Analyzing land use/land cover changes and its dynamics using remote sensing and GIS: A Case study in the Tirupati Revenue Division, Andhra Pradesh

Dr. V.Charan Kumar Reddy

Sri Venkateswara University, Tirupati, Andhra Pradesh, India

Abstract

This research examines the dynamics of Land Use and Land Cover (LULC) within a 3667.36 square kilometer region over a span of two decades (1997-2016) via the use of satellite images and Geographic Information Systems (GIS). The term "Land Use" refers to human activities that are directly associated with the use of land, while "Land Cover" applies to the physical characteristics of the Earth's surface, including flora and water. Using a scale of 1:50,000, terrain Use and Land Cover (LULC) maps were produced for the years 1997, 2008, and 2016. These maps categorized several terrain types, including settlements, agricultural areas, barren-fallow land, water bodies, woods, streams, and tanks. The findings indicate significant changes in the distribution of land use, as the area of agricultural land saw a decline from 1615.98 square kilometers in 1997 to 1336.49 square kilometers in 2016. The growth of human settlements had a substantial expansion, with notable increases seen in the regions of Tirupathi and Srikalahasti. This expansion is shown by a recorded rise of 1.73% in settlement size by the year 2016. The study observed a decrease in forested regions, however there was an increase in barren-fallow land and aquatic bodies. The use of supervised classification techniques with LANDSAT data resulted in the identification of five distinct categories: agricultural land, water bodies, forested areas, settlements, and barren-fallow terrain. This research highlights the significance of precise remote sensing and Geographic Information Systems (GIS) methodologies in the context of comprehensive land management and planning. The patterns revealed in this study emphasize the need of promptly implementing water resource and agricultural development strategies to ensure sustainable land use in the examined region. This research highlights the efficacy of satellite data and Geographic Information Systems (GIS) in the monitoring of Land Use and Land Cover (LULC) changes, hence facilitating resource management and development planning.

1. Introduction

To combat issues like unplanned growth, declining environmental quality, the loss of prime agricultural land, the destruction of crucial wetland areas, and the depletion of fish and wildlife habitat, more and more attention is being paid to the specifics of a country's land use and land cover. Land use/land cover is two independent terms which are often used interchangeably. Vegetation, water, soil, and other physical aspects of the land, including those formed purely by human activity such as settlements, all contribute to what is known as "land cover," which describes the observable qualities of Earth's surface. Land-use, on the other hand, describes how land has been put to use by humans and other organisms in their environment, with a focus on the land's practical value in supporting economic endeavors. Natural and socioeconomic variables, as well as man's use of them throughout time and space, determine a region's land use and land cover pattern.

Despite their frequent interchangeability, "Land Use" and "Land Cover" have very different natural meanings. The term "land use" describes how the land is put to work or inhabited. Vegetation, water, bare soil, and other forms of land cover are all considered types of land cover. "Man's activities on land which are directly related to the land" (Clawson and Stewart, 1965) is a definition of land use that has much to recommend it. "The vegetation covering the land surface" is what is meant by "land cover" (Burley, 1961).

Changes in land cover have an impact on land use, and vice versa. Changes in land cover as a result of land use may not always indicate land deterioration (Caillault & Marie, 2023). Land cover changes affect biodiversity, water and radiation budgets, trace gas emissions, and other processes that collectively affect the climate and biosphere, but many varying land use patterns driven by a variety of societal causes result in these changes. Land use/land cover change detection is highly vital for better knowledge of landscape dynamic within a known period of time having sustainable management. Changes in land use and land cover are on the rise globally, fuelled by both natural and human-caused events that have consequences for ecosystems (Koranteng, 2021). When it comes to land management and decision making, having a firm grasp on how landscapes evolve over time and how human activities and natural phenomena interact is crucial. Research into the identification of shifts in land use and land cover can now benefit greatly from remote sensing satellite data.

Satellite images with moderate to high resolution have assisted scientific research operations at landscape and regional dimensions (Gaur & Singh, 2023). Satellite imagery's availability means it can provide geographical resolutions of 0.5m for assessing and monitoring urban expansion and transportation infrastructure improvement. Further analysis and classification of climatic variables, land cover and change detection, and how urbanization and accompanying transportation development effect these conditions are all made possible by the enhanced spectral resolution provided by multispectral bands. In conjunction with GIS, which provides an appropriate platform for data analysis, update, and retrieval, the use of remotely sensed data has allowed for the study of changes in land cover to be conducted more quickly, cheaply, and accurately. Because of improvements in image processing and GIS technology, routine and consistent monitoring and modeling of land use/land cover patterns have replaced occasional surveys. Land use/land cover mapping is now one of the most important applications of remote sensing due to its widespread use in updating land use/land cover maps (Gaur & Singh, 2023).

