

Monitoring Urban Expansion and Environmental Transitions Using Remote Sensing and AI Techniques

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We are third-year students in Digital Techniques for Designing and Planning. Our joint research centers on the project titled Monitoring Urban Expansion and Environmental Transitions Using Remote Sensing and AI Techniques. By looking at multi-temporal satellite images from Sentinel and Landsat, we measure how the ground reflects light in many wavelength bands. We compute spectral indices such, as the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Built-Up Index (NDBI) to tell apart built infrastructure, tree canopy, water bodies and open soil. To deal with land surface patterns we use supervised Artificial Intelligence and machine learning algorithms that learn from carefully chosen sample areas so that the system can automatically label land cover across the whole study area. By processing satellite data from years our AI-driven remote sensing workflow shows where city limits grow and records how much natural and permeable land disappears over time. We also do field checks to test how accurate our classifications are. This work gives data-based spatial insights that help urban planners and local officials see growth trends and plan more sustainable cities.

ABSTRACT

Rapid urbanization has become an environmental problem in developing cities. The problem arises because more people move into cities. As a result many new buildings appear. New roads and other infrastructure are also built. People use land in new ways. The growth of cities leads to loss of plants, farmland and water areas. This loss makes the environment worse. The ground becomes hotter. The way the environment works inside the city also changes. Traditional methods of watching these changes take a time. Traditional methods do not show details. Therefore data-focused methods are needed to understand how cities and the environment are changing. This study shows a way to watch and understand city growth and environmental changes. The study uses sensing and intelligent computers. The study uses satellite images taken at times. These images help people see how land is used and how buildings, plants and water areas change. Remote sensing tools such, as the Normalized Difference Vegetation Index, the Normalized Difference Built-up Index and the Normalized Difference Water Index are used. These tools help describe how land and the environment change as cities expand. Geographic Information System techniques are used to examine these changes. These techniques help people show and measure the changes. Machine learning is used to guess what type of land is where. These guesses help show how cities grow. This study should show how buildings grow over time. The study should show how this growth affects plants, water and ground temperature. The study should help find places that grow fast and change a lot. The study should also help predict how cities might grow in the future. Combining sensing, GIS and intelligent computers gives a way to understand how cities and the environment influence each other. The results can help city planners and environmental workers. Planners and workers can use these results to plan city expansion in a way that protects the environment. They can also use these results to monitor the environment and manage land better.

INTRODUCTION

A key component that is increasingly recognized as a cause of land-use and environment change in large growing cities is rapid urbanization. It is shown that for Hyderabad the capital of Telangana an increasing population with rapidly developing infrastructure and industrial activities in conjunction with rising space requirements drive the sustained growth of built-up areas. During the past many years it has undergone profound modifications of its land-use and land-cover classes.

Built up area expansion transformed most of natural vegetation, agricultural fields and natural open space into anthropogenic settlements.

These modifications cause impact on condition of vegetation, availability of surface-water and land-surface temperature which impact heavily the environment of city.

Typically field surveys, tabular data and manual-digitized maps have been traditionally employed for the tracking of urban growth. Such traditional methods of observing change and urban sprawl over space have been expensive, and time-consuming as far as updating is concerned on a broad scale. Remote sensing provides a method that has the advantage to repeatedly observing the surface of the Earth with satellite images, where spatial analysis methods are used to estimate the change of land-cover based on satellite imageries taken in different times for identification of urban spread using spatial analysis and G.I.S (Geographic Information System).

Artificial Intelligence (AI) and Machine Learning technique improved substantially the tracking of changes and earth observations within the last years. Models created through machine learning are capable of identify spectral and spatial structures in satellite imagery leading to accurate land-cover classification. It has combined with remote sensing technique and GIS for analysis of urban sprawls and associated effects on the environment. The objective of this study has been to examine how urbanization affects certain environmental factors, namely vegetation cover changes and land-surface temperature distributions in Hyderabad City.

