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Spatio-Temporal Analysis of Land Use & Land Cover Change Detection using Geospatial Technology in Kurnool District, Andhra Pradesh

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Abstract

This research investigates the spatio-temporal dynamics of land use and land cover (LULC) changes in Kurnool District, Andhra Pradesh, from 2017 to 2024. Advanced geospatial technologies, such as remote sensing and Geographic Information Systems (GIS), are utilized to analyze satellite imagery along with ancillary datasets, enabling an assessment of the extent and patterns of land cover changes. The main factors dynamic these alterations urbanization, agricultural strengthening, and communications development are identified and observe for their implications on environmental sustainability and natural resource executive.

The methodology includes the classification of multi-temporal satellite imagery to distinguish various land cover categories, such as forests, agricultural land, urban areas, and water bodies. The analysis reveals significant transitions in land use, mainly the growth of urban areas at the expense of agricultural and forested lands. These results emphasize the vital need for sustainable land management strategies aimed at explanatory harmful impacts on biodiversity, soil quality, and ecosystem services.

In conclusion, this research enhances the understanding of LULC dynamics in Kurnool District and provides valuable insights for policymakers, planners, and environmental managers. By integrating remote sensing and GIS methodologies, the study underscores the significance of geospatial tools in fostering data-driven decision-making to address the challenges posed by rapid socio-economic and environmental changes.

Keywords: LULC, Spatio-Temporal Analysis, RS, GIS, Geospatial Technology

1. Introduction

Land use and land cover (LULC) are crucial for perceptive the interaction between natural resources and human activities. Monitoring and analyzing LULC dynamics provide essential insights into patterns of agricultural increase, urban growth, deforestation, and ecological transformations. These changes not only reproduce socio-economic development but also have significant implications for environmental sustainability, water resources, and biodiversity conservation. In regions that are ecologically perceptive and prone to climatic variability, LULC studies become even further vital for planning and policy-making.

Kurnool District, located in the Rayalaseema region of Andhra Pradesh, is characterized by a semi-arid climate, recurrent droughts, and a strong dependence on agriculture. Over the past decade, the district has experienced express agricultural increase, urbanization, and land resource utilization, leading to noticeable shifts in land cover patterns. The use of geospatial technology, particularly remote sensing and GIS, enables precise mapping and temporal analysis of these changes, offering a inclusive accepting of land transformation processes. This study focuses on the spatio-temporal analysis of LULC changes in Kurnool District from 2017 to 2024, aiming to identify key transitions, quantify area changes, and assess their implications for sustainable land management and regional development.

Study Area

Kurnool District, situated within the Rayalaseema region of Andhra Pradesh, encompasses an approximate area of 17,658 square kilometers and comprises fifty-four mandals. The geographical coordinates of the district array from 14°15′ to 16°15′ north latitude and from 77°15′ to 79°15′ east longitude, establishing it as a transitional zone between the Eastern Ghats and the Deccan Plateau. The district is bounded to the north by Jogulamba Gadwal District of Telangana, to the south by Anantapur and Kadapa Districts, to the east by Prakasam District, and to the west by Bellary District of Karnataka. The executive headquarters is located in Kurnool town, which serves as an important urban and possible center within the area (see Fig. 1).

The district is characterized by a variety of physiographic features, including expansive plains, undulating uplands, and isolated hill formations, with altitudinal variations ranging from 100 meters to 650 meters above mean sea level. Major rivers, including the Krishna, Tungabhadra, Hundri, and Kunderu, traverse the district, facilitating the development of fertile alluvial tracts that support intensive agricultural practices. The climate is classified as semi-arid tropical, marked by elevated summer temperatures, mild winters, and recurrent drought occurrences. The mean annual precipitation ranges from 650 to 750 millimeters, primarily occurring during the southwest monsoon season from June to September.

