LAND USE LAND COVER CHANGE ANALYSIS HYDERABAD METROPOLITAN REGION 1988 TO 2024

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Abstract

The major challenges and changes in the Hyderabad metropolitan region due to rapid urbanization and population growth over the past few decades, Hyderabad is experiencing rapid population growth and urbanization, leading to increased demand for urban development in terms of residential complexes and work facilities. Over the last 30 years, there has been substantial development in terms of wealth, modernization, and infrastructure. However, this has also led to increased demand for land and environmental degradation. The study aims to analyse land use and land cover changes in the Hyderabad metropolitan region from 1988 to 2024 using Landsat satellite data. It specifically focuses on the expansion of urban areas over this period. According to the results, the urban area of Hyderabad has expanded significantly, particularly towards the north-western side of the metropolitan region. This expansion indicates the intensification of urban development to accommodate the growing population. Given these changes, effective planning schemes are essential to manage and control the growth of the Hyderabad metropolitan region. This includes addressing population issues, infrastructure development, and environmental concerns.

Keywords: Geographic Information System, supervised classification, remote sensing, LULC, geometric correction, Radiometric correction, Atmospheric correction models

Introduction

This is the process where people move from rural areas to urban areas, leading to an increase in the urban population [1]. Urbanization brings significant changes to social, economic, and environmental aspects of a region. This refers to the rate at which the population of an urban area increases over time [2]. It is a result of urbanization—the movement of people from rural to urban areas [3]. Urban growth can lead to economic development by generating more employment opportunities and contributing to economic growth. Urban growth is seen as an indicator of a country's economic condition because it affects economic development directly [4]. As urban areas expand, they can accommodate more businesses, industries, and services [5], thus boosting economic activities and improving living standards.

Urbanization and urban growth have social implications. While they can provide better living standards and opportunities [6], they also concentrate poverty and create challenges related to infrastructure, housing, and social services. Rapid urbanization can strain natural resources and lead to environmental degradation if not managed properly [7]. Sustainable urban development aims to address these challenges by efficiently managing resources and reducing environmental footprint [8]. Urbanization is considered crucial for economic growth as it fosters industrialization, enhances productivity, and creates markets for goods and services. It also stimulates demand for non-farm goods [9], which are typically produced in urban areas. It seems like you are discussing urban sprawl and urbanization, describing how populations move from rural to urban areas seeking better economic and social opportunities. Urban sprawl typically refers to the expansion of urban areas into surrounding rural spaces [10], driven by factors such as industrialization, commercialization, and the availability of social services [11].

Urbanization is indeed the process where people migrate from rural to urban areas in search of improved standards of living, including better job prospects, education, healthcare, housing, and overall quality of life [12]. This movement is influenced by the perception that cities offer more opportunities and amenities compared to rural areas [13].