The need for a nationwide land use/land cover analysis on a 5-year cycle ("Analysis of Land Use/Land Cover Change in Jammu District Using Geospatial Techniques," 2015), as part of the Natural Resources Data Infrastructure, was felt at the regional level. With 2000–2001 as the baseline year, it is proposed to publish a nationwide Status of NR Census report every five years that details Land Use/Cover statistics and other key themes. Information on irrigated and rain-fed lands, present fallows, forest kinds, and canopy density at different administrative levels, as well as human settlement areas and the dimensional changes in urban, town, and rural communities will all be included. The frequency with which data on water body changes is collected can be used as a proxy for the severity of drought in various regions. Important environmental characteristics can be gleaned from studying the dynamics of waterlogged/wetlands areas.

2. Materials and Methods

2.1 Description of the study area

The Tirupati Revenue Division, which is located in the middle of the Chittoor district in Andhra Pradesh, is a prime example of how cultural wealth and burgeoning urbanization may coexist harmoniously. Tirupati, which is widely known as the spiritual capital of Andhra Pradesh, is a destination for pilgrims from all over the world, which has a tremendous impact on the socio-economic and geographical environment of the region. The division includes not only the city of Tirupati but also the areas surrounding it, such as Chandragiri, Renigunta, Tirupati urban, and Tirupati rural, all of which have experienced significant expansion and development in recent years.

Srikalahasti, which is home to the famed Lord Shiva temple, is an essential component in determining the demographic profile as well as the cultural make-up of the district. This spiritual hub has contributed to the growth of nearby areas such as Yerpedu, Thottambedu, and K.V.B Puram as its impact has spread to those areas and radiated outward from it.

The patterns of land use in the Tirupati Revenue Division exhibit a complex mix of urbanization, agricultural pursuits, and the protection of cultural heritage sites. Industrialization has led to the development of noteworthy projects like as the Special Economic Zone (SEZ) of Sri City and industrial estates in Renigunta and Srikalahasti, which have further impacted the economic dynamics and land utilization of the area.

Andhra Pradesh's Chittoor district has developed into a dynamic and culturally significant region thanks to the deep interplay between spirituality and commerce, as well as tradition and modernity. This division, which is still in the process of developing, stands as a witness to this complicated interplay.

2. 2 Data Source

The study area utilized standard satellite data from the United States Geological Survey, specifically LANDSAT 4-5 and LANDSAT 7 (Path-Row: 143-50, 51 & 142-51) for March, April, and December of 1997, 2008, and 2016. The spatial resolution was 30 meters, and the band combinations 1-7, 1-8 & 4-9 were employed. Data were obtained from USGS Earth Explorer.

S.No	Satellite	Sensor	Path/Row	Month & Year	Resolution
1.	LANDSAT 4-5	TM	143/50&51 ,142/50	March 1997 December 1997	30m
2.	LANDSAT-7	ETM	143/50&51 ,142/50	April 2008 December 2008	30m
3.	LANDSAT-7	ETM	143/50&51,142/50	April 2016 December 2016	30m
4.	ASTER GLOBAL DEM	SWIR	143,142&141	2016	30m

Source: United States Geological Survey.

The pre-processing of NASA LANDSAT TM, ETM data involves converting digital number (DN) values to radiance and reflectance. For Landsat-4, 5, and 7, DN values are first converted to at-sensor radiance using sensor parameters. Subsequently, at-sensor radiance is transformed into top-of-atmospheric reflectance, considering Earth-sun distance, exoatmospheric solar irradiance, and solar zenith angle. Landsat-8 OLI data is converted to top-of-atmospheric planetary reflectance using reflectance rescaling coefficients from the metadata file. This process ensures accurate representation of spectral signatures, crucial for meaningful land use and land cover analysis, with each step utilizing satellite-specific parameters and coefficients.

2.3 Pre-Processing of Satellite Data:

NASA LANDSAT TM, ETM satellites have an 8-bit radiometric resolution, storing DN values in the 0-255 range. However, DN values don't directly represent the Earth's spectral signature, influenced by sun location, satellite viewing geometry, and Earth-sun distance. To derive meaningful information, DN values are converted to radiance and reflectance.

