

SPATIO-TEMPORAL ANALYSIS OF URBAN EXPANSION AND ITS IMPACT ON GREEN SPACES IN RELATION TO POPULATION GROWTH (1951-2023): A CASE STUDY OF DISTRICT HYDERABAD

Marvi Pirzada^{*1}, Imtiaz Hussain², Munwar Ali³, Komal Ujjan⁴, Oshaque Ali Lashari⁵

^{*1}Lecturer, Department of Geography, Government Girls (Zubeda) College, Hyderabad, Sindh

²Lecturer, Government Degree College Therhi

³Assistant Professor, Department Geography, Government Ghazali College & Post Graduate Center Latifabad Hyderabad, Sindh

⁴Teaching Assistant, Department of Geography Shah Abdul Latif University Khairpur Mirs, Sindh

⁵Supervisor, HESCO Computer Centre Hyderabad, Sindh

^{*1}marvipirzada@yahoo.com

DOI: <https://doi.org/10.5281/zenodo.17646525>

Keywords

Urban expansion; Green spaces; Population growth; Land use and land cover (LULC); GIS; Spatio-temporal analysis; District Hyderabad; Sustainable urban planning

Article History

Received: 11 September 2025

Accepted: 21 October 2025

Published: 16 November 2025

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Corresponding Author: *

Marvi Pirzada

Abstract

District Hyderabad's urban expansions (1951-2023) has transformed its spatial and ecological structure. This study investigates the spatio-temporal patterns of urban growth and its impact on green spaces in relation to population dynamics. Using Landsat satellite imagery (1972, 1986, 2000, and 2023) and population census data, land use and land cover (LULC) changes were analyzed through supervised classification and change detection techniques in GIS. The results reveal a substantial increase in built-up areas, primarily at the expense of agricultural and vegetated lands. The population of Hyderabad District has increased sharply since 1951, intensifying land demand for housing, infrastructure, and services. Statistical analysis indicates a strong positive correlation between population growth and urban expansion, and an inverse relationship between population density and green space availability. Taluka-wise comparisons show that Hyderabad City and Latifabad experienced the most extensive urban growth, while Hyderabad (Rural) still retains some green cover. The study concludes that the rapid pace of urbanization, driven by population pressure and unplanned development, poses a serious threat to ecological sustainability and urban livability. It emphasizes the urgent need for integrating green infrastructure, land-use regulation, and sustainable urban planning policies to preserve and restore green spaces in District Hyderabad.

INTRODUCTION

Urban expansion is reshaping landscapes, converting green/agricultural lands to impervious surfaces, and reducing natural vegetation/open spaces (Seto et al., 2012). Across the developing world, rapid urbanization has accelerated the conversion of green and agricultural lands into impervious surfaces, leading to the loss of

natural vegetation and open spaces (Seto, Güneralp, & Hutya, 2012). In Pakistan's cities like Karachi, Lahore, and Hyderabad, rapid urbanization driven by population growth, migration, and development has led to declining green spaces, impacting microclimates, air quality, and quality of life (Qureshi, 2019; Arshad et al., 2022).

District Hyderabad, Sindh, Pakistan, serves as a representative example of this urban–environmental transformation. Historically known for its agricultural productivity and orchards, Hyderabad has undergone extensive land use changes since the mid-20th century onward (Ul Din & Mak, 2021). The city's population has risen steeply from 1951-2023 creating pressure on available land resources and contributing to the conversion of vegetated and agricultural lands into built-up areas. This expansion has resulted in the fragmentation and degradation of green spaces, posing challenges for sustainable urban management and environmental balance.

This study analyzes urban expansion (1972-2023) and green space decline in District Hyderabad, linking it to population growth (1951-2023). Using remote sensing and GIS, it highlights unplanned urbanization's

environmental impacts, aiming to inform sustainable urban planning and green infrastructure integration.

Data and Methods

Study Area

District Hyderabad, Sindh, Pakistan, is one of the oldest and most urbanized district and It is situated in the southern part of the province between 24°46' to 24°06' N latitude and 68°16' to 68°59' E longitude. The district consists of four administrative Talukas: Hyderabad City, Latifabad, Qasimabad, and Hyderabad Rural (Figure 1). Each Taluka exhibits distinct spatial and demographic characteristics, reflecting varied levels of urbanization and land use intensity (Anilkumar *et al.*, 2022; Arain & Naqvia, 2022).

