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Spatial and Physical Transformation of Urban Gaya: A GIS-Enabled Temporal Assessment (1961–2011)

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Abstract: ***This study investigates the spatial and physical transformation of urban Gaya, Bihar, over a fifty-year period (1961–2011), employing Geographic Information System (GIS) tools for temporal analysis. Utilizing historical topographic maps, satellite imagery, and census data, it examines changes in urban extent, built-up areas, and land use/land cover (LULC). The findings reveal significant urban expansion into peripheral rural zones, primarily driven by demographic pressure, infrastructural growth, religious tourism, and the rise of informal settlements. This expansion often occurred at the cost of agricultural and open land, outpacing planned infrastructure development and resulting in uneven urban growth. The study emphasizes the urgent need for integrated and sustainable urban planning to ensure balanced development and mitigate environmental degradation. The outcomes provide critical insights for urban planners, policymakers, and researchers engaged in managing urban growth in similar contexts.***

Keywords: Urban Expansion, GIS, Land Use Change, Gaya, Sustainable Urban Planning

I. INTRODUCTION

Urbanisation is one of the most visible manifestations of global change occurring for anthropogenic reasons.Urbanization is a global phenomenon characterized by the increasing proportion of a nation's population residing in urban areas. It is closely tied to the growing economic, political, and cultural significance of cities. This process not only reflects demographic growth but also marks a structural transformation in society, typically involving a shift in employment from agriculture to non-agricultural sectors. Thus, urbanization can be seen as a geographical response to broader economic changes.Historically, urbanization has been associated with industrialization and economic advancement. Although the causal relationship has been debated, there is broad agreement among scholars that urbanization entails significant socio-economic shifts. It signifies the increasing concentration of populations in cities and towns, often accompanied by rising per capita resource consumption and substantial landscape alteration (McDonnell and Pickett, 1990). Thomson (1955) provided a comprehensive view of urbanization, describing it as the movement of people from smaller to larger communities, where economic activities are predominantly centred around governance, commerce, construction, and related sectors.In this context, Geographic Information Systems (GIS) have become essential tools in understanding and managing urbanization. GIS enables spatial analysis, mapping of land use changes, infrastructure planning, resource management, and urban expansion monitoring. It supports data-driven decision-making, helping planners design sustainable, efficient, and resilient urban environments while addressing challenges such as congestion, sprawl, and environmental degradation. The integration of GIS with remote sensing technologies offers powerful capabilities for scenario simulation, allowing researchers and policymakers to forecast future land use and cover changes based on development stages, city-scale data, and urban planning parameters (Wang et al., 2021).

II. OBJECTIVES

1) To analyze the patterns and trends of population growth across various cities within Gaya district.
2) To investigate the spatial dynamics and extent of urban expansion in the cities of Gaya district.
3) To assess the changes in land use and land cover (LULC) in different urban centres of Gaya district over time.

III. HYPOTHESIS

Urban expansion in Gaya district (1961–2011) is primarily driven by population growth and tourism, leading to significant conversion of agricultural land into built-up areas.

IV. METHODOLOGY

The study adopts a geospatial methodology to assess urban expansion and land use/land cover (LULC) changes in the cities of Gaya district using remote sensing and GIS tools. Landsat satellite imagery from Landsat-5 Thematic Mapper (TM) for 1991 and Landsat-8 Thermal Infrared Sensor (TIRS) for 2024, both with a 30-meter spatial resolution and less than 10% cloud cover, were sourced from the USGS Earth Explorer platform (https://earthexplorer.usgs.gov). To ensure seasonal consistency and optimal classification accuracy, images were selected from early March (Chettri & Surawar, 2021). ArcMap was used for image processing, classification, and spatial analysis, while Google Earth Pro supported visual interpretation and validation. Pre-processing steps such as geometric and radiometric corrections were applied, followed by supervised classification to categorize land use types. Post-classification comparison enabled the detection and quantification of changes over time. This integrated approach facilitated accurate mapping of urban growth and LULC dynamics, providing a foundation for sustainable urban planning and policy formulation in the region.

V. POPULATION GROWTH

Kingsley Davis (1908–1996), a pioneer in the study of historical urban demography, emphasized that the demographic dimension is fundamental to understanding the process of urbanization and the trajectory of urban history. Population growth acts as a catalyst for urban expansion, as cities must adapt to accommodate increasing numbers of inhabitants. Rapid population increases place significant pressure on existing infrastructure, necessitating the development of new residential, commercial, and industrial zones. Urbanization is thus driven, in part, by both natural population growth and rural-to-urban migration, as individuals seek better employment opportunities, services, and living standards. In the context of Bihar, the city of Gaya has experienced notable urban population growth, influenced by factors such as economic development, infrastructural improvements, and significant rural in-migration. Additionally, Gaya's status as a major religious and cultural centre attracts both domestic and international pilgrims and tourists, further contributing to the city's demographic expansion and urban transformation.

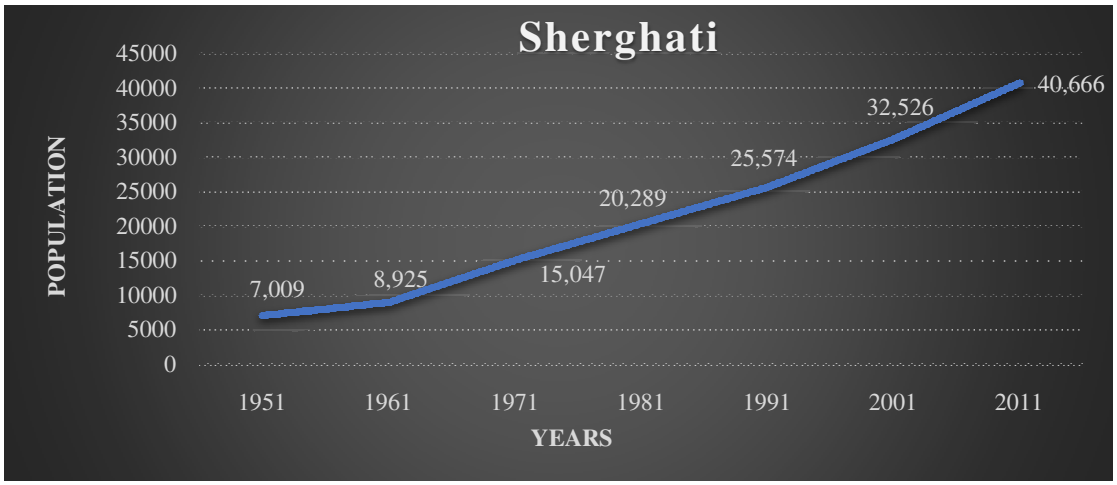
Table1:PopulationGrowthinVariousUrbanAreasofGaya(1951-2011)

S.No.	UrbanCentre sofGayaDist rict.	1951	1961	1971	1981	1991	2001	2011
1	GayaTown	1,33,700	1,51,105	1,79,884	2,47,075	2,94,427	3,94,945	4,75,987
2	Sherghati	7,009	8,925	15,047	20,289	25,574	32,526	40,666
3	Tikari	6,278	7,392	8,700	12,281	14,202	17,621	21,324
4	Bodhgaya	.....	6,299	6,968	15,724	21,692	30,857	38,439
5	Guraru	---	---	---	---	---	---	5,185
	Total	1,46,987	1,73,721	2,10,599	2,95,369	3,55,895	4,75,949	5,81,601

Source:DistrictCensusHandbookGaya,PartXII-A, page-45&1789

Table 1 presents the population growth trends across various urban towns in Gaya district between 1951 and 2011. The district headquarters, Gaya city, experienced significant demographic expansion, with its population increasing from 133,700 in 1951 to 475,987 in 2011. This substantial growth reflects broader urbanization trends likely driven by factors such as rural-to-urban migration, economic opportunities, and infrastructural development. Similarly, Sherghati's population surged from 7,009 in 1951 to 40,666 in 2011, indicating notable urban growth and economic progress in the region. Tekari exhibited moderate population growth, with its urban population rising from 6,278 in 1951 to 21,324 in 2011, suggesting gradual urbanization. Bodhgaya, known for its religious significance, saw its population grow from 6,299 in 1961 to 38,439 in 2011, largely attributable to tourism and related economic activities. The town of Guraru appears to have initiated its growth post-2001, reaching a population of 5,185 by 2011. Collectively, these figures underscore the demographic transitions and urbanization processes occurring in Gaya district, shaped by the complex interaction of economic, social, and cultural influences over the decades.