STUDY AREA

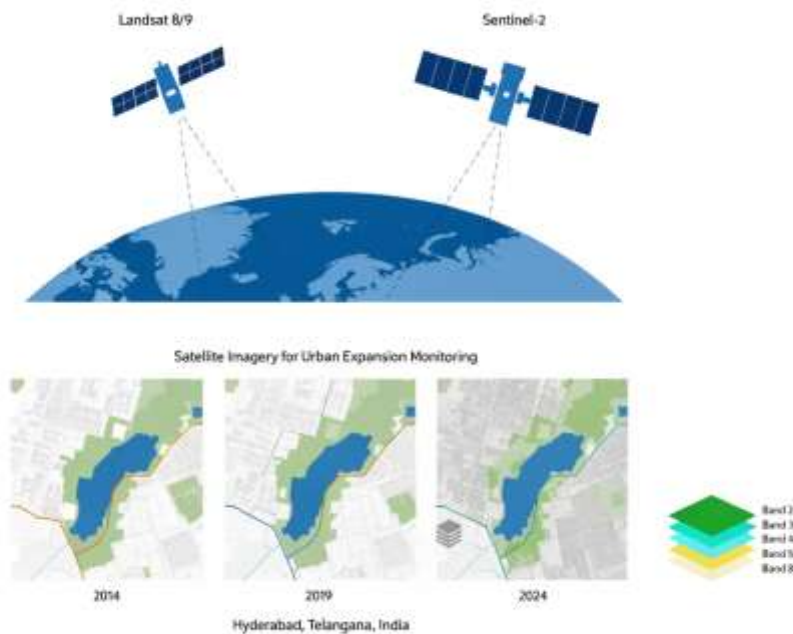
The area of study of the research work is Hyderabad City, Telangana, India. Hyderabad city is one of the leading metropolitan cities of South India with an ever-growing population, development of infrastructures and sprawling urban regions, for the last few decades. The region is a mixture of both heavily built-up and built up, residential and commercial areas, and corridors and networks of transport, green patches of vegetation, agriculture land and others, several water bodies at the surface. Due to the unprecedented development the Hyderabad city undergone, a considerable amount of natural and semi natural land cover classes were lost and converted into built-up surface. Such development along the corridors and at the periphery of the city modified the structure of the study region. The above mention mentioned attributes of the region makes the selected area of study as ideal one to use remote sensing, GIS and AI techniques for the relation between urban development and transformation.

METHODOLOGY

The methodology used in the proposed study uses integrated approach of remote sensing, GIS and AI for tracking urban growth and environmental changes in Hyderabad City. The approach has stages of satellite data acquisition, preprocessing of image, classification of land use and land cover by artificial intelligence method, generation of remote sensing indices, and change detection, using spatial analysis through GIS.

i.Data Acquisition

Multi-temporal satellite imagery for Hyderabad will be collected from 2014, 2019, and 2024. For analysis, appropriate Landsat and Sentinel-2 datasets will be acquired in order to maintain good spatial, spectral, and temporal resolutions. GIS layers like administrative boundaries and roadways, along with water bodies etc., will be added to supplement the analysis.

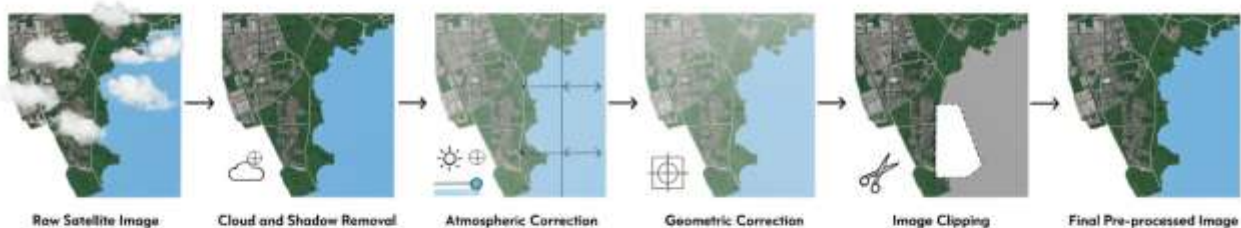


ii. Image Pre-processing

Before data analysis, Landsat and Sentinel-2 images will be pre-processed to obtain higher quality imagery with more accuracy through techniques like masking cloud and shadow, making radiative corrections, geometrical corrections, re-registration in a common coordinating frame, etc. And finally clipping the images for analysis in a specific study area.