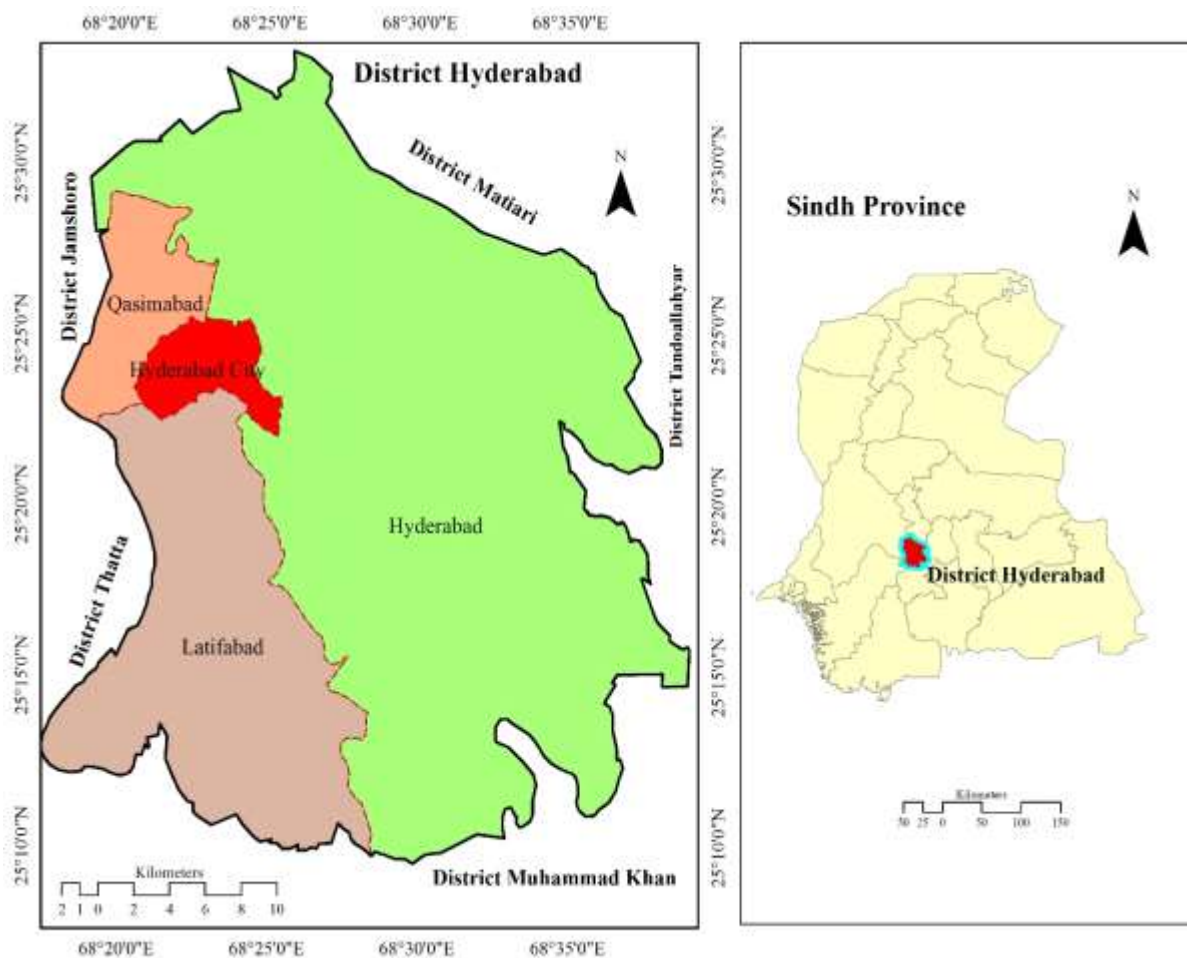


Figure 1 Location map of District Hyderabad

Source: Prepared in ArcGIS 10.8

Demographics

Hyderabad's population grew from 0.37 million (1951) to 2.4 million (2023), a >6x increase. Urban areas (Hyderabad City, Latifabad, Qasimabad) are densely populated, driving urban expansion and converting agricultural land/green spaces to settlements due to housing, infrastructure, and commercial demands (Ahmad & Mahmood, 2024).

