Time Series Study Of Vegetation Cover Of Bhitarkanika National Park Region, Odisha, India Using Geospatial Technology

Abstract—

Studying changes in land use and land cover (LULC) is crucial for sustainable development, planning, and resource management. This research focuses on analyzing the evolving LULC patterns within the Bhitarkanika Wildlife Sanctuary in Odisha's Kendrapara District from 2009 to 2021. Using advanced Remote Sensing (RS) and spatial information system (GIS) techniques, we cover an area of 672 km^2. By examining satellite imagery, we track shifts in LULC over 13 years, with 5-year intervals. Our observations show a consistent decline in vegetation cover during this period. These findings highlight the significant impact of changing land use categories and the spread of mangroves within the sanctuary. This study contributes to the ongoing efforts to monitor and conserve mangrove ecosystems in the Bhitarkanika Sanctuary.

Keywords: Geographic Information System, LULC pattern, mangroves ecosystem, satellite imageries, vegetation cover, spatial proliferation

1. Introduction

The changes in land use and land cover (LULC) trigger a series of consequences that affect various interconnected processes, ultimately disrupting the delicate balance of Earth's ecosystems. These alterations also reshape the physical landscape and distribution of different LULC categories[1,2]. The term "land cover" encompasses the physical and biological features that adorn the Earth's surface, including vegetation, water bodies, barren soil, and human-made structures such as buildings[3]. The patterns of land use are influenced by technological advancements, socioeconomic factors, and institutional frameworks, which are in turn shaped by ecological conditions, topography, and geological attributes[4]. These changes in land cover dynamics have profound impacts on climate, biogeochemical cycles, energy flows, and human welfare[5]. Urbanization and population growth exacerbate the conversion of extensive forested areas into alternative land use types.

2. Materials and methods:

2.1 Study area:

Situated along India's eastern coastline, the Bhitarkanika Mangrove Ecosystem is renowned as one of the country's largest and most diverse mangrove forests. Covering a vast area between certain latitudes and longitudes, this unique environment comprises dense mangrove forests, intricate estuarine channels, expansive mudflats, and a rich variety of plant and animal species. It gained international recognition as a Ramsar site in 2002 due to its ecological significance. Located in the northeastern part of Odisha's Kendrapara District, the ecosystem is formed by the Brahmani, Dhamra, and Baitarani rivers' deltaic region. Initially established as a wildlife sanctuary in 1975, it was later expanded and declared a National Park in 1992, with a core area of 145 km^2 within a larger wetland spanning 672 km^2. The region experiences a tropical monsoon climate, characterized by high humidity and heavy rainfall from June to September, followed by relatively warm temperatures during the dry season from October to May. These favorable conditions support the flourishing growth of mangrove forests and sustain a diverse range of plant and animal species, making Bhitarkanika a crucial sanctuary for biodiversity conservation..