Satellite Image Pre-processing Workflow

Hyderabad, India

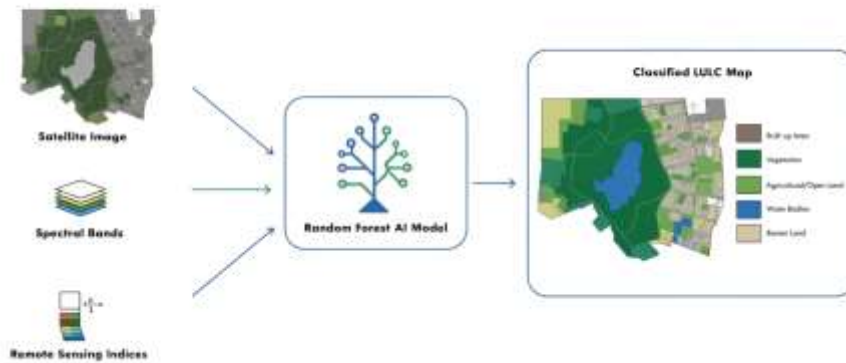


iii. LULC Classification

Land Use/Land cover (LULC) patterns such as Built-up, Vegetation, Agricultural/Open land, Water body, Barren land will be identified in the study area using the machine learning method Random Forest classification. Remote sensing

indices, combined with spectral indices, will help to obtain an accurate and effective LULC classification.

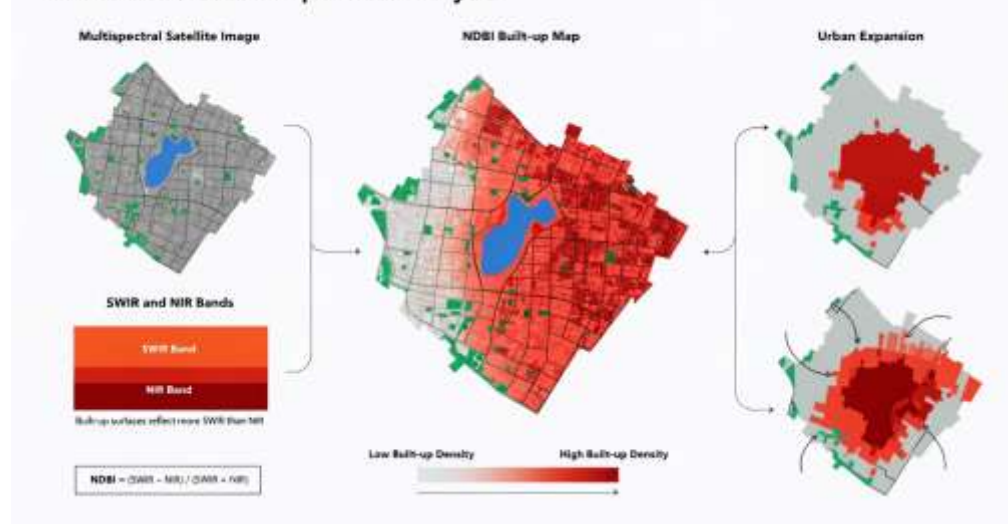
AI-Based Land Use/Land Cover Classification



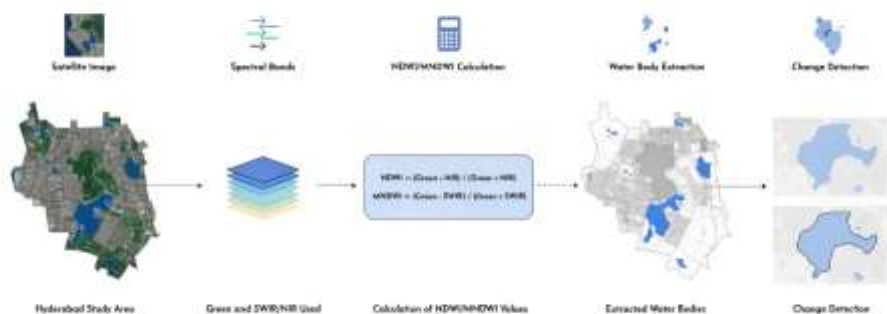
IV. Environmental Index Analysis

Various remote sensing indices like Normalized Difference Vegetative Index (NDVI), Normalized Difference Build-up Index (NDBI) for urban features, Normalized Difference Water Index (NDWI) or Modified NDWI (MNDWI) for water-body detection, etc., would be computed for various environmental indices in Hyderabad. Besides, these Land Surface Temperature (LST) would be calculated using Landsat thermal bands.

