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Temporal Analysis of Land Use and Land Cover Changes in Vizianagaram District, Andhra Pradesh, India using Remote Sensing and GIS Techniques

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Abstract

Land use and land cover change (LULCC) has become a significant global concern due to its wide-ranging environmental, social and economic impacts. This literature review aims to provide a comprehensive overview of the key ideas, drivers, consequences and approaches to studying LULCC. By synthesizing various research articles, this review offers insights into the causes and impacts of LULCC, as well as the methods used to analyze and monitor these changes. The review also highlights the importance of understanding LULCC dynamics for sustainable land management and policy making. Between 2017 and 2022, the LULC categories underwent several changes. Data acquisition process for satellite imagery combining Sentinel-2 digital remote sensing data digital remote sensing data through the Copernicus Open Access Hub. The spectral resolution is 10, 20, and 30 meters respectively, while the spatial resolution is 10 meters which was used for the LULC analysis of the study area. This analysis underscores the importance of LULCC monitoring to inform sustainable land management practices and conservation efforts. The trends identified provide a basis for further investigation into the underlying drivers of these changes and their potential impacts on ecosystems, water resources and human well-being. Continued monitoring and proactive measures are essential to mitigate adverse impacts and promote sustainable land use in the future.

1. Introduction

Land use and land cover changes (LULCC) refer to the transformation of the Earth's surface due to human activities, which change the physical and biological appearances of the land. These changes encompass various processes such as deforestation, urbanization, agricultural expansion, industrialization, and infrastructure development (Aneesha Satya et al., 2020; Krishna & Reddy, 2017; Reddy et al., 2019; Singh et al., 2019). LULCC is a global phenomenon that has profound implications for the environment, society, and economy. The significance of studying LULCC lies in its far-reaching impacts on both natural and human systems. Understanding the drivers, consequences, and patterns of LULCC is crucial for effective land management, conservation, and sustainable development (Pattanaik et al., 2011).

Environmental Implications: LULCC significantly affects ecosystems, biodiversity, and natural resources. Deforestation and habitat fragmentation, for example, lead to the loss of species and disruption of ecological processes. Changes in land cover also impact carbon sequestration, water resources, soil quality, and climate regulation, contributing to global environmental encounters for instance climate change and loss of ecosystem services (Kandrika & Roy, 2008).

Social and Economic Impacts: LULCC directly influences human societies and economies. Urbanization and industrialization drive economic growth but often result in land degradation, pollution, and social inequalities. Changes in land use can displace communities, trigger land conflicts, and affect traditional livelihoods, thereby impacting social stability and human well-being (Kandrika & Roy, 2008; Sethi et al., 2014). Understanding these social and economic consequences is crucial for equitable and sustainable development.

Policy and Decision-Making: LULCC research provides valuable insights for policymakers, land managers, and urban planners. Comprehensive understanding of the drivers and consequences of LULCC can inform the formulation of land-use policies, zoning regulations, and resource management strategies. By integrating scientific knowledge and evidence-based approaches, decision-makers can address environmental and socio-economic challenges, promote sustainable land use practices, and mitigate the negative influences of LULCC (Buyadi et al., 2014; Kandrika & Roy, 2008; Langat et al., 2021; Sethi et al., 2014; Srivastava et al., 2020).

Climate Change Mitigation and Adaptation: LULCC play a significant role in climate change mitigation and adaptation. Forest conservation and restoration efforts, for instance, contribute to carbon sequestration and the decrease of greenhouse gas releases (Sudhakar et al., 2006). Recognizing the potential of land-based solutions is essential for achieving climate goals and enhancing resilience to climate change impacts.

Conservation and Biodiversity Protection: LULCC research contributes to the conservation and protection of biodiversity and ecosystems. Identifying areas of high ecological value, understanding habitat connectivity, and assessing the impacts of LULC decisions on biodiversity are critical for prioritizing conservation efforts and designing effective protected area networks (Cihlar & Jansen, 2001; Jaiswal et al., 1999; Yadav et al., 2012). The importance of studying the LULCC in India cannot be overstated due to the country's unique socio-economic and environmental context. Here are some key reasons why studying LULCC in India is crucial:

Rapid Urbanization: India is undergoing significant urbanization, with a rapidly growing population and increasing migration from rural to urban areas. This urban expansion leads to the conversion of agricultural land and natural habitats into built-up areas, impacting ecosystems, water resources, and biodiversity (Jiang & Tian, 2010; Wolch et al., 2014). Understanding the patterns and consequences of urbanization is vital for sustainable urban planning, resource management, and mitigating the associated environmental and social challenges.

