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# Dynamics of the Maniyari River and its meandering nature in the Achanakmar Tiger Reserve Area, Chhattisgarh, India: A Geospatial analysis

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**ABSTRACT**

The Achanakmar Tiger Reserve (ATR) is an integral part of the Achanakmar Amarkantak Biosphere Reserve (AABR) with a total area of 914.017 sq. km. The Maniyari River, which flows through the reserve, is known as its life line. It originates from the core zone (Sihawal sagar) of ATR and merges in the Seonath River of the Mahanadi Basin. It flows about 105 km through Mungeli and Bilaspur districts. This river supplies its catchment area with water seasonally (6-8 months) and flows more than half of its length (about 60 km) within the protected area. Its catchment area has a rich biodiversity of tree species such as *Shorea robusta*, *Terminalia tomentosa, Diospyros melanoxylon, Adina cordifolia, Pterocarpus marsupium, Madhuca indica, Anogeissus latifolia, Dendrocalamus strictus* etc. A geospatial analysis was performed to understand the course of the Maniyari River within the ATR area over a fourteen year period between 2000 and 2013. Imagery from Indian Remote Sensing (IRS) satellite 1D and P6 for years 2000, 2004, 2008, 2010 and 2013 and Survey of India toposheets were analyzed to examine the changes in planform characteristics of the Maniyari River. The meander shift of the river was delineated considering the R1 (11.61 km), R2 (11.19 km), R3 (5.33 km) and R4 (5.02 km) reach's respectively. Sinuosity Index (SI) for different reaches was calculated and evaluated. The SI ranged from 1.40 to 1.63, 1.20 to 1.29, 1.17 to 1.37, and 1.20 to 1.49 in R1, R2, R3 and R4 respectively and the magnitude of the shift was analyzed with the year 2000 as the base year. The overall SI for all the reach's ranges between 1.30 and 1.36. The present study will be helpful in understanding the river dynamics as well as to maintaining the flow of the Maniyari River and preventing bank line erosion. The study will be helpful for the conservation of river flow and its tributaries in the ATR area in Central India.

***Key words***: *Achanakmar Tiger Reserve (ATR), River Maniyari, Meander, LISS III, Sinuosity Index, Geospatial analysis.*

## Introduction

Rivers play an important role in landscape development (Ahmed and Rao, 2019). In response to the earth's atmospheric system, water bodies such as rivers, streams, nallas and their drainage systems are dynamic and constantly changing (Pan, 2013). Quantifying bank line migration shows that river courses are unstable (Hazarika *et al.*, 2015) and to maintain dynamic equilibrium, the river balances the flow of water and sediments transported along its path. Over time, rivers continually undergo changes in their orientation and shape, changing their morphodynamic and hydrodynamic processes due to their slope, terrain, vegetation cover etc.

When river channels are altered under naturally

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dynamic hydrologic conditions, the river readjusts itself with respect to dimension, profile and pattern to reach its former equilibrium or balance (Couture, 2008). The river dynamics and course change due to lateral migration is controlled by factors such as the catchment area, topography, soil type, vegetation cover, tectonic activity, land use pattern and most importantly its climatic factors such as precipitation and temperature of the region.

Flowing through the Central Indian Landscape, Maniyari River is known to be the life line of Achanakmar Tiger Reserve. It originates in the reserve area and flows for about 105 km and meets the Seonath river of the Mahanadi River basin. The flouvial action of Maniyari River and its tributaries divert rainwater from Maikal hill tracts to Mahanadi plains. More than half of its length (approx. 60 km) flows within this protected area. Many small and large natural tributaries that flow into this river provide water seasonally to its catchment. The tributaries are seasonal and are filled with water for six to eight months.

Remote Sensing and GIS play a crucial role in studying the planform features of large rivers and their decadal evolution (Trigg *et al.,* 2012). Studies have been conducted by researchers (Dixon *et al.,* 2018, Debnath *et al.,* 2017; Nigam *et al.,* 2016; Sekac and Jana 2013; Hudson and Kesel 2000, Best and Ashworth 1997) on the course change and meandering of various rivers around the world.