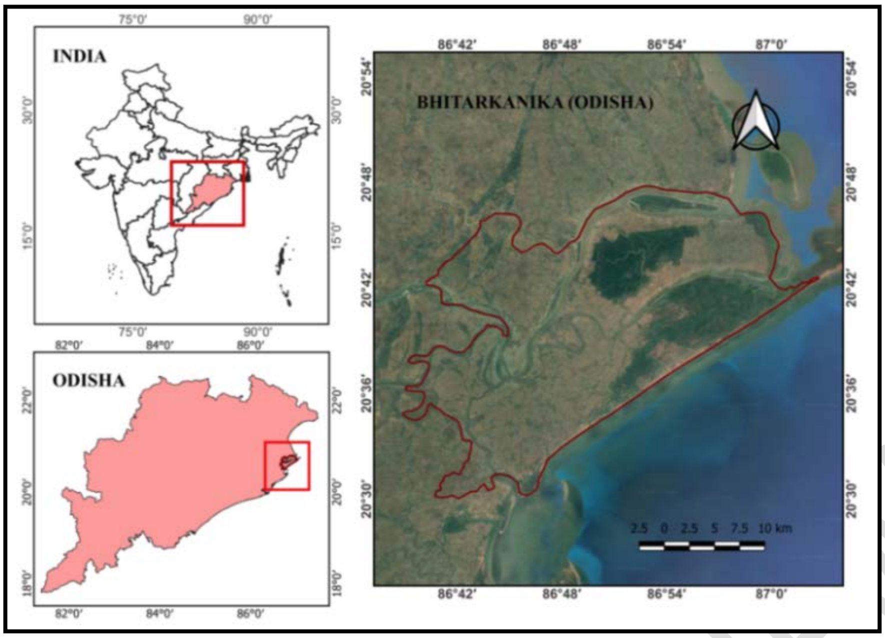

Fig. 1 Study area map: Bhitarkanika Mangrove Ecosystem,Odisha, India

2.2 Data acquisition:

Throughout this study, ~~we~~ utilized data obtained from both the Landsat series of satellite images and IRS-LISS-III, covering the period from 2009 to 2021. ~~We~~ specifically employed Landsat 7 TM imagery from 2009 and Landsat 8 OLI_TIRS imagery from 2013, 2017, and 2021, with path/row 139/046 and cloud coverage less than 30%. Landsat TM data had a resolution of 30 meters, while OLI/TIRS data had a resolution of 15 meters once the panchromatic band was included. These images were sourced from the United States Geological Survey (USGS) portal, Earth Explorer (http://earthexplorer.usgs.gov/). Subsequently, ~~we~~ conducted geo-rectification and registration of the Landsat images at the source. LISS-III data were obtained from the BHUVAN portal of ISRO (Table-1).

Table 1 – The characteristics of the remotely sensed data acquired from satellite sources

Years	Satellite	Sensor	Spectral Resolution	Path	Row
2009	Landsat-5	TM	30 meter	139	046
2013	Landsat-8	OLI_TIRS	15 meter	139	046
2017	Landsat-8	OLI_TIRS	15 meter	139	046
2021	Landsat-8	OLI_TIRS	15 meter	139	046

2.3 LULC Classification:

After finishing the extraction and projection process for ~~our~~ study area, we merged the various subtypes of land-use data to define five distinct categories: water bodies, vegetation, agricultural land, open land, and barren areas, as illustrated in Table 2. This classification was accomplished using the reclassifying tool within QGIS 3.26.3. also computed Normalized Difference Vegetation Indices (NDVI) for each dataset to quantify vegetation density. Among various LULC classification techniques, supervised classifications are used in which the user selects representative training samples from the image for each class of interest and assigns labels or categories to these samples. The classifier then uses these labeled samples to identify and classify similar pixels across the entire image. Following this, ~~we~~ conducted a comprehensive analysis of NDVI changes across different time periods to understand temporal fluctuations in land cover and vegetation density.

Table 2 – Classification system of LULC

LULC types	Description
Water body	Rivers, lakes, ponds, and dams
Vegetation coverage	Different kinds of woodland areas
Agriculture	Agricultural, cultivated land, parks, open areas, and grazing area
Open land	Built-up area, residential, commercial, and other infrastructure
Barren land	All types of barren land

2.4 Mangrove Forest Cover Change Analysis:

~~We~~ used the Modules for Land-Use Change Simulation (MOLUSCE) plugin within QGIS to examine changes in land use and land cover (LULC) over five-year intervals. This analysis resulted in four LULC change maps, showing how the landscape evolved over time. By organizing LULC data into rows and columns representing landscape categories for different years, ~~we~~ created an area change and transition likelihood matrix. These tools, commonly used in LULC change analysis, helped us understand how both natural and human factors influence changes in land use and cover over time.

2.5 Prediction and Model Validation:

~~We~~ utilized the CA-ANN technique within the MOLUSCE plugin to model transition potentials and simulate future scenarios. This method is preferred by many researchers due to its perceived effectiveness compared to linear regression[6]. MOLUSCE (Modules for Land Use Change Simulation) is a valuable tool for analyzing and modeling land use changes over time. It allows users to simulate various scenarios and assess the potential impacts of different factors on land use dynamics. Conducting a time series study spanning more than a decade helped us prepare a predictive model and project the LULC changes expected by 2030. To validate the model and ensure accuracy, the MOLUSCE plugin provides a kappa validation technique. This allows ~~us~~ to compare the actual LULC images with the projected ones, ensuring reliability and precision in our assessments. After achieving satisfactory validation results, we used LULC data from 2010 and 2020 to forecast the LULC in 2030, as illustrated in Figure 7.

