

## REVIEW ARTICLE

## SPATIO-TEMPORAL ANALYSIS OF URBAN LAND USE AND LAND COVER IN HYDERABAD CITY USING REMOTE SENSING AND GIS (2000–2020)

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## ARTICLE DETAILS

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## ABSTRACT

The process of urbanization has increasingly transformed landscapes, especially in rapidly developing cities like Hyderabad, which has witnessed considerable growth over the past two decades. This study investigates the spatio-temporal changes in land use and land cover (LULC) in Hyderabad city from 2000 to 2020 by utilizing multi-temporal satellite imagery and advanced geospatial techniques. The study aims to understand the extent, pattern, and nature of urban growth and its impact on other land categories such as vegetation, agricultural lands, and water bodies. Satellite data from Landsat missions (2000, 2010, and 2020) were classified using supervised image classification methods to derive LULC maps. A detailed change detection analysis was conducted to quantify the transitions among different land categories. The results reveal a significant expansion of built-up areas, especially along the peripheries and in the direction of the IT corridor and Outer Ring Road (ORR), indicating spatially uneven and corridor-based urban growth. Simultaneously, a sharp decline in vegetation and agricultural lands, along with the encroachment of water bodies, was observed. These findings underline the growing pressure on natural resources, increasing fragmentation of green spaces, and the degradation of ecological functions due to unplanned and rapid urban expansion. The study highlights the effectiveness of Remote Sensing and GIS tools in detecting, visualizing, and analyzing urban changes and advocates for their application in urban planning and management. The paper concludes by recommending sustainable development practices and the integration of geospatial monitoring in urban governance frameworks to ensure environmental sustainability and resilience in Hyderabad's future urban growth.

## KEYWORDS

Urban Land Use, Land Cover Change, Remote Sensing, Geographic Information Systems (GIS), Urban Sprawl, Hyderabad Metropolitan Region, Satellite Imagery

### 1. INTRODUCTION

Urbanization is one of the most dominant processes influencing land use and land cover (LULC) changes worldwide, particularly in developing countries where economic liberalization and population growth accelerate spatial transformations (Seto et al., 2012). Hyderabad, the capital of Telangana state in southern India, has undergone rapid urban development over the past two decades, driven by the growth of the information technology (IT) sector, infrastructural expansion, and increasing migration. This urban growth has led to significant modifications in natural landscapes, particularly the reduction of vegetation, conversion of agricultural land, and shrinking water bodies (Bhat et al., 2017).

The study of LULC changes provides crucial insights into urban dynamics and environmental sustainability. Remote Sensing (RS) and Geographic Information Systems (GIS) have emerged as powerful tools for monitoring, analyzing, and visualizing such changes across time and space with accuracy and efficiency (Campbell and Wynne, 2011). Multi-temporal satellite imagery enables researchers to capture surface-level alterations, while GIS helps in understanding spatial patterns and planning implications (Herold et al., 2003).

In the context of Hyderabad, urban sprawl has increasingly replaced open

and ecologically sensitive lands with built-up infrastructure. The development of the Outer Ring Road (ORR), IT hubs like HITEC City, and expansion of peri-urban zones have accelerated this process, often without adequate environmental planning (Reddy et al., 2020). As a result, the city faces challenges such as increased surface temperatures, flooding due to poor drainage, and loss of biodiversity (Mundia and Aniya, 2006).

This study aims to conduct a spatio-temporal analysis of LULC changes in Hyderabad from 2000 to 2020 using satellite imagery and GIS techniques. The objectives are to (i) classify major LULC types in selected years, (ii) identify the nature and extent of changes, and (iii) evaluate the environmental implications of urban expansion. This research contributes to urban geography and geoinformatics by offering empirical evidence to support sustainable land management policies in metropolitan areas.

### 2. LAND USE IN HYDERABAD

In terms of land use, Hyderabad is a rapidly growing city with a diverse range of land uses, including residential, commercial, industrial, and agricultural. The city's central business district is located in the heart of the city and is surrounded by residential neighbourhoods. The city also has several industrial areas located on the outskirts of the city, which include manufacturing plants, warehousing, and logistics centers.

Agriculture is an important aspect of land use in Hyderabad, and the

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surrounding areas are known for their fertile land and rich agricultural practices. The city has several parks, gardens, and recreational areas, which provide residents with much-needed green spaces in the midst of a bustling city. The city is also home to several lakes, which not only add to the city's beauty but also play an important role in maintaining the city's ecosystem.

Land use in Hyderabad is diverse and complex, with various competing interests vying for limited land resources. The challenge for the city's policymakers is to balance the competing demands of development, preservation, and sustainability, while ensuring that the city's growth is inclusive and benefits all its residents.

<b>Table 1: Land Use Of Hyderabad (Municipal Corporation of Hyderabad)</b>					
<b>S. No.</b>	<b>Category</b>	<b>1993</b>	<b>%</b>	<b>2001</b>	<b>%</b>
1.	Residential	63.38	36.72	75.2	43.56
2.	Commercial	3.00	1.74	20.6	11.94
3.	Manufacturing	3.76	2.20	3.07	1.78
4.	Public / Semi Public	15.07	8.78	23.48	13.62
5.	Utility including Grave yards	3.47	2.01	28.14	16.30
6.	Recreation	5.35	3.10		
7.	Agricultural Hillocks / Vacant	47.92	27.76		
8.	Water bodies	21.79	12.62	8.63	5.00
9.	Transport & Communication	8.86	5.13	13.48	7.80
	<b>TOTAL</b>	<b>172.60</b>	<b>100.00</b>	<b>172.60</b>	<b>100.00</b>

Source: Hyderabad Vision 2020, 2003

Land under graveyards, recreation, hillocks, vacant land category accounted for 33% in 1993 but has come down to 16% in 2001, the largest proportion under this category hillocks / vacant land, seem to have been built-up and occupied. Further it is a matter of grave concern that the water bodies of MCH which made upto 12.6% of the land use in 1993 declined by 7% in seven years to show 5% occupancy in 2001. A huge area in terms of road widening is acquired by MCH. Transport & Communication Land use has increased from 5.1% to 7.8%.

