Identification of Vulnerable Land use and Land Cover Change: A Case Study of Super Cyclone (1999), Cyclone Titli (2018), Cyclone Yaas (2021) of Bhadrak District, Odisha, India using Geospatial Techniques.

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Abstract

Tropical Cyclones are well known for massive devastation in many parts of the world including loss of human lives, property damage and environmental degradation. Owing to its unique physiographic and climatic setting, the eastern coast of India is inherent to tropical cyclones that impacts large scale damage to social, economic, land surface process as well as coastal ecosystems. In the present study, Land use and land cover (LULC) changes were studied during three severe cyclones that impacted Bhadrak district of Orissa from (1999-2021). Multi spectral high resolution satellite data were used for mapping and monitoring the change detection before and after the cyclone of 1999 (Super Cyclone), 2018 (Titli Cyclone) and 2021 (Yaas Cyclone) . The Kappa coefficient accuracy assessment of the LULC data of 1999, 2018 and 2021 is consistent with the accuracy of 85%, 86% and 90% respectively. The results suggest that during the super cyclone of 1999, the study area was inundated by 17%. Likewise, during the cyclone Titli the impacted area was just 4%, whereas during the cyclone Yaas the area of inundation has been 9%. The present findings are helpful for disaster management authorities and relevant stakeholders for assessment of cyclone vulnerability and zonation in the study area.

Keywords: *Cyclone Hazard, GIS, Supervised Classification, LULC Change detection, kappa Coefficient Statistical Analysis.*

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1. Introduction

The term "land cover" corresponds to the Land surface properties as represented by the dispersion of plant, water body, as well as other environmental features. Land use is the term used to describe how humans and their environment have altered the land. Regardless of the fact that land use is typically inferred from cover, land use / land cover are always related. Human settlement, for example, is covered, but adding construction, if used for residential and commercial purposes, reveals the territory use characteristic (Chaudhary et al, 2008). Land use/land cover modification has now become a crucial facet in prevailing ways of managing natural environmental challenges. Understanding how human activities affect the planet's natural resource base over time requires a close-up look at Earth from orbit. Observations of Earth objects from orbit give us objective knowledge about how humans have used the landforms in circumstances where land use change is occurring quickly and frequently going unreported. In recent years, data from Planet's surface platform has become critical for modeling the world's surface elements, regulating its ecological environment, and studying environmental changes (Zubair, 2006).

Concerning the effects of shifting associated with land and land-cover (LULC) on catchments attaching hilly regions and marine habitats have led to cultural, financial, and environmental issues at the native, provincial, and federal levels in huge area of globe' (Zhou et al.2014, Yang et al. 2005, Castillo et al. 2014, Sugimoto et al. 2021, Huang et al.2012).'Ability to detect LULC changes (LULCCs) seems to have become relevant in understanding land-use structures, assessing environmental changes, and managing environment for future generations as a result of these concerns'.(Rawat et al. 2013, Kumari et al. 2014, Rawat et al. 2015, Wang et al. 2020). Globally, LULC has been caused by both man-made and natural factors (Zhao et al. 2013, Munoth et al. 2020). As a result of urbanization, growth, and development activities, the growing emphasis on mental and behavioral has changed many provinces that are connected to ports. (Huang et al. 2014; Fan et al. 2019).This appears to be especially true in growing economies. (Dada et al. 2019, Barnieh et al. 2020).

Three cyclones have been used in this study to demonstrate the sequence of events change in land utilization and land cover. Landsat 7 ETM+ data of the month august (before cyclone) and October (after cyclone) for Super cyclone 1999 has been used to

show LULC change. Sentinel 2A optical real time satellite data of the month January (before cyclone) and October (after cyclone) has been use for the cyclone Titli. For cyclone Yaas 2021, multispectral sentinel 2A data of the month January 2021 and May 2021 has been used.

2. Description of Study Area:

Bhadrak district is situated on the east coastal region of Odisha state. It lies between latitudes 20°43' to 21°13' north and 86°16' to 87° east longitudes. The Bhadrak District occupies an area of 2505 square kilometers. The district is surrounded by Kendujhar district on the West and Bay of Bengal, Kendrapara district on the East, Baleshwar district on the North, Jajpur district and River Baitarani on the South. For the convenience of revenue administration, Bhadrak district is divided into 7 blocks namely Bant, Bhadrak, Dhamanagar, Chandabali, Tihidi, Basudevpur and Bhandaripokhari (Fig 1). The mean daily maximum temperature during summer is 36.40C and the mean daily minimum temperature is 24.60C. During winter the mean daily maximum temperature is about 270C and the mean daily minimum temperature is about 140C. The period of June to September comprises the south-west monsoon season. October and November constitute the post-monsoon season. The average annual rainfall of Bhadrak district is 1427.9 mm. About 70% of the annual rainfall is occurred during southwest monsoon season, i.e. June to September. The district is located on the tracks of most of the cyclonic storms and has a landfall of cyclone which forms in the Bay of Bengal in the monsoon season and cross over the Odisha coast. These cause widespread heavy rainfall and strong winds.

