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Environmental implications of Spatio-Temporal Dynamics of Land use Land Cover of East Godavari District

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Abstract-With the fleeting and profound transformations currently occurring in this planet, one of the crucial issues to be contemplated is the availability and limitations of resources in meeting the human demands. Land use and Land cover (LULC) change is a multiplex occurrence which is affected by various social, economic, and environmental factors. The framework of this study approaches the exploration of the diverse dynamics of land use and land cover change in East Godavari district of Andhra Pradesh for two decades, i.e. 2004-2024. Utilizing multi spectral and multi temporal satellite imagery, image pre-processing and supervised classification of LULC change in the East Godavari region have been carried out. The classification consists of six LULC classes: build-up area, agricultural land, water bodies, forest, barren land and sand. An accuracy assessment for the classification has been performed. The result of this study demonstrates the increase and decrease in build-up areas, agricultural land, water bodies, forest and barren land for the years 2004, 2014 and 2024.Changes in build-up area for the major cities of East Godavari, i.e. Kakinada, Rajahmundry, and Amalapuram have been demonstrated. An increase in built-up area leads to the development of urban heat islands, an increase in surface runoff, and flash floods. A decrease in greenery and forest cover reduces the ecological balance and impacts biodiversity. Land cover and land use change impart information on anthropogenic, climatic, and environmental conditions, which is crucial for sustainable land management and helps us make strategic decisions for the betterment of this planet.

Keywords **:** Land use Land cover, Supervised classification, Accuracy assessment, Satellite imagery, Change detection

1. INTRODUCTION

The Earth's surface is constantly undergoing changes in land use and land cover, driven by human activities and natural processes. These spatio-temporal dynamics have significant environmental implications, affecting ecosystems, biodiversity, water resources, climate patterns, and socio-economic systems. Understanding and managing these implications is crucial for achieving sustainable development and preserving the planet's ecological integrity. One of the primary environmental implications of land use and land cover changes is the disruption of ecosystems. (Fei Yuan et al. 2005, Dharani, M et al 2019). Conversion of natural habitats for agriculture, urbanization, or industrial activities leads to habitat fragmentation, isolating species populations, and disrupting ecological processes. Fragmentation reduces biodiversity and ecosystem resilience, making ecosystems more vulnerable to environmental stressors and increasing the risk of species extinction. Land use changes often result in the loss of biodiversity, as natural habitats are replaced with monoculture crops, urban infrastructure, or other human-dominated landscapes. This loss of biodiversity not only affects individual species but also entire ecosystems and the services they provide. Reduced biodiversity can impair ecosystem functioning, decrease ecosystem resilience, and disrupt the balance of ecological interactions. (Jieying Xiao et al, 2006, Kogo, B.K et al, 2021) Changes in land use and land cover have profound effects on water resources. Deforestation, urbanization, and agricultural expansion can alter the hydrological cycle, leading to changes in surface runoff, groundwater recharge, and water quality. Deforested areas are more prone to soil erosion and sedimentation of water bodies, while urban areas increase impervious surfaces, reducing infiltration and increasing surface runoff. These changes can exacerbate flooding, water pollution, and shortages, impacting both human communities and aquatic ecosystems. (Jin S. Deng et al, 2009, Kiranmai, S.V et al, 2020)

Land use and land cover changes are both drivers and consequences of climate change. Deforestation, for example, contributes to greenhouse gas emissions by releasing stored carbon into the atmosphere. Conversely, changes in climate patterns, such as temperature and precipitation, can influence land use decisions, such as agricultural practices or the expansion of urban areas. Climate change exacerbates existing environmental pressures, making ecosystems more vulnerable to disturbances and increasing the frequency and intensity of extreme weather events. (Xinchang Zhang et al, 2010, Da Silva, V.S. et al, 2020)

