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Assessing Disappearance and Degradation of Water Bodies in Sarayan Watershed: A Remote Sensing-Based Temporal Analysis

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Abstract

This study uses remote sensing and GIS tools to evaluate temporal changes in surface water bodies in the Sarayan Watershed from 1974 to 2024. Over the last five decades, the number of water bodies in the watershed has dropped dramatically—from 833 in 1974 to only 309 in 2024, a 62.9% decrease. Similarly, the overall area under water bodies has decreased by 32.5%, with several notable tals, such Ludhaura, Lohara, and Bhinsara, completely disappearing. This concerning trend is linked to urbanization, agricultural development, groundwater extraction, sedimentation, and climate variability. Spatial research demonstrates growing fragmentation, with water bodies concentrating around natural depressions and river networks. The reduction has had a substantial impact on groundwater recharge, flood regulation, local agriculture, biodiversity, and microclimates. Seasonal and small-scale water bodies, which were formerly critical to rural livelihoods and ecological equilibrium, have declined or disappeared. These findings highlight the critical need for integrated watershed management, the restoration of traditional water bodies, and legislative interventions to prevent future degradation. The study provides useful information for environmental planners, regulators, and water resource managers working to ensure long-term water conservation in the region.

Keywords

Water body reduction, Sarayan Watershed, remote sensing, GIS, land use change, climate impact, groundwater recharge, spatial analysis, temporal change, watershed degradation.

1. Introduction

Water is one of the most vital natural resources that support life, sustains biodiversity, and promotes socio-economic development. It plays a crucial role in agricultural production, industrial processes, and ecosystem regulation [1]. In India, rapid population growth, urbanization, and erratic rainfall patterns have put tremendous pressure on existing water resources [2]. Watersheds serve as important hydrological units for the sustainable management and conservation of these resources [3]. The Sarayan Watershed, located in the Sitapur district of Uttar Pradesh, has been experiencing significant land use and hydrological changes due to both natural and anthropogenic drivers. These changes have resulted in the alteration of water bodies, leading to concerns about the long-term sustainability of regional water resources. Studying such changes using geospatial tools provides valuable insights into the dynamic nature of water bodies and helps in formulating sustainable water management strategies. Water bodies such as rivers, lakes, wetlands, ponds, and reservoirs are integral components of the hydrological cycle and contribute significantly to maintaining ecological balance. They support groundwater recharge, act as flood buffers, serve as habitats for aquatic biodiversity, and support agriculture and drinking water supplies [4]. Besides their ecological importance, they also hold economic, social, and cultural values in India [5]. Unfortunately, many of these water bodies are under threat due to encroachment, pollution, excessive withdrawal, and climate variability [6]. Systematic monitoring of these resources is therefore essential for their sustainable management. Recent advancements in geospatial technologies, particularly Remote Sensing (RS) and Geographic Information Systems (GIS), have significantly enhanced the capacity for spatial and temporal analysis of natural resources. Remote sensing enables the collection of repetitive, synoptic, and multispectral data over large areas, which is crucial for monitoring changes in land and water resources [7]. GIS allows for the integration, visualization, and analysis of spatial data from multiple sources, making it an effective tool for water resource management and decision-making [8]. Numerous studies have demonstrated the effectiveness of RS and GIS in detecting changes in water body extent using indices like the Normalized Difference Water Index (NDWI) and Modified NDWI [9], [10]. The Sarayan River originates in the Shahjahanpur district and traverses through Sitapur before joining the Gomti River in Uttar Pradesh. The watershed lies between latitudes 27°15'N to 27°55'N and longitudes 80°30'E to 81°10'E, covering an area of approximately 2,500 km^2 [11]. It falls within the Indo-Gangetic Plains and experiences a subtropical climate with annual rainfall ranging from 1000 to 1200 mm, predominantly during the monsoon. Agriculture is the dominant land use, and water bodies within the watershed are essential for irrigation, fisheries, and local water supply. However, in recent years, the number and spatial extent of these water bodies have declined due to land use changes, groundwater exploitation, and sedimentation, making it imperative to undertake temporal assessments. Watershed management refers to the sustainable planning, development, and conservation of land and water resources within a watershed to achieve ecological and economic benefits [12]. The concept involves a multi-disciplinary approach encompassing hydrology, soil conservation, forestry, and environmental sciences. The Indian government, through various programs such as the Integrated Watershed Management Programme (IWMP), has emphasized scientific watershed planning [13]. RS and GIS tools have proven effective in delineating watersheds, identifying micro-watersheds, monitoring land and water changes, and prioritizing areas for conservation [14]. The primary objective of this study is to analyse the spatial and temporal changes in water bodies in the Sarayan Watershed using remote sensing and GIS techniques. The study seeks to map the water bodies, detect changes across different time periods, and generate thematic layers for decision support. The findings are intended to inform planners, policymakers, and local stakeholders about the status and trends in water body distribution, thereby contributing to more effective watershed management.

2. Study Area Description

2.1. Location and Geographical Extent

The Sarayan Watershed is located in the northern part of Uttar Pradesh, covering Lakhimpur Kheri and Sitapur districts. The Sarayan River, a left-bank tributary of the Gomti River, originates near Gola Gokaran Nath in Lakhimpur Kheri and flows southward approximately 170 km before joining the Gomti River near Kaintain Village in Sidhauli Tehsil, Sitapur [15]. The watershed extends between 27°11′N to 28°06′N latitude and 80°25′E to 80°52′E longitude, covering an area of about 3,800 km².