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2.4 Supervised Classification:

Supervised classification, vital for accurate mapping, relies on image specialists' cognition. Specialists recognize classes based on prior knowledge, establishing discrete classes and assigning category names (Attieh & Tekli, 2023). Training sites, representing homogeneous areas of known land cover categories, are delineated. Mean values and variances of DNs for each band within these sites are calculated, forming spectral signatures. Classification involves statistical processing, comparing pixel signatures to assign each pixel to the closest class.

2.5 Maximum Likelihood:

The maximum likelihood classifier, a popular remote sensing classification method, assigns a pixel to the class with the highest likelihood (VENKATESWARLU & SINGH, 1995). The likelihood (Lk) is based on prior probability (P(k)) and conditional probability (P(X/k)). A multivariate normal distribution is applied, considering mean vectors (μk), variance-covariance matrices (Σk), and determinants (|Σk|). Care is needed for stable results, requiring sufficient ground truth data and managing issues like high band correlation.

2.6 Accuracy Assessment:

Quantitative assessment involves comparing remote sensing-derived and assumed true maps. Overall accuracy evaluates total area or category agreement, excluding construction errors. Site-specific assessment, based on training pixels, may be biased but offers insights. Alternatively, independent test locations can provide a more credible accuracy assessment, necessitating additional ground truth data.

Contingency tables express classification accuracy, highlighting errors of commission and omission. Kappa coefficient, a discrete multivariate technique, measures agreement statistically.

3. Results & Discussion

3.1 Land use/land cover classification

The examination of land use and land cover (LULC) in the Tirupati Revenue Division spanning a period of twenty years, from 1997 to 2016, offers significant insights into the evolving dynamics of the region following the monsoon season. The research utilizes remote sensing data and employs supervised classification techniques utilizing ERDAS Software to evaluate and classify different land cover categories.

The LULC analysis conducted in 1997 indicated that the landscape was primarily characterized by the presence of settlements, woods, barren-fallow terrain, agriculture, and water bodies. The evaluation of correctness, performed using an error matrix, revealed a comprehensive accuracy rate of 88.37%. It is worth noting that settlements demonstrated a significantly higher level of accuracy, reaching 93.83%, compared to aquatic bodies which exhibited a somewhat lower accuracy of 84.35%.

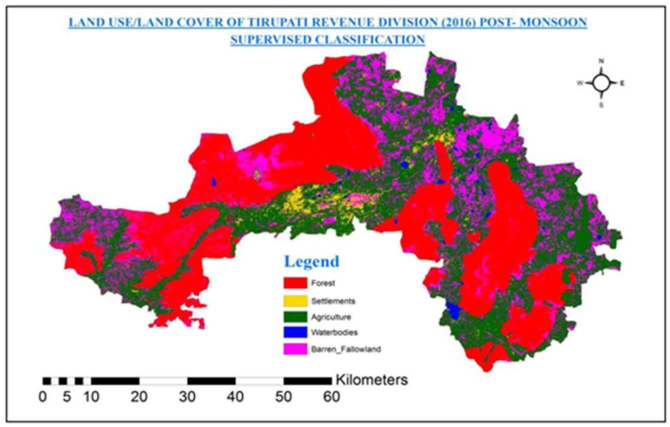

Fig.1 LULC Image of 1997 post -Monsoon

Transitioning to the year 2008, the analysis indicated notable alterations in land cover. The density of forest cover increased in the North-Western and extreme Eastern regions, but water bodies exhibited a clustering pattern in the central area. The field of agriculture had a consistent trend, with an observable increase in the extent of barren-fallow land, notably in regions characterized by rocky terrain. The results of the accuracy assessment demonstrated a notable overall accuracy rate of 90.52%. Additionally, the producer's accuracy for forest and settlements were found to be strong, with rates of 95.33% and 93.33% respectively.

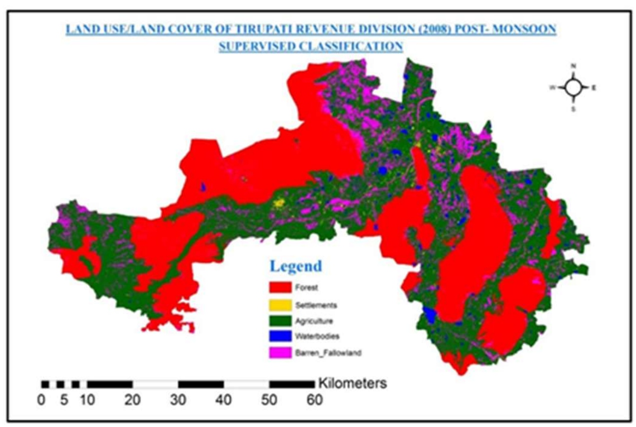

Fig. 2 LULC Image of 2008 Post-Monsoon

The year 2016 witnessed a substantial expansion of settlements in the southern region, particularly in the metropolitan centers of Tirupati and Srikalahasti, where notable increase was observed. The forest cover exhibited resilience, while formerly unproductive fallow area became more noticeable. The agricultural sector demonstrated a high level of concentration in the South-East region, whereas water bodies displayed a significant extent of distribution. The accuracy evaluation conducted in 2016 revealed a commendable overall accuracy rate of 94.54%.