Unsustainable land use practices, such as intensive agriculture or deforestation, can lead to soil degradation. Soil erosion, salinization, and loss of soil fertility are common consequences of land use changes, reducing agricultural productivity and impairing ecosystem functioning. Soil degradation not only affects food security and livelihoods but also contributes to environmental problems such as sedimentation of water bodies and loss of carbon sequestration potential. (Divine Odame Appiah et al, 2015, Shao, Z. et al, 2021)

Land use and land cover changes also have socio-economic implications, impacting local communities' livelihoods, cultural values, and socio-economic well-being. Traditional land management practices and cultural landscapes are often lost or degraded due to changes in land use, affecting community identity and heritage. Moreover, environmental degradation resulting from land use changes can exacerbate social inequalities and undermine sustainable development efforts. (Md.Surabuddin Mondal et al, 2015, Dash, P.P et al, 2015)

Addressing these implications requires integrated approaches that balance human needs with environmental conservation and sustainability goals. Sustainable land management practices, conservation strategies, and policy interventions are essential for mitigating the adverse effects of land use changes and promoting the long-term health and resilience of ecosystems and communities. (M. Alkan et al, 2013, Haque, A et al, 2008)

By providing this background information, researchers and policymakers can gain insights into the dynamics of barren lands in East Godavari and develop effective strategies for land use planning, conservation, and sustainable development in the region. Causes of Barren Lands The factors contributing to the formation and expansion of barren lands in East Godavari include natural processes like soil erosion, geological features, climatic conditions (such as low rainfall in certain areas), and anthropogenic activities like deforestation, overgrazing, and improper land management practices.(Milton O. Smith et al, 1995, Strohschon, R et al, 2013)

This information provides a general overview of the LULC in East Godavari, highlighting its agricultural, forest, buildup area, sand, water bodies and barren land etc. Urbanization is the primary driver of land use change in East Godavari, leading to the conversion of agricultural and natural land covers. Climate change influences land use patterns in East Godavari, resulting in shifts in vegetation cover and water availability. Land use changes in coastal areas of East Godavari are influenced by factors such as sea level rise, erosion, and saltwater intrusion. Implementation of land management policies and conservation measures has a positive impact on reducing land degradation in East Godavari. Community-based natural resource management practices contribute to sustainable land use and livelihoods in rural areas of East Godavari. (K. Sundara Kumar et al, 2012, Vivekananda, G.N. et al, 2021)

The research methods and design for studying the LULC of East Godavari district using satellite imagery typically involve several key steps. Data Acquisition: Obtain high-resolution satellite imagery from sources like Landsat, Sentinel, or other remote sensing platforms. Ensure the imagery covers the entire extent of East Godavari district and captures multiple spectral bands (e.g., visible, near-infrared and thermal). Pre-processing: Pre-process the satellite imagery to correct for radiometric distortions, atmospheric effects, and sensor artifacts. This step is crucial for ensuring accurate and reliable LULC classification. (K. Sundara Kumar et al, 2015, Vishwakarma, C.A. et al, 2016)

Image Enhancement: Apply image enhancement techniques to improve the visual quality and interpretability of the satellite imagery, such as contrast stretching, histogram equalization, and sharpening filters. Image Classification: Use supervised or unsupervised classification algorithms to categorize pixels in the satellite imagery into different land cover classes (e.g., water bodies, agricultural land, urban areas, forests, barren land) based on their spectral signatures. ERADS imagery enhances the spectral information, making classification more accurate. Accuracy Assessment: Conduct an accuracy assessment of the LULC classification results by comparing them with ground truth data or high-resolution imagery. Use metrics like overall accuracy, producer's accuracy, user's accuracy, and kappa coefficient to evaluate the classification performance. (K. Sundara Kumar et al, 2015, Alexander, C et al, 2020)

Change Detection If studying land use changes over time, perform change detection analysis by comparing LULC classifications from multiple time periods. Identify areas of land cover change, such as urban expansion, deforestation, agricultural encroachment, or degradation of natural habitats. (K. Sundara Kumar et al, 2016, Arveti, N et al, 2016)

2. STUDY AREA

East Godavari district is one of the richest district of Andhra Pradesh situated in the Southern part of India. It is located between latitude 16°30’00” N and 18°00’00” N and longitude 81°30’00” E and 82°30’00” E. The district is bordered by Bay of Bengal and the Godavari River flows through the heart of the district. It covers an area of approximately 10807 square kilometre. The study area selected is shown in the following Figure 1.