Agricultural Expansion and Intensification: Agriculture is a vital sector for India's economy and sustenance of its large population. However, the expansion and intensification of agriculture, driven by factors such as population growth and changing consumption patterns, result in the conversion of forests, grasslands, and wetlands into agricultural lands (Areendran et al., 2013). Studying LULCC related to agriculture helps identify sustainable farming practices, balance food security with environmental conservation, and address issues such as soil erosion, water scarcity, and pesticide use.

Forest Conservation and Biodiversity: India is home to diverse and ecologically significant forest ecosystems, including tropical rainforests, mangroves, and dry deciduous forests. LULCC studies play a crucial role in monitoring deforestation rates, identifying areas of high biodiversity value, and understanding the drivers of forest loss, such as logging, encroachment, and infrastructure development (Butt et al., 2015). This knowledge supports conservation efforts, restoration initiatives, and the protection of endangered species and their habitats.

Water Resource Management: India faces significant challenges related to water scarcity, pollution, and unsustainable water management practices. LULCC studies provide insights into land cover changes affecting watersheds, rivers, and aquifers. Understanding the impacts of LULCC on water availability, quality, and hydrological processes helps inform water resource management strategies, groundwater recharge initiatives, and sustainable irrigation practices (Rajasekhar et al., 2019; Rajasekhar et al., 2020).

Climate Change Adaptation and Mitigation: India is vulnerable to the impacts of climate change, including increased frequency and intensity of extreme weather events, rising temperatures, and changing rainfall patterns. LULCC research is essential for assessing the contribution of land-based activities to greenhouse gas emissions, identifying carbon sinks, and developing climate change adaptation strategies. Sustainable land management practices, such as afforestation, agroforestry, and sustainable land-use planning, can play a crucial role in climate change mitigation and adaptation (Kudnar & Rajasekhar, 2019; Pradesh, 2018; Rajasekhar et al., 2019; Rajasekhar, 2019; Siddi Raju et al., 2018).

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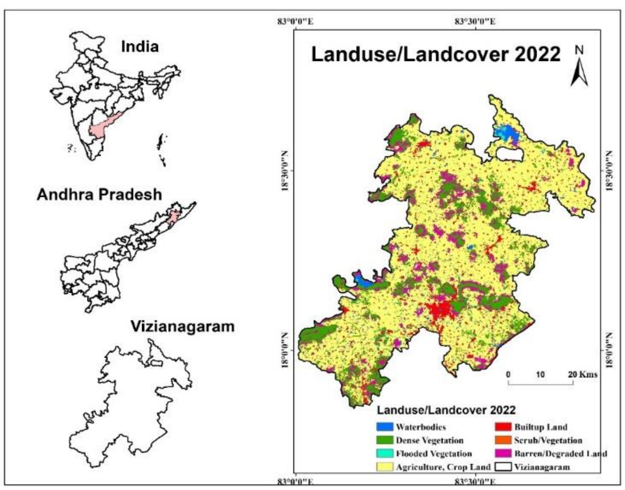
Policy Formulation and Planning: Comprehensive studies on LULCC provide valuable inputs for policy formulation and planning processes. Evidence-based research helps policymakers understand the drivers and consequences of land-use changes, assess the effectiveness of existing policies, and design strategies to promote sustainable land use practices (Rajasekhar et al., 2018; Rajasekhar et al., 2019; Rajasekhar et al., 2019). This includes formulating land-use zoning regulations, protecting ecologically sensitive areas, and integrating socio-environmental considerations into urban and regional planning.