Notably, the assessment indicated high levels of accuracy for barren-fallow terrain (97.76%) and settlements (96.84%).

The comprehensive investigation of Land Use/Land Cover (LULC) in the Tirupati Revenue Division, conducted over a period of two decades from 1997 to 2016, has unveiled noteworthy patterns in the post-monsoon seasons. The presence of significant growth in urban settlements, particularly in Tirupati urban, Srikalahasti, and Tirumala, highlights the impact of commercial and educational forces on the expansion of built-up regions.

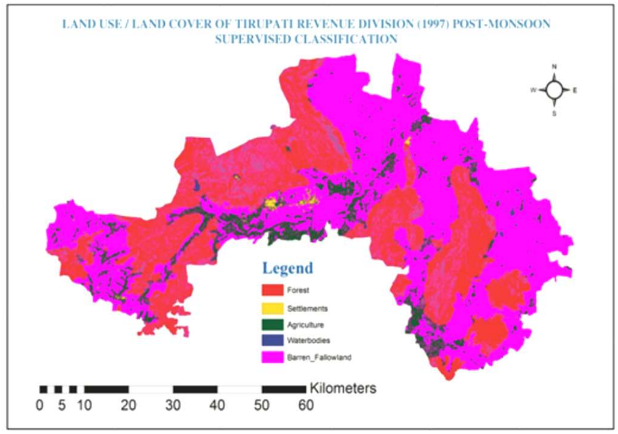

Fig. 3 LULC Image of 2016 Post-Monsoon

Simultaneously, the analysis reveals a decrease in the surface area of water bodies, influenced by the processes of urbanization and encroachment. These changes exhibit significant disparities that can be related to variances in regional rainfall patterns. The area of barren-fallow lands exhibited significant expansion, increasing from 301.92 square kilometers in 1997 to 731.6 square kilometers in 2016. Conversely, agricultural lands had a favorable transformation, particularly in the cultivation of Kharif crops, with a decline from 1615.98 square kilometers in 1997 to 1336.49 square kilometers in 2016. The forest cover demonstrated a downward trajectory, with a decrease from 1655.67 square kilometers in 1997 to 1474.65 square kilometers in 2016. This study expands upon its examination of the land use and land cover (LULC) patterns during the pre-monsoon period, with a particular focus on the ever-changing nature of the region's terrain and its ability to adapt to seasonal fluctuations.

S.No	Class Name	Year1997 Area (Sq Km)	Year 2008 Area (Sq Km)	Year 2016 Area (Sq Km)
1	Settlements	21.89	36.33	85.35
2	Forest	1655.67	1567.11	1474.65
3	Barren-Fallow land	301.92	410.71	731.60
4	Agriculture	1615.98	1585.51	1336.49
5	Water bodies	71.90	67.70	39.27