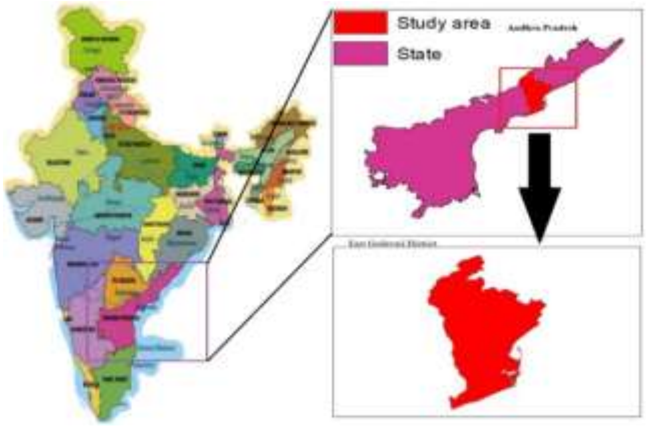

Fig. 1: Study area

The East Godavari district in Andhra Pradesh, India, has a varied land use and land cover (LULC), encompassing urban regions, forests, aquatic bodies, agricultural land, and barren territory, among other features. Rich in agricultural terrain, East Godavari is well-known for its significant cultivation of rice, sugarcane, coconut, and pulses. There is a substantial amount of forest cover in the district, including national parks, restricted forests, and dense woods. East Godavari is traversed by several rivers and has numerous water bodies, including reservoirs and tanks, which support agriculture and provide water for domestic use.

Coming to Build-up area the district also has urban areas like Rajahmundry, Kakinada, and Amalapuram, which are centers of commerce, education, and administration. Studying the LULC of barren land in East Godavari is crucial for understanding land degradation processes, implementing sustainable land management practices, conserving natural resources, and promoting ecosystem resilience in the face of environmental changes and human activities.

3. METHODOLOGY

This study includes the collection of satellite imagery, pre-processing of image, mosaicing of image, Geo-referencing, Extraction of AOI, Supervised classification and Accuracy Assessment and finally change detection analysis of the classified images.

The methodology adopted in this research work is shown in the following Figure 2.

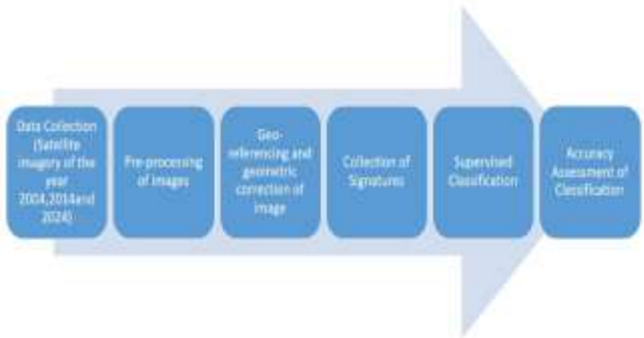

Fig. 2: Methodology adopted in this work

Data Collection

Various data for the studies are collected from Google earth, Google maps and most importantly, the satellite imagery collected from EarthExplorer.usgs.gov. The data from Google earth is shown in Figure 3.

Fig. 3: Google Earth Image

Satellite imagery for the particular years were collected according to the path and row to obtain the desired data. The path and Row are shown in Figure 4.