Methodology

The study employs a combination of Remote Sensing, Geographic Information System (GIS) and population data analysis to assess the spatio-temporal dynamics of

urban expansion and its impact on green spaces in district Hyderabad from 1972 to 2023. The methodology integrates both quantitative and spatial approaches to establish the relationship between population growth (1951-2023) and land use land cover (LULC) transformation.

Data Sources

The study is based on a combination of both primary and secondary datasets obtained from reliable sources (Figure 2).

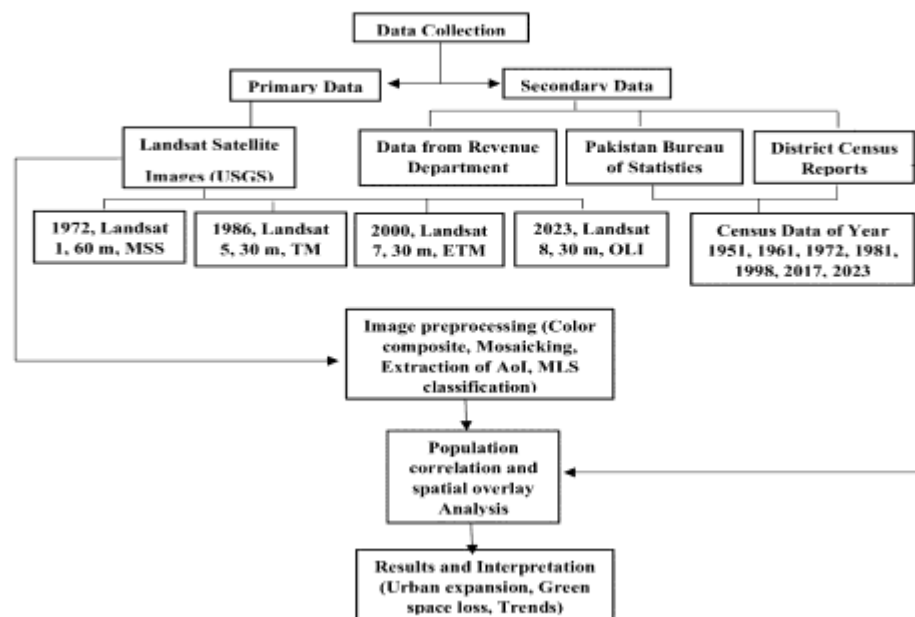


Figure 2: Flow chart showing data sources and methodological frame work used in the analysis

Image preprocessing

Multi-temporal Landsat imagery (1972–2023) was used to analyze LULC changes in District Hyderabad for four benchmark years – 1972, 1986, 2000, and 2023 – using ArcGIS 10.8.2. The datasets included Landsat 1 MSS, Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI images, representing spatial resolutions of 60 m (MSS) and 30 m (TM, ETM+, OLI). All images corresponded to

Path 152/Row 042 of the World Reference System (WRS-2) to ensure spatial consistency.

Two scenes covering District Hyderabad were downloaded, preprocessed, and mosaicked to generate a cohesive image. Preprocessing steps included false color composite creation, georeferencing, and AOI extraction. Training samples for five LULC classes were collected, and Maximum Likelihood Classification (MLC) was applied to produce final LULC maps.

Land use Land cover (LULC) Classification

The Maximum Likelihood Classification (MLC) method was employed for supervised image classification in ArcGIS 10.8.2. Five major LULC categories were identified for the study area i.e. Agriculture, Orchards, Water, Barren Land, and Built-up Areas (Table 1). A total of 200–300 training samples were collected for each class to ensure classification accuracy. The respective area were

computed in square kilometers. This method proved to be both reliable and flexible, effectively accommodating different environmental conditions and data sources (Hemati, Hasanlou, Mahdianpari, & Mohammadimanesh, 2021; Lillesand, Kiefer, & Chipman, 2015).

Table: 1 Descriptions of Land Use Land Cover Classes

LULC Classes	Description
Agriculture	All types of cultivated area/agricultural fields and other vegetation.
Orchards	Different fruit orchards like banana, mango, guava, sugarcane, etc...
Water	River, canal, ponds, seasonal wetlands
Barren Land	Uncultivated or unused land, bare soil or land
Built-Up Area	Residential, industrial and commercial services

Population Data Analysis

Population data were compiled from census years 1951, 1961, 1972, 1981, 1998, 2017 and 2023 (GoP, 1998, 2017; PakistanBureauofStatistics, 2023). These data were used to calculate the population growth rate, density, urban-rural ratio and migration trends to show the relationship between population increase and built-up area expansion (Kazi, Khan, & Talpur, 2023). The data were collected from Pakistan Bureau of Statistics, Islamabad, Hyderabad District Census Reports and Data from the Revenue Department.

