Uluslararası İleri Doğa Bilimleri ve Mühendislik Araştırmaları Dergisi
Sayı 9, S. 95-103, 2, 2025

Araştırma Makalesi

IJANSER
https://as-proceeding.com/index.php/ijanser
ISSN:2980-0811

International Journal of Advanced Natural Sciences and Engineering Researches
Volume 9, pp. 95-103, 2, 2025

Research Article

Impact of Urban Sprawl on River Banks-A Review of Case Studies

Saood Ahmed[1] Ishtiaq Hassan [2] and Talha Ahmed [*]

[1,2,3] Department of Civil Engineering, Capital University of Science & Technology, Pakistan

[*]*engr.talhaahmed@outlook.com*

***https://orcid.org/0000-0003-0528-0729*.**

(Received: 30 January 2025, Accepted: 03 February 2025)

(2nd International Conference on Pioneer and Innovative Studies ICPIS 2025, January 30-31, 2025)

ATIF/REFERENCE: Ahmed, S., Hassan, I. & Ahmed, T. (2025). Impact of Urban Sprawl on River Banks-A Review of Case Studies. *International Journal of Advanced Natural Sciences and Engineering Researches*, 9(2), 95-103.

***Abstract* –** Urban sprawl, characterized by the uncontrolled expansion of urban areas into rural and natural landscapes, poses a significant threat to riverbank ecosystems by disrupting hydrological cycles, increasing pollution, and accelerating soil erosion. Runoff from impervious surfaces carries sediments, heavy metals, and contaminants into rivers, degrading water quality and aquatic habitats. Urban areas can contribute up to 40% more sediment loads compared to natural landscapes, with sedimentation rates near urbanized riverbanks rising by 30%–50% due to vegetation loss. Erosion rates often double, leading to significant morphological changes and weakened riverbanks. These impacts heighten flood risks, diminish biodiversity, and compromise essential ecosystem services. This study synthesizes to evaluate urban sprawl's effects on riverbank stability, water quality, and ecosystem health, employing Geographic Information Systems (GIS), remote sensing, hydrological modeling, to analyze alterations and socio-economic consequences. Land-use classification and change detection techniques reveal how urbanization influences riverbank morphology. Findings highlight interventions like riparian buffer zones, land-use regulations, sustainable urban design, and riverbank restoration projects, alongside innovative approaches such as green infrastructure and nature-based solutions. Integrating environmental considerations into urban planning is critical for enhancing ecosystem resilience, reducing flooding risks, and ensuring river health. Collaborative efforts among policymakers, researchers, and stakeholders are vital for sustainable urban development.

Keywords – Urban Sprawl, Riverbank Ecosystems, Hydrological Cycles, Sedimentation And Erosion, Sustainable Urban Development, Nature-Based Solutions.

I. INTRODUCTION

Urban development is a pervasive form of environmental disturbance that globally threatens stream systems. Urbanization causes major changes in stream hydrology, geomorphology, water quality, and stream communities [1]. Degradation of stream ecosystems occurs at low levels of urban land cover, and a growing body of evidence suggests that the impact of urbanization is more severe than other land uses such as agriculture or forestry. The river channel dynamics research began in the early 1800's with remarkable contributions from Richard Finster Walder (1954); during this era, the river morphological study reached the zenith in the understanding of vicissitudes taking place in river banks and its cross sections, this decade envisioned around 923 items of review literature which emphasized the importance of changes in the river channel and its bed [2] Further determining drainage morphometric parameters manually was a laborious and time-consuming task; the spatial limitations provided by the mathematical and physical models decelerated the literature growth of river morphology, but in the same century, the advent of aerial photography by the French inventor Nicephore Niepce gave the required impetus for large river basin analysis, especially after the 1850 Gaspard-Felix Tourna chon aka Nadar, initially took the in-flight photograph, with the help of an inflated thermal air balloon, Nadar created the first successful airborne photograph of a French village in 1858. River morphological researchers can better understand the variables influencing the formation and evolution of drainage basins by geospatially processing data using both commercial and free Geographic Information System (GIS) tools.