Table 3.1: Area extent of LULC for the years of 1997, 2008 and 2016 post monsoon

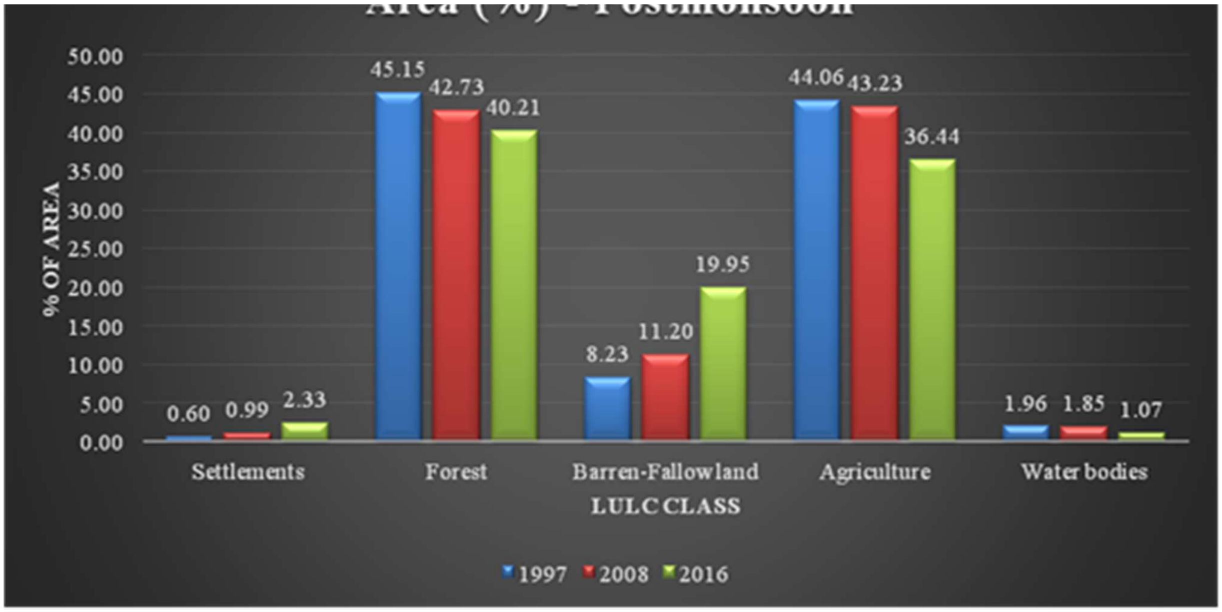

Fig .4 LULC Distribution of the study area in Post Monsoon

The use of remote sensing and satellite data to analyze the transformation of land use and land cover over a certain time frame has been widely recognized as a valuable tool in delivering relevant and reliable information for decision-making support systems in the field of natural resource management. The alteration of landscape is mostly driven by land use and land cover.

Numerous strategies for detecting land use and land cover (LULC) changes have been developed over several decades. The current research on change detection analysis is conducted throughout two distinct seasons, namely the Pre-monsoon and Post-monsoon periods. The analysis focuses on identifying and examining changes that have taken place during the timeframes of 1997 to 2008, 2008 to 2016, and 1997 to 2016.

An Analysis of Change Detection in Land Use and Land CoverThe use of remote sensing and satellite data to analyze the transformation of land use and land cover over a certain time frame has been widely recognized as a valuable tool for supplying pertinent information to diverse decision-making support systems in the field of natural resource management. The alteration of landscape is mostly driven by land use and land cover.

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The period of change detection analysis was divided into three parts based on change characteristics; the first and second parts covers a period of 10 years (1997-2008 and 2008-2016) while the second part covers a period of 20 years 1997-2016. The changes in the LULC pattern have been identified by using multi-temporal Landsat satellite images of 1997, 2008 and 2016 on a GIS based platform.

3.2 1997 to 2008 post monsoon change detection

The study conducted a comprehensive analysis of change detection over three distinct time periods (1997-2008, 2008-2016, and 1997-2016) within a study area spanning 3667.36 square kilometers. To identify transformations in Land Use and Land Cover (LULC), a Geographic Information System (GIS) platform was utilized, employing multi-temporal Landsat satellite images from 1997, 2008, and 2016. Significantly, an analysis of the period from 1997 to 2008 reveals the presence of adverse developments in the domains of Agriculture, Forest, and Water Bodies. The area of agricultural land had a decrease from 1615.98 square kilometers in 1997 to 1585.51 square kilometers in 2008. Simultaneously, the geographical area occupied by human settlements saw a notable increase from 21.89 square kilometers in 1970 to 36.33 square kilometers in 2008. This expansion was mostly centered in the regions of Tirupati and Srikalahasti, which together accounted for 0.4% of the overall land area by the year 2008. The upper north and south-east regions had a 3% increase in barren/fallow land, whilst forest areas in the same regions suffered a reduction of 2.5%. This shift has had an influence on the Seshachalam and Eastern Ghats forests. The reduction in surface water areas had a negative impact on the development of plants, leading to a decline of 0.8% in agricultural output by the year 2008.

