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The Implication of Urbanization, LULC Changes, and Their Environmental Impact Assessment: A Case Study of Tirupati, Smart City

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Abstract. Land use and land cover (LULC) mapping is an effective way to communicate land resources that help to identify and understand the availability of various land features and communicate their probable future use. The LULC changes are inevitable with time but urbanization and modern developments are having a catalytic effect on changes in the physical occur and other parameters of the setting. Urbanization is a global phenomenon and happening at the high potential at present throughout the world. However, most of the changes that occur in an urbanizing world are instantaneous/unplanned and unsymmetrical. Therefore, it is vital for sustainable development to track the LULC changes and identify the potential availability of resources for sustainable use. Assessment of LULC changes was a tedious process as land use in the urban environment changes very frequently. At the same time, the recent advancement in technology and computational tools has made the analysis process plain and effective. The present study emphasizes monitoring land use and land cover change for the Tirupati Urban with the help of satellite remote sensing and GIS technique. The land use of the study area is categorized into four vibrant land use classes: residential/built-up area, water bodies, open land, and vegetation. Further, the assessment of changes in the LULC of Tirupati Urban is communicated to identify the rapid land development over the years from 2000-2020 and its significant impact on the environment.
Keywords: Urbanization, LULC, Environment, GIS, Development.

1. Introduction

Along with climate change, urbanization is another worldwide enduring phenomenon. [5] More than 50% of the world's population lives in urban regions today, and by 2050, another 30% is expected to do so. [16] India is progressing quickly. A sizable portion of the country's population is migrating to cities because of urbanization and technological advancement. [19, 3] Cities are booming enormously to accommodate this influx of people. In India, the area devoted to urban uses (7933 towns) grew from 77,370.50 square kilometres in 2001 to 102,220.16 square kilometres in 2011, suggesting that 24,850.00 square kilometres of more land were dedicated to urban uses. [14] Urban areas that are expanding quickly are more susceptible to climate change unless appropriate adaptation strategies are established. [6, 8] Intense urbanization has a wide impact on catchment areas including runoff generation, the heat island effect, and local weather patterns in addition to global weather patterns. [2] Further, unchecked urbanization puts a tremendous amount of strain on land use. The amount of fertile

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agricultural land, woods, and surface water bodies is steadily declining because of urbanisation. [12, 11, 1] Considering all these facts, The Atal Mission for Rejuvenation and Urban Transformation (AMRUT) programme, which has recently been started by the Government of India (GoI), with a focus on the endowment of water supply, sanitation, stormwater drains, green areas, and public transportation in 500 different cities across India.

Land use land cover (LULC) variations have been identified as a significant driver of environmental alteration at all geographical and temporal stages. [15] To analyse trends in urban expansion, local and regional planning studies must keep track of changes in land use. [18] The development strategies must be aided by current and reliable data on LULC. Therefore, urban planners require a system to efficiently and effectively identify, monitor, and analyse alterations in urban LULC patterns. By studying a geographic feature at various intervals, the process of "change detection" can be used to spot changes in its condition. [13, 9] This study used Landsat data to analyse the effects of urbanisation on changes in land use and land cover in Tirupati over the course of the last four decades (2000–2020). It reveals changes in residential, agricultural, and other sectors, such as water bodies. Land use and land cover change have thus become an integral aspect of modern policies to manage natural resources and track environmental alterations for sustainable planning and management.

The present study discusses the use of geospatial techniques and satellite imagery for applying classification strategy and identifying and comprehending changes to the study area's land use and land cover. The changes in the study area within the period 2000-2020 are detected and presented in the result section. Further, sample change-detecting images derived from google earth imagery [7] of the same period are included as an addition to the results and reasoning part. The results show a significant rise in settlements at the cost of open land, vegetation and water bodies.

2. Study Area and Data Collection

Figure 1 presents a map that demonstrates the location of the research area. Tirupati is situated at a latitude of 13.65 degrees North and an easterly longitude of 79.42 degrees East. It is the most populous city in the Rayalaseema region and, following Vizag and Vijayawada, it is the third fastest-growing city in the state of Andhra Pradesh, India. The Tirupati Municipal Corporation has an area of 27.44 square kilometres, with an estimated population of 3,74,260 people (based on data from the 2011 census), 50 election wards, and 69 slums in total, including both notified and unnotified neighbourhoods.