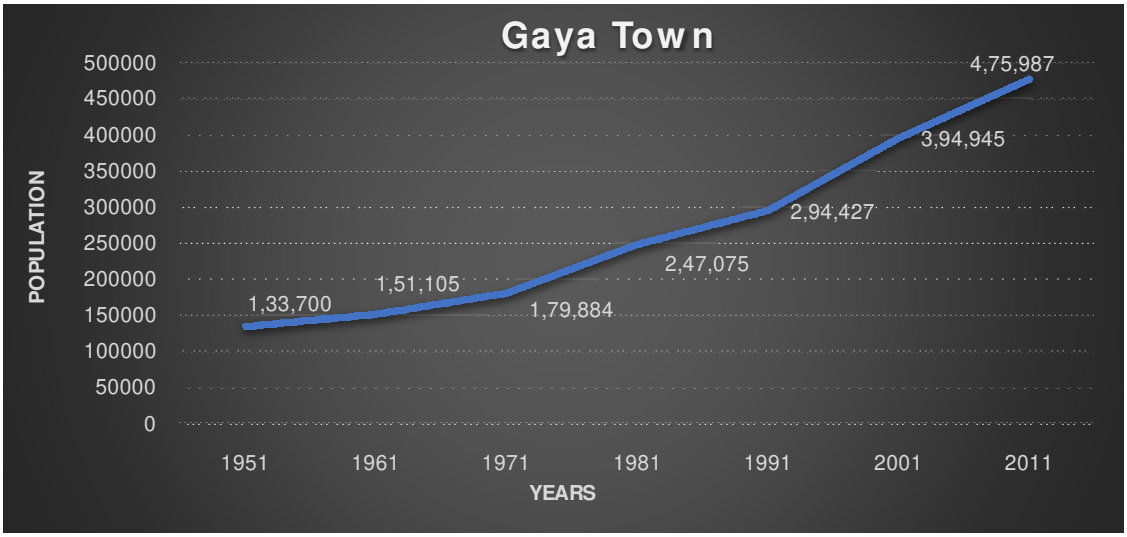
Fig.1:UrbanPopulationinSherghati(1951-2011)



Source: DistrictCensusHandbookGaya,PartXII-A,page-1789

According to Figure 1, urban population growth was slow between 1951 and 1961 but nearly doubled during 1961–1971. This surge was primarily driven by rural-to-urban migration following India's independence, as challenging rural conditions—such as unemployment, food scarcity, lack of healthcare, and limited educational opportunities—pushed people toward cities. From 1971 to 1991, migration to urban areas continued steadily, with an approximate decadal increase of 5,000 residents. Between 1991 and 2011, the growth rate accelerated again, fueled by expanding economic opportunities that attracted migrants seeking employment. Additionally, improvements in urban amenities in Sherghati, including healthcare, education, and infrastructure, contributed significantly to this population increase.

Fig.2:UrbanPopulationinGayaTown(1921-2011)

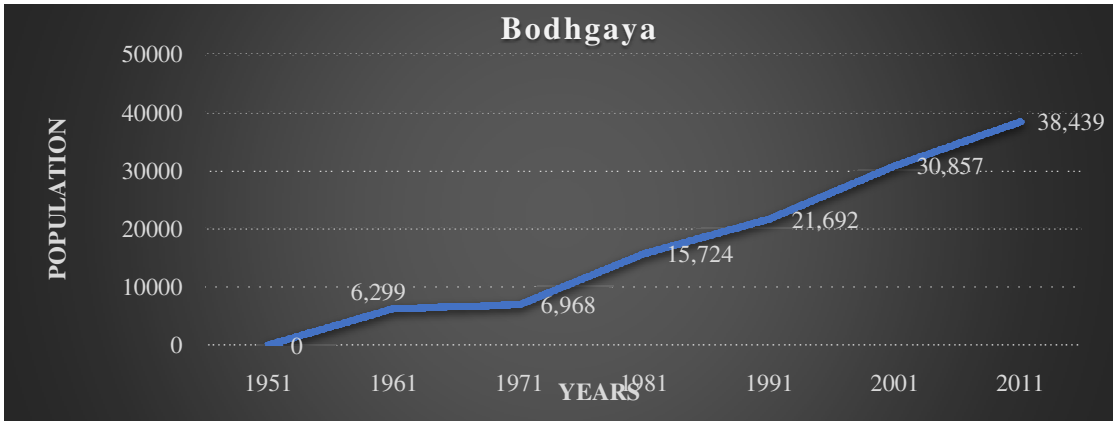


Source: District Census Handbook Gaya, Part XII-A ,page-1789

Figure 2 illustrates the steady population growth of Gaya city from 1951 to 2011, reflecting ongoing urbanization. The city's population increased from 133,700 in 1951 to 151,105 in 1961, marking a decadal growth rate of 13.02%. This upward trend continued between 1961 and 1971, with a growth rate of 19.01%. Between 1971 and 1981, the population growth accelerated to 37.1%. The most significant increase occurred from 1981 to 2001, when the urban population nearly doubled, exhibiting a growth rate of 59.84%. Although the growth rate slowed to 26.6% between 2001 and 2011, the overall pattern of sustained urban population growth persisted.

Key drivers of this increase include economic development, expanding employment opportunities, improved healthcare and education, and advancements in transportation and communication infrastructure. Additionally, Gaya's role as the administrative centre of the Magadh division and district has likely reinforced its status as a focal point for urban migration.

Fig.3:UrbanPopulationinBodhGaya(1951-2011)

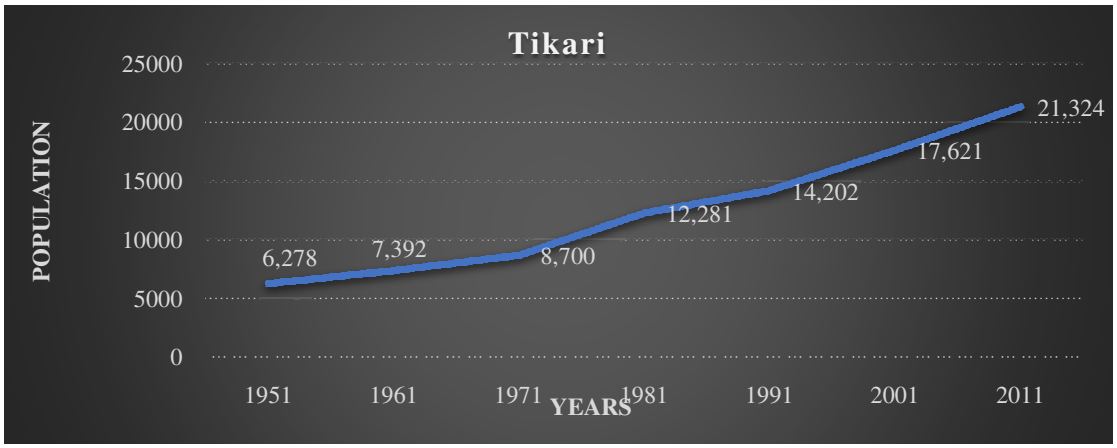


Source: DistrictCensusHandbookGaya,PartXII-A, page-1789

Figure 3 illustrates the steady growth of Bodhgaya's urban population over five decades, from 1961 to 2011. While the population increase was modest between 1961 and 1971, a significant surge began in the 1980s and continued through the next three decades. The sharp upward trends in the graph reflect key phases of urban development.

