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Analyzing the Impacts of Urbanization on the Cultural Heritage of Varanasi City Heritage Zone 1, India

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ABSTRACT

Urbanization is a transformative force of spatial and socio-cultural transformation, particularly in historic cities like Varanasi, India, which stands as a living repository of cultural and religious traditions. As modernization accelerates, Varanasi's sacred and heritage-rich landscapes, especially along its iconic riverfront, are increasingly threatened by infrastructure growth, population pressure, and mass tourism. This study examines the impact of urban expansion on Varanasi's Heritage Zone 1, which encompasses five culturally significant ghats symbolically linked to Lord Vishnu's body in Hindu cosmology. The research aims to assess how land use and land cover (LULC) changes between 2003 and 2023 have influenced the integrity of these ritual landscapes. Using multi-temporal Landsat satellite imagery, supervised classification techniques (via Maximum Likelihood and Random Forest), GIS analysis, and field validation, the study provides a robust spatiotemporal assessment of urban growth. Results indicate a 10.21% increase in urban land and significant losses in vegetation (−7.12%) and water bodies (−0.71%), largely encroaching upon sacred zones. The classification achieved an overall accuracy of 96.45% and a Kappa coefficient of 0.9437, confirming the methodological reliability. The study concludes that urbanization is not merely a physical phenomenon but a culturally disruptive force, diluting ritual spaces, visual coherence, and traditional ecological knowledge systems. It offers a novel framework by integrating geospatial change detection with cultural heritage analysis, thereby bridging technical precision with socio-cultural insight. Research limitations include the Heritage Zone 1 only. Practical implications involve the urgent need for heritage-sensitive zoning, GIS-based monitoring, and participatory planning. Socially, the study highlights the displacement of communities, rituals, and intangible heritage due to unchecked urbanization. This research contributes to urban heritage planning by advocating a culturally embedded approach aligned with the UNESCO Historic Urban Landscape framework, to ensure that development coexists with preservation in heritage cities like Varanasi.

1. INTRODUCTION

India's remarkable tangible and intangible heritage is deeply interwoven with its identity and plays a pivotal role in national development [1]. However, the escalating demands of urban expansion, population growth, and modern infrastructure pose a significant threat to this cultural wealth. Varanasi, revered as India's cultural and spiritual capital [2], is among the oldest continuously inhabited cities in the world. Its sacred character, rooted in Hinduism, Buddhism, and other faiths [3, 4], is increasingly at risk due to unregulated urbanization and mass tourism [5-7]. These pressures have not only compromised the city's architectural integrity and ecological balance but have also contributed to the gradual erosion of its unique cultural identity [8].

Rapid urban transformation in Varanasi is especially visible in its core heritage zones, where commercial complexes, modern housing, and tourism-driven infrastructure are displacing traditional land uses. The cityscape now includes over 3,000 temples, 85 ghats, and numerous hotels, guesthouses, and markets—all catering to a growing population of pilgrims and visitors, according to Varanasi Development Authority. This uncoordinated development has strained both natural and cultural resources, often resulting in the encroachment and commercialization of sacred sites [9].

Land Use and Land Cover (LULC) change detection is an essential tool for assessing these urban transformations. By analyzing satellite imagery, LULC studies help evaluate how urbanization—especially tourism-driven—has altered the physical and socio-cultural landscape of Varanasi [10]. Remote sensing offers distinct advantages, such as wide spatial coverage and long-term data availability, making it particularly suitable for analyzing urban dynamics over time [11]. In the context of environmentally and culturally sensitive cities like Varanasi, understanding LULC change is critical for sustainable urban planning and heritage conservation. Recent

studies underscore the utility of geospatial technologies for this purpose. Kennedy et al. [12] contributed ecological perspectives to change detection through long-term Landsat datasets.

To ensure the reliability of classified land use maps, accuracy assessment becomes crucial. The Kappa coefficient, a statistical measure that compares observed accuracy with random chance, is employed in this study to evaluate classification precision. This metric enhances the robustness of remote sensing analyses by quantifying the degree of agreement between classified data and reference ground truth. As India continues to urbanize, particularly in heritage-rich cities like Varanasi, incorporating LULC analysis and accuracy assessments like the Kappa coefficient can inform data-driven, culturally sensitive, and ecologically responsible urban policies [13, 14]. LULC change is not merely a physical phenomenon; it is a spatial manifestation of socio-economic pressures—such as migration, tourism, and modernization—that restructure the cultural landscape. The loss of vegetation and water bodies, documented through GIS, correlates with the decline of cultural ecosystem services, which are crucial to Varanasi's ritual and aesthetic identity. Similarly, urban expansion into heritage zones disrupts the integrity, authenticity, and continuity of place—core concepts in heritage theory.

Despite these advances, a gap remains in the focused application of these tools and theories to the case of Varanasi or other ancient cities. The present study addresses this gap by combining geospatial change detection with heritage zone analysis to inform policy-relevant urban planning. This study aims to:

- Develop a classified LULC map using remote sensing and GIS;
- Analyze changes in land use in Varanasi; and
- Evaluate the impact of urbanization on Heritage Zone 1.