The Land Cover map of Hyderabad city is based on Land Sat 7 ETM Bands 1-7 and recognizes 5 Land Cover classes i.e., open spaces; buildings; vegetation; forests and water bodies, built-up cover dominates over the other coverages. More than half of the area is covered by the built-up category followed by sparse Vegetation and thick vegetation. Water bodies come a close fourth, with open spaces as the last category. The pockets of open spaces are associated with every category of land cover, more so with the built-up cover. From the map it is evident that thick vegetation cover is predominant in the North Western part of the city with isolated pockets to the North, East and South. River Musi too is full with green cover, subsuming the river channel. Mir Alam Tank, Hussain Sagar and Saroor Nagar stand out as major water bodies occupying large parts of city area.

The city has a fairly densely built-up area at times interspersed by vegetation and open spaces which are more on the periphery. There are also quite a few water bodies, dotting the urban landscape, the prominent among them being lakes Hussain Sagar and Mir Alam and River Musi. Thick vegetation is more on the Western part of the city. The almost rectangular patch in the West-central part is Kasu Brahmananda Reddy National Park; the quadrangular patch to the South of it is the Military area in Mehdiapatnam which has a lot of concentrated greenery. The Western concentration of thick vegetation is in and around the Golconda fort, which also has Army establishments with in its precincts. To the South-central part a proper rectangular patch is the Malakpet Race course ground. A map of the contour line showing elevation has been prepared for Hyderabad.

The spatial effects of the City Improvement Board programme on urban sprawl between 1930 and 1944 (Haynes, 2020). Throughout this time, the urban build-up has continued to spread to the northwest; see Figure. Suburbanization was hastened by the City Improvement Board. Banjara Hills Ameerpet, Masab Tank, and Toli Chowki, for example, developed as neighborhood's (Haynes, 2020). The projects' main goals between 1914 and 1930 were to improve cleanliness and overpopulation. The City

Improvement Board started concentrating on business and economic growth after 1930 (Beverly, 2015). A plan to develop a 120-acre industrial area in Musheerabad, east of Hussain Sagar, marked the beginning of the first significant economic planning project in 1932.

The City Improvement Board can be seen as a proto-masterplan covering the metropolitan region, as illustrated in Figure .1, even though not all suburban growth was a result of it (Haynes, 2020). After Hyderabad acceded to India in 1948, the City Improvement Board and the Secunderabad Town. CIB projects until 1944 Improvement Board were merged into the Andhra Pradesh Housing Board. This organisation continued till Andhra Pradesh and Telangana were divided in 2014. The City Improvement Board serves as the cornerstone for all metropolitan-level planning in Hyderabad and has had a long-lasting influence on the city's urban morphology. During this time, there was also tremendous private development (Haynes, 2020).

Two key elements helped Hyderabad become a prominent metropolis in the years following independence. First, the political developments that followed India's division. Second, the beginning in the 1960s of mass migration of people, particularly Muslims, to Gulf nations. India's division occurred in 1947. The Nizam had the conviction that he could uphold his suzerainty and preserve their political identity (Zyskowski, 2008). India coerced the Nizam into abdicating after diplomatic talks between the two countries broke down. In 1948, Hyderabad State became part of India. Hyderabad became the capital of a new state called Andhra Pradesh after the states were reorganised in 1956. Hyderabad and Secunderabad were significantly impacted by these political events.

Political developments after independence had an effect on the city's demographics (Alam, 1962). Numerous Muslims from lower socioeconomic classes moved to Hyderabad as a result of communal unrest in north India, whereas the majority of wealthier Muslims moved to Pakistan. Wealthy landowners in Andhra Pradesh were forced to relocate to the city as a result of communist uprisings in the countryside. The metropolitan growth of Hyderabad was strengthened as a result of the state reorganisation (Alam, 1962).

After the 1960s, migration emerged as a significant force in Hyderabad. "Only 341 persons had left Hyderabad State as of the 1921 census (Ali, 2007). According to a 1984–1986 random sample survey of Muslim households in the old city, 21% of them had at least one relative living in the Gulf (Naidu 1990, 1996; Ali, 2007)". According to a different survey, 60% of all male youths aged 10 to 17 were employed in the Gulf (Ali, 2007). Work, educational, and travel opportunities all contribute to migration. However, the social and political transformations Hyderabad underwent after being a part of the Indian Republic had a big impact on migration.