This growth has been largely driven by the expansion of tourism-related economic activities and employment opportunities, attracting migrants from surrounding rural areas. Improvements in infrastructure—particularly in transportation, education, and tourism facilities—have enhanced Bodhgaya's appeal. As the site where Lord Gautama Buddha attained enlightenment, Bodhgaya draws millions of international and domestic pilgrims, spurring tourism and associated sectors such as hospitality, transport, and handicrafts. The convergence of spiritual significance and economic growth has transformed Bodhgaya into a globally recognized cultural and urban centre.

Fig.4:UrbanPopulationinTikari(1951-2011)



Source: District Census Handbook Gaya, Part XII-A, page-1789

Figure 4 illustrates the trend of urban population growth in Tekari from 1951 to 2011. During the initial decade (1951–1961), growth was relatively modest compared to the rapid increases observed in the following decades. Between 1961 and 1981, population growth began to accelerate, reflecting Tekari's development as a Class-5 town primarily through rural-to-urban migration. The rise in small-scale industries and commercial activities during this period attracted migrants seeking livelihood opportunities. The steepest increase is visible between 1981 and 2011, with each decade witnessing a population rise of approximately 4,000. This surge can be attributed to intensified migration and urban expansion. Strategically located along a key roadway, Tekari has evolved into a hub for trade and commerce, particularly as a marketplace for agricultural produce, further enhancing its role in the district's urban network.

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VI. EXPANSION OF VARIOUS TOWNS IN GAYA

The spatial growth of urban areas in Gaya district over the decades is presented in the table, indicating a consistent increase in the built-up area of major towns from 1961 to 2011.

The Table- 2 below illustrates that Gaya town, the largest urban centre, expanded from 30.51 sq. km in 1961 to 38.62 sq. km in 1981, reaching 50.17 sq. km by 2011—reflecting substantial urban sprawl over five decades. Sherghati's area also grew significantly, from 3.89 sq. km in 1961 to 10.70 sq. km in 1981, with a slight increase to 10.79 sq. km by 2011. Tikari witnessed modest spatial expansion, growing from 1.81 sq. km in 1961 to 2.66 sq. km in 1981, maintaining the same area in 2011. Bodhgaya experienced notable spatial growth as well, with its area increasing from 11.0 sq. km in 1961 to 19.58 sq. km in 1981, remaining stable through 2011. Overall, the total urban area of these towns combined increased from 47.21 sq. km in 1961 to 83.20 sq. km by 2011, highlighting the steady physical development of urban spaces across the district.

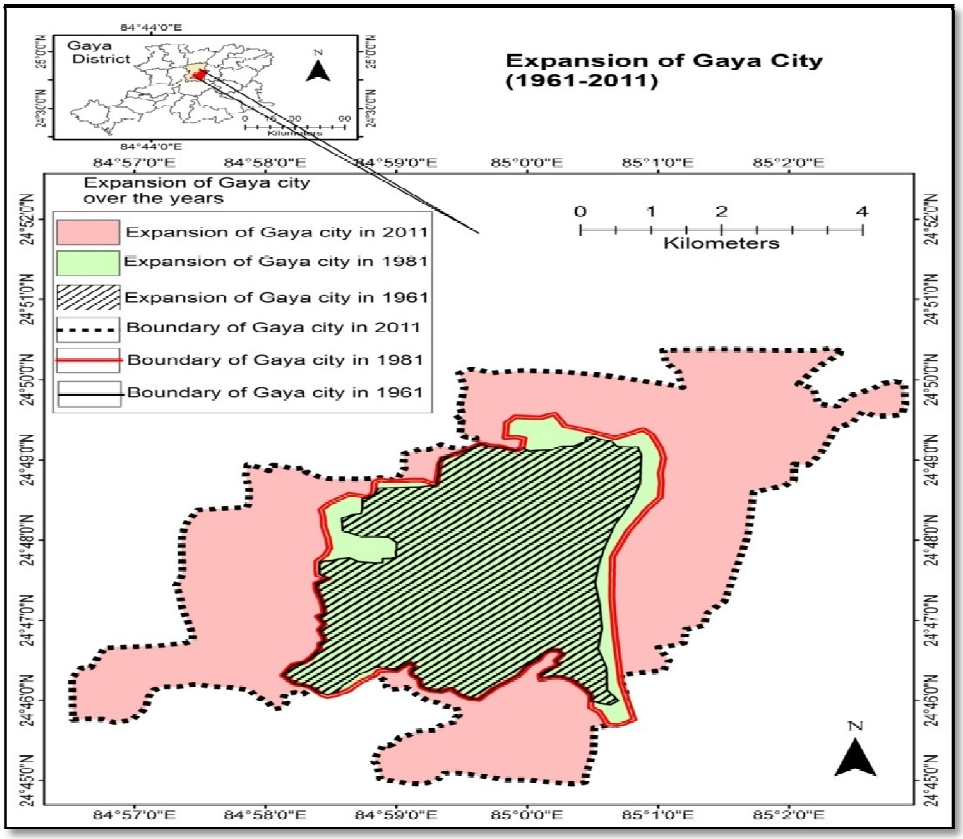
Table2 :TrendofRegionalExpansionofVariousTownsinGaya(1961-2011)

S.No.	NameoftheTowns	Area(sq.km)		
		Years		
		1961	1981	2011
1	GayaTown	30.51	38.62	50.17
2	Sherghati	3.89	10.70	10.79
3	Tikari	1.81	2.66	2.66
4	Bodhgaya	11.0	19.58	19.58
	Total	47.21	71.56	83.20

Source: DistrictCensusHandbookGaya,1961,1981&2011

A. GayaCity

Map1:ExpansionofGayaCity(1961,1981,2011)



Source:DevelopedbyResearchScholarwiththehelpofArcMap

Gayacitygrowthhasbeenaffectedbythecity'sreligiousandhistoricalimportance.GayaisaveryoldcityofIndia.AsperTable- 2,post-independence,thespatialgrowthofGayacityin1961roseto50.17km²in2011.Thisimpliesthatinthelast50years,thecityareaincreasedby64.44%.Thisgrowthiscertainlyduetothefollowingreasons:

(a)GayaisaprominentreligioushubforHinduism,Buddhism,andJainism.Thearrivalofpilgrimsanddevoteesofthesereligionshasspurredthegrowthofinfrastructureanddifferentservicesinthecity.Thishasbeenamajorcontributortotheurbanizationof Gaya.