3. Result and Discussion:

We analyzed the NDVI for each dataset spanning from 2009 to 2021 to understand vegetation dynamics over time. LULC maps were created based on NDVI data, with accuracies ranging from 93.52% in 2009, 91.94% in 2013, 96.66% in 2017 and 91.33% in 2021. NDVI, a remote sensing metric, gauges vegetation health and density by measuring the reflectance of near-infrared and red light. NDVI-based LULC maps were generated for each year and compared with other maps to analyze temporal changes in land cover types over the specified period.

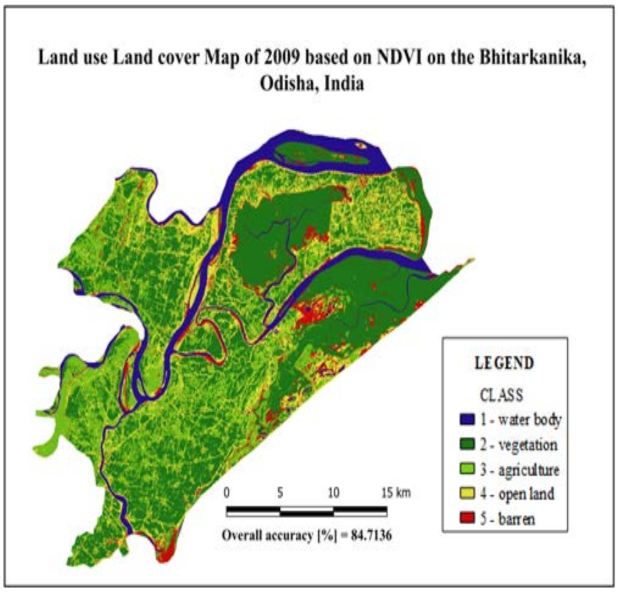

Fig. 2 - LULC map of 2009 based on NDVI

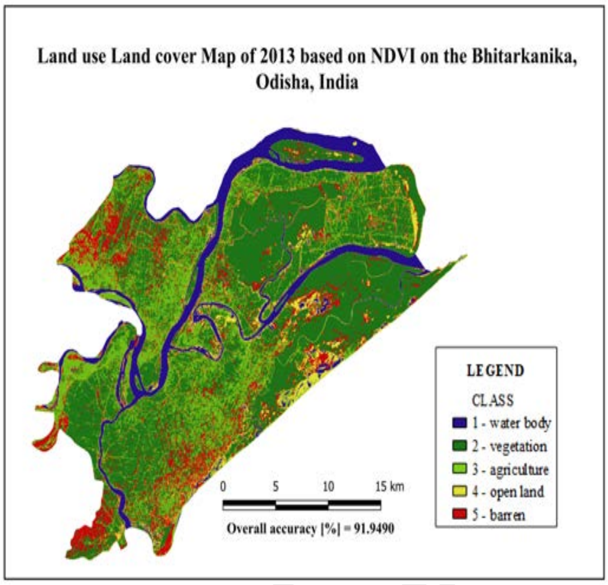

