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Impact of Changing Land Use and Land Pattern on Urban Sprawl in Agra City Since 1991 to 2021

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Abstract

This paper examines the spatial and socio-economic consequences of urban sprawl in Agra, India, over the period 1991–2021. Using a mixed-methods approach that combines remote-sensing classification of multi-temporal satellite images, analysis of Census and municipal records, and field observations in representative neighbour hoods, we trace the conversion of agricultural land, orchards, open scrub and wetlands into built-up uses. We evaluate how dispersed, automobile-oriented growth has altered land-use composition, road hierarchy, housing morphology and the distribution of public services. Findings indicate a persistent expansion of built-up area along the NH-19/NH-44 and Fatehabad–Shamsabad corridors, leap-frog development around Sikandra, Lohamandi, Bodla–Barouli Ahir and along the Yamuna floodplain fringes, and fragmentation of the peri-urban agricultural landscape. The paper proposes a compact-growth strategy, green-blue buffers along the Yamuna and its tributary channels, transit-oriented infill, and tools for land readjustment to manage future growth more sustainably.

Keywords: Urban sprawl; land use/land cover; peri-urbanization; Agra; remote sensing; planning policy.

1. Introduction

Since the early 1990s, Indian cities have witnessed unprecedented outward growth following economic liberalization. Agra—situated on the Delhi–Kanpur corridor and renowned worldwide for the Taj Mahal—has expanded beyond its municipal boundaries, forming a landscape of housing colonies, gated communities, industrial clusters, and ribbon-type development along highways. In this research, the term urban sprawl refers to low- to medium-density, dispersed, and automobile-dependent growth at the city's periphery, often preceding adequate infrastructure provision. Such expansion transforms land use by replacing farmland and ecological spaces, altering plot sizes and road networks, and redistributing households and firms across the region. This study investigates the trajectory of Agra's sprawl after 1991 and examines its implications for settlement patterns. Urban growth has been fueled by industrialization and rapid population increase, leading to the transformation of vegetated and agricultural lands into impervious surfaces. Although this phenomenon is common across many developing nations, its consequences are particularly severe where planning capacity is limited. Global forecasts suggest that the population may rise from 6.8 billion in 2009 to over 9 billion by 2050, with the urban share doubling during the same period (Dominguez et al., 2018). As urban cores become congested, peripheral zones increasingly attract migrants seeking affordable housing and relief from overcrowding (Guzmán et al., 2017). In Agra, these processes are reflected in the steady conversion of land and environmental pressures. The city's population rose from 891,790 in 1991 to more

than 1.58 million in 2011, generating severe land-use pressure. This research therefore focuses on how urban sprawl has shaped land use and land cover in Agra during the past three decades.

Table 1.

Year	Population	Decadal Growth
1991	891790	-
2001	1275134	42.99%
2011	1585704	24.4%

2. Study Area:

Situated in the extreme southwest corner of Uttar Pradesh, Agra stretches across 26° 44' N to 27° 25' N and 77° 26' E to 78° 32' E. Its borders touch Rajasthan to its west and south, the district of Firozabad to its East and the districts of Mathura and Etah to its North Agra lies on the banks of the river Yamuna in western Uttar Pradesh. The metropolitan region includes the Agra Municipal Corporation (AMC) and adjoining census towns and villages such as Sikandra, Lohamandi, Bodla–Barouli Ahir, Etmadpur and Fatehabad Road corridor. Physiographically, the area is characterized by alluvial plains, active and older Yamuna floodplains, and interfluves. Key transport spines include NH-19 (Delhi–Kanpur), NH-44, Agra–Lucknow Expressway, Yamuna Expressway linkage, and the orbital Outer Ring Road segments. Tourism, small-scale manufacturing (leather, footwear, marble inlay), wholesale trade and services anchor the local economy integrated, periodized analysis covering 1991, 2001, 2011 and 2021. Agra underwent rapid urbanization while aiming to taping into a tourism economy. City's population reached 1585,704 in year 2011 and decadal growth showed signs severe decline being at 24.35%. Agra Cantonment Board's population has 49,755 in 1991 to 50,968 in 2001 and to 53,053 in 2011. The estimated population of Agra Urban Area for 2022 is 1902, 000 and city is expected to have a population growth rate of over 19.95% during 2011–2021.