The remaining sections are structured as follows: Section 2 outlines the materials and methods, Section 3 presents the results, and Section 4 includes the discussion and conclusions drawn.

2. MATERIALS AND METHODS

2.1 Materials

Varanasi, also known as Banaras or Kashi, is situated in the Gangetic plains of North India, within the state of Uttar Pradesh. Geographically, it spans between latitudes 25.32754°N and 25.20652°N and longitudes 82.87302°E and 83.04623°E [4]. The study area is confined to the Varanasi municipal boundary, which encompasses ninety-two administrative wards. As part of the Varanasi Master Plan 2011, the Varanasi Development Authority (VDA) delineated five heritage zones across the city.

These heritage zones play a crucial role in reinforcing Varanasi's identity as the cultural capital of India [15], reflecting its deep historical and cultural significance. This study specifically focuses on assessing the impact of urbanization on Heritage Zone 1 – the Riverfront Ghat Area, a core segment of the city's sacred and cultural landscape. The location of the study area, including the heritage zones within the Varanasi municipal boundary, is illustrated in Figure 1.

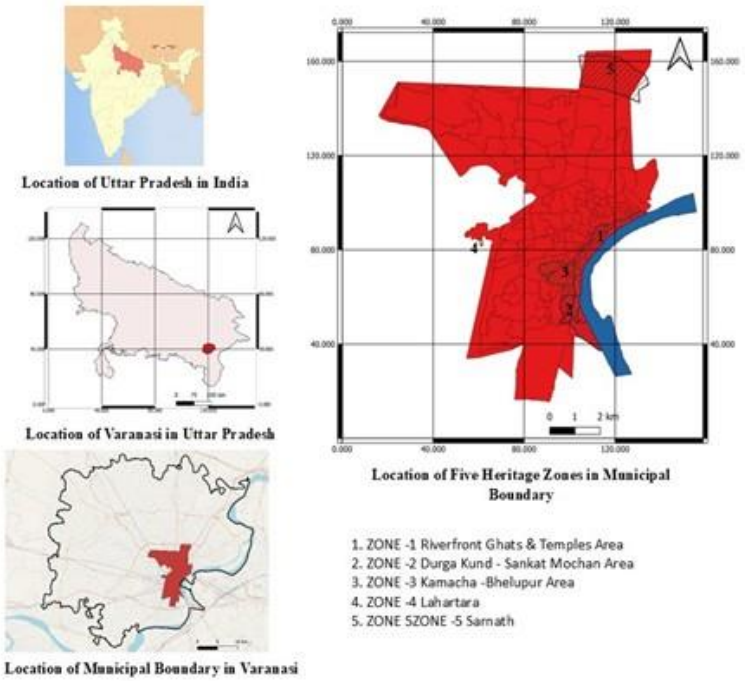


Figure 1. Location map of Varanasi municipal boundary and heritage zones
Source: Author's primary study

2.2 Literature review

Heritage Zone 1 of Varanasi, encompassing the riverfront ghat area with a total of 85 ghats, temples, mosques and kunds, constitutes the spiritual and cultural heart of the city. An overview of the prominent cultural heritage assets located within this zone. This sacred landscape is embedded within a dense matrix of residential, commercial, and religious spaces, where the riverfront functions both as a site of living heritage and as a vibrant hub of cultural tourism. Among these, five ghats—Asi, Dashashwamedh, Manikarnika, Panchganga, and Adi Keshava—stand out as the most significant. These form

the core pilgrimage circuit and are instrumental in shaping Varanasi's identity as a destination for both spiritual seekers and cultural tourists [16]. The prominent five ghats forming the Pañchatīrthī pilgrimage route are shown in Figure 2 and an inventory of cultural heritage assets located within Heritage Zone 1 is detailed in Table 1.

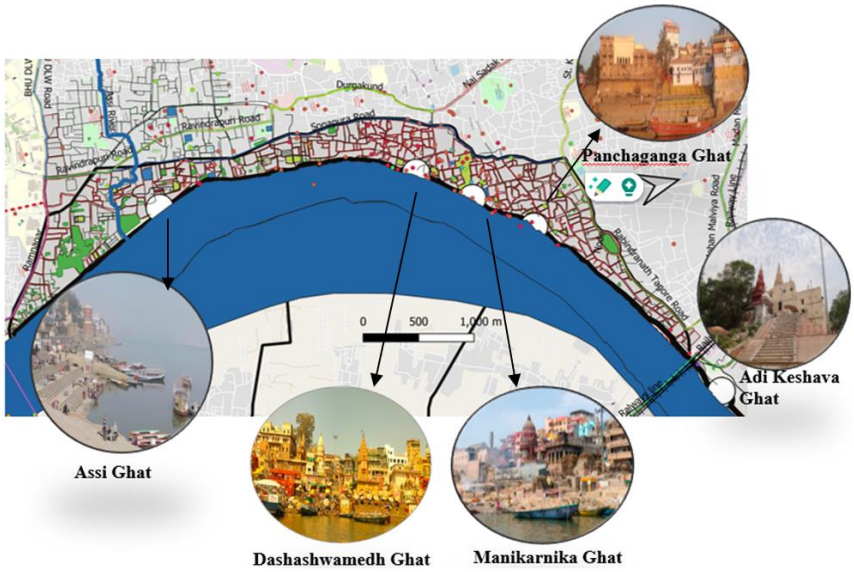


Figure 2. Riverfront Ghat Area – Heritage Zone 1 and prominent five ghats
Source: Author's primary study

