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Land Use and Land Cover Change Detection in Medinipur Division, West Bengal, India

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Abstract

This study aims to analyze land use changes in Medinipur Division between 2000 and 2020 using satellite images. The objective is to create land use/land cover maps for three time points (2000, 2010, and 2020) and detect changes that have occurred over the past two decades. Five land use/land cover classes were identified: vegetation, waterbody, cultivated land, sand deposit, and built-up areas.

The study utilized image processing techniques in ArcGIS 10.3 to identify land use changes. The results show significant changes in land use patterns over the 20-year period, with 3534.33 sq/km of land converted to built-up areas. Conversely, vegetation and cultivated land decreased by 3684.7 sq/km, indicating a notable shift in land use patterns.

Keywords: *Landuse; Landcover; Change Detection.*

1. Introduction

Land is the most important natural resource which embodies soil, water and associated flora and fauna involving the total ecosystem. The growing population and human activities are increasing the pressure on the limited land and soil resources for food, energy and several other needs. Comprehensive information on the spatial distribution of the land use/land cover categories and the pattern of their change is a prerequisite for planning, utilization and management of the land resources of the country. Landcover inventories are assuming increasing importance in various resource sectors like agricultural planning, settlement and cadastral surveys, environmental studies and operational planning based on agro climatic zones. As the population increases particularly in the urban areas by attracting job opportunities and city spreads outward from its limit, encroachment on the surrounding available land starts. Due to increasing number of population, agricultural land starts converting into built up area and forest areas starts converting into agricultural land, built up etc.

2. Study Area

Medinipur Division, situated in the westernmost part of West Bengal, India, has been chosen as the study area due to its distinct geographical and climatic characteristics. The region spans 27,223 km², encompassing five districts: Purba Medinipur, Paschim Medinipur, Jhargram, Bankura, and Puruliya. With a population of 18,672,669 as per the 2011 census, Medinipur Division exhibits a tropical climate with a monsoon weather pattern. The region's climate is

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categorized as 'Aw type' according to Koppen's classification scheme, characterized by tropical savanna, hot climate, and dry winters.

The division's urban composition includes 20 census towns and 5 municipalities in Purba Medinipur, 11 census towns and 8 municipalities in Paschim Medinipur, 9 census towns and 3 municipalities in Bankura, and 25 census towns and 3 municipalities in Puruliya. The region's climate is marked by an oppressive hot summer, high humidity, and well-distributed rainfall during the monsoon season. The temperature varies significantly, with maximum temperatures reaching up to 47° C in Bankura during the summer months.

Given its unique geographical characteristics and urban composition, Medinipur Division is an ideal study area for investigating the impact of urban growth on surface air temperature. The region's climate, population, and urbanization trends make it an suitable location for analyzing the effects of urbanization on temperature and developing effective mitigation strategies.

3. Methodology And Materials

Three satellite images of the year 2000 (Landsat 5 TM), 2010 (Landsat 7 ETM) and 2020 (Landsat 8 OLI_TIRS) have been used for the analysis of urban growth within the Medinipur Division. Maximum Likelihood of Supervised Classification using 'Equal' priori probability weighting method, five classes have been identified, namely Vegetation, Waterbody, Cultivable Land, Sand Deposit and Builtup to find out the temporal changes within the span of 10 years of Urban Growth.

Table 1: Satellite data within Medinipur Division used for LULC classification

SPACECRAFT ID	SENSOR ID	WRS PATH	WRS ROW	DATA ACQUIRED	RESOLUTION
LANDSAT 5	TM	138	45	DECEMBER 2000	30
		139	44		
		139	45		
		140	44		
LANDSAT 7	ETM	138	45	DECEMBER 2010	30
		139	44		
		139	45		
		140	44		
LANDSAT 8	OLI TIRS	138	45	DECEMBER 2020	30
		139	44		
		139	45		
		140	44		

Four scenes of different satellites for year 2000, 2010 and 2020 with the paths (138, 139 & 140) and rows (44 & 45) used to classify the land use land cover area to analyze the growth of urban area. The study area of Medinipur Division comprises with 26569.1 Km^2.