The LULCC research in India is essential for addressing urgent environmental, social, and economic issues. India can develop and implement effective policies and strategies that promote sustainable development, safeguard biodiversity, ensure water security, and contribute to climate change mitigation and adaptation by comprehending the drivers, consequences, and patterns of land-use changes. In conclusion, the primary goals of LULCCs include understanding the drivers, assessing environmental and socio-economic impacts, devising sustainable land use strategies, enhancing climate change resilience, and supporting informed policy and decision making. Researchers can contribute to the preservation of natural resources, the promotion of sustainable development, and the health of ecosystems and human societies by pursuing these goals.

2. Data and Methods

2.1. Study Area

The study focuses on analysing land use and land cover changes in Vizianagaram District, located in the state of Andhra Pradesh, India. Vizianagaram District is situated in the north-eastern part of the state, between 17° 49' 42" N and 18° 43' 21" N latitude and 82° 59' 51" E and 83° 50' 55" E longitude. It covers an area of approximately 3846 square kilometres (Fig 1). The district is characterized by a diverse landscape, encompassing various land use types such as agricultural fields, forests, urban areas, water bodies, and barren land. It is known for its agricultural productivity and is a key contributor to the state's economy. Vizianagaram District is subject to ongoing development and urbanization pressures, which have led to significant LULCC over time.



Source: Analysis, 2022

Figure 1. Location map of the Vizianagaram District, Andhra Pradesh, India

The analysis aims to understand the extent and patterns of these changes, identifying areas of conversion, expansion, and degradation of different land cover types. The study utilizes spatial approaches to analyze multi-temporal satellite imagery, including data from different sensors such as Landsat, Sentinel, or similar sources. Various spatial analysis tools and classification algorithms will be employed to delineate and quantify land use and land cover classes accurately. The findings of this study will provide valuable insights into the changing aspects of LULC in Vizianagaram District, facilitating better land management and planning decisions for sustainable development in the region.

2.2. Methodology

We primarily employed two categories of data in the current study. These are remote sensing and topographic map data. Sentinel 2's georeferenced and combined digital remote sensing data are obtainable through the Copernicus Open Access Hub. The spectral resolutions are 10, 20, and 30 meters, respectively, while the spatial resolution is 10 meters used for the analysis of the LULC in the study area.

2.2.1. Data Acquisition

The data acquisition process for Sentinel-2 satellite imagery involves several steps. Here is a detailed overview of the data acquisition process for Sentinel-2 imagery. The Sentinel-2 mission is part of the European Space Agency's (ESA) Copernicus program, which aims to provide Earth observation data for various applications. Sentinel-2 satellites are equipped with multispectral sensors that capture high-resolution imagery of the Earth's surface. Sentinel-2 satellites have a global coverage and provide regular and systematic acquisition of data over specific regions (Buyadi et al., 2014; Perea-Ardila et al., 2022; Singh et al., 2019). The imagery is freely available to users worldwide through various data access portals, including the Copernicus Open Access Hub and commercial providers.

The hub provides access to the complete archive of Sentinel-2 data, allowing users to search, browse, and download imagery for their desired location and time period. Sentinel-2 data is available in different product types, including orthorectified top-of-atmosphere reflectance values, while Level-2A products include atmospherically corrected surface reflectance values. The choice of product type depends on the specific analysis requirements. Sentinel-2 imagery has a spatial resolution of 10 meters (for visible and near-infrared bands) and 20 meters (for red-edge and shortwave infrared bands). The sensors onboard Sentinel-2 capture data in 13 spectral bands, ranging from visible to shortwave infrared.

Sentinel-2 imagery undergoes rigorous calibration and validation processes to ensure its quality and accuracy (Ayele et al., 2018; Buyadi et al., 2014; Falcucci & Maiorano, 2007; Hegazy & Kaloop, 2015; Perea-Ardila et al., 2022; Singh et al., 2019; Yang & Lo, 2002). Calibration parameters and metadata accompany the imagery, allowing users to assess the quality and make any necessary adjustments during subsequent analysis. It is important to note that the availability and access to Sentinel-2 imagery may vary based on the specific user's location, data access agreements, and any limitations or restrictions imposed by the data providers.