Riverbanks are greatly impacted by urbanization, which greatly accelerates natural processes like erosion, collapse, and sedimentation. Roads, pavements, and buildings are examples of impermeable surfaces that frequently replace natural landscapes due to rapid urban expansion, disrupting the natural water cycle. Because water cannot penetrate the soil, this change increases surface runoff during rainfall. Greater pressure from the increased flow accelerates erosion and removes protecting soil layers from riverbanks. Furthermore, the loss of plant roots that stabilize soil due to vegetation removal for urban expansion erodes riverbanks even more. Riverbanks are more likely to collapse as a result of this deterioration, particularly during times of strong water flow or flooding. Because upstream soil erosion, deforestation, and construction debris increase sediment loads in rivers, urban activities also contribute to sedimentation. These sediments change the natural form of rivers and may obstruct waterways when they settle along riverbeds and banks. In addition to decreasing river capacity and raising the possibility of flooding, too much silt suffocates habitats and deteriorates water quality, upsetting aquatic ecosystems. The ecological balance, water management systems, and infrastructure stability are all jeopardized by the combined effects of erosion, collapse, and sedimentation. This emphasizes the necessity of sustainable urban development techniques and riverbank conservation measures [3].

II. LITERATURE REVIEW

The impact of urban sprawl on riverbank ecosystems has been extensively studied, with research focusing on its effects on hydrological processes, water quality, and the stability of riverbanks. , such as sedimentation processes, erosion dynamics, riverbank collapse, hydrological changes, ecological effects, sustainable mitigation techniques, and socioeconomic ramifications. Because urbanization increases surface runoff from impermeable surfaces like buildings and roads, erosion is greatly accelerated. Riverbanks become more vulnerable to deterioration as a result of this increased runoff and the removal of vegetation for construction [4]. The literature emphasizes how riverbank stability is changed by urban-induced erosion, especially in areas with high development density and inadequate land management. Modern river development planning and project evaluation greatly depend on good and affordable scientific instruments and methodologies for geomorphodynamic mapping and monitoring. Due to their ability to cover different regions and at different times, i.e., the spatiotemporal features using data analytical power, and data integration [5]. Geoinformation tools and techniques like remote sensing (RS) and geographical information systems (GIS) have lately developed as geomorphological aids for acknowledging the dissimilarities in rivers and their alluvial plain dynamics at the highest efficiency [6]. They offer great tools for river channel spatial analysis, visualization, data mining, storage, and processing, in contrast to conventional geomorphology inquiry methods that demand significant data gathering through field surveys and processing.

Riverbank collapse is another typical result that is usually linked to destabilization induced by humans. The weakening of riverbanks due to building near rivers, the removal of supporting vegetation, and modifications to natural water flows causes land subsidence and structural collapses. Increased sedimentation due to upstream erosion, deforestation, and urbanization is another significant cause. Excess sediments alter the shape of rivers, reduce channel capacity, and increase the risk of flooding. This sediment accumulation can smother habitats, disrupt aquatic ecosystems, and degrade water quality, all of which exacerbate environmental issues. Because urbanization increases water flow rates through runoff and drainage networks, it drastically changes hydrological patterns. These alterations exacerbate sedimentation, erosion, and riverbank instability, calling for advanced management techniques [7].

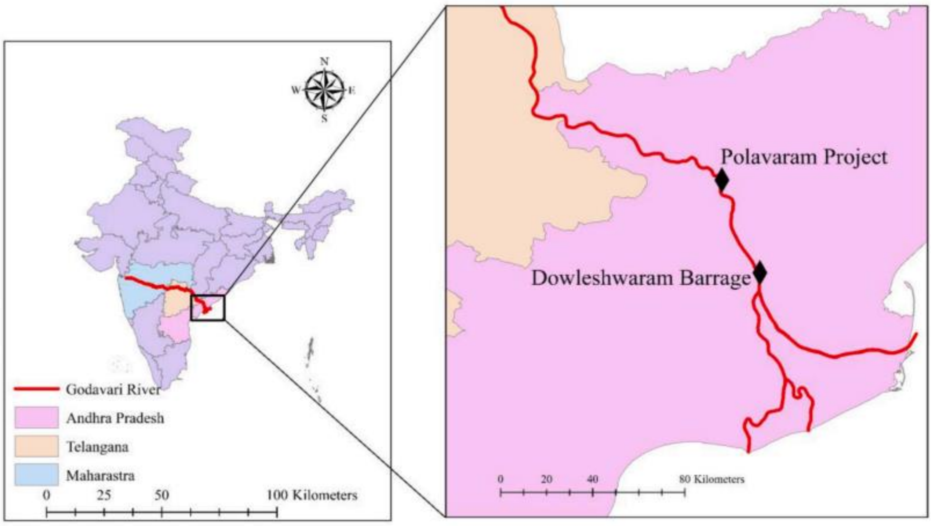

Figure 1 A location map of Godavari River on the downstream of Polavaram Project [8]