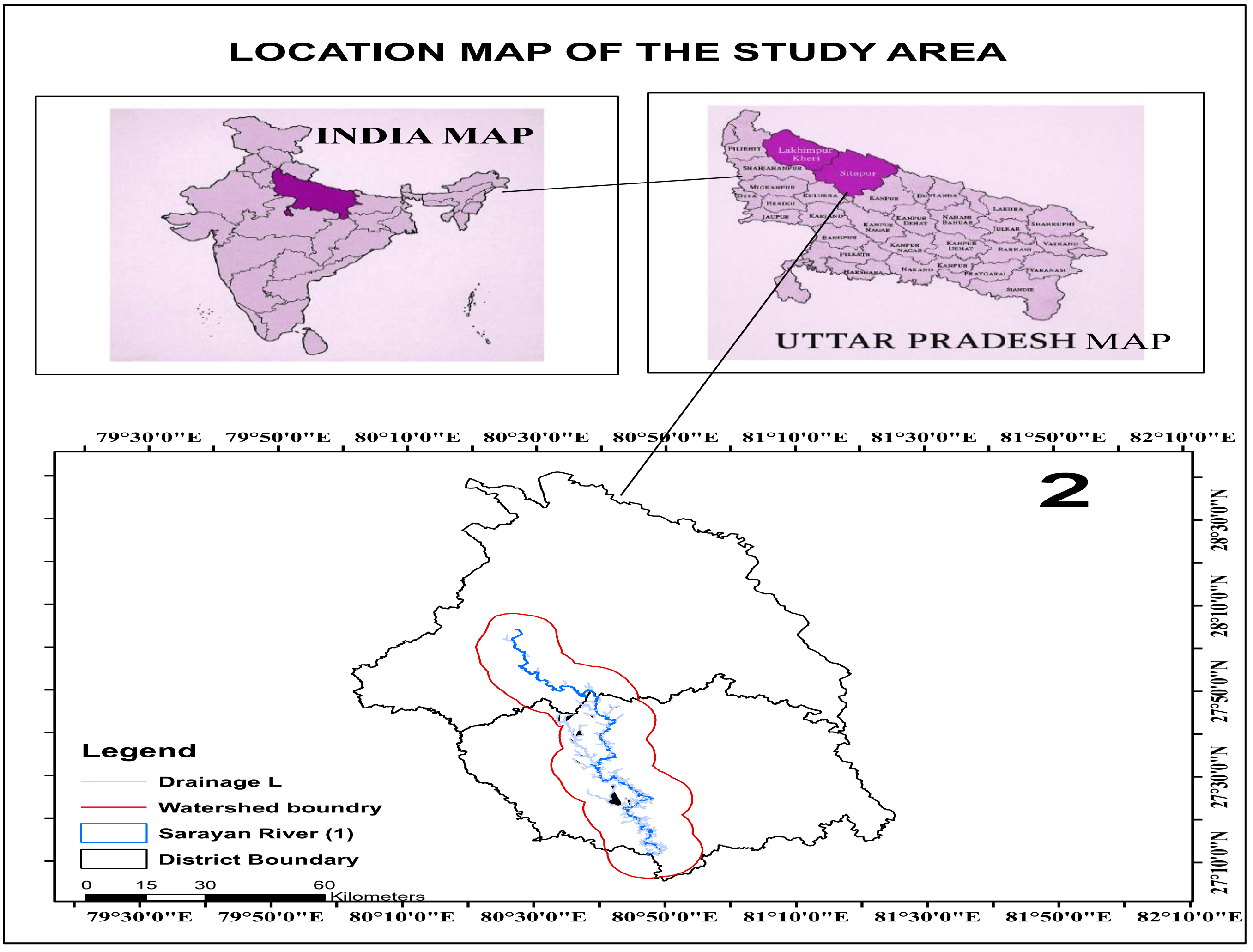

Figure 1. Location map of Study Area showing Sarayan Watershed

2.2. Physiography and Topography

The Sarayan River situated in the Indo-Gangetic Plains, the watershed comprises alluvial deposits shaped by Himalayan River systems [16]. The terrain is mostly flat to gently undulating with elevations ranging between 120 and 150 m above mean sea level [17]. The general slope is northwest to southeast, consistent with the flow direction of the Sarayan and its tributaries. This physiography supports dendritic drainage patterns and intensive agriculture, but low-relief zones are prone to seasonal waterlogging and flooding during monsoons due to poor drainage and human interventions such as embankments and roads [18].

2.3. Geology and Soil Characteristics

The region consists of Quaternary alluvial sediments with alternating layers of sand, silt, clay, and gravel, forming fertile soils suitable for agriculture [19]. The dominant soil types include loam and sandy loam in upland areas and clay loam in low-lying poorly drained zones. These soils support crops such as wheat, rice, sugarcane, and pulses but are susceptible to sheet erosion, especially on bare or degraded land [20].

2.4. Climate

The subtropical climate consists of three distinct seasons: hot and dry summers (March–June) with temperatures exceeding 45°C; monsoon (July–September) delivering 900–1,200 mm rainfall, accounting for 80–90% of annual precipitation; and mild, dry winters (October–February) with limited rainfall from western disturbances [21], [22]. Rainfall variability, including delayed monsoon onset and dry spells, affects water availability, agriculture, and resource management [23], [24].

2.5. Hydrology and Drainage

The watershed features a dendritic drainage pattern typical of homogeneous lithology and gentle slopes [25]. The Sarayan River, supported by tributaries such as the Gond River, Jamwari Nala, and Kalyani River, exhibits seasonal and perennial flows. The Gond and Jamwari mainly flow during monsoon, while Kalyani maintains base flow via local aquifers and check dams. Surface water peaks during monsoons and declines in dry seasons, with ponds and tanks supplementing water needs. GIS-based studies highlight spatiotemporal variability in drainage density, flood potential, and water availability [26].