In the present study, recent technology of RS and GIS was used to delineate the river dynamics of Maniyari River within the ATR area. The aim of this paper is to understand the river course change detection with special reference to the sinuosity index during the years 2000 to 2013 using IRS 1D and P6 satellite imageries. About 60 km length of Maniyari river from its source has been studied and divided into four reaches (R 1, R 2, R 3 and R 4) for detailed study. The present study will be helpful in understanding the river dynamics as well as to maintaining the flow of the Maniyari River and preventing bank line erosion.

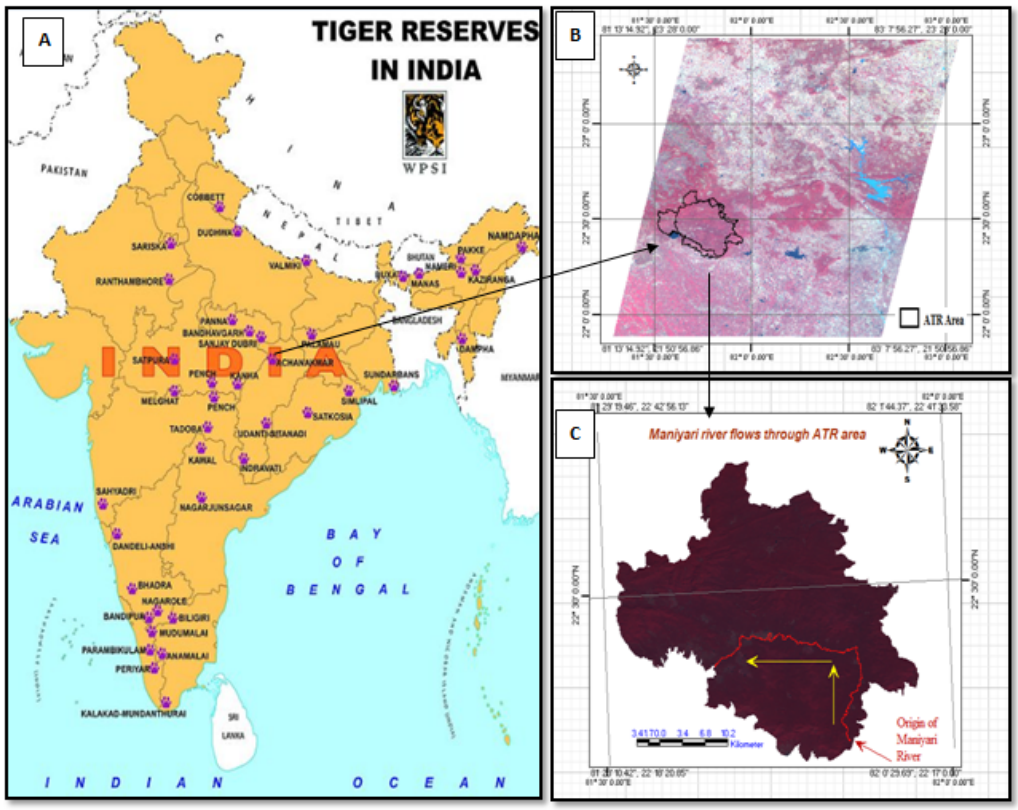



**Fig. 1.** The location map of the study area

A-Tiger Reserves of India, B- Location of ATR in IRS LISS III imagery, C-Flow direction of Maniyari River inside ATR area

## Study Area

The Achanakmar Tiger Reserve (ATR) embraces an area of 914.017 km$^2$, consisting of 626.195 km$^2$ core area (critical tiger habitat) and 287.822 km$^2$ as buffer area. The geographical extent of the area is between 22°17' and 22°38' North latitude and 81°31' and 81°57' East longitude. The Maniyari River originates from ATR's Sihawal sagar and joins the river Seonath near Madku Island in Bilaspur district. The river flows from south to north in the ATR area and merges into the Maniyari dam.