Tirupati City has been chosen by India's Ministry of Urban Development to be one of the country's top 100 smart cities. The Tirupati Municipal Corporation is now working on developing smart city concepts, which are intended to provide creative and innovative solutions to the challenges posed by urban infrastructure. Citizens of Tirupati City are being asked to pole their views on how Tirupati Municipal Corporation is to provide services related to the city's basic infrastructures. These services include sanitation, water supply, management of solid waste, underground drainage, stormwater, housing, amenities linked to recreational activities and non-motorized transport, as well as security. To properly structure the Visio diagrams for the smart city plans, this step is essential.

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The Tirupati Municipal Corporation (TMC) is consulted for information on the areal expanse and boundary of Tirupati Smart City. High-resolution 10 m Cartosat Digital-Elevation-Model (DEM) data from the National Remote Sensing Center (NRSC), Hyderabad, is processed to produce spatial data for the study area. To create land use and land cover maps, the study area's ETM+ and LISS III satellite photos from 2000 and 2020 are downloaded from USGS Earth Explorer. [17] The LISS III and ETM+ satellite pictures covering the study area are presented in Figure 2.

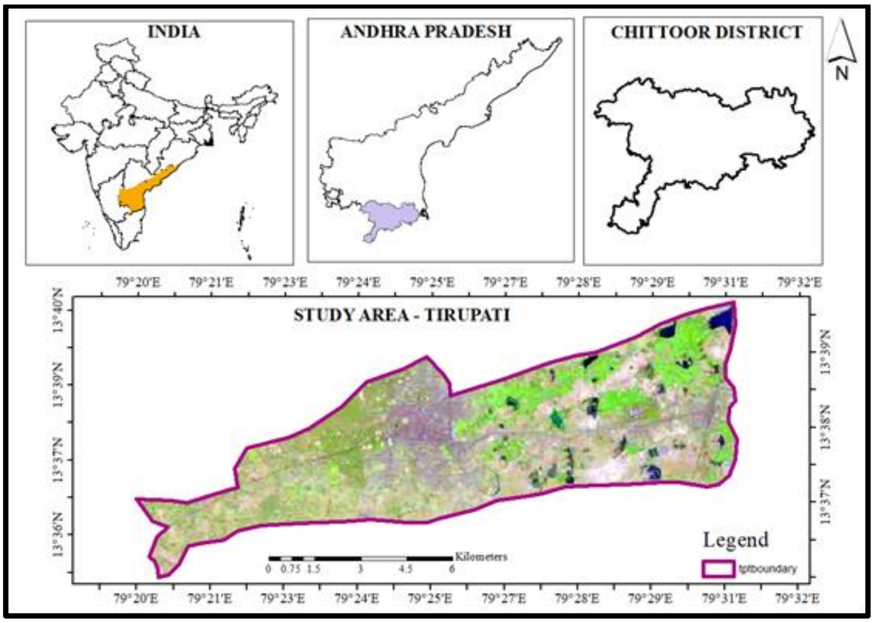

Figure 1. Location map of Tirupati

ETM+(2000) ETM+(2005) ETM+ (2010) LISS-3 (2015) LISS-3 (2020)

Figure 2. Satellite images covering the study area derived from USGS

3. Methodology and Model Description

The flowchart in Figure 3. illustrates the process used to develop LULC maps for the Tirupati Smart City. With the development of technology, high-quality satellite images and spatial data are now widely available for free download and use from a variety of sources. For Tirupati Smart City, the current work creates land use and land cover maps using LISS III and ETM+ satellite imagery. The satellite images are derived from USGS Earth Explorer. High-quality LISS III images for 2015, 2020 and ETM+ images for 2000, 2005, and 2010 are downloaded and pre-processed to remove the parallax by geometric corrections and redefining the projection system as WGS_1984_UTM_Zone_43N in ArcGIS environment. [4, 10]

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Google Earth imagery was used as a guide to accomplish the land use categorization, and the band combination of the photos changed to differentiate the feature classes. To create maps of land use and cover, the approach adopted is maximum likelihood supervised classification. Maximum likelihood supervised classification delivers a consistent approach for estimating the required parameters and can create reliable results in a wide range of estimation scenarios. The assumption that the statistics for each class in each band follow a normal distribution is what allows this method to calculate the probability that a specific pixel belongs to a particular class. This is done by looking at the statistics for each band individually. Every pixel is put into a category unless a specific probability threshold is selected. Here, we marked user-defined training samples to represent pixels with the same spectral properties as the same category of land use to accelerate the classification process. Four vibrant training classes of land use are defined viz. residential/built-up area, water bodies, open land, and vegetation. To substantiate and support the precision of the land use classification, Google Earth Imagery was used as a reference in the backdrop.