2.2.2. Image Pre-processing

The pre-processing of Sentinel-2 data involves several steps to prepare the imagery for further analysis. Sentinel-2 imagery undergoes radiometric calibration to convert the raw digital numbers (DN) acquired by the satellite sensors into calibrated at-sensor radiance values. This step corrects for sensor-specific characteristics, such as detector variations and radiometric response. Atmospheric correction is performed to remove the effects of atmospheric scattering and absorption on the satellite imagery (Ayele et al., 2018; Buyadi et al., 2014; Cihlar & Jansen, 2001; Falcucci & Maiorano, 2007; Hegazy & Kaloop, 2015; Park & Lee, 2016; Perea-Ardila et al., 2022; Scroll & For, n.d.; Singh et al., 2019; Yang & Lo, 2002).

This step is crucial for obtaining accurate and comparable surface reflectance values across different time periods and locations. Various algorithms, such as the Sen2Cor algorithm, can be applied for atmospheric correction. Geometric correction, also known as orthorectification, is carried out to remove geometric distortions caused by the sensor viewing geometry and Earth's terrain. It involves aligning the imagery to a geodetic reference system and correcting for distortions such as terrain relief, tilt, and rotation. Ground control points (GCPs) from accurate reference data sources, such as high-resolution orthophotos or digital elevation models (DEMs), are used for accurate georeferencing.

Sentinel-2 data is acquired in tiles, and for larger areas of interest, it may be necessary to mosaic multiple tiles together to create a seamless composite image. Mosaicking involves aligning and blending adjacent tiles to create a continuous image. Additionally, if multiple acquisitions of the same area are available, they can be temporally assembled to create composite images representing a specific time period.

Sentinel-2 imagery has different spatial resolutions for different spectral bands. If needed, the imagery can be resampled to a common spatial resolution to ensure consistency in subsequent analysis steps. Each of these pre-processing steps is essential to ensure accurate and reliable analysis results using Sentinel-2 imagery. The specific pre-processing workflow may vary based on the analysis objectives, software tools, and user requirements.

2.2.3. Image Classification

ERDAS Imagine software provides a range of tools and capabilities for image classification of Sentinel data. Start by importing the Sentinel imagery into ERDAS Imagine. This can be done by accessing the "Data Manager" and selecting the appropriate data format for Sentinel data, such as GeoTIFF. The Sentinel imagery to enhance its quality and prepare it for accurate classification. This may involve radiometric calibration, atmospheric correction, geometric correction, and noise reduction techniques.

ERDAS Imagine provides a range of pre-processing tools to perform these tasks (Division & Road, 2013; Munahar et al., 2022). To perform supervised classification, you need to collect training data representing different land cover classes within the Sentinel image. This involves selecting representative sample areas on the imagery and assigning them to specific classes. ERDAS Imagine provides tools for interactive digitizing, polygon creation, or importing training data from external sources (Boori & Voženílek, 2014; Fahad et al., 2020; Keerthi & Nehru, n.d.). Extract relevant features from the Sentinel imagery that can discriminate between different land cover classes.

ERDAS Imagine offers various spectral, textural, and contextual feature extraction methods. These features can include band values, vegetation indices (e.g., NDVI), texture measures (e.g., GLCM), or spatial attributes. ERDAS Imagine provides a range of classification algorithms that can be applied to the extracted features and training data. These include Maximum Likelihood, Support Vector Machines (SVM), Random Trees, Neural Networks, and Decision Trees. Each algorithm has its own advantages and limitations, and the choice depends on the specific analysis requirements. Once the model is trained, it can be applied to classify the entire Sentinel image.

ERDAS Imagine provides tools for applying the classification algorithm to the image and generating a classified image or a thematic map (Civco et al., 2002; Malaviya et al., 2010; Schmid, 2017; Shalaby & Tateishi, 2007). The classified image assigns each pixel to a specific land cover class based on the model's classification results. ERDAS Imagine offers a comprehensive set of tools and functionalities for image classification of Sentinel data, allowing users to extract meaningful information about land cover and land use patterns from the imagery.

2.2.4. Accuracy Assessment

Assess the accuracy of the classification results by comparing them with reference data or ground truth information. ERDAS Imagine provides tools for accuracy assessment, such as error matrices, kappa coefficient calculation, and class-level or pixel-level accuracy metrics. After classification, you can perform post-classification processing to refine the results and generate thematic maps. This may include techniques like majority filtering, sieve filtering, or object-based classification to remove small or isolated classification errors and improve map accuracy. It is important to note that the specific methodology adopted for land use/land cover analysis and change detection analysis may vary depending on the study objectives, available data, and the chosen software or tools.