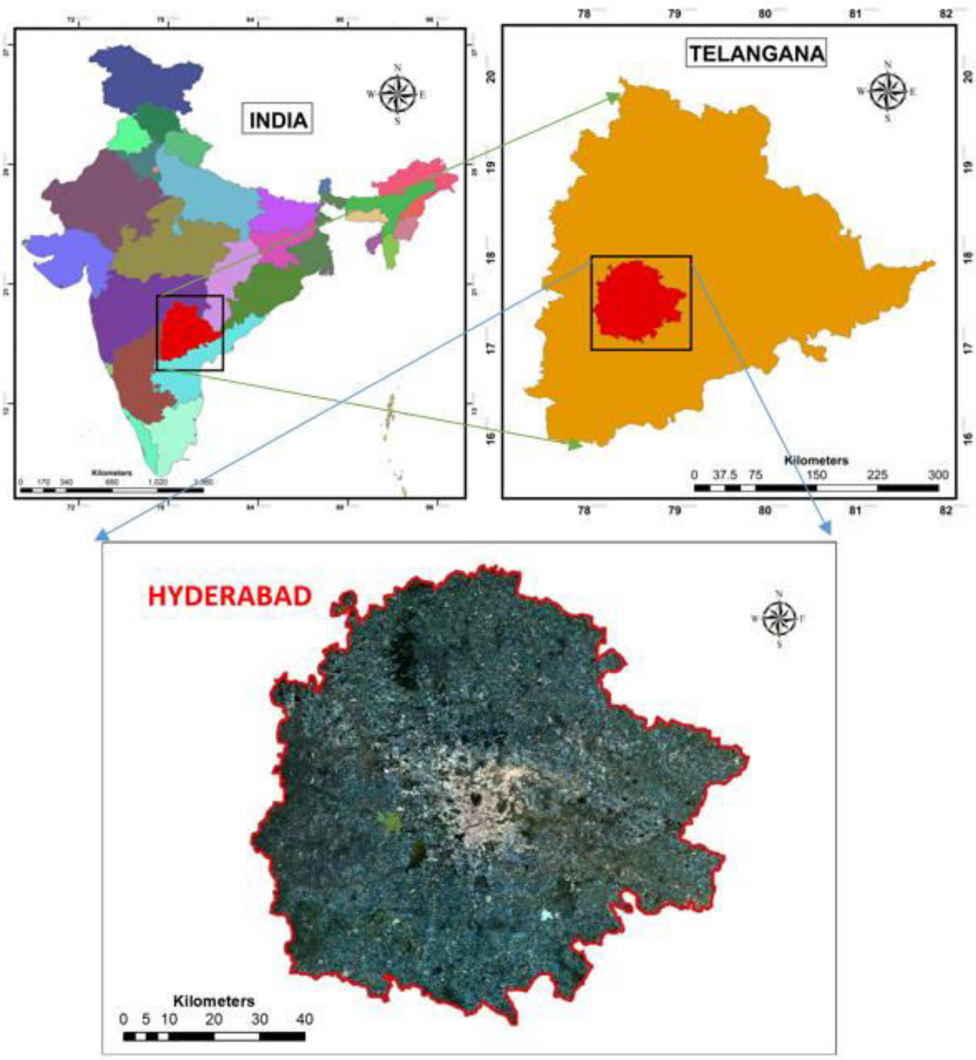
Industrialization plays a crucial role in urban growth by creating new job opportunities in non-agricultural sectors [14], which attracts rural populations seeking employment in modern industries. Additionally, commercialization and trade contribute to urbanization, as cities become centres for commerce, offering increased market opportunities and commercial activities [15].

Hyderabad, historically known for its rich cultural heritage, has undergone significant demographic shifts over the decades [16]. Originally boasting a population of 415,039 in 1897, the city has since evolved into a sprawling metropolis covering 650 square kilometres. Today, it houses approximately 6,809,970 residents, making it the fourth most populous city in India. Within its boundaries, there are 3,500,802 males and 3,309,168 females, reflecting a sex ratio of 945 females per 1000 males, higher than the national average. The city's population density stands at a bustling 18,480 persons per square kilometre.

In 2007, the creation of the Greater Hyderabad Municipal Corporation expanded the city's administrative area from 170 to 650 square kilometres [17], responding to the growing urban demands. Despite challenges posed by rapid population growth, Hyderabad maintains a commendable literacy rate of 82.96%, surpassing the national average [18]. Governed by the Greater Hyderabad Municipal Corporation within the Hyderabad Urban Agglomeration, encompassing 7.7 million inhabitants [19], the city is continually expanding. Plans are underway to further enlarge its jurisdiction to 721 square kilometres, potentially incorporating surrounding villages and gram Panchayats, underscoring Hyderabad's ongoing evolution as a dynamic urban centre [20].

Study Area

Hyderabad, located in the southern part of India, is a prominent city in the state of Telangana with a rich historical and economic background. Formerly renowned as a centre for pearl and diamond trading, it earned the moniker "city of pearls. In the 20th century, Hyderabad witnessed significant industrialization, attracting numerous Indian manufacturing, research,



and financial institutions. Notable establishments include Bharat Heavy Electricals Limited, the National Geophysical Research Institute, and the Centre for Cellular and Molecular Biology. The city's development has been bolstered by special economic zones dedicated to information technology, drawing companies from across India and around the globe.

Hyderabad is a key contributor to India's gross domestic product, ranking as the fifth largest metropolitan area in economic output. The Hyderabad Metropolitan Development Authority oversees a vast region encompassing seven districts: Hyderabad, Medchal, part of Rangareddy, Sangareddy, Medak, Yadadri, and Siddipet. This expansive metropolitan area includes 70 mandals and 1032 villages, with the Greater Hyderabad Municipal Corporation alone covering 175 villages and 12 municipalities or Nagar Panchayats, which include 31 villages.Geographically, the city spans an area of 7,257 square kilometres, situated between 17.607999″ N to 17.203936″ N latitudes and 78.669388″ E to 78.235366″ E longitudes. Hyderabad's metropolitan region is divided into three zones based on economic activity and urbanization: the metropolitan core, extending 10 to 13 kilometres from the city centre; the peri-urban zone, stretching up to 26 kilometres from the core; and the rural hinterland, reaching up to 64 kilometres from the city centre.