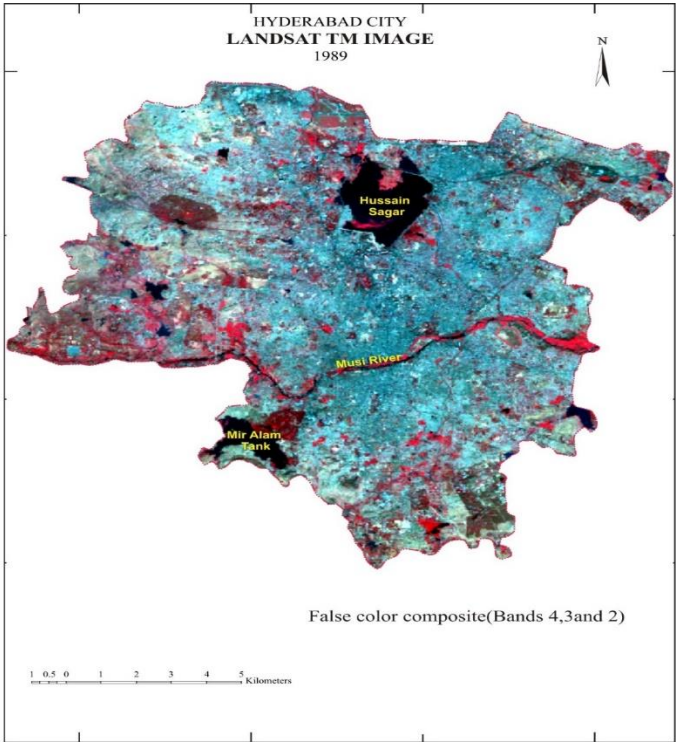
A rigid social hierarchy based on a person's connection to the Nizam existed in the regional monarchy of the Nizam until 1948 (Ali, 2007). The Nizam was the centre of all social, political, and economic activity. The social and political structure collapsed in the wake of the Nizam's abdication in 1948. Later, the Nawabs' landholdings were taken away, which destroyed the economic system. "Muslims were at the top of the Nizam hierarchy because social and political status was determined by ties to the Nizam and the economic system was heavily reliant on social and political status. Muslims' system of social stratification disintegrated". There was minimal room for economic advancement under the seventh and final Nizam (Ali, 2007).

The Indian secular capitalism system was put in place very immediately after the social stratification system was overthrown. Education and work prospects expanded social mobility opportunities by the 1950s and 1960s, when individual success began to define status more so than caste or aristocracy (Ali, 2007). The opportunity, though, seemed unfair. The discrimination against Muslims and the discrimination against lower caste Hindus made it difficult for many non-elite Muslims and Hindus who were educated in the 1960s to obtain employment (Haynes, 2020). Muslims have continued to migrate to the Gulf region as a result of these socioeconomic changes. "Hyderabad has always been a cosmopolitan metropolis, but regular migration since the 1960s as a result of political events in the middle of the twentieth century has cemented Hyderabad's cosmopolitan" character.

Between the 1940s and the 1970s, the population more than doubled, from roughly one to two million people. However, the city's built-up area did not increase considerably. In just 14 years, the city's population grew to about 4 million people. In the later part of the twentieth century, the effects of population expansion and uncontrolled urbanisation resulted in urban sprawl. For the first time since 1865, new urban development expanded southward. The city also expanded to the north-west, for the first-time encompassing Hussain Sagar. During this time, the urban footprint of Secunderabad expanded as well.

Remote sensing data reveal a decline in urban build-up between 1989 and 1996 due to over-classification of urban areas. Except for 1980, which was shot in the spring, all of the satellite photos for this study were obtained in the early fall. This resulted in alterations to the image's spectral properties (Haynes, 2020). Between 1980 and 1989, Landsat was unable to get a cloud-free photograph of Hyderabad. For these reasons, a spring image was chosen for this research. This allows for unique spectral signatures of

urban development and barren land. Concrete is the most commonly utilized building material in Hyderabad. During the dry season, remote sensing classification is difficult due to the closeness of spectral signatures between dry, barren soil and urban build-up erected with concrete made from the same barren soil. It is possible that the 1989 classification over classified urban development where none existed.

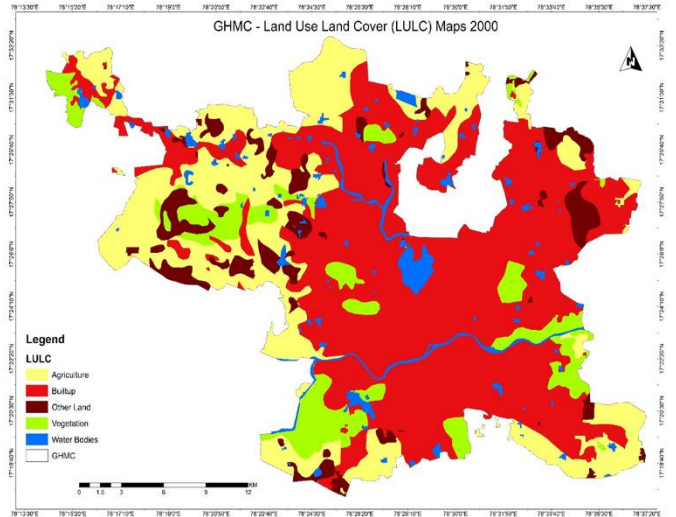


Source: Internet Image date 21-11-1989.

Suburban development expanded in the city's western outskirts in the 1990s. It was a period of significant change in both Hyderabad and the world. Globalization places new demands on urban morphology. There was a significant increase in the number of nodal settlements around the city, particularly to the northwest but also to the south and southwest. The first skyscraper of Hitech City, Cyber skyscraper, was dedicated on

November 22, 1998. Hitech City became the hub of Cyberabad, a larger IT special economic zone. Major road-widening projects were carried out in several regions of the city between 1995 and 2001. These proposals were included in some of the terms of the Municipal Corporation of Hyderabad's 1975 Development Plan (Hyderabad, 2020).