Results:**LULC Change in District Hyderabad (1972-2023)**

The multi-temporal analysis of Landsat imagery (Tables 2 and 3) demonstrates pronounced spatial and temporal transformations in the land use and land cover (LULC) of District Hyderabad between 1972 and 2023. The overall trend reveals rapid urban expansion accompanied by a consistent decline in agricultural, orchard, and barren lands, reflecting the district's shift from a semi-agricultural landscape to an increasingly urbanized environment.

The built-up area shows the most substantial growth among all classes, increasing from 123.7 km² (12.1%) in 1972 to 351.7 km² (34.3%) in 2023—a total expansion of 184.3% over the study period (Table 3). This increase was gradual during the first two decades (58.0% during 1972–1986 and 9.8% during 1986–2000) but

accelerated sharply after 2000, recording a 100% rise between 2000 and 2023. The growth of built-up land corresponds with population expansion and the intensification of housing and infrastructure development, particularly within Hyderabad City, Latifabad, and Qasimabad Talukas. In contrast, agricultural land declined steadily throughout the study period, decreasing from 234.9 km² (22.9%) in 1972 to 162.9 km² (15.9%) in 2023—a total reduction of 30.7%. The most substantial decline occurred between 1986 and 2000 (–16.6%), coinciding with accelerated urban development. Similarly, orchard decreased from 390.8 km² (38.1%) to 325.1 km² (31.7%), with a total loss of 16.8%, mainly during 1986–2000 when peri-urban agricultural lands were converted to residential use. Barren land showed fluctuating trends, initially declining by 41.9% (1972–1986), then increasing by 115.1% (1986–2000) due to temporary land clearance and construction, and finally decreasing again by 49.2% (2000–2023), resulting in a net loss of 36.5% over the full study period. Water bodies exhibited irregular variations—rising significantly in 1986 (+181.2%) due to seasonal or infrastructural influences, followed by reductions in later periods, stabilizing with a minor net gain of 2.5% by 2023. Overall, both tables 2 and 3 and figure 3 indicate that urban expansion has been the dominant driving force of land cover transformation in District Hyderabad.

Table 2 Land Use Land Cover changes in District Hyderabad (1972-2023)

Categories	1972	%	1986	%	2000	%	2023	%
Agriculture	234.9	22.9	227.1	22.1	189.5	18.5	162.9	15.9
Water	25.7	2.5	72.3	7.06	22.3	2.1	26.3	2.5
Orchards	390.8	38.1	384.4	37.5	286.6	27.9	325.07	31.7
Barren Area	248.7	24.2	144.5	14.1	310.7	30.3	157.8	15.4
Built up Area	123.7	12.08	195.5	19.09	214.6	20.9	351.7	34.3
Total	1023.9		1024.0		1023.9		1023.9	

Source: Classified images of 1972, 1986, 2000 and 2023.