Table 1. Inventory of cultural heritage assets in Heritage Zone 1 – Riverfront Ghat Area

Cultural Heritage Assets of Riverfront Ghat Area			
Type of Cultural Heritage Assets	**Image**	**Description w.r.t Varanasi City**	**Total Number of Cultural Heritage in Zone 1**
Ghat		**Ghats** are the iconic riverfront steps leading to the Ganga River, where rituals, pilgrimages, and daily activities like bathing and cremation take place making them vital to Varanasi's spiritual identity.	85
Temple		**Temples** dominate the cityscape, with thousands scattered throughout, including the revered Kashi Vishwanath Temple, reflecting the deep-rooted Hindu traditions and continuous religious practices.	32
Mosque		**Mosques** in Varanasi showcase the city's Islamic heritage and the coexistence of diverse religious communities over centuries emphasizing syncretic traditions.	2
Kund		**Kunds**, or sacred water tanks, are ancient reservoirs that serve both ritualistic and ecological functions, symbolizing the sacredness of water in Hindu cosmology.	2

Collectively known as the Pañchatīrthī, these five ghats hold deep cosmological and ritual significance. According to the Kashi Khanda (84.114), a pilgrim who bathes at all five sites transcends the five elemental states of the physical body and attains the divine form of Pañchamukha Shiva (five-faced Shiva). Symbolically, these ghats are mapped onto the microcosmic body of Lord Vishnu: Asi represents the head, Dashashwamedh the chest, Manikarnika the navel, Panchganga the thighs, and Adi Keshava the feet. Through this sacred embodiment, the entire stretch of the riverfront is believed to be sanctified. The Matsya Purāṇa (6th century CE) further reinforces this belief, stating that ritual immersion at these five ghats grants the same spiritual merit as bathing at all 85 ghats along the Ganga in Varanasi [17]. This layered sacred geography underscores the exceptional religious significance of Heritage Zone 1. The sacred geography of Varanasi is uniquely shaped by the crescent-like course of the Ganga River along its western bank. This natural ridge, averaging 72.2 meters (250 feet) in elevation, has influenced the characteristic arc-shaped settlement pattern of the old city. A historic arterial route connecting Asi to Raj Ghat via Godaulia, Chauk, Maidagin, and Matyodari—defines the western boundary of the 'Riverfront Old City Heritage Zone' [18].

Despite increasing pressures from urban expansion, the riverfront has retained much of its traditional character. It continues to serve as a central locus for ritual practices, spiritual tourism, and cultural continuity. As the most visited and photographed part of the city, the riverfront draws a steady flow of domestic pilgrims and international tourists. Approximately five kilometres to the south of the ghat cluster.

In essence, Heritage Zone 1 represents a dynamic integration of tangible and intangible heritage. Architecturally significant structures such as temples, kunds, mosques, and ghats, interact with living traditions, ritual performances, and the daily practices of local custodians, reinforcing the zone's identity as the epicentre of cultural tourism in Varanasi [19].

2.3 LULC changes

The Kappa statistic considers the off-diagonal entries of the error matrix and estimates the level of agreement after excluding the agreement expected by chance. It was established by Cohen [20], and the kappa coefficient calculates the proportion of agreement after the chance agreements are eliminated from the calculation. Kappa approaches one as the chance agreement reduces and turns negative, as the agreement is less than chance. The perfect Strength of agreement is between values 0.81-1 [21], Kappa Coefficient can be calculated using Eq. (1).

$$k = P(A) - P(E)/(1 - P(E)) \quad (1)$$

where, *P(A)* = number of times *k* rates agree, *P(E)* = number of times *k* rates are expected to agree by the Cohen [20].

2.4 Change detection

2.4.1 Remote sensing and classification

Land Use Land Cover (LULC) data were derived from Landsat 7 surface reflectance imagery for the years 2003, 2013, and 2023, each with a spatial resolution of 30 meters. These time points were chosen to capture decadal changes over 20 years. All satellite images were geometrically corrected using Survey of India toposheets to ensure alignment with ground features. A supervised classification approach employing the Maximum Likelihood Algorithm was used to categorize land cover into four classes: Water, Urban, Vegetation, and Barren Land. Band combinations 4 (NIR), 3 (Red), and 2 (Green) were used to enhance interpretability. The classification of the scheme is shown in Table 2. Training samples for each class were collected from over 50 ground control points, verified through field surveys conducted in March 2023. The classification process was carried out using ERDAS Imagine and cross-validated via Google Earth Engine (GEE). The classification scheme used for the LULC categories is summarized in Table 2.

