). Condition of rivers

If proper management strategies can be implemented then the rivers again will become a healthy rivers just like before. Again, it will be a good source of water resource. Based on these rivers, very good fishing grounds can be developed which will again support many people economically. Maaß et. al, (2021) stated that depending upon substantial knowledge on historical as well as characteristics of fluvial morpho dynamics, the success in the process of river restoration may achieve. For management of decaying river, first of all, illegal capturing and fragmentation of river should to stop. Stoffers et. al, (2024), emphasized the key components of the European nature restoration law of 2023 for reviving European rivers through law establishment for restoring degraded rivers, prioritizing area of interest, adequate financial support, collaborating nature among all stakeholders, public awareness, etc and they focused on the natural restoration law for reviving rivers. It is very necessary to free the river from all its barriers. EEA (2021) mentioned in their report that different barriers on rivers like dam, weir, culvert etc. alters natural flow of rivers and they deteriorating the quality of water of rivers. EEA (2021) suggested different strategies to improve river continuity by removing barriers, constructing fish migratory way etc. Bellitti (2020) showed that the major predictors of barrier density of European rivers are pressure related to agriculture, construction of river road crossing on rivers etc.. Dredging is needed to maintain the course of river in the affected areas and maintain the navigability of channels. River encroaching has introduced siltation on river bed. Illegal capturing of river banks and river bed should to take off to maintain the natural flow of decaying rivers. EEA (2021) emphasized on the importance of free the rivers from all the barriers to improve river ecosystem. In the study area, to manage channelization and flow regulation of decaying rivers management of stream corridor is necessary to maintain healthy channel flow (Fig. 18).

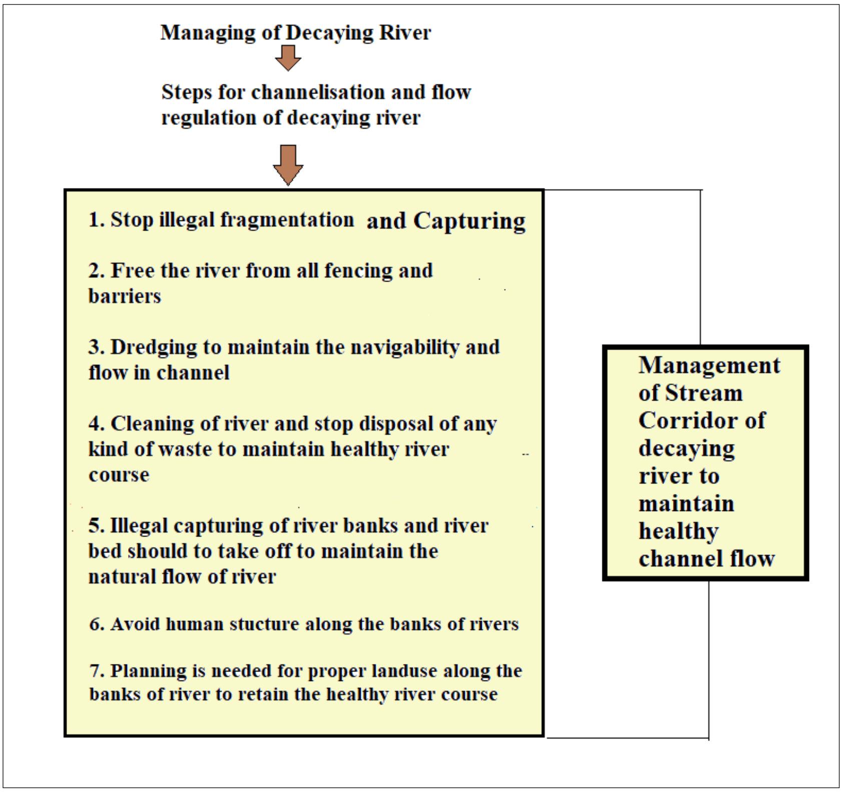

Fig. 18. Management strategies to prevent channel decay

Maaß et. al, (2021) stated that maintenance of flood plain area is very essential to manage degraded rivers in Western Europe. It can be concluded that river decay is really a burning problem for the human society. It is continuously bringing various problems in human livelihood and in natural environment. The preconceived idea in this research is "Decay of river is highly caused by various anthropogenic activities" and the application of different methods like width measurement to find out the shrinking width of river, supervised image classification to identify drastic changes in land use and land cover specially decreasing area of water bodies, increasing areas of settlements, increasing use of area on the river channel, etc. NDWI and NDVI both have in most of the cases negative values which indicates not good condition in respect of water bodies and vegetation cover respectively. All the used Indies have scientifically supported the taken hypothesis. The main reason of decay of river is various anthropogenic activities which is clear from the foregoing discussion. The case studies of river Kharkhari, river Churni, river Anjana and in many sites of river Jalangi also scientifically proved that positive change in the area under settlement and agricultural land from the year 1991 to 2025 has significant impact on encroaching of river width of river Kharkhari, river Churni, river Anjana and in many sites of river Jalangi from 1991 to 2025. The problem of river decay or encroaching river can be stopped by the concerned authority. Legal steps need to be taken to stop illegal capturing and fragmentation of rivers; free the channel from all fencing and barriers, maintenance of river bed by dredging, stop dumping waste and garbage into the rivers' water and its surroundings, use of land along the river or the management of watershed needs to be maintained. Construction of houses, other concrete structures need to avoid along the river banks. Decaying river again can be reformed in its previous living condition if suggested strategies can be implemented by concern authority.

