CONTENT-BASED IMAGE RETRIEVAL AND SAR IMAGERY ADDRESSING URBANIZATION CHALLENGES

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Abstract. Radar satellite imagery is frequently subject to noise interference. This study introduces the NEST Tool, which is designed to mitigate such noise using despeckling techniques. The tool employs statistical operations to reduce the noise on a bandwise basis. The results indicate that the NEST Tool surpasses the existing state-of-the-art methods. This study explores the impact of urbanization on land use and land cover (LULC) changes in the Warangal urban region from 2015 to 2022 using remote sensing and Geographic Information System (GIS) methodologies. Landsat imagery was processed using ArcGIS, and supervised classification was used to generate the LULC maps. The study revealed significant urban expansion, with bare soil and areas integrating agricultural and forestland being the most affected. Despite a slight increase in water bodies, the region faces challenges in meeting growing population demands. The mine and dump areas contracted by 192.5 hectares due to reduced production, while the forest area decreased by 184 ha. Agricultural and forest areas declined by 18.85% in urban zones and 16.3% in existing areas. This study emphasizes the need for effective planning to mitigate the adverse effects of urbanization on LULC in urban and rural contexts. These findings highlight the role of remote sensing and GIS technologies in understanding LULC dynamics, with implications for mine reclamation, closure planning, and sustainable urban development in Warangal

Keywords: Radar satellite imagery, remote sensing, Geographic Information System, land use and land cover, synthetic aperture radar, content-based image retrieval.

1. Introduction

In today's technological landscape, content-based image retrieval (CBIR) has emerged as a promising field, particularly owing to the widespread use of images in real-time applications. The integration of advancements in remote sensing and geographic information systems (GIS), coupled with technologies such as the Global Positioning System (GPS), has made this domain a compelling subject of research. The focus is on extracting features from synthetic aperture radar (SAR) images and creating innovative image descriptors to improve the precision of image retrieval systems. A significant challenge with SAR images is the inherent noise, which must be addressed before feature extraction can occur. Once noise reduction was achieved, feature extraction was performed using the proposed efficient SAR image-retrieval (ESIR) algorithm.

Traditional image retrieval systems that depend on image labels frequently yield less than optimal results. Content-based image retrieval (CBIR) leverages the Query By Example (QBE) approach to bridge the semantic gap, thereby enhancing the performance of image-retrieval systems. Various visual descriptors, including Speeded-Up Robust Features (SURF), scale-invariant feature transform (SIFT), and Histograms of Oriented Gradients (HOG), were employed to enable content-based image retrieval. SURF and SIFT are used to extract local features, whereas HOG is used to extract global features [1]. CBIR presents potential benefits over conventional text-based keyword search methods that rely on metadata. The images presented in Figure 1 were categorized into two semantic classes: beach (depicted in the first row) and mountain (depicted in the second row). These images were sourced from the Corel 1000 Image Dataset.

Fig. 1: Different semantic class but with similar visual contents

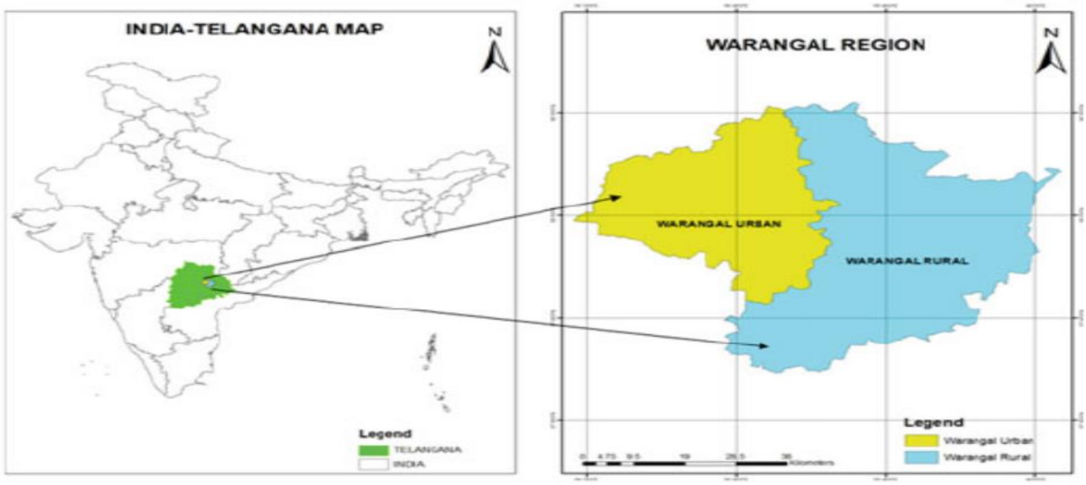
Notably, all four images exhibit similar visual characteristics, which poses challenges in achieving high-quality image retrieval that aligns with the user intent. This challenge, known as the semantic gap, is addressed using content-based image-retrieval (CBIR) systems. Recognizing the significance of CBIR, Synthetic Aperture Radar (SAR) imagery is highly valuable for Earth observations (EO) and other geographical research endeavors.

