Assessment of Land Use and Land Cover & Normalized Difference Vegetation Index for Drought Prone Area of Guntakal, Andhra Pradesh Using Geo-Informatics Techniques

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Abstract- The present study examines alterations in Land Use and Land Cover (LULC) within Guntakal mandal, a region characterized by susceptibility to drought in Andhra Pradesh, through the application of remote sensing and geospatial technologies. Significant shifts in land use have been identified by analyzing Sentinel-2A satellite imagery from 2017 to 2024, alongside data from Landsat-8 and Landsat-9, which were utilized to evaluate vegetation health via the Normalized Difference Vegetation Index (NDVI) from 2013 to 2024. Notable findings encompass the expansion of urban areas, a rise in agricultural activities, and a decline in forest cover. The NDVI analysis reveals fluctuations in vegetation health that are associated with seasonal variations, persistent drought conditions, and anthropogenic influences on the local ecosystem. The effectiveness of remote sensing in monitoring the dynamics of land resources over time is demonstrated through the integration of these satellite datasets. By correlating changes in LULC with trends in vegetation health, the study emphasizes the critical role of geospatial tools in the management of semi-arid environments that are vulnerable to drought. The insights derived from this research hold significant value for policymakers, environmental planners, and local communities who seek to formulate sustainable land management strategies and adapt to the challenges posed by climate change.

Key words: RS, GIS, LULC & NDVI

I. INTRODUCTION

Land resources are indispensable for human survival and sustainable development; however, they are increasingly strained by population growth, urbanization, agricultural expansion, and the looming threats of climate change. In this context, the systematic monitoring of Land Use and Land Cover (LULC) changes becomes a critical necessity. Examining the period from 2017 to 2024 using Sentinel-2A satellite data provides an opportunity to better understand the complex interplay between anthropogenic pressures and natural processes (Anderson 23).

Such studies are particularly important because they shed light on shifts in agricultural land, forest cover, urban growth, barren terrain, and water resources. These elements form the backbone of sustainable resource planning and environmental management (Jensen 45).

In semi-arid regions, such as Rayalaseema in Andhra Pradesh, the challenges are amplified. Land degradation, erratic rainfall, and recurrent droughts are characteristic of this landscape. Within this region, the northeastern part of Anantapur district specifically Guntakal mandal is highly vulnerable. Its undulating terrain, shallow soil depth, and limited water resources intensify the environmental stress faced by local communities. Since agriculture in this region remains predominantly rain-fed, fluctuations in rainfall patterns and land management practices exert a direct influence on productivity and livelihoods (Rao 112). Therefore, evaluating LULC transformations in such ecologically fragile areas becomes vital to striking a balance between productive land use and the expansion of barren or fallow lands.

To achieve this, indices such as the Normalized Difference Vegetation Index (NDVI) are essential tools. NDVI, derived from satellite platforms such as Landsat 8 and 9 (OLI/TIRS-C2 L2), is widely used for assessing vegetation vigor, canopy density, and stress responses. The index effectively distinguishes between vegetated and non-vegetated areas, making it especially useful in semi-arid landscapes with sparse greenery (Tucker 227). When combined with LULC mapping, NDVI enables researchers to trace ecological shifts, evaluate drought impacts, and monitor land productivity over time (Singh 89).

Study Area

Guntakal Mandal is located in the northeastern part of Anantapur district, Andhra Pradesh, with approximate geographic coordinates of 15.17° N latitude and 77.38° E longitude. The mandal covers an area of about 402 square kilometers and comprises both rural and urban environments (Fig. 1). It lies at an elevation ranging from 432 to 450 meters above sea level and is characterized by gently undulating topography forming part of the Rayalaseema plateau, interspersed with scattered hillocks and shallow valleys.

The geological setting of the region is dominated by ancient granite-gneiss formations. The soils are primarily red sandy loams and gravelly soils, with occurrences of black cotton soils in the valleys. Drainage is largely seasonal, with ephemeral streams active during the southwest monsoon, draining into the Pennar basin and forming a dendritic drainage pattern.

