ASSESSING RIVER CHANNEL MIGRATION AND BANK EROSION OF PANCHGANGA RIVER USING GEOSPATIAL TECHNIQUES

Amol P. Jarag[1]., B. S. Jadhav[2]., S. D. Shinde[3]., Vaishali Gawade[4]

[1]*Department of Geography, Shikshanmaharshi Dr. Bapuji Salunkhe College, Miraj*
[2]*Department of Geography, Vijaysinha Yadav College, Pethvadgaon*
[3]*Department of Geography, Shivaji University, Kolhapur*
[4]*Department of Geography, Vivekanand College, Kolhapur*

Abstract:

This study investigates the active change of the Panchganga River over a 30-year period, focusing on river meandering one of its key morphological characteristics. It evaluates factors responsible for the continuous transformation of the river channel, including geomorphic, climatic, and human-induced activities in the surrounding region. Using advanced Geographic Information System (GIS) and Remote Sensing (RS) techniques, multi-temporal satellite imagery from 1990 to 2020 was analyzed to detect significant changes in channel behavior. The results revealed 15 high-risk zones for erosion, with the average accretion rate being 5.93 hectares per year. The highest recorded rate was 14.16 hectares per year, while the lowest was 0.35 hectares per year. Notable lateral movement of up to 14 meters was observed in high-curvature sections due to increased water velocity, vegetation removal, and sand excavation. Temporal comparisons highlight how floods, violent water flow, and soil excavation have contributed to riverbank instability. The integration of GIS and RS technologies offers not only change detection but also valuable recommendations for controlling bank erosion and river channel shifting. These findings help fill a gap in river management literature and provide a foundation for sustainable development strategies.

Keywords: River Meandering, Bank Erosion, Channel Shifting, Geomorphic Changes, River Management

INTRODUCTION

River Meandering process is the most common morphological process that a river takes when observed over its time dependent changes. Because of this, the hydraulic, hydrologic, and topographic features characteristic of both the river and the river's surrounding drainage area most strongly shape and control the process. With meander rivers, the extension is perpetual due to erosion on the inner bank of a bend. As noted by Gilvear et al, the properties, rates, and reasons for change in the river channel are particularly important in regions where large-scale disturbance threatens built infrastructure and property. (1999). Furthermore, these features are important for the maintenance of biodiversity in vegetation communities along the river corridor (Gilvear, 1993; Marston et al. (1995), and Bravard et al. (1997). Regional activities, including sand mining, infrastructure construction along riverbanks, artificial cutoffs, bank revetment, reservoir construction, and changes in land use, have significantly altered the natural geomorphological dynamics of rivers. This transformation is evident in studies conducted by Surian (1999), Kesel (2003), Surian and Rinaldi (2003), and Batalla et al. (2004).

Rivers undergo distinct stages of development as part of the erosion cycle, progressing through youth, maturity, and old age. While the river's stage typically aligns with the surrounding topography, exceptions exist. Contrary to expectations, the stream is often less youthful in character near its mouth compared to its headwaters (Hack 1960). Initiating from a newly uplifted landmass and observing the successive changes over time, the first developmental stage of a stream is youth. In the youth stage, rivers exhibit relatively steep slopes, actively cutting their channels downward. Lateral erosion and valley widening are minimal during this phase. The cross-sectional profile of the stream takes on a V-shaped configuration with a limited or absent floodplain. This initial stage is characterized by the dynamic process of channel incision and vertical erosion as the river establishes its course.

The shifting of channel and bank erosion in the Panchganga Basin has been a major threat to the region's agricultural lands and riverine infrastructure. The dynamic river behavior causes erosion, which results in soil fertility loss and adversely affects adjacent settlements, particularly in the western part of the basin. The Panchganga River system is subject to channel degradation as a result of flooding, but it is not clear how floods contribute to channel degradation.

River bank erosion can be monitored both directly and indirectly. Field measurements of linear erosion rates, erosion volume, and cross-sections of channels are part of their direct approach. Alternatively, an indirect approach uses sediment records in conjunction with archival data to interpret archival data over a range of timescales. It consists of analyzing past data and sediments to provide a better understanding of river bank erosion over time. Understanding the processes involved in bank erosion dynamics requires both direct and indirect approaches. A comprehensive analysis of channel dynamics at large scales is well suited to satellite remote sensing techniques. The use of this technique has been widely used to study the migration of river channels and to identify palaeo-braided channels on terraces.