The soil composition throughout Kurnool District is diverse, comprising several predominant types. Black cotton soils, which are expansively distributed in the central and western regions, are particularly favorable to the cultivation of cotton and pulses. In the southern and upland areas, red sandy loams and red soils prevail, supporting the growth of groundnuts, millets, and oilseeds. Fertile alluvial soils found along the river basins sustain paddy and other cash crops, while mixed soils in transitional zones exhibit moderate productivity. This diverse soil and climatic command exerts a significant influence on the agricultural patterns of the district, illustration Kurnool a representative landscape for the assessment of land use and land cover dynamics in semi-arid environments.

Aim and Objectives

The primary objective of this research is to study the spatial and temporal dynamics of land use and land cover (LULC) across the fifty-four mandals of Kurnool District, Andhra Pradesh, for the years 2017 and 2024. This study focuses on identifying the extent and patterns of land cover transformations that have transpired during this timeframe, with particular emphasis on alterations driven by agricultural increase, urban development, and climatic variability.

The specific objectives of the research are delineated as follows:

1. The major LULC categories of Kurnool District for the years 2017 and 2024 will be classified and mapped utilize RS and GIS techniques.
2. The spatial and temporal variations among different LULC classes during the study period will be quantified.
3. Major transitions between land cover categories, including agriculture, rangeland, built-up areas, forested regions, and water bodies, will be known and analyze.
4. The implications of LULC dynamics for agricultural yield, urbanization trends, and ecological sustainability within the district will be evaluate.
5. Geospatial insights will be provided to contribute to sustainable land resource management, environmental protection, and regional planning in drought-prone areas of Kurnool District.

Methodology

A geospatial analytical structure that integrates remote sensing and GIS techniques is working in this study to evaluate LULC changes in Kurnool District between 2017 and 2024. Sentinel-2 satellite imagery for the years 2017 and 2024 was acquired and processed to create thematic land cover maps. The Area of Interest (AOI) was delineated based on administrative boundaries through on-screen digitization. Then, multi-temporal satellite datasets underwent preprocessing, which included radiometric and geometric corrections to make sure spatial precision and comparability across the years.

Supervised classification methods were utilized for LULC classification, wherein training samples representing distinct land cover types were famous through field verification and ancillary data. The classified images were then employed to produce thematic maps depicting land use and land cover for each study year. Statistical techniques were applied to calculate the areal extent and percentage composition of each LULC class, thereby enabling the quantification of spatio-temporal changes.

Data Used

The research primarily relied on Sentinel-2 L1C/L2A imagery from the European Space Agency (ESA), accessible through the Esri database. These images, which possess a spatial resolution of 10 meters across visible and near-infrared spectral bands, were utilized for LULC classification and vegetation analysis. Ancillary datasets, including district boundary shapefiles and field validation data, were incorporated to enhance classification accuracy and contextual understanding.

Software Utilized

All spatial analyses and map generation were conducted using ArcGIS 10.3 for geospatial processing, while Microsoft Office was working for statistical analysis, data tabulation, and records.

Result & Discussion:

