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Geospatial Analysis of Land Use and Land Cover Changes in Tiggaleru Sub-Basin YSR Kadapa, Andhra Pradesh, India

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Abstract

Land use and land cover within subriver basins greatly affect hydrological processes, making accurate assessment and monitoring of past and present land use/cover changes essential for effective watershed development, management, and understanding of ecological and hydrological dynamics. In this study, we have to adopt supervised classification with maximum likelihood algorithm in ERDAS imagine 9.2, to notice land use/cover changes (LU/LCC) analyzed in Tiggaleru sub river basin, YSR Kadapa District, Andhra Pradesh, India using multispectral satellite data gained from Landsat Satellite-8 OLI series for the years 2014 and 2023. These satellite data is intended for land use/cover through supervised classification in ERDAS 2015, software. In the result, we could identify six land use/land cover (LU/LC) classes, namely agricultural land, built-up land, fallow land, forest land, Scrubland and water bodies. The results shown that during the 2014 and 2023, built-up land and Agriculture land and have been increased about 2.31% (such as 6.84 km^2) and 6.66% (19.76 km^2), respectively, whereas the area under other land categories such as forest land, and scrubland have decreased about 0.99% (2.93 km^2) and 10.07% (29.88 km^2) and remaining fallow land and water bodies are increased about 0.12 (0.36 km^2) and 1.97% (5.85 km^2) respectively.

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Finally, accuracy assessment has been carried out and their result shows that overall accuracy of classified images of the year 2006 and 2018 are 86.62% and 91.85% respectively. The overall Kappa coefficient values of classified images of the year 2006 and 2018 are 0.8343 and 0.8987. Hence, these values indicate that acceptable accuracy of the classified LU/LC features.

Keywords: Land Use Land Cover, Change detection, Tiggaleru, Geospatial analysis

Introduction

Land use and land cover (LULC) within subriver basins significantly influence hydrological processes and environmental conditions of a watershed. Subriver basins are smaller catchment areas within a larger river basin, consisting of tributaries, streams, and surrounding land that drain into specific sections of the main river. The patterns of LULC-such as forests, agriculture, urban areas, and wetlands—directly affect infiltration rates, surface runoff, sediment load, and water quality. Changes in land use, like deforestation or urban expansion, often lead to increased runoff and soil erosion, impacting both local ecosystems and downstream water availability (Jha et al., 2021). Monitoring and managing LULC at the subriver basin level is essential for sustainable water resource management, flood control, and ecosystem conservation (Gao et al., 2018; Zhang & Chen, 2020). Land cover refers to the physical characteristics of the Earth's surface, while land use describes how humans utilize the land for agriculture, urban development, forestry, and other activities (Rawat et al., 2015). These spatial and temporal patterns are influenced by natural factors and human activities, with recent decades seeing rapid urbanization and intensified land exploitation that affect natural resources and ecological processes (Riebsame et al., 1994; Ruiz-Luna et al., 2003). Remote sensing (RS) and Geographic Information Systems (GIS) are vital tools for mapping and analyzing LULC changes due to their ability to capture real-time spatial data over large areas and provide long-term historical datasets (Chander et al., 2009; USGS, 2014). Understanding LULC dynamics is particularly critical in ecologically sensitive regions such as river basins, where land and water systems are closely linked. When shale is located in valley portions surrounded by quartzite hills, it can significantly influence runoff and flood potential. Quartzite hills, being highly resistant to erosion, channel rainfall runoff toward the shale-filled valleys. Since shale has low permeability and poor drainage capacity, water tends to accumulate and flow rapidly over its surface, increasing the risk of runoff-related flooding in these valley areas. This geological contrast between permeable quartzite ridges and impermeable shale valleys can lead to concentrated surface water flow, elevating flood hazards during heavy rainfall events (Gupta & Singh, 2017).

This study focuses on assessing the spatial and temporal dynamics of LULC in the Tiggaleru River basin using Landsat satellite imagery and geospatial techniques. The findings aim to improve understanding of landscape changes and support better natural resource management and environmental planning.

Study area

The Tiggaleru sub river basin, a significant tributary of the Penneru river, is situated within Survey of India Toposheet Nos: 57/N01 and 57/N02, precisely spanning North longitudes 79.016 to 79.168 and East latitudes 14.704 to 14.978 decimal degrees (Fig.1) in Kadapa. Originating from Dupadu village in Prakasham district, Tiggaleru river defines the initial point of this basin.