A number of studies have examined the geomorphic changes in channels using geospatial techniques, such as overlaying historical channel maps in several river systems (Downward, S. R., Gurnell, A. M., & Brookes, A. (1994). In India, the remote sensing data are skilfully used for monitoring the shifting of river channels, anthropogenic interventions, and activities related to changes in land use patterns. Riverside erosion continued to be a major issue each year and ravaging the banks of the Panchganga River, resulting in massive land loss. The river floods during monsoon season, washing away its banks with increased water levels and flow. In contrast, the river water level falls in winter, resulting in the formation of sandbanks along its banks. However, there is a dynamic process of erosion and deposition along the river that leads to both the loss of fertile agricultural land of the Kolhapur district and the deposition of sandbanks, which gradually shapes the landscape.

This study is mainly focused on assessing bank line movement trends over the last three decades along the Panchganga River in Kolhapur districts as well as quantifying morphological changes on both a spatial and temporal basis. Therefore, the present study not only analyses the channel migration of Panchganga River, but also attempts to understand the relationship between aggradation and degradation at different points along the river. The paper aims to comprehensively assess changes in fluvial morphology and channel dynamics of the Panchganga River, with the ultimate goal of recommending a predictive map along with protective measures for the future in the study area.

The methodology employed involves the use of time-series analysis of multi-spectral satellite images to examine the dynamic behavior of the river channels. The outcomes of this study are expected to enhance our understanding of the morphological behavior of the Panchganga River, encompassing channel shifting, erosion, and deposition. This understanding, in turn, will contribute to the formulation of predictions that can guide future protective measures in the region.

STUDY AREA

The study area, delineated in Figure 1, is situated between 16°25'–16°55'N latitude and 74°5'–74°30'E longitude. Encompassing parts of Karveer, Hatkanangle, and Shirol tahsils within Kolhapur district, the catchment area spans a total of 615 square kilometers. The region exhibits a diverse physiography marked by a complex geological structure. Geologically, it is characterized by the Deccan Trap Formation, which overlies the Kaladgi beds. The underlying Kaladgi and Dharwar group of rocks may have been exposed due to extensive erosion of the lava-beds along river valleys.