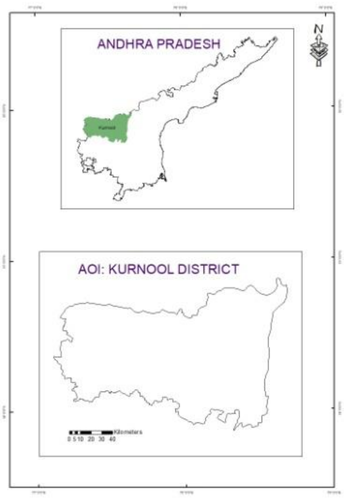


Fig: 1

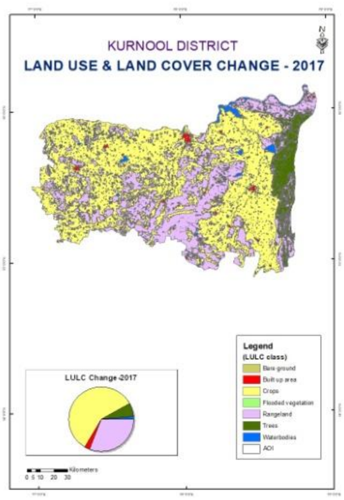


Fig: 2

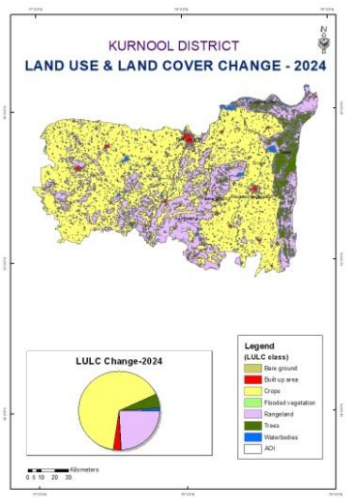


Fig: 3

Table: 1
Land Use & Land Cover Change -2017

S.no	Name of the Class	Area Sq.km
1	Water bodies	297.230346
2	Trees	1172.144192
3	Flooded vegetation	3.584863
4	Crops	10371.65561
5	Built up area	429.478676
6	Bare ground	29.430372
7	Rangeland	5509.042201

Land Use and Land Cover: 2017

Table 1 and Figure 2 provide a comprehensive impression of the land use and land cover (LULC) patterns observed in Kurnool District during the year 2017. The data, expressed in square kilometers, offer a quantitative assessment of the spatial allocation of various land cover classes. This analysis provides valuable insights into the relationship between ecological processes and human activities shaping the district's landscape.

The findings indicate that cropland constitutes the largest LULC category, occupying approximately 10,371.66 square kilometers. This extensive agricultural coverage underscores the predominance of farming as the principal land use in Kurnool District, reflecting the region's reliance on agrarian livelihoods. Such widespread cultivation also highlights the need for sustainable agricultural management practices to mitigate potential issues related to soil degradation, groundwater depletion, and loss of native vegetation.

The second most extensive category is rangeland, covering about 5,509.04 square kilometers. This substantial area dedicated to grazing activities emphasizes the importance of livestock in the local economy and rural livelihood systems. However, continuous grazing pressure, if unmanaged, may contribute to vegetation depletion and land degradation in semi-arid environments such as Kurnool.

The built-up area, accounting for approximately 429.48 square kilometers, represents the extent of urban development and infrastructural expansion within the district. Although this proportion remains relatively humble compare to agricultural and rangeland areas, it indicates gradual urbanization processes that may build up in the coming years due to population growth and economic development.

Water bodies, including rivers, tanks, and reservoirs, occupy around 297.23 square kilometers. These aquatic ecosystems are vital for underneath biodiversity, irrigation, and domestic water supply. Maintaining the ecological integrity of these resources is essential for sustaining agriculture and justifying drought impacts.

Tree-covered areas constitute about 1,172.14 square kilometers, significantly contributing to carbon sequestration, soil conservation, and habitat stability. Although forest cover remains limited, its ecological role in maintaining environmental balance is extensive. The presence of flooded vegetation, occupying around 3.58 square kilometers, reflects seasonal hydrological variations, while bare ground, totaling 29.43 square kilometers, indicates regions that may be degraded, eroded, or in transitional stages of land recovery.

Reciprocally, the 2017 LULC data depict a landscape dominated by agricultural and grazing activities, intersperse with small but vital patches of tree cover and water bodies. These findings illustrate the delicate balance between human utilization and natural systems, underscoring the necessity for integrated land management approaches to make sure ecological sustainability and resilience against climatic variability.

Table: 2

Land Use & Land Cover Change -2017

S.no	Name of the Class	Area Sq.km
1	Water bodies	217.8038
2	Trees	1051.501
3	Flooded vegetation	2.183926
4	Crops	11627.28
5	Built up area	567.3125
6	Bare ground	13.35939
7	Rangeland	4331.648

Land Use and Land Cover: 2024

Table 2 and Figure 3 provide a comprehensive overview of land use and land cover (LULC) patterns in Kurnool District for the year 2024, measured in square kilometers across various land cover categories. The data exemplify a diverse landscape shaped by both natural and human-induced factors, reflecting the changing environmental and developmental dynamics within the region.

Water bodies cover approximately 217.80 square kilometers, including rivers, lakes, and reservoirs that are necessary hydrological resources for agriculture, domestic use, and biodiversity conservation. The sensible extent of this category indicates some variability in surface water availability, which may be affected by fluctuations in rainfall and water running practices.