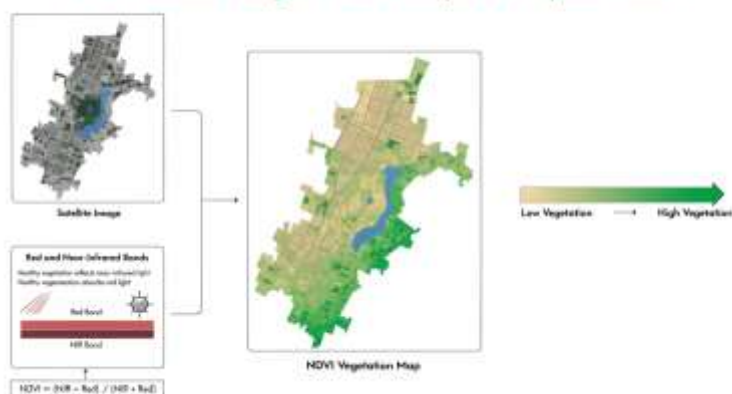
NDBI-Based Urban Expansion Analysis



NDWI/MNDWI-Based Surface Water Analysis



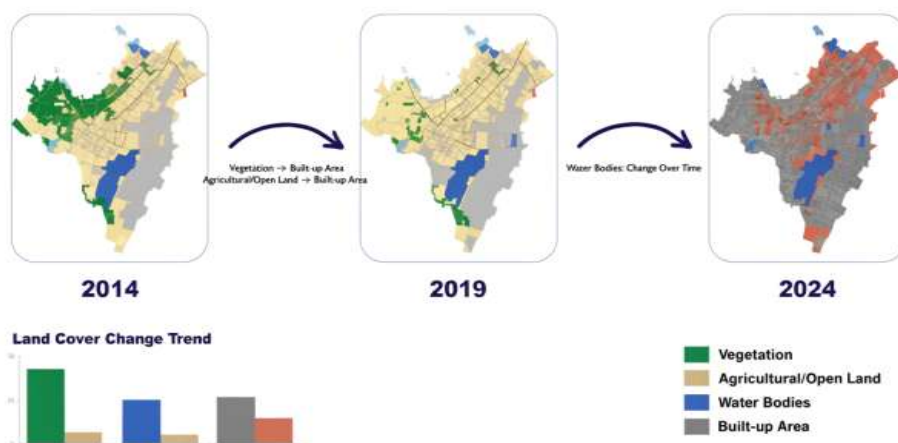
NDVI-Based Vegetation Analysis of Hyderabad



V.Change Detection

From the LULC Maps developed for 2014, 2019, and 2024 a trend of changes will be analyzed. Changes in development of urban LULCs along with decline of the natural landscape like vegetation cover, water bodies and open land will be detected and mapped. Along with mapping the changing pattern in LULCs the overall area change, which denotes percentage change will also be analyzed.