Urban and ecological facilities are seriously threatened by riverbank erosion. Remote sensing technologies are essential for monitoring riverbank conditions and enabling prompt interventions that can lessen the consequences of erosion, claim [9] stress the significance of incorporating ecological factors into urban development, arguing that efficient riverbank protection measures protect urban structures while promoting biodiversity. The analysis of drainage morphometric became straightforward, quick, and precise with the introduction of commercial and open-source GIS software. Understanding the history of remote sensing in the fluvial domain helps to put where we are and where we might be going into context. Researchers started utilizing early kinds of remote sensing during the 20th century by looking at aerial photographs to look at river morphology and the processes that drive it [10]. When the Landsat programmed was introduced in 1972, remote sensing for fluvial research quickly took off; for example, to map flood hazards [11], identify former river channels, investigate water quality and suspended sediment, and identify the interactions between rivers and vegetation [12]. Data with a resolution of 1 m were regarded as high resolution around the turn of the century, however, this is no longer the case. For applications like flood modeling, such as those made possible by advancements in aerial laser scanning (ALS), the accuracy of data obtained has been improved, and a detailed classification was made possible to study the impact of land use land cover change effects [13]. The positioning of acoustic Doppler current profiling (ADCP) and multibeam echo sounding (MBES) methods in the early 2000s led to the application of subsurface techniques previously reserved for oceanic studies on fluvial systems for research [14]. The usage of terrestrial laser scanning (TLS) in the late 2000s broke past the earlier restrictions of spatial resolution supplied by ALS and in conjunction with Mertes, although with restricted spatial extent [15]. Last but not least, the practice of using unmanned aerial vehicles (UAVs) has increased significantly in today's scenario, enabling the assortment of high-resolution images from which shortened models of the earth's surface can be generated over areas that are larger in contrast to those with TLS [16].

Rapid development of urbanization in Nanjing City, the degree of urbanization in the basin reached 59.3% in 2000. The underlying surface, river network structure, and hydrological processes changed greatly due to urban trails and construction of development zones. Water area decreased and impervious surface increased significantly. In addition, the basin encounters huge floods, and the lives of people and property are threatened when large rainstorms occur due to the limited capacity of the pipe network and river drainages and low standard of flood control and drainages. In this study, midstream and downstream river networks of Qinhuai River Basin, from Qianhan village down to the Wudingmen floodgate and Qinhuai New River floodgate were selected (Figure 1). Referring to the topographic condition of the Qinhuai River Basin and adjusting as per the Nanjing water resources planning maps, the study area was divided into 10 water conservancy districts, namely Yuntaishan, Niushoushan, Waigang River, Qinhuai New River, Qinhuai River mainstream, Zhang village, Xiangshui River, North Qinhuai River, Huchang River, and Yunliang River as shown in Figure 2 [17].

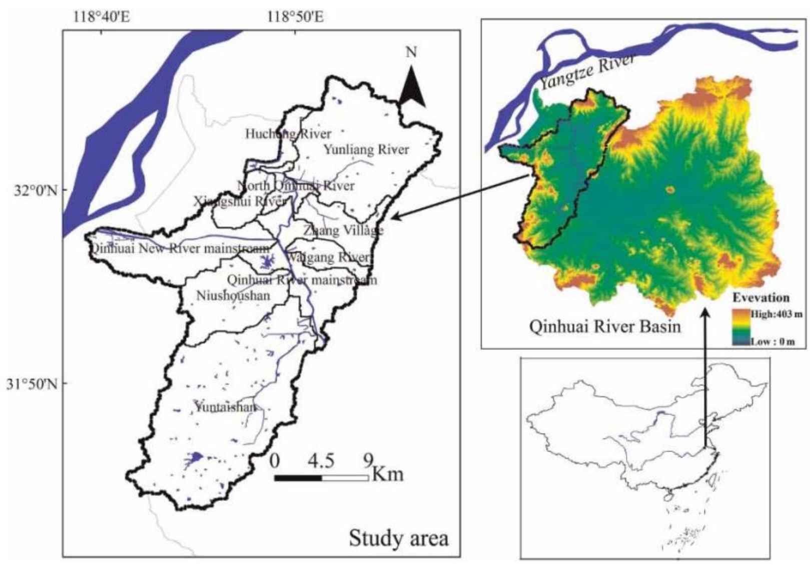

Figure 2 river networks of Qinhuai River Basin

The little increase in water surface is due to a large increase in ponds which were constructed for fish culture in the suburbs of Nanjing despite the decrease of river number and length. Spatially, the WSR decreased in the highly urbanization, but increased slightly in areas of medium and low degree of urbanization because of the constructing of ponds. Hence, except for a slight increase in Zhang village and Yuntaishan districts, both the water body area and the WSR have an overall decreasing trend from the 1980s to 2009.