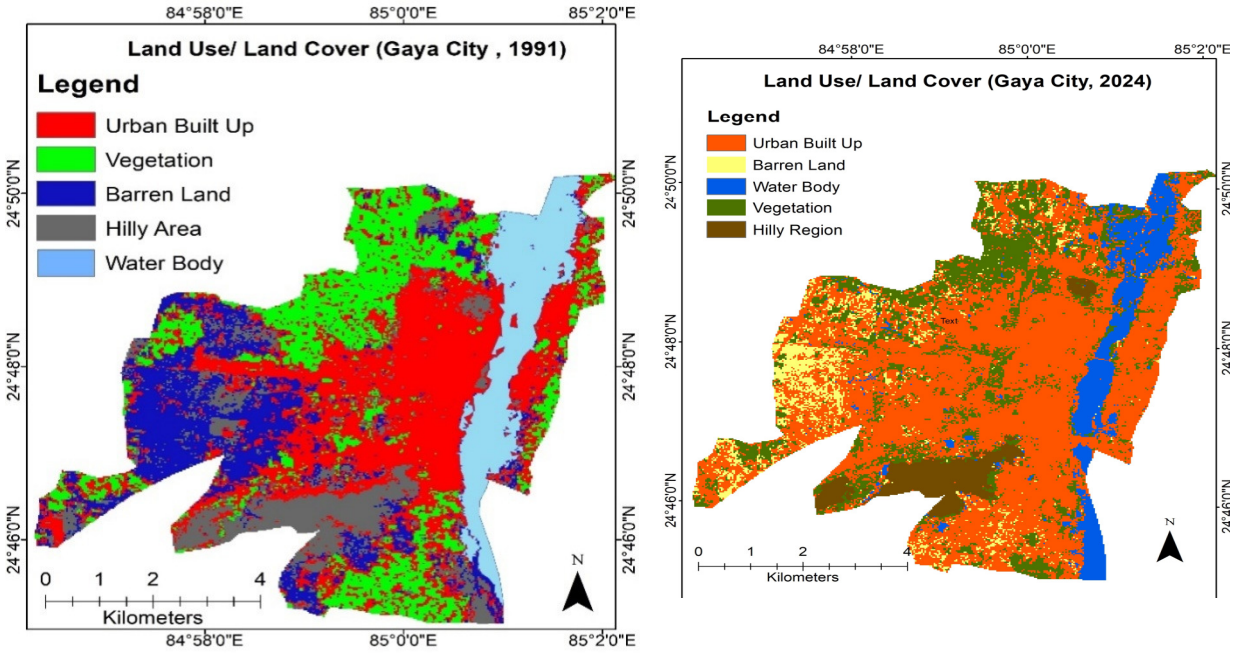
(b)Gayaisfavourablylinkedwithotherbigcitiesinthecountrybyroad,rail,andairtransportation.GayaJunctionissituatedalongtheDelhi-HowrahGrandChordrailwaycorridor,amajorcommercialrailwayroute.Itslocationalongancienttraderouteshavetraditionallyfavouredtradeandcommerceactivities.Thishasbeenpivotalinmaking Gayaacommercialcentreanditsgrowth.

(c)GayaisalsotheadministrativehubofGayadistrictandMagadhdivision,whichmakesitstrategicallyimportant.

(d)Accesstobasichumandevelopmentneedslikeeducation,medicalcare,potablewater,andjobshasalsohastenedthedevelopmentofGayacity.

(e)Governmentpoliciesfacilitatingdevelopment,combinedwithprojectsandinvestments,havehelpedGayacitygrow.

Map 2: Change in Land Use Pattern in Gayacity (1991- 2024)



Source: Developed by Research Scholar with the help of ArcMap

The maps of Gaya City's land use/land cover for the years 1991 and 2024 highlight significant spatial transformations over the 33-year period. Between 1991 and 2024, Gaya City underwent extensive urban sprawl, consuming both vegetated and barren lands. The maps clearly depict a shift towards urban dominance at the expense of ecological spaces, underlining the need for sustainable planning to protect natural assets like greenery, hills, and water bodies

Table 3: Change In Land Use & Land Cover Pattern in Gaya city (1991- 2024)

S. No.	Land Use	Area (K.M.^{2}) (Years)	
		1991	2024
1	Urban Built Up	19.37	30.17
2	Vegetation	10.4	5.96
3	Hilly region	5.83	5.83
4	Water Body	6	4.84
5	Barren Land	8.57	3.37
	Total	50.17	50.17

Source: Self calculated by Research Scholar with the help of USGS Earth Explorer &ArcMap

Above table no- 3 shows significant changes in the spatial pattern of land use types within a period of 33 years. It addresses five major land categories: Urban Built-up, Vegetation, Hilly Region, Water Body, and Barren Land.

The change is most remarkable in the Urban Built-up category, which has grown considerably from 19.37 km² in 1991 to 30.17 km² in 2024, registering an increase of around 10.8 km². It shows the fast urbanization of Gaya, and factors such as population growth, religious tourism, and growing infrastructure may have facilitated this change. The rise points toward a shift towards more dwelling, commercial, and institutional development.On the other hand, Vegetation decreases from 10.4 km² to 5.96 km², a decrease of close to 42%. This indicates that green natural spaces have been utilized for urban or agricultural purposes, potentially undermining local biodiversity and environmental sustainability.

Hilly Areas, staying at 5.83 km², also seem to be development-free, probably because of geographical limitations or the safeguarding regulations. Still, their ecological function is still crucial and can be affected indirectly by the changes around them.

Water Bodies also saw a fall from 6 km² to 4.84 km², showing a 19.3% decline. This reduction could result from encroachments, contamination, or non-conservation, making water security and ecological well-being questionable.

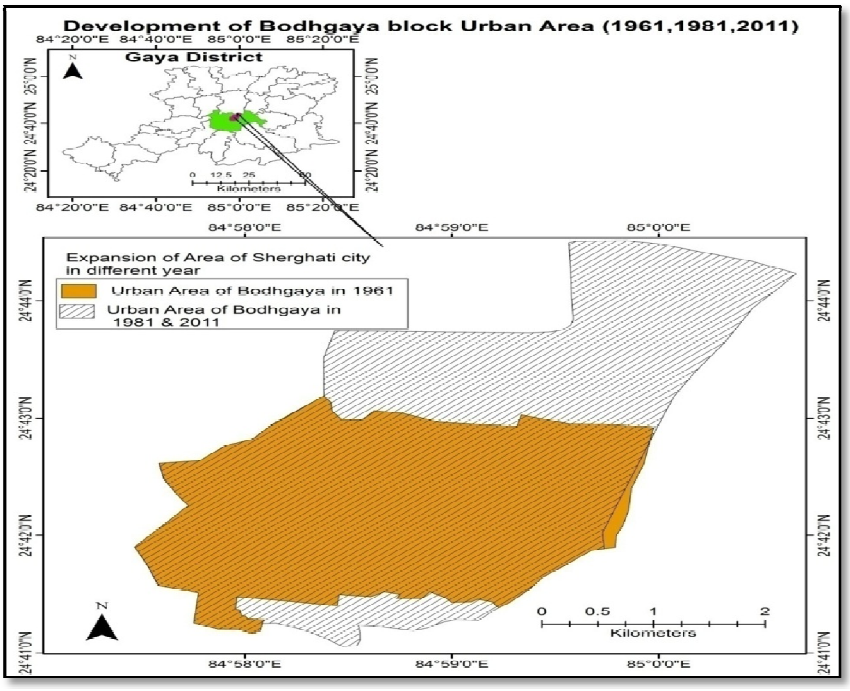
Finally, Barren Land was reduced from 8.57 km² to 3.37 km², which might reflect its development into usable land. Though this might be for development, it also implies extensive land use without necessarily guaranteeing ecological balance.Overall, the figures show a distinct trend of urban expansion over natural and ecological areas, highlighting the importance of sustainable land use planning in Gaya City.

B. BodhGaya

Between 1961 and 2011, Bodh Gaya's urban area expanded by approximately 78%, reaching 19.58 km². This significant spatial growth can be attributed to several key factors.