ArcGIS and MS-Excel software have been used for the image classification and analysis.

3.1 Land Use Land Cover Analysis

The impact of Land Use Land Cover (LULC) changes on Land Surface Temperature (LST) and Urban Heat Island (UHI) effects has been extensively studied in various urban areas worldwide (Arnfield, 2003; Mirzaei, 2015). Research has shown that LULC patterns significantly influence LST, with different land cover types exhibiting distinct thermal characteristics (Chun & Guldmann, 2014). Studies have investigated the linear association between Surface Temperature (ST) and LULC indexes in cities such as Brisbane (Deilami & Kamruzzaman, 2017), Raipur (Guha et al., 2017), and Shanghai (Nie et al., 2016).

In Medinipur Division, the relationship between LULC, Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI), Normalized Difference Water Index (NDWI), and ST was examined using Landsat satellite images from 2000, 2010, and 2020. The results indicate that while urban built-up areas expanded during this period, vegetation areas also increased in 2020. This study aims to investigate the relationships between LULC changes, ST, and spectral indices, as well as the effects of severe cyclonic disasters on the study area.

The study's objectives include analyzing the pattern of urban growth, projecting LULC changes, ST, and spectral indices for 2030, and identifying strategies to maintain a sustainable environment. By exploring the dynamics of LULC changes and their impact on ST, this research can inform urban planning decisions and contribute to the development of sustainable and resilient cities.

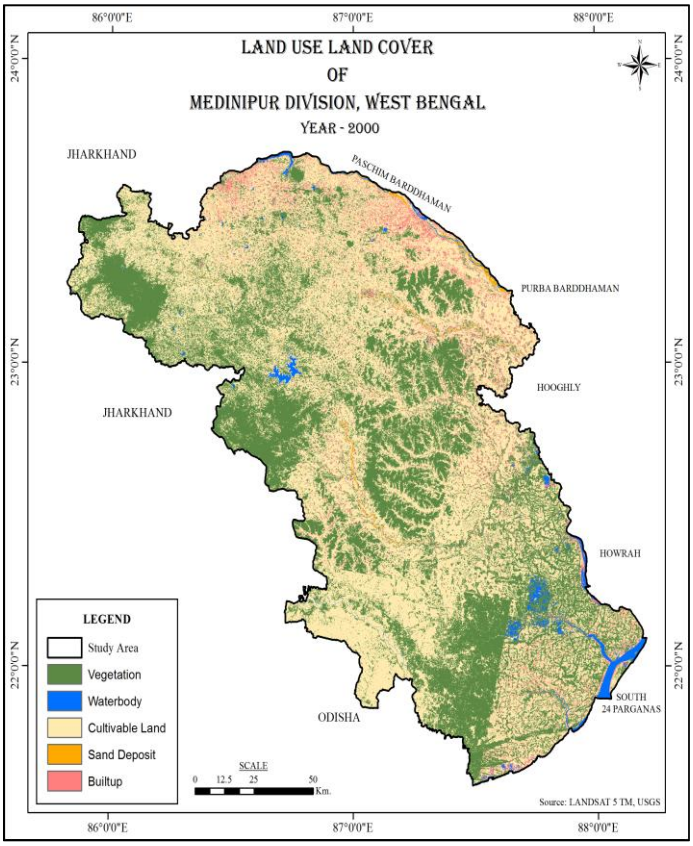

Figure 1: Land Use Land Cover of Medinipur Division for the year 2000

The classified satellite image (Figure 1) and LULC data (Table 2) reveal the land use patterns in the study area. According to the data, the dominant land cover classes are:

The LULC data suggests that vegetation and agricultural land are the primary land cover types, which helps to maintain a healthy environment and reduce surface temperature. In contrast, built-up areas and sand deposits contribute to increased surface temperature, although they occupy a relatively small portion of the study area. In the year 2000, the built-up areas, including dwelling units, roads, and other constructed areas, covered a limited extent.