Fig. 3 - LULC map of 2013 based on NDVI

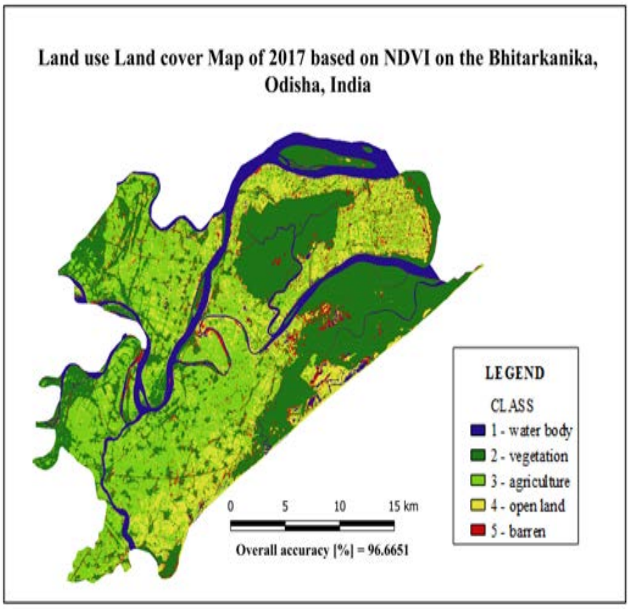

Fig. 4 - LULC map of 2017 based on NDVI

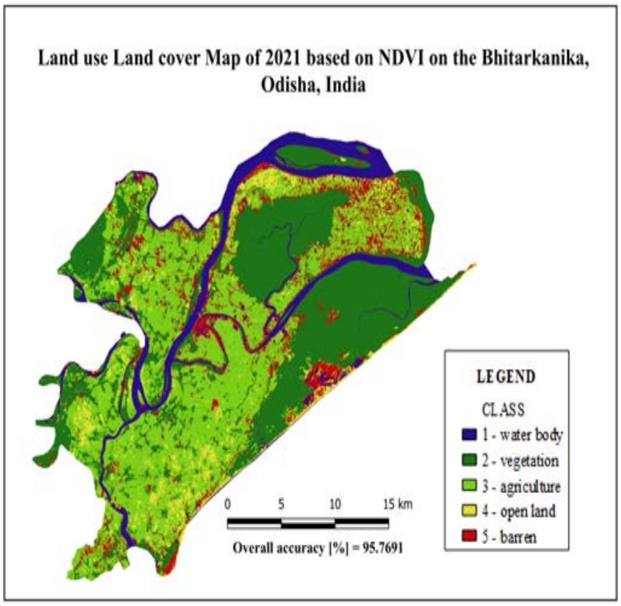

Fig.5 - LULC map of 2021 based on NDVI

Table-2 displays notable alterations in vegetation cover within the study area. A change detection matrix has been compiled for various time periods based on the NDVI outcomes, highlighting significant shifts in vegetation dynamics over time. Changes between 2009-2021 have been shown in fig 6.

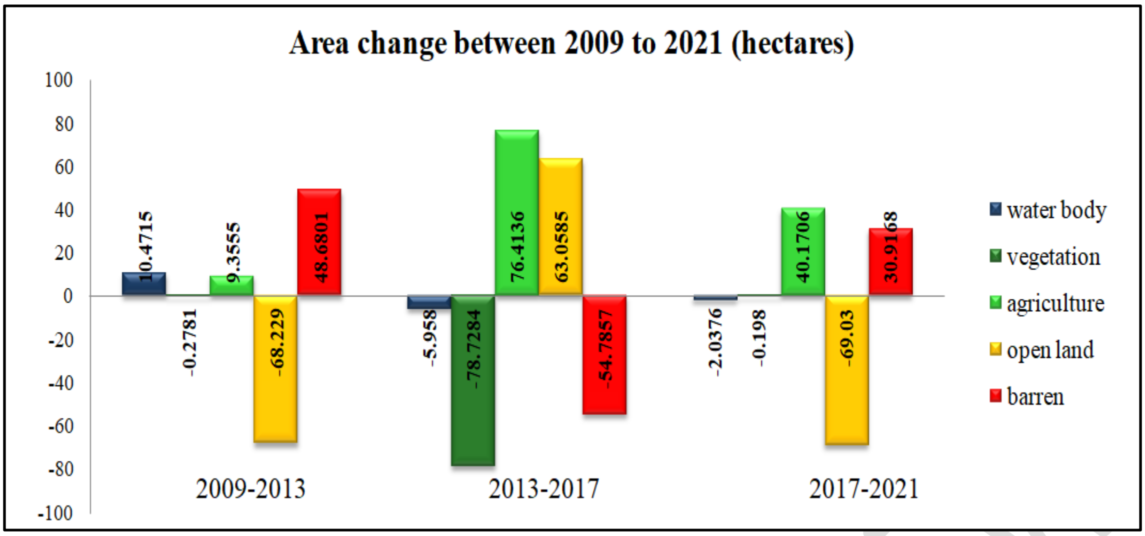

Chart - 1: The chart compares the alterations in land use between the periods 2009-2013, 2013-2017, and 2017-2021, illustrating the changes in area percentages over time.