- First, as one of the most sacred sites in Buddhism, Bodh Gaya attracts millions of pilgrims and international tourists annually, prompting the development of hospitality infrastructure and support services.
- Second, increasing demand for residential and commercial spaces has driven real estate expansion beyond the traditional city core, contributing to outward urban sprawl.
- Third, improvements in road connectivity and the provision of public services have further facilitated urban expansion, as rising population pressure and tourism inflows necessitate continual infrastructure development across a broader geographic area.

Map3:ExpansionofBodhGayaCity(1961,1981,2011)



Source: Developed by Research Scholar with the help of ArcMap

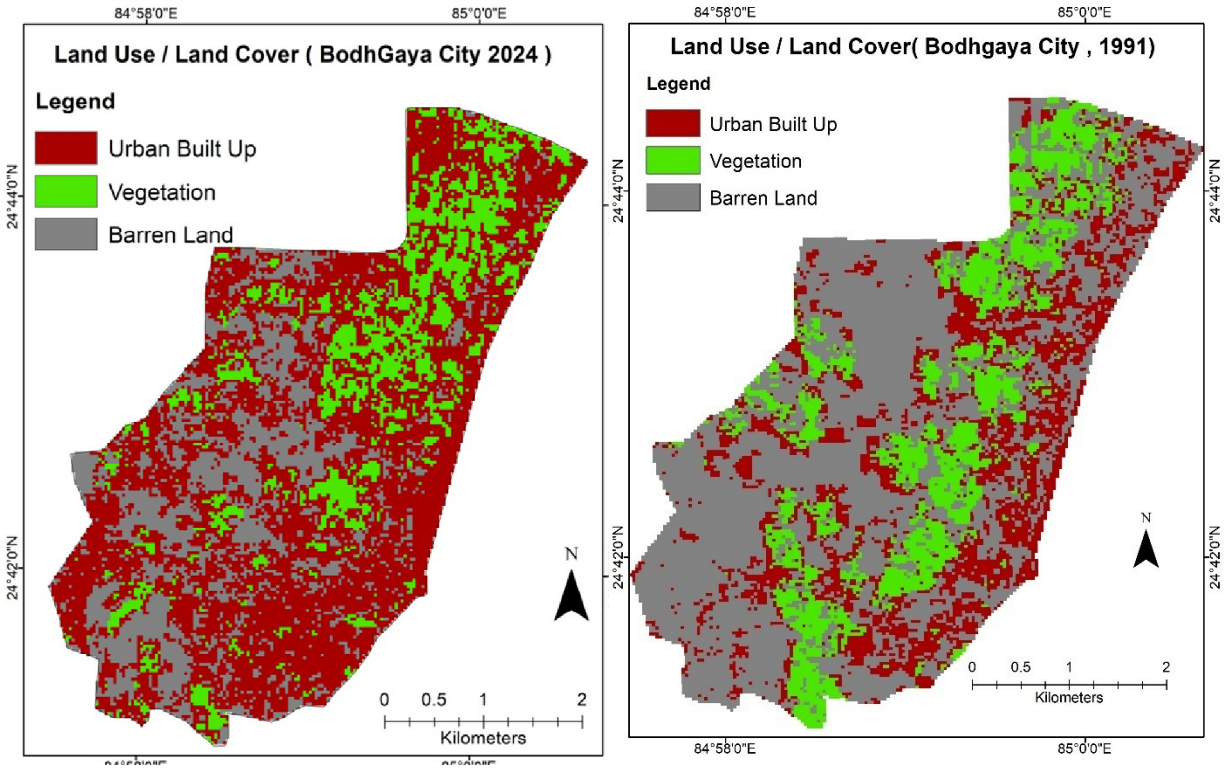
Table 4 : Change In Land Use & Land Cover Pattern in Bodhgaya city (1991- 2024)

S. No.	Land Use	Area (K.M.^{2}) (Year)	
		1991	2024
1	Urban Built Up	6.39	12.52
2	Vegetation	3.39	2.96
5	Barren Land	9.8	4.10
	Total	19.58	22.58

Source: Source: Self calculated by Research Scholar with the help of USGS Earth Explorer &ArcMap

The table no- 4 highlights significant land use changes in Bodhgaya over a 33-year period, focusing on three key categories: Urban Built-up, Vegetation, and Barren Land. The most prominent transformation is observed in the Urban Built-up area, which nearly doubled from 6.39 km² in 1991 to 12.52 km² in 2024—an increase of 6.13 km². This rapid expansion reflects intensified urbanization driven by population growth, religious tourism, and infrastructure development, leading to widespread construction of housing, roads, commercial facilities, and institutional spaces. Concurrently, Vegetation has seen a slight decline from 3.39 km² to 2.96 km². Though modest at 0.43 km², this reduction poses ecological concerns, as even small-scale loss of green cover can affect biodiversity and local environmental quality. The most substantial decline is in Barren Land, which fell from 9.8 km² to 4.10 km²—a decrease of 5.7 km²—indicating conversion of underutilized land into built-up or functional urban spaces. Overall, the land use pattern in Bodhgaya from 1991 to 2024 reveals a strong urban growth trajectory, underscoring the need for integrated and environmentally sensitive planning to balance development with ecological sustainability.

Map 4 :Change In Land Use Pattern in Bodhgaya City(1991- 2024)



Source: Developed by Research Scholar with the help of ArcMap

The two maps illustrate significant land use and land cover changes in Bodhgaya City between 1991 and 2024. In **1991**, much of the city was covered by **barren land** (grey) and **vegetation** (green), with **urban built-up areas** (red) relatively limited and scattered. By **2024**, there is a visible and substantial expansion of **urban built-up land**, now occupying a majority of the area, especially in the southern and central regions. This expansion has clearly come at the cost of both **vegetation** and **barren land**, which have significantly declined.

These spatial patterns highlight rapid urbanization over the past three decades, driven by population growth, tourism, and infrastructure development in Bodhgaya. The trend reflects a shift from natural and unused lands to more intensive urban land uses.