2.6. Geomorphology

Floodplains, paleo-channels, and natural levees highlight the dynamic geomorphology. Historical shifts in river courses are evident from meander scars and oxbow lakes. Remote sensing techniques are essential for identifying these features and understanding terrain dynamics.

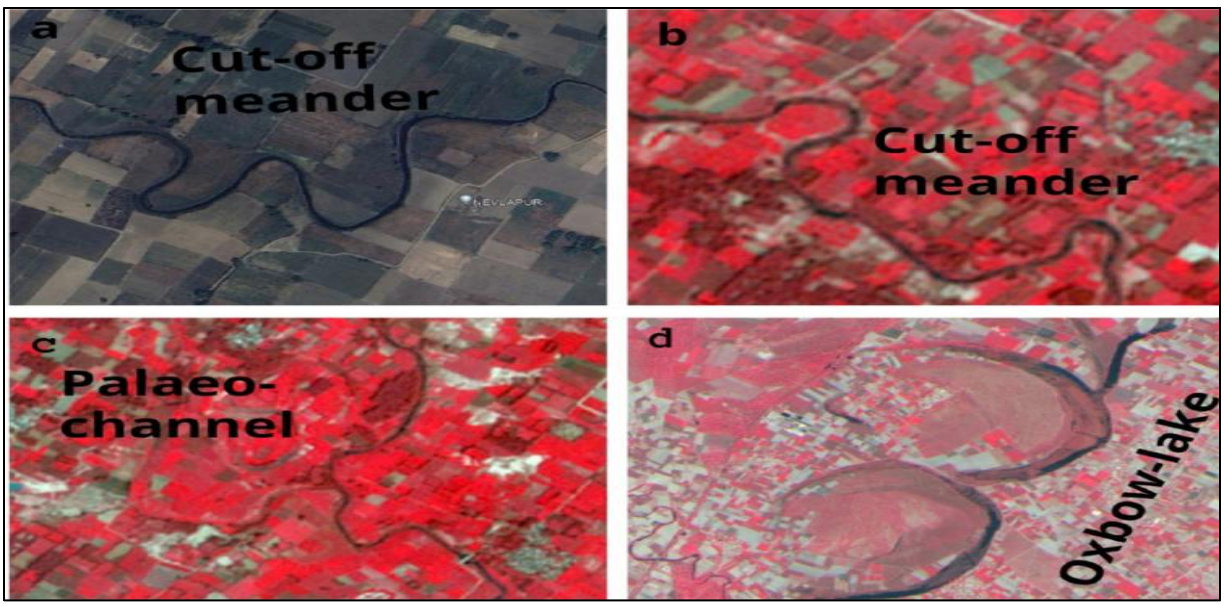

Figure 2. Various geomorphic features shown by the river: (a) cut–o meander, (b) cut–o meander, (c) palaeo–channel, (d) oxbow lake.

2.7. Land Use and Land Cover

Land use arises from human utilization of land for activities like agriculture, housing, and industry, influenced by both its purpose and natural characteristics [27]. Tropical ecosystems face degradation due to pollution from agriculture and industry, especially in developing countries where population pressure worsens the impact [28]. Land cover refers to physical and biological surface features, while land use relates to human functions and economic activities on the land [29]. Though often used interchangeably, land cover is observable through remote sensing, whereas land use requires social and environmental analysis [30]. Changes in land use and land cover (LULC) are a major type of global environmental change, reflecting both natural and human forces [31]. These changes indicate not just ecological shifts but also socio-economic dynamics and human–environment interactions [32], often driven by climate and resource availability [33].

Over 75% of the area is used for agriculture, cultivating rice, wheat, and sugarcane Urban development and land use changes have reduced natural water bodies, while siltation and encroachment pose threats [34].

2.8. Significance of the Study Area

The Sarayan Watershed represents a typical riverine Indo-Gangetic landscape, with high agricultural dependence. Mapping water bodies using remote sensing and GIS is vital for sustainable water management, disaster mitigation, and climate adaptation.

3. Methodology

In this study the ancillary and satellite data was collected for which twelve Survey of India toposheets (62 D/8, 62 D/12, 63 A/5, 63 A/6, 63 A/8, 63 A/9, 63 A/10, 63 A/11, 63 A/13, 63 A/14, 63 A/15, and 63 A/16) were selected to cover the entire Sarayan Watershed and satellite data was downloaded from Copernicus website. The methodology utilized Remote Sensing and GIS techniques in a systematic way. “Georeferencing” was conducted in the Projected Coordinate System (WGS 84, UTM Zone 44N) to ensure that spatial alignment was accurate. In ArcMap 10.4.1, mosaicking was done for all the sheets to produce a single georeferenced composite layer. Water bodies such as rivers, ponds, tanks, and wetlands were manually digitized from both historical maps and recent satellite images to create vector shapefiles. Sentinel-2 satellite data from April 2024 was used, and indices like NDWI and MNDWI were applied to enhance water feature detection. The methodology made systematic use of GIS and remote sensing techniques. To guarantee precise spatial alignment, "georeferencing" was done in the Projected Coordinate System (WGS 84, UTM Zone 44N). All of the sheets in ArcMap 10.4.1 underwent mosaicking in order to create a single georeferenced composite layer.

4. Result and Discussions

4.1. Reduction in Number of Water Bodies

Table 1. Comparison of number of water bodies (1974 vs 2024)

Year	No. of Water Bodies	Wet Water Bodies	Dry Water Bodies
1974	833	779	54
2024	309	309	0

The number of water bodies in the Sarayan Watershed has decreased significantly over the past 50 years. In 1974, there were 833 water bodies, of which 779 were wet and 54 were dry. By 2024, the total had dropped to just 309 wet water bodies, representing a 62.9% reduction. This indicates a substantial loss, particularly of smaller seasonal ponds, tanks, and wetlands that historically formed a critical component of the surface water network (Fig.3).