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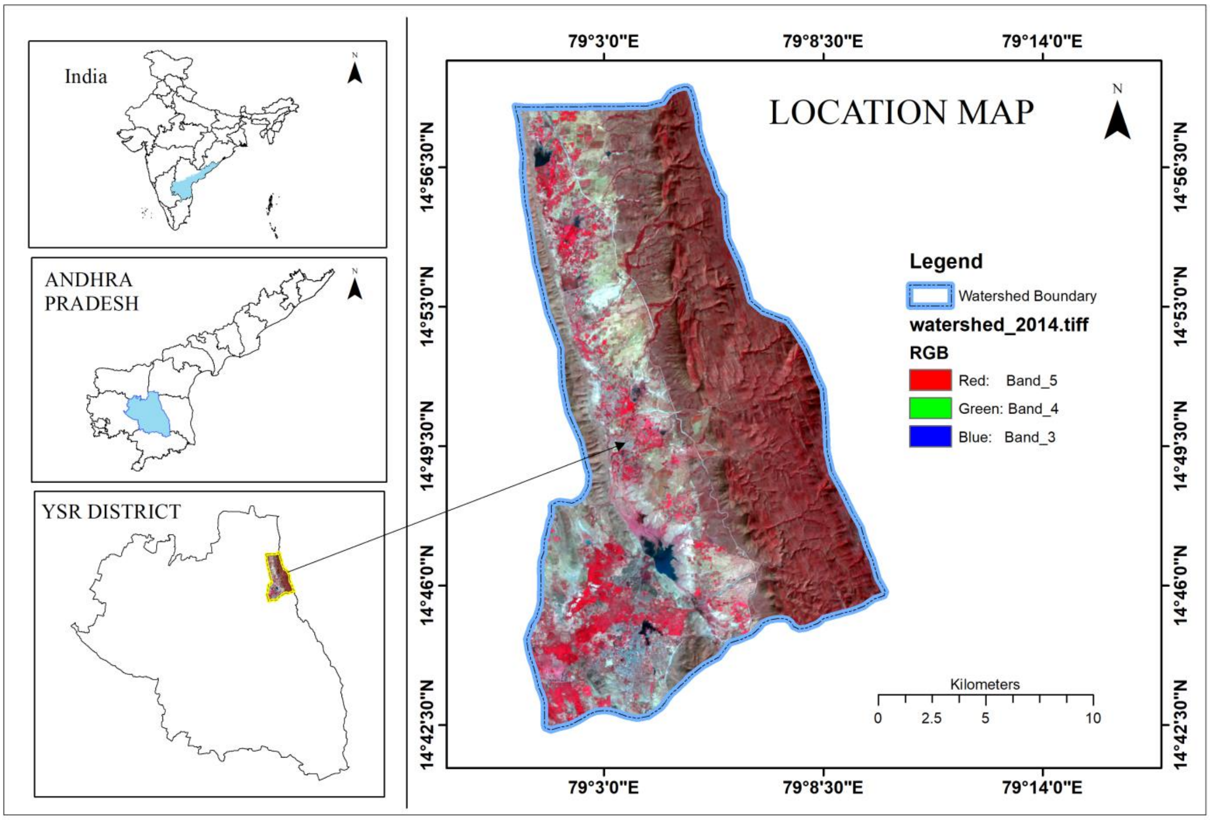

Fig. 1: *Landsat-8 OLI Satellite imagery showing the Study Area Location.*

Encompassing a total geographical area of 296.71 sq. km, the present study area holds a crucial position within Kadapa district. A comprehensive soil survey conducted in this region has revealed distinctive soil sequences and their associations, providing valuable insights into the areas soil composition.

Geology

The geological features of the study region are characterized by a diverse range of Cuddapah super group rocks, including The Bairenkonda Quartzites cover an area of 134.97 km² (45.55%), followed closely by the Cumbum Shales with phyllites, which extend over 134.39 km² (45.36%). The Cumbum Shales Quartzites span an area of 26.92 km² (9.09%).

Quartzites

Quartzite is a hard, non-foliated metamorphic rock formed from quartz-rich sandstone under high temperature and pressure. However, in the present study area, it is only partially metamorphosed and is referred to as a meta-sedimentary rock in the Cuddapah Supergroup (Ramam & Murty, 1997). Quartzite has low primary porosity and permeability due to its dense crystalline structure, but when fractured, its secondary porosity allows limited groundwater storage and flow (Todd & Mays, 2005). Despite low water retention, its chemical stability makes it a durable aquifer component in fractured zones.

Shale

Shale is a fine-grained sedimentary rock with low permeability, often serving as a confining layer in groundwater systems. Shale may exhibit moderate total porosity, but its effective porosity is low due to poorly connected, tiny pores, and its high clay content retains bound water while limiting fluid transmission, reducing overall permeability and influencing structural stability. Although typically a barrier to groundwater flow, fractured shale can allow water movement through connected fractures, making fracture analysis essential in hydrogeological evaluations (Fetter, 2001).

Phyllite

Phyllite is a fine-grained, foliated metamorphic rock formed from the low- to medium-grade metamorphism of shale or mudstone. Hydrogeologically, it has low primary porosity and permeability, but fractures and foliation planes can allow limited groundwater movement, making it generally a weak aquifer or more often an aquitard when unfractured and continuous (Fetter, 2001; Domenico & Schwartz, 1998).