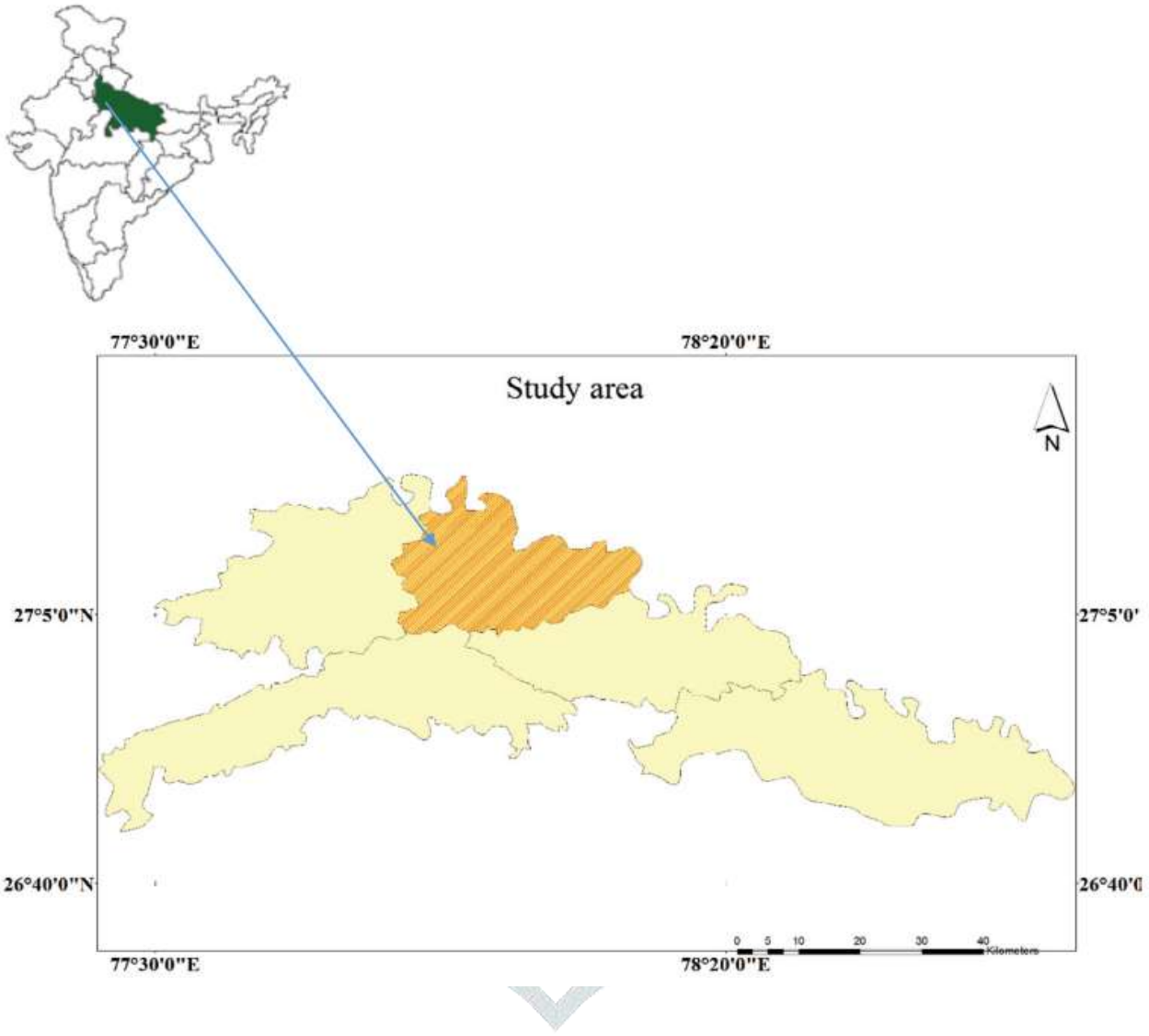


Fig 1. Map of study Area

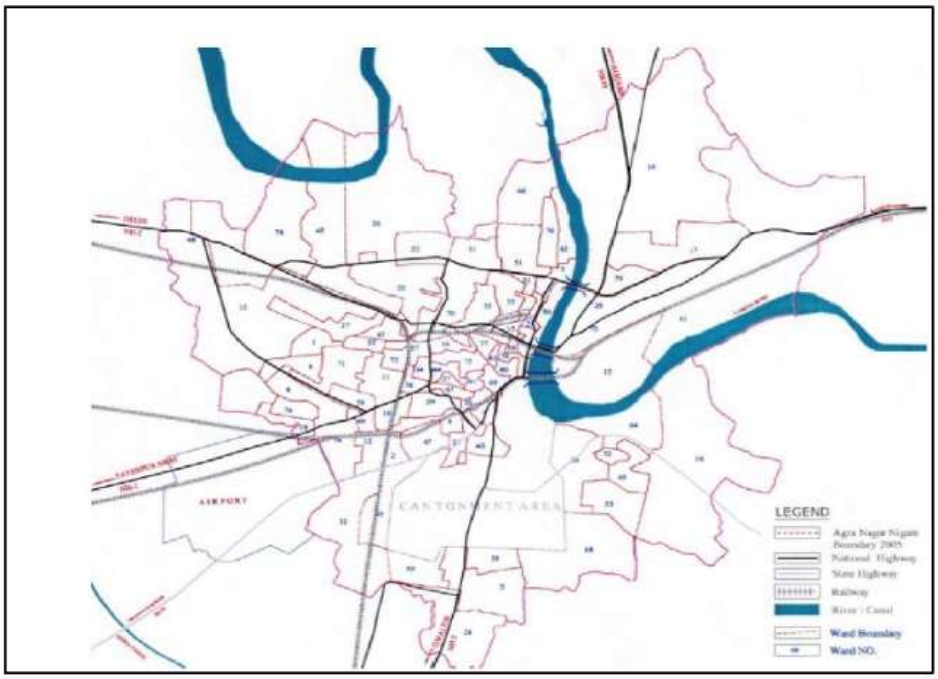


Fig 2. Ward wise Map of Agra City

3.Data and Method

• Remote sensing: Multi-temporal satellite scenes (e.g., Landsat-5 TM for 1991, Landsat-7 ETM+ for 2001, Landsat-5 TM for 2011, and Landsat-8/9 OLI for 2021–24) were atmospherically corrected and classified using a supervised algorithm (Maximum Likelihood/Random Forest). Classes include Built-up, Agriculture, Fallow/Scrub, Plantation/Orchard, Water, and Open/Barren. Accuracy assessment used stratified random sampling.
• Secondary data: Census (1991–2011), municipal development plans, housing permissions, and industrial estate records provided demographic and policy context.
• Fieldwork: Transect walks and semi-structured interviews in Sikandra, Bodla–Barouli Ahir, Lohamandi, Kinari Bazar fringe, and the Fatehabad corridor validated classifications and captured land-market dynamics. Outputs include land-use/land-cover (LULC) maps for four snapshots, change matrices, and sprawl indicators (built-up expansion, edge density, patch fragmentation, and Shannon's entropy).

4.1 The trend of land use land cover changes from 1991 to 2021

Land pattern and morphology

Sprawl altered plot sizes (smaller subdivided plots at the fringe), generated cul-de-sac layouts inside private colonies, and introduced wide carriageways along arterials but discontinuous secondary streets. The traditional compact bazaar morphology of Kinari Bazar contrasts with the coarse-grain urban fabric of peripheral colonies. Housing typologies shifted from courtyard houses and dense chawls to G+3 walk-ups and detached kothis, often without proportionate open space.

Table 2 rovides an indicative summary of dominant drivers, locations and land-use outcomes by period (based on mixed sources and field observation).