Table 2: LULC areas for the year 2000

Year – 2000 (Division Area 26569.10 Sq. Km)		
Sl. No.	**LULC**	**Area in Sq. Km.**
1	Vegetation	10476.94
2	Waterbody	492.74
3	Cultivable Land	14116.80
4	Sand Deposit	104.10
5	Builtup	1378.52

It seems that most of the areas are covered by cultivable land and vegetation along with waterbody.

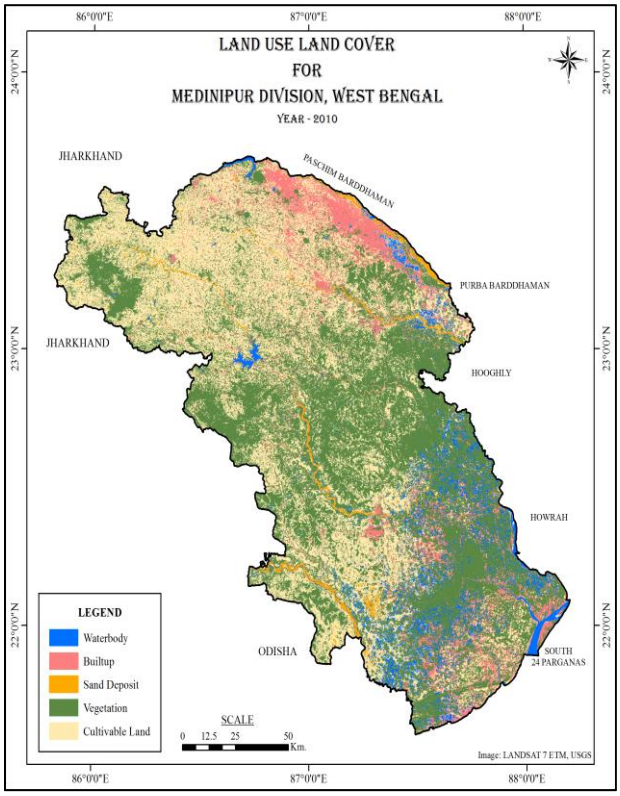

Figure 2: Land Use Land Cover of Medinipur Division for the year 2010

Figure 2 above and Table 3 below are the classified satellite image and LULC areas respectively for the year 2010, showing different classes like Vegetation 11273.71, Waterbody 737.75, Cultivable Land 10693.27, Sand Deposit 294.96 and Builtup 3569.41 in square kilometer respectively.

Table 3: LULC areas for the year 2010

Year – 2010 (Division Area 26569.10 Sq. Km)		
Sl. No.	**LULC**	**Area in Sq. Km.**
1	Vegetation	10273.71
2	Waterbody	637.75
3	Cultivable land	9693.27
4	Sand Deposit	594.96
5	Builtup	3359.41