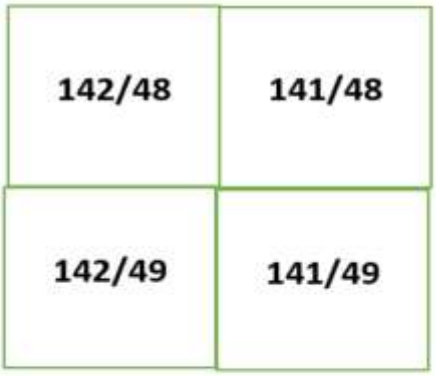

Fig. 4: Path and Rows of the satellite images covering the study area

Landsat 5 TM data is used to collect data for the year 2004, where Landsat 8 OLI/TIRS is used for the year 2014 and 2024 the satellite imagery of single band is shown in Figure 5.

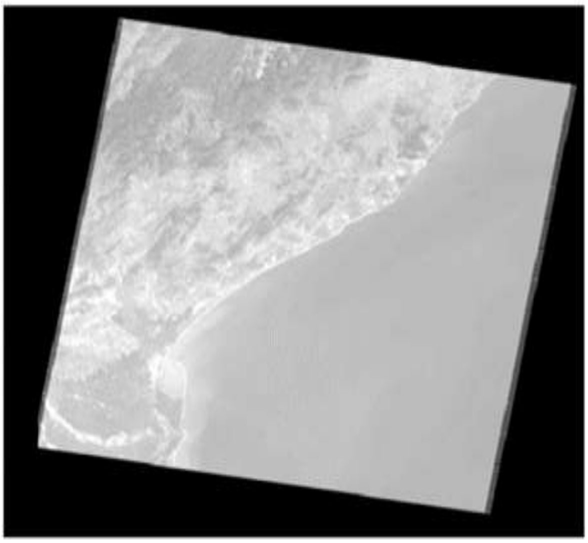

Fig. 5: Satellite imagery 141/48

Fig. 6: Layer stack image using ERDAS

Pre-processing of image

After the data collection ERDAS IMAGINE 2015 software carried out the further processing. The downloaded images are converted from TIFF format to IMAGINE format as each image contains one band different images i.e. different bands were stacked together. The stacking of band is performed from band-1 to band-7. The layer stack image is shown in Figure 6. The layer stack images are merged to form the desired image by using MOSAIC which is shown in the following Figure 7.

Geo-referencing and Geometric correction of image

To convert map coordinates to Universal Transverse Mercator using the WGS 84 coordinate system, geo-referencing and geometric image rectification are done. The area of interest (AOI) is primarily extracted using it. Rectangular AOI was retrieved for categorization in this study, while polygon AOI was used for comparison of results. The rectangular AOI image is shown in Figure 8 and the polygon AOI image showing the actual boundaries of the study area is shown in Figure 9.

Fig. 7: Mosaicked image using ERDAS

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Figure 8: Rectangular AOI

Fig. 9: Polygon AOI

Collection of Signatures

Signature collection is necessary task to carry out supervised classification. Signatures are collected from every corner of the image based on our LULC classes i.e. Build-up area, Water bodies, agricultural land, barren land, Forest and sands.

Supervised classification

Supervised classification of satellite imagery using ERDAS Imagine is a powerful technique for extracting land cover information from remote sensing data. This process involves training the software to recognize specific land cover classes based on spectral signatures and then applying this knowledge to classify the entire image. Before classification, it's essential to pre-process the satellite imagery to enhance its quality and remove any noise or distortions. This may involve geometric correction, radiometric calibration, and atmospheric correction to ensure accurate classification results. In supervised classification, training samples representing different land cover classes are selected from the satellite imagery. These samples should be representative of the spectral characteristics of each class and should cover a diverse range of conditions within each class.

ERDAS Imagine provides various supervised classification algorithms, such as Maximum Likelihood, Minimum Distance, and Spectral Angle Mapper. The chosen algorithm is trained using the selected training samples to create spectral signatures or statistical models for each land cover class. Once the classifier is trained, it is applied to the entire satellite image to classify each pixel into one of the predefined land cover classes. The classification process assigns a class label to each pixel based on its spectral similarity to the training samples. After classification, post-processing techniques may be applied to refine the results and improve accuracy. This may include filtering, smoothing, and classification aggregation to eliminate noise and inconsistencies in the classified image.