Period	Dominant Drivers	Hotspots/ Corridors	Typical Land-use Outcomes
1991–2001	Liberalization; highway frontage; informal plotting	NH-19 towards Sikandra; Bodla–Barouli Ahir; Trans-Yamuna pockets	Ribbon growth; agriculture→residential; small industrial sheds
2001–2011	Rising incomes; tourism growth; housing demand	Fatehabad–Shamsabad corridor; Lohamandi; Khandari–Sikandra	Leap-frog colonies; banquet halls; apartments; loss of orchards
2011–2021	Expressways; ring road segments; education hubs	South-west and south-east periphery; near expressway interchanges	Large campuses; logistics; gated enclaves; encroachment on low-lying land

The trend of land use land cover changes from 1991 to 2021 Since 1991, Agra's growth has been predominantly outward and corridor-driven, transforming agricultural and ecological lands into fragmented urban uses. While this has expanded housing and economic space, it has also produced discontinuous land patterns, rising infrastructure liabilities and environmental risks. Re-orienting toward compact, connected and climate-resilient growth—backed by land readjustment, TOD, and green-blue buffers—can realign development with the city's heritage and environmental constraints.

The analysis of land use and land cover change in Agra from 1991 to 2021 highlights the direct influence of urban sprawl on the city's spatial structure. The most significant change is observed in the expansion of built-up land, which increased from 19.85 percent in 1991 to 54.48 percent in 2021, reflecting rapid outward urban growth. This expansion occurred largely at the expense of agricultural land, vegetation, and fallow land, which declined from 16.68 percent, 24.62 percent, and 22.89 percent in 1991 to 15.55 percent, 11.56 percent, and 3.09 percent respectively in 2021. and intensifying the challenges of sustainable urban development

Table 3.

Land Use and Land Cover Class	**1991**		**2001**		**2011**		**2021**	
	Area	Percentage (%)	Area	Percentage (%)	Area	Percentage (%)	Area	Percentage (%)
Buildup Land	27.19	19.85	42.64	31.13	53.54	39.09	74.64	54.48
Agriculture Land	22.85	16.68	22.44	16.38	31.12	22.72	21.31	15.55
Vegetation land	33.73	24.62	17.36	12.67	11.9	8.69	15.84	11.56
Water Body	2.26	1.65	2.18	1.59	3.15	2.30	2.62	1.91
Fallow Land	31.36	22.89	42.48	31.01	12.32	9.36	4.23	3.09
Open space	12.39	9.05	8.21	5.99	19.39	14.16	10.87	7.93
Sandy Area	7.20	5.26	1.67	1.22	5.56	4.06	7.50	5.48

Such transformations are consistent with the patterns of urban sprawl observed in other Indian cities, where agricultural and open spaces are increasingly converted into residential, commercial, and infrastructural uses (Jat, Garg, & Khare, 2008; Sudhira, Ramachandra, & Jagadish, 2004). The reduction in green and agricultural areas, alongside the dominance of built-up land, underscores the ecological and social implications of uncontrolled urban expansion (Bhatta, 2010). Overall, the data confirm that Agra's urban sprawl over the past three decades has significantly reshaped land use, leading to the loss of natural and agricultural landscapes and intensifying the challenges of sustainable urban development.