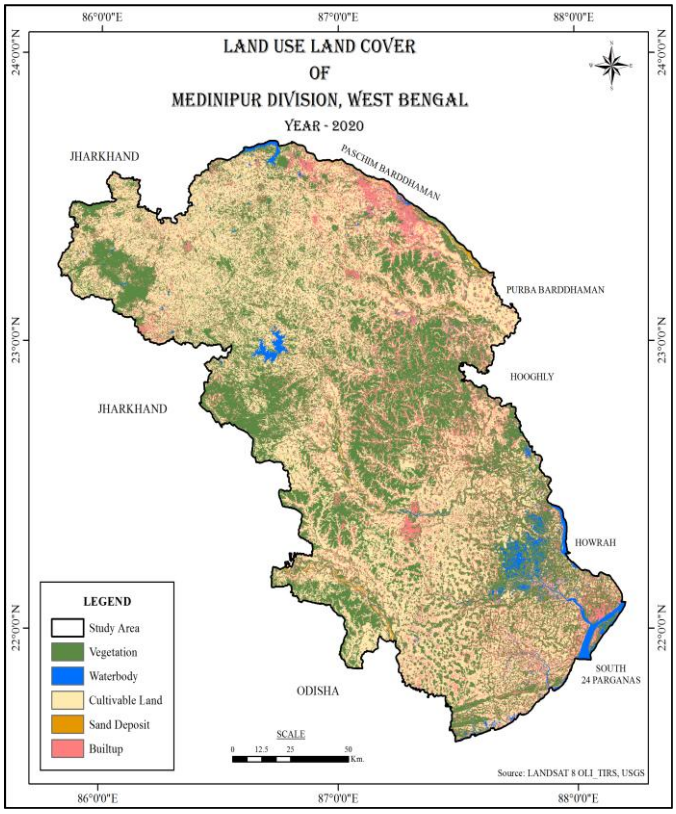

Figure 3: Land Use Land Cover of Medinipur Division for the year 2020

Figure 3 and Table 4 above are the classified satellite image and LULC areas respectively showing different classes like Vegetation 10649.10, Waterbody 487.05, Cultivable Land 9224.89, Sand Deposit 714.28 and Builtup 5483.78 in square kilometer respectively for the year 2020.

Table 4: LULC areas for the year 2020

Year – 2020 (Division Area 26569.10 Sq. Km)		
Sl. No.	**LULC**	**Area in Sq. Km.**
1	Vegetation	10049.10
2	Waterbody	687.05
3	Cultivable land	7624.89
4	Sand Deposit	704.28
5	Builtup	5483.78

4. Result and Discussion

4.1 Accuracy Assessment of Classified Images for the year 2000, 2010 and 2020

The accuracy of the classified map was assessed using the Confusion Matrix tool. This analysis generated several key metrics, including the Kappa Index of Agreement, which evaluates overall classification accuracy. The Intersection over Union (IoU) metric measured the overlap between predicted and actual classes.

The User's Accuracy metric revealed instances where pixels were incorrectly classified as a particular class, while the Producer's Accuracy metric identified cases where pixels of a known class were misclassified. The Total column displayed the number of points assigned to each class.

By examining these metrics, the accuracy of the classified map was thoroughly evaluated, providing valuable insights into the classification process.

Table 5: Accuracy Assessment of LULC for the year 2000

Accuracy Assessment Report of Classified Image for the year 2000								
Class	**Vegetation**	**Waterbody**	**Cultivable Land**	**Sand Deposit**	**Builtup**	**Total**	**User's Accuracy**	**Kappa**
Vegetation	30.00	0.00	3.00	0.00	0.00	33.00	0.91	0.00
Waterbody	0.00	2.00	0.00	0.00	0.00	2.00	1.00	0.00
Cultivable Land	3.00	0.00	47.00	0.00	2.00	52.00	0.90	0.00
Sand Deposit	0.00	0.00	0.00	4.00	0.00	4.00	1.00	0.00
Builtup	0.00	0.00	0.00	0.00	9.00	9.00	1.00	0.00
Total	33.00	2.00	50.00	4.00	11.00	100.00	0.00	0.00
Producer's Accuracy	0.91	1.00	0.94	1.00	0.82	0.00	0.92	0.00
Kappa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.87**

The classification accuracy assessment revealed an overall accuracy of 0.87, indicating a high level of precision. The accuracy value ranges from 0 to 1, with 1 representing perfect accuracy. However, due to the 30-meter resolution of the LANDSAT 5 TM satellite image used for classification, some classes may have been misclassified or overlaid, affecting the accuracy.