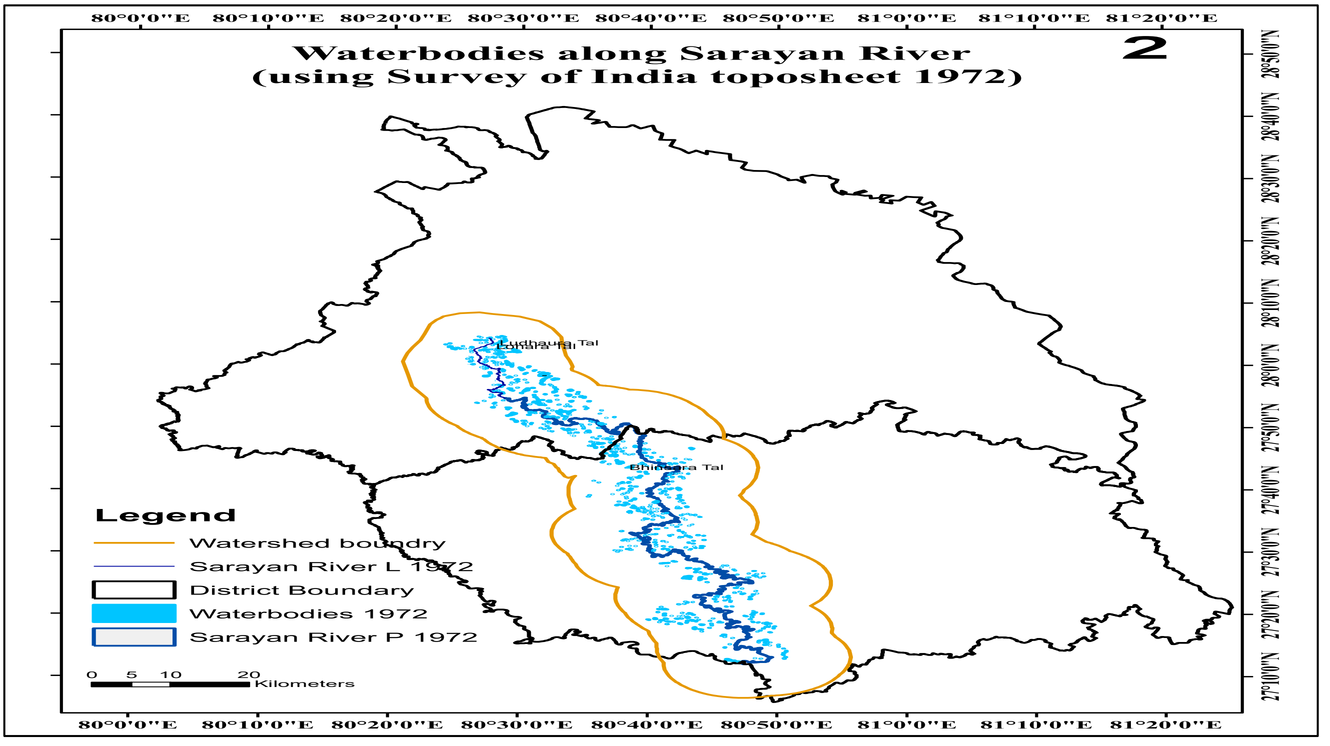

Figure 2. Mapping of water bodies along with Sarayan River (using SOI toposheets)

