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Analyzing the Impact of Changing Land Use Patterns in the Coastal Zones of West Bengal

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Abstract:

The foundation of many other human endeavors rests on land, the most fundamental resource for human survival. There are usually a number of interrelated causes that influence changes in land use and land cover. Changes in land use and land cover are driven by a complex interplay of natural and anthropogenic factors, which shift over time and across geographic regions. Alterations in the quality of the water along the Hooghly River in India as a result of LULC. The research relies heavily on previously published works. This research considers the general land use features of the region for two separate time periods: 2000 and 2015. Due to factors such as population increase, development of agricultural fields, rising settlement areas, and so on, there has been a decline in water body, vegetation, and fallow land area. The shifting patterns of land use and land cover are critical components of the broader issue of environmental change on a global and regional scale.

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1. Introduction

A coastal zone is defined as the region of territorial waters that extends up to the highest point on land. The coastal zone extends from 200 meters above sea level to 200 meters below sea level and is defined by long, narrow characteristics of the landmass, islands, and seas. The whole continental shelf is located in coastal zones, which make up around 18% of the Earth's surface area. These zones are responsible for 25% of primary production and 90% of the world's fish harvest, but they are also some of the most vulnerable places on Earth.

Up to the high tide mark, territorial waters are what define coastal zones. The coastline is the outside limit of the coastal domain, which typically extends from 200 meters above sea level to 200 meters below sea level and consists of long, narrow features of land, islands, and water. Coastal zones include the whole continental shelf and make up almost 18% of the Earth's surface. They are also among the most vulnerable areas, but they provide 25% of the world's primary production, 90% of the world's seafood catch, and more.

The study of global change relies heavily on the geographical and temporal monitoring of changes in land use and land cover (LULC). Settlements, semi-natural ecosystems like arable fields and pastures, and managed woodlands are all products of land use, which also includes the management and alteration of wild or natural environments. Everything from grass and asphalt to trees and barren ground to water and more is considered land cover. Loss of biodiversity, deforestation, increased frequency of natural disasters, and global warming are among of the most significant outcomes of LULC changes caused by humans and other natural forces. Changes in LULC are often associated with these environmental issues.

In the previous half-century, the idea of land use change has undergone a radical transformation as a result of the instruments and technologies made available throughout industrialization. The locals make do with what they have by hunting, gathering materials (wood, lumber, food, etc.), and transforming uncultivated ground into arable land (in certain areas, this involves clearing vegetative cover). However, aquaculture is now only one of many reasons why land is being altered. Land cover and natural ecosystems are both susceptible to change due to this dramatic shift in land use patterns. Deforestation, soil erosion, temperature, rainfall, groundwater availability, greenhouse gas emissions, and other occurrences may be influenced by changes in land use and land cover (LULC).

Massive population pressure is the primary driver of LULC modification. In order to make conclusions, the historical shifts in LULC are examined from many angles. In order to identify this shift in LULC, a one-of-a-kind tool using GPS and geographical information systems (GIS) is available. Locating and comprehending shifts over time is aided by this. This study aims to provide light on the dynamics of LULC in the Nandakumar Community Development (CD) block of the Purba Medinipur district from the years 2000 to 2022.

It is possible to generalize the results from studying the Hooghly River's LULC fluctuations, population shifts, and water quality to areas that are experiencing comparable problems. This work is a significant addition to the scientific community worldwide since it may help shed light on water quality concerns and provide potential remedies in other regions of the globe. In addition, the research may contribute to the development of regulations and standards for the prevention and mitigation of water pollution, which can significantly enhance the standard of living for people throughout the world. Because it may aid in solving the issue of water contamination caused by LULC changes and population shifts in different regions of the globe, this work is therefore of great worldwide importance.

2. Litreature Review

Saha, Jayanta & Paul, Suman. (2020). Tourism is often seen as a means of economic development in poor nations. Numerous potentials for the construction of tourist enterprises exist in the coastal pristine environment. There are a plethora of tourist hotspots dotting the shoreline of the Purba Medinipur district in West Bengal, India. Tourist numbers in the Mandarmani-Tajpur region have skyrocketed in the last ten to fifteen years. The environmental impacts of land use change surrounding these places from 2009 to 2019 as a result of tourism are examined in this research. The LULC categorization was done using Google Earth satellite pictures of the research region taken in 2009 and 2019 respectively. A land use change matrix has been created to determine the land use and land cover change that occurred between 2009 and 2019 using data obtained from LULC categorization. The findings verified a decline in arable land, vegetative cover, aquaculture in relation to bodies of water, and sand dunes. In contrast, there is a growing amount of natural fallow, habitation, and tourist-related activity areas. Hotels, resorts, and other businesses connected to tourism have taken over what were formerly farmlands, sand dunes, and vegetative cover, turning them into a popular tourist destination. The clearance of forestland has allowed for the construction of many hotels and resorts.