Table 2. Classification scheme used for LULC categories in the study

Sl. No	Class	Color Code
1	Water	
2	Urban	
3	Vegetation	
4	Barren land	

2.4.2 Change detection and validation

To detect temporal changes, a post-classification comparison method was applied, which minimizes atmospheric and radiometric inconsistencies across multi-temporal datasets. The accuracy of classification was assessed using an error matrix and a confusion matrix, with 20% of the total sample size reserved for validation. Additionally, the Random Forest algorithm was used as a benchmark classifier. The overall classification accuracy achieved was 96.45%, with a Kappa Coefficient of 0.9437, indicating almost perfect agreement with ground truth data. This integrated methodology, comprising supervised classification, field validation, and statistical accuracy assessment, ensures the reliability and transparency of the spatial analysis, providing a solid empirical foundation for evaluating the effects of urbanization on cultural heritage.

2.4.3 Theoretical context

Change detection is the process of identifying variations in the state of an object or phenomenon by analysing observations from different periods. It aims to understand spatial and temporal changes and assess their underlying causes and implications.

Effective change detection requires reliable multi-temporal datasets and is influenced by sensor calibration, image quality, and classification accuracy [22-24]. This study employed a blended method that integrates GIS tools and ERDAS Imagine for analysing Landsat 7 data within the municipal boundary of Varanasi [25]. The analysis involved subset image processing, use of high-resolution ancillary data (e.g., SPOT and IRS), and robust classification using multi-temporal Landsat images to interpret LULC dynamics [26, 27]. Field surveys were conducted to verify classification accuracy, ensuring high-quality, up-to-date insights into spatial trends and transformations [28, 29].

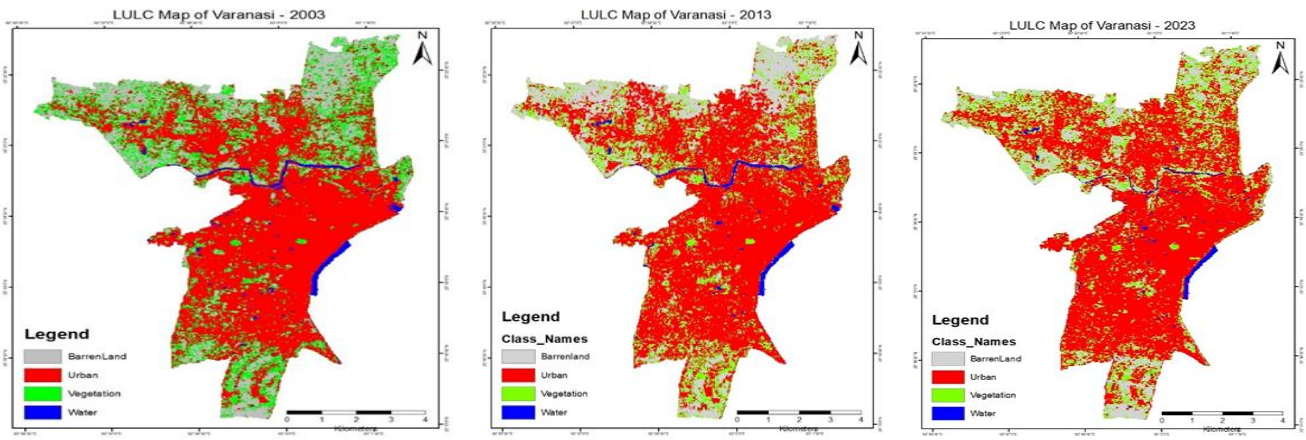


Figure 3. Classified LULC maps of Varanasi for the years 2003, 2013, and 2023
Source: Author primary study

The LULC analysis over three decades: 2003, 2013, and 2023 reveals changes across various migration, tourism, and modernization that restructure the cultural landscape [30]. The loss of vegetation and water bodies, documented through GIS, correlates with the decline of cultural ecosystem services, which are crucial to Varanasi's ritual and aesthetic identity. Similarly, urban expansion into heritage zones disrupts the integrity, authenticity, and continuity of place, core concepts in heritage theory. The classified LULC maps for the years 2003, 2013, and 2023 are presented in Figure 3.

2.4.4 Changing cultural heritage of Zone 1

To assess the impact of urbanization on Heritage Zone 1 – the Riverfront Ghat Area – a mixed-methods approach was employed, integrating both primary and secondary surveys. The primary survey entailed ground truthing to document the present condition of the heritage zone, as illustrated below. Complementing this, the secondary comparative survey involved an in-depth review of existing literature, historical maps, archival records, and previous research to track changes over time. This dual-layered methodology offers a holistic perspective on the transformations within the heritage zone driven by urban expansion. The 2005 base map was sourced from the Survey Map 2005, while the 2025 base map was derived from Google Maps dated 17th March 2025. Findings and interpretations from this analysis are presented in Section 3.1.