ISSN: 10123407

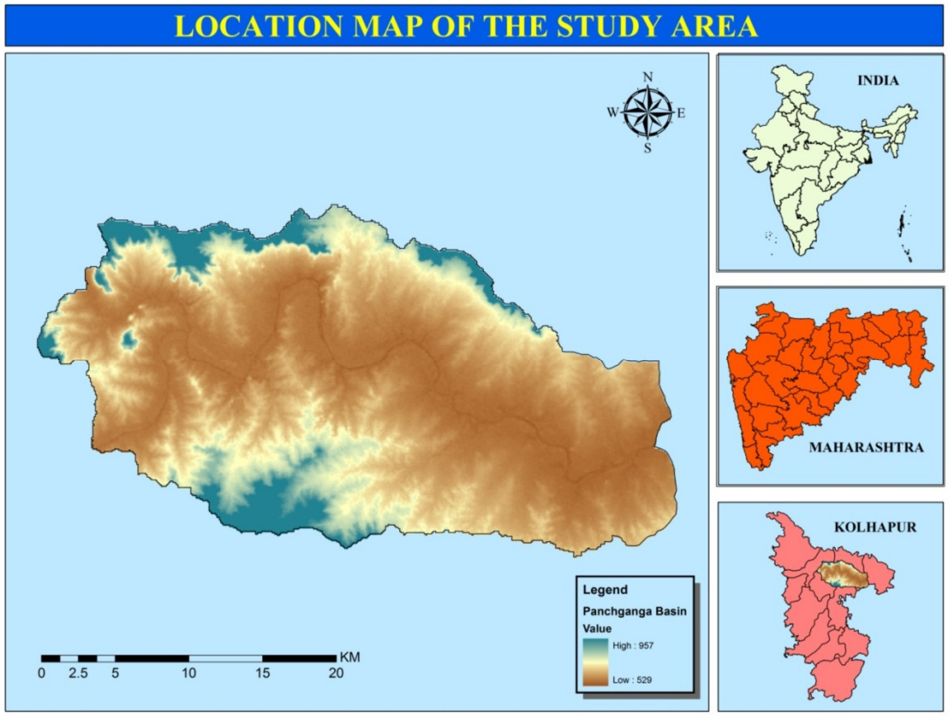


Fig.1: Location Map of Study Area

MATERIALS AND METHODS

For this research, essential data were primarily sourced through satellite image analysis. The research methodology employed in this study is analytical in nature, as it seeks to discern trends in the shifting of riverbanks, erosion, and deposition along the Panchganga River in Kolhapur districts. Both Kolhapur and Ichalkaranji cities are situated along the banks of the Panchganga River, where river bank shifting and channel migration occur rapidly, resulting in significant erosion and deposition. Secondary data consist mainly of satellite images obtained from the United States Geological Survey (USGS) website, with additional maps sourced from the Survey of India (SOI). To analyze 30 years of river bank erosion, satellite images from 1990 to 2020 were collected. Notably, the oldest image utilized is from Landsat 5 TM in the 1990s. To ensure consistency in spatial resolution and band configuration, Landsat 5 TM and Landsat 8 OLI-TIRS were selected. The tools and software employed for this study include Erdas Imagine 2014 and ArcGIS 10.8.

Table 1: The chosen satellite images provide intricate and comprehensive information.

Satellite ID	Sensor ID	Path/Row	Acquisition Date	Spatial Resolution (m)	Quality	Cloud Coverage
Landsat 5	TM	146/49	19-11-1990	30	9	1
Landsat 8	OLI &TIRS	146/49	25-10-2020	30	9	0.8