From a hydrogeological perspective, Cumbum Quartzite with shale forms a more confining system due to the low permeability of shale, while Cumbum Quartzite with phyllite may allow limited groundwater flow through foliation and microfractures. The region, characterized by significant weathering, occasional alluvial cover, and a dendritic drainage pattern, reflects a largely uniform lithology and the distinct geological setting of the Tiggaleru sub-river basin.

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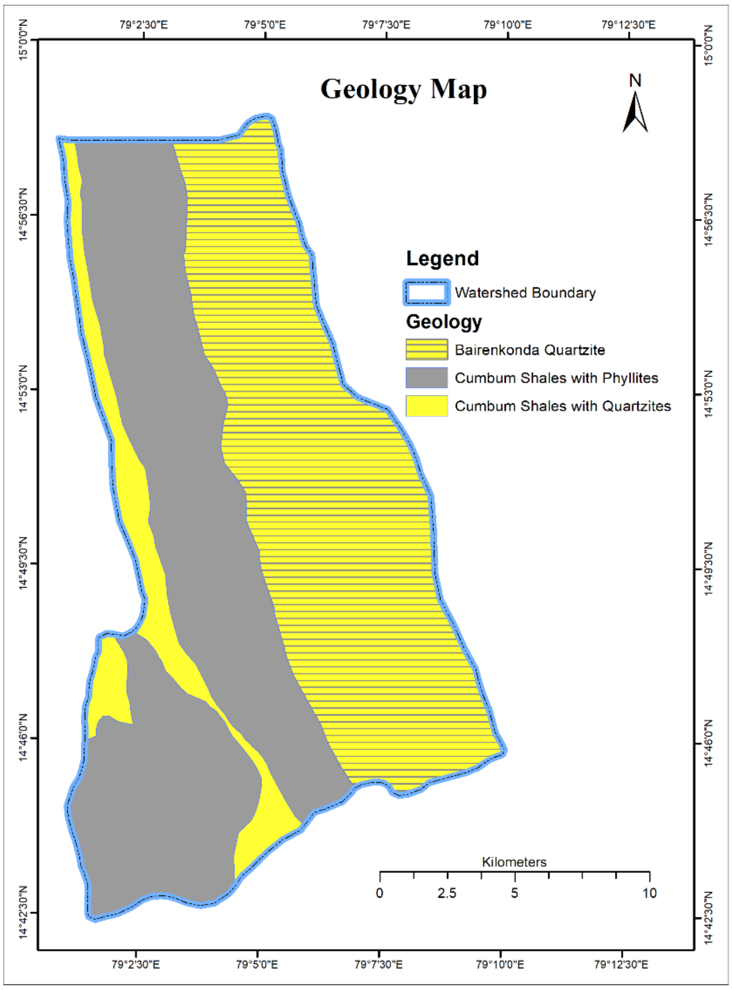

S. No.	Geology	Area in Sq. km	%
1	Bairenkonda Quartzite	134.97	45.55
2	Cumbum Shales with Quartzites	26.92	9.09
3	Cumbum Shales with Phyllites	134.39	45.36

Methodology

The research methodology employed in this study encompassed several crucial steps. Initially, the process involved the comprehensive collection of diverse data sets. These data were subjected to meticulous preprocessing, which included cleaning, transformation, and integration. The data compilation incorporated information from various sources, with 1:50,000 scale toposheet data sourced from the Survey of India (SOI) forming a significant component. This data was meticulously processed using Arc GIS 10.4, ensuring precision and accuracy.

***Table 1** Data used in the present work*

S. No.	Type of data	Details of Data	Source
1	Toposheets	Toposheet No.'s 57/N01 & 57/N02	Survey of India (SOI)
2	Satellite data	Landsat-8, OLI	https://earthexplorer. usgs.gov/

Additionally, Landsat-8 Operational Land Imager (OLI) data from the years 2014 and 2023 were acquired from the Earth Explorer website, with a spatial resolution of 30 meters. These datasets were instrumental in the analysis of land use/cover changes and dynamic features over time. The integration and processing of these datasets were carried out using Arc GIS 10.4, ensuring a seamless workflow.

For a detailed land use and land cover analysis, Landsat data sets were imported into ERDAS Imagine version 2015. A false color composite (FCC) was generated to facilitate a comprehensive visual analysis. To focus on the specific study area, satellite images were sub-setted using the geo-referenced outline boundary of the Mandavi river basin map as the Area of Interest (AOI).

To ensure the accuracy and reliability of the analysis, a supervised classification method employing the Maximum Likelihood Classification (MLC) algorithm was employed. This method, widely accepted in Remote Sensing (RS) data analysis, was executed using ERDAS Imagine software. Subsequently, ground verification was conducted using German GPS (Global Positioning System) in areas that raised doubts or were misclassified. This step was pivotal in correcting inaccuracies and enhancing the overall quality of the maps.