Table – 3 Change Assessment in individual Years (2009, 2013, 2017 and 2021)

NDVI CHANGE ANALYSIS OF BHITARKANIKA AREA(2009-2021), ODISHA

Class	Water body	Vegetation coverage	Agriculture	Open land	Barren land	Total
			Year-2009			
Area in hectares	67.9761	319.8816	139.284	109.6956	37.548	674.3853
Area Percentage	10.0797	47.4330	20.65347	16.26601	5.56773	100
			Year-2013			
Area in hectares	78.4476	319.6035	148.6395	41.4666	86.2281	674.3853
Area Percentage	11.63246	47.39182	22.04074	6.1488	12.78618	100
			Year-2017			
Area in hectares	72.4896	240.8751	225.0531	104.5251	31.4424	674.3853
Area Percentage	10.74899	35.71773	33.37159	15.49931	4.662379	100
			Year-2021			
Area in hectares	70.452	240.8553	265.2237	35.4951	62.3592	674.3853
Area Percentage	10.44685	35.71479	39.32821	5.263326	9.246821	100

The spatial coverage of water bodies showed a fluctuating pattern over the years, increasing from 10.07% in 2009 to 11.63% in 2013, after gradually decreasing to 10.44% in 2021. This variation could be attributed to factors like flooding and seasonal changes observed during the imaging process on study area. On the other hand, decline in dense vegetation coverage from 47.43% in 2009 to 35.71% in 2021 suggests a significant alteration in vegetation patterns, possibly attributable to a combination of factors including pollution, land conversion, climate change, natural disturbances, or overexploitation. Concurrently, agricultural land expanded significantly from 20.65% in 2009 to 39.32% in 2021, highlighting a substantial transformation in land use dynamics over the years.

Throughout the observed years, there has been a discernible decrease in the overall area categorized as non-vegetated, with percentages declining from 21.82% in 2009 to 14.5% in 2021. This trend mirrors shifts in land use dynamics, such as urbanization, agricultural expansion, and infrastructure development, which have encroached upon formerly non-vegetated regions, thereby affecting the surrounding mangrove ecosystems.

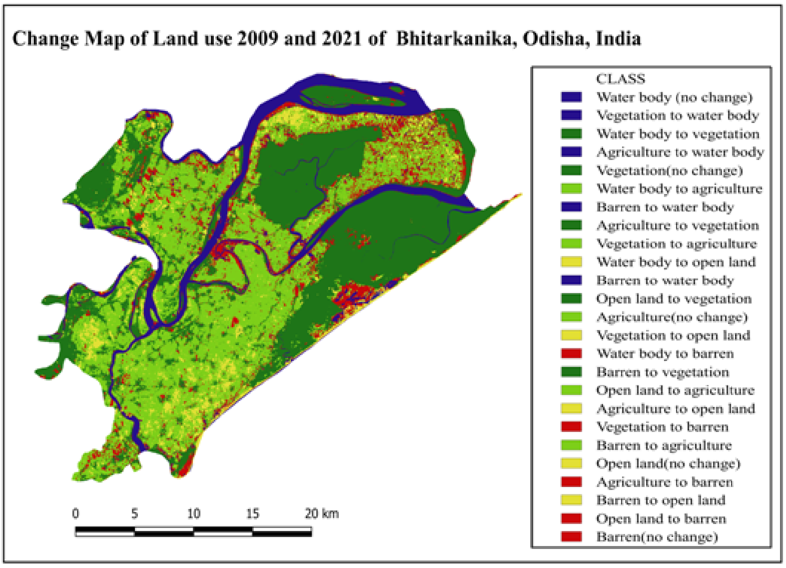

Fig. 6 Change area between 2009 and 2021

The future land use and land cover (LULC) changes for the year 2030 have been forecasted using transition probabilities matrix, analyzing the probable percentages of changes from 2021 to 2030. Cellular Automata Artificial Neural Network (CA-ANN) methods were employed to provide insights into both the quantity of change and the spatial distribution of LULC prediction in the study area. The model is considered validated when the Kstandard (overall kappa) score surpasses 70%. A k-index greater than 80% indicates strong alignment between the projected and actual LULC maps, surpassing the minimum acceptable standard. In this case, the indices exceeding 80% signify a commendable overall agreement and predictive accuracy of the model.