Fig: 1

Methodology:

Data acquisition and Image processing

Data collection is the first and most crucial stage of any research or study, as it fundamentally shapes the direction and outcomes of the research. This process is particularly intricate in developing countries, where rigorous security checks are necessary even for seemingly insignificant data. Moreover, data costs are prohibitively high compared to those in developed nations, necessitating complex procedures that consume significant time. Obtaining up-to-date data can also be challenging.

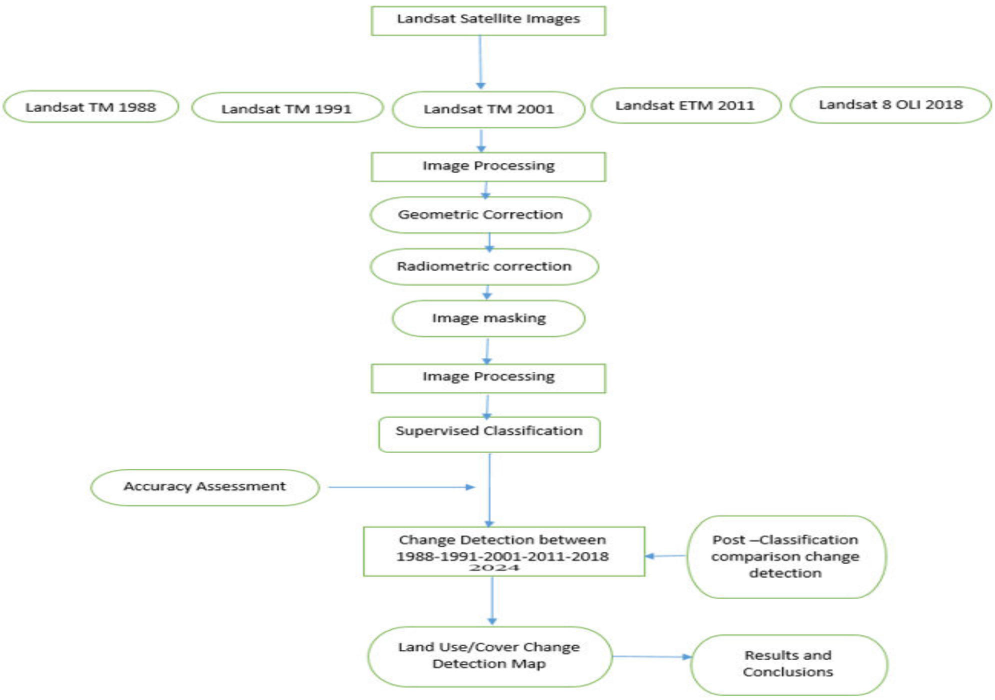
In this study, six satellite images were sourced from the United States Geological Survey (USGS) databases via Earth Explorer (Landsat TM, Landsat ETM+, and Landsat 8). These images, acquired in January 1988, January 1991, January 2001, January 2011, and January 2018, along with a projected image for January 2024, were obtained.

Despite the availability of numerous satellite images spanning the study period, it was imperative to select images captured during the summer season to ensure full cultivation of agricultural lands around Hyderabad. Additionally, images were chosen with the sun elevation angle closest to nadir. All images were originally referenced to Universal Transverse Mercator (UTM zone 36 N).

Satellite image pre-processing is a critical component in the workflow of analytical remote sensing. Before performing tasks such as image classification and change detection, it is essential to address radiometric and geometric errors inherent in satellite imagery. Typically, pre-processing involves a series of steps, including atmospheric correction or normalization, image registration, geometric correction, and masking. Additionally, the process may include combining single-band images into a composite multi-band image.

In this particular study, pre-processing also encompasses the generation and organization of data layers necessary for subsequent classification and change detection analyses. These preparatory steps are vital because they aim to correct distortions caused by factors such as relief displacement, atmospheric refraction, earth curvature, and sensor imperfections like nonlinearities in the field of view.

Geometric Correction:



Manipulating image data so that its projection precisely matches a specific surface or shape. This correction compensates for distortions caused by off-axis projector or non-flat screen surfaces, applying an inverse distortion digitally. It aims to ensure equal areas on the projection surface map to equal areas in the source image, adjusting for any geometric irregularities in the display setup.