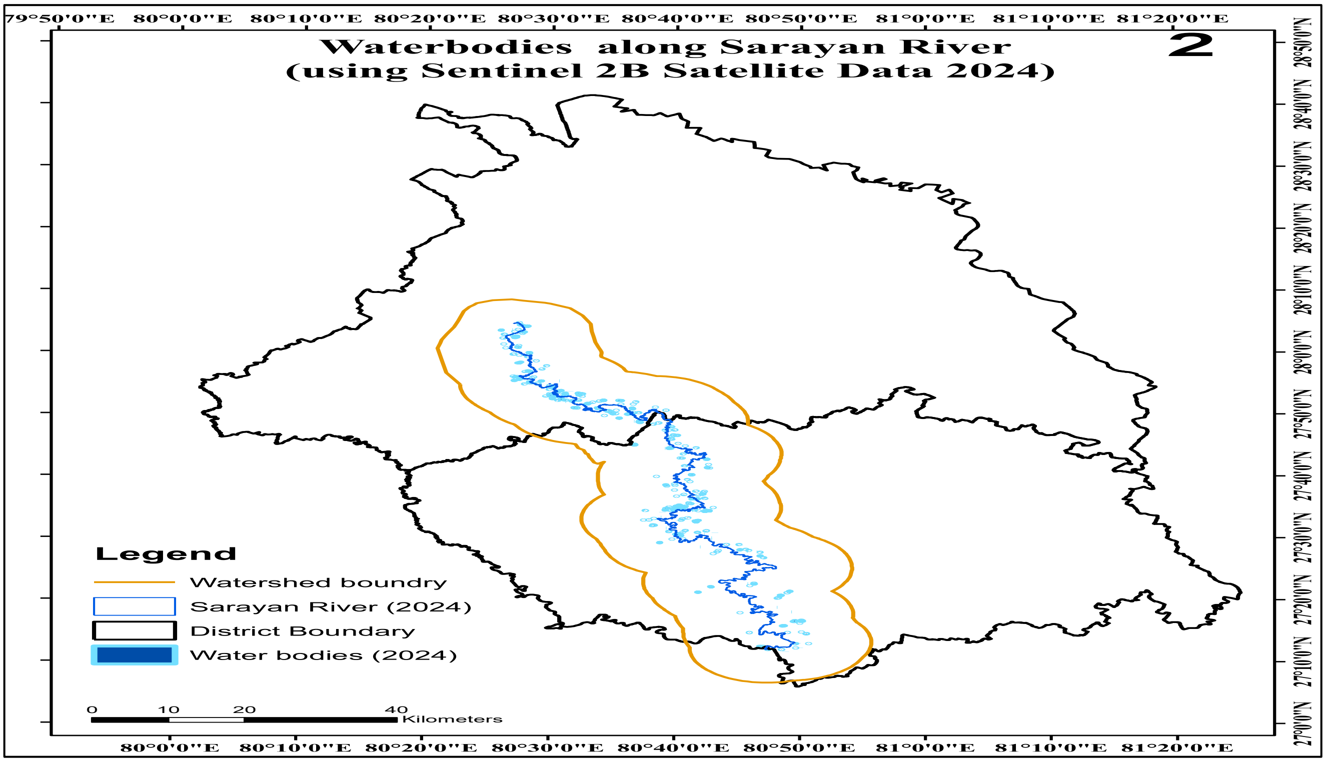

Figure 3. mapping of water bodies along with Sarayan River (using Sentinental 2B Satellite Data 2024)

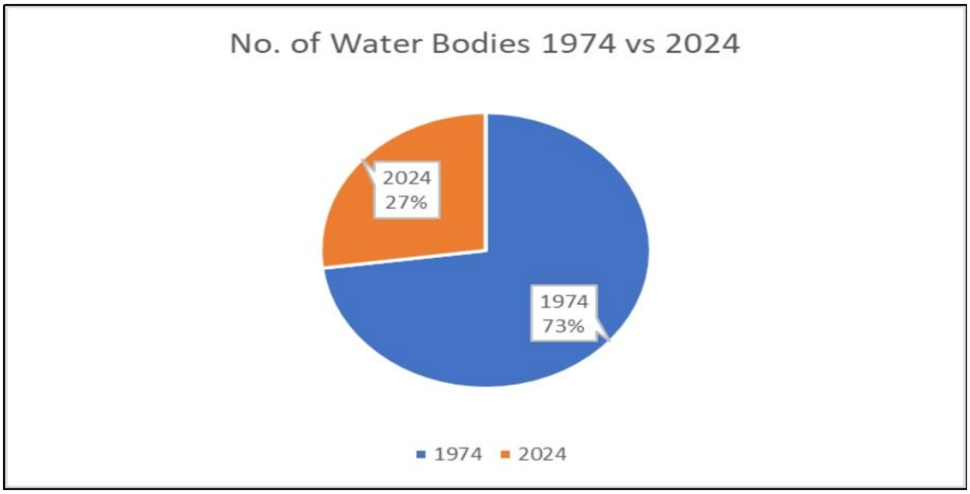

Figure 4. Pie chart showing the number of Water Bodies (1974 vs 2024)

Possible Causes

Urbanization and Encroachment The region has likely experienced increased urbanization and encroachment over the past few decades. As settlements expand, water bodies are often converted into built-up areas or agricultural lands. Encroachment for agriculture is particularly common, where small ponds and wetlands are drained to increase cropland [35].

Water Extraction for Irrigation The increasing reliance on groundwater for irrigation in the region may have reduced the need for surface water bodies, which are sometimes filled in or allowed to dry up to make space for farming.

Land Reclamation Many traditional water bodies, especially in rural areas, have been filled for land reclamation or construction, reducing the natural capacity for water storage.

Lack of Maintenance Many small ponds and lakes, particularly in rural areas, have not been maintained or desilted, leading to their gradual shrinking and disappearance over time [36].

4.2. Water Body Area Reduction

Table 2. Comparison of Water Body Area (1974 vs 2024)

Year	Total Water Body (km²)
1974	246.1912
2024	166.1214

The total area covered by water bodies has decreased by 32.5%, declining from 246.19 km² in 1974 to 166.12 km² in 2024. This substantial reduction indicates a marked decrease in the watershed's capacity to store surface water. Notably, in 2024, all 309 remaining water bodies were wet, contrasting with 1974 when a significant proportion (54) were dry. This pattern suggests that many seasonal and ephemeral water bodies have vanished over time (Fig.5).