S, Rajakumari et.al. (2020). Mangroves, mudflats, sand dunes, beaches, spits, sand bars, and barrier islands are some of the numerous land cover characteristics found along India's coastline. The pattern of land use reflects the dynamic relationship between humans and their natural surroundings. Threatening the coastal land cover pattern include increased human activities, such as urbanization and the conversion of landscapes into commercial operations like aquaculture. Analysis of the dynamics of land use/land cover (LULC) change using remote sensing and GIS methods is made easier using multi-temporal time series data. This research looks at the Deshapran block in West Bengal's Purba East Medinipur district to see how coastline characteristics have changed as a result of human-induced land use changes. The purpose of the research was to evaluate the effects of LULC shifts during the last 45 years on coastal landscape characteristics. The alterations were described in several instances spanning certain time periods. Using the CA-MARKOV prediction model, the research was further scaled up to forecast land cover changes over the next 20 years. A study of future projections found that the unpredictable growth of aquaculture will endanger the coastal dynamics of Deshapran block and put a tremendous strain on croplands and other coastal characteristics.

Das, Tanmoy & Das, Subhasish. (2022). Using Landsat satellite data, this study looks at four distinct time periods—the pre- and post-monsoon of 1988 and 2020—to try to piece together the spatial and temporal patterns of the urban heat phenomenon (UHP) and how it relates to the change of land-use and land-cover in the Indian city of Chandannagar. The city's thermal and environmental characteristics can be studied more effectively if UHP and non-UHP sectors are distinguished. The forecasting of land surface temperature (LST) by several remote sensing indices and UHP by built-up regions may be imagined using models such as multiple linear regression (MLR) and simple linear regression (SLR). The findings show that between 1988 and 2020, the mean LST in the premonsoon and post monsoon periods rose by 0.11°C and 0.1°C each year, respectively. In those directions from the city center, when vegetation cover and non-UHP areas decline fast, built-up areas, UHP areas, and mean LST grow linearly. Additionally, compared to post-monsoon conditions, pre-monsoon conditions show better application of MLR and SLR models, the greatest rise in UHP intensity, and the creation of many UHP locations.

Goswami, Ghritartha et.al. (2023). As sources of potable, agricultural, and industrial water, rivers play an essential role in human society. Furthermore, they convey garbage from homes and businesses to the ocean. An important river in India, the Ganga flows south from its northern source in Gangotri before emptying into the Bay of Bengal after passing through five states. Water quality along the Indian River Hooghly was the focus of this research, which looked at how LULC affected the river. In order to assess different parameters, the study included collecting water samples from several sites and evaluating them in a laboratory setting. According to the results, water quality is declining as a result of less forest cover and fewer bodies of water caused by the growth of agricultural and built-up areas. In order to keep the river's ecology intact and the water quality consistent, the research stresses the need of sustainable land use practices and better water management. In particular, the research found that areas close to Dakshineshwar, Shibpur, and Garden Reach are at a higher risk of water quality degradation as a result of changes in land use and population increase.

Nath, Anindita et.al. (2023). By combining remote sensing data with field observations of shoreline characteristics along coastlines worldwide, geospatial techniques can be utilized to evaluate the changing conditions of coastal land use and land cover. This, in turn, can help with making informed decisions regarding future management strategies for sustainable development. For the purpose of researching intricate coastal systems at various scales, geospatial approaches provide a useful tool. A complex interplay between land and water constantly modifies the coastal land use and land cover throughout the Bay of Bengal, from the Subarnarekha in Orissa to the Rasulpur estuaries in West Bengal. The changes in the landscape are caused by a combination of natural and human-made influences. The main objective of this study was to identify the periodical transformation and changes in land-use/land-cover (LULC) features by the USGS-

LULC classification method using a maximum-likelihood classifier (MLC) algorithm and satellite images for the period 1975–2018. The whole research region was partitioned into three distinct "littoral zones" (LZs). As a result, we may learn more about the effects of human activities on coastal ecosystems and trace the evolution of LULC.