The tree cover class comprises about 1,051.50 square kilometers, indicating the ongoing presence of forested and woody vegetation. These areas perform vital ecological functions such as carbon confiscation, microclimate regulation, and soil stabilization. However, the small decrease in forest area compared to previous years may reflect pressures from agricultural growth and urban development.

Flooded vegetation, covering nearly 2.18 square kilometers, includes areas that undergo seasonal inundation, behind specialized plant and animal communities adapted to wetland conditions. Although limited in spatial extent, these ecosystems are vital for maintaining ecological diversity and hydrological balance.

The cropland category dominates the landscape, extending over 11,627.28 square kilometers, importance the region's significant reliance on agriculture. This increase in cultivated land underscores the increase of agricultural practices driven by population growth and food demand. However, this trend also raises concerns about land degradation, groundwater reduction, and vulnerability to drought in a semi-arid environment.

Built-up areas, totaling about 567.31 square kilometers, reflect a noticeable rise in urbanization and infrastructural development. This growth signifies socio-economic progress but also indicates the gradual advance of human settlements into agricultural and natural areas, potentially foremost to habitat destruction and environmental pressure.

The bare ground category, which spans about 13.36 square kilometers, represents areas lacking vegetation, possibly due to soil erosion, overgrazing, or construction activities. Although comparatively small in extent, these patches may mean localized environmental poverty.

Finally, rangeland, covering 4,331.65 square kilometers, consists of lands mainly used for livestock grazing. This category remains a vital part of the region's rural economy, supporting pastoral communities and contributing to ecological spirit. However, overexploitation of grazing lands could worsen soil erosion and vegetation loss if not manage sustainably.

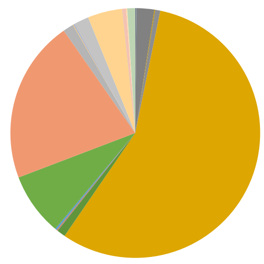
In conclusion, the 2024 LULC data expose a landscape increasingly characterized by cropland and built-up areas, accompanied by a steady decline in natural vegetation and water bodies. These patterns highlight the dual influence of human development and environmental processes on land use dynamics, stress the necessity for included land management strategies that balance economic growth with ecological conservation.

Table: 3
Land Use & Land Cover Change Detection: 2017-2024

Change Detection :2017-2024	Area Change (sq.km)
Bare ground-Bare ground	8.797325
Bare ground-Built up area	5.427843
Bare ground-Crops	5.127543
Bare ground-Flooded vegetation	0.000094
Bare ground-Rangeland	8.377414
Bare ground-Trees	0.010074
Bare ground-Water bodies	1.673317
Built up area-Bare ground	0.324258
Built up area-Built up area	406.228321
Built up area-Crops	19.676065
Built up area-Rangeland	2.81151
Built up area-Trees	0.104224
Built up area-Water bodies	0.283159
Crops-Bare ground	0.620343
Crops-Built up area	114.833622
Crops-Crops	10036.82657
Crops-Flooded vegetation	0.794234
Crops-Rangeland	192.320041
Crops-Trees	7.497768
Crops-Water bodies	17.681437
Flooded vegetation-Bare ground	0.014932
Flooded vegetation-Built up area	0.5504
Flooded vegetation-Crops	1.536575
Flooded vegetation-Flooded vegetation	0.382868
Flooded vegetation-Rangeland	0.713421
Flooded vegetation-Trees	0.101372
Flooded vegetation-Water bodies	0.285295
Rangeland-Bare ground	2.864096
Rangeland-Built up area	38.986788
Rangeland-Crops	1449.986079

Rangeland-Flooded vegetation	0.506771
Rangeland-Rangeland	3756.564538
Rangeland-Trees	244.807923
Rangeland-Water bodies	14.276436
Trees-Bare ground	0.000468
Trees-Built up area	0.273326
Trees-Crops	22.258789
Trees-Flooded vegetation	0.001119
Trees-Rangeland	347.658442
Trees-Trees	800.968722
Trees-Water bodies	0.130536
Water bodies-Bare ground	0.742926
Water bodies-Built up area	0.895085
Water bodies-Crops	86.522906
Water bodies-Flooded vegetation	0.500757
Water bodies-Rangeland	24.671986
Water bodies-Trees	0.249331
Water bodies-Water bodies	183.603536