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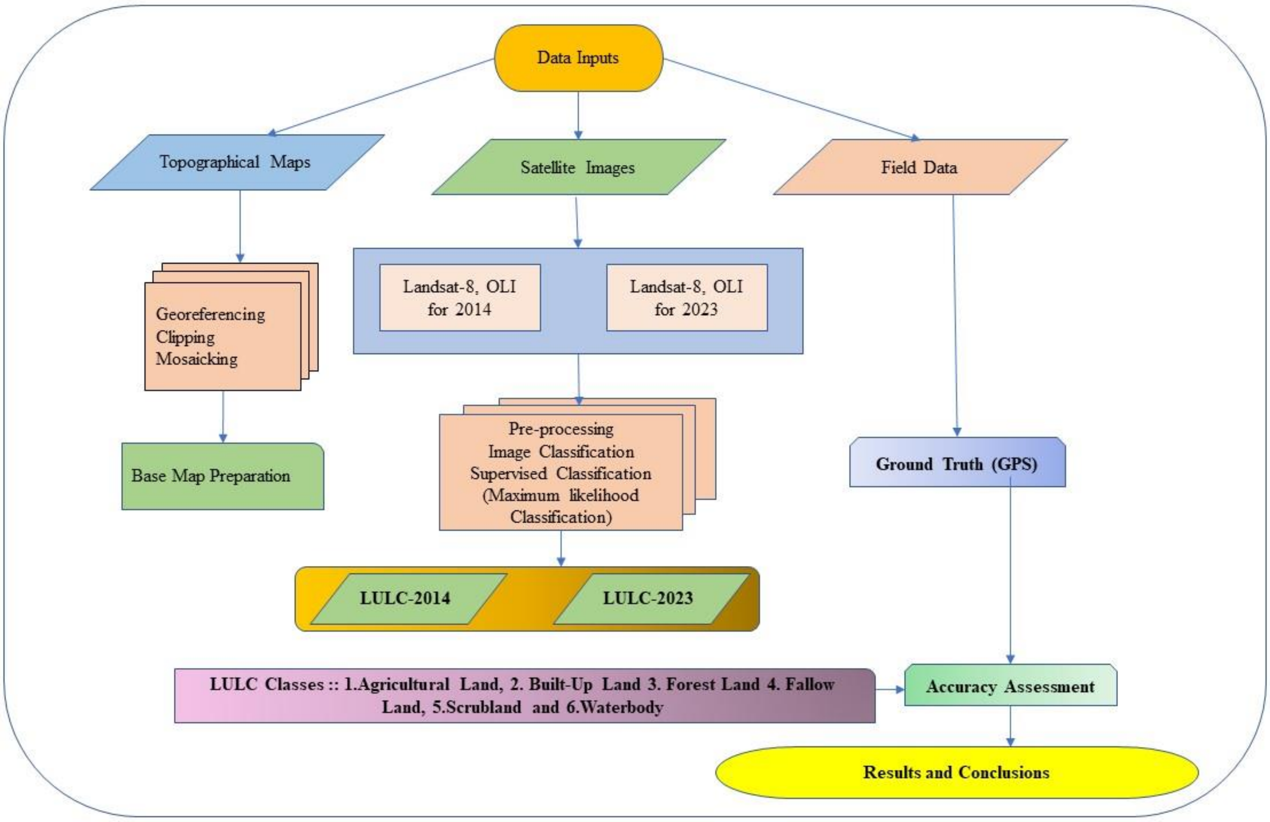

Fig. 2: *Methodology for Monitoring of Land Use Land Cover Change Analysis.*

An indispensable aspect of this methodology was the incorporation of an accuracy assessment process. Through this assessment, the reliability and precision of the classified images were thoroughly evaluated. This step was essential, as it ensured that the generated maps met the required standards of accuracy, providing a robust foundation for the study's conclusions and insights. The entire methodology, as illustrated in Figure 2 and Table 1, was systematically designed and executed, ensuring the integrity and validity of the research outcomes.

Results and conclusions

Land use/cover change analysis

The study employed the widely recognized supervised classification method, specifically the Maximum Likelihood Classification (MLC) algorithm in ERDAS 2015 Imagine software, to assess land use/cover changes spanning the years 2014 to 2023 (Figure 3). In the study area, land was categorized into six distinct classifications: Agricultural land, built-up land, fallow land, forest land, scrubland, and water bodies, each accounting for varying proportions of the total area.