Dividing the water bodies into lakes, rivers, and low-grade rivers, the lake and low-grade area decreased, while the area of main rivers increased from the 1980s to 2009, During the urbanization process, soil became less permeable to water due to building constructions. Many small water bodies were buried, gradually disappeared, and replaced by urban impervious surface. Caused by dikes, artificial lakes, and other hydraulic construction along with farming and other human activities, some small water bodies fragmented into smaller pieces, resulting in significantly reduced area of small water bodies. Among them, the most obvious area reduction of lakes occurred in Qinhuai New River district and Qinhuai River mainstream district. These apparently indicated the impacts of the high level of urbanization along the Qinhuai River [18].

III. METHODOLOGY

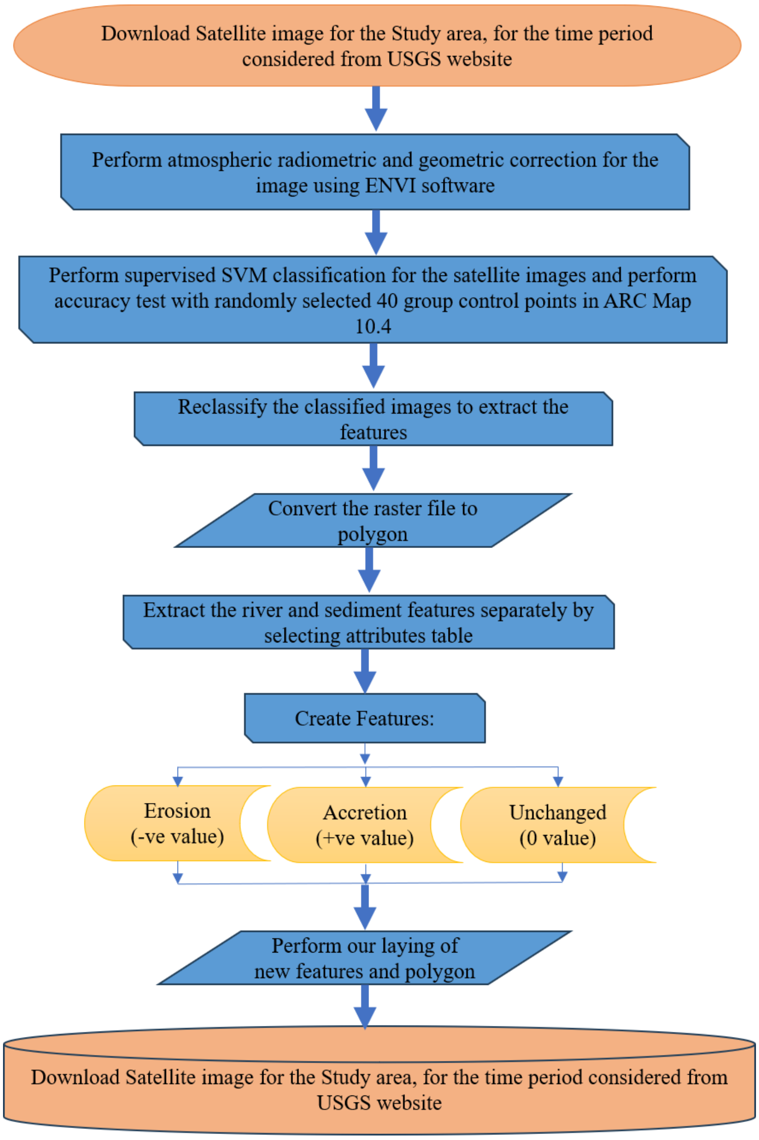

Figure 3 Methodology [19]

The activities linked with rivers; it has been shown that places with recent soil deposits have greater moisture levels than other regions close to river banks. In the recent past, the river was either running through that location, or was submerged underwater during a time of strong river flow. After the demarcation and extraction of river features, the intersection tool in ArcMap is used to find the river's shift and also the flow's intersection area between two years under comparison, as depicted in Fig. 3.