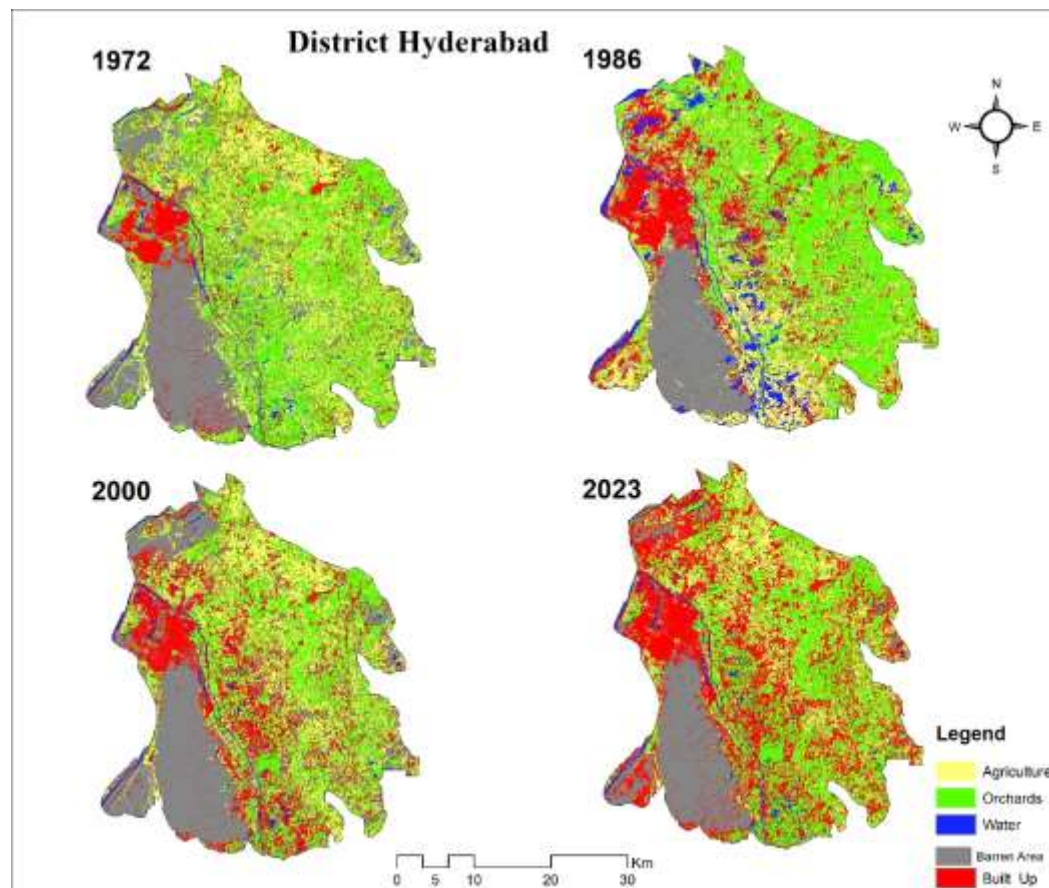


Figure 3 Temporal comparison of LULC Classes of District Hyderabad (1972-2023)

Source: Classified images of 1972, 1986, 2000 and 2023

Table 3 Periodic changes in LULC in District Hyderabad (1972-2023)

Categories	Period 1	Period	Period 3	Total Change
Agriculture	-3.3	-16.6	-14.0	-30.7
Barren Area	-41.9	115.1	-49.2	-36.5
Built up Area	58.0	9.8	100.0	184.3
Orchards	-1.6	-25.4	13.4	-16.8
Water	181.2	-69.1	18.1	2.5

Source: Classified images of 1972, 1986, 2000 and 2023.

Note: Period 1 indicates the duration from 1972 to 1986, Period 2 from 1986 to 2000, period 3 from 2000 to 2023 and total from 1972 to 2023.

Correlation between Population Growth and Built-up Area Expansion (1951–2023)

Population data from 1951 to 2023 (Table 4) reveal a substantial increase in District Hyderabad's population from 319,232 to 2,432,540, representing a 278% rise in

total population and a 593% increase in the urban population. Over the same period, built-up area expanded from 123.7 km² in 1972 to 351.7 km² in 2023, marking 184% growth (Tables 2 and 3). The population density rose from 321 to 2,450 persons/km² as shown in figure 4, demonstrating a strong positive correlation between population pressure and urban land expansion.

Table 4 Population statistics of District Hyderabad (1951-2023)

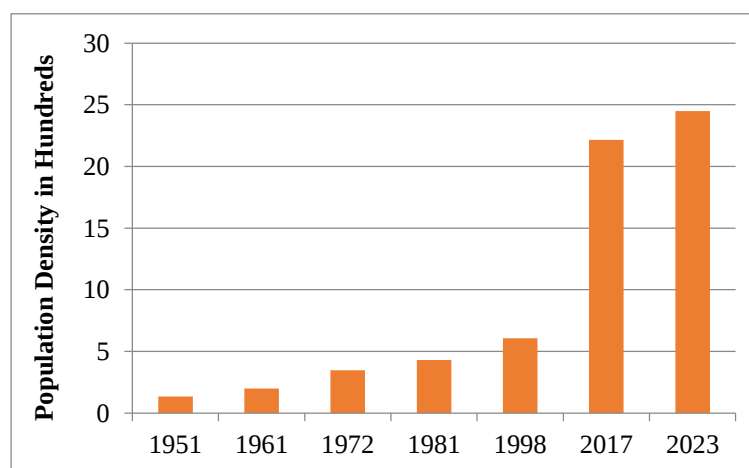
Year	Total Pop.	Pop. Growth rate	Area km ²	Density	Urban	%	Rural	%	Increase in total pop.(1951-2023) %	Increase in urban pop. (1951-2023) %
1951	319232	4.8	993	321	246453	44.2	359219	55.8	278	593
1961	537000	5.5		541	441686	51.6	462862	48.4		
1972	814060	74.9		820	640333	45.2	909888	54.8		
1981	1005460	5.1		1013	768830	44.3	1147787	55.7		
1998	1494866	3.3		1505	1193340	50.8	1422387	49.2		
2017	2199928	2.0		2215	1826518	83.0	373410	17.0		
2023	2432540	1.7		2450	2022379	83.1	410161	16.9		