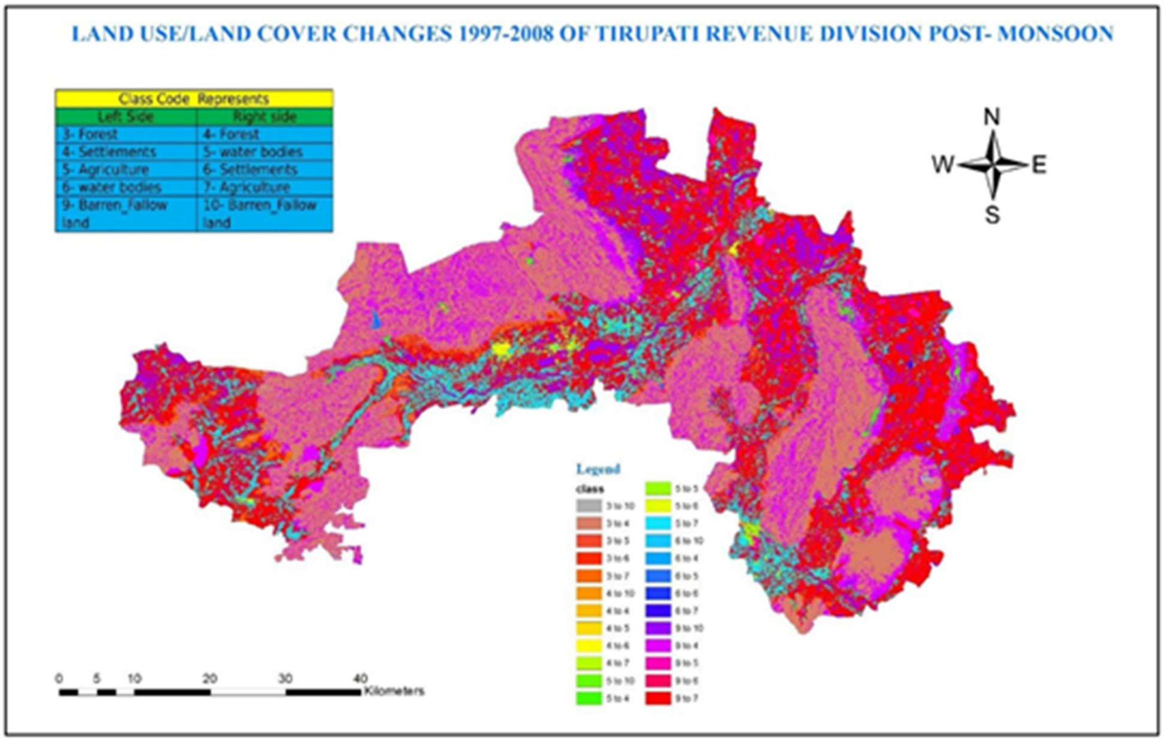
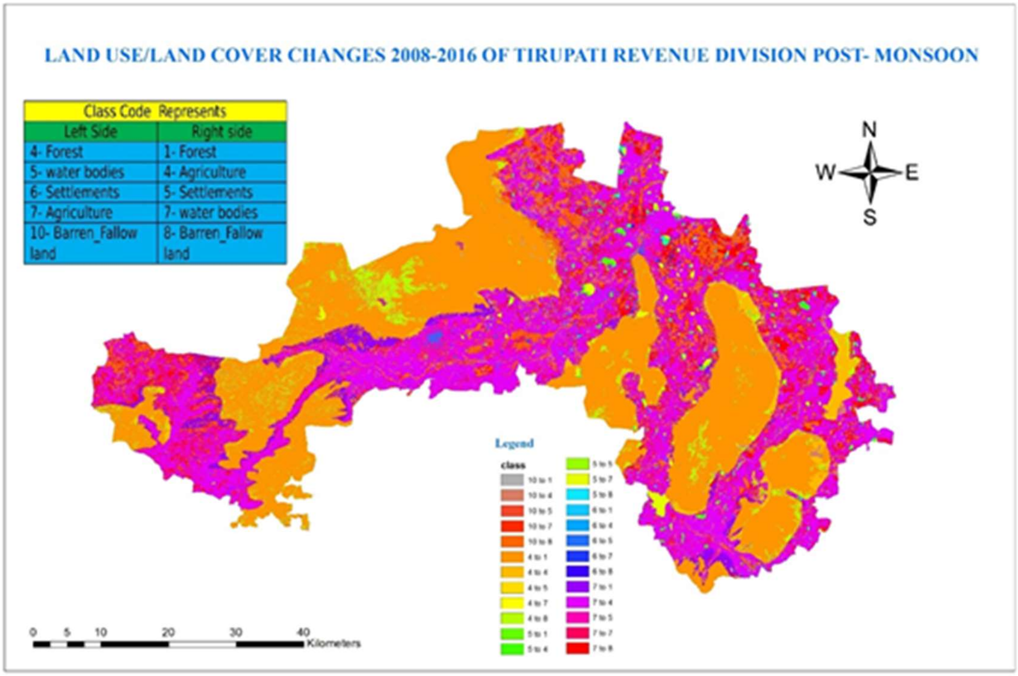