3. Research Methodology

The eastern Indian state of West Bengal is located in the subcontinent. Situated on the Bay of Bengal, it has an area of 88,752 km2 (34,267 sq mi) and is home to more than 91 million people as of 2011. As of 2023, the population is projected to be 99,723,000. In terms of both population and land area, West Bengal ranks as the thirteenth biggest state in India and the ninth most populated country subdivision in the world. It is located in the Indian subcontinent's Bengal region and has borders with Bangladesh to the east and Nepal and Bhutan to the north.

Jharkhand, Odisha, Bihar, Sikkim, and Assam are the Indian states that it has borders with. Kolkata is the capital of the state and the third-largest metropolitan and seventh-largest city in India in terms of population. West Bengal include the coastal Sundarbans, the Bay of Bengal, the Rarh area, the Ganges delta, and the Darjeeling Himalayan hill region.

Part of India's eastern bottleneck, which stretches from the northern Himalayas to the southern Bay of Bengal, lies the state of West Bengal. An extensive 88,752 square kilometers (34,267 sq mi) make up the state's overall area. Located in the far north of the state, in the Darjeeling Himalayan hill area, lies a portion of the eastern Himalayas Mountain range. The state's tallest mountain, Sandakfu, is located here; it stands at 3,636 meters (11,929 feet). There are two streams of the Ganges River, the most important river in West Bengal. The Padma (or Poda) River goes into Bangladesh, whereas the Bhagirathi (or Hooghly) River and the other branch travel through West Bengal. Through a feeder canal, the Hooghly River branch receives water from the Farakka barrage, which is located on the Ganges.

In order to assess different characteristics, water samples were taken from the specified places and tested in a laboratory, as shown in Tables 1 and 2. The relationships among LULC, population, and Hooghly River water quality may be better understood by looking at the outcomes of various tests.

Figure 1: Location map of study area

4. Data analysis

Land Cover/Use Analysis - 2000: In order to identify changes in several categories, the land use/cover of the research region was analyzed between the years 2000 and 2015. Five distinct categories, drawn from Landsat ETM satellite images, make up the 2000 land use/land cover categorization. The map (fig.2) and table 1 (which details each land use/land cover class) show the extents of these features. In 2000, the entire area under water bodies accounted for 65.75 Sq. km, or about 6.94% of the study area, according to Table 1 and Figure 3. Vegetation comprised about 39.69% of the whole research area, or 375.98 sq. km. The entire area that falls under the Settlement category is 88.91 sq. km, or about 9.39% of the total. For a total area of 46.93 sq. km, or 4.95 percent, is fallow land. On a total area of 369.73 sq. km, or about 39.03 percent, was devoted to agriculture. Our research region in 2000 had the highest vegetation area at 39.69% and the lowest barren land category at 4.95%. There are 947.30 square kilometers in all.

Table 1: Land use/land cover of the study area (2000)

Land use/land cover	Area (Sq. km)	Area (%)
Water bodies	65.75	6.94
Vegetation	375.98	39.69
Settlement	88.91	9.39
Fallow Land	46.93	4.95
Agricultural Field	369.73	39.03
Total	947.30	100.00