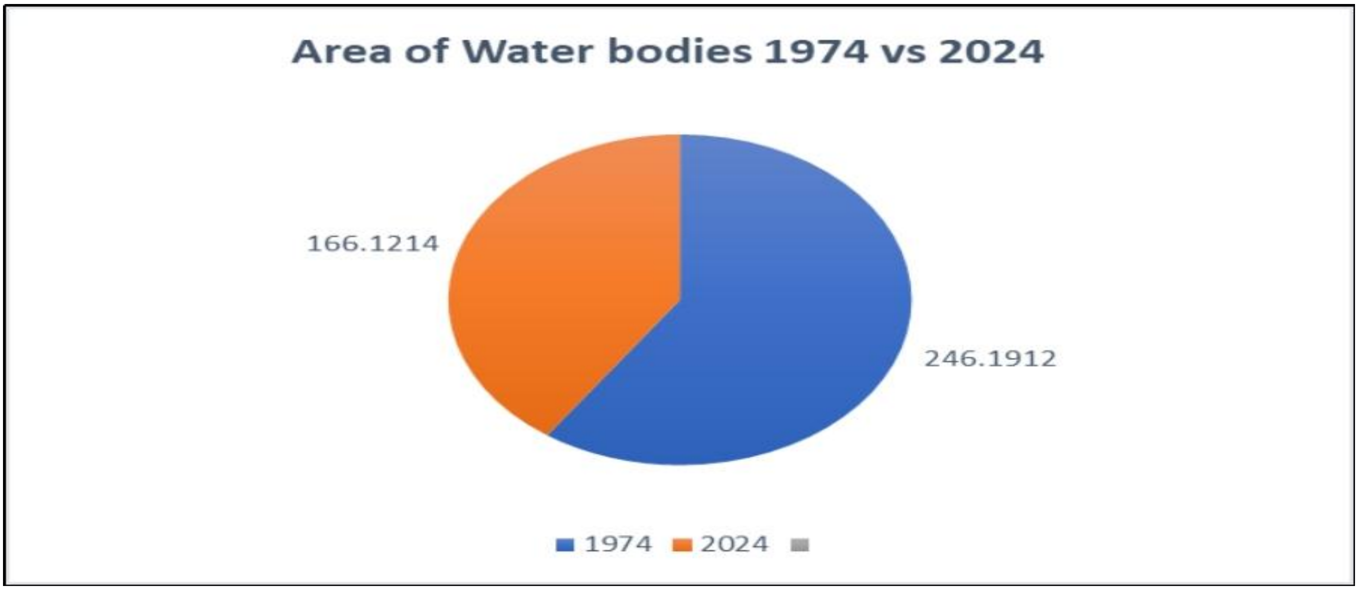

Figure 5. Pie chart showing Area of Water Bodies 1974 vs 2024

Possible Causes

Sedimentation and Siltation Small ponds and lakes naturally fill up with silt over time, especially without proper management practices. This makes them shallower, and in many cases, they dry up completely as their storage capacity diminishes.

Climate Change Changes in rainfall patterns, specifically reduced or erratic monsoon rainfall, could have led to insufficient water replenishment in these water bodies. The increased frequency and intensity of dry spells lead to evaporation and drying out of shallow water bodies (Prasad et al.,[37].

Water Management Issues Insufficient or lack of active water conservation efforts, such as the cleaning and desilting of traditional water bodies (ponds, tanks), have contributed to their gradual disappearance

4.3. Disappearance of Major Water Bodies (Tals)

Table 3. Comparison of major tals (1974 -2024)

Name of Tal	Area	1974 Status	2024 Status
Ludhaura Tal	36.50417	Present	Disappeared
Lohara Tal	11.25173	Present	Disappeared
Bhinsara Tal	25.78903	Present	Disappeared

Several large, historically significant lakes and tals (wetlands) such as **Ludhaura Tal, Lohara Tal, and Bhinsara Tal,** which were present in the 1974 toposheets, have completely disappeared by 2024.

Possible Causes

Land Use Change The conversion of wetland areas to agricultural land or settlement zones is the primary reason behind the disappearance of these water bodies. Wetlands often serve as important sources of water for irrigation and community use, and as human settlements expanded, these tals were reclaimed for farming or urbanization.

Water Extraction for Agriculture Groundwater extraction through tube wells for irrigation reduces the water table, directly affecting the seasonal wetlands and shallow lakes, which depend on groundwater recharge and surface runoff from the monsoon season.

Natural Sedimentation Over the years, many lakes and taals may have experienced natural sedimentation, leading to a loss of their depth and surface area, which eventually causes them to dry up.

Encroachment and Development In many parts of India, wetland encroachment is a common problem. These water bodies often get converted into farmlands or built-up areas due to the perceived value of land for construction and agriculture. Without effective regulations to preserve these natural resources, their disappearance is inevitable [38].

4.4. Spatial Distribution and Fragmentation of Water Bodies

In 1974, water bodies were widely distributed throughout the watershed, creating a more continuous network of surface water. By 2024, the water bodies are more fragmented, with fewer small ponds and lakes in the central and southern parts of the watershed. This reflects a pattern of water bodies being concentrated around rivers and natural depressions.

Possible Causes

Climate Change Changes in the hydrological cycle, including irregular rainfall patterns and droughts, could have led to more pronounced fragmentation in water bodies. As water resources become scarcer, smaller ponds and lakes may dry up, leaving only the larger, perennial bodies of water intact.

Agricultural Expansion As agriculture expanded, especially in the rural regions, many small ponds were converted into cropland, reducing the number of available surface water bodies.

Land Use Changes Urbanization in certain areas has fragmented the landscape, breaking up natural water body systems and making water bodies more concentrated in the remaining natural depressions [39].

4.5. Temporal Analysis and Change Detection

Comparing the 1974 toposheets with the April 2024 satellite imagery clearly shows major changes in water body coverage. Large water bodies such as Lodhaura Tal and Bhinsara Tal have completely disappeared, and seasonal ponds that were abundant in 1974 have shrunk in size or dried up.

Possible Causes

Erratic Monsoon Patterns Changes in monsoon rainfall intensity and timing may be a significant factor in the reduction of these water bodies. Less rainfall leads to reduced runoff and water supply to surface water bodies.

Increased Groundwater Extraction As irrigation practices rely heavily on groundwater extraction, the natural replenishment of water bodies has been severely impacted.

4.6. Effects of Water Body Reduction

a) Reduced Groundwater Recharge

Water bodies play a critical role in recharging groundwater. The decline in ponds, tanks, and lakes limits natural infiltration of rainwater, leading to falling groundwater tables [40-42].

b) Increased Flood Vulnerability

Loss of wetlands and ponds reduces the natural flood-buffering capacity of the watershed. During heavy rains, absence of water bodies leads to faster runoff and urban flooding.

c) Decline in Agricultural Productivity

Farmers dependent on tanks and ponds for irrigation face water shortages. Decrease in water availability affects crop yields, especially during dry seasons.

d) Loss of Biodiversity

Wetlands and ponds are crucial habitats for birds, fishes, and amphibians. Their disappearance leads to loss of aquatic biodiversity and disruption of local ecosystems.

e) Climatic Impacts

Water bodies act as natural coolers of local climate by moderating temperatures. Their loss results in increased land surface temperatures, creating localized urban heat islands.

f) Socio-economic Implications

Villages depending on ponds for drinking water, livestock use, and fishing face economic hardship. Increased reliance on groundwater extraction puts pressure on limited resources.