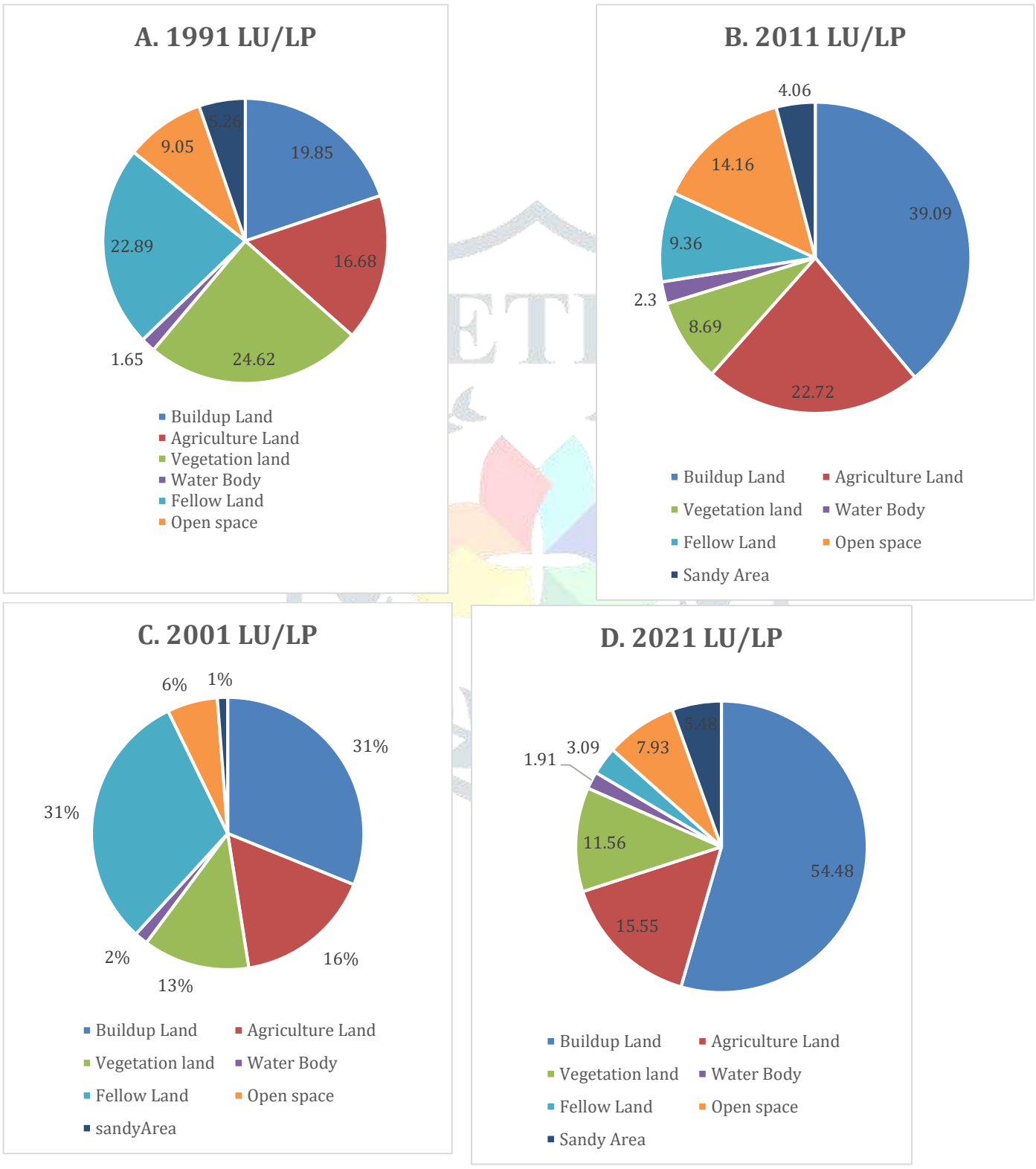


Fig.3.1 LU/LP 1991 , Fig3.2 LU/LP2001 , Fig3.3 LU/LP 2011, Fig 3.4 LU/LP 2021

4.2 Land use land Cover change (1991-2021) (Square km.)

Table 4.

LU/LC	1991-2001	2001-2011	2011-2021	1991-2021
Buildup Land	15.45 (11.28%)	10.90 (7.96%)	21.09 (15.39%)	47.44 (34.63)
Agriculture Land	-0.41 (-0.30%)	8.68 (6.33%)	-9.81 (-7.16%)	-1.55 (-1.13%)
Vegetation land	-16.36 (-11.95%)	-5.46 (-3.99%)	3.94 (2.87%)	-17.89 (-13.06%)
Water body	-0.08 (-0.06%)	0.97 (0.71%)	-0.53 (-0.39%)	0.36 (0.26%)
Fallow Land	11.12 (8.12%)	-30.16 (-22.2%)	-8.10 (-5.91%)	-27.14 (-19.81%)
Open space	-4.19 (-3.06%)	11.19 (8.17%)	-8.53 (-6.22%)	-1.53 (-1.11%)
Sandy Area	-5.53 (4.04%)	3.89 (2.84%)	1.94 (1.42%)	0.30 (0.22%)