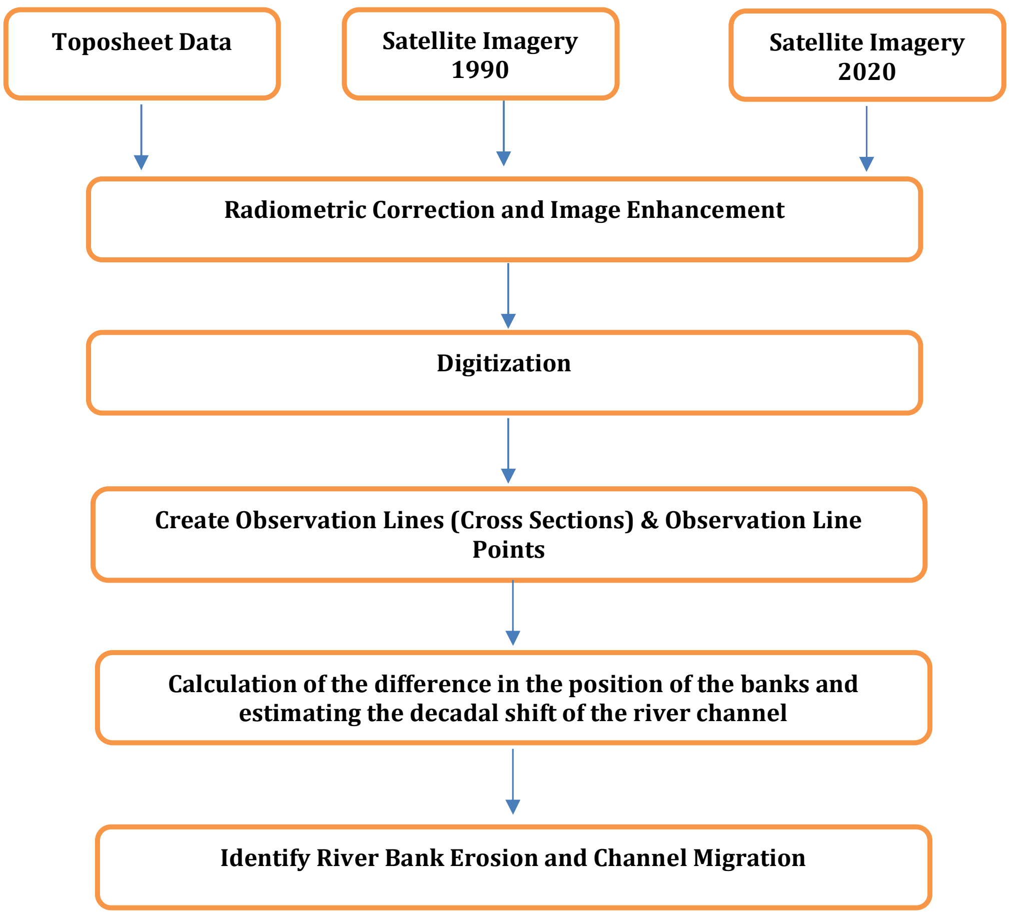
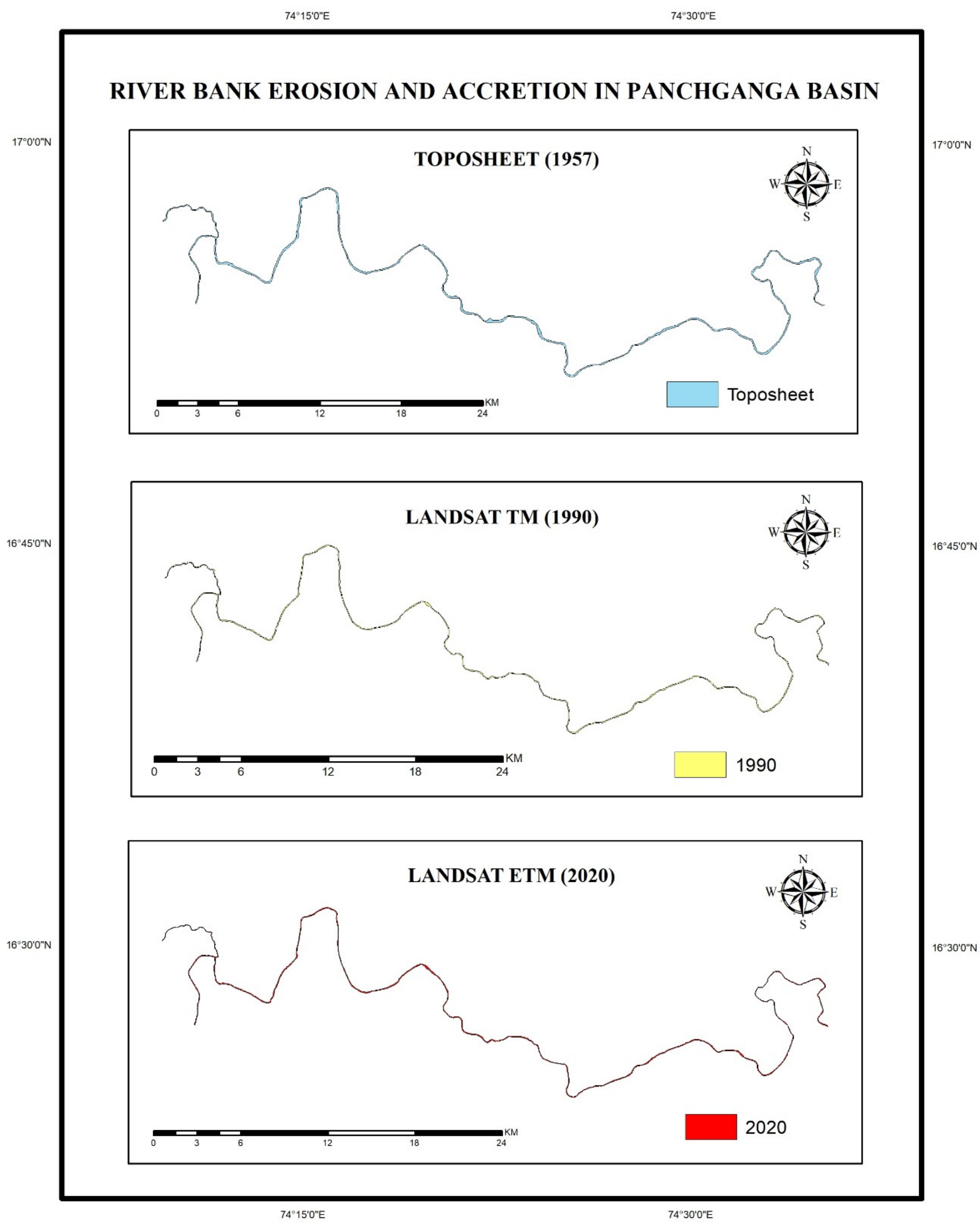


Fig.2: Research Methodology

ANALYSIS OF RIVER BANK SHIFTING

In regions characterized by a tropical wet-dry climate, rivers typically undergo a three-stage process of development: young, mature, and old. During the old stage, rivers exhibit a meandering course due to the gentle slope of the terrain. Consequently, lateral erosion and channel shifts occur within the river valley. Bank failure, defined as the separation and entrainment of bank materials in the form of grains, aggregates, or blocks, is a common phenomenon, particularly in the lower reaches of rivers. The Panchganga River, in particular, experiences frequent changes in its course. This study examines select years from the past to illustrate the dynamic shifting of the Panchganga River (Fig. 3).