Table 6: Accuracy Assessment of LULC for the year 2010

Accuracy Assessment Report of Classified Image for the year 2010								
Class	**Vegetation**	**Waterbody**	**Cultivable Land**	**Sand Deposit**	**Builtup**	**Total**	**User's Accuracy**	**Kappa**
Vegetation	32.00	0.00	1.00	0.00	0.00	33.00	0.97	0.00
Waterbody	0.00	9.00	0.00	0.00	0.00	9.00	1.00	0.00
Cultivable Land	2.00	0.00	44.00	0.00	2.00	48.00	0.92	0.00
Sand Deposit	0.00	0.00	0.00	3.00	0.00	3.00	1.00	0.00
Builtup	0.00	0.00	0.00	0.00	7.00	7.00	1.00	0.00
Total	34.00	9.00	45.00	3.00	9.00	100.00	0.00	0.00
Producer's Accuracy	0.94	1.00	0.98	1.00	0.78	0.00	0.95	0.00
Kappa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.92**

The above table shows that the overall accuracy is 0.92 (The accuracy rates range from 0 to 1 in which 1 represents 100 percent accuracy). Due to the resolution (30 meter) of the satellite image (LANDSAT 7 ETM) used for the classification; there are some overlaid classes which have been classified in different classes.

Table 7: Accuracy Assessment of LULC for the year 2020

Accuracy Assessment Report of Classified Image for the year 2020								
Class	**Vegetation**	**Waterbody**	**Cultivable Land**	**Sand Deposit**	**Builtup**	**Total**	**User's Accuracy**	**Kappa**
Vegetation	33.00	0.00	1.00	0.00	0.00	34.00	0.97	0.00
Waterbody	0.00	5.00	0.00	0.00	0.00	5.00	1.00	0.00
Cultivable Land	3.00	0.00	46.00	0.00	0.00	49.00	0.94	0.00
Sand Deposit	0.00	0.00	0.00	3.00	0.00	3.00	1.00	0.00
Builtup	0.00	0.00	3.00	0.00	6.00	9.00	0.67	0.00
Total	36.00	5.00	50.00	3.00	6.00	100.00	0.00	0.00
Producer's Accuracy	0.92	1.00	0.92	1.00	1.00	0.00	0.93	0.00
Kappa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.89**

The above table shows that the overall accuracy is 0.89 (The accuracy rates range from 0 to 1 in which 1 represents 100 percent accuracy).

4.2 LULC Analysis for the year 2000, 2010 and 2020

The region experienced significant changes in land cover and surface temperature due to severe cyclones. In 2019, cyclones 'Fani' and 'Bulbul' brought heavy rainfall, resulting in increased water bodies and vegetation cover. This, in turn, led to a decrease in minimum and maximum surface temperatures. A similar pattern was observed in 2010, following cyclone 'Aila'. The data suggests that cyclones and associated heavy rainfall can lead to increased water bodies and vegetation, ultimately reducing surface temperatures.

Table 8: Year wise LULC areas of Medinipur Division

YEAR WISE LULC AREA IN SQ. KM.				
Sl. No.	**CLASS**	**2000**	**2010**	**2020**
1	Vegetation	10476.94	10273.71	10049.10
2	Waterbody	492.74	637.75	687.05
3	Cultivable land	14116.80	9693.27	7624.89
4	Sand Deposit	104.10	594.96	704.28
5	Builtup	1378.52	3359.41	5483.78