Acknowledgement: The authors are really thankful to the local respondent for their support. The authors are thankful to USGS, Bhuban, and Google Earth for providing satellite images. We want to convey our deep gratitude to Mr. Samiron Das for his endless support until completion of the study.

Conflicts of Interest: The authors declare no conflict of interest.

Publisher's Note: Serbian Geographical Society stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

Abdelmohsen, K., Famiglietti, J. S., Ao, Y. Z., Mohajer, B., & Chandanpurkar, H.A. (2023). Declining Freshwater Availability in the Colorado River Basin Threatens Sustainability of Its Critical Groundwater Supplies. *Geophysical Research Letters,* 52(10). https://doi.org/10.1029/2025GL115593

Belletti, B., Garcia de Leaniz, C., & Jones, J. (2020). More than one million barriers fragment Europe's rivers. *Nature, 588*, 436–441. https://doi.org/10.1038/s41586-020-3005-2

Charlton, R. (2008). *Fundamentals of Fluvial Geomorphology*. London, United Kingdom: Routledge.

Census of India. (2011a). *District census hand book: Village and town dictionary part-XII-A (20).* Murshidabad, Nadia, West Bengal. Retrieved January, 2018, from https://censusindia.gov.in/census. website/ 1

Census of India. (2011b). *District census hand book: Village and town dictionary part-XII- B(20).* Murshidabad, Nadia, West Bengal. Retrieved January, 2018, from https://censusindia.gov.in/census. website

Crini, M. N., Lichtfouse, E., Liu, G., Balaram, V., & Lado Ribeiro, A. R. L. (2022). Worldwide cases of water pollution by emerging contaminants: a review. *Environmental Chemistry Letters, 20*, 2311-2338. ff10.1007/s10311-022-01447-4ff. ffhal-03662990f

Dragićević, S., Pripužić, M., Živković, N., Novković, I., Kostadinov, S., Langović, M., Milojković, B., & Čvorović, Z. (2017). Spatial and Temporal Variability of Bank Erosion during the Period 1930–2016: Case Study - Kolubara River Basin (Serbia). *Water, 9*(10), 748. https://doi.org/10.3390/w9100748

Ekka, A., Pande, S., Jiang, Y., & Zaag, P.V.D. (2019). Understanding the impact of anthropogenic activities on river ecosystem services in India: A hydro-economic approach. *Geophysical Research Abstracts, 21*, EGU2019-8753.

European Environmental Agency (EEA). (2021). Tracking barriers and their impacts on European river ecosystems. https://www.eea.europa.eu/en/analysis/publications/tracking-barriers-and-their-impacts-on-european-river-ecosystems#:~:text=Another%20category%20captured%20by%20the,barriers%20(AMBER%2C%202020)

Gaur, A. S., & Gaur, S. S. (2009). *Statistical methods for practise and research: A guide to data analysis by using SPSS*. India: Sage Publications India Pvt Ltd. http://dx.doi.org/10.4135/9788132108306

Ghosh, D., & Sahu A. S. (2019a). The impact of population displacement due to river bank erosion on the education of erosion victims: a study in jangipur sub-division of murshidabad district, West Bengal, India. *Bulletin of Geography, Socio-economic Series, 46*, 103-118. https://doi.org/10.2478/ bog-2019-0037

Ghosh, D., & Sahu, A.S. (2019b) Bank Line Migration and Its Impact on Land Use and Land Cover Change: A Case Study in Jangipur Subdivision of Murshidabad District, West Bengal. *Journal of the Indian Society of Remote Sensing, 47,* 1969–1988. https://doi.org/10.1007/s12524-019-01043-0

Ghosh, D., & Sahu, A. S. (2023). Population Shifting and Its Consequences on Women's Life: A Case Study Along the River Banks of Ganga-Bhagirathi in Jangipur Sub-division, West Bengal. In: A. S. Sahu & N. Das Chatterjee (Eds.), *Environmental Management and Sustainability in India* (pp. 411-424). Springer, Cham. https://doi.org/10.1007/978-3-031-31399-8_20

Knighton, D. (1998). *Fluvial forms and processes: A new perspective*. London, United Kingdom: Hodder Education.