In 2014, the analysis revealed that agricultural land occupied 4.89% (14.51 sq km) of the area, built-up land covered 8.38% (24.85 sq km), fallow land constituted 17.53% (52.02 sq km), forest land encompassed

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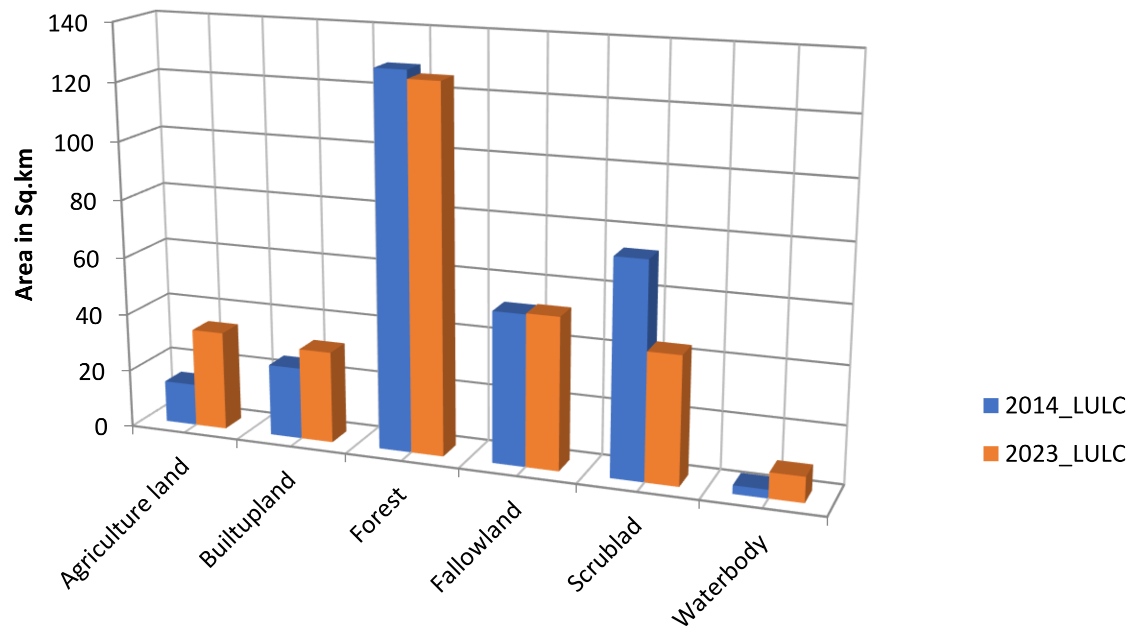
43.32% (128.54 sq km), scrubland accounted for 24.89% (73.86 sq km), and water bodies comprised 0.98% (2.92 sq km) of the total area (Figure 5).



	Agriculture land	Builtupland	Forest	Fallowland	Scrublad	Waterbody
2014_LULC	14.51	24.85	128.54	52.02	73.86	2.92
2023_LULC	34.27	31.70	125.62	52.38	43.98	8.76

Fig.3 Land use and land cover during the 2014 & 2013

By 2023, there was a noticeable shift in these land use/cover categories. Agricultural land expanded to 11.55% (34.27 sq km), indicating a 6.66% increase. This growth was attributed to a decrease in available water resources, leading to a 2.95% rise (8.76 sq km) in water bodies, signifying a 1.97% increase in surface water. Built-up lands also saw an increase, covering 10.68% (31.70 sq km) of the area, indicating a 1.97% rise. Fallow land accounted for 17.65% (52.38 sq km), reflecting a minor 0.12% increase. However, forest land experienced a decrease, occupying 42.34% (125.62 sq km) of the area, marking a 0.99% reduction compared to the 2014 land use/cover data (Table 2). These changes highlight the dynamic nature of the region's landscape over the specified period, emphasizing the impact of environmental factors on land use patterns.

Table 2 Land use and land cover during the 2014 & 2023

Class Name	**2014_LULC Area in sq.km**	**2023_LULC Area in sq.km**	**2014_LULC Area in %**	**2023_LULC Area in %**	**change in %**
Agriculture land	14.51	34.27	4.89	11.55	6.66
Built-up land	24.85	31.70	8.38	10.68	2.31
Forest	128.54	125.62	43.32	42.34	-0.99
Fallow land	52.02	52.38	17.53	17.65	0.12
Scrubland	73.86	43.98	24.89	14.82	-10.07
Water body	2.92	8.76	0.98	2.95	1.97

Waterbody

Water bodies in the region include both natural and man-made features such as rivers, lakes, streams, channels, tanks etc., visible as dark areas in satellite imagery. Shallow water areas support crop cultivation. Tanks, often square-shaped and found mostly in the central region, are highlighted in blue tones, with a few dry ones in the North. Based on the data, the area covered by water bodies decreased from 2.92 sq.km in 2014 to 0.98 sq.km in 2023, dropping from 8.76% to 2.95% of the total area. This represents a significant decline of 1.97% in water body coverage over the period.

Scrub land

Scrubland is a type of land covered primarily with low-growing vegetation such as shrubs, bushes, and small trees. It often occurs in dry or semi-arid regions and can serve as important habitat for wildlife. Scrublands are typically less dense than forests and may be used for grazing or left as natural open space. Between 2014 and 2023, scrubland area decreased significantly from 73.86 sq.km (24.89%) to 43.98 sq.km (14.82%), showing a decline of 10.07% in overall land cover.