*Shorea robusta* (Sal) is the dominant tree species of the area, followed by Sal mixed forest which includes tree species like *Terminalia tomentosa* (Saja), *Diospyros melanoxylon* (Tendu), *Adina cordifolia* (Haldu), *Pterocarpus marsupium* (Bija), *Madhuca indica* (Mahua), *Anogeissus latifolia* (Dhaora), *Tectona grandis* (Teak) (plantation). Bamboo (*Dendrocalamus strictus*) is also found on higher and lower slopes with different tree species (Mandal *et al.*, 2017)

## Climate

The study area is characterized by the three district seasons monsoon, summer and winter. This protected area experiences wide range of temperatures, with the lowest temperature in winter being 2 °C and the summer temperature rising to a maximum of 46 °C. The average annual rainfall during 2000 to 2013 was 1228.07 mm and the maximum rainfall was received in the months of July, August and September. The area also receives occasional showers throughout the year.

## Materials and Methods

Geospatial technologies are proving to be an effective and accurate tool for quantifying changes in river channel characteristics. The Survey of India (SOI) topographical maps and satellite imageries were used to identify the bank line migration and Sinuosity Index (SI). The details of the dataset used in this study are presented in Table 1. Imageries were obtained from National Remote Sensing Centre (NRSC), Hyderabad. The georeferenced satellite images are used with Projection Type: Universal Transverse Mercator (UTM), Spheroid Name: WGS 84, Datum Name: WGS 84, UTM Zone: 43, UTM Row: N. 1:50,000 scale topographic maps published by SOI, Dehradun were used for the study. Within the study area, the flow direction of the Maniyari River was digitalized as polygons for five years and the Sinuosity Index (SI) was calculated for four different reaches. The entire datasets are integrated into IGIS software version 1.0 for digitalization, further processing and analysis of the planform dynamics.

**Course Change Detection and Analysis -** To assess the course change detection and analysis of the Maniyari River within the ATR area, it is divided into 4 reaches- reach 1 (11.61 km), reach 2 (11.19 km), reach 3 (5.33 km) and reach 4 (5.02 km) respectively. Channel boundaries were digitized as polygons into a geographic information system and the sinuosity index was examined and analyzed. To investigate the shifts in channel course bank-lines are digitized for the years 2000, 2004, 2008, 2010 and 2013 and the change in distance between banks is measured.

Sinuosity (S) deals with the meandering nature of the river. It is the degree to which a river departs from a straight line (Schumm and Khan, 1972).

Channel sinuosity = OL/EL (Schumm; 1963)

Where, OL = observed (actual) path of a stream.

EL = expected straight path of a stream.

According to Sinuosity Index (SI), channels can

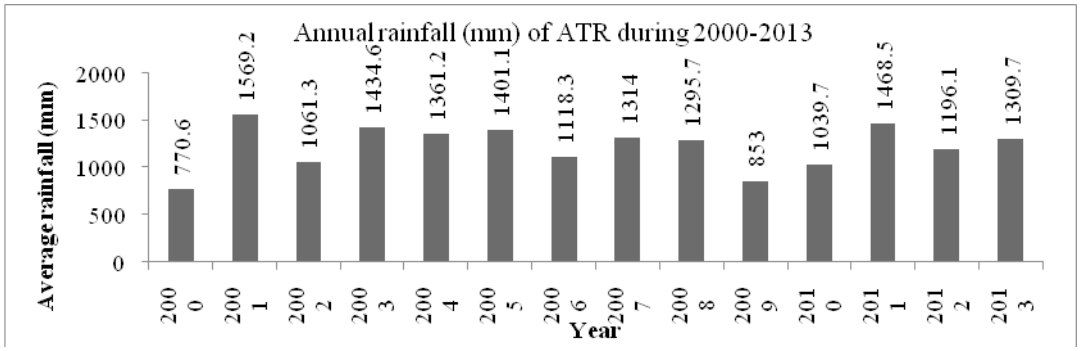



**Fig. 2.** Average annual rainfall (mm) of ATR during 2000-2013

be classified into three classes: straight (SI < 1.05), sinuous (SI 1.05–1.5), meandering (SI > 1.5) and Braided (SI>2.0).

## Results

### Digital Elevation Model of ATR

The elevation range of ATR is between 305 and 1080 meters above mean sea level. The highest peaks (910-1080 m) have been in Lamni and Khuriya ranges. The central part of the area falls at a low elevation with a range of 305-437 m, the Maniyari river flows in this region, and major settlements are also located here.