Fig. 5 Change detection Image of 1997-2008 Post-Monsoon

3.3. 2008 to 2016 post monsoon change detection

During the period from 2008 to 2016, a change detection analysis was conducted within a study area of 3667.36 square kilometers. This analysis revealed significant negative changes in the land use and land cover (LULC) categories of Agriculture, Forest, and Water Bodies. According to the derived satellite imagery data, there was a decrease in the extent of agricultural land from 1585.51 square kilometers in 2008 to 1336.49 square kilometers in 2016. Simultaneously, there was a notable rise in settlement areas from 36.33 sq. km. in 2008 to 85.35 sq. km. in 2016. This development was mostly seen in the urban regions of Tirupathi and Srikalahasti, resulting in a 1.3% growth in settlement areas by 2016. The upper north and south-east regions had a notable increase of 8.75% in barren/fallow land, but forest areas in the same regions suffered a reduction of 2.52%. This shift had a significant influence on the Seshachalam and Eastern Ghats forests. The reduction in surface water areas had a negative impact on the development of plants, leading to a significant decline of 6.8% in agricultural production by the



year 2016. The aforementioned results highlight the dynamic characteristics of land use and land cover (LULC) patterns and their consequential effects on the overall landscape.

Fig. 6 Change detection Image of 2008-2016 Post-Monsoon

3.4 1997 to 2016 post monsoon change detection

In the extensive 1997-2016 change detection analysis within the 3667.36 sq. km. study area, discernible negative shifts were identified in Agriculture, Forest, and Water Bodies LULC categories. Satellite imagery calculations revealed a substantial decrease in agricultural land, from 1615.98 sq. km. in 1997 to 1336.49 sq. km. in 2016. Simultaneously, settlements witnessed a noteworthy increase from 21.89 sq. km. in 1997 to 85.35 sq. km. in 2016, with prominent urban expansion observed in Tirupathi and Srikalahasti areas, constituting a 1.73% rise in settlement areas by 2016. Barren/fallow land exhibited a positive change of 11.72%, while forest areas experienced a decline of 5% in the upper north and south-east regions, encompassing Seshachalam and Eastern Ghats forests. Diminished surface water areas negatively impacted vegetation growth, leading to a considerable 7.62% decrease in agriculture by 2016. These findings underscore the dynamic and transformative nature of Land Use and Land Cover patterns over the examined period.