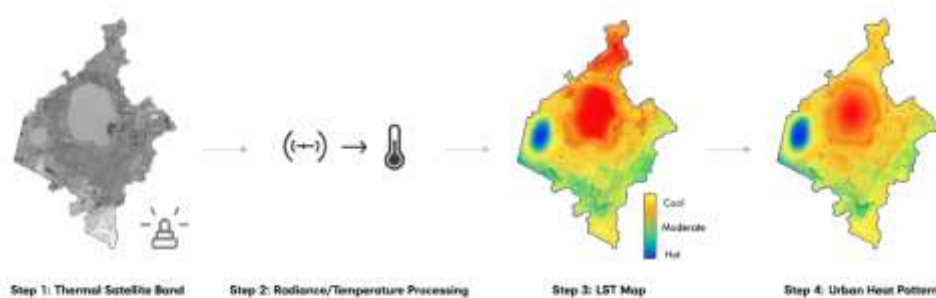
Multi-Temporal LULC Change Detection



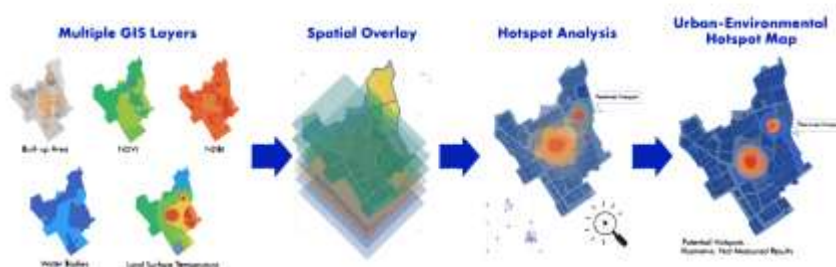
VI. GIS-Based Spatial Analysis

A GIS analytical tool will be used to examine the overlaying spatial distribution of resulting LULC maps and environmental Indices, by performing overlay, proximity analysis and hot spot analysis, to identify critical urban expansion areas, shrinking nature of vegetation cover in an area, changes occurring in the water bodies and their interrelationship with the Land surface temperature; will be highlighted.

Land Surface Temperature Analysis



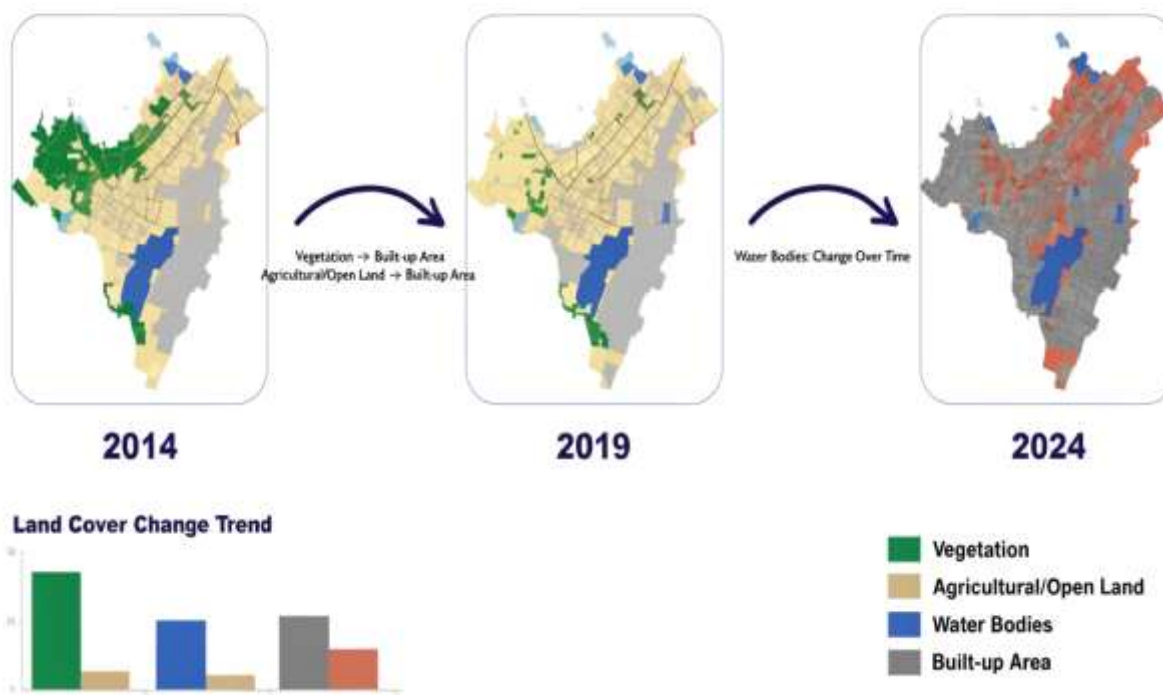
GIS-Based Urban-Environmental Hotspot Analysis