### Geomorphology

The Achanakmar Tiger Reserve is dominated by hills. Other geomorphological features of the region are inselbergs, intermountain valleys, pediments, plateaus and valleys. A segment of a linear ridge is present in the northwestern region. Faults were recorded in the N-W and E-W directions of ATR. The major portion of the Central Indian shear zone passes through the metamorphic formations in E-W direction. The area is drained by the Maniyari River and its tributaries, which flow in a southwesterly direction. Other water bodies in the region include smaller rivers, nallas and their tributaries and ponds.

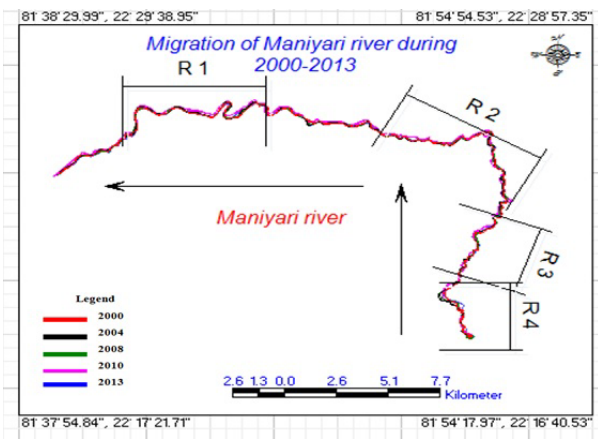



**Fig. 3.** Course change of Maniyari river during 2000 to 2013 Where, R1= Reach 1, R2= Reach 2, R3=Reach 3 & R4=Reach 4

### Meandering nature of Maniyari River

In the present work, Sinuosity Index (SI) and course change of the River Maniyari flowing in the Achanakmar Tiger Reserve (ATR) area were analyzed between the years 2000 to 2013, considering 2000 as the base year. Reach 1 is to the west; reach 2 is in the center, while reach 3 and 4 are in the southern part of the study area. The SI of four reaches ranged from 1.40 to 1.63, 1.20 to 1.29, 1.17 to 1.37, and 1.20 to 1.49 in R1, R2, R3 and R4 respectively, while Sinuosity Index of the entire Maniyari river ranged from 1.30 to 1.36 within ATR. The change in SI can be attributed to a change in flow rate due to a change in rainfall pattern. The Maniyari River has an alluvial channel character and detection and analysis of the river course changes reveals an uneven pattern of bank line shift.

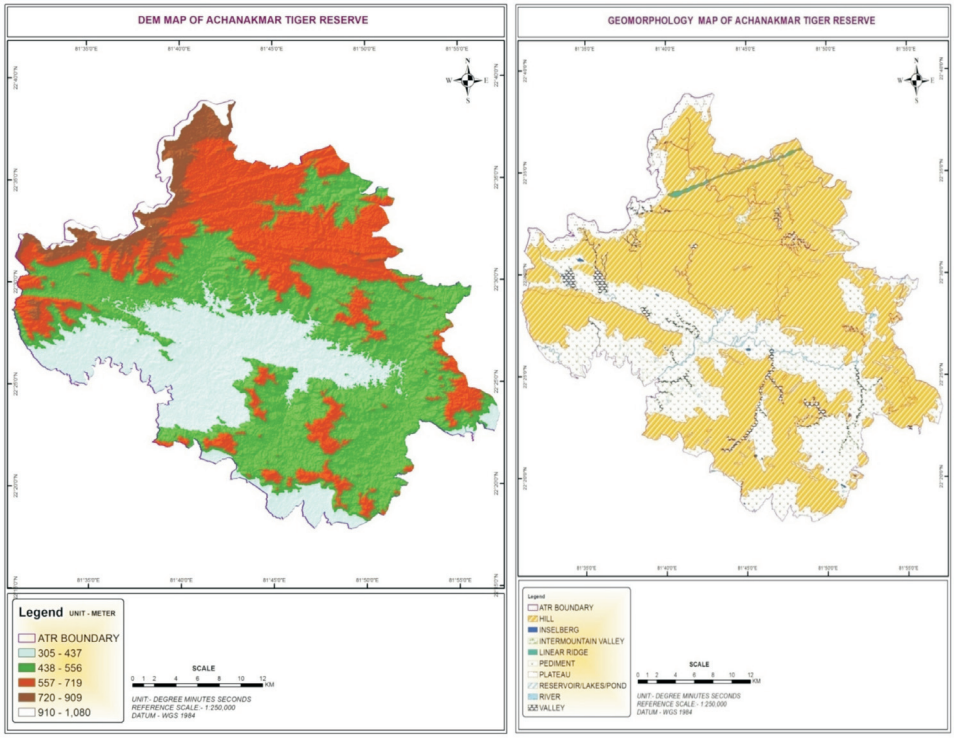
The mean sinuosity of the river shows a decreasing trend from 1.42 in 2000 to 1.35 in 2013. In 2008 the average sinuosity index was lowest with SI value of 1.21, while in 2004 and 2010 the SI was 1.28. The river Maniyari develops discrete meandering curves towards its lower reaches.