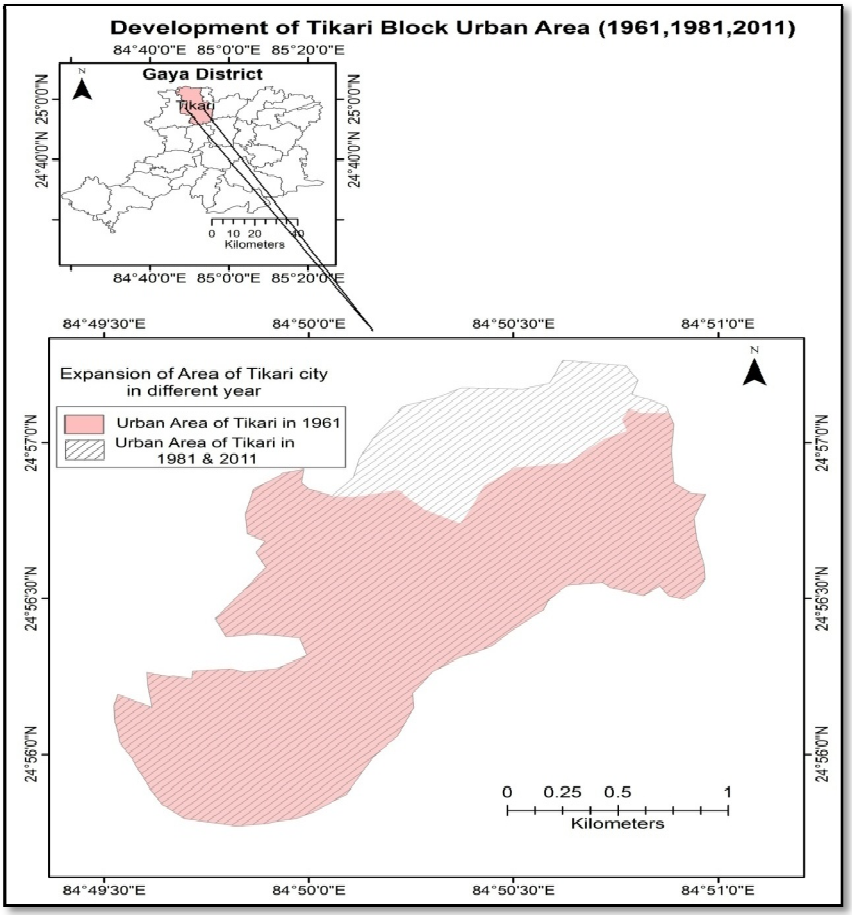
C. Tekari

The map no- 5 illustrates the development and spatial expansion of the urban area of Tikari Block in Gaya District, Bihar, across three census years: 1961, 1981, and 2011.The inset map at the top shows the location of Tikari within Gaya District in Bihar.The main map below highlights the urban area of Tikari city.The legend indicates two zones:

- The solid pink area represents the extent of the urban area in 1961.
- The hatched pink area shows the additional urban area developed by 1981 and 2011.

The map visually demonstrates significant urban growth, with the city expanding beyond its 1961 boundaries by 1981 and 2011.A scale bar is provided for distance reference, and geographic coordinatesare marked around the map.In summary, the map documents the outward expansion of Tikari's urban area over five decades, highlighting urbanization trends in the region.

Map5 :ExpansionofTekaricity(1961,1981,2011)

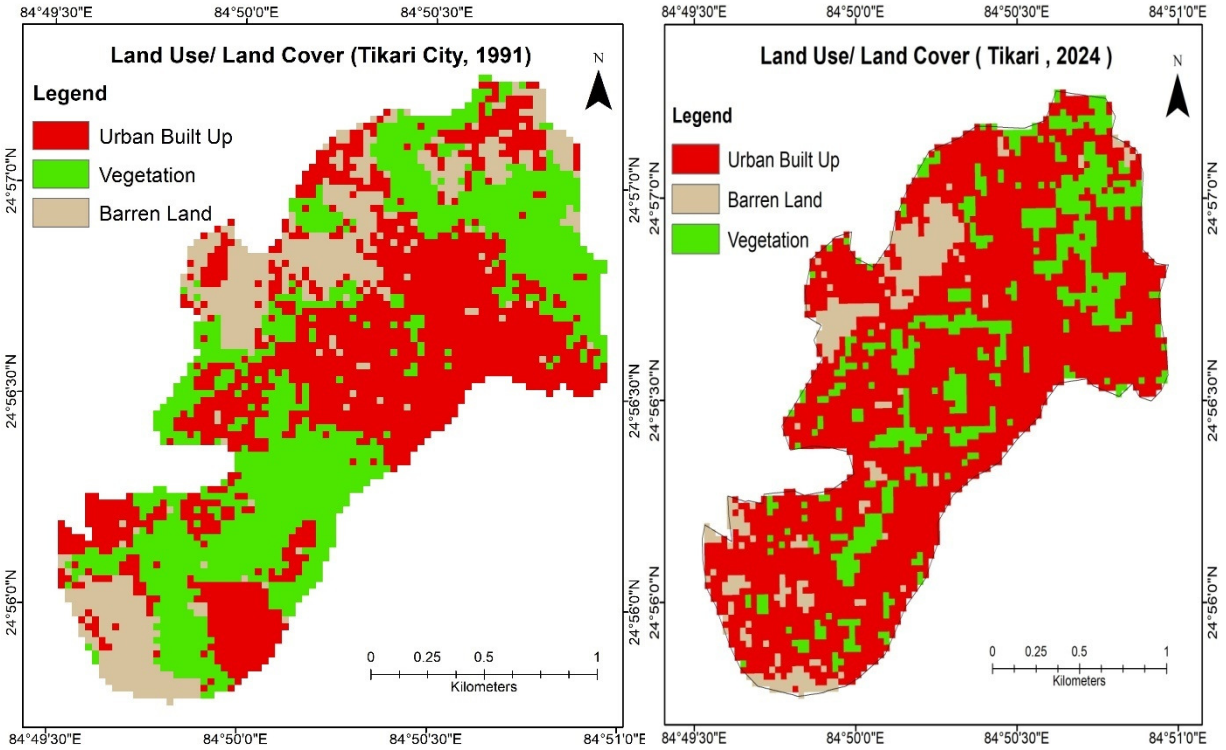


Source: Developed by Research Scholar with the help of ArcMap

According to Table 5, Tekari is the smallest urban locality in the district by area, covering just 2.66 km² as of 2011. Historically, it began as a small colony after India's independence, though its roots trace back much further. Tekari is an ancient town, respectfully referenced in Mughal religious texts. One of its most prominent landmarks is the Tekari Fort, a popular attraction.

Traditionally a hub for grain storage, Tekari played a key role in preserving agricultural produce. The town's growth has been largely driven by economic activities such as agricultural trade and small-scale industries. It provides employment opportunities for people from surrounding villages, particularly cultivators who come to sell their produce. Since agriculture remains the primary livelihood in the region, Tekari's development is closely tied to the prosperity of its farming community.

Map 6: Change In Land Use Pattern in Tikari City (1991- 2024)



Source: Developed by Research Scholar with the help of ArcMap

The two maps display the **Land Use/Land Cover (LULC)** changes in **Tikari City** between **1991** and **2024**, highlighting shifts in urbanization and natural land cover.**Urban Built-Up Area (Red)**There is a **substantial increase** in red areas from 1991 to 2024, indicating significant **urban expansion** across the city.**Vegetation (Green)**:Green areas have **declined noticeably**, reflecting a **loss of green cover** due to urban development.**Barren Land (Beige)**Barren land has also **reduced**, suggesting that much of this previously unused land has been converted into urban or productive land uses.Between 1991 and 2024, Tikari has experienced **widespread urban growth**, largely at the cost of **vegetation and open (barren) land**. The spatial patterns underscore an ongoing trend of **urbanization**, emphasizing the need for **balanced development and green space preservation** in the future.

Table 5: Change In Land Use & Land Cover Pattern in Tikari city (1991- 2024)

S. No.	Land Use	Area (K.M.^{2}) (Year)	
		1991	2024
1	Urban Built Up	1.23	2.15
2	Vegetation	1.01	0.37
5	Barren Land	0.44	0.14
	Total	2.68	2.66

Source: Self calculated by Research Scholar with the help of USGS Earth Explorer &ArcMap

Table No. 5 presents a comparative overview of land conversion in Tikari over a 33-year period. It categorizes land use into three primary types: Urban Built-up, Vegetation, and Barren Land. The data highlights Tikari's gradual transformation into a modest yet steadily expanding urban hub in Bihar.