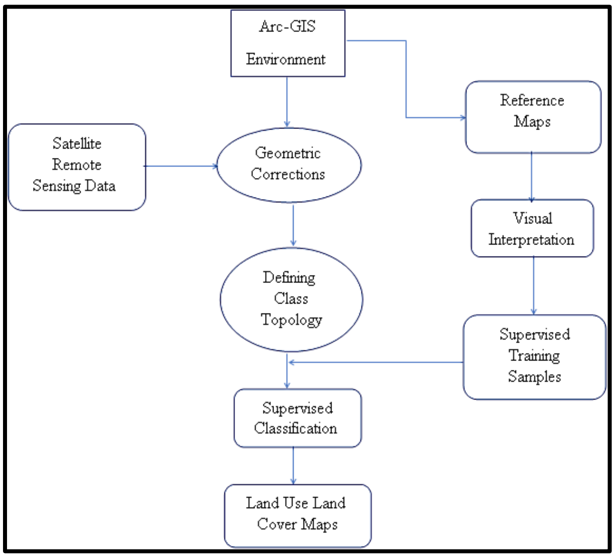

Figure 3. Flow chart of the methodology

4. Results and Discussion

Figure 4. displays maps of the study area's land use and land cover for the years 2000 and 2020. To create the land use and land cover maps of the research region, four categories of land use—residential/built-up area, water bodies, open land, and vegetation.—are established. The area falling under each class type is estimated, along with the pixels assigned to each class type. Urban areas show in a steel-grey tone, vegetation regions in a reddish tone, and aquatic frames in a dark blueish tone in a false colour composite satellite pictures. With only a few discernible pockets of bright red tone and a general decline in the number of water bodies (dark-bluish tone), open land can be seen to have significantly decreased. By creating random sample points from the created LULC in ArcGIS and exporting them as a KML layer to Google Earth, the LULC output was confirmed. A match accuracy of 87.2% and 88.8%, respectively, were observed when the KML layer was placed over the historically preserved photos made

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available by Google Earth (kappa coefficient > 0.83). A significant agreement and precision in the method are shown by a kappa value greater than 0.80. Tirupati City's impervious area has increased by around 47.15% from its 2000 level of 9.97% to its current level of almost 57.12% of impervious surfaces. The encroachment of vegetative regions, other open spaces, and water bodies caused by urban growth mostly increased imperviousness by 4.1%, 0.40%, and 42.72%, respectively. Flooding results from increased runoff from urbanised catchments, which can increase by up to six times and peak flows by up to 1.8 to eight times as a result of increased imperviousness that hinders the infiltration process [10].