Li, P., Fang, L., Yuanzhu, W., Mi, W., Ji, L., Uixiang, Z.G., Yang, P., Chen, Z., & Bi, Y. (2022). Anthropogenic activities accelerated the evolution of river trophic status. *Ecological Indicators, 136*(8), Article 108584. https://doi.org/10.1016/j.ecolind.2022.108584

Langović, M., Dragićević, S., Novković, I., Živković, N., Tošić, R., Milojković, B., & Čvorović, Z. (2021). Assessment of the soil loss caused by riverbank erosion in Serbia: A remote sensing and GIS based analysis of lateral channel migration and soil loss. *Bulletin of the Serbian Geographical Society, 101*(1), 31–47. https://doi.org/10.2298/GSGD2101031L

Maaß, A. L., Schüttrumpf, H., & Lehmkuhl, F. (2021). Human impact on fluvial systems in Europe with special regard to today's river restorations. *Environmental Sciences Europe, 33*, Article 119. https://doi.org/10.1186/s12302-021-00561-4

Milijašević J. D., Jakovljević, D., & Jojić G. T. (2025). Evaluation of Water Quality in the Tamiš River in Serbia Using the Water Pollution Index: Key Pollutants and Their Sources. Water, 17, Article 1024. https://doi.org/10.3390/w17071024

Manojlović, S., Dobrić, M., & Petronijević, J. (2025). Dynamics of suspended sediment in the Južna Morava River, South-Eastern Serbia. *Bulletin of the Serbian Geographical Society*, *105*(1), 1–18. https://doi.org/10.2298/GSGD2501001M

Mackline, M. G., & Lewin, J. (2015). The rivers of civilization. *Quaternary Science Reviews, 114*, 228-244. https://doi.org/10.1016/j.quascirev.2015.02.004

Meter, K. V., Thompson, S., & Basu, N. B. (2016). Human impacts on stream hydrology and water quality. In: J. B. Jones & E. H. Stanley (Eds.), *Stream Ecosystems in a Changing Environment* (pp. 441-490). Academic Press. https://doi.org/10.1016/B978-0-12-405890-3.00011-7

Ofuoku, A. U. (2011). Rural farmers' perception of climate change in central agricultural zone of delta state, Nigeria. *Indonesian Journal of Agricultural Science, 12*(2), 63-69. http://doi.org/10.21082/ijas. v12n2.2011.p63-6

Roy Choudhury, S. (2020). *Human activities put dolphins at survival risk*. Environmental sciences Ecology Conservation Biology and Research. https://indiabioscience.org/news/2020/human-activities-put-dolphins-at-survival-risk

Sidabutar, N. V., Namara, I., Hartono, D. M., & Soesilo, T. E. B. (2017). The effect of anthropogenic activities to the decrease of water quality. *IOP Conference Series Earth and Environmental Science 67*(1), Article 012034. http://doi.org/10.1088/1755-1315/67/1/012034.

Sahu, S. (2023). River water pollution, sources, and human health effect in India. *Sustainability Agri Food and Environmental Research, 12*.

Stoffers,T., Altermatt, F., Baldan, D., Bilous, O., Borgwardt, F., Buijse, A. D., Bondar Kunze, E., Cid, N., Erős, T., Ferreira, M. T., Funk, A., Haidvogl, G., Hohensinner, S., Kowal, J., Nagelkerke, L., Neuburg, J., Peller, T., Schmutz, J., Singer, A. J., Unfer, G., Vitecek, S., Jähnig, S. C., & Hein, T. (2024). Reviving Europe's rivers: Seven challenges in the implementation of the Nature Restoration Law to restore free-flowing rivers. *Wires Water, 11*(3), Article e1717. https://doi.org/10.1002/wat2.1717

Sekharan, S., Samal, D. R., Phuleria, H. C., Chandel, M. K., Gedam, S., Kumar, R., Sethi,R., Supate, A. R., & Karmakar, S. (2022). River pollution monitoring over an industrial catchment in urban ecoArticle system: Challenges and proposed geospatial framework. *Environmental Challenges, 7*, Article 100496. https://doi.org/10.1016/j.envc.2022.100496

Spinti, R. A., Condon, L. E., & Zhang, J. (2023). The evolution of dam induced river fragmentation in the United States. *Nature Communications, 14*, Article 3820. https://doi.org/10.1038/s41467-023-39194-x

Winton, R. S., Teodoru, C. R., Calamita, E., Kleinschroth, F., Banda, K., Nyambe, I., & Wehrli, B. (2021). Anthropogenic influences on Zambian water quality: Hydropower and land-use change. *Environmental Science Processes & Impacts, 23*(7), 981–994.

Wang, H., & He, G. (2022). Rivers: Linking nature, life, and civilization. *River, 1*(1), 25-36. https://doi.org/10.1002/rvr2.7

Yang, J., Zou, C., Will, R., Wagner, K., Ouyang, Y., King, C., Winrich, A., & Tian,H. (2023). River flow decline across the entire Arkansas River Basin in the 21st century. *Journal of Hydrology, 618*, Article 129253. https://doi.org/10.1016/j.jhydrol.2023.129253