Table – 4 Temporal changes 2021-2030

Class	2021 area in hectares	2030 area in hectares	Δ in hectares	2021%	2030%	Δ %
water body	70.45	72.15	1.70	10.446	10.699	0.25223
vegetation	240.86	224.77	-16.09	35.714	33.329	-2.38577
agriculture	265.22	293.09	27.86	39.328	43.459	4.131763

open land	35.50	27.70	-7.79	5.263	4.107	-1.15545
barren	62.36	56.68	-5.68	9.246	8.404	-0.84277
Kappa value = 94.29%; Overall accuracy = 0.91						

Over the span of the decade from 2021 to 2030, significant changes in land cover are anticipated within the study area. While water bodies are predicted to experience a marginal increase of around 10.44% in 2021 to 10.69% in 2030, vegetation cover is dropping from 35.71% in 2021 to 33.32% in 2030. approximately. Conversely, agricultural land is forecasted to expand notably, with an estimated increase of about 4.13%. However, open land and barren areas are both projected to decline, with open land decreasing by approximately 1.15% and barren land decreasing by approximately 0.84% by 2030. Detailed insights into these changes are provided in figure 7 and table 4, illustrating the evolving landscape over time. These predictions highlight potential shifts in land use dynamics and emphasize the importance of informed land management strategies to address emerging challenges and promote sustainable development in the region.

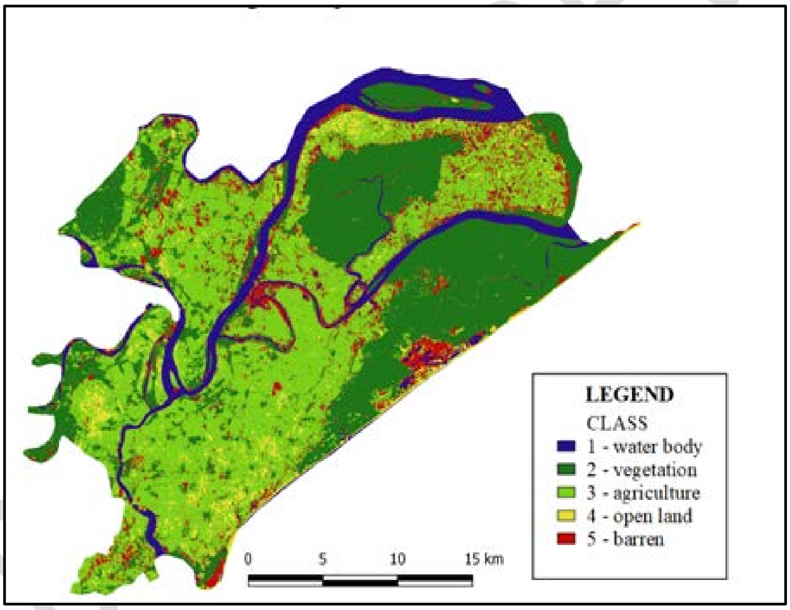

Fig. 7 Projected LULC for 2030

The changes driving alterations in the Bhitarkanika ecosystem can be broadly classified into two main categories: natural and human-induced factors. Natural occurrences like tropical cyclones, severe flooding, water logging, and shifts in shoreline dynamics play a significant role in the depletion of vegetation cover. Conversely, human activities such as the construction of aquaculture ponds, settlements on reclaimed land, and urbanization further exacerbate the decline in vegetation. Bhitarkanika has witnessed notable flooding events in various years, including 1995, 1999, 2001, 2003, 2005, 2006, 2007, 2008, 2009, 2011, and 2013. These floods, often triggered by heavy rainfall and tropical cyclones, have had far-reaching consequences on the area's ecosystems and local communities.

4. Conclusion

This study marks an initial attempt to forecast the future trajectory of the Bhitarkanika mangrove ecosystem by analyzing multiple Land Use and Land Cover (LULC) maps to evaluate mangrove health. Examination of historical land cover maps derived from Landsat 5 and 8 imagery unveiled a decline in dense mangrove coverage alongside an expansion of open mangrove and agricultural areas. Despite conservation efforts, projections suggest a potential decrease in dense mangrove cover to as low as 2.30% by 2030. The increasing spread of settlements is placing significant strain on the dynamic coastal environment. To address these pressures on mangrove ecosystems, governmental and forestry authorities should advocate for comprehensive conservation measures both in-situ and ex-situ. Moreover, management entities of the sanctuary and mangrove regions must devise alternative strategies to support local communities reliant on mangroves for their livelihoods, thereby easing pressure on these vital ecosystems.

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