Accuracy Assessment

It's essential to assess the accuracy of the classified image to evaluate the reliability of the classification results. This is typically done by comparing the classified image with reference data or ground truth information through methods such as error matrices, confusion matrices, and accuracy indices. Accuracy assessment is accomplished to check the accuracy of the classifications of the classified classes with the real satellite image and Google earth.

4. RESULTS

In 2004 Dominant Land Use Types Agricultural land, forested areas, water bodies, urban settlements, and some areas of barren land. Spatial Distribution agricultural land is widespread, especially in rural areas. Forest cover is relatively stable, with minor changes due to human activities. Urban areas show moderate expansion. Land Use Changes limited changes observed, primarily related to urban growth and agricultural intensification some conversion of natural land covers to built-up areas noted. Drivers of Change Population growth, agricultural practices, infrastructure development, and initial signs of urbanization influence land use dynamics. The LULC image developed for the year 2004 is shown in Figure 10.

In 2014 Agricultural land continues to be dominant, urban areas expand further, forest cover remains stable or experiences slight decline, water bodies relatively unchanged.

Spatial Distribution urban areas show significant expansion, especially near major towns and transportation corridors. Agricultural intensification leads to changes in land use patterns in rural areas. Land Use Changes noticeable increase in built-up areas, conversion of agricultural land and natural habitats to urban uses, ongoing changes in water bodies due to anthropogenic activities. Rapid urbanization, population pressure, agricultural modernization, infrastructure projects, and economic development drive land use changes. The LULC image developed for the year 2004 is shown in Figure 11.

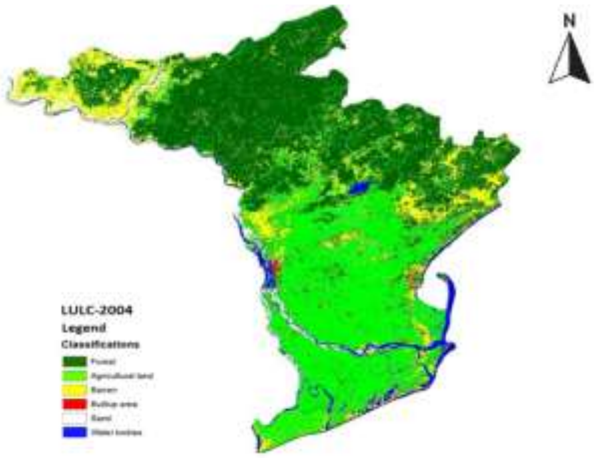

Fig. 10: Classified image of 2004

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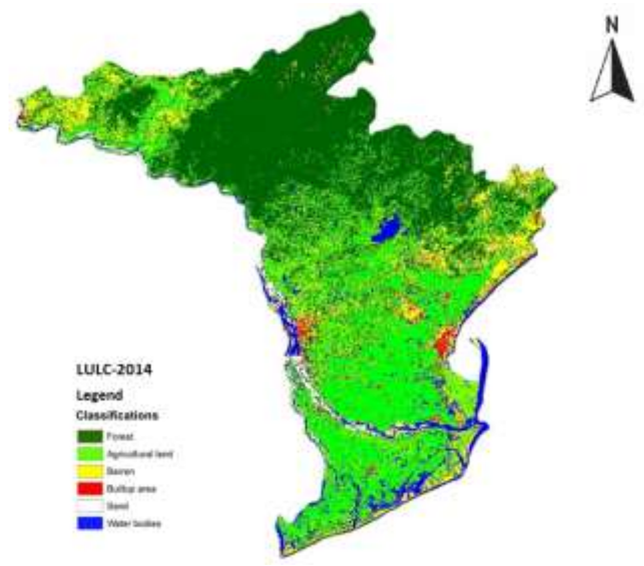