3. RESULTS AND DISCUSSION

3.1 Result

3.1.1 Analysis of change in LULC

The results of the LULC Change Detection Analysis for Varanasi from 2003 to 2023 provide critical insight into the spatiotemporal transformations occurring in the city. By analyzing multi-temporal Landsat 7 imagery in Google Earth Engine (GEE), significant patterns of urban expansion, vegetation loss, and water body encroachment have been identified. Between 2003, 2013 and 2023, there have been significant changes in land use and land cover distribution. These changes underscore the substantial urban expansion.

3.2 Summary of key changes

The LULC analysis of Varanasi from 2003 to 2023 reveals a significant urban expansion of 508.01 km² (10.21%), highlighting rapid urbanization. This growth has led to a notable decline in vegetation (353.07 km², 7.12%), likely due to infrastructure development, agricultural shifts, and environmental changes. Additionally, water bodies have reduced by 35.11 km² (0.71%), while barren land has decreased by 119.95 km² (2.42%), suggesting land conversion for urban and economic activities. These findings emphasize the ongoing transformation of Varanasi's landscape, which is impacting the city's cultural fabric. The percentage change in land use and land cover categories between 2003 and 2023 is depicted in Figure 4.

B Accurate Assessment Test – Kappa Coefficient
List (4 elements)
1: [0,265,12,0,0]
2: [0,0,10199,13,391]
3: [0,0,112,4255,42]
4: [0,0,75,103,5632]
Random Forest Confusion Matrix
0.9645480828475284
Random Forest Overall Accuracy
Validation error matrix (Random Forest)
List (4 elements)
1: [0,2,1,1,0]
2: [0,1,5,2,0]
3: [0,0,2,3,2]
4: [0,0,0,1,3]
Validation accuracy (Random Forest)
0.5652173913043478
Kappa statistic
0.9437028866601119

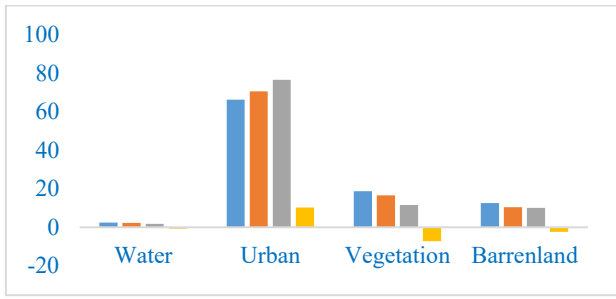


Figure 4. Percentage change in land use and land cover in Varanasi from 2003 to 2023
Source: Author's primary study

The Kappa coefficient of 0.9437 and the overall classification accuracy of 96.45% validate the reliability of the change detection analysis. Moreover, Random Forest classification further supports these findings, showing consistent accuracy across multiple validation methods. Spatially, the change is concentrated in Heritage Zone 1, where the traditional urban fabric is being replaced or overshadowed by modern constructions. Analysis across the five sacred ghats (Asi, Dashashwamedh, Manikarnika, Panchganga, and Adi Keshava) shows varied degrees of transformation, from beautification and commercial expansion to loss of natural vegetation and riverbank erosion. The interpretation of these patterns reflects that urban growth is not only altering physical landscapes but is also displacing cultural and ritual practices. The encroachment upon sacred spaces, loss of visual coherence in heritage streetscapes, and commercialization of spiritual zones collectively suggest that urbanization is not culturally neutral, it is reshaping the socio-spiritual identity of Varanasi.

3.3 Analysis of the impact of urbanization on Varanasi's cultural heritage

3.3.1 Transformation of the urban fabric

Over the years, each of the five sacred ghats of Varanasi—Asi, Dashashwamedh, Manikarnika, Panchganga, and Adi Keshava—has witnessed notable changes due to both natural fluvial dynamics and anthropogenic pressures. The spatial transformation of the Heritage Zone 1 from 2005 to 2025 is compared in Figure 5, and the results of LULC change detection for Varanasi are shown in Table 3.

Asi Ghat (Head of Vishnu)

Once a relatively quiet southern boundary of the city's sacred riverfront, Asi Ghat has undergone significant

transformation since the early 2000s. The Ghat Area has experienced extensive beautification under the National Mission for Clean Ganga (NMCG), featuring widened steps, improved lighting, and tourist facilities. However, urban sprawl around this ghat has resulted in increased encroachments, commercialization, and a decline in natural vegetation. Seasonal sedimentation has also changed its riverfront shape.