3. Result and Discussion

Change detection analysis examined land use/land cover variability. LULC photos for 2017–2022. These LULC pictures show land use land cover variations in Vizianagaram district, Andhra Pradesh, India, over the research period. This range matches the 2017–2022 natural vegetation range across Puliyeru river basin (Gandhi et al., 2015). The employed spectral data offers land use landcover Vizianagaram at low spatial resolution (10 m).

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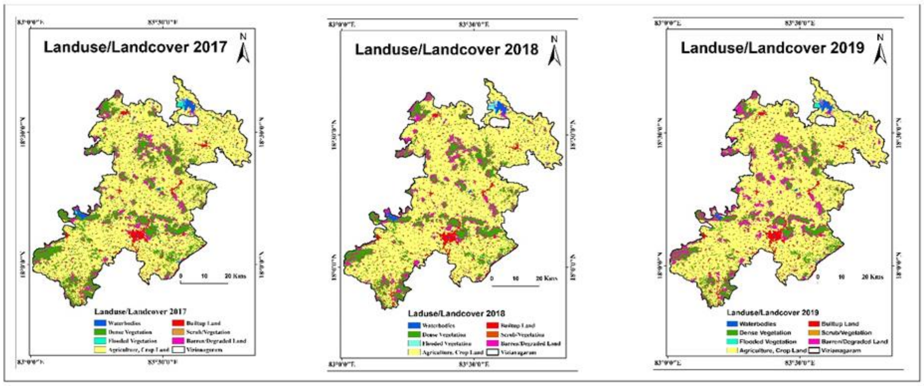
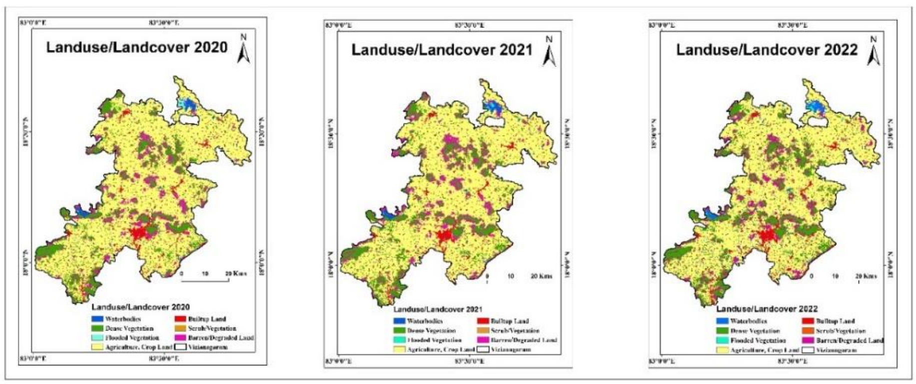


Source: Analysis, 2022

Figure 2. *Land Use Land Cover Analysis 2017, 2018 and 2019 years of The Study Area*



Source: Analysis, 2022

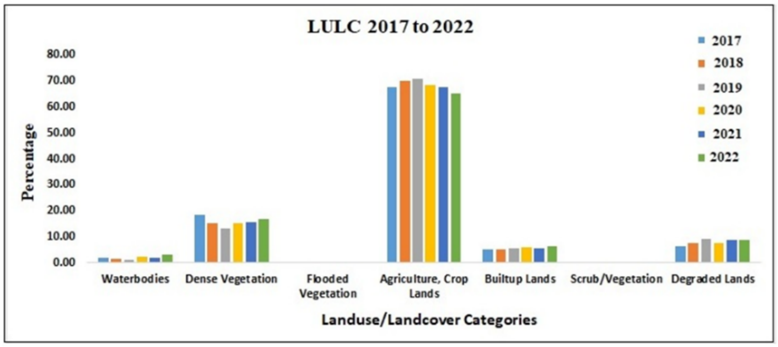
Figure 3. Land Use Land Cover Analysis 2020, 2021 and 2022 years of The Study Area

The LULC changed from 2017 to 2022 in the research region (Fig 2 and Fig 3). In the Dry zone, October to February is moist and May to September is dry. LULC decreased in the dry season and increased in the rain season in both Dry and Intermediate zones. The late dry season (July–October) has the lowest vegetation values in the dry zone. Thus, LULC readings may track Dry zone dry and wet episodes throughout the year.