Radiometric Correction:

Radiometric correction is crucial for converting satellite digital image data into calibrated surface quantities in Earth science. This correction process addresses various factors affecting photon paths from the sun to the satellite sensor. It involves sensor radiometric calibration, retrieving surface reflectance, spectral characterization, and accounting for geo radiometric effects. Raw data is initially captured as Level zero, progressing to Level 1 after calibration to top-of-atmosphere radiance (TOA). For quantitative analysis, Level 2 data, which includes calibrated physical variables like surface reflectance and temperature, are preferred. Correcting digital numbers (DN) to ground reflectance factors considers sensor calibration and solar radiation alterations due to atmospheric conditions.

Atmospheric Correction Models:

Atmospheric models play a crucial role in mitigating the impact of scattering and absorption within the atmosphere. To effectively perform atmospheric correction, several parameters must be considered, such as the concentration of water vapor and the distribution of aerosols.

Fig: 1.1

Image Classification

Image classification is the process of categorizing all pixels in an image into distinct land cover classes or themes. This categorization relies on the spectral patterns present in the data for each pixel, which serve as the numerical basis for classification. Typically, multispectral data is used for this purpose, where different land features exhibit unique combinations of digital numbers based on their spectral reflectance.

Spatial classifiers identify patterns by analysing the spatial relationships among neighbouring pixels. Factors considered include image texture, pixel proximity, feature size, shape, directionality, repetition, and context. These classifiers mimic the spatial synthesis performed by human analysts during visual interpretation. In addition to image restoration and enhancement techniques, classifiers may operate in hybrid modes. The choice of classification method depends on factors such as data characteristics, available computing resources, and the intended application of the classified data. Supervised classification involves guiding the process by specifying spectral signatures for known land cover types, ensuring minimal overlap between classes. This method relies on prior knowledge of the location and identity of land cover types within the image.

Accuracy Assessment

Accuracy assessment is a critical process in the realm of image analysis for information extraction. It evaluates the degree of agreement between a presumed correct standard and a classified image of uncertain quality [18]. Precision, on the other hand, delineates the level of detail present in the classification. Simplifying classifications to broader categories, such as distinguishing between trees and crops rather than specific types, can enhance overall accuracy by minimizing classification errors. However, this approach sacrifices precision, limiting the ability to make detailed assertions about specific points on a map for users reliant on finer distinctions. Thus, accuracy assessment balances the trade-offs between precision and accuracy to ensure the reliability of classified data in practical applications.

Accuracy Assessment						
Class Name	1988	1991	2001	2011	2018	2024
Built up	93.63%	96.11%	93.75%	93.63%	91.56%	96.11%
Agricultural	98.21%	90.15%	88.75%	78.05%	82.75%	90.15%
Water body	98.21%	100.00%	99.19%	99.46%	98.21%	100.00%
Shrubs and Fallow land	93.55%	96.57%	87.56%	96.13%	93.55%	96.57%

Forest & Green Cover	86.26%	90.43%	86.26%	90.86%	90.48%	90.43%
Column Total	**93.97%**	**94.65%**	**91.10%**	**91.62%**	**91.31%**	**94.65%**
		Overall Accuracy = 92.88%				

Table: 1

Change detection analysis

In supervised classification, the process is guided by the user or image analyst who oversees the pixel classification. This involves specifying pixel values or spectral signatures corresponding to each class of interest. To achieve this, the analyst selects representative sample sites known as Training Areas, which embody the characteristics of the classes. These training areas provide the spectral signatures used by computer algorithms to classify the entire image. The goal is to minimize overlap between classes, ensuring distinct categorization.

Supervised classification heavily relies on prior knowledge of the location and identity of land cover types within the image. It entails using known samples (pixels already assigned to classes) to classify unknown pixels (unclassified pixels) into these predefined classes. The selection of appropriate training areas is crucial as it determines the accuracy of the classification process. Image processing software calculates statistical parameters for each class based on the training areas, and subsequently assigns each pixel to the class that best matches its spectral characteristics.

For instance, when classifying images using Landsat data, specific band combinations such as 7, 4, and 2 are chosen for optimal RGB display. This combination enhances distinctions between different land cover types like vegetation, soil, and water. Bands like green (Band 2: 0.52-0.60µm), near infrared (0.76-0.90µm), and middle infrared (2.08-2.35µm) are particularly useful for discriminating vegetation types, water bodies, and soil compositions due to their distinct spectral responses.