Source: District Census Report of Hyderabad

Periods of rapid demographic growth, particularly between 1972–1981 and 1998–2017, correspond to accelerated increases in built-up land, largely due to rural-to-urban migration, industrialization, and administrative centralization. By 2023, urban residents constituted 83% of the total population compared to 44% in 1951, reflecting a major structural shift from rural to urban dominance.

Statistical analysis indicates that population growth is a major driver of land cover transformation. These findings highlight the urgent need for sustainable urban planning to balance development with the conservation of green spaces (Lillesand et al., 2015; Peña-Arancibia et al., 2021).

Figure 4 Population density of district Hyderabad (1951-2023)

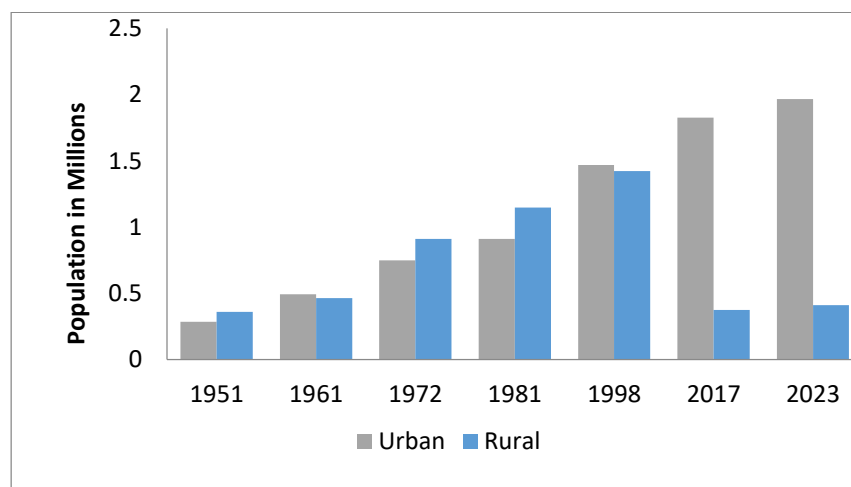


Source: District Census Report of Hyderabad.

Comparison of Urban-Rural Population Structure

The figure 5 shows a major demographic shift from rural to urban dominance in District

Figure 5 Urban and rural population of district Hyderabad (1951-2023).



Source: District Census Report of Hyderabad

Hyderabad. In 1951, the urban population was 44.2%, increasing to 51.6% in 1961, before fluctuating around 45–50% until 1998. After 1998, urbanization accelerated sharply, reaching 83.0% in 2017 and 83.1% in 2023. Meanwhile, the rural population declined from 55.8% in 1951 to only 16.9% in 2023. This trend reflects rapid urban expansion, population growth, and conversion of rural land into built-up areas, particularly in Hyderabad City, Latifabad, and Qasimabad Talukas.

Discussion

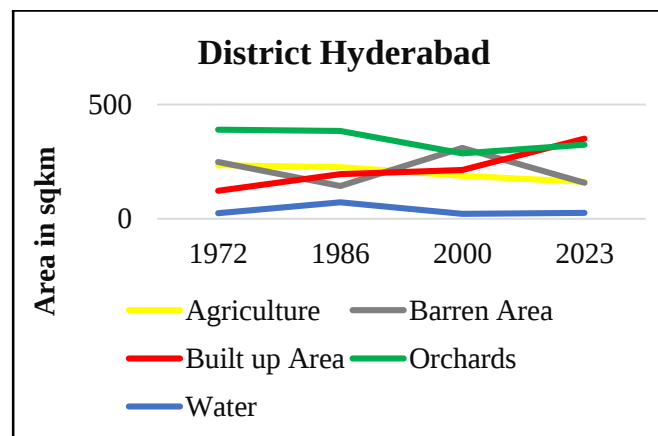
This study analyzed the impact of urban expansion on green spaces in District Hyderabad using multi-temporal satellite imagery and population data from 1951 to 2023.