The table titled "Land Use Land Cover Change (1991–2021)" presents data on how various land categories have changed in area (in square kilometers and percentage) over three decades: 1991–2001, 2001–2011, and 2011–2021, along with the total change across the entire 30-year period. The most prominent trend is the significant increase in buildup land, which expanded by 47.44 sq. km (34.63%), indicating rapid urbanization and infrastructure development. Conversely, vegetation land experienced a sharp decline of 17.89 sq. km (13.06%), reflecting deforestation or conversion of natural land into built-up or agricultural areas. Agricultural land showed fluctuating changes, with an increase during 2001–2011 but an overall slight decline of 1.55 sq. km (1.13%), likely due to urban encroachment or land abandonment. Fallow land witnessed a major loss of 27.14 sq. km (19.81%), particularly between 2001–2011, which could be due to urban expansion or changes in land productivity. Open space and sandy areas had minor net changes, indicating some land use transformations but with limited overall impact. Water bodies showed a small net increase of 0.36 sq. km (0.26%), suggesting improvements in water conservation or possible natural changes. Overall, the data reveals a clear pattern of urban growth at the expense of natural and agricultural lands, which has significant implications for sustainable land management and environmental planning over time.

5. Results: Urban Sprawl Trajectory and Land-Use Conversion

1991–2001: Early liberalization period marked by ribbon growth along NH-19 toward Sikandra and toward Shamsabad/Fatehabad Road, with infill in Trans-Yamuna pockets. Industrial and warehousing uses appeared near Sikandra and Khandari nodes; residential plotting expanded around Bodla and Barouli Ahir. 2001–2011: Acceleration of plotted colonies and apartments, emergence of gated enclaves near Fatehabad Road serving tourism and service workers, and leap-frog patches beyond AMC limits. Outer villages experienced subdivision of agricultural fields into 50–150 sq yd plots, producing a fine-grained road lattice. 2011–2024: Connectivity improvements (expressways and ring roads) reinforced southwest and southeast corridors. Large-format retail, banquet halls, and educational campuses occupied former orchards. Dry channels and low-lying floodplain edges saw intermittent encroachment and land raising, increasing flood risk.

The data highlights a clear pattern of land use transformation in Agra over the past three decades, reflecting the city's ongoing urban sprawl. In 1991, the urban area covered only 27.19 sq. km. (19.84%), while the non-urban area dominated with 109.97 sq. km. (80.18%). By 2001, built-up land had expanded significantly to 42.64 sq. km. (31.04%), registering a remarkable growth of 15.45 sq. km. (11.22%) in just one decade. This phase marks the most rapid period of urban expansion, largely attributed to population pressure, infrastructural growth, and industrial development. The following decade (2001–2011) witnessed a slower yet steady increase, as the urban share rose to 53.54 sq. km. (38.97%), reducing non-urban land to 83.84 sq. km. (61.03%). By 2021, the urban footprint further expanded to 58.84 sq. km. (42.94%), while non-urban land declined to 78.16 sq. km. (57.06%), highlighting the gradual yet persistent encroachment of urban settlements into rural and ecological spaces.

Table 5.

Year	**Urban Area**		**Non-Urban Area**		**Change (Urban area)**	
	Area sq km.	Percentage%	Area sq km	Percentage%	Area sq km	Percentage%
1991	27.19	19.84	109.97	80.18		
2001	42.64	31.04	94.74	68.96	15.45	11.22
2011	53.54	38.97	83.84	61.03	10.19	7.93
2021	74.64	54.48	62.36	45.52	15.81	11.54