Conclusion

The mapping and analyzing of water bodies over the Sarayan Watershed were done precisely using remote sensing and GIS tools. Assessing resources was rather easier thanks to the use of Sentinel 2 satellite images and topographical sheets provided by India's Survey Institute. The analysis showed stark stratification in the distribution of ponds and tanks, where an agricultural zone was more concentrated than the elevated region of the watershed. Moreover, the raised region had a comparatively lower availability of surface water. Water bodies certainly grew during the monsoon months, while receding during the dry seasons. Concerning terrain was also noted due to changing land use practices and climatic stress. Some older ponds and wetlands have declined, which is thought to be due to land use changes and climatic pressures.

The development of modern and precise maps of water resources enables improved management, assists in the protection of water bodies, facilitates in efficient discharge of irrigation systems, and helps in mitigating floods and droughts. The dendritic drainage pattern of the Sarayan River system ensures the simple-formed structure and mono-formed lithology of the basin helps in hydrological simplifications.

The results have significant consequences on the sustainable utilization of the water resources in the area. The updated spatial information forms a good base for government and other relevant bodies to address critical areas affected by potential low water availability, in order to design and implement targeted conservation plans. The knowledge of seasonal water availability optimizes ground water recharge through controlled discharge and restoration of wetlands. Also, the mapping of water bodies enables efficient management of drought and flood risk by developing early warning systems. It is also important to emphasize that the conservation of small ponds and water-logged areas is very important for the protection of biological diversity and ecological balance.

Most noteworthy, disseminating information pertaining to water resources to local people enhances participatory management as well as strengthens collaborative conservation practices. This study shows that using remote sensing and GIS in water resource assessment is beneficial for sustainable watershed management, particularly in rural areas, and that this methodology can extend to other similar regions.

References

[1]. Agarwal and R. D. Garg, "Role of Water Resources in Sustainable Development of India," *International Journal of Water Resources and Environmental Engineering*, vol. 8, no. 4, pp. 49–56, 2016.

[2]. R. Kumar, A. P. Singh, and P. R. Yadav, "Impact of Urbanization on Water Resources in India," *Environment and Urbanization ASIA*, vol. 9, no. 1, pp. 125–137, 2018.

[3]. R. P. Singh and M. K. Jain, "Watershed as a Unit of Hydrological and Environmental Management," *Hydrology Journal*, vol. 38, no. 3–4, pp. 47–56, 2015.
[4]. R. Sharma and S. Rani, "Ecological Significance of Inland Water Bodies: A Case Study of Punjab," *Journal of Environmental Biology*, vol. 38, no. 6, pp. 1333–1338, 2017.
[5]. A. Mishra and R. Das, "Socio-Cultural and Economic Importance of Water Bodies in India," *International Journal of Social Sciences and Economic Research*, vol. 4, no. 5, pp. 4034–4043, 2019.
[6]. S. Verma and A. Tripathi, "Threats to Urban Water Bodies: A Review," *Environmental Conservation Journal*, vol. 21, no. 3, pp. 13–21, 2020.
[7]. T. M. Lillesand, R. W. Kiefer, and J. W. Chipman, “Remote Sensing and Image Interpretation”, *7th ed. Hoboken, NJ: Wiley*, 2015.
[8]. P. A. Burrough and R. A. McDonnell, “Principles of Geographical Information Systems”, *2nd ed. Oxford: Oxford University Press*, 1998.
[9]. S. K. McFeeters, "The Use of the Normalized Difference Water Index (NDWI) in the Delineation of Open Water Features," *International Journal of Remote Sensing*, vol. 17, no. 7, pp. 1425–1432, 1996.
[10]. H. Xu, "Modification of Normalized Difference Water Index (NDWI) to Enhance Open Water Features in Remotely Sensed Imagery," *International Journal of Remote Sensing*, vol. 27, no. 14, pp. 3025–3033, 2006.
[11]. Department of Mining, "District Survey Report of Sitapur," *Government of Uttar Pradesh, India*, 2021.
[12]. S. P. Wani, P. Pathak, L. S. Jangawad, and H. M. Tam, "Integrated Watershed Management for Sustainable Agriculture," *Indian Journal of Dryland Agricultural Research and Development*, vol. 17, no. 1, pp. 1–8, 2002.
[13]. Ministry of Rural Development, Government of India, “Guidelines for Integrated Watershed Management Programme (IWMP)”, *New Delhi*, 2011.
[14]. R. K. Jaiswal, R. Thomas, R. Srivastava, and P. K. Singh, "Application of Remote Sensing and GIS in Watershed Management: An Overview," *Journal of the Indian Society of Remote Sensing*, vol. 42, no. 4, pp. 601–610, 2014.
[15]. A. K. Singh and A. Bharti, “Hydrological study of Gomti River Basin using geospatial tools,” *International Journal of Geomatics and Geosciences,* vol. 6, no. 3, pp. 1543–1550, 2015.
[16]. P. K. Rai, “Land use and land cover analysis in Indo-Gangetic plain using remote sensing techniques: A case study,” *Journal of the Indian Society of Remote Sensing,* vol. 36, no. 4, pp. 289–297, 2008.
[17]. S. Sharma and R. Goyal, “Topographical analysis of flood-prone areas in Uttar Pradesh,” *Geographical Review of India*, vol. 74, no. 2, pp. 135–142, 2012.
[18]. A. Singh and S. Sharma, “Assessment of flood hazards using GIS: A case study of Sarayan Basin,” *International Journal of Environmental Sciences*, vol. 3, no. 5, pp. 2049–2056, 2013.
[19]. M. Gupta and R. Yadav, “Soil characteristics and classification of Sarayan watershed,” *Journal of Soil and Water Conservation*, vol. 12, no. 1, pp. 31–37, 2013.
[20]. R. P. Singh, “Soil erosion assessment and land use planning in northern plains,” *Indian Journal of Geography and Environment,* vol. 17, pp. 27–35, 2012.
[21]. N. Singh and A. Bhatnagar, “Climatic classification and monsoonal behaviour in central Uttar Pradesh,” *Climate and Environmental Research*, vol. 14, no. 2, pp. 75–82, 2010.
[22]. R. K. Mall and A. Srivastava, “Rainfall trends and variability in the Indo-Gangetic Plain,” *Journal of Climate Research*, vol. 9, no. 3, pp. 109–117, 2014.
[23]. A. Mishra and A. Srivastava, “Impacts of monsoonal anomalies on groundwater recharge in the Sarayan basin,” *Hydrology Journal of India*, vol. 21, no. 2, pp. 63–71, 2016.
[24]. N. Rathore and S. Lodha, “Agricultural vulnerability due to climatic variability in Northern India,” *Journal of Agricultural Meteorology*, vol. 19, no. 1, pp. 46–53, 2017.
[25]. S. Kumar and S. K. Jain, “Drainage pattern analysis of Sarayan watershed using geospatial techniques,” *Journal of Water Resource and Protection*, vol. 7, no. 10, pp. 790–800, 2015.
[26]. R. Prasad, P. Tiwari, and A. Sharma, “GIS-based hydrological modeling of Sarayan watershed,” *International Journal of Remote Sensing and GIS*, vol. 8, no. 1, pp. 12–19, 2019.
[27]. P. H. Verburg, A. Veldkamp, and L. O. Fresco, “Simulation of changes in the spatial pattern of land use in China,” *Landscape Ecology*, vol. 14, no. 4, pp. 379–392, 2009.
[28]. W. B. Meyer and B. L. Turner, “Human population growth and global land-use/cover change,” *Annual Review of Ecology and Systematics*, vol. 23, pp. 39–61, 1992.