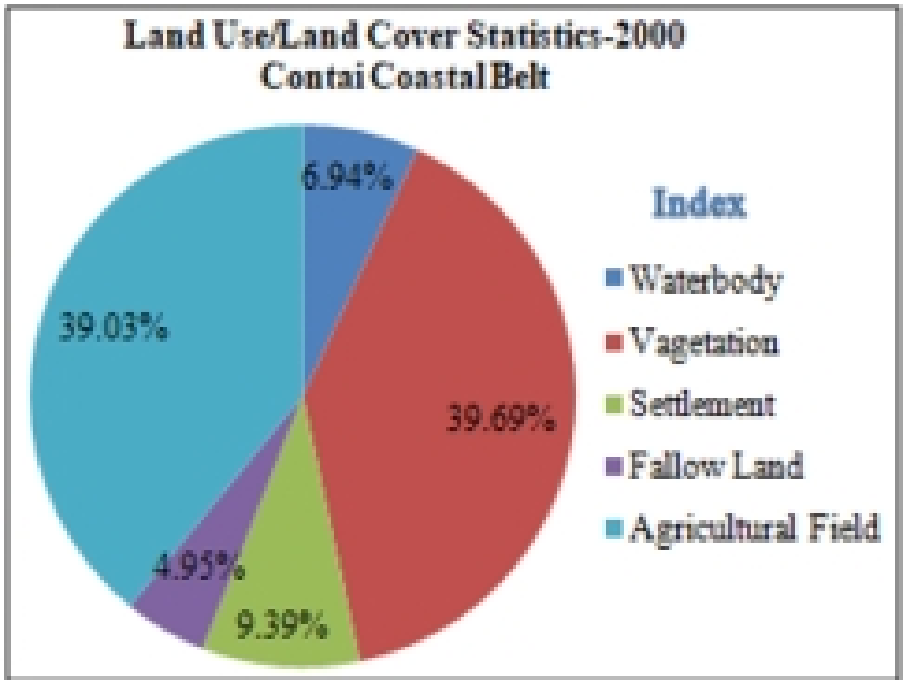

Figure 2: Land use and land cover-2000 Source: Landsat-ETM (2000)

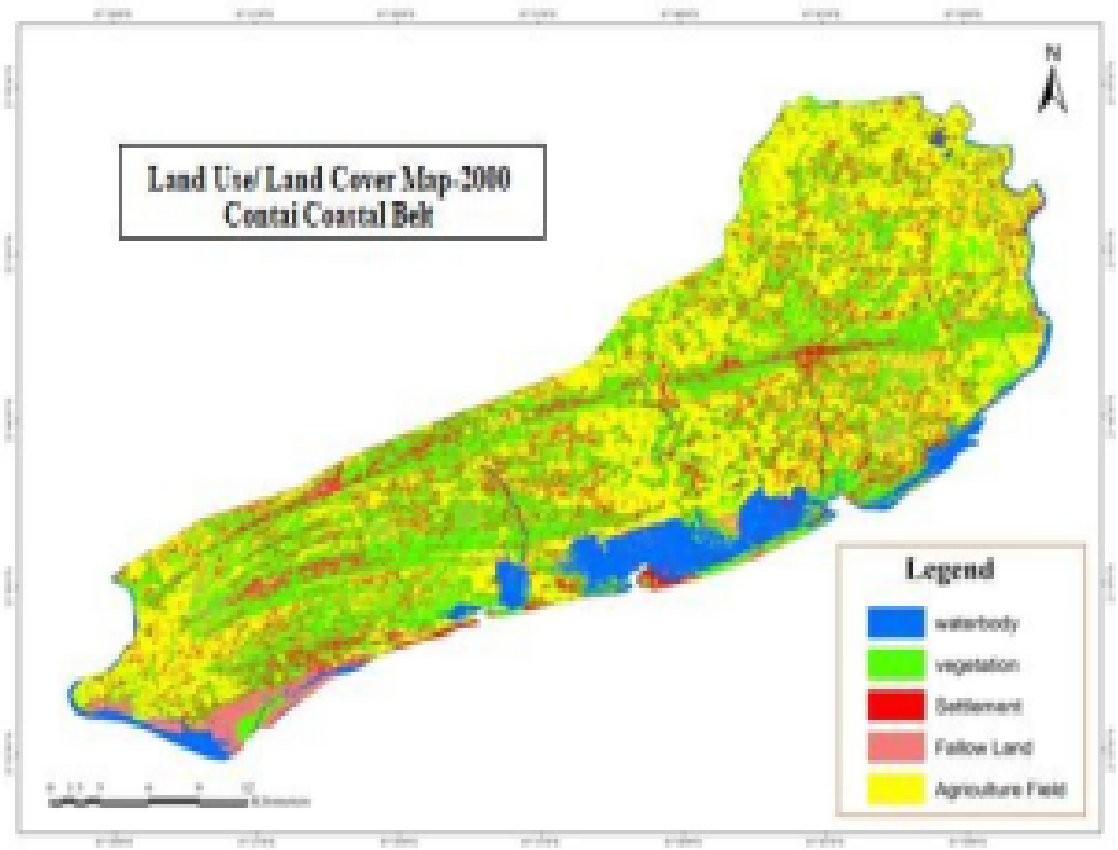

Figure 3: Land use and land cover map-2000 Source: Landsat-ETM (2000)