Climatically, Guntakal falls within the semi-arid zone, recording an annual rainfall of about 500 to 600 mm. Precipitation is low, erratic, and unevenly distributed, making the region highly vulnerable to drought. Summers are hot and dry, whereas winters remain comparatively mild. Natural vegetation belongs to the tropical dry deciduous thorn forest type, now largely degraded into scrubland. The present vegetation mainly consists of thorny bushes and scattered trees, including neem (*Azadirachta indica*), tamarind (*Tamarindus indica*), and acacia (*Acacia spp.*).

Agriculture in the mandal is predominantly rainfed, with groundnut, cotton, sunflower, and millets as the principal crops. Irrigation is limited, primarily dependent on borewells, which restricts crop productivity and leaves significant areas as fallow or barren land. These conditions, coupled with recurring droughts, underscore the ecological vulnerability of the region and its dependence on sustainable land and water management practices.

Objectives:

1. To analyze and classify the land use and land cover (LULC) patterns in the Guntakal region using remote sensing and GIS techniques, with a focus on identifying areas vulnerable to drought conditions.
2. To evaluate the Normalized Difference Vegetation Index (NDVI) across different land cover types in Guntakal, to assess vegetation health and its correlation with drought severity over the past decade.

II. METHODOLOGY

Data Sources and Pre-Processing

This study utilized multi-temporal satellite imagery from the Sentinel-2A program (2017–2024) alongside Landsat 8 and 9 OLI/TIRS-C2 L2 datasets. These datasets were selected for their medium spatial resolution and consistent temporal coverage, making them particularly well-suited for land use and land cover (LULC) monitoring (Roy et al. 201). The raw satellite images were imported into image-processing software and subsequently georectified through image-to-image registration techniques using the Universal Transverse Mercator (UTM), WGS 1984 projection system, ensuring accurate spatial alignment across all datasets (Richards and Jia 78).

GIS Integration and Data Analysis

After pre-processing, the imagery was systematically analyzed within a Geographic Information System (GIS) environment to enable the integration of spatial and attribute data. The classification and interpretation of land cover types were supported by band combination and spectral index analysis. Simple statistical methods were applied to quantify temporal changes in land categories, while cartographic techniques were employed to generate maps and diagrams that visually represented the spatiotemporal transformations (Campbell and Wynne 134).

Data Collection

The analysis incorporated more than two million Earth observation datasets derived from Sentinel-2A and Landsat OLI/TIRS-C2 L2 imagery, each capturing information across six spectral bands. These datasets were processed using data models to generate detailed thematic maps capable of highlighting subtle changes in vegetation, water, and barren land surfaces. Satellite images were freely acquired through the USGS Earth Explorer portal, which serves as an open-access platform for Earth observation data (USGS). The primary software tools utilized in the study included ArcGIS 10.3 for spatial processing and mapping and Microsoft Office for tabulation and chart presentation.

III. RESULT & DISCUSSION

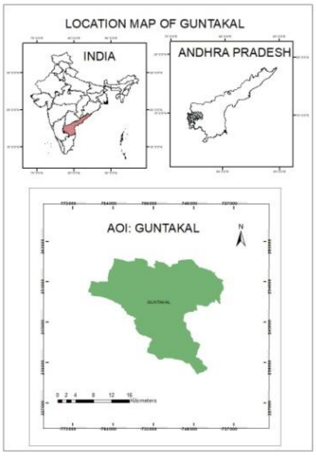
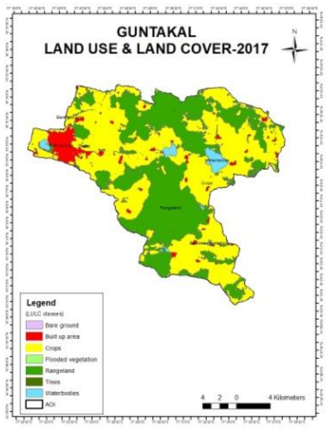


Fig:1



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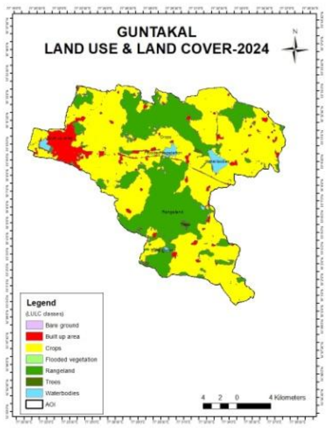