Table 2: Land use and land cover 2000	
LU/LC 2000	AREA IN ASQKM
Agriculture	175.93
Builtup	325.99
Other Land	52.91
Vegetation	65.25
Water Bodies	29.92



The land use and land cover (LU/LC) data for Hyderabad in the year 2000 reflects the city's transitional phase, where urban expansion was beginning to reshape the landscape while agriculture and natural

ecosystems still held a significant presence. The distribution of land categories highlights the early signs of Hyderabad's rapid urbanization and the pressures exerted on its natural resources due to increasing



developmental activities.

The built-up area emerged as the dominant land use category, covering approximately 325.97 sq. km. This significant land allocation to urban infrastructure indicates that by 2000, Hyderabad had already developed into a major urban center. The expansion of residential, commercial, and industrial zones, particularly in areas like HITEC City, Secunderabad, and Banjara Hills, contributed to the rise in built-up spaces. The growth of IT hubs and real estate projects marked the beginning of large-scale urbanization, which would continue to accelerate in the coming decades.

Despite the increasing urban footprint, agriculture still accounted for 155.91 sq. km, making it the second-largest land use category. This suggests that peri-urban and rural areas around Hyderabad were still largely dependent on agriculture. However, the steady conversion of agricultural lands into commercial and residential areas was already evident, indicating an impending decline in farmlands as urban expansion intensified. The trend suggested that the demand for housing, industries, and IT corridors would eventually replace agricultural landscapes in the following years.

Vegetation cover occupied 59.98 sq. km, signifying a moderate presence of green spaces, which included forest patches, tree plantations, and open parks. Although this suggested some degree of environmental balance, increasing urbanization posed a threat to the city's natural greenery. The reduction of vegetation over time has been associated with environmental concerns such as rising temperatures, loss of biodiversity, and

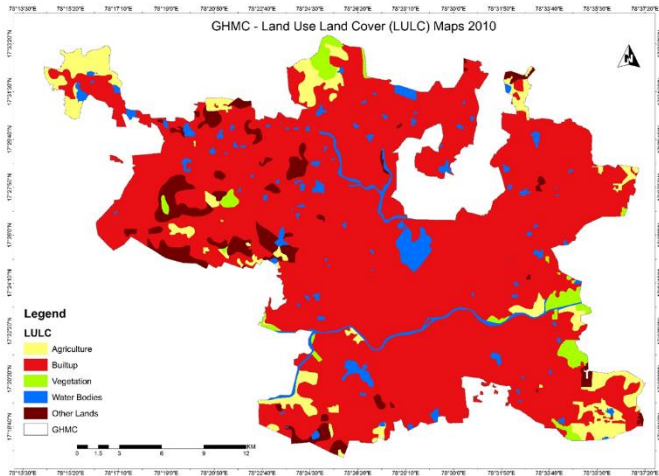
deterioration of air quality. The gradual decline in green spaces highlighted the need for conservation measures to maintain ecological stability.

Water bodies, covering 24.92 sq. km, formed an essential part of Hyderabad's natural ecosystem. Lakes such as Hussain Sagar, Osman Sagar, and Himayat Sagar were crucial sources of water supply and played a vital role in groundwater recharge. However, urban encroachments, pollution, and land reclamation activities posed serious threats to these water bodies, foreshadowing the water crisis that the city would face in later years.

The other land category, which covered 42.71 sq. km, likely comprised barren lands, rocky surfaces, and wastelands. These lands were typically found on the outskirts and were later converted for industrial or urban expansion purposes. The presence of such land suggests that Hyderabad had potential areas available for future development, which would eventually be utilized for industrial and residential projects.

The LU/LC data of Hyderabad in 2000 showcases the city's early urban transformation, with built-up areas expanding at the cost of agricultural land and natural ecosystems. The patterns observed in this data provide crucial insights into the challenges of urbanization, particularly concerning land resource management, environmental sustainability, and water conservation. As Hyderabad continued to grow, strategic urban planning and policy interventions became essential to balance development with ecological preservation, ensuring sustainable urban expansion.

Table 3: Land use and land cover 2010	
LU/LC 2010	AREA IN ASQKM
Agriculture	60.45
Builtup	502.70
Other Land	34.90
Vegetation	18.48
Water Bodies	33.47



The land use and land cover (LU/LC) patterns of Hyderabad in 2010 reveal substantial urban expansion and transformation over the preceding decade. A comparative assessment of 2000 and 2010 highlights significant shifts in land utilization, with a marked increase in built-up areas and a considerable reduction in agricultural and vegetative cover. These changes are largely attributed to rapid urbanization, infrastructure development, and the expansion of the IT and industrial sectors.

One of the most striking observations is the growth in built-up areas, which surged from 325.97 sq. km in 2000 to 502.70 sq. km in 2010, reflecting an increase of 176.73 sq. km. This transformation underscores Hyderabad's evolution into a leading IT and economic center, with extensive real estate development, commercial hubs, and residential townships. The emergence of HITEC City, Gachibowli, and the Financial District as major business zones significantly contributed to this expansion. The establishment of Special Economic Zones (SEZs) and a growing influx of migrants seeking employment further fueled this urban growth, resulting in an unprecedented demand for housing and commercial infrastructure.