The relevant information regarding the research area was gathered from satellite pictures obtained between 1973 and 2022. The following section covers satellite image processing for information extraction. The majority of the image preprocessing was done using ERDAS Imagine version 14. Additionally, to increase classification efficiency, the Google Earth plugin was utilized during the land use classification process. The Landsat images are accurately ortho-rectified using the following parameters: I. Type of projection: Spheroid Universal Transverse Mercator (UTM) ii. iii. Path: 142 and Row: 48 iv. UTM Zone: 43 Datum: WGS 1984 A mosaic of the research region of interest has been produced using Landsat TM and Landsat-8 pictures. After then, a particular image of Google Earth was captured in comparison to the Landsat image. Using a second order polynomial and closest neighborhood resampling, each image was georeferenced with a grid size of 30 m. At least 30 m pixels have been removed from the root means square error. Maps have been used to determine the ground control points (GCPs) on Google Earth Engine and Landsat data.

Georeferenced photos from the same year were used to build a mosaic. Due to the area's close vicinity to important agricultural areas and the eastern shore, as well as the fact that it is cloud-covered for much of the year, it was not possible to get satellite photos for the same day or month of the year. The radiometry of the photos varies significantly as a result. A mosaic cannot be created that yields appropriate results if the radiometry is not balanced. Therefore, radiometric normalization was achieved using histogram equalization and matching prior to mosaicking. A good outcome is that the brightness levels of connected features are now consistent throughout the whole river basin. During mosaicking, the feather option was also used to create seamless borders between multiple photos taken in the same year[20].