The SI for Reach 1, Reach 2 and Reach 4 shows a decreasing trend over the period of 2000 to 2013. The SI has decreased from 1.63 to 1.41, from 1.28 to 1.21 and from 1.49 to 1.40 in Reach 1, Reach 2 and Reach 4 each over a fourteen year period, while in Reach 3 the SI exhibit increasing trend with a value

**Table 1.** Dataset utilized in the study.

| Data | Path/row | Spatial resolution | Acquisition date and year | Source |
|---|---|---|---|---|
| IRS 1D, LISS 3 | 102/56 | 23.5(m) | 28th Feb 2000 | NRSC[a] |
| IRS P6, LISS 3 | 102/56 | 23.5(m) | 29th Feb 2004 | NRSC |
| IRS P6, LISS 3 | 102/56 | 23.5(m) | 03rd March 2008 | NRSC |
| IRS P6, AWiFs | 102/56 | 23.5(m) | 06th Feb 2010 | Downloaded from bhuvan |
| IRS P6, LISS 3 | 102/56 | 23.5(m) | 05th Feb 2013 | NRSC |
| Topographical Map | 64F10, 64F11, 64F14, 64F15 | 1:50,000 | 2010 | SOI[b] |

a NRSC: National Remote Sensing Centre, b SOI: Survey of India




(*Source:* District resource map (DRM) of Mungeli district, Chhattisgarh)
**Fig. 4.** Digital Elevation Map (DEM) (A) and Geomorphology map of ATR