In this study, a Maximum Likelihood classification algorithm was employed, defining six primary classes: water, forest, and open vegetation, soil and shrimp farms. Each class represents a specific land cover type found within the image, facilitating detailed mapping and analysis.

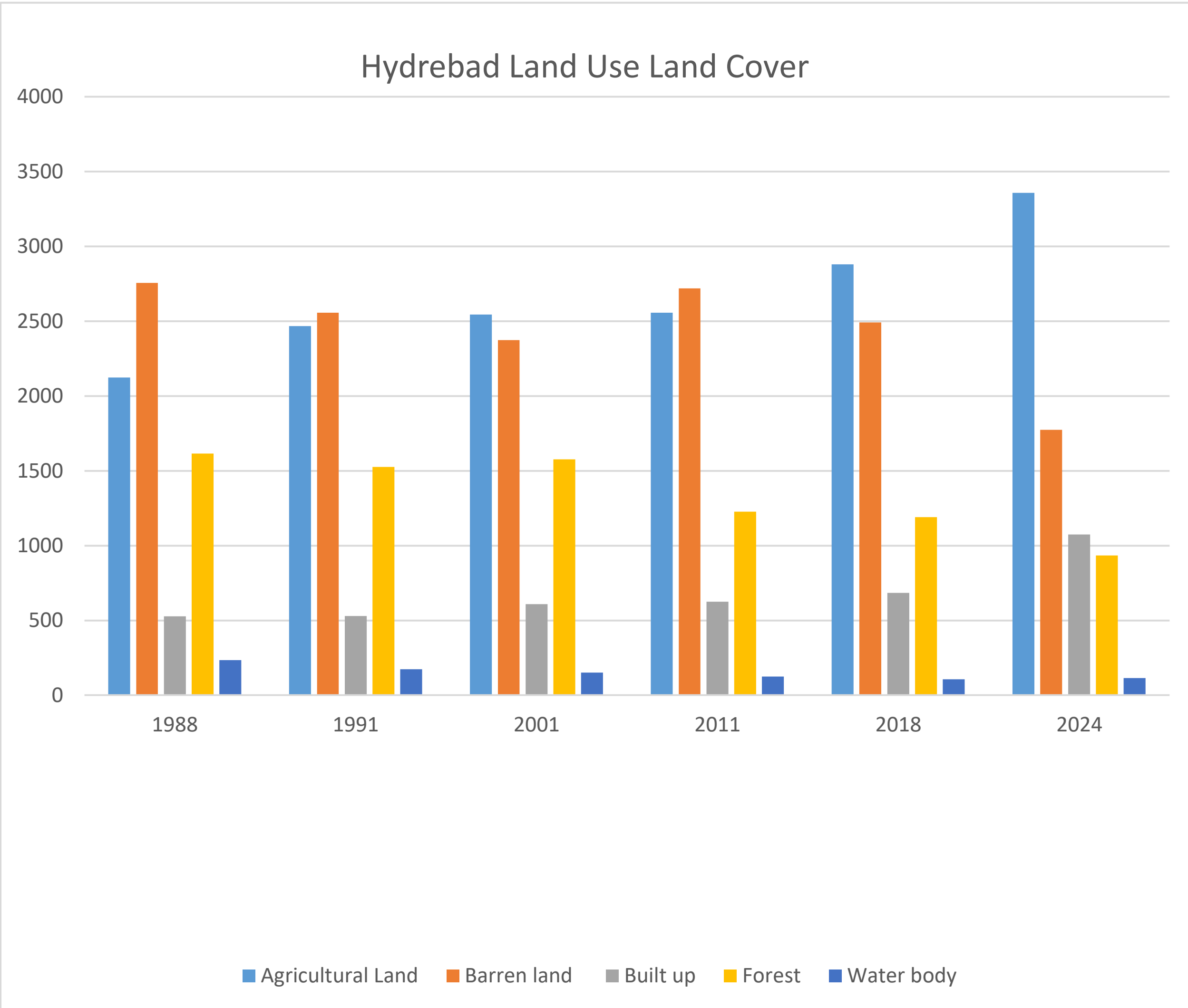
Results

Urbanization is a significant driver of land use change and conversion, leading to unpredictable and enduring transformations in the landscape. Detecting and understanding these changes is crucial, particularly in identifying shifts between different land use classes.