Table 1. Percentage of Area under Different LULC 2017 to 2022 of Vizianagaram, Andhra Pradesh, India

LULC Categories	**Area of Percentage**					
	2017	**2018**	**2019**	**2020**	**2021**	**2022**
Waterbodies	2.05	1.59	1.23	2.19	2.00	3.02
Dense Vegetation	18.40	15.39	13.05	15.37	15.53	16.66
Flooded Vegetation	0.30	0.29	0.18	0.32	0.15	0.23
Agriculture, Crop Lands	67.42	69.99	70.69	68.42	67.76	65.05
Built up Lands	5.18	5.17	5.57	5.90	5.76	6.29
Scrub/Vegetation	0.09	0.06	0.05	0.07	0.06	0.07
Degraded Lands	6.56	7.51	9.22	7.71	8.74	8.67

Source: Analysis, 2022



Source: Analysis, 2022

Figure 4. Percentage based Land Use/Land Cover Trends (2017-2022) of Vizianagaram, Andhra Pradesh, India

Based on the results of the land use/land cover change detection analysis (Table. 1 and Fig 4), the following results were obtained:

1. Waterbodies encompass natural and artificial bodies of water such as lakes, rivers, ponds, and reservoirs. In 2017, waterbodies covered 2.05% of the total land area, which decreased slightly to 1.59% in 2018. However, there was a subsequent increase to 1.23% in 2019 and a significant jump to 2.19% in 2020. In 2021, it slightly decreased to 2.00%, but then rose again to 3.02% in 2022;
2. Dense vegetation category represents areas with dense vegetation, including forests, woodlands, and regions with a high concentration of trees and plants. In 2017, dense vegetation covered 18.40% of the land area, which decreased to 15.39% in 2018. The percentage continued to decline to 13.05% in 2019 but showed a slight increase to 15.37% in 2020. In 2021 and 2022, there was a further rise to 15.53% and 16.66%, respectively;
3. Flooded vegetation refers to areas that are temporarily flooded or inundated with water. This category includes marshes, swamps, and locations prone to seasonal flooding. The percentage of flooded vegetation was relatively low throughout the years, ranging from 0.18% in 2019 to 0.32% in 2020 (Fig 4). In 2022, it reached its lowest point at 0.15% but slightly increased to 0.23% in the same year;
4. Agriculture, crop lands comprise areas utilized for cultivating crops such as farmlands, plantations, and fields. In 2017, agriculture occupied 67.42% of the land area, which increased to 69.99% in 2018 (Table 1). The percentage continued to rise, reaching its highest point at 70.69% in 2019. However, there was a decline in subsequent years, with values of 68.42% in 2020, 67.76% in 2021, and 65.05% in 2022;
5. Built-up lands pertain to areas transformed by human activities, encompassing structures like buildings, roads, and urban developments. The percentage of built-up lands remained relatively stable over the years, ranging from 5.17% to 6.29%. The highest value was observed in 2022 (Table 1), indicating a slight increase in urbanization and infrastructure development;
6. Scrub vegetation refers to low-lying vegetation characterized by shrubs, bushes, and sparse plant cover. The percentage of scrub/vegetation was consistently minimal, ranging from 0.05% to 0.09% throughout the years;
7. Degraded lands represent areas that have undergone ecological deterioration, often due to human activities or natural factors. The percentage of degraded lands varied from 6.56% in 2017 to 9.22% in 2019. Although there were fluctuations, the values remained relatively consistent in subsequent years, with a range of 7.51% to 8.74% from 2018 to 2021. In 2022 (Table 1), the percentage of degraded lands decreased slightly to 8.67%. These percentages provide insights into the spatial distribution and changes in land cover categories over time.

The fluctuations in each category reflect the dynamics of land use and can be indicative of environmental changes, urbanization, and shifts in agricultural practices (El-Kawy et al., 2011; Mishra et al., 2020; Poyatos et al., 2003).