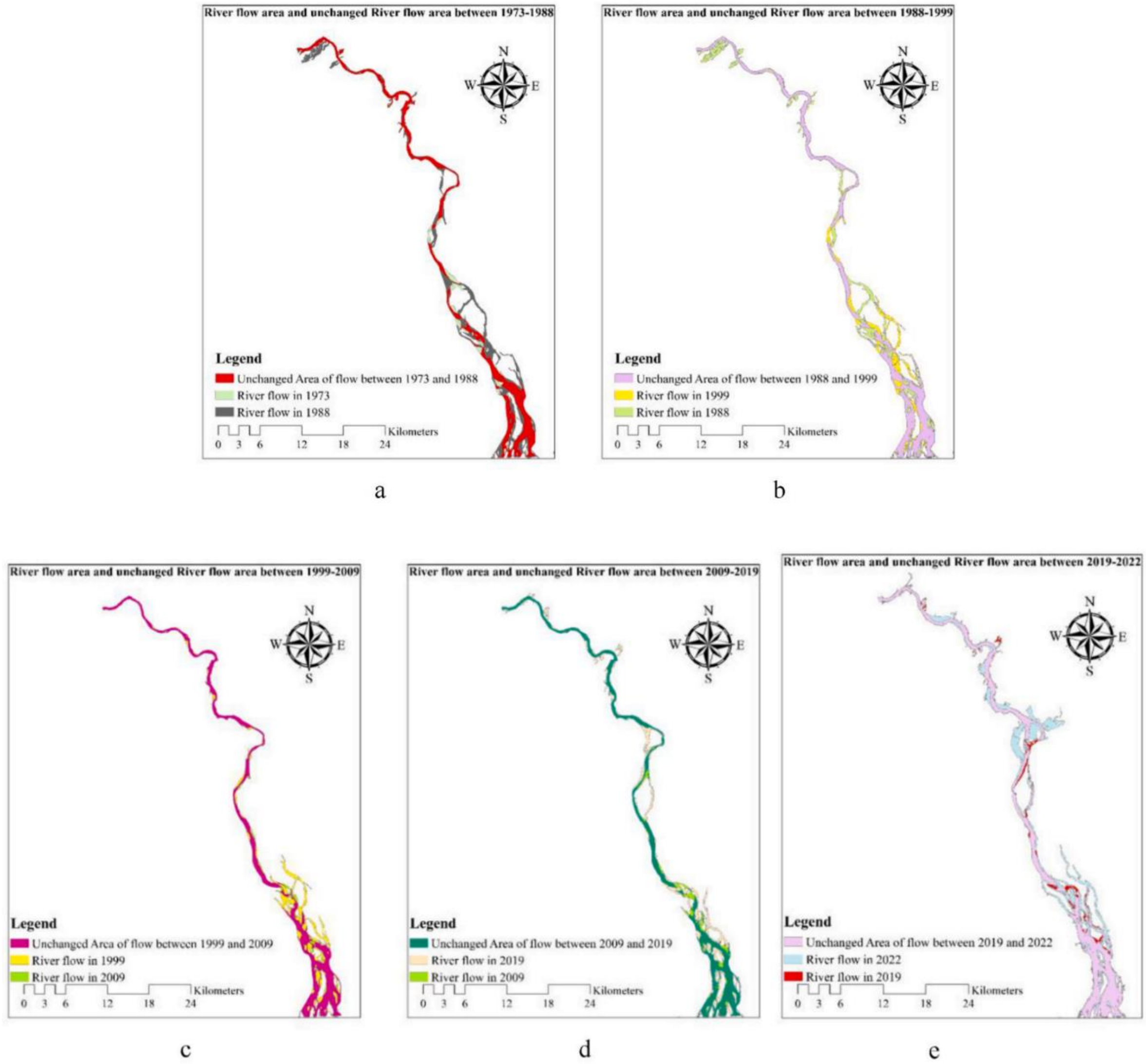

Figure 4 Erosion and accretion of Godavari River between Polavaram project and Dowleshwaram Barrage observed during the year (a) 1973–1988 (b) 1988–1999 (c) 1999–2009 (d) 2009–2019 (e) 2019–2022.[21]

The best way to properly define the various river styles that appear whenever water and sediment conveyance is split amongst numerous distinct channels is still mostly the braiding nature of the channel; for instance, braiding indicates rapid degrees of sediment transport and indigenous sediment loading in the river channel, while the planform is analytical of the sort of channel processes prevalent in the river system at that point. Like many rivers, the Godavari has a densely meandering planform situated among vast floodplains and is more ecologically sensitive due to the topography and ecosystem it flows within. Braiding ensues when the sediment deposit supply exceeds the transport ability of a river or when transport proportions are naturally very high, which is also influenced by geological phenomena occurring due to accretion and erosion. The erosion and accretion of the river is deliberated using conversion of the classified raster images to polygon features, then the unchanged area is calculated using the intersection tool in the ArcMap, as presented in Fig. 4.

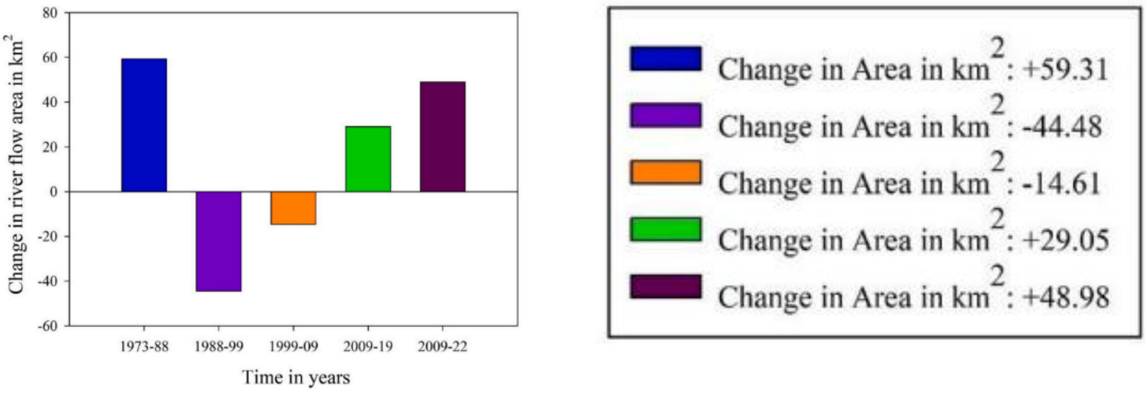

Figure 5 Change in river flow area in km2 [22]

The graph (Fig. 5) illustrates detailed changes in river flow area (in km²) over time, highlighting fluctuations similar to those in Fig. 4. It shows significant reductions during 1988–99 and 1999–09, with notable increases during 1973–88 and 2009–22, emphasizing temporal variations in river morphology and flow dynamics.

Landsat images:

i. Projection type: Universal Transverse Mercator (UTM) Spheroid
ii. Datum: WGS 1984
iii. Path: 142 and Row: 48
iv. UTM Zone: 4

Table 1. Sources of data procurement [23].