Fig:3

Table: 1
LULC change of Guntakal-2017

S.no	Name of the class	Area sq km
1	Water bodies	8.316678
2	Trees	1.000258
3	Flooded vegetation	0.234166
4	Crops	209.5829
5	Built up area	16.73744
6	Bare ground	0.014032
7	Rangeland	153.8613

LULC Distribution in 2017

The land use and land cover (LULC) classification for Guntakal in 2017 highlights the spatial arrangement of multiple land categories, measured in square kilometers (Table 1). The most extensive category was cropland, which occupied approximately 209.58 km², demonstrating the dominance of agriculture as both an economic foundation and a source of livelihood for the region's inhabitants. The size of this agricultural footprint underscores the dependency of the local population on rain-fed farming systems (Rao 115).

The second most prominent class was rangeland, covering about 153.86 km², indicating its importance for livestock grazing and biodiversity conservation. Built-up areas accounted for roughly 16.74 km², reflecting modest but growing urban development in Guntakal. Water bodies extended over 8.32 km², providing crucial resources for irrigation, drinking water, and aquatic ecosystems. Tree cover, however, was minimal at 1.00 km², suggesting limited forest presence and thus reduced carbon sequestration capacity in the region (Anderson 27). Additionally, flooded vegetation occupied 0.23 km², while bare ground was negligible at 0.01 km². Collectively, these figures reveal a region strongly defined by agriculture, supported by rangelands, and only marginally influenced by urbanization and forest resources.

Table: 2
LULC change of Guntakal-2024

S.no	Name of the class	Area sq km
1	Water bodies	6.739377
2	Trees	2.763743
3	Flooded vegetation	0.002213
4	Crops	238.245243
5	Built up area	22.513163
6	Bare ground	0.054311
7	Rangeland	119.433289

LULC Distribution in 2024

By 2024, the LULC profile of Guntakal had undergone notable transformations (Table 2). Cropland expanded to 238.25 km², consolidating its position as the most significant land use type. This growth underscores the intensification of agriculture in response to population pressure and food security demands (Jensen 52). Meanwhile, rangeland decreased to 119.43 km², a decline suggesting that portions of grazing land may have been converted to cropland, reflecting broader shifts in land management priorities.

Urbanization also increased, with built-up areas expanding to 22.51 km². This moderate yet meaningful rise demonstrates the region's ongoing urban growth, which, while still limited in scale compared to agriculture, points toward long-term trends of settlement expansion (Roy et al. 209). Water bodies diminished slightly to 6.74 km², raising concerns about hydrological stress and potential overuse of surface water. Tree cover rose to 2.76 km², indicating minor afforestation or natural regeneration efforts, though forest resources remain restricted. In contrast, flooded vegetation contracted to just 0.002 km², suggesting either improved drainage or ecological shifts away from wetland conditions. Bare ground, though still minimal, increased slightly to 0.05 km². These changes collectively reveal a dynamic landscape shaped by agricultural intensification, urban growth, and marginal ecological adjustments.

LULC Change Analysis, 2017–2024

The comparative analysis of LULC transitions between 2017 and 2024 (Table 3) highlights the dynamism of Guntakal's land systems. The most stable category was cropland, with 195.45 km² remaining under cultivation, signaling the continued centrality of agriculture. However, transitions were also substantial. For example, 4.60 km² of cropland was converted to built-up area, reflecting urban expansion into fertile land. Simultaneously, 41.01 km² shifted from rangeland to cropland, indicating a process of agricultural intensification at the expense of grazing areas (Campbell and Wynne 142).

Table: 3
LULC Change Detection of Guntakal: 2017 – 2024

Change Detection Anlysis-2017-2024	Area change sq km
Bare ground-Built up area	0.000635
Bare ground-Crops	0.01157
Bare ground-Water bodies	0.001827
Built up area-Built up area	16.315432
Built up area-Crops	0.361845
Built up area-Rangeland	0.050728
Built up area-Trees	0.008323
Built up area-Water bodies	0.000141
Crops-Built up area	4.60261
Crops-Crops	195.450661
Crops-Rangeland	8.932248
Crops-Trees	0.559307
Crops-Water bodies	0.023671
Flooded vegetation-Built up area	0.001383
Flooded vegetation-Crops	0.166518
Flooded vegetation-Flooded vegetation	0.002213
Flooded vegetation-Rangeland	0.021992
Flooded vegetation-Trees	0.037808
Flooded vegetation-Water bodies	0.004191
Rangeland-Bare ground	0.041902
Rangeland-Built up area	1.535727
Rangeland-Crops	41.008087
Rangeland-Rangeland	109.410133
Rangeland-Trees	1.731215
Rangeland-Water bodies	0.122245
Trees-Built up area	0.027813