The land use and land cover (LULC) categories underwent several changes between 2017 and 2022. The waterbodies category experienced fluctuations throughout the period, with a decrease from 2.05% in 2017 to 1.59% in 2018 and a further decline to 1.23% in 2019. However, there was a significant increase in 2020, reaching

2.19%, followed by a slight decrease to 2.00% in 2021 (Table 2). The most notable change occurred in 2022, with the waterbodies category expanding to cover 3.02% of the area. Dense vegetation showed a general decreasing trend, starting at 18.40% in 2017 and gradually declining to 13.05% in 2019. However, there was a recovery in 2020, with coverage increasing to 15.37%. In 2022, dense vegetation covered 16.66% of the area, resulting in an overall decrease of 1.73% (Table 2). The flooded vegetation category remained relatively small, ranging from 0.18% in 2019 to 0.32% in 2020, with a decrease to 0.23% in 2022. Agriculture, crop lands represented a significant portion of the land area, but there was a decrease from 67.42% in 2017 to 65.05% in 2022. Built-up lands showed a slight increase, from 5.18% in 2017 to 6.29% in 2022 (Table 2). Scrub/vegetation and degraded lands experienced minimal changes, with slight fluctuations over the years. Overall, these changes reflect the dynamic nature of LULC patterns over the specified period (Arévalo et al., 2020; Erener et al., 2012; Singh et al., 2019; Suneela & Mamatha, 2016; Treitz & Rogan, 2004).

Table 2. Percentage of Area Changes Under Different LULC 2017 to 2022 of Vizianagaram, Andhra Pradesh, India

LULC Categories	2017	2018	2019	2020	2021	2022	Changes
Waterbodies	2.05	1.59	1.23	2.19	2.00	3.02	0.97
Dense Vegetation	18.40	15.39	13.05	15.37	15.53	16.66	-1.73
Flooded Vegetation	0.30	0.29	0.18	0.32	0.15	0.23	-0.07
Agriculture, Crop Lands	67.42	69.99	70.69	68.42	67.76	65.05	-2.37
Built-up Lands	5.18	5.17	5.57	5.90	5.76	6.29	1.11
Scrub/Vegetation	0.09	0.06	0.05	0.07	0.06	0.07	-0.01
Degraded Lands	6.56	7.51	9.22	7.71	8.74	8.67	2.11

Source: Analysis, 2023

4. Conclusion

In conclusion, the analysis of land use and land cover changes across different categories from 2017 to 2022 provides valuable insights into the dynamic nature of the landscape. Waterbodies experienced a fluctuating pattern, with a decrease in 2018 and 2019, followed by an increase in 2020 and a slight decrease in 2021, before experiencing a significant rise in 2022. This suggests potential shifts in water resources and the need for further investigation into the factors driving these changes.

Dense vegetation exhibited a gradual decline over the years, indicating potential deforestation or land clearing activities. While the decline was relatively small, it raises concerns about the preservation of biodiversity and ecosystem health in the area. Flooded vegetation remained relatively stable throughout the period, with only minor fluctuations. This category may be influenced by seasonal variations or specific hydrological patterns in the region. Agriculture, crop lands maintained a dominant presence, although a gradual decline was observed. This decrease may indicate a shift in land use practices, potentially driven by factors such as urbanization, changing agricultural practices, or the conversion of agricultural lands to other uses.

Built-up lands experienced a steady increase over the years, indicating urban expansion and infrastructure development in the area. This trend highlights the need for sustainable urban planning and land management strategies to ensure efficient use of resources and minimize environmental impacts. Scrub/vegetation and degraded lands showed relatively minor changes during the analyzed period. However, these categories are still important in terms of ecological balance and the restoration of degraded ecosystems. Efforts to preserve and rehabilitate these lands should be considered to maintain biodiversity and ecosystem services.

Overall, the analysis underscores the importance of monitoring LULCCs to inform sustainable land management practices and conservation efforts. The identified trends provide a basis for further investigation into the underlying drivers of these changes and the potential impacts on ecosystems, water resources, and human well-being. Continued monitoring and proactive measures are crucial to mitigate adverse effects and promote sustainable land use in the future.

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