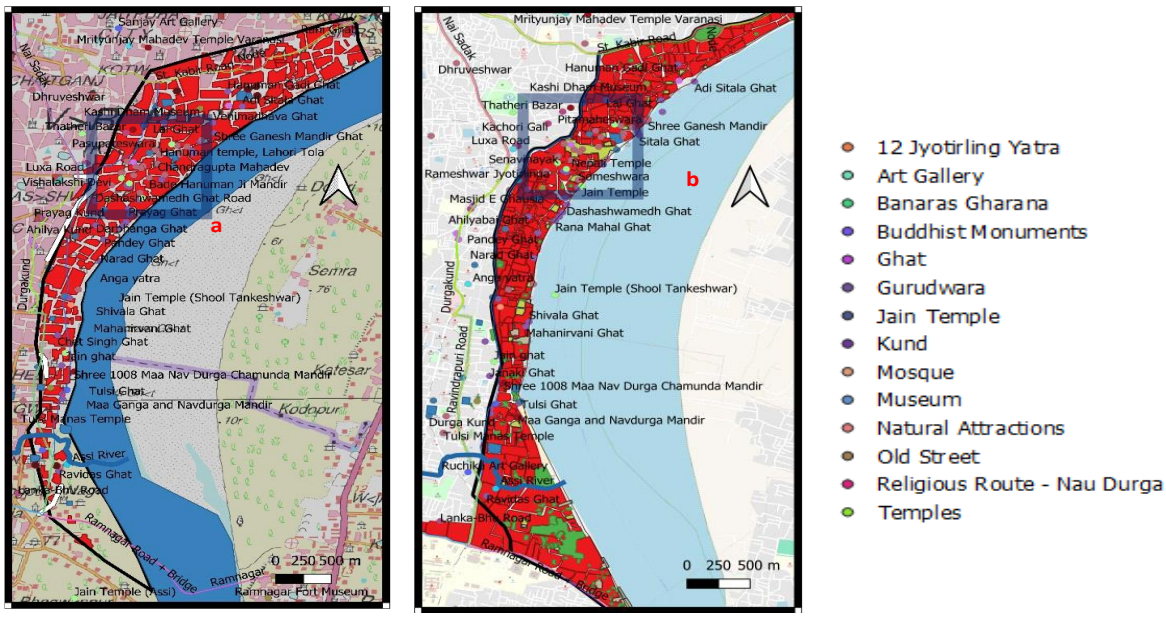


Figure 5. Spatial transformation of Heritage Zone 1 – Riverfront Ghat Area: a) Comparison of 2005 and 2025 maps, and b) Manikarnika Ghat
Source: Author's primary study

Table 3. Land use and land cover changes in Varanasi: Area and percent change from 2003 to 2023

Sr. No.	Class Name	Area (km^2) 2003	Percent	Area (km^2) 2013	Percent	Area (km^2) 2023	Percent	Total Change During the Period	Percentage Change
1	Water	124.03	2.50	115.94	2.33	88.92	1.79	-35.11	-0.70
2	Urban	3288.7	66.28	3501.79	70.58	3796.71	76.49	508.01	10.21
3	Vegetation	925.97	18.66	825.35	16.63	572.9	11.54	-353.06	-7.12
4	Barrenland	622.5	12.54	518.10	10.44	502.55	10.12	-119.95	-2.42
	Total	4961.20	**100**	4961.20	100	4961.209	100	--	

Source: Author's primary study

Dashashwamedh Ghat (Chest of Vishnu)

This ghat, the busiest and most iconic, has undergone major infrastructural development due to heavy tourist and pilgrim footfall. Permanent structures like platforms for the Ganga Aarti, CCTV surveillance systems, and embankment reinforcements have been added. Riverbank erosion due to increased boat activity and water pollution has become a concern. The surrounding area has become densely urbanized, leading to traffic congestion and solid waste stress.

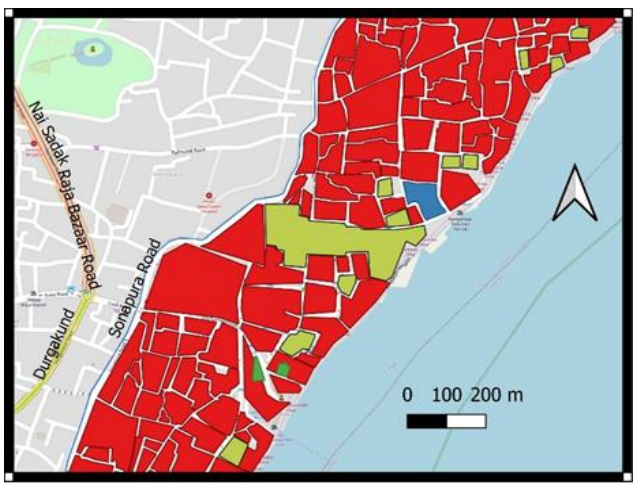
Manikarnika Ghat (Navel of Vishnu)

Renowned for its cremation rituals, this ghat has largely preserved its spiritual essence over time. However, notable transformations have occurred, including the introduction of more organized cremation zones and improved firewood management systems aimed at reducing environmental pollution. Despite these efforts, smoke emissions and runoff from cremation remains continue to negatively affect water quality. High resolution satellite imagery reveals a modest spatial expansion of the Ghat Area, accompanied by an increase in built-up structures and a decline in open spaces. In the 2005 spatial plan, dense habitation is clearly depicted, whereas the 2019 development of the Kashi Vishwanath Corridor marks a significant and visible transformation, as illustrated zoomed-in view of the Manikarnika Ghat Area in 2005 and 2025, which is highlighted in Figure 6.