[29]. E. F. Lambin, B. L. Turner, H. J. Geist, S. B. Agbola, A. Angelsen, J. W. Bruce et al., “The causes of land-use and land-cover change: moving beyond the myths,” *Global Environmental Change,* vol. 11, no. 4, pp. 261–269, 2001.

[30]. B. L. Turner II, D. Skole, S. Sanderson, G. Fischer, L. Fresco, and R. Leemans, “Land-Use and Land-Cover Change: Science/Research Plan,” *IGBP Report No. 35, HDP Report No. 7*, 1994.

[31]. J. A. Foley, R. DeFries, G. P. Asner, C. Barford, G. Bonan, S. R. Carpenter et al., “Global consequences of land use,” *Science*, vol. 309, no. 5734, pp. 570–574, 2005.

[32]. E. F. Lambin and H. J. Geist, “Land-Use and Land-Cover Change: Local Processes and Global Impacts”, *Springer, Berlin*, 2006.

[33]. P. M. Vitousek, H. A. Mooney, J. Lubchenco, and J. M. Melillo, “Human domination of Earth's ecosystems,” *Science*, vol. 277, no. 5325, pp. 494–499, 1997.

[34]. S. Ghosh and M. P. Sharma, “Urbanization and its impact on water bodies: A GIS based study of greater Hyderabad,” *International Journal of Environmental Sciences*, vol. 1, no. 2, pp. 105–114, 2010.

[35]. M. Gore, A. Singh, and R. Kumar, "Impact of Urbanization on Water Bodies: Encroachment and Land Use Changes in Indian Watersheds," *International Journal of Environmental Studies*, vol. 77, no. 4, pp. 567–579, 2020.

[36]. P. Mishra, S. Sharma, and R. Yadav, "Assessment of Pond Degradation and Its Causes in Rural Watersheds," *Journal of Water Resources and Protection*, vol. 13, no. 8, pp. 675–688, 2021.

[37]. R. Chaudhary, P. Kumar, and S. Mishra, "Wetland Encroachment and Its Impact on Water Security in India," *Environmental Science and Pollution Research*, vol. 27, pp. 7890–7902, 2020.

[38]. S. Singh, R. Kumar, and A. Sharma, "Land Use Change and Fragmentation of Water Bodies in Indian Rural Landscapes," *Journal of Land Use Science*, vol. 13, no. 2, pp. 198–215, 2018.

[39]. Central Ground Water Board (CGWB), "Groundwater Year Book - India 2019-20," *Ministry of Water Resources, Government of India*, 2020.

[40]. S. Jain, R. Kumar, and P. S. Singh, "Flood Risk Assessment Using Remote Sensing and GIS: A Case Study," *Natural Hazards*, vol. 98, no. 1, pp. 1–18, 2019.

[41]. V. Singh and R. Tiwari, "Impact of Surface Water Decline on Agriculture in North Indian Watersheds," *Journal of Agricultural Science and Technology*, vol. 20, no. 3, pp. 345–355, 2018.

[42]. A. Prasad, M. Verma, and S. K. Singh, "Effects of Climate Change on Water Resources in Semi-arid Regions of India," *Environmental Monitoring and Assessment*, vol. 191, no. 4, pp. 235, 2019.