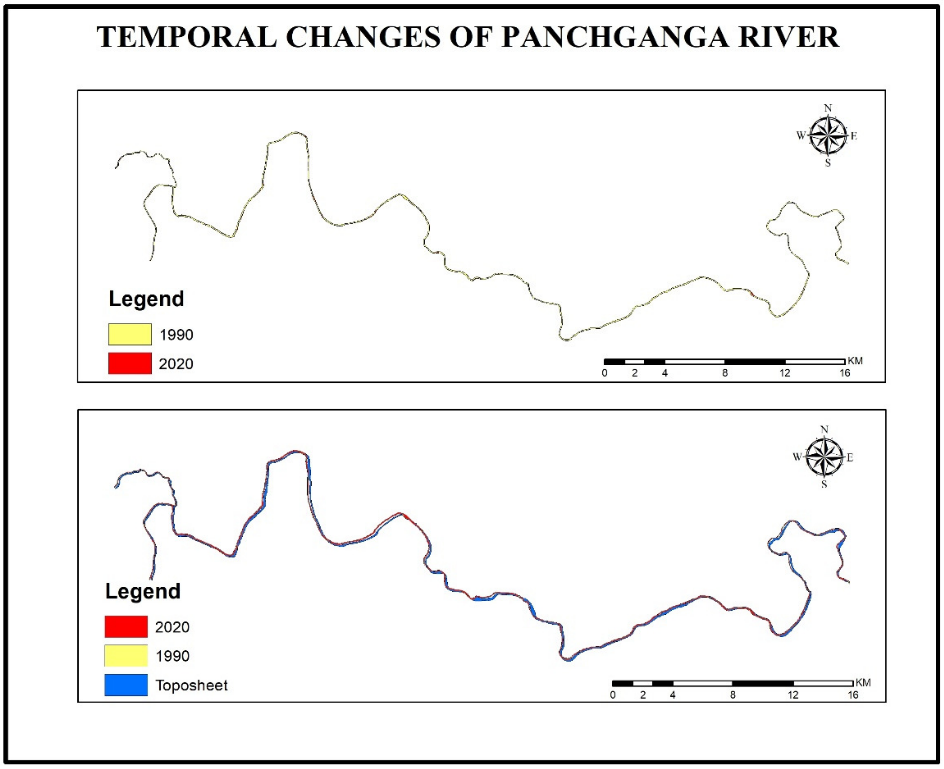


Figure 3. Temporal change of Panchganga River a Bank shifting.

The dynamic nature of the Panchganga River in our study area is a commonplace fluvio-geomorphic phenomenon observed in various river systems. To illustrate this shifting nature, a map has been constructed based on data from the years 1957, 1990, and 2020, depicting the position of the Panchganga channel. Examining Figure 3, it is evident that in 1957, the river exhibited westward movement. During this period, the upper section of the river was broad, and the middle part formed a braided channel, extending eastward. By 1990, the upper portion of the river had shifted eastward, with the flow now directed from east to west, and the channel exhibiting a narrower configuration compared to the previous structure. In the lower section, the river had developed a meandering channel pattern, and the major distributaries in the lower part had shifted westward.

Analysis of Figure 3 reveals that in 1990, the river exhibited a less meandering course compared to 2020, flowing almost straight. The upper section was more expansive than before, lacking sub-channels. In the middle portion, a sub-channel extended north eastward with braided characteristics. The lower section mirrored the upper part, with a slight alteration in the river course. Subsequently, from 1990 to 2020, the river underwent significant changes, particularly in the lower portion. The upper section widened, the middle section remained largely unchanged, and the lower portion shifted westward at a considerable angle, maintaining its braided characteristics. Overall, the analysis indicates that although the river displays braided features, it still exhibits a tendency to meander. This suggests that the river has not yet reached an equilibrium state, and future bank erosion is likely to be prominent.

IDENTIFY AND MEASUREMENT STREAM CHANNEL MIGRATION

Identifying and measuring stream channel migration involves assessing the lateral movement of a river's channel over time. This process can be crucial for understanding changes in river morphology and planning for potential impacts on the surrounding environment. An examination of river shifting patterns over the past three decades reveals a peak erosion period between 2005 and 2020, during which no mitigation measures were implemented in the area. This interval witnessed significant soil erosion in the vicinity of the riverbank. Notably, the most substantial channel shifts occurred at Cross sections 22, 23, 29, 31, 34, 41, 52, 57, 65, 71, and 74 of the Panchganga River, with the channel moving as much as 11 to 14 meters from its original path. This extensive channel migration has directly impacted the land use in the area, particularly affecting floodplain settlements.