The results revealed significant land use and land cover (LULC) transformations, characterized by a substantial increase in built-up areas and a marked decline in agricultural and barren lands. These changes correspond closely with population growth and rapid urbanization, particularly after 1998.

Interconnection of LULC change and agricultural land in District Hyderabad

Figure 6 illustrates the temporal variation in major land use and land cover (LULC) categories of District Hyderabad from 1972 to 2023.

Figure 6 Interconnection of LULC change and agricultural land in District Hyderabad



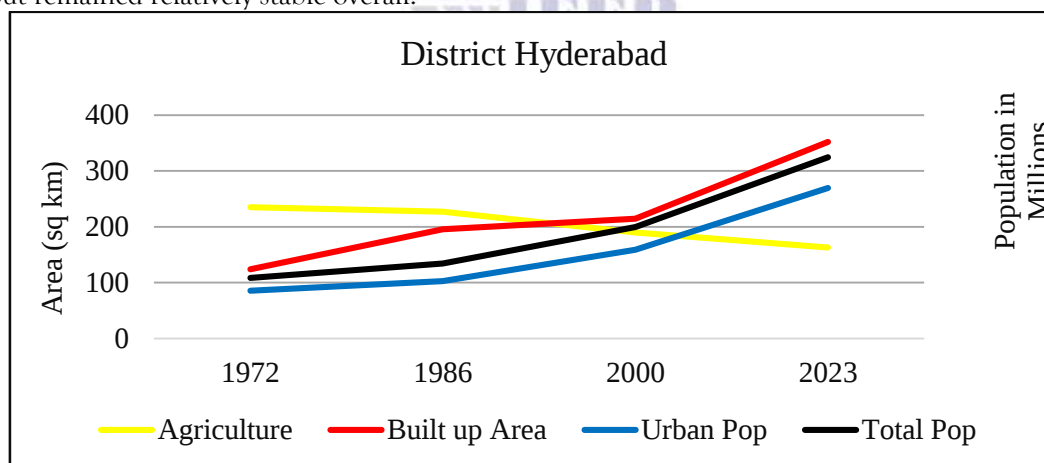
Source: Classified images 1972-2023

The data show a substantial rise in built-up areas, which increased sharply after 1986, surpassing all other land use categories by 2023. In contrast, agricultural land and barren areas show a consistent decline, indicating large-scale conversion of open and cultivated land into urban zones. Orchards initially declined until 2000 but slightly recovered by 2023, suggesting limited restoration or mixed land-use development. Water bodies fluctuated over time but remained relatively stable overall.

Interconnections of Population Growth, Built-up Area, and Agricultural Land (1972–2023)

Figure 7 illustrates the strong interrelationship between population growth, built-up area expansion, and the decline of agricultural land in District Hyderabad from 1972 to 2023.

Figure 7 Interconnections of population growth, built up area and agricultural land in District Hyderabad



Source: Classified images 1972-2023 and census reports 1951-2023

The results show that as both total and urban populations increased sharply, the built-up area expanded significantly—from below 130 km² in 1972 to over 350 km² in 2023. In contrast, agricultural land consistently declined during the same period, reflecting the conversion of fertile land into residential, commercial, and infrastructural zones.

Conclusion

This study examined the long-term impact of urban expansion on green spaces in District Hyderabad using multi-temporal Landsat imagery (1972–2023) and population data (1951–2023). The findings reveal a substantial transformation in land use and land cover (LULC), marked by a 184% increase in built-up areas and a corresponding decline in agricultural land (–30.7%) and

orchards (−16.8%). These changes are strongly correlated with rapid population growth and the sharp rise in urban population, particularly after 1998.

The results clearly indicate that urban expansion has occurred at the expense of green and agricultural areas, leading to significant environmental and ecological consequences. Uncontrolled population growth, rural-to-

urban migration, and expansion of infrastructure have been the main driving forces behind this transformation. To ensure sustainable urban development, there is an urgent need for integrated urban planning and green space conservation policies in District Hyderabad. Implementing land use regulations, promoting vertical expansion, and restoring degraded green zones can help balance urban growth with environmental sustainability.

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