Data	Path/Row	Resolution	Data	Source
Landsat MSS	142/048	60 m	1973	Earth Explorer(usgs.gov)
Landsat TM	142/048	30 m	1988	Earth Explorer(usgs.gov)
Landsat ETM+	142/048	30 m	1999	Earth Explorer(usgs.gov)
Landsat ETM+	142/048	30 m	2009	Earth Explorer(usgs.gov)
Landsat OLI	142/048	30 m	2019	Earth Explorer(usgs.gov)
Landsat OLI	142/048	30 m	2022	Earth Explorer(usgs.gov)

USGS=United States Geological Survey, Landsat MSS= Landsat Multi-spectral Scanner System (MSS), Landsat TM = Landsat Thematic Mapper (TM), Landsat ETM+ = Landsat Enhanced Thematic Mapper Plus (ETM+), Landsat OLI=Landsat Operational Land Imager (OLI).

The Godavari River basin spans 312,812 sq km, with Maharashtra covering 48.6% , followed by Telangana (18.8%), Chhattisgarh (11%), Odisha (5.7%), Andhra Pradesh (4.5%), and Karnataka (1.5%). Agricultural land dominates the basin, accounting for approximately 59.57% of the total area, while water bodies cover just 3.6%. The research methodology involved analyzing six Landsat images across six decades (1973, 1988, 1999, 2009, 2019, and 2022) to track landscape and hydrological transformations in the river basin. Table 1.

IV. DISCUSSION

The discussion highlights the significant impact of urbanization on riverbank ecosystems and hydrological dynamics, as demonstrated by the case studies of the Godavari River basin and urbanized regions like the Qinhuai River Basin. Urban development has been a major driver of riverbank instability, with impermeable surfaces replacing natural landscapes, leading to increased surface runoff, erosion, sedimentation, and changes in hydrological patterns. The Godavari River exhibits dynamic morphological changes over decades, with fluctuations in river flow area linked to sediment deposition and erosion, as observed in satellite images spanning 1973 to 2022. Advanced geospatial tools like GIS and remote sensing have proven essential for analyzing these spatiotemporal changes, offering insights into sediment transport, erosion dynamics, and land use impacts. The Godavari's braided nature reflects its high sediment transport capacity, while the loss of water bodies and increased urbanization, as seen in the Qinhuai Basin, emphasize the urgency of sustainable management practices. The findings underscore the importance of integrating remote sensing technologies with ecological and urban planning to mitigate riverbank degradation and promote sustainable development.

V. CONCLUSION

The analysis of six decades of Landsat images highlights significant changes in the Godavari River basin and inhuai Basin due to urbanization, agricultural expansion, and natural processes. The basin's hydrology and morphology experienced marked transformations, including shifts in river flow area, erosion, accretion, and sedimentation dynamics. Urbanization has accelerated the replacement of permeable surfaces with impervious ones, increasing surface runoff, sedimentation, and riverbank instability. Advanced remote sensing tools like Landsat imagery and GIS-based methodologies enabled precise mapping of temporal and spatial changes, particularly in erosion and accretion patterns between Polavaram and Dowleshwaram. These findings emphasize the urgent need for sustainable land-use practices, effective river management strategies, and integration of modern geoinformation technologies to mitigate the ecological and hydrological impacts of urbanization on river systems.

REFERENCES

[1] Baer, S.A., & Pringle, C.M., "Urban development impacts on stream ecosystems: Hydrology, geomorphology, and ecological transformations," Environmental Science & Technology, vol. 34, no. 5, pp. 123-135, 2000.

[2] A. Anish, K.R. Baiju, P.K. Thomas, M. Anns, P.B. R, and S. Babu, "Status of GIS enabled morphometric analysis of river basins of Kerala, Southern India: a review and assessment," Reg. Stud. Mar. Sci., vol. 44, pp. 101792, 2021.

[3] S. Ghimire and D. Higaki, "Dynamic river morphology due to land use change and erosion mitigation measures in a degrading catchment in the Siwalik Hills, Nepal," Taylor & Francis, vol. 13, no. 1, pp. 27-39, 2015.

[4] Z. Yao, W. Ta, X. Jia, and J. Xiao, "Bank erosion and accretion along the Ningxia–Inner Mongolia reaches of the Yellow River from 1958 to 2008," Geomorphology, vol. 127, no. 1-2, pp. 99-106, 2011.