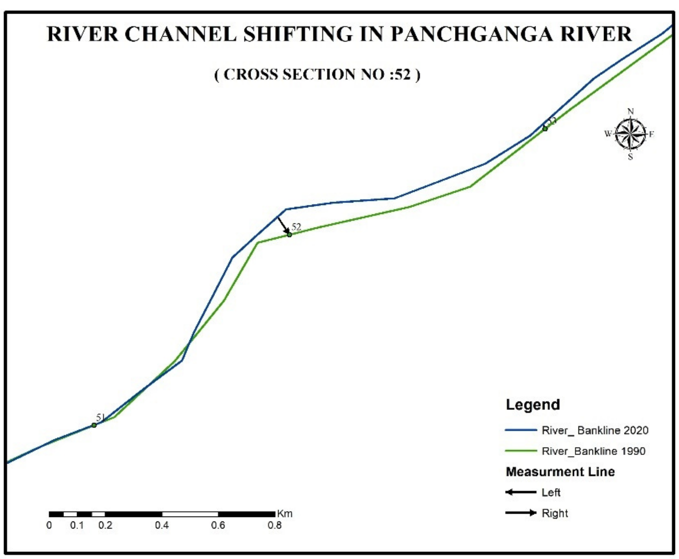
Table 2: Mapped bank erosion with shifted direction in Panchganga River

CS. No	Start Year	End Year	Direction	Shifted in meter
1	1990	2020	Right	8.47
2	1990	2020	Right	1.69
3	1990	2020	Right	2.41
4	1990	2020	Right	6.20
5	1990	2020	Right	4.92
6	1990	2020	Right	1.15
7	1990	2020	Right	7.40
8	1990	2020	Right	1.05
9	1990	2020	Right	3.95
10	1990	2020	Right	9.98
11	1990	2020	Right	6.36
12	1990	2020	Right	0.35
13	1990	2020	Right	1.94
14	1990	2020	Right	2.78
15	1990	2020	Right	0.28
16	1990	2020	Right	4.82

17	1990	2020	Left	9.67
18	1990	2020	Right	1.21
19	1990	2020	Right	1.28
20	1990	2020	Right	2.34
21	1990	2020	Right	2.37
22	1990	2020	Right	13.21
23	1990	2020	Right	10.81
24	1990	2020	Right	4.26
25	1990	2020	Right	5.43
26	1990	2020	Right	9.35
27	1990	2020	Right	2.25
28	1990	2020	Right	9.92
29	1990	2020	Left	11.80
30	1990	2020	Right	6.59
31	1990	2020	Right	11.40
32	1990	2020	Left	7.84
33	1990	2020	Right	7.29
34	1990	2020	Right	12.42
35	1990	2020	Right	7.48
36	1990	2020	Right	1.25
37	1990	2020	Right	3.69
38	1990	2020	Right	9.45
39	1990	2020	Right	2.72
40	1990	2020	Right	5.61
41	1990	2020	Right	13.50
42	1990	2020	Right	3.91
43	1990	2020	Right	5.37
44	1990	2020	Left	5.10
45	1990	2020	Left	5.13
46	1990	2020	Right	1.75
47	1990	2020	Right	8.80
48	1990	2020	Right	4.70
49	1990	2020	Right	3.48
50	1990	2020	Right	2.09
51	1990	2020	Right	1.63
52	1990	2020	Right	10.79
53	1990	2020	Right	8.34
54	1990	2020	Right	7.92
55	1990	2020	Right	7.33
56	1990	2020	Right	2.01
57	1990	2020	Left	11.03
58	1990	2020	Right	4.77
59	1990	2020	Right	9.73
60	1990	2020	Right	2.40

61	1990	2020	Right	12.65
62	1990	2020	Right	4.94
63	1990	2020	Right	3.54
64	1990	2020	Right	7.13
65	1990	2020	Left	13.64
66	1990	2020	Right	5.99
67	1990	2020	Left	5.92
68	1990	2020	Right	3.02
69	1990	2020	Left	2.95
70	1990	2020	Left	5.14
71	1990	2020	Left	12.59
72	1990	2020	Left	5.09
73	1990	2020	Right	8.22
74	1990	2020	Left	14.16
75	1990	2020	Right	4.95

A consistent trend emerges, indicating that areas with higher river curvature experience more pronounced erosion of fertile soil due to the force of active water, exacerbated by a lack of vegetation cover along the riverbank curves. Specifically, 15 risk zones have been identified in the study area, displaying rapid erosion and loss of fertile soil attributable to high water velocity in regions characterized by river curvature and insufficient vegetation cover. Field visits and photographic sampling confirm this situation.