Land Use/ Land Cover-2015:

The 2015 Land Use/Land Cover Status Report indicates that there have been notable changes to a few of the categories. The area under this land use has been declining, as indicated in table 2 and figure 5, as 45.74 sq. km, or 4.83% of the total, is occupied by water bodies. Vegetation cover, which accounts for 38.57 percent of the total land area (365.33 sq. km), has been trending downward. Out of the entire land area, the settlement took up 100.04 sq. km, or 10.56 percent. Fallow land covered 46.26 sq. km, or about 4.88 percent of the region we studied. Nearly 41.16% of the total land area was used for agriculture, which amounted to around 389.82 sq. km.

Table 2: Land use/land cover of the study area (2015)

Land use/land cover	Area (Sq. km)	Percent (%)
Water bodies	45.74	4.83
Vegetation	365.33	38.57
Settlement	100.04	10.56
Fallow Land	46.26	4.88
Agricultural Field	389.82	41.16
Total	947.19	100.00

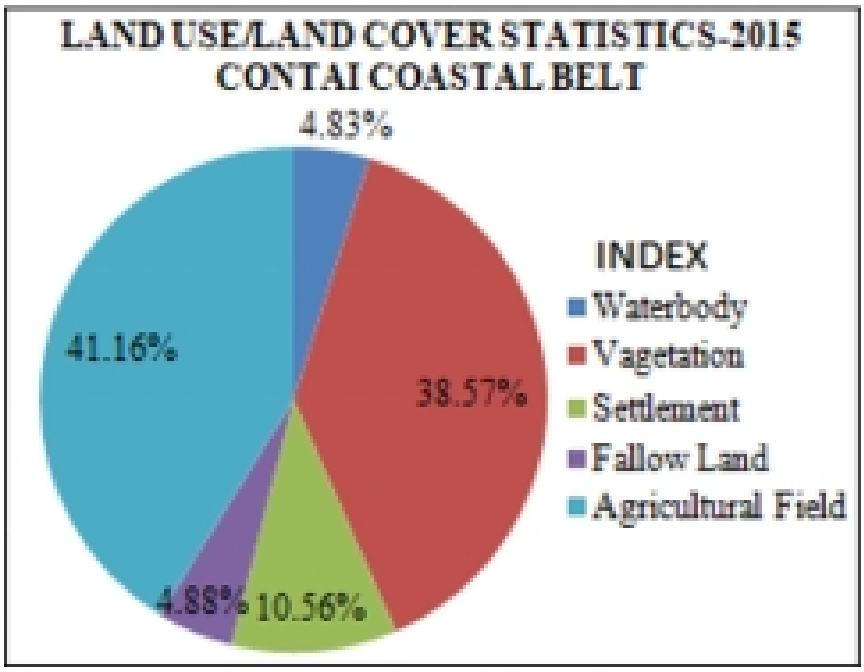

Figure 4: Pie-graph of land use and land cover-2000 Source: Landsat-ETM (2015)