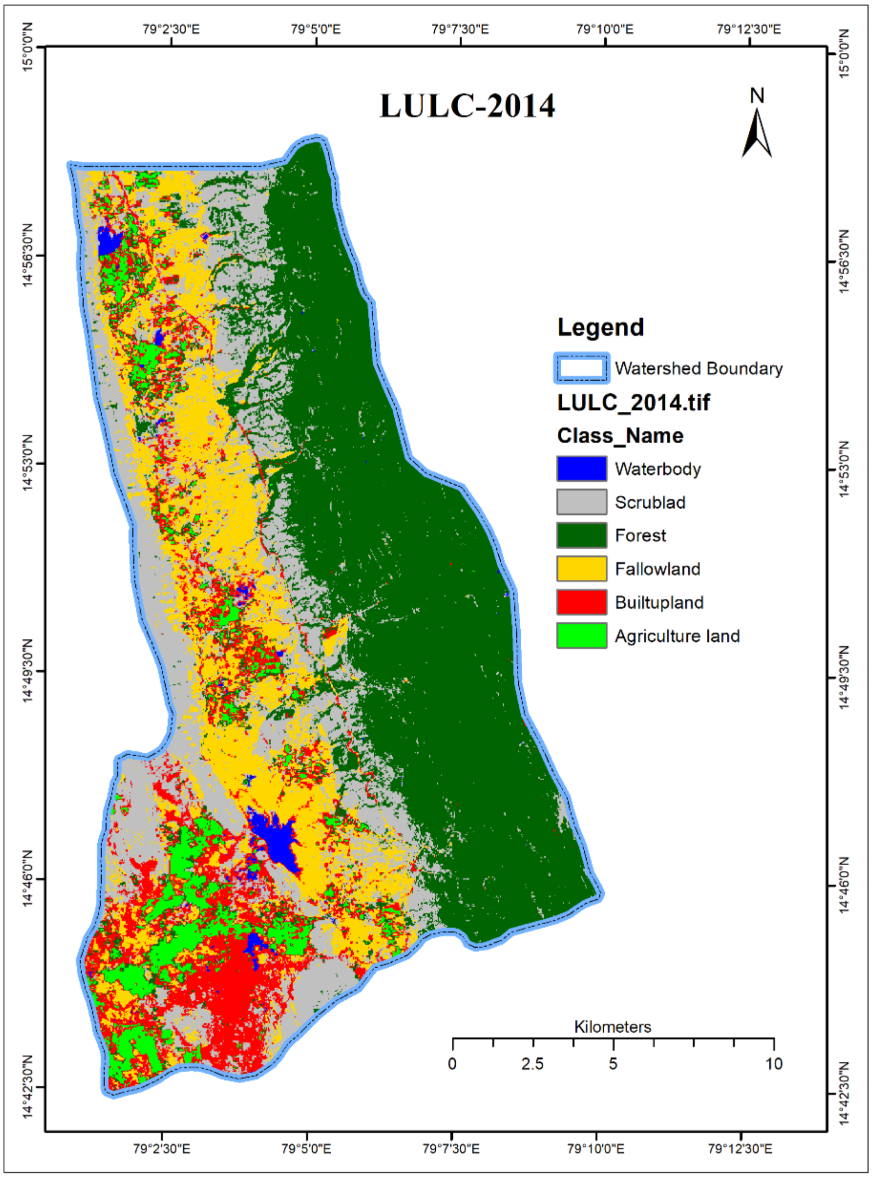


Fig.4 Land Use & Land Cover Map 2014

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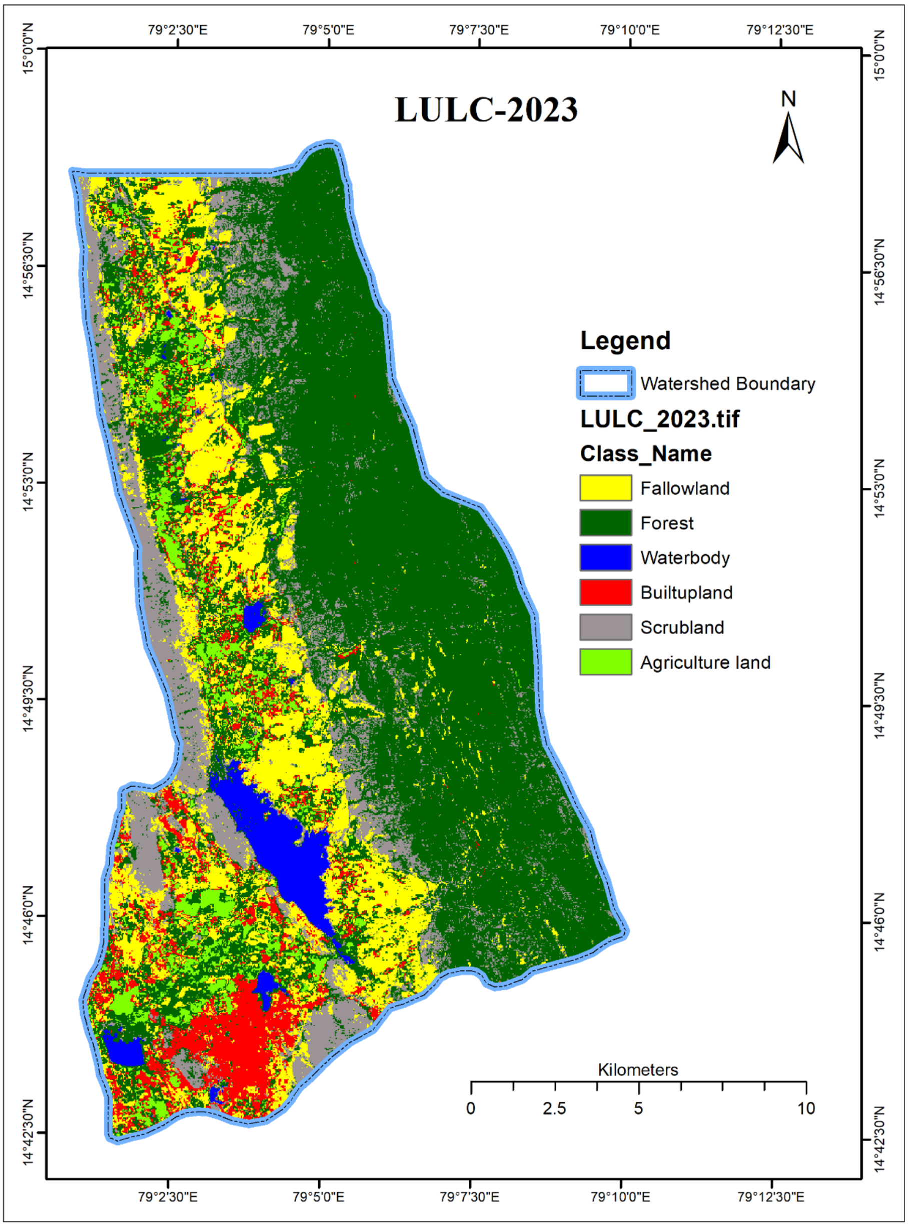

Fig.5 Land Use & Land Cover Map 2023

Forest

The forest area consists of dense tree cover that plays a crucial role in maintaining ecological balance, supporting biodiversity, and regulating the climate. It provides habitat for wildlife, helps in soil conservation, and acts as a carbon sink. Despite a slight decline, the forest remains a significant part of the landscape. Between 2014 and 2023, the forest area slightly decreased from 128.54 sq.km (43.32%) to 125.62 sq.km (42.34%), reflecting a minor decline of 0.99% in forest cover.

Builtup land

Built-up land refers to areas developed for human activities, including residential, commercial, industrial, and infrastructure spaces. These areas are characterized by buildings, roads, and other constructed features, often leading to reduced natural vegetation and changes in land use patterns. Between 2014 and 2023, built-up land increased from 24.85 sq.km (8.38%) to 31.70 sq.km (10.68%), showing a growth of 2.31% in urban and developed areas.

Fallow land

Fallow land is agricultural land that is left unplanted for a period to restore its fertility and improve soil health. It may appear unused temporarily but plays an important role in sustainable farming by allowing the soil to recover nutrients naturally. From 2014 to 2023, fallow land area remained relatively stable, increasing slightly from 52.02 sq.km (17.53%) to 52.38 sq.km (17.65%), with a minimal change of 0.12%.

Agricultural land

Agricultural land is used for cultivating crops and raising livestock. It includes fields for growing food plants like grains, vegetables, and fruits, as well as pasture areas for animals, playing a vital role in food production and rural economies. Between 2014 and 2023, agricultural land increased significantly from 14.51 sq.km (4.89%) to 34.27 sq.km (11.55%), showing a growth of 6.66% in cultivated area.