Figure 6 provides a comparative representation of the dramatic changes at Varanasi's ghats over the past century. The historic Manikarnika Ghat, a sacred cremation site, has witnessed an overwhelming influx of concrete structures replacing traditional wooden and stone-built edifices. The following impacts are observed:

- Increased urban pressure: Expansion of unregulated structures, encroaches upon the sacred spaces of the ghats, altering their traditional form and function.
- Degradation of cultural authenticity: The modern constructions obscure the historical skyline of Varanasi, replacing its ancient aesthetics with contemporary urban forms.
- Altered socio-religious practices: The crowding of commercial and residential buildings around the ghats limits the space available for religious and cultural activities, affecting the traditional ways in which rituals and ceremonies are conducted. A historical photograph of Manikarnika Ghat from circa 1905 is shown in Figure 6(a) and the present-day appearance of Manikarnika Ghat in 2025 is illustrated in Figure 7.

(a)



(b)

Figure 6. (a) Zoomed-in view of Heritage Zone 1 area (Manikarnika Ghat shown in Figure 5 in 2005), (b) Zoomed-in view of Heritage Zone 1 area (Manikarnika Ghat shown in Figure 5 in 2025)
Source: Author's primary study GIS IMAGE) and Google Earth Pro image

(a)

(b)

Figure 7. Comparative historical and contemporary views of Manikarnika Ghat (a) Circa 1905, 9Google Search (b) present-day 2025
Source: Author credit

Panchganga Ghat (Thighs of Vishnu)

Historically important as the confluence of five mythical rivers, this ghat has seen a decline in religious activity prominence compared to Dashashwamedh or Manikarnika. Encroachment by local settlements, limited maintenance, and seasonal siltation have resulted in partial submergence of the steps and reduced accessibility. The religious infrastructure has deteriorated, although there have been recent attempts at heritage restoration.

Adi Keshava Ghat (Feet of Vishnu)

Situated at the northern edge, this ghat remained relatively undisturbed for a long time. However, from 2003 to 2023, change detection shows increased urban encroachment from the adjoining Raj Ghat Area, growth in informal settlements, and a decrease in riparian vegetation. The ghat has also faced seasonal flooding, leading to erosion of its earthen embankments. Yet, it still retains a more serene atmosphere compared to the central ghats.

Table 4 summarizes the land use, ecological, and cultural changes observed between 2003 and 2023 across the five sacred ghats of Varanasi, symbolically associated with the microcosmic body of Lord Vishnu.

3.4 Broader environmental and structural trends

Land subsidence across the riverfront is significant, 2 mm

to 8 mm/year—fuelled by groundwater depletion, river erosion, and the highly permeable layered soils beneath the city. Sewage treatment capacity has quadrupled since 2015 (to ~420 MLD), with nearly all city drains now intercepted and treated—greatly improving ghat water quality. Ecological uplift: As a result of these initiatives, the river near Varanasi is cleaner, healthier, and supports species like dolphins, otters, and turtles. Table 5 summarizes the major structural and ecological transformations experienced by each of the five sacred ghats between 2003 and 2025.

Table 4. Comparative changes in cultural, ecological, and urban aspects across the five sacred ghats of Varanasi (2005–2025)

Ghat Name	Urban Expansion (2005–2025)	Vegetation Change	Waterline Shift / River Impact	Cultural Integrity
Asi	Moderate – ghat beautification, public spaces added	Decline – landscaping replaced natural green	Moderate erosion control observed	Well-preserved with improved amenities
Dashashwamedh	High – dense commercial build-up and floating platforms	Decline – almost no vegetation left	Reduced direct river access for tourist avoiding overcrowding	Active and vibrant, though highly commercialized
Manikarnika	Low – mostly stable with cremation-related activity	Stable – limited due to primary cremation use	Sediment accumulation is visible near the cremation site	Strong ritual continuity, but under environmental stress
Panchganga	Moderate – adjacent residential expansion, access improvement	Slight decline – some loss to footpath expansion	Seasonal water recession noted	Moderately preserved, some neglect of structures
Adi Keshava	High–upstream urbanization and encroachment	Sharp decline – paved surfaces increased	Sediment load is visible, riverbank is narrowing	Spiritually intact but facing accessibility changes

Source: Author credit

Table 5. Major structural and environmental changes across the five ghats of Varanasi (2005–2025)