Fig. 11: Classified image of 2014

In 2024 Urban areas continue to expand, agricultural land undergoes further intensification or transformation, forest cover may experience continued decline, water bodies face ongoing pressures. Spatial Distribution urban sprawl extends into per-urban and rural areas, agricultural landscapes undergo changes in land use practices and cropping patterns, natural land covers face fragmentation and degradation. Land Use Changes continued increase in built-up areas, conversion of agricultural land and natural ecosystems to urban uses, alterations in water bodies due to human interventions and climate change impacts. Drivers of Change urban growth, economic activities, infrastructure development, land-use policies, environmental changes, and societal preferences shape land use dynamics in the district. These summaries are hypothetical and based on common trends observed in land use studies over time. Actual findings would depend on the specific research methodology, data sources, and analysis techniques used in the study of East Godavari's LULC. The LULC image developed for the year 2024 is shown in Figure 12. Area Statistics of LULC in 2004, 2014 and 2024 are presented in Table.1. Percentage change in LULC is presented in Table.2. Bar chart for comparison LULC for 2004, 2014 and 2024 in % is shown in Fig.13. LULC changes in Amalapuram, Kakinada, Rajahmundary are given in Fig 14,15,16 respectively. Water bodies changes observed in respective years in riverbanks and coastal areas was shown in Fig.17.

Table 1: Area Statistics of LULC in 2004, 2014 and 2024

S.no.	**Class name**	**Area in (km2) LULC**	
		2004	
		Area (km2)	**Area (%)**
1.	Water bodies	268.67	2.49%
2.	Build up area	876.823	8.15%
3.	Forest	6309.459	58.67%
4.	Agriculture land	2347.371	21.83%
5.	Barren Land	815.224	7.54%
6.	sand	131.399	5.22%
		2014	
		Area (km^2)	Area (%)
1.	Water bodies	409.20	3.81%
2.	Build up area	1162.92	10.8%
3.	Forest	5677.78	52.82%
4.	Agriculture land	1992.61	18.53%
5.	Barren Land	1393.27	12.96%
6.	sand	152.18	7.05%
		2024	
		Area (km^2)	Area (%)
1.	Water bodies	523.23	5.63%
2.	Build up area	1503.32	16.32%
3.	Forest	4852.56	47.87%
4.	Agriculture land	1686.02	15.98%
5.	Barren Land	1864.56	16.36%
6.	sand	170.23	9.95%

Table 2: Percentage change in LULC

S. no.	**Class name**	**Area(km^2) changed (2004-2014)**	**Area(km^2) changed (2014-2024)**	**% Change in LULC**
1.	Water bodies	140.3	114.03	(+)1.316%
2.	Build up area	286.1	340.4	(+) 2.65%
3.	Forest	-631.68	-825.22	(-) 5.85%
4.	Agriculture land	-354.76	-306.61	(-) 3.3%
5.	Barren Land	578.04	471.29	(+) 5.42%
6.	sand	18.22	22.95	(+) 2.17%