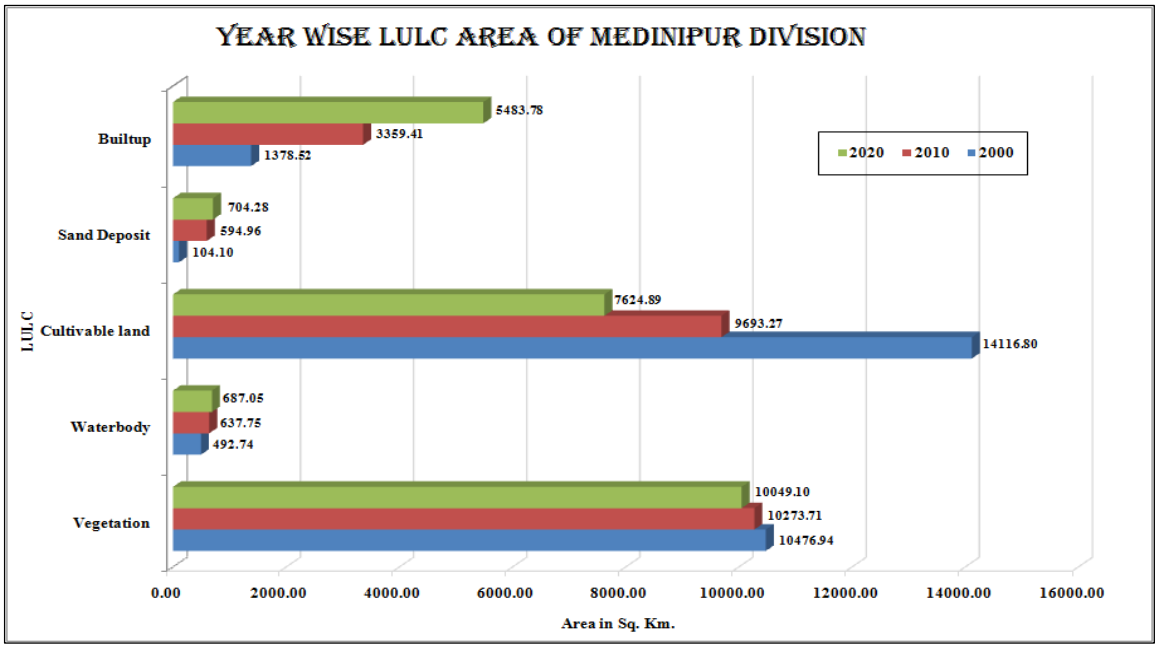

Figure 4: Year wise LULC in Medinipur Division

The analysis of land use land cover (LULC) changes in Medinipur Division from 2000 to 2020 reveals a notable increase in built-up areas, which has contributed to rising surface temperatures. The expansion of sand deposits has also played a role in this temperature increase.

Conversely, the presence of water bodies, vegetation, and cultivable land has a cooling effect on the environment. However, the data indicates a decline in vegetation and cultivable land over the years. On the other hand, the area of water bodies has increased, primarily due to the impact of severe cyclones that brought heavy rainfall and flooding to the region. This increase in water bodies has helped mitigate the rise in surface temperatures.

Table 9: Changed areas of LULC classes of the year 2010 compare to 2000

Sl. No.	LULC	2000	2010	Change
1	Vegetation	10476.94	10273.71	-203.23
2	Waterbody	492.74	637.75	145.01
3	Cultivable land	14116.80	9693.27	-4423.53
4	Sand Deposit	104.10	594.96	490.86
5	Builtup	1378.52	3359.41	1980.89

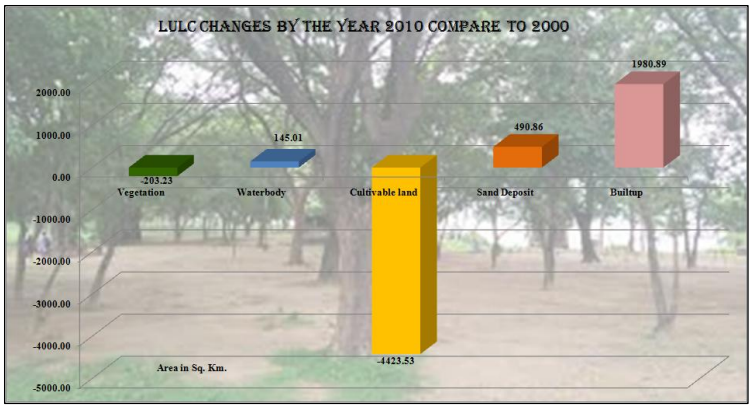

Figure 5: Graphical representation of LULC changes by the year 2010

The above bar graph (figure 5) of LULC classes illustrates that the Cultivable Lands and Vegetation have been decreased to the tunes of 4423.53 and 203.23 sq. km. respectively. Other LULC classes like Waterbody, Sand Deposit and Builtup areas have been increased 145.01, 490.86 and 1980.89 sq. km. respectively by the year 2010 compare to 2000. Though one of the temperature reducing LULC factor, Waterbody increased but refrained areas of Sand Deposit and Builtup had ample opportunities to increase the surface temperature of Medinipur Division by the year 2010.