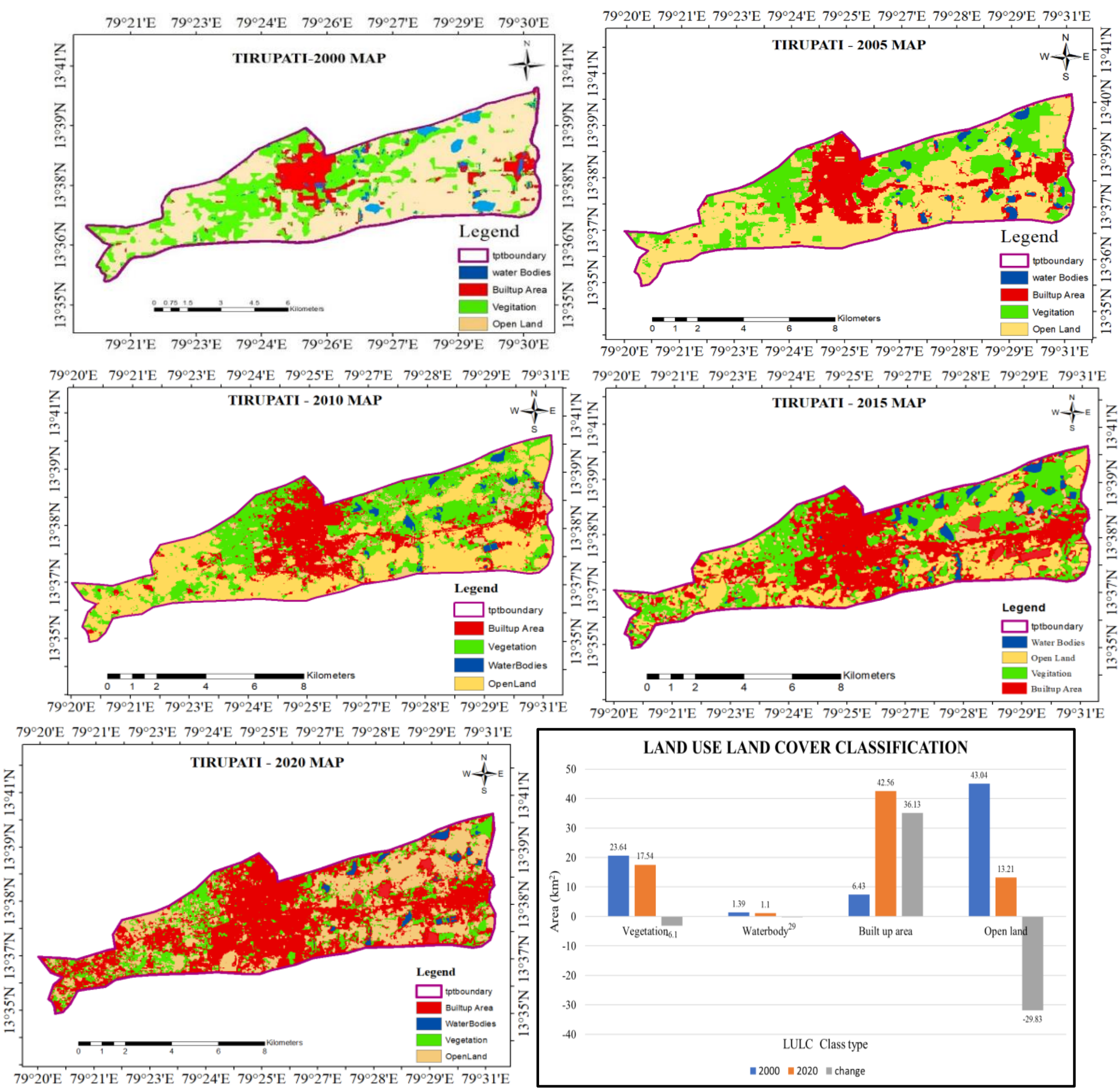

Figure 4. Study area's land use and land cover for the years 2000 and 2020

Table 1. Results of change detection between 2000 and 2020 in Tirupati

Year/Class	Area (km^2)				
	2000	2005	2010	2015	2020
Vegetation	23.64	22.56	22.18	21.9	17.54
Waterbody	1.39	1.33	1.28	1.21	1.19
Built up area	6.43	17.50	20.11	29.98	42.56
Open land	43.04	33.11	30.94	21.41	13.21

5. Indicative changes in land use of Tirupati region

The expansion of urban areas through a process known as urbanisation results in an increase in population, an expansion of built-up areas, high population densities, and a psychological stage that is characteristic of the urban way of life. The unchecked momentum of urbanisation and land use/land cover change could have both positive and negative effects, and some of the issues that have been raised as a result of this include unchecked urban sprawl, the loss of agricultural land, skyrocketing land values, and other associated difficulties. These are just a few of the issues that have been raised as a result of this momentum. Indicative changes in land use of Tirupati region (2000-2005) are assessed using google earth imagery of corresponding time to have visuals of changes and their impacts on the environment (Figure 5). From the Google Earth imagery of 2000 and 2020, it is clear that a waste area of agricultural land and open land had been converted into settlements. Many fields are converted for housing, commercial and social use such as shops, aligning new roads, parks, restaurants etc. The effect of these encroachments is increasing air temperature, a decrease in air quality, agricultural income loss, and ultimately loss of employment and environment.

(a) 2000 **(b) 2020**

Figure 5. Indicative changes in land use of Tirupati region from 2000-2020 (Source: Google Earth)

6. Summary and Conclusions

The current study's use of geospatial methodologies along with a supervised image classification strategy has significantly aided in comprehending changes to the study area's land use and land cover. The study area's land use and land cover patterns will be very helpful in developing the policies and programmes needed for developmental planning. The ecosystem is being harmed by the shrinking area covered by vegetation, water bodies, fallow land, and agricultural land, among other things. The main outcomes of the picture analysis showed a large rise in the area of built-up land near the city's periphery. The city's centre or older areas are already congested as a result of population strain, and most of the outlying fringe land is under stress from unplanned construction. It causes issues including poor sanitization, poor road connectivity, and an unfavourable population-to-public amenity ratio. It puts sustainable urban growth of the city on the back foot.

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