Ghat	Major Changes (2005–2025)
Asi	Beautification, sewage interception, and still some sanitation issues
Dashashwamedh	Tourist-friendly redesign; improved Aarti area; sewage STP
Manikarnika	Land subsidence 2–8 mm/yr; structural reinforcement possibly underway
Panchganga	Restoration & cleaning after earlier neglect; structural repairs
Adi Keshava	Upgraded public amenities; subsidence threat similar to others

Source: Author credit

4. DISCUSSION

This study offers a critical analysis of how rapid urbanization has transformed the cultural and physical landscape of Varanasi's Heritage Zone 1 between 2003 and 2023. The LULC change detection, combined with cultural mapping of five sacred ghats, reveals significant disruptions to both ecological and socio-cultural systems. Unlike previous studies that primarily focused on urban growth or environmental degradation in isolation, this research uniquely integrates remote sensing analysis with a cultural heritage perspective, thus bridging the gap between technological tools and heritage planning. For instance, while works by Rogan and Chen [31] and Kennedy et al. [12] effectively mapped LULC transformations, they did not address how these spatial changes affect spiritual landscapes or intangible practices. This study makes that connection explicit.

Through a geospatial-temporal framework, the study confirms that urban expansion—particularly in Heritage Zone 1—has occurred at the expense of vegetation (-7.12%) and water bodies (-0.71%). These losses are not just ecological but cultural, as vegetation and riverine elements play a symbolic and ritualistic role in Hindu cosmology. The degradation of sacred corridors, such as the Pañchatīrthī path linking the five ghats, results in both visual incoherence and ritual displacement. The symbolic framing of the ghats as the microcosmic body of Vishnu further underscores the cultural gravity of these losses. Changes like increased concrete structures, loss of open cremation spaces, and visual obstructions disrupt the experiential and spiritual authenticity of the zone. In this way, the paper reframes urban growth not as neutral development but as cultural erosion and spatial injustice, especially for communities whose livelihoods and identities are tied to these sacred geographies.

Furthermore, the classification accuracy (96.45%) and Kappa Coefficient (0.9437) validate the robustness of the methodology. However, beyond technical precision, this research proposes a heritage-resilient urbanization model, emphasizing that heritage-sensitive planning must be central—not peripheral—to city development. It argues for integrating remote sensing tools with local cultural narratives to design policies that protect heritage while managing urban growth. This fusion of technology and tradition is essential to preserve Varanasi's identity amid modernization pressures.

5. CONCLUSION

The analysis of LULC changes in Varanasi from 2003 to 2023 reveals that rapid and often unregulated urban expansion has significantly altered the city's cultural, spiritual, and physical landscape. A marked increase in urbanized areas—largely at the cost of vegetation and open land—has encroached upon traditional heritage zones, undermining both tangible heritage (temples, ghats, sacred streets) and intangible cultural practices.

Modern construction around sacred and historic sites continue to dilute the city's unique character and disrupt the ritualistic and communal use of space. The key findings of the study highlight the urgent challenges facing Varanasi's heritage in the context of rapid urban transformation. Over the past two decades, urban expansion in the city has surged by more than 90%, often at the expense of natural areas and culturally significant landscapes. One of the most affected

regions is Heritage Zone 1, which includes prominent ghats and temples that are central to Varanasi's religious and cultural identity. This zone is increasingly threatened by encroachment and unregulated construction, undermining its historical integrity and public accessibility. A critical concern is the lack of a coordinated urban planning policy that integrates heritage protection into the broader framework of city development. Although initiatives like the Smart Cities Mission and AMRUT have introduced important infrastructural improvements, they fall short in effectively addressing the preservation and promotion of Varanasi's tangible and intangible heritage, leaving significant cultural assets vulnerable to degradation or loss.

5.1 Policy recommendations

✧ Mandate Heritage Impact Assessments (HIA)

Require HIA for all infrastructure projects near heritage zones, aligning with UNESCO's Historic Urban Landscape (HUL) framework.

✧ Implement GIS-Based Zoning Regulations

Develop GIS-enabled zoning maps to enforce buffer zones, visual corridors, and construction restrictions. Use annual remote sensing-based LULC monitoring to track unauthorized changes.

✧ Establish Community-Led Planning Bodies

Form inclusive committees involving residents, priests, ghat workers, and conservationists to guide culturally appropriate development and ensure grassroots stewardship.

✧ Update Regulatory Frameworks

Revise the Varanasi Master Plan 2031 and Development Control Rules to: Impose height and density restrictions near heritage sites

• Enforce traditional architectural styles in core heritage areas

• Introduce visual impact norms for riverfront construction

✧ Create a Cultural Heritage Management Authority

Institutionalize a dedicated authority to oversee planning, monitoring, and enforcement of heritage-sensitive urban development, with participation from experts and local stakeholders.

Varanasi stands at a critical juncture. To protect its timeless cultural legacy while accommodating urban growth, the city must adopt a multi-tiered, participatory, and technology-enabled approach. Integrating heritage into the core of urban policy is not optional—it is essential for sustainable and resilient development.

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