Analysing spatial and temporal changes in land use and land cover provides valuable insights into the environmental condition and ongoing transformations over specific periods, such as 1988, 1991, 2001, 2011, 2018 and 2024. The study's objectives underpin all subsequent analyses in this chapter. Results are presented through maps, charts, and statistical tables, detailing both static changes and projected scenarios for each land use and land cover class. This comprehensive approach aids in assessing the current Detecting urban growth in Hyderabad metropolitan region

Class Name	1988	1991	2001	2011	2018	2024
Agricultural Land	2122.62	2467.11	2544.65	2556.55	2879.40	3,357.96
Barren land	2755.02	2555.98	2374.12	2720.12	2491.57	1,774.82
Built up	526.84	529.83	608.83	624.13	684.88	1073.65
Forest	1614.52	1526.33	1575.70	1227.38	1190.51	933.45
Water body	234.87	174.66	150.41	125.70	107.52	113.85
Total	7253.90	7253.92	7253.73	7253.91	7253.91	7253.73

Table: 1.1



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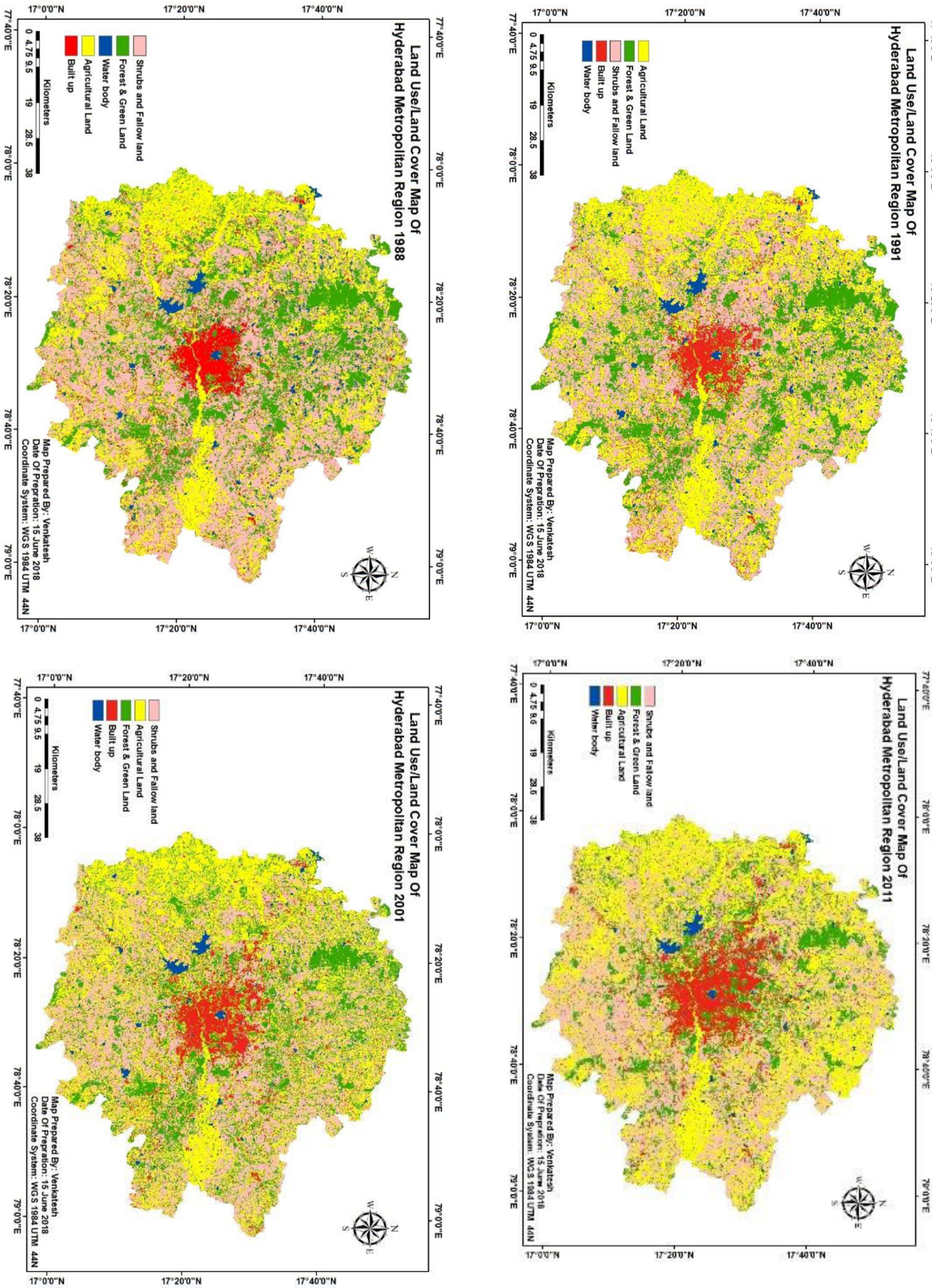