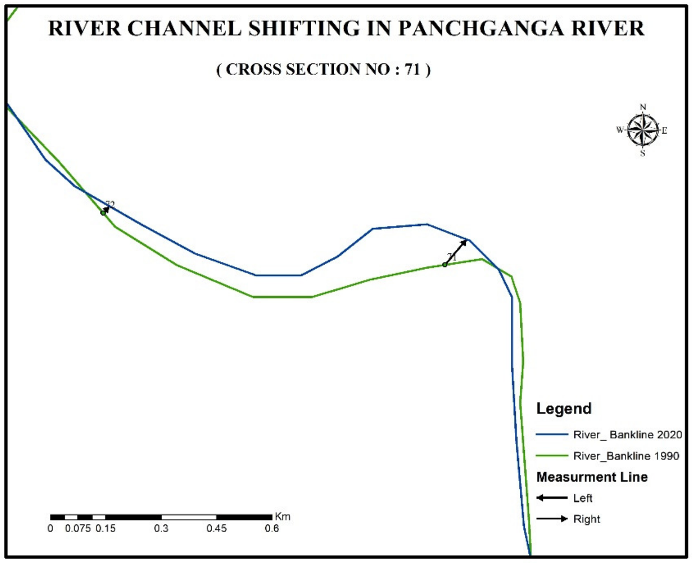


Fig.4: River Channel Shifting in Panchganga River

The results underscore the role of human activities as contributing factors to accelerated bank erosion. Practices such as sand excavation, agricultural activities within the river stream, and vegetation removal have been identified as key elements exacerbating the rate of erosion. This comprehensive analysis integrates field observations with quantitative data, shedding light on the multifaceted factors influencing river dynamics and the associated consequences on the landscape and settlements in the study area.

UNDERSTANDING THE CAUSES AND ASSESSING IMPACTS OF BANK EROSION AND SHIFTING CHANNELS

On the Earth's surface, dynamic geological forces continuously shape landscapes and associated morphologies. As a result, morphology in arid, glacier, karst, and coastal environments evolve at a slower rate than fluvial morphology (Mason 1997 Hashim et al. There is a considerable azimuth variation in the character of the Panchganga river, which originates the Deccan Trap. There are five dams near the Western Ghats in Kolhapur district that influence the river's flood dynamics, particularly during the Indian monsoon (June and July). In most cases, the river passes through plains that have fertile loamy soil structures that are susceptible to erosion. Several natural factors influence erosion, including rainfall, vegetation cover, soil stability on riverbanks, sediment composition, bedrock characteristics, relief slope features, and hydraulic conditions. As a result of other human activities, the Panchganga River has also been subjected to aggravated erosion and sedimentation. This interaction between natural evolutionary processes and anthropogenic effects illustrates the complexity of fluvial systems and their response to external influences. In order to ensure management and sustainability across the region, it is imperative to be familiar with these influences.

Rivers and the birth of civilizations It is well known that human civilizations were born when people settled on rivers, as river banks became home to many human settlements (Ashok, 2020). Involves complex interaction serving many purposes toward general well-being of organic life Since biological components directly or indirectly rely on rivers, any change in river systems would have consequences on the affected ecosystems. This study highlighted some major consequences. Applying the best practices in the field during the design stage is of paramount importance. That causes problems for dwellers because there is erosion that forms on the banks of the river, hampering the growth of plants that degrades fertile soil of high productivity and quality. Sediment transport to deeper riverbeds leads to a reduction in the level of the water, while the deposition of sand against the flow of the river has little impact. Environmental risks, like floods, become a major worry.

Moreover, the shape and form of rivers may change, leading to migration or diversification of settlements as a result of an increase in bank cutting activity. Along the banks of the creek, more valuable species are being removed, severing many of the fauna and flora from their food sources. All of these factors have important implications for human life and much of the activity reliant upon river ecosystems. It is also important to note that river meandering is also affected by variations in stream flow and the geometry of the river and its banks. In flood-prone zones, standing crops may be destroyed, highlighting the interconnected nature of river systems and their environment. Fundamentally, it alters not only the morphology of the rivers themselves, but also the morphology of their riverscapes -- which demonstrates the broader impact of human activity on the planet.

MITIGATION MEASURES FOR BANK EROSION

The study area under consideration is located in the southern part of the Panchganga river with flat topography dominated by the agriculture system and other complementary occupations because of the fertile soil and ample water. But the river course is changed, during which the banks erode; this is the main causes of loss of fertile soil, plantation clearing and so forth. In others, it will be critical that effective solutions are found now so that it does not happen again. This may be addressed through the building of embankments and tall structures, as well as the setting out of wire-creating spurs, which have been shown to assist in reducing flow velocity. Strict river training management on scientific grounds and awareness programs to local communities are important to stop the leveling up of farms near riverbanks and to reduce deforestation and improper agriculture on the river bed area.