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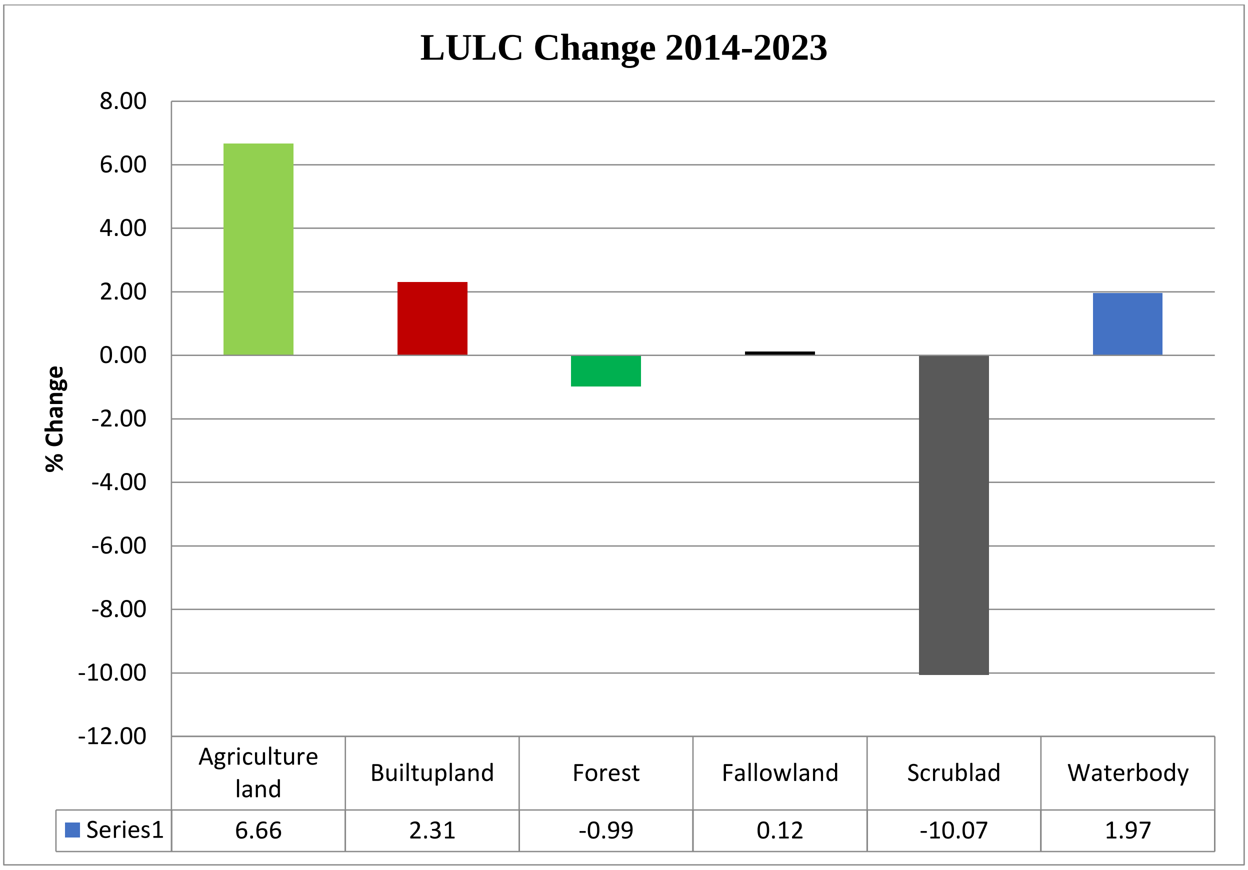

Fig.6 Land Use and Land Cover Change during the 2014 and 2023

Accuracy assessment

Accuracy assessment is a vital step in satellite image classification, ensuring the reliability of results. According to Bradley (2009), image classification is incomplete without accuracy assessment. In this study, accuracy assessment was conducted for 2014 and 2023 images using a standard methodology known as the confusion matrix. This matrix compares classified pixels with reference pixels, determining agreements and disagreements. Producer’s accuracy measures correctly classified pixels for a specific class, while user’s accuracy indicates the accurately classified class pixels. Overall accuracy assesses all correctly classified pixels, and the Kappa coefficient evaluates classification accuracy for diagonal elements.

The study utilized stratified random methodology, Google Earth historical data, and topographic sheets for accuracy assessment. Ground truth data (GPS points) and topographic sheets were employed for accuracy assessment of land use/land cover maps. The confusion error matrix compared 114 reference points with corresponding pixels in classified images, calculating user’s accuracy, producer’s accuracy, and Kappa coefficients for various land use/land cover classes. The results showed overall accuracy rates of 86.62% for 2014 and 91.85% for 2023 images, with corresponding Kappa coefficients of 0.8343 and 0.8987, indicating acceptable accuracy of the classified land use/land cover features.

Conclusion

This study successfully assessed land use and land cover (LU/LC) changes in the Tiggaleru sub-river basin using Landsat-8 satellite data from 2014 and 2023 through supervised classification in ERDAS imagine 9.2. Six major LU/LC classes were identified: agricultural land, built-up land, fallow land, forest, scrubland, and water bodies. Results showed significant increases in agricultural land (6.66%) and built-up areas (2.31%), while scrubland and forest areas declined by 10.07% and 0.99%, respectively. Water bodies and fallow land saw minor increases. The accuracy assessment confirmed the reliability of the classification, with overall accuracy exceeding 86% for both years and strong Kappa values (0.8343 for 2014 and 0.8987 for 2023). These findings highlight dynamic landscape transformations, emphasizing the importance of continuous LU/LC monitoring for informed watershed management and sustainable land use planning.

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