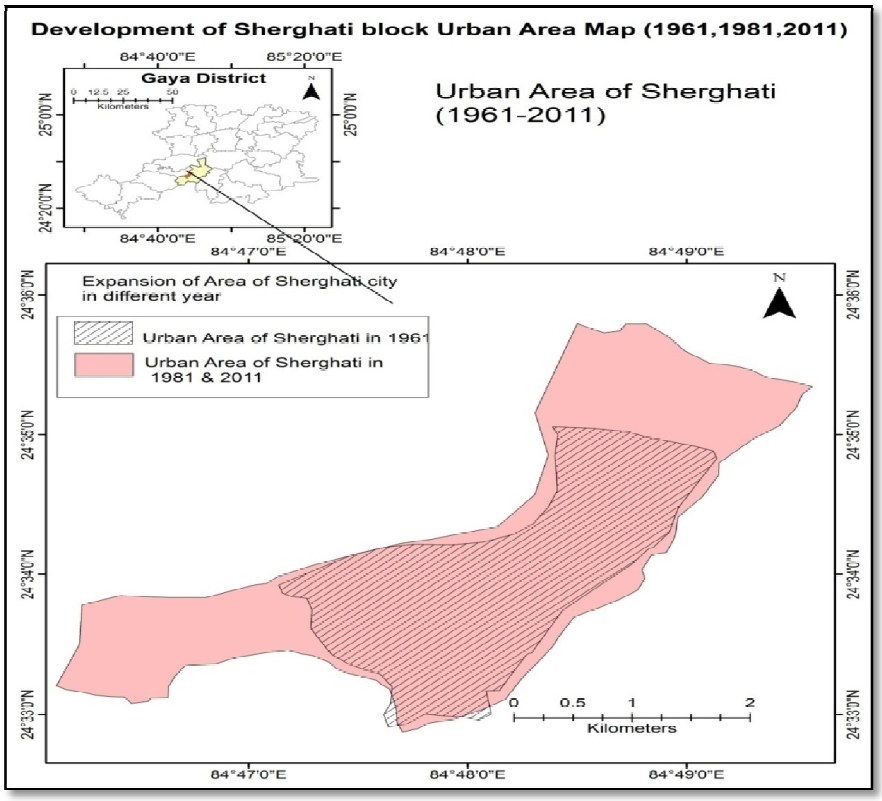
The Urban Built-up area has increased from 1.23 km² in 1991 to 2.15 km² in 2024—an expansion of 0.92 km², or approximately 75%. This steady growth reflects factors such as population increase, administrative expansion, and the development of infrastructure, including housing, roads, and public services. While the absolute growth is modest compared to larger urban centers, the relative increase is substantial for a town of Tikari's size, clearly signalling ongoing urbanization.In contrast, the area under Vegetation has declined significantly—from 1.01 km² to 0.37 km²—marking a reduction of nearly 63%.

This sharp decrease in green cover points to the growing pressure of urban development on natural land resources and raises concerns about environmental sustainability in a town with limited ecological reserves.

Similarly, Barren Land has decreased from 0.44 km² to 0.14 km², suggesting that previously unused or marginal lands have been brought under urban or productive use. While this may indicate efficient land utilization, it also reflects the shrinking availability of open spaces.Overall, Tikari is undergoing measured but meaningful urban expansion, accompanied by a notable loss of natural and open land. This trend underscores the need for strategic urban planning to balance growth with environmental conservation.

D. Sherghati

Map 7: Expansion of Sherghati City (1961, 1981, 2011)



Source: Developed by Research Scholar with the help of ArcMap

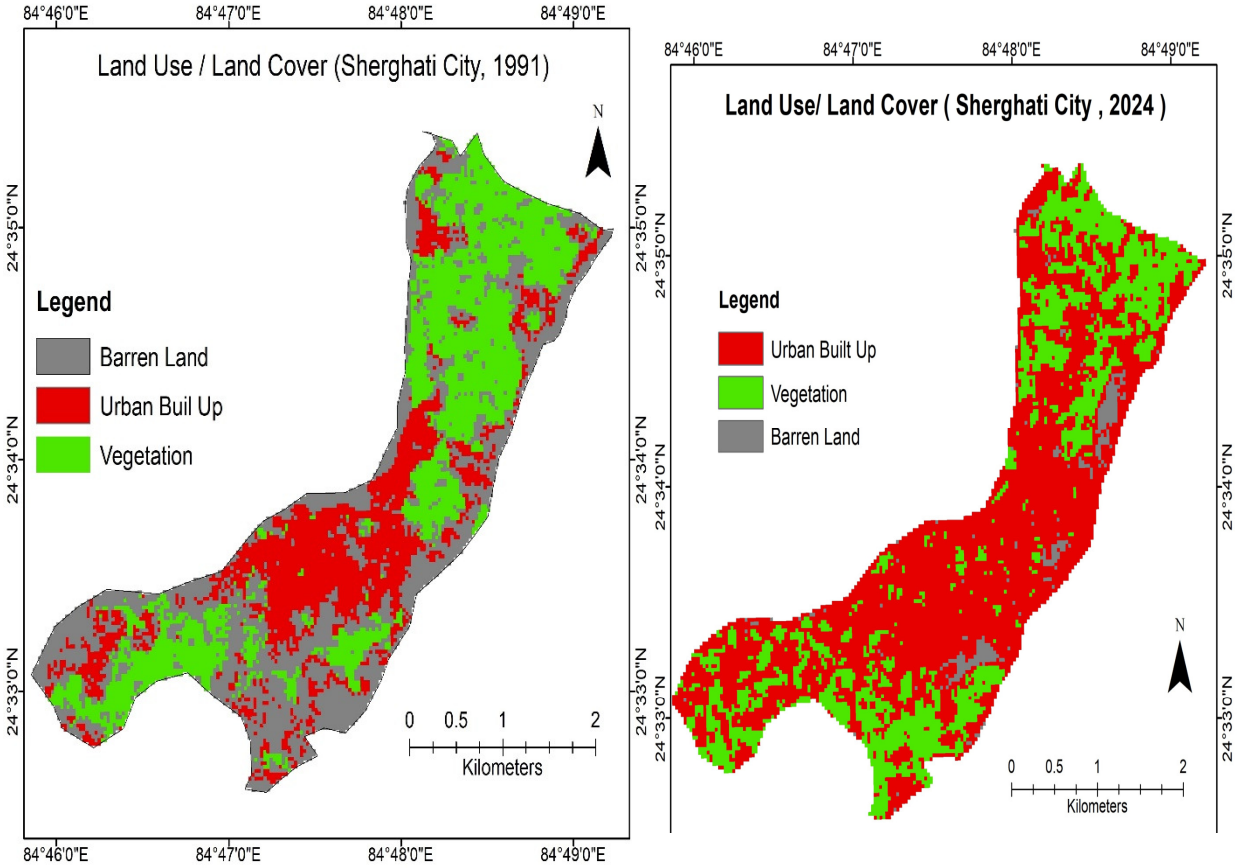
The map titled **"Urban Area of Sherghati (1961–2011)"** illustrates the **spatial expansion of Sherghati city** over a 50-year period, highlighting two key phases of urban growth.

- Inset Map**:**
  Located in the top-left corner, it shows the location of Sherghati block within Gaya District**, Bihar.**
- Urban Area in 1961**:**
  Represented with **diagonal hatching**, this shows the core urban area of Sherghati as it existed in 1961.

Urban Expansion in 1981 & 2011:

The **solid pink shaded area** represents the expanded urban footprint as of **1981 and 2011**, indicating significant outward growth beyond the 1961 boundary.The map demonstrates that **Sherghati city has undergone steady and considerable urban expansion** from 1961 to 2011. The urban area has extended in multiple directions, especially to the east and west, reflecting **population growth, increased infrastructure, and urban development** over the decades. This visualization highlights the town's transformation from a small core settlement to a more extensive urban space.