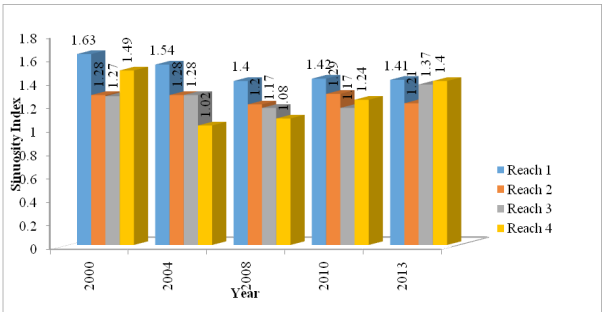



**Fig. 5.** Sinuosity index of the river Maniyari at different reach during the year 2000, 2004, 2008, 2010 and 2013


(*Source* Google earth, 2012).
**Fig. 7.** Google earth image of reach 1

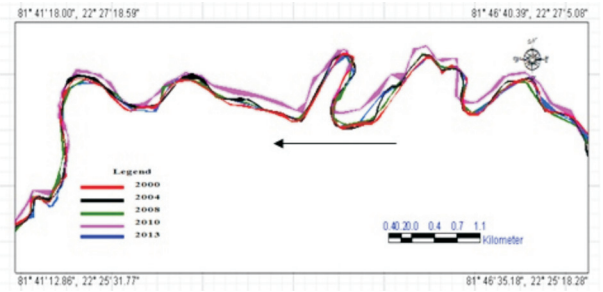



**Fig. 6.** Flow direction of Maniyari River in Reach 1

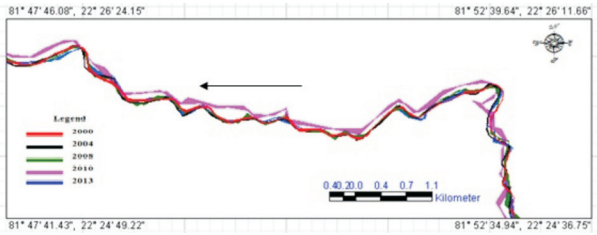
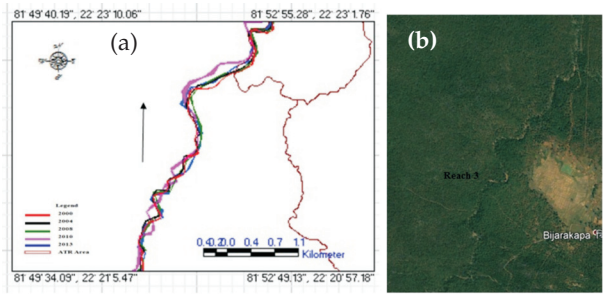



**Fig. 8.** Area captured by Maniyari River in Reach 2 during 2000-2013

of 1.27 in 2000 and 1.37 in 2013.On average, the flow was observed to be more sinuous in Reach 1 and Reach 3. The lateral migration rate increases as channel sinuosity increases (Kuang, 2011).

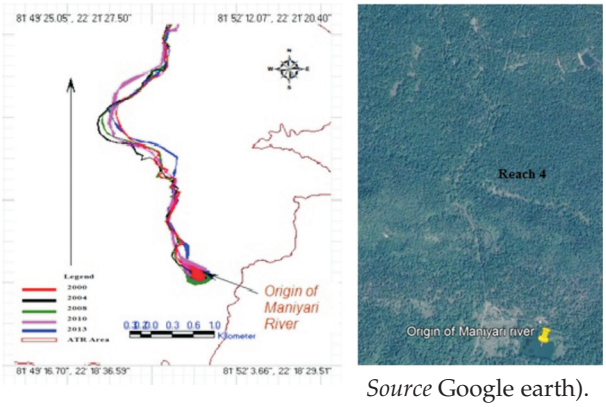

(*Source* Google earth, 2011).

**Fig. 9.** Google earth image of reach 2




*Source* Google earth, 2013).

**Fig. 10.** Areas captured in reach 3 (A) and its Google earth image (B)




*Source* Google earth).

**Fig. 11.** Flow direction of Maniyari River (A) and Google earth image (B) of Reach 4 during 2000-2013

State Highway 8 intersects the river throughout the reachs and major villages of the ATR area are within this range (Fig. 8). The Google earth image in Fig. 10 (b) depicts that reach 3 which passes through a dense vegetation canopy.

The reach 4 where the river originates is in the densely forested region. The average shift in reach 4 between 2000 and 2013 is due to rainfall that year.

## Discussion

Within the protected areas, water bodies such as rivers, streams, ponds, waterholes etc. are essential for wildlife and in India the provision of water to wildlife has been left to nature (Epaphras, 2008). The Maniyari River and its tributaries within the ATR area are also seasonal and the situation for wildlife worsens during the dry summer months. The meandering of the Maniyari River is natural and influenced by its geomorphology, riparian coverage and anthropogenic influence. Variation in rainfall, runoff and climate of an area affect the change in planform and the change in natural meander migration rates.

The spatio-temporal change detection and erosion of some major rivers has been studied and assessed by researchers (Prakash *et al*., 2016; Rawal *et al*., 2015; Das, 2012; Kotoky *et al*., 2012; and Yang *et al*., 2000) using RS & GIS technology. The present research evaluated the channel migration of Maniyari River within the Achanakmar Tiger Reserve (ATR) area.