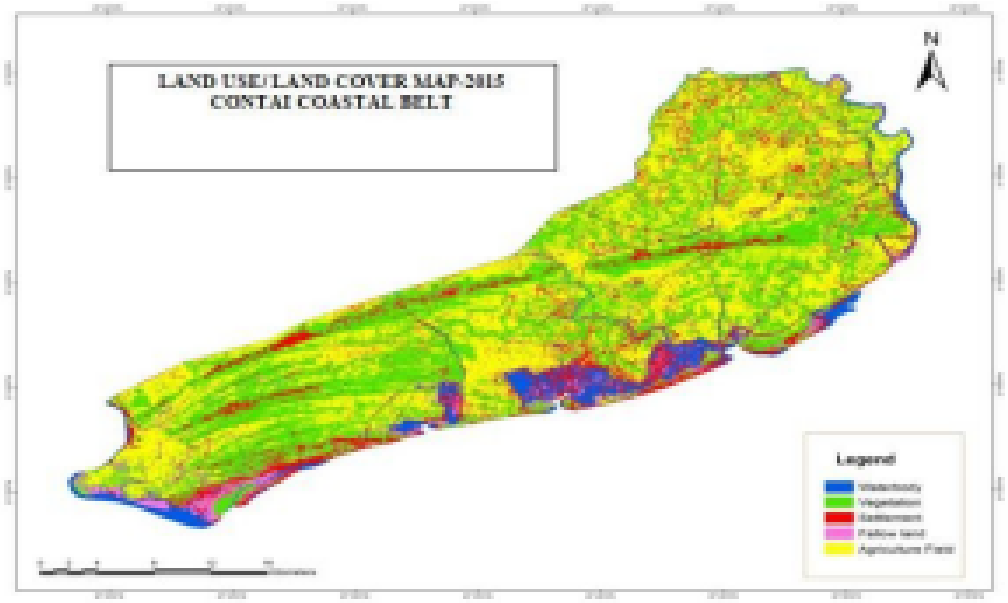

Figure 5: Land use and land cover map-2015 Source: Landsat-ETM (2015)

Change Detection Analysis of Land Use/Land Cover (2000-2015)

To examine the changes in land use and land cover that took place between the years 2000 and 2015, researchers used a change detection study. According to Table 3, the study area's land use and land cover changed noticeably between 2000 and 2015. A dramatic shift has occurred in the landmass under bodies of water, with a decline from 65.75 sq. km in 2000 to 45.74 sq. km in 2015, a decrease of 20.01sq. km depicting a negative growth rate of 2.11 percent and an average annual negative growth of 0.14 percent. In 2000 an area of vegetation cover was 375.98 sq. km and whereas in 2015 the area under this category was 365.33 sq. km. showing a decrease of about 10.65 sq. km. This category shows decline of 1.12 percent and an annual growth of 0.07 percent.

There was a growth of 11.13 square kilometers, from 88.91 square kilometers in 2000 to 100.04 square kilometers in 2015, for the settlement area. This group had a 1.18 percent gain, with an average yearly growth of 0.08 percent. There was an 8.64% decrease and an average yearly negative increase of 0.07% in the total area classified as fallow land, from 46.93 sq. km. in 2000 to 46.26 sq. km. in 2015. There has been a tremendous expansion of arable land. There was a growth of around 20.09 square kilometers between 2000 and 2015, when it was 369.73 sq. km. and 389.82 sq. km. With an average yearly growth rate of 0.14%, this category grew by 2.13 percent between 2000 and 2015.

Table 3: Change in land use/cover from 2000 to 2015

Land Use/Land Cover -2000			Land Use/Land Cover - 2015			Growth in sq. km		Growth in percentage	
Land use/ land cover	Area (Sq. km)	Area (%)	Land use/ land cover	Area (Sq. km)	Area (%)	Growth in sq. km	Annually growth in sq.km	Growth (%)	Annually Growth (%)
Water body	65.75	6.94	Water body	45.74	4.83	-20.01	-1.33	-2.11	-0.14
Vegetation	375.98	39.69	Vegetation	365.33	38.57	-10.65	-0.71	-1.12	-0.07
Settlement	88.91	9.39	Settlement	100.04	10.56	11.13	0.74	1.18	0.08
Fallow Land	46.93	4.95	Fallow Land	46.26	4.88	-0.67	-0.04	-0.07	Trace
Agricultural Field	369.73	39.03	Agricultural Field	389.82	41.16	20.09	1.34	2.13	0.14
Total	947.30	100.00	Total	947.19	100.00	-0.11	-0.01		