Map 8 :Change In Land Use Pattern in Tikari City (1991- 2024)



Source: Developed by Research Scholar with the help of ArcMap

Table 6 :Change In Land Use & Land Cover Pattern in Sherghati city (1991- 2024)

S. No.	Land Use	Area (K.M.^{2}) (Year)	
		1991	2024
1	Urban Built Up	3.41	7.05
2	Vegetation	4.27	3.49
5	Barren Land	3.02	0.25
	Total	10.70	10.79

Source: Self calculated by Research Scholar with the help of USGS Earth Explorer &ArcMap

The table titled **"Change in Land Use & Land Cover Pattern in Sherghati City, Gaya (1991–2024)"** presents a clear picture of the city's transformation over 33 years. The three primary land use categories—**Urban Built-up**, **Vegetation**, and **Barren Land**—reveal the pace of urbanization and associated environmental shifts. The most significant change is observed in the **Urban Built-up area**, which expanded from **3.41 km² in 1991 to 7.05 km² in 2024**—an increase of **3.64 km²** or over **106%**. This rapid urban growth reflects factors such as population rise, improved connectivity, expanded infrastructure, and economic development, particularly in commerce and trade within this sub-regional town of Gaya district. Meanwhile, **Vegetation cover** declined from **4.27 km² to 3.49 km²**, a reduction of **0.78 km²**. Although moderate, this reduction indicates the gradual encroachment of green spaces due to urban expansion. The most dramatic change occurred in **Barren Land**, which shrank from **3.02 km² to just 0.25 km²**, marking a decline of over **90%**. This suggests that previously unused land has been converted for residential, commercial, or institutional purposes.

In summary, **Sherghati is undergoing rapid urbanization**, marked by a substantial increase in built-up areas and a notable loss of natural and open land. While this growth reflects development, it also underscores the pressing need for **sustainable urban planning and environmental management** to ensure balanced and resilient urban growth

After the analysis of multiple layers of evidence from demographic, spatial, and thematic evidence the hypothesis formulatedUrban expansion in Gaya district (1961–2011) is primarily driven by population growthand tourism, leading to significant conversion of agricultural land into built-up areas is proved.

The census data shows a steady and significant rise in urban population in Gaya district. Other towns in Gaya district (e.g., Bodhgaya, Tekari) also recorded substantial growth in both population and urban area, confirming widespread urban expansion. Inference: Rising population led to increased demand for housing, roads, institutions, and services — pushing cities to expand outward into agricultural and open lands. Spatial Evidence from Land Use Maps (1991 vs 2024) shows agricultural and natural land is being converted into urban land use to meet the needs of expanding populations. Growth in tourism places pressure on urban infrastructure and fuels expansion, particularly in towns like Bodhgaya. Improved connectivity accelerates land development and encourages rural-to-urban migration and urban sprawl.

VII. CONCLUSION

The data assessed for Gaya district between 1951 and 2011 provides valuable insights into the region's infrastructural development and socio-demographic transformation, driven by a steadily growing urban population. The urban areas within the district experienced significant spatial expansion, particularly between 1961 and 2011.Gaya City, the district's most populous urban center, expanded by 64.44%, reaching 50.17 km². Bodh Gaya, benefiting from its status as a major Buddhist pilgrimage site, grew by 78% to 19.58 km². Sherghati, strategically located near NH-19 and boosted by agricultural trade, saw the most dramatic growth of 177.37%, expanding to 10.79 km². In contrast, Tekari remained relatively small, covering just 2.66 km², reflecting its traditional and agricultural character.

Overall, the total urban area in the district grew from 47.21 km² in 1961 to 83.2 km² by 2011, influenced by factors such as religious tourism, transport connectivity, and economic activity. Gaya City's population rose sharply from 133,700 in 1951 to 475,987 in 2011, and similar trends were observed in Bodh Gaya, Sherghati, and Tekari, driven by rural-to-urban migration, employment opportunities, and tourism.

This population growth catalyzed improvements in infrastructure, including road networks, healthcare facilities, educational institutions, and overall living standards. However, the district also faces challenges such as unplanned urban expansion and urban sprawl. Despite these issues, there is considerable potential for implementing sustainable urban planning policies to guide future development in a balanced and inclusive manner.

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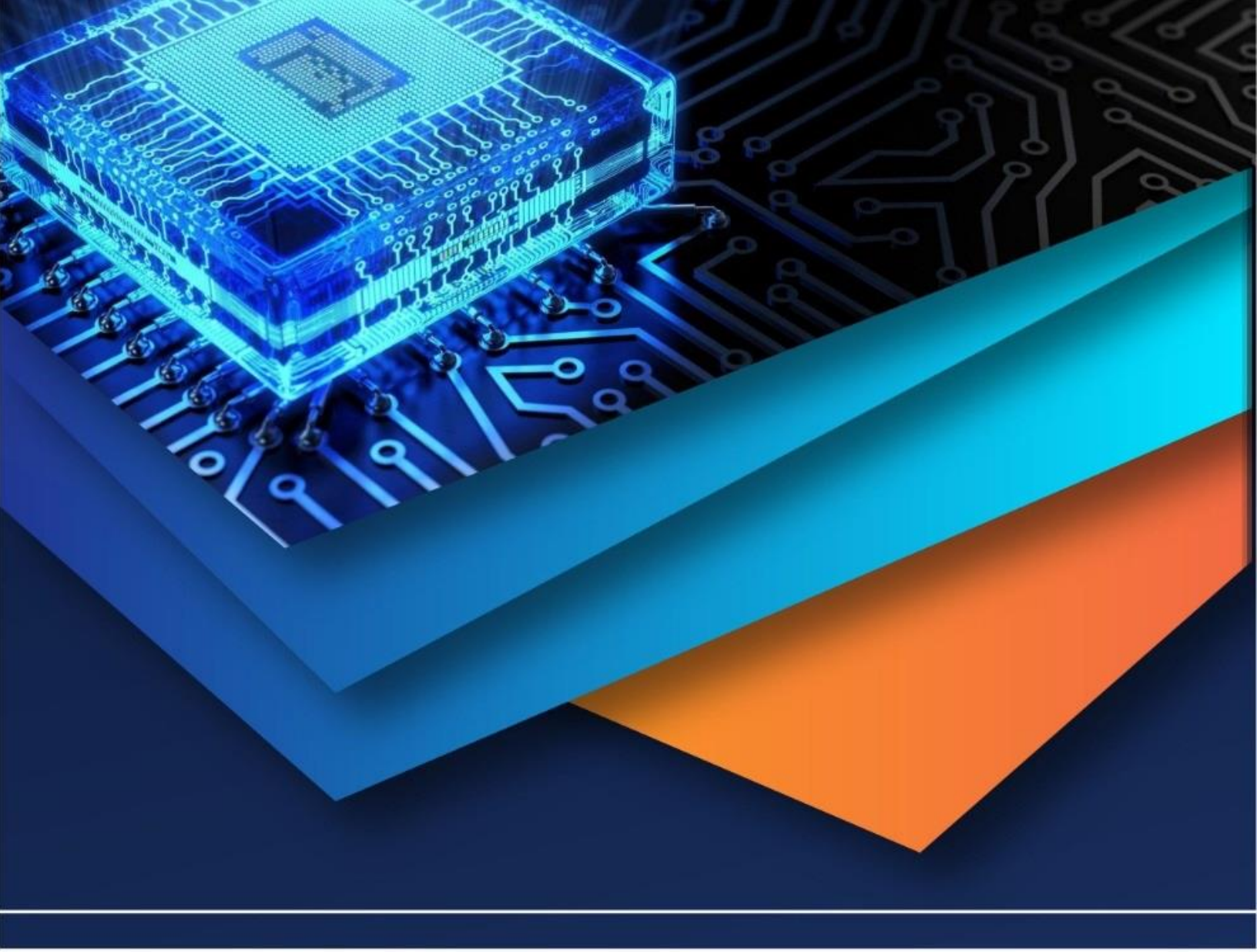

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