Conversely, agricultural land witnessed a dramatic decline, shrinking from 155.91 sq. km in 2000 to 60.45 sq. km in 2010, a net loss of 95.46 sq. km. This reduction highlights the conversion of farmlands into urban settlements, industrial parks, and commercial complexes. The impact of

this shift was particularly evident in peri-urban areas such as Kondapur, Manikonda, and Shamshabad, where farmland was extensively repurposed for real estate projects. The steady loss of agricultural land not only affected traditional farming communities but also altered the city's food supply dynamics, increasing dependence on external sources for agricultural produce.

A similar trend was observed in vegetation cover, which decreased significantly from 59.98 sq. km in 2000 to 18.48 sq. km in 2010, signifying a loss of 41.50 sq. km of green space. The reduction in forested and vegetated areas can be attributed to land clearance for urban expansion, deforestation, and encroachments. This decline has contributed to rising temperatures, increased air pollution, and disruption of local ecosystems, making the city more vulnerable to urban heat island effects and environmental degradation. The diminishing green cover also affected biodiversity and soil stability, further intensifying ecological challenges.

On the other hand, water bodies exhibited a positive change, expanding from 24.92 sq. km in 2000 to 33.47 sq. km in 2010. This increase can be linked to lake restoration projects, water conservation initiatives, and the construction of artificial reservoirs to address the growing water demands of the city. However, despite this increase in surface water area, many lakes and water bodies continued to face pollution, encroachments, and reduced catchment areas. Prominent water bodies such as Hussain Sagar, Osman

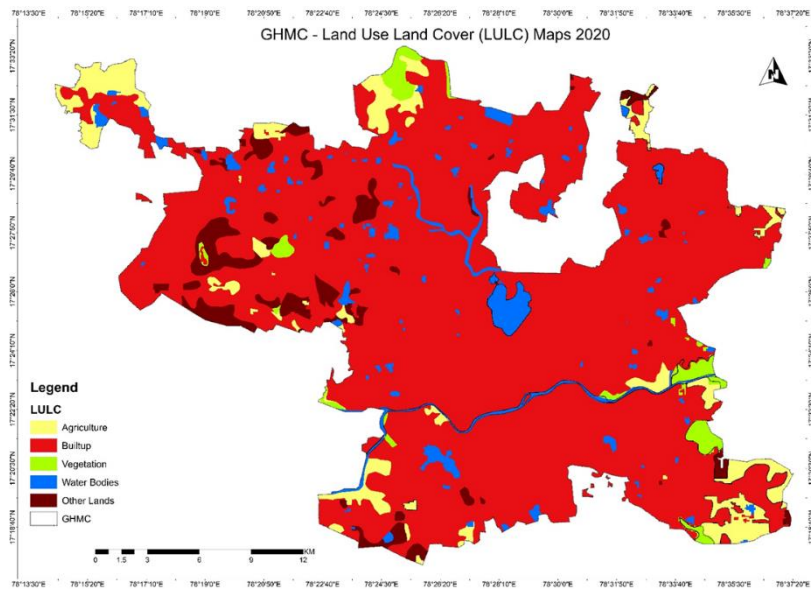
Sagar, and Shamirpet Lake experienced deterioration due to industrial effluents, urban runoff, and unregulated waste disposal, posing long-term threats to water sustainability.

The other land category experienced a marginal decrease, reducing from 42.71 sq. km in 2000 to 34.90 sq. km in 2010, indicating that previously vacant or unused land was being converted for infrastructure and urban development projects. The decline in available open land suggests that Hyderabad was approaching higher levels of land saturation, necessitating more strategic urban planning to optimize space utilization and prevent haphazard expansion.

The LU/LC data for 2010 clearly illustrate Hyderabad’s rapid urban growth, characterized by the expansion of built-up areas at the cost of agricultural land and vegetation cover. While certain measures, such as the increase in water bodies, indicate positive developments, the overall pattern raises concerns regarding environmental sustainability, land resource management, and the long-term viability of Hyderabad’s urbanization model. Addressing these challenges requires a balanced approach to development, ensuring that economic progress does not come at the cost of ecological degradation and loss of natural resources.

Table 4: Land use and land cover 2020

LU/LC 2010	AREA IN ASQKM
Agriculture	43.89
Builtup	534.75
Other Land	28.83
Vegetation	12.89
Water Bodies	29.64



The land use and land cover (LU/LC) patterns of Hyderabad in 2020 reflect a continuation of the urbanization trends observed in previous decades, with further expansion of built-up areas and a persistent decline in agricultural land and vegetation cover. The data highlights the city’s transformation into a densely populated metropolitan hub, driven by rapid infrastructure growth, increased economic activities, and real estate expansion.

The most significant observation is the rise in built-up areas, which increased from 502.70 sq. km in 2010 to 534.75 sq. km in 2020, marking a further expansion of 32.05 sq. km. This trend indicates ongoing urban sprawl, the proliferation of commercial and residential projects, and the emergence of new business districts. Areas such as Kokapet, Narsingi, Tellapur, and Uppal have witnessed large-scale developments, contributing to Hyderabad’s reputation as a major IT and industrial hub. The continued growth of HITEC City, Gachibowli, and the expansion of financial and technology parks have reinforced the city’s position as one of India’s leading economic centers. Additionally, metro rail expansion, road network enhancements, and infrastructure projects like ORR (Outer Ring Road) and flyovers have further facilitated urbanization.

Simultaneously, agricultural land has continued to decline, reducing from 60.45 sq. km in 2010 to 43.89 sq. km in 2020, a net loss of 16.56 sq. km. The decrease in farmland indicates an ongoing conversion of rural and peri-urban areas into residential townships, industrial estates, and commercial centers. Many agricultural regions surrounding Shamshabad, Shankarpally, and Medchal have been repurposed for real estate ventures, limiting traditional farming activities. This transition poses challenges for food security, rural employment, and sustainable land use practices, necessitating policies that balance urban growth with agricultural preservation.