2. Synthetic Aperture Radar

Synthetic Aperture Radar (SAR) is an advanced radar technology that generates detailed two- or three-dimensional images of geographical features and landscapes. By utilizing the motion of a radar antenna across a target area, SAR achieves a spatial resolution that surpasses that of conventional beam-scanning radar. Typically mounted on spacecraft or aircraft, SAR technology traces its origin to Side-Looking Airborne Radar (SLAR) [1]. SAR collects radar pulses to create a large synthetic aperture with larger apertures, resulting in a higher

image resolution. The term "synthetic" refers to the moving antenna, as opposed to a large stationary "physical" antenna. This method enables SAR to produce high-resolution images superior to those generated by physical antennas. The quality of SAR images remains unaffected by weather conditions or flight altitude because the system can select an optimal frequency range. Despite its advantages, SAR imagery encounters challenges, particularly noise issues, such as phase or speckle noise, with speckle being the most common. This noise arises from multiple coherent reflections from the environment surrounding a target. Techniques, such as multi-looking or adaptive edge-preserving filtering, can be employed to reduce noise. Landsat images, spanning band1 to band7, were obtained from the USGS Earth Explorer and combined using the composite band tool in ArcGIS [6]. To enhance these images, supervised classification was performed using remote-sensing techniques. This process involves selecting training areas for each land cover class to be developed. A signature file was generated from the collected training sample data. A GIS signature file was then used as an input to classify the study area. In the classification tool, the maximum likelihood supervised classification method was applied to create LULC maps.
Figure 2. (a, b) illustrates the proposed area map and land use and land cover (LULC) maps for the Warangal Urban and Rural regions for 2015, 2020, and 2022. The analysis demonstrated a pronounced increase in urbanization, slight augmentation in water bodies, and marked reduction in agricultural and forested areas from 2015 to 2022. To improve performance, it is imperative to address speckle noise, after which Synthetic Aperture Radar (SAR) images are subjected to classification and Content-Based Image Retrieval (CBIR). Existing literature on CBIR systems for conventional and SAR images [1], [3], [6], [7], [14] reveals various techniques for managing CBIR processes. However, in SAR image retrieval for Earth Observation (EO) applications, a more efficient framework should adopt a holistic approach to enhance the performance of Image Retrieval (IR) encompassing browsing, searching, and retrieving the desired images from extensive digital image databases. This need has arisen because of the rapid expansion of digital libraries [1-2]. IR has been extended to applications such as medical analysis [3] and biometric security [4]. IR techniques employed in image processing include Text-based IR (TBIR), which retrieves images using text as input [5]. Sketch-based IR (SBIR) retrieves images based on sketches [6]. Region-based IR (RBIR) encompasses region-to-region and image-to-image matching [7–8]. CBIR retrieves images based on characteristics, such as color, shape, and texture features [9]. CBIR and RBIR are two common IR techniques [10]. Traditional text-based methods do not facilitate appropriate retrieval from query images because it is challenging to express specific objects within an image, which necessitates extensive keyword systems. To address this, CBIR retrieves images by considering features, such as color, texture, and shape [11-13]. This review highlights significant changes in vegetation and water bodies due to urbanization, impacting the climate and environment, and underscores the need for efficient planning to mitigate adverse effects on agricultural and forest areas [15] [14].