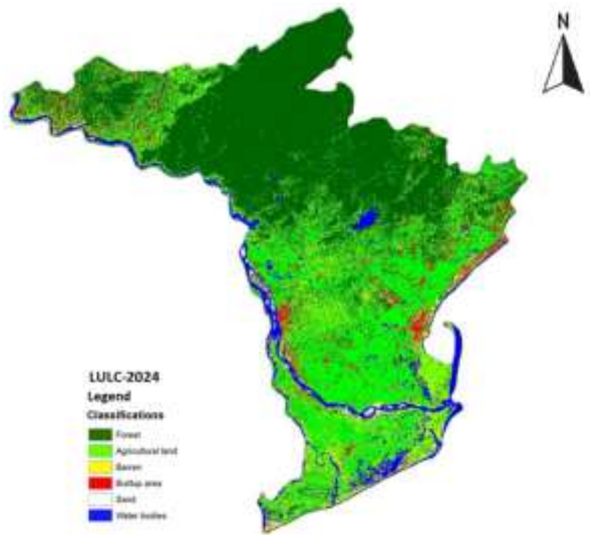

Fig. 12: Classified image of 2024

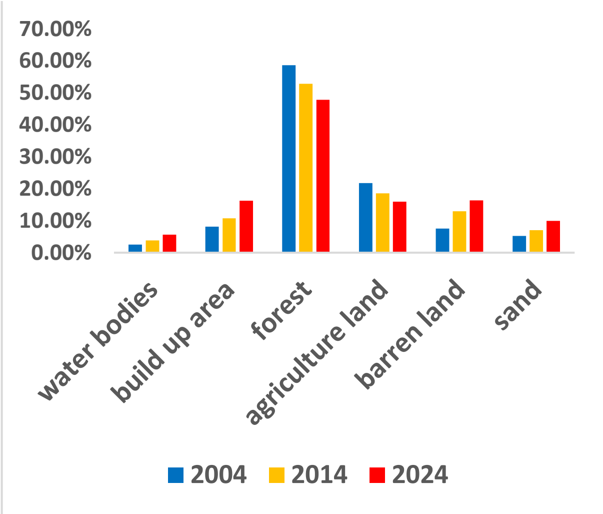

Fig. 13: Bar chart for comparison LULC for 2004, 2014 and 2024 in %

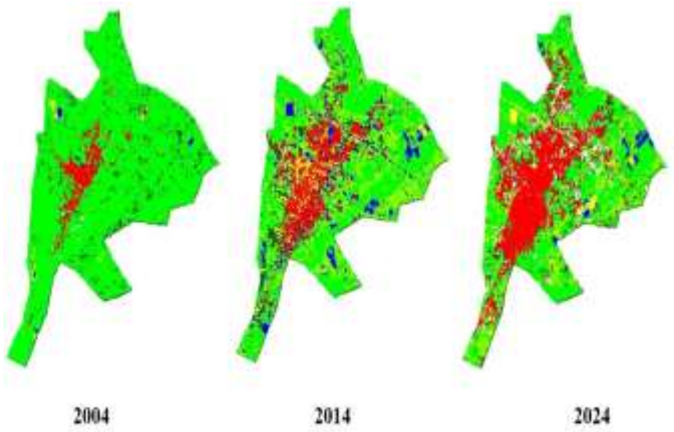

Fig. 14: LULC changes in Amalapuram

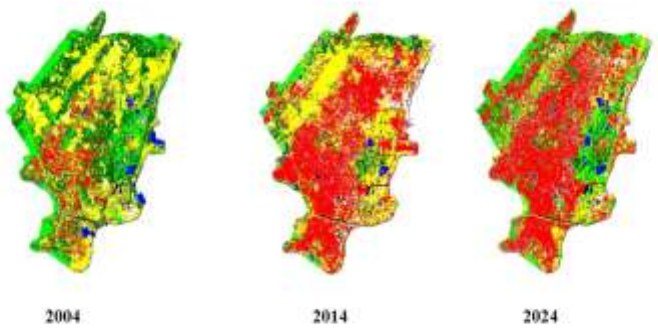

Fig. 15: LULC changes in Kakinada

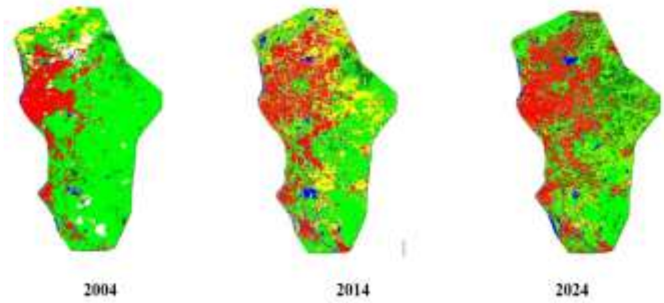

Fig. 16: LULC changes in Rajahmundary

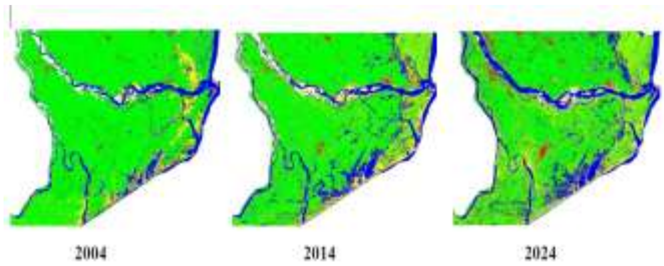

Fig. 17: Water bodies changes observed in respective years in riverbanks and coastal areas