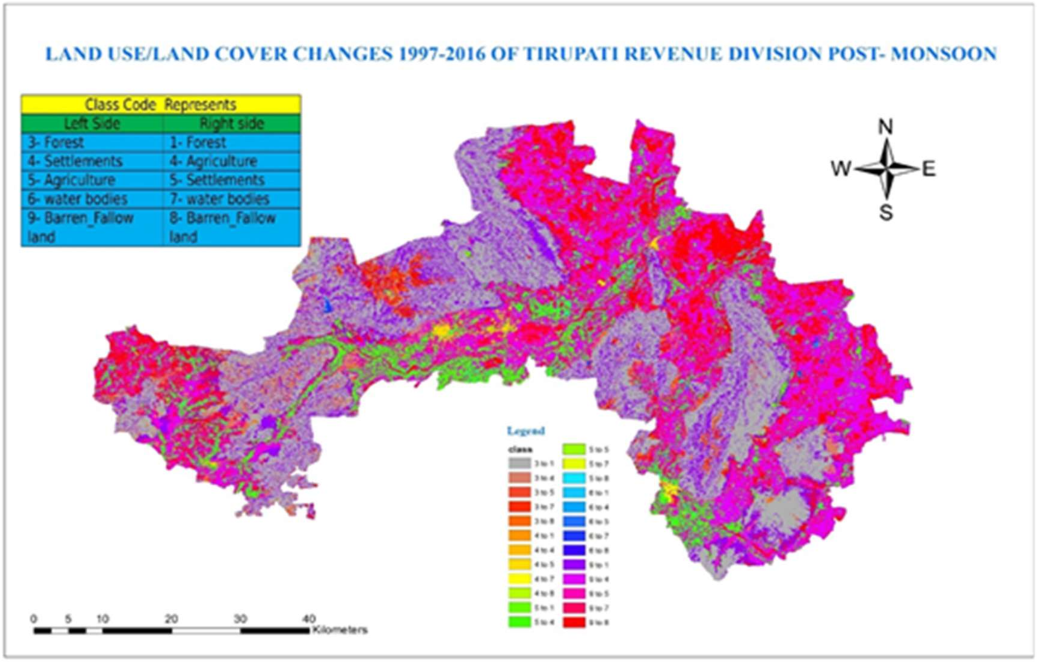


Fig. 7 Change detection Image of 1997-2016 Post-Monsoon

LULC categories	**Area covered (Sq.km) in 2008**	**% of Area in 2008**	**Area covered (Sq.km) in 2016**	**% of Area in 2016**	**Change**	
Agriculture	1585.51	43.23	1336.49	36.44	-6.79	-ve
Barren_Fallowland	410.71	11.20	731.60	19.95	8.75	+ve
Forest	1567.11	42.73	1474.64	40.21	-2.52	-ve
Settlements	36.33	0.99	85.35	2.33	1.34	+ve
Water bodies	67.70	1.85	39.28	1.07	-0.77	-ve
Grand Total	3667.36	100	3667.36	100	-	-

Table 3.2: Post-monsoon Change Analysis 1997-2016

4. Conclusion:

The location under consideration is the Tirupati Revenue Division, situated in the Chittoor district of Andhra Pradesh. Tirupati, renowned as the spiritual capital of Andhra Pradesh, is a temple town that attracts a significant number of pilgrims, making it one of the most visited destinations globally. Moreover, it is seeing rapid growth within the Tirupati revenue division due to a notable influx of individuals migrating to the city. The factors contributing to the population expansion and urbanization in the adjacent areas of Chandragiri, Renigunta, Tirupati urban, and Tirupati rural are as follows. Srikalahasti, renowned for its Lord Shiva temple and commonly referred to as Dhakshina Khasi, has played a significant role in the population growth and urban development of Yerpedu, Thottambedu, and K.V.B Puram, in addition to Srikalahasti itself. Hence, the aforementioned factors are contributing to the transformation of urban environments, including agricultural land, forests, and barren-fallow land, into developed areas for human populations. The conversion of agricultural land into barren-fallow land and forest land, as well as the transformation of water bodies into agricultural land, may be attributed to various factors in this region. One such factor is the real estate boom, which has led to the effective usage and extensive exploitation of groundwater resources. Additionally, the encroachment of land has played a significant role in this process. In addition to the aforementioned industrial corridor in the region, such as Sri City SEZ and industrial estates like Renigunta and Srikalahasti, another contributing element to the development of agriculture and the conversion of barren or fallow land is observed. This study suggested that satellite data possesses a distinct capability to swiftly and accurately discern alterations in land use.

5. References

VENKATESWARLU, N. B., & SINGH, R. P. (1995, January). A fast maximum likelihood classifier. *International Journal of Remote Sensing*, *16*(2), 313–320. https://doi.org/10.1080/01431169508954397

Attieh, J., & Tekli, J. (2023, February). Supervised term-category feature weighting for improved text classification. *Knowledge-Based Systems*, *261*, 110215. https://doi.org/10.1016/j.knosys.2022.110215

Koranteng, A. (2021, October 6). Multi-Temporal Study of Land Use Land Cover Changes. *International Journal of Environmental Sciences & Natural Resources*, *29*(1). https://doi.org/10.19080/ijesnr.2021.29.556254

Caillault, S., & Marie, M. (2023, April). Is a village level always relevant to describe land cover changes? Analysing the landscape to understand socio-environmental changes in western Burkina Faso. *Land Use Policy*, *127*, 106569. https://doi.org/10.1016/j.landusepol.2023.106569

Analysis of Land Use/Land Cover Change in Jammu District Using Geospatial Techniques. (2015, November 5). *International Journal of Science and Research (IJSR)*, *4*(11), 769–773. https://doi.org/10.21275/v4i11.nov151136

Martínez, S., & Mollicone, D. (2012, April 17). From Land Cover to Land Use: A Methodology to Assess Land Use from Remote Sensing Data. *Remote Sensing*, *4*(4), 1024–1045. https://doi.org/10.3390/rs4041024

Extraction of Road Segments from High Resolution Satellite Images using Wavelets and Watersheds. (2018, May 21). *International Journal of Recent Trends in Engineering and Research*, *4*(5), 48–56. https://doi.org/10.23883/ijrter.2018.4289.hxgua

Gaur, S., & Singh, R. (2023, January 4). A Comprehensive Review on Land Use/Land Cover (LULC) Change Modeling for Urban Development: Current Status and Future Prospects. *Sustainability*, *15*(2), 903. https://doi.org/10.3390/su15020903