Fig:4
LULC Change Detection:2017-2024



Comparative Analysis of Land Use and Land Cover Changes (2017–2024)

Table 3 and Figure 4 present a comparative analysis of land use and land cover (LULC) dynamics in Kurnool District between 2017 and 2024, importance area changes in square kilometers across major land cover categories. The data illustrate wide transitions among different land types, glossy both human influences and environmental factors that have shaped the area landscape over the study period.

The most prominent transformation is observed in the cropland category, which recorded a net increase of over 10,036 square kilometers. This significant expansion suggests intensified agricultural activity, possibly driven by population growth, economic confidence on farming, and the adoption of modern irrigation and cultivation practices. While this agricultural growth contribute to regional food production, it may also place additional pressure on groundwater resources and natural ecosystems in the semi-arid environment.

The built-up area also experienced notable growth, expanding by regarding 406 square kilometers during the study period. This trend signifies rapid urbanization and infrastructure development, particularly in and around major towns and transport corridors. The conversion of bare ground to built-up land, amounting to roughly 5.43 square kilometers, underscore the gradual transformation of previously immature areas into residential, industrial, or commercial zones.

The rangeland category display important spatial deviation, with a net increase of nearly 3,757 square kilometers. This change may be attributed to alterations in land executive practices, such as shifting cultivation or the extension of grazing areas. The practical transitions from rangeland to cropland (approximately 1,450 square kilometers) and rangeland to tree cover (around 348 square kilometers) further emphasize the reallocation of land resources toward agricultural and forestry uses.

The water bodies category remained relatively stable, exhibiting only minor spatial fluctuations. On the other hand, transitions from cropland to water bodies, accounting for roughly 86 square kilometers, advise localized hydrological changes potentially related with new reservoirs, irrigation projects, or increased runoff due to land modification.

Collectively, these findings underline the dynamic nature of land use in Kurnool District, where agricultural increase and urban growth are reshape traditional land cover structures. The relationship between cropland expansion, rangeland modification, and urban development places of interest the need for sustainable land management strategies that balance economic progress with ecological stability. Perceptive these transitions is vital for guiding future policy decisions related to water management, soil conservation, and environmental planning in this drought-prone region.

Conclusion

The analysis of land use and land cover (LULC) dynamics from 2017 to 2024 reveals important spatial and temporal transformations across multiple categories, illustrate the complex interaction between human activities and natural processes in Kurnool District. The most definite change is observed in the cropland category, which recorded a net increase of over 10,036 square kilometers, signifying intensify agricultural expansion and the exchange of previously fallow land for farming purposes. This growth reflects both economic need on agriculture and the pressures of people growth on available land resources.

Similarly, the built-up area category expanded by around 406 square kilometers, primarily as a result of urbanization and infrastructural expansion. The conversion of bare ground amounting to about 5.43 square kilometers into built-up areas underscores the steady advance of human settlements into immature landscapes. The rangeland category exhibited substantial growth as well, with a net increase of nearly 3,757 square kilometers, suggesting shifts in land executive practices and ecological responses to climatic variability. The transitions from rangeland to cropland (1,450 square kilometers) and from rangeland to tree cover (348 square kilometers) specify constant land reallocation toward agricultural and forestry activities.

The water bodies category remained comparatively stable, showing only minor fluctuations. However, the conversion of cropland to water bodies (86 square kilometers) may point to localized hydrological changes, such as the creation of irrigation reservoirs or seasonal flooding.

Overall, the observed patterns underline the dynamic and mutually dependent nature of land systems in Kurnool District. The growth of agriculture and urban areas, coupled with modifications in rangeland and tree cover, highlights the urgent need for included land resource management strategies. Sustainable planning approaches that balance economic development with ecological protection are essential to maintaining environmental stability, enhancing flexibility to drought, and ensuring lasting resource sustainability in this semi-arid region.

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