A further decline in vegetation cover is also evident, shrinking from 18.48 sq. km in 2010 to 12.89 sq. km in 2020, signifying a loss of 5.59 sq. km of green space. The reduction in natural vegetation is a direct consequence of

deforestation, land clearance for urban expansion, and encroachments on open lands. The impact of diminishing greenery has led to rising temperatures, increased air pollution, and a decline in biodiversity. The lack of adequate green spaces in newly developed areas has also raised concerns about the city’s ecological balance, groundwater recharge, and the worsening urban heat island effect.

Interestingly, water bodies have experienced a slight decrease, reducing from 33.47 sq. km in 2010 to 29.64 sq. km in 2020, a loss of 3.83 sq. km. Although previous efforts were made to restore and protect water bodies, the continued encroachment and pollution of lakes, reservoirs, and wetlands remain a critical issue. Many historical lakes such as Osman Sagar, Himayat Sagar, and Durgam Cheruvu have faced decreasing water levels due to illegal construction, urban runoff, and reduced catchment areas. Additionally, the increased dependency on groundwater extraction has further aggravated water resource depletion, emphasizing the need for strict conservation measures and sustainable water management strategies.

The category of other land has also seen a reduction from 34.90 sq. km in 2010 to 28.83 sq. km in 2020, indicating that previously unutilized or vacant land has been steadily transformed into built-up or industrial zones. This trend reflects Hyderabad’s ongoing land saturation, with fewer open spaces available for future development. The decreasing availability of vacant land suggests that future urban planning will need to incorporate innovative strategies such as vertical expansion, mixed-use developments, and eco-friendly urbanization models.

The LU/LC data for 2020 highlights Hyderabad’s continued trajectory of urban expansion, with built-up areas increasing at the cost of agricultural land, vegetation, and other open spaces. While the city’s economic growth and infrastructure advancements have been remarkable, the environmental and ecological consequences of rapid urbanization remain a growing concern. The loss of green cover, declining water bodies, and shrinking agricultural zones call for more sustainable and balanced urban

planning approaches. Moving forward, integrating green infrastructure, adopting smart city solutions, and enforcing stricter land-use policies will be crucial in ensuring that Hyderabad's growth remains both economically and environmentally sustainable.

**Table 5:** Presents selected land-use-cover (LULC) statistics for the years 2000, 2005, 2010, 2015, and 2020 as well as the area in hectares (ha).

LULC	2000	2005	2010	2015	2020
Rainfed cropland	72,817	69,601	53,361	46,815	37,902
Irrigated cropland	15,553	14,589	19,966	19,510	19,678
Built-up land	38,863	62,000	68,560	74,131	80,111
Water Bodies	12,535	3584	5417	5694	2283
Other LULC	161,635	151,562	154,288	155,445	161,583

Source: Telangana.gov.in

Table 5 provides an overview of land use and land cover (LULC) changes in Hyderabad from 2000 to 2020, highlighting key transformations in various land categories such as rainfed cropland, irrigated cropland, built-up land, water bodies, and other land uses. These changes reflect the ongoing urbanization, industrial expansion, and environmental alterations that have shaped the city's landscape over two decades.

A significant decline in rainfed cropland is observed, with the area decreasing from 72,817 hectares in 2000 to 37,902 hectares in 2020. This sharp reduction suggests that agricultural land is increasingly being converted into urban and industrial areas. The expansion of residential, commercial, and infrastructure projects has contributed to this decline, making rainfed agriculture less viable. Additionally, factors such as irregular monsoons, groundwater depletion, and real estate development have played a role in shrinking rainfed agricultural zones. This loss of cropland raises concerns about food security, rural livelihoods, and environmental sustainability, requiring careful planning to balance urban expansion and agricultural preservation.

Unlike rainfed cropland, irrigated cropland has shown relative stability, fluctuating slightly over the years. The area of irrigated land decreased from 15,553 hectares in 2000 to 14,589 hectares in 2005, but then increased to 19,966 hectares in 2010. This indicates that while some irrigation-based farming has persisted, the overall expansion of urban infrastructure and industrial zones has placed pressure on farmland. However, government initiatives promoting efficient irrigation systems and technological advancements in water conservation methods have helped sustain irrigated agriculture to some extent.

The most prominent transformation is observed in the built-up land category, which has witnessed a massive increase from 38,863 hectares in 2000 to 80,111 hectares in 2020. This more than doubling of built-up land highlights the rapid urbanization and industrialization of Hyderabad, driven by IT hubs, commercial centers, and residential townships. The growth of key urban areas like HITEC City, Gachibowli, and Financial District has significantly contributed to this expansion. Additionally, large-scale infrastructure projects, such as the Outer Ring Road (ORR), Hyderabad Metro Rail, and expansion of national highways, have fueled the spread of urban settlements. While this growth has enhanced economic development, employment opportunities, and connectivity, it has also led to traffic congestion, pollution, and loss of green spaces, necessitating sustainable urban planning policies.

The area covered by water bodies has shown significant fluctuations, initially dropping from 12,535 hectares in 2000 to 3,584 hectares in 2005. Although there was a slight recovery in subsequent years, reaching 5,694 hectares in 2015, the water body area declined again to 2,283 hectares in 2020. This alarming trend suggests that rapid urbanization, encroachments, and shrinking wetlands have severely impacted Hyderabad's water resources. The loss of traditional lakes and ponds, such as Hussain Sagar, Osman Sagar, and Himayat Sagar, has increased urban flooding risks and water scarcity issues. The reduction of groundwater recharge zones further exacerbates these problems, highlighting the urgent need for lake restoration initiatives, strict anti-encroachment policies, and sustainable water management strategies.