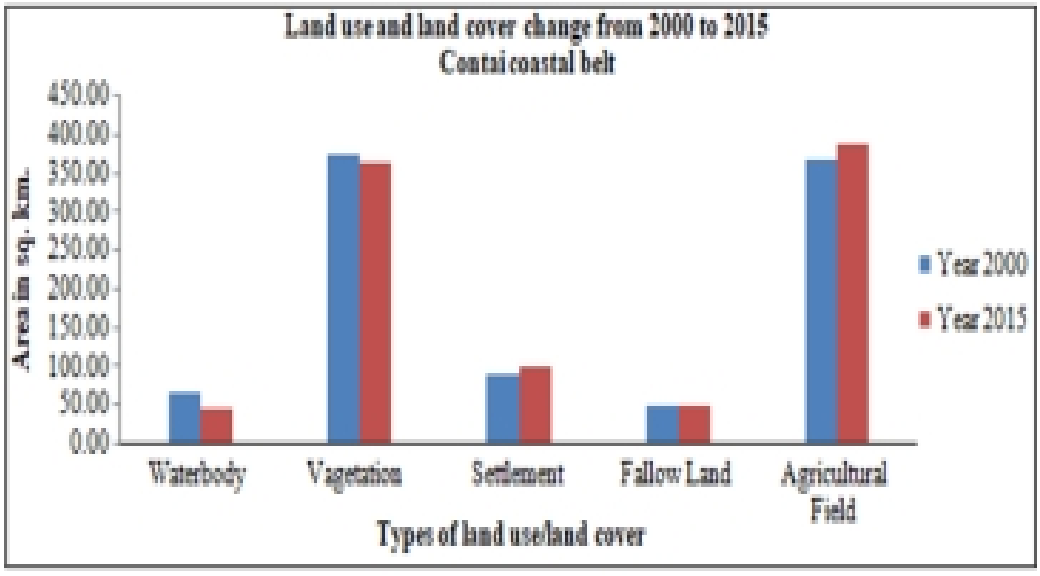

Figure 6: Land use and land cover change (2000-2015) Source: Landsat-ETM (2000 & 2015)

The majority of the area has been converted to agricultural fields and settlements, as was noted during the field work. The primary cause of development is the enticing return on investment in the agricultural and settlement sectors, which is prompting farmers to quickly convert their water bodies and uncultivated land into these new uses. The later discovery of a decline in vegetation was also discovered.

Land Use and Land Cover of Buffer Zones of Holly River

LULC for various buffer zones were generated using the SVM classifier; these zones range from 1 km to 15 km. The research area's LULC was prepared using four parameters: waterbody, built-up, tree cover, and agriculture. The results of the LULC layers' accuracy evaluations are shown in Tables 4 and 5. The kappa value for 1988 was 0.85 and for 2022 it was 0.87, resulting in an estimated 91% and 92% overall accuracy, respectively.

Table 4. Accuracy assessment of LULC of 1988

LULC Classes	WB	BU	TC	AG	Total	User's Accuracy
Waterbody	28	4	0	0	32	0.88
Built-up	3	33	0	0	36	0.92
Tree Cover	0	0	120	13	133	0.90
Agriculture	6	5	10	258	279	0.92
Total	37	42	130	271	480	
Producer's Accuracy	0.76	0.79	0.92	0.95		
			Overall Accuracy			0.91
			Kappa			0.85

Table 5. Accuracy assessment of LULC of 2022.

LULC Classes	WB	BU	TC	AG	Total	User's Accuracy
Waterbody	29	3	0	0	32	0.91
Built-up	2	34	0	0	36	0.94
Tree Cover	1	0	120	12	133	0.90
Agriculture	6	5	8	260	279	0.93
Total	38	42	128	272	480	0.00
Producer's Accuracy	0.76	0.81	0.94	0.96	0.00	
					Overall Accuracy	0.92
					Kappa	0.87

Since ancient times, agricultural activities have dominated the region surrounding Holly River. The area devoted to agriculture rose from 56.7% in 1988 (11,324 km2) to 67% in 2022 (13,360.1 km2) of the entire area (from river borders to a 15 km buffer zone). In contrast, the study region's built-up area likewise grew (almost quadrupled) between 1988 and 2022. The percentage of land covered by buildings rose from 7.7 percent in 1988 to 14.6 percent in 2022. The rapid expansion of the Agriculture and Built-up LULC classes has a significant effect on forest cover and bodies of water. A considerable reduction in the area covered by trees and bodies of water was estimated.

5. Conclusion

The purpose of this research is to utilize GIS and remote sensing to track the changes in land use and land cover along the coastal belt from the years 2000 to 2015. Satellite imaging provides more accurate land use data than more conventional approaches, according to research on land cover and land use categorization.

The various land use types may be readily examined and mapped using image processing methods. The shifting patterns of land use and land cover are critical components of the broader issue of environmental change on a global and regional scale. Those involved in land resource management, including planners and decision makers, rely heavily on data about land use and land cover. The combination of change detection methods with time-series remote sensing data allows for a comprehensive evaluation of land use dynamics. The Hooghly River supplies drinking water and is an important waterway for the Indian state of West Bengal. Primarily, LULC and population affect the river's water quality. Specifically, the LULC along a 15-kilometer radius of both the left and right sides of the river have been assessed. The locals make do with what they have by hunting, gathering materials (wood, lumber, food, etc.), and transforming uncultivated ground into arable land (in certain areas, this involves clearing vegetative cover).

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