Engineering solutions play a pivotal role in problem reduction. Bank revetment emerges as a highly effective engineering response to combat severe river bank erosion along the Panchganga River. While alternative bank protection methods are under global research, the implementation of special grass planting methods proves useful in minimizing impact and stabilizing river banks. Moreover, one alternative measure that can be taken to prevent the erosion of executive power is the establishment of walls, spaces that are heavily curved and vulnerable.

Implementing these solutions can help directly reduce the negative effects of bank erosion and contribute to a permanent solution for the local ecosystem. The incorporation of these solutions, with local awareness and inflexibility with science, provides a general framework of the sine qua non conditions for working with river dynamics of the explored area.

Conclusion

The purpose of this paper is to demonstrate how modern Geographic Information Systems (GIS) and Remote Sensing (RS) technologies may be used to identify bank erosion and detect changes in the banks. It also demonstrates how RS data, when combined with Geographic Information System (GIS) works, can assist in river studies and different assessments. The average accretion rate of 5.93 hectares per year was calculated over 30 years from 1990 to 2020. Accretion rates ranged from 0.35 hectares per year (in 1990–2020) to 14.16 hectares per year (in 2001–2020) across the study sites. The mapping results clearly show the change of the Panchganga River from its baseline channel. Additionally, the mapping analysis is able to locate hotspots of riverbank erosion usually in places near and within highly curved areas of the river, signifying that the river is in its meandering stage. Certain bends and turns of the river have extremely high rates of bank erosion. These results highlight the potential of GIS and RS methods for not just monitoring changes but also deducing significant information on geomorphic transitions of the Panchganga river within the temporal domain of the study.

REFERENCE

Batalla, R.J., Gomez, C.M. and Kondolf, G.M. (2004). Reservoir-induced hydrological changes in the Ebro River basin (NE Spain). Journal of Hydrology, 290:117–13.

Bravard, J., Amoros, C., Pautou, G., Bornette, G., Bournaud, M., Creuze Des Chatelliers, M., Gibert, J., Peiry, J., Perrin, J., Tachet, H., 1997. River incision in south-east France: morphological phenomena and ecological effects. Regulated Rivers: Research and Management 13, 75–90.

Downward, S. R., Gurnell, A. M., & Brookes, A. (1994). A methodology for quantifying river channel planform change using GIS. IAHS Publications-Series of Proceedings and Reports-Intern Assoc Hydrological Sciences, 224, 449–456.

Gilvear, D.J. (1993). River management and conservation issues on formerly braided river systems: the case of the River Tay, Scotland. Braided Rivers. In: Best, J.L., Bristow, C.S. (Eds.), Geological Special Publication 75, pp. 231– 240.

Gilvear, D.J., Winterbottom, S.J., Sichingabula, H. (1999). Character of channel planform change and meander development: Luangwa River Zambia. Earth Surface Processes and Landforms 24, 1–16.

Hack, J.T, Interpretation of Erosional Topography in Humid Temperature Regions. Am. Jour. Sci. Vol. 285A, pp. 80-97, (1960).

Kesel, R.H. (2003). Human modifications to the sediment regime of the Lower Mississippi River flood plain. Geomorphology, 56:325–334.

Marston, R.A., Girel, J., Pautou, G., Piegay, H., Bravard, P., Arneson, C. (1995). Channel metamorphosis, floodplain disturbance, and vegetation development: Ain River France. Geomorphology 13, 121–131.

Sainath P. Aher, S. I. ,2012. River Change Detection and Bank Erosion Identification using Topographical and Remote Sensing Data. International Journal of Applied Information Systems (IJAIS),7.

Sapkale, J. B. "Shifts in tarali river channel, a tributary of Krishna inpost monsoon low flow condition." Transactions. Inst. IndianGeographers 29 (1), pp 43-54, 2007

Singh, Savindra Physical Geography, Prayag Pustak Bhawan, Allahabad: 2009, p.p. 215-230 & p.p. 249-265.

Surian, N. (1999). Channel changes due to river regulation: the case of the Piave River, Italy. Earth Surf Proc Land 24:1135–1151.

Surian, N. and Rinaldi, M. (2003). Morphological response to river engineering and management in alluvial channels in Italy. Geomorphology, 50:307–326.