The 'Other LULC' category, which includes barren land, forested areas, wastelands, and rocky outcrops, has remained relatively stable over the years, with only minor fluctuations. The area under this category was

161,635 hectares in 2000, which slightly declined in the following years before returning to 161,583 hectares in 2020. While this category has not been directly affected by urban expansion, its potential for future land-use change remains high, especially as industrial and infrastructure development continues to expand into previously undeveloped regions.

The analysis of LULC changes from 2000 to 2020 reveals that Hyderabad has experienced rapid urban expansion at the cost of agricultural land and water bodies. The reduction in rainfed cropland, depletion of water bodies, and expansion of built-up areas highlight the environmental and socio-economic implications of urbanization. While Hyderabad's growth as an IT and industrial hub has brought economic benefits, it has also led to loss of natural resources, increased pollution, and challenges in sustainable land management. Moving forward, urban planning strategies must focus on balancing development with environmental conservation, preserving agricultural zones, restoring water bodies, and promoting green infrastructure to ensure sustainable urban growth.

### 3. ANALYSIS OF CHANGES IN LAND USE, TRANSPORTATION, AND URBAN INFRASTRUCTURE IN HYDERABAD

Over the past two decades, Hyderabad has experienced a profound transformation in its land use, transportation network, and urban infrastructure. This transformation has been largely driven by rapid urbanization, the expansion of the IT and industrial sectors, and government policies promoting economic development. While these changes have contributed to the city's emergence as a major economic and technological hub, they have also introduced challenges related to environmental sustainability, transportation congestion, and unplanned urban sprawl. An in-depth analysis of these aspects highlights both the opportunities and concerns associated with Hyderabad's urban growth.

#### 3.1 Changes in Land Use Patterns

Land use in Hyderabad has changed significantly over the last two decades, marked by a steady decline in agricultural land and vegetation cover and a sharp increase in built-up areas. The expansion of Hyderabad's IT sector, real estate development, and industrialization has redefined the city's landscape, leading to a significant shift in land utilization patterns.

- In 2000, agricultural land was the dominant land use, covering 155.91 sq. km. However, by 2010, this area had reduced to 60.45 sq. km, and by 2020, it had further declined to 43.89 sq. km. The rapid conversion of farmland into residential, commercial, and industrial zones reflects the city's increasing demand for urban infrastructure. This shift has led to rural displacement, food security concerns, and ecological imbalance.
- Built-up land has expanded considerably, growing from 325.97 sq. km in 2000 to 502.70 sq. km in 2010 and reaching 534.75 sq. km in 2020. The establishment of IT hubs such as HITEC City, Gachibowli, and the Financial District has been the primary driver of this increase. Additionally, the rise of gated communities, high-rise apartments, and commercial complexes has reshaped Hyderabad's skyline.
- Vegetation cover has drastically reduced, from 59.98 sq. km in 2000 to just 12.89 sq. km in 2020. Deforestation for urban expansion, lack of green space conservation policies, and large-scale infrastructure projects have contributed to this decline. The reduction in green cover has had environmental consequences, including higher temperatures, poor air quality, and the urban heat island effect.
- Water bodies, which are crucial for groundwater recharge and biodiversity, have also faced significant changes. The city's lakes and reservoirs have been encroached upon or polluted, leading to a decline in water quality and availability. While some conservation efforts have been initiated, they remain insufficient to counteract the rapid urbanization pressures.

The shifting land use pattern indicates a growing focus on economic expansion at the cost of environmental sustainability. Although Hyderabad has emerged as a leading metropolitan center, uncontrolled urbanization poses risks to ecological balance, water security, and climate resilience. Addressing these concerns requires sustainable land-use policies, eco-friendly urban planning, and strict regulatory enforcement.

#### 3.2 Evolution of Transportation Infrastructure

The rapid expansion of Hyderabad has necessitated significant improvements in transportation infrastructure to accommodate increasing population density, economic activity, and vehicular traffic. Over the years, the city has witnessed massive investments in road



networks, metro rail, and public transport systems to enhance connectivity and ease congestion.

### 3.3 Expansion of Road Networks

The Outer Ring Road (ORR), a 158-kilometer-long expressway, has played a crucial role in improving interconnectivity between different parts of the city and decongesting the central business districts. The ORR has facilitated faster movement of goods, improved accessibility to IT corridors, and enhanced intra-city travel. Additionally, flyovers, elevated corridors, and radial roads have been constructed to address the growing traffic volume. However, despite these developments, Hyderabad continues to struggle with high traffic congestion due to increasing private vehicle ownership, inadequate public transport accessibility in suburban areas, and rapid population growth. The reliance on personal vehicles has contributed to rising carbon emissions and worsening air quality. There is a need for better integrated transport planning, expansion of non-motorized transport infrastructure, and promotion of sustainable mobility solutions.

### 3.4 Development of Public Transportation

The Hyderabad Metro Rail project, inaugurated in 2017, has significantly improved urban mobility by providing a fast, efficient, and environmentally friendly mode of transport. The metro network, which currently covers nearly 69 kilometers, has helped reduce traffic congestion along major corridors, particularly in high-density areas like Ameerpet, Kukatpally, and Miyapur. Apart from the metro, the Telangana State Road Transport Corporation (TSRTC) operates extensive bus services that connect different parts of the city. However, last-mile connectivity issues, overcrowding, and lack of bus priority lanes remain major challenges. To encourage public transport usage, better feeder services, improved infrastructure, and digital payment systems need to be implemented.