Changes of LULC classes of the year 2020 compare to 2010 shown by the table 9 and figure 10 below.

Table 10: Changed areas of LULC classes of the year 2020 compare to 2010

Sl. No.	LULC	2010.00	2020.00	Change
1	Vegetation	10273.71	10049.10	-224.61
2	Waterbody	637.75	687.05	49.30
3	Cultivable land	9693.27	7624.89	-2068.38
4	Sand Deposit	594.96	704.28	109.32
5	Builtup	3359.41	5483.78	2124.37

The graph (figure 1.5.2.3 below) and table 1.5.2.3 above show that the vegetative cover has been decreased to the tune of 224.61 sq. km. by the year 2020 compare to the year 2010. Similarly agricultural land also converted to builtup areas as well as sand deposited by the side of river banks which were used for cultivation of crops. Waterbody areas have increased a little bit (49.30 sq. km.), which can force to demean the surface temperature. Augmentation of builtup and sand deposit areas were the major factor to increase the surface temperature as well as degradation of environmental conditions.

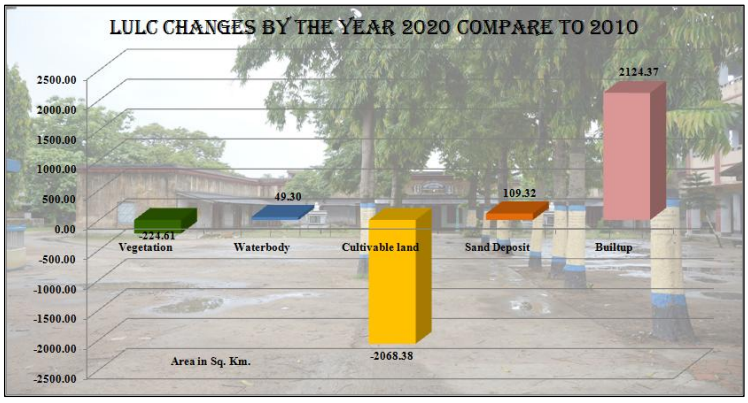

Figure 6 : Graphical representation of LULC changes by the year 2020

5. Conclusion

The year 2020 was marked by the severe super cyclone 'Amphun' and the SARS Covid-19 pandemic lockdown. The lockdown led to a significant reduction in human activities and construction, resulting in changes to the landscape. The combined effects of cyclones 'Bulbul' and 'Fani' in 2019 and the lockdown in 2020 led to an unexpected increase in water bodies and greenery in previously vacant areas.

Notably, the rate of vegetation degradation slowed down in 2020 compared to 2010. Although built-up areas continued to expand, the growth rate was slower than in the previous decade, with most of the expansion occurring before the pandemic period in 2019.

6. Conflict of Interest

The authors declare that they have no conflict of interest.

7. Funding Declaration

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About Author

Angana Roy is a Ph.D. scholar in the Department of Geography and Applied Geography at North Bengal University. Her research centers on analyzing urban growth trends and their influence on surface air temperature in the Medinipur Division of West Bengal, India. The key objectives of her study include detecting patterns and rates of urban expansion in terms of built-up areas and urban population, identifying trends and abrupt changes in surface air temperature, and evaluating the impact of urbanization on local climate variability.

She holds a Master's degree in Geo-informatics with a specialization in Remote Sensing and GIS from Birla Institute of Technology, Mesra (Jharkhand), and a Bachelor's degree in Geography from Shri Shikshayatan College, University of Calcutta.

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