5. DISCUSSION

Supervised classification was carried out using ERDAS in the study area. The land use land cover categories were defined and the area under each class was calculated by adding area field. Later accuracy assessment process was done with already defined class values that are re placed by the given reference values and then generates the reports where the Overall Classification Accuracy of 84%,80% and 82% for the year 2004, 2014 and 2024 along with overall kappa statistics of 0.8057, 0.7713 and 0.7703 respectively. The result obtained for water bodies, built-up area and barren land increased from 2.49 to 3.81%, 8.15to 10.8% and 7.58 to 12.96% respectively. Conversely, forest, agricultural lands and sand areas decreases from 58.7 to 52.82%, 21.83% to 18.53% and 5.22 to 7.05% respectively. Shows that the area under water bodies increased from 268.67 km2 in 2004 to 409.20km2 in 2014, to 523.23 km2 2024 representing a net gain of 140.3km2. Mostly the built-up area increase is seen in central portion of the study area and around areas of Kakinada, Rajahmundry, Amalapuram (reference). The area under forest decreased from 6309.459 km2 in 2004 to 5677.78km2 in 2014 to 4852.56 km2 2024 which represents a net decrease of 631.67 km2. The decrease in forest area is attributed to the conversion of forest area into built-up areas, such as buildings, roads, and industrial places. The area under agricultural land decreased from 2347.371 km2 in 2004 to 1992.61 km2 in 2014 to 1686.02 km2 in 2024 which represent a net decrease of 354.76 km2. Farmers have been abandoning farming and demonstrating interest in other industries or industrial lab our which has resulted in the growth of barren land/other land even though some barren land was converted into habitation and farmland. We have observed a gross change in water bodies in this area due to increase aquaculture, most of this change are observed in the bank of river and coastal areas.

Significant changes in the water bodies around the riverbanks and coastal areas are observed in the past decades and increment is observed. In the past decades in the year 2004 it covers 268.67 km2 to 409.20 km2 in 2014 further 523.23 km2 in the year 2024 with increased percent of 2.49% to 5.63% in the past two decades.

6. CONCLUSIONS

Most significant changes are observed in the barren land and built-up area category. Mostly built-up area is increased around the portions of major cities over the two decades due to increase in population. In view of LULC analysis of Landsat data for the year 2004, 2014 and 2024, it was observed that the LULC change patterns shifted fundamentally during the periods referenced above. The results showed that most of the forest and agricultural land converted into built-up areas. The forest land was decreased from 58.67% in 2004 to 52.82% in 2014 and 47.87% in 2024 because of an increase in population to meet their demand for agricultural land was also decreased from 21.83% in 2004 to 18.53% in 2014 and 15.98% in 2024 because of the conversion of agricultural land to aquaculture land by farmers for more economical activities. On the other hand, the built-up area was increased from 8.15% to 10.8% to 16.32%. As the changes in LULC highly influenced by human activities and natural processes it is very critical to observe these changes. Through this study the findings illustrate how important it is to be updated about LULC changes to understand the effect that might have on biodiversity, ecosystems and mankind. Concerns regarding habitat fragmentation, biodiversity loss, and potential effects on ecosystems are raised by LULC changes. The information gained through this study is valuable for natural resource management, environmental conservation, and sustainable planning. The LULC changes must be tracked continuously and managed efficiently to maintain environmental integrity while meeting the demands for land resources to reduce the negative effects for the present and future generations.

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