### 3.5 Rising Private Vehicle Dependency and Associated Challenges

Hyderabad has witnessed an exponential increase in vehicle ownership, leading to severe traffic congestion, longer commute times, and increased fuel consumption. The city's roads are often gridlocked during peak hours, affecting productivity and overall quality of life. Additionally, vehicular emissions contribute significantly to air pollution, posing health risks to residents. To tackle these issues, the city must invest in robust traffic management systems, pedestrian-friendly infrastructure, and incentives for electric vehicle adoption.

### 3.6 Urban Infrastructure Development and Challenges

Hyderabad's urban infrastructure has evolved in response to growing demands for housing, commercial spaces, and public services. The city's Smart City Initiative has focused on technological advancements, digital governance, and improved civic amenities to make urban living more efficient and sustainable.

### 3.7 Housing and Commercial Infrastructure

The rapid urbanization of Hyderabad has led to the proliferation of gated communities, high-rise apartments, and commercial complexes. Areas like Kondapur, Madhapur, and Kokapet have become major residential and business hubs. While these developments have improved housing availability and economic opportunities, they have also increased pressure on water supply, sewage systems, and waste management infrastructure.

### 3.8 Water and Waste Management

Hyderabad faces persistent water shortages and inefficient waste disposal mechanisms. While efforts have been made to enhance rainwater harvesting and sewage treatment, rapid urban expansion continues to outpace infrastructure development. Encroachments on lakes, groundwater depletion, and unregulated industrial waste discharge have worsened water security issues. Comprehensive water conservation policies and stricter regulations are necessary to mitigate these challenges.

### 3.9 Smart City Initiatives and Technological Integration

Hyderabad has embraced smart city solutions, such as real-time traffic monitoring, digitized municipal services, and smart lighting systems. These initiatives aim to enhance urban efficiency, improve governance, and provide better public services. However, digital divide, lack of infrastructure in peripheral areas, and challenges in implementation remain concerns. Strengthening public-private partnerships and increasing investments in digital infrastructure can accelerate the success of these initiatives.

The transformation of Hyderabad's land use, transportation, and urban infrastructure over the past two decades reflects the city's rapid economic growth and urbanization. While increased built-up areas, expanded transportation networks, and modernized urban infrastructure have contributed to Hyderabad's emergence as a global IT and business hub, they have also resulted in environmental degradation, congestion, and water scarcity issues.

Addressing these challenges requires a balanced approach that integrates economic development with sustainable urban planning. Policy measures should focus on green infrastructure, improved public transport, better land-use management, and enhanced environmental conservation efforts. By adopting innovative urban planning strategies and technology-driven solutions, Hyderabad can ensure equitable and sustainable growth while maintaining its position as a leading metropolitan city.

## 4. CONCLUSION

The present study provides a comprehensive spatio-temporal assessment of urban land use and land cover (LULC) changes in Hyderabad city over a 20-year period (2000–2020), employing remote sensing and GIS technologies. The findings offer strong evidence of the dynamic and often unregulated urban expansion that the city has experienced during these two decades. The most significant transformation observed was the dramatic increase in built-up areas, particularly in peripheral zones and along major transportation corridors such as the Outer Ring Road (ORR) and near emerging IT hubs. This growth has come at a considerable cost to ecologically valuable land categories, most notably agricultural lands, dense vegetation, and natural water bodies.

The study not only quantifies the magnitude of these changes but also sheds light on the spatial patterns and directionality of urban sprawl. Urban growth in Hyderabad has followed a radial-concentric model in the early 2000s but has gradually evolved into a corridor and node-based model due to infrastructure-led development and real estate expansion. The conversion of open lands into impervious surfaces has serious ecological implications, such as reduced groundwater recharge, loss of biodiversity, increased surface runoff, and intensified urban heat island effects—all of which contribute to a decline in the city's overall environmental quality and livability.

The effectiveness of remote sensing and GIS tools in this research is noteworthy, as they have enabled a multi-temporal, multi-scalar analysis of LULC patterns with high spatial resolution. These tools allowed for a precise and scientific understanding of how Hyderabad's landscape has been restructured under the pressure of urbanization. The integration of satellite-based imagery with GIS spatial modeling serves as a replicable and scalable approach for urban environmental monitoring and planning in other metropolitan regions.

Given the gravity of the observed changes, this study underscores the urgent need for sustainable urban planning that balances developmental imperatives with ecological preservation. Urban governance in Hyderabad must move beyond reactive infrastructure development to embrace proactive spatial planning frameworks that integrate green buffers, protect natural drainage systems, and prioritize sustainable land use. Strategies such as enforcing urban growth boundaries, promoting vertical growth over horizontal sprawl, conserving remnant green spaces, and restoring degraded water bodies can contribute to a more resilient and sustainable urban ecosystem.

In conclusion, the study advocates for the institutionalization of geospatial technologies in city planning and monitoring, ensuring that rapid urban expansion does not compromise environmental sustainability or the quality of urban life. It also calls for interdisciplinary collaboration between urban planners, geographers, environmentalists, and policymakers to formulate adaptive strategies that guide Hyderabad—and other growing Indian cities—towards a more inclusive and ecologically responsible urban future.

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