VII. Integrated Analysis

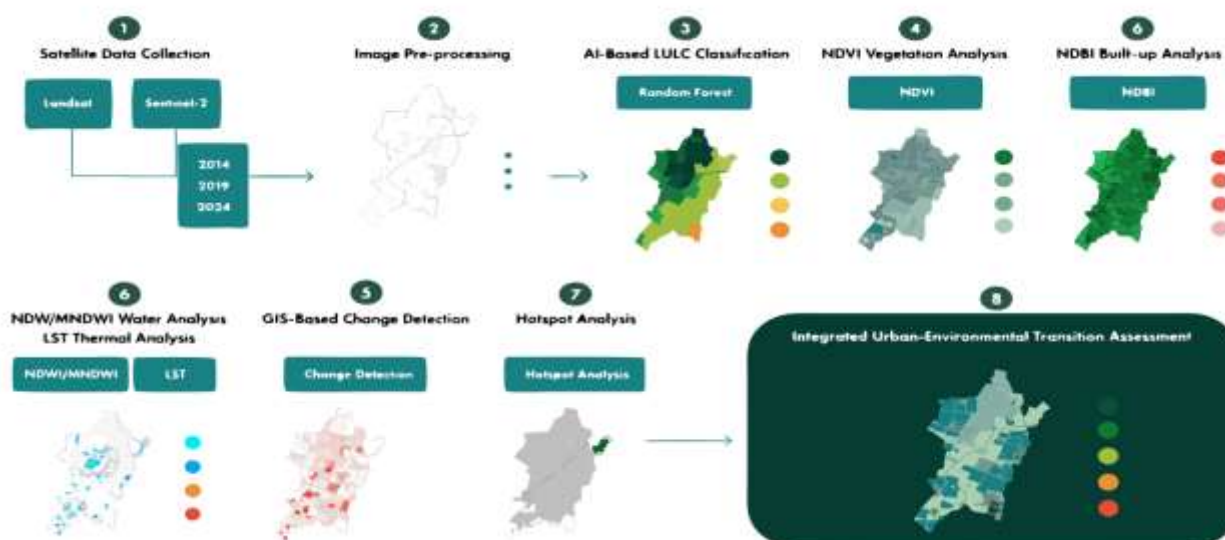
All results, i.e., AI-based LULC map classification, remote sensing indices, GIS based spatial analysis will be integrated. The identified significant urban expanding area will serve for finding out some hot spots of Hyderabad from environmental perspective. Places experiencing rapid temperature increase combined with the increase of urban land uses and decline of vegetation cover, water bodies etc will act as environmental hot spots.

Multi-Temporal LULC Change Detection



INTEGRATED URBAN AND ENVIRONMENTAL TRANSITION ANALYSIS

The final phase of the study will use the result from AI based classification along with remote sensing indices and GIS analysis, to compare the trends of built-up area changes with changes of vegetation, water and land surface temperature, and establish the link between urban environmental transitions. Zones will be considered as a potential urban-environmental transition area if they appear as having rising trends of both built-up density and land surface temperature coupled with declining vegetation trend. Similarly, transition of surface-water availability due to built-up expansion will be assessed. The resulting information based on simultaneous trends of these variables will provide evidence about the effects of Hyderabad's expansion on its neighbor's surroundings. The combination of analysis on the values of NDVI, NDBI, NDWI or MNDWI, and LST at the same location at two times will present multiple environmental changes at that place, rather than looking one after the other on three variables independently. The spatial correlation between the transitions will then establish an interaction of changing conditions and determine urban-environmental transition areas that simultaneously experience multiple, parallel changes.



CONCLUSION

This study proposes a combined system to observe land transformations and environmental degradation inside Hyderabad city using tools of Remote Sensing, GIS and Artificial Intelligence. By employing Landsat images; LULC changes are assessed. Spectral indices that is NDVI, NDBI, NDWI/MNDWI and LST are retrieved in order to detect vegetation presence, urban developments, water surfaces and surface temperature. For AI, the ML model like Random Forest was used to categorize landcover and detection of LULC change will be performed by using GIS approach showing the sprawl of land area and environmental consequences

Areas that expand in high speed; reducing green coverage areas, expanding built ups which covers urban sprawl areas and modifying waterbody areas and higher temperatures will be extracted.

Information derived is very much useful to planers, land owners and city planers of urban city Hyderabad. These spatial data created are highly useful for implementation of smart sustainable land-use techniques and proper conservation techniques of the land surfaces and better control over rapid urbanization.

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