Fig: 1.2

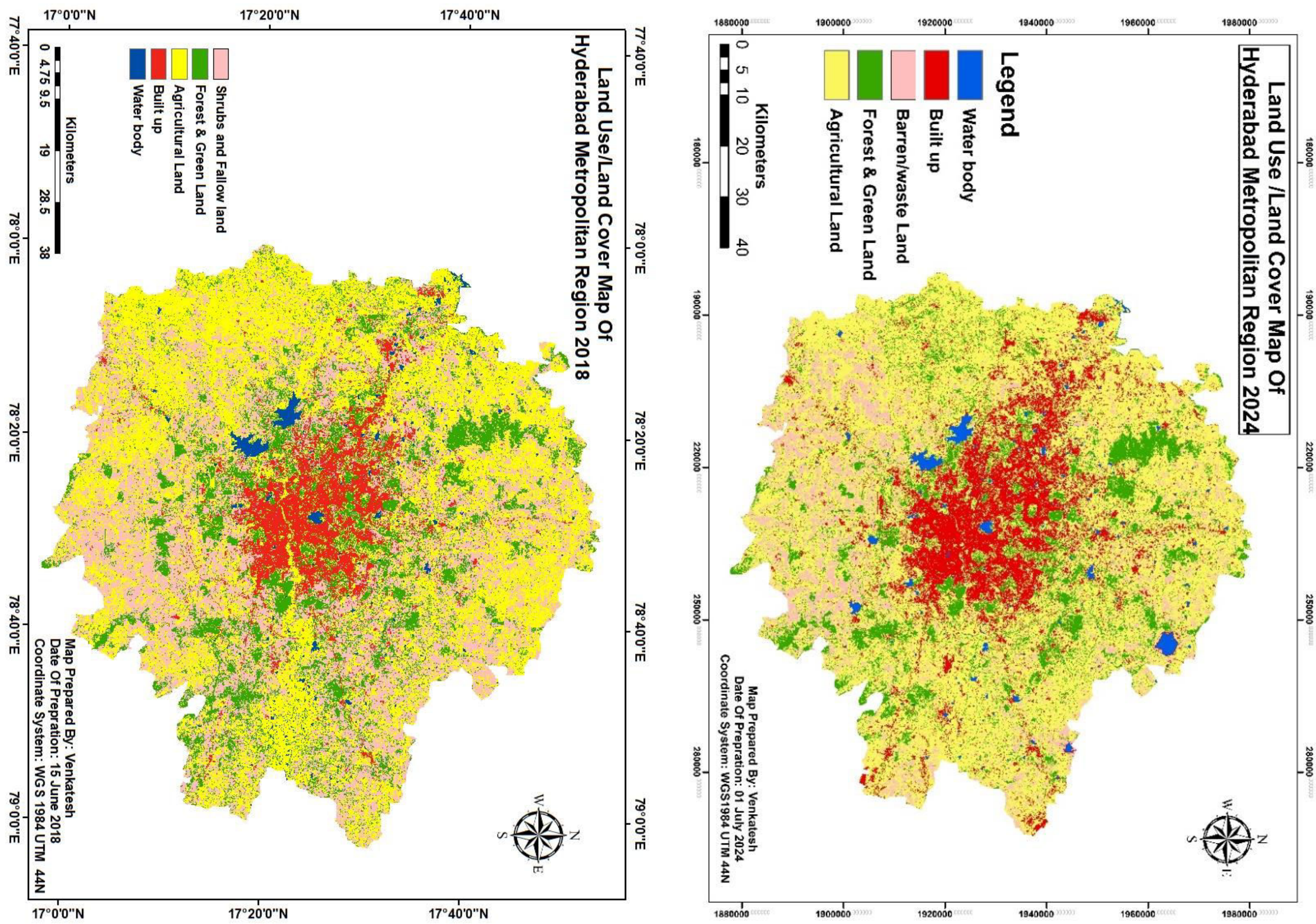

Fig: 1.3

The dominant causative factors contributing to various types of land degradation were thoroughly examined, with urbanization emerging as the principal human-induced driver in the surveyed region. Assessment of the extent of degradation utilized multi-date satellite imagery spanning six intervals: 1988, 1991, 2001, 2011, 2018, and 2024, across a comprehensive study area encompassing 7000 square kilometres.