Fig. 2 a. Proposed area image



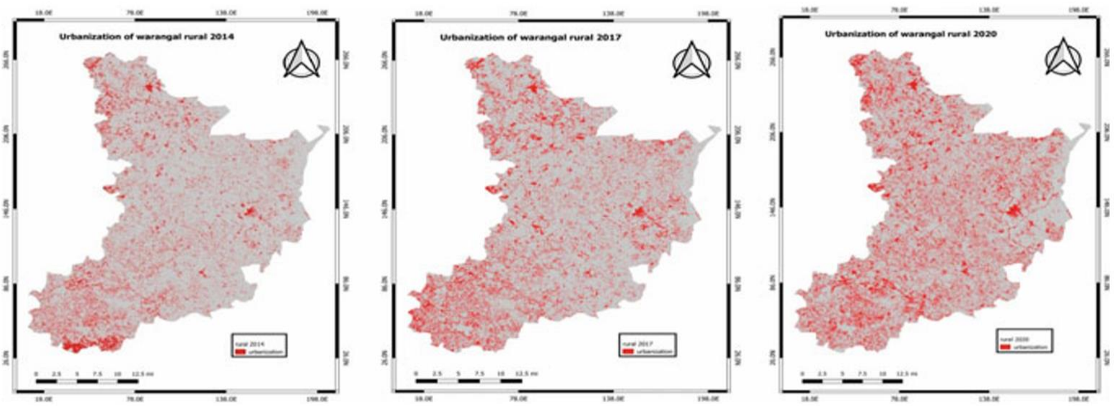


Fig. 2 b. Proposed area image 2015,2020,2022

3. Methodology

This section addresses the challenge of image retrieval and demonstrates how the proposed approach can effectively resolve this issue. This study examines the effects of urbanization on land use and land cover (LULC) changes in urban areas of Warangal from 2015 to 2022. It utilizes Remote Sensing and Geographic Information System (GIS) techniques to extract and categorize LULC features. This study aims to comprehend urban expansion and its impact on natural resources such as vegetation and water bodies. Landsat images encompassing bands 1 through 7 were acquired from the USGS Earth Explorer and combined using the composite band tool in ArcGIS. To enhance the quality of these images, supervised classification was conducted using remote-sensing techniques. This process involved selecting training areas for each type of land cover to be developed. A signature file was created from the collected training data and a GIS signature file served as the input for classifying the study area. The classifier tool used the maximum likelihood supervised classification method to produce

LULC maps, as shown in Figure 2. Figure 1 presents a flowchart outlining the fundamental components of the model used in this study. The primary steps were (1) database development and image classification, (2) applying the Markov model to predict LULC, and (3) validating the results.