Trees-Crops	0.296871
Trees-Rangeland	0.283504
Trees-Trees	0.391754
Trees-Water bodies	0.000166
Water bodies-Bare ground	0.01241
Water bodies-Built up area	0.026847
Water bodies-Crops	0.928128
Water bodies-Rangeland	0.727171
Water bodies-Trees	0.034719
Water bodies-Water bodies	6.587083

Urban expansion is further illustrated by the conversion of 1.54 km² from rangeland to built-up areas. Such shifts highlight the challenges of balancing development with ecological stability. Water bodies showed mixed patterns, with 6.59 km² remaining stable but 0.93 km² converted to cropland and 0.73 km² converted to rangeland. These transitions suggest hydrological stress and potential misuse of aquatic resources for agricultural expansion. Changes in categories such as trees and bare ground were relatively minor for instance, only 0.30 km² of trees were converted to cropland, reflecting limited deforestation. Collectively, these shifts illustrate the growing tension between agricultural growth, urban expansion, and environmental conservation in Guntakal.

Normalized Difference Vegetation Index:

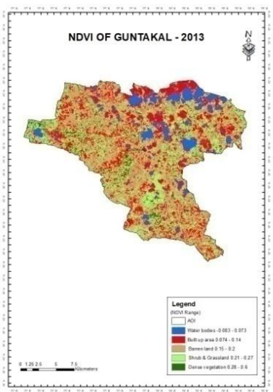

Fig: 4

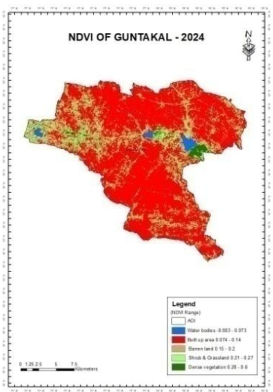

Fig:5

The Normalized Difference Vegetation Index (NDVI) provides an additional layer of insight by assessing vegetation health and density across the study period. NDVI is calculated using the Formula: NDVI=(NIR−RED)(NIR+RED)NDVI=\frac{(NIRRED)}{(NIR+RED)}NDVI=(NIR+RED)(NIR−RED) Where Band 5 (NIR) and Band 4 (Red) from Landsat 8 and 9 are used for computation (Tucker 229). Values approaching +1 signify dense, healthy vegetation, while values near 0 or negative indicate barren or stressed surfaces.

From 2013 to 2024, NDVI analysis of Guntakal shows temporal variability tied to rainfall fluctuations and recurring droughts. Periods of positive NDVI values correlate with productive agricultural cycles, while declines highlight drought impacts and vegetation stress. This temporal assessment not only reveals the resilience of local ecosystems but also indicates how cropping patterns and land cover changes influence ecological stability. Moreover, NDVI trends support the observation that rangeland reduction and agricultural intensification have reshaped the vegetation landscape, with potential long-term consequences for soil health and biodiversity (Singh 93).

CONCLUSION

The LULC analysis of Guntakal between 2017 and 2024 illustrates a landscape primarily dominated by agriculture, supported by rangelands, and increasingly influenced by urban expansion. While agriculture has expanded, this growth has largely come at the expense of rangelands and water resources, suggesting a shift in land-use priorities that may threaten ecological stability. Tree cover remains minimal despite modest gains, underscoring the continued vulnerability of forest resources.

The integration of NDVI analysis provides critical evidence of how these land-use dynamics influence vegetation health, particularly under drought conditions. The findings reveal an intricate balance between economic development and ecological sustainability, emphasizing the need for strategic land management policies. Without such interventions, the long-term sustainability of agriculture, water resources, and biodiversity in Guntakal could be at risk.

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