In 1988, urbanized areas covered 123 square kilometres, with an additional 123 square kilometres added by 1991. This trend continued with an equivalent increment by 2001, maintaining the pace through 2011. However, the expansion slowed notably by 2018, with only 12 square kilometres added, indicating shifts in land use patterns over the study period. Finally, by 2024, the built-up area had expanded to 388.77 square kilometres, marking the culmination of urbanization's impact on land degradation in the area.

Land Use Land Cover change dynamics

The land use and land cover maps derived from Landsat Thematic Mapper (TM) data offer a detailed portrayal of the evolving landscape from 1988 to 2024, employing supervised classification techniques. In 1988, the built-up area spanned 526.8 sq. km, accompanied by water bodies covering 234.8 sq. km. Agriculture dominated with 2755 sq. km, followed by shrubs and fallow land at 2122.6 sq. km, and forest covering 1614.5 sq. km. By 1991, the built-up area saw a slight increase to 529.8 sq. km, while water bodies decreased to 174.6 sq. km. Agriculture expanded to 2467.1 sq. km, with forest covering 1526.3 sq. km, and shrubs and fallow land at 2555.9 sq. km. In 2001, built-up areas grew to 608.8 sq. km, water bodies decreased to 150.4 sq. km, agriculture expanded to 2544.6 sq. km. Forests covered 1575.7 sq. km, and shrubs and fallow land were 2374.1 sq. km. By 2011, built-up areas further increased to 624.13 sq. km, water bodies reduced to 125.7 sq. km, agriculture expanded marginally to 2556.5 sq. km, while forests decreased to 1227.38 sq. km, and shrubs and fallow land increased to 2720.1 sq. km. In 2018, the built-up area continued to grow to 684.8 sq. km, water bodies decreased to 107.5 sq. km, agriculture expanded notably to 2879.4 sq. km, while forests decreased to 1190.5 sq. km, and shrubs and fallow land were 2491.5 sq. km.

By 2024, significant transformations in land use and cover patterns have been observed through detailed mapping. The maps provide a comprehensive view of urbanization, agricultural dynamics, and environmental changes spanning decades. Over this period, there has been notable conversion of barren land into built-up areas and agricultural land, amounting to 1073.65 sq. km and 3357.96 sq. km, respectively. Concurrently, barren land has decreased by 1774.82 sq. km. The forest area has contracted to 933.45 sq. km, while water bodies have expanded to 113.85 sq. km. These changes underscore ongoing shifts reflective of socioeconomic and environmental trends, illustrating the evolving landscape and its implications.

Conclusion

The study of urban growth in Hyderabad between 1988 and 2024 reveals significant changes in land cover patterns. Land cover maps derived from supervised classification depict a remarkable expansion of the built-up areas, notably towards the east, northeast, and west. In 1988, the built-up area covered 244.6 sq. km, which increased to 344.6 sq. km by 1991, marking an addition of 100 sq. km. Over the subsequent decade, from 1991 to 2001, an additional 108.1 sq. km of built-up area was added, reaching a total of 452.7 sq. km. This trend continued with 140.2 sq. km added between 2001 and 2011, resulting in a total of 592.9 sq. km of built-up area by 2011. From 2011 to 2018, the built-up area expanded dramatically by 328.3 sq. km, reaching 921.2 sq. km in 2018, indicating a rapid urbanization rate of 41 sq. km per year during this period. From 2018 to 2024 there is rapid change in the urbanization it got increased from 921.2 sq. km to 1073.65 sq. km.

Conversely, green lands around Hyderabad exhibited fluctuations over the years, starting at 111.5 sq. km in 1988. While there was decrease of 7.3 sq. km from 1988 to 1991, green lands increased by 28.7 sq. km from 1991 to 2001. However, subsequent periods saw reductions: 12.9 sq. km between 2000 and 2008, and 7.4 sq. km from 2008 to 2018. Meanwhile, desert areas also underwent substantial changes, increasing significantly over the years as urbanization expanded.

Overall, this study highlights a total increase in built-up area from 244.6 sq. km in 1984 to 921.2 sq. km in 2018, marking a net growth of 676.6 sq. km over the 32-year period. The interplay between urban expansion, green land decline, and desertification underscores the complex dynamics of urban growth and environmental change in Hyderabad.

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