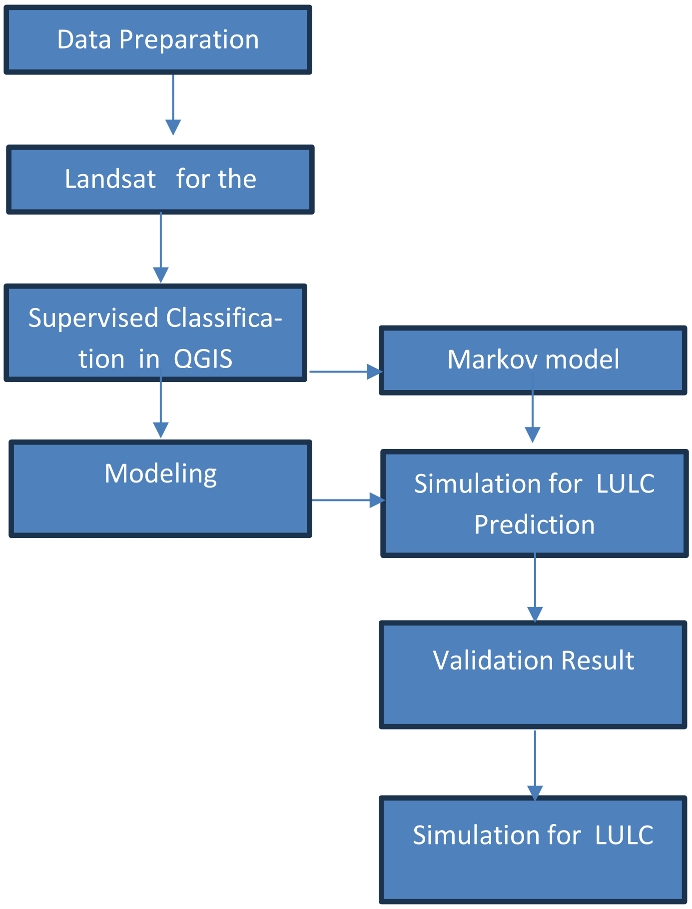


Fig: 2. LULC Simulation using GIS Dataflow

4. Experiment Result

Geographic Information System (GIS) methodologies were used to obtain vector and shape files for the Warangal region. Landsat imagery was synthesized using the ArcGIS composite-band tool. Supervised classification enhances image quality and classifies land cover. The maximum likelihood supervised classification produced Land Use and Land Cover (LULC) maps. Remote sensing and GIS techniques facilitate temporal quantification and spatial trend analysis. The LULC feature extraction was conducted through supervised classification in urban and rural contexts. This study assessed the impact of urbanization on LULC transformation over seven years. A sample subset of Synthetic Aperture Radar (SAR) images was analysed by introducing a single-looking speckle in subset format, with Table 1 displaying the band-wise mean and sigma results for certain out-of-subset images. In all but one scenario, the subset images showed superior performance, with averages over the reference techniques for the VH, VV, and HV bands.

Table 1: Mean and sigma over SAR image

pixel_no	pixel_x	pixel_y	Intensity_VH_mean	Intensity_VH_sigma
1	860	163	41.8	96.9
2	861	163	42.2	27.2
3	862	163	74.8	94.8
4	863	163	52.8	45.8
5	864	163	28.2	61.8
6	865	163	42.2	11.2
7	866	163	79.1	70.9
8	867	163	17.8	80.7
9	868	163	39.2	53.9
10	869	163	74.5	51.1
AVG			45.34	59.43

Urban areas significantly influence land use and land cover (LULC) in the Warangal region, necessitating strategic planning. Water body expansion remains minimal, insufficiently supporting the growing population demand. Effective planning is essential to address the implications of urbanization on LULC transformations in urban and rural contexts. Strategies to mitigate the urbanization challenges in Warangal are imperative. This study highlights the critical role of remote sensing and GIS technology in understanding the LULC dynamics. Between 2015 and 2021, the mine and dump area contracted by 192.5 hectares due to dwindling reserves and reduced production. The forest area decreased by 184 hectares, with a classification accuracy of 98.70%, surpassing previous studies (92.86%) and facilitating the effective monitoring of land use changes in surface coal mining regions. Agricultural and forest areas declined by 18.85% in urban zones and 16.3% in existing areas.

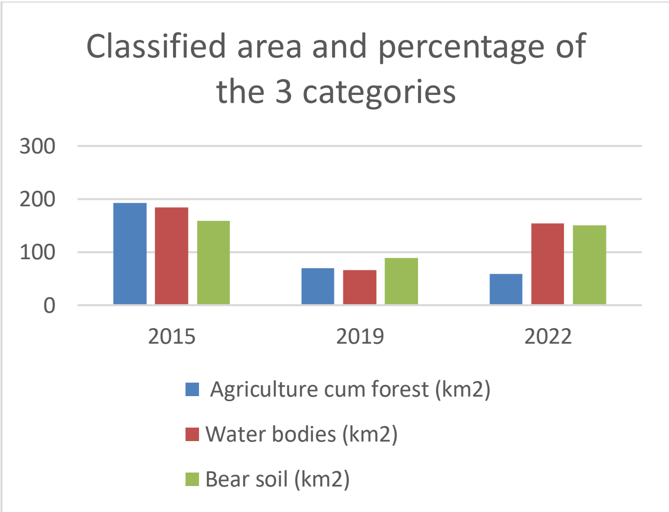


Fig 3. Classified area and percentage of the 3 categories

Conclusion.

The analysis revealed that Land Use and Land Cover (LULC) dynamics in the Warangal region exert considerable influence, necessitating strategic planning. Urban expansion significantly affects bare soil and areas that integrate agricultural and forestland. Warangal's urban areas have experienced only a slight increase in water bodies, falling short of satisfying escalating population demands. This increase is linked to heightened rainfall and the Kakatiya Scheme mission of the Telangana government. These findings are pivotal in informing mine reclamation and closure plans. It is crucial to devise plans aligned with the population growth and LULC transformations in Warangal’s urban and rural sectors. Employing Remote Sensing (RS) and Geographic Information System (GIS) methodologies is essential for comprehending urbanization's repercussions on LULC changes in Warangal. It is imperative to implement strategies to mitigate the urbanization challenges in the region. Understanding the effects of urbanization on Warangal land use and cover through RS and GIS techniques is critical for understanding alterations in the area's land cover.

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