The river has greater width and open area with sand and stony coverage at various locations. Maghsoudi *et al.* (2017) and Lindenschmidt and Carr (2018) clarified that river geomorphological features such as bed form and sediment transport are influenced by the geomorphological features of the catchment area. The flow area of Maniyari River comes under forested watershed catchment area. The presence of dense vegetation cover in the catchment area prevents heavy erosion and reduces the effects of channel displacement. Ielpi and Lapotre (2020) illustrated that the magnitude of meandering of un-vegetated rivers are faster than vegetated ones.

Vegetation also promotes good soil moisture and ground water recharge of the area. The ground thruthing reveals that few tree species grow in close vicinity of the flow line of the river. Most tree species along the river are Sal (*Shorea robusta*), Arjuna (*Terminalia arjuna*), Bamboo (*Dendrocalamus strictus*) etc. Hickin and Nanson (1975) showed that sedimentation rates in the river correlate with distance from the channel and vegetation density in the flood plain. Lightbody *et al.* (2019) and Zhu *et al.* (2018) reported that the presence of riparian vegetation reduces the sediment supply to the main channel, thereby preventing channel migration. Since the tiger reserve is the protected area with good forest


Channel showing flow of Maniyari river

View of rich riparian vegetation along the river banks

River bank showing soil erosion due to bank line shift

View of dry river during summer.

**Fig. 12.** View of Maniyari river (A-D) at different locations

cover and underground vegetation, the area near the river channel which has low ground vegetation density causes channel migration in different directions and reaches. Ielpi *et al.* (2022) studied the meandering rivers and its impact on vegetation. Their study reported that vegetation plays an important role in stabilization of meandering rivers.

Twelve villages are located along the river basin and some of them near the riparian zone which due to very sparse population density, exerts negligible anthropogenic pressure on the river and its riparian zone. The reach 2 passes through many core and buffer villages in ATR such as Achanakmar, Siwalkhar, Bijarakachhar and Bindawal. In this stretch, the channel shift was observed from south to south-west direction. The average shift of reach 1 and reach 3 shows a decreasing trend over the period 2000-2013, as the curved shapes retain their recognizable bank outline until they are filled in by subsequent sedimentation over an extended period (Toonen *et al*., 2012; Kleinhans *et al*., 2011). In contrast, high population density and increased anthropogenic activities such as bridge and embankment construction between 1990 and 2010 accelerated the water flow and meandering nature of the Ganges in Allahabad (Kumar *et al*., 2016).

When the river moves in the downstream direction from the forest, the Khudia dam is on the river outside of the ATR area that controls the river water flow downstream. The discharge water from the Khudia dam is used for agriculture. This controlled drainage of the river water prevents excess water from directly draining into the main channel, thus maintaining the flow of the river.

## Conclusion

The present study summarizes the course change of the Maniyari River within the ATR area using RS & GIS geospatial technology. As alluvial rivers erode

and deposit sediments on their banks, meanders migrate across the flood plains, causing a general shift in the channel. The west-flowing reach 1 has been observed to exhibit a meandering nature of the river Maniyari in the 2000 and 2004, while it becomes sinuous in 2008, 2010 and 2013. Reach 2 and 3, located in the central portion of the ATR shows sinuous pattern in the region. The sinuosity is high in the year 2000 at reach 4 near the origin of the Maniyari River. In 2004, an almost straight pattern with a sinuosity value of 1.02 was observed at reach 4. The overall sinuosity of the river Maniyari has decreased between 2000 and 2010, which further increased to 1.32 in 2013 due to variations in rainfall. The sinuous nature of the river is mainly due to the large channel width and lower water flow as it originates from ATR itself. It is adjoined by many streams and tributaries that are seasonal and therefore reaches maximum water levels during monsoons, resulting in channel migration. Due to the alluvial soil, the rate of soil erosion and sedimentation at meandering loops was medium, since the water force directly impact the curvatures, but rich vegetation cover prevents heavy erosion.

Rainfall is the main source of water for the Maniyari River, and fluctuations in the rate and amount of rainfall cause fluctuations in the river flow, thus affecting the dynamics and behavior of the river. In order to keep the river flow constant, anicuts and check dams must be built at various points to prevent bank line erosion. The study may be helpful for the conservation and management of the Maniyari River and its tributaries, which in turn will contribute to the conservation and proliferation of wildlife in the tiger reserve.

### Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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