[5] A. Singh, R. Kumar, and S. Mehta, "Urbanization and Environmental Impacts," Environ. Res. Lett., vol. 17, no. 2, pp. 245-260, Jun. 2022.

[6] J. Walsh and C. Nittrouer, "River Dynamics and Sedimentary Processes," in Coastal Environments, vol. 1, City, Country: Publisher, 2009.

[7] W. A. Fairbairn, "Erosion in the River Findhorn valley," Taylor & Francis Group, vol. 83, no. 1, pp. 46-52, 2008.

[8] S. Anish et al., "Status of GIS enabled morphometric analysis of river basins of Kerala, Southern India: a review and assessment," Reg. Stud. Mar. Sci., vol. 44, pp. 101792, 2021.

[9] S. Ghimire and D. Higaki, "Dynamic river morphology due to land use change and erosion mitigation measures in a degrading catchment in the Siwalik Hills, Nepal," Taylor & Francis, vol. 13, no. 1, pp. 27-39, 2015.

[10] G. Chander, B. L. Markham, and D. L. Helder, "Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors," Remote Sens. Environ., 2009.

[11] A. Rango and A. T. Anderson, "Flood hazard studies in the Mississippi river basin using remote sensing," J. Am. Water Res. Assoc., vol. 10, no. 5, pp. 1060-1081, 1974.

[12] Salo, J., Kalliola, R., H¨ akkinen, I., Makinen, ¨ Y., Niemela, ¨ P., Puhakka, M., Coley, P.D., 1986. River dynamics and the diversity of Amazon lowland forest. Nature 322 (6076), 254–258. https://doi.org/10.1038/322254a0. 1986 322:6076, Nature Publishing Group.

[13] Z. H. Bowen, K. D. Bovee, and T. J. Waddle, "Effects of flow regulation on shallow-water habitat dynamics and floodplain connectivity," Wiley, vol. 132, no. 4, pp. 809-823, 2011.

[14] J. D. Creutin, M. Muste, A. A. Bradley, S. C. Kim, and A. Kruger, "River gauging using PIV techniques: a proof-of-concept experiment on the Iowa River," J. Hydrol., vol. 277, no. 3-4, pp. 182-194, 2003.

[15] G. L. Heritage and D. Hetherington, "Towards a protocol for laser scanning in fluvial geomorphology," Earth Surf. Process. Landforms, vol. 32, no. 1, pp. 66-74, 2007.

[16] M. A. Fonstad, J. T. Dietrich, B. C. Courville, J. L. Jensen, and P. E. Carbonneau, "Topographic structure from motion: a new development in photogrammetric measurement," Earth Surf. Process. Landforms, vol. 38, no. 4, pp. 421-430, 2013.

[17] G. M. Foody and A. Mathur, "A relative evaluation of multiclass image classification by support vector machines," IEEE Trans. Geosci. Remote Sens., vol. 42, no. 6, pp. 1335-1343, 2004.

[18] X. Wang, L. Mei, and Z. Chen, "Impacts of Urbanization on River System Structure: A Case Study on Qinhuai River Basin, Yangtze River Delta," Water Science and Technology, vol. X, no. Y, pp. XX-XX, Year.

[19] G. L. Heritage and D. Hetherington, "Towards a protocol for laser scanning in fluvial geomorphology," Earth Surf. Process. Landforms, vol. 32, no. 1, pp. 66-74, 2007.

[20] T. S. U. Holtz, "Introductory digital image processing: a remote sensing perspective," Environ. Eng. Geosci., vol. 13, no. 1, pp. 89-90, 2007.

[21] S. Zoysa, V. Basnayake, J. T. Samarasinghe, M. B. Gunathilake, K. Kantamaneni, N. Muttil, et al., "Analysis of multi-temporal shoreline changes due to a harbor using remote sensing data and GIS techniques," Sustainability, vol. 15, no. 9, pp. 7651, 2023.

[22] S. Zoysa, V. Basnayake, J. T. Samarasinghe, M. B. Gunathilake, K. Kantamaneni, N. Muttil, et al., "Analysis of multi-temporal shoreline changes due to a harbor using remote sensing data and GIS techniques," Sustainability, vol. 15, no. 9, pp. 7651, 2023.

[23] S. Ghimire and D. Higaki, "Dynamic river morphology due to land use change and erosion mitigation measures in a degrading catchment in the Siwalik Hills, Nepal," Taylor & Francis, vol. 13, no. 1, pp. 27-39, 2015