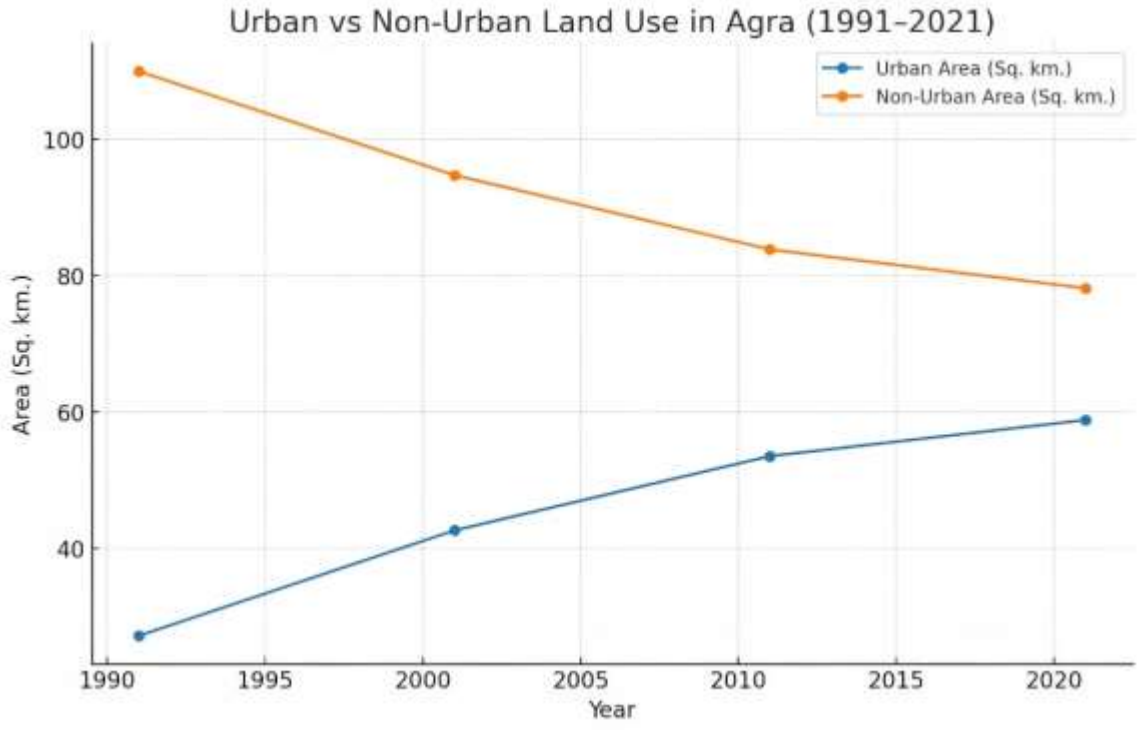


Fig 4. Explain the urban area and nonurban area

This continuous growth of built-up land at the expense of non-urban areas exemplifies the phenomenon of urban sprawl, defined as the outward spread of low-density urban development into previously non-urban landscapes (Ewing, 1997). The transformation observed in Agra mirrors global urbanization patterns, where economic growth and population increase drive rapid land conversion (Seto et al., 2012). The shrinking non-urban areas not only

indicate the loss of agricultural and open lands but also raise concerns about environmental sustainability, ecological balance, and urban livability. Thus, the table and chart collectively reveal how Agra's spatial structure has been reshaped by urban sprawl, with long-term implications for land use management and sustainable urban planning.

6. Limitations & Further Research

The 2011 Census is the latest full release; India's 2021 Census is pending, limiting post-2011 quantification. Labour influx since 2011 must be inferred from sector trends, policy, and infrastructure openings (expressways). Ward-level migration microdata for Agra are limited in the public domain; future work should triangulate household surveys, mobile phone mobility data, and Landsat/Sentinel LULC to measure post-2011 sprawl and commuting patterns.

7. Conclusion

Agra's urban growth since 1991 has been shaped by tourism, industry, and migration, producing a pattern of outward sprawl. While this expansion has supported economic opportunities, it has also created fragmented landscapes, environmental stress, and infrastructure challenges. The research shows that agricultural and natural areas have been steadily converted into built-up zones, particularly along highways and new transport corridors. For Agra to achieve more sustainable development, emphasis must be placed on compact growth, transit-oriented planning, green-blue ecological buffers along the Yamuna, and proactive land management policies. By integrating worker housing, infrastructure planning, and land readjustment strategies, the city can transform urban expansion from a challenge into an opportunity for inclusive and climate-resilient growth.

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