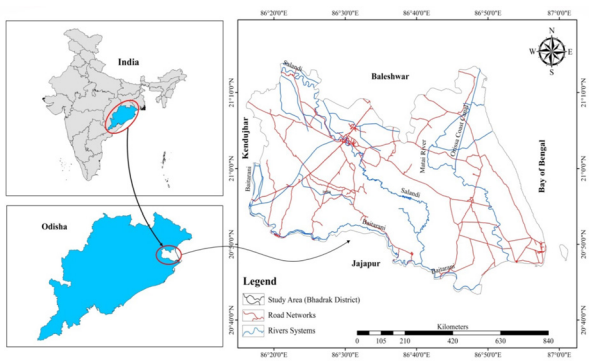

Figure 1 Study Area Map

3. Data Sets and Methodology

3.1 Methodology:

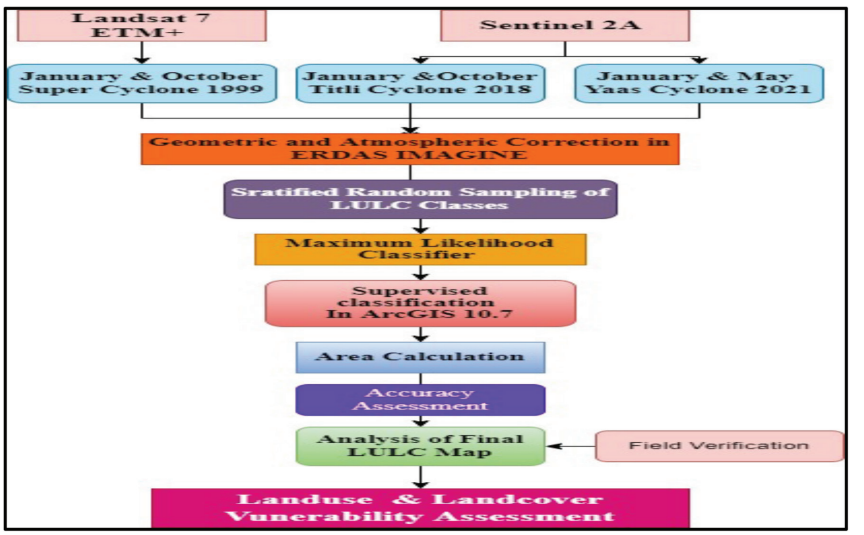

Figure 2 Flowchart of Methodology

3.2 Method of Data Collection:

The temporal satellite data Landsat 7 ETM+ and Sentinel 2A of the study area is pertained to two different seasons, pre-monsoon and post-monsoon (Fig.2) The atmospheric and radiometric correction Hence the images had to be co-registered normalized and subset for input into the classification and change detection process. For validation of the data, field verification has been done around the urban and rural area of Bhadrak district.

Table.1 Details of Dataset used in the Study

SL. NO	Satellite Data	Resolution (Meters)	Period	Sources
1.	Landsat 7 ETM+	30 m.	1999	USGS
2.	Sentinel 2A	10 m.	2018 & 2021	Sentinel Copernicus

3.3 Land use Land Cover Change Analysis

The maximum likelihood classifier is being used in the investigation's supervised classification strategy. The signature file was created using the stratified random sampling method. 50 samples are taken from each stratum (LULC classes) to operate the classification procedure (Toushif et al. 2022). The maximum likelihood classifier, a well-liked supervised classification technique, has been widely employed by Chaudhary et al. (2008), Remi et al. (2007), and Rao&Narendra (2006) for the LULC classification investigations. Following supervised image classification, the initial LULC map is adjusted by surface validation of pendulous zones, and certain categories are transcoded into their correct classes. During this procedures, land use / land cover maps have been tried to introduce, and Jonathan et al. (2007) determined that such Probabilistic Categorization may have been an effective method because it is a well-known algorithm that has been successfully used in a wide range of remotely sensed difficulties while also being very simple to implement. (Lillesand & Kiefer, 2000). Throughout this research, the image analysis scheme ArcGIS 10.7 has been used to identify land use and land cover using supervised categorization (using a Maximum Likelihood Classification algorithm). The study region has been broken down into six LULC classes: river and water body, vegetation and mangrove, farming, built-up, aquaculture, and barren land.

3.4. Kappa Coefficient Statistical Accuracy Assessment Analysis:

The key element in determining a map's legitimacy is accuracy assessment. No picture classification is considered complete until its accuracy has been evaluated. A sample of the pixels from the classified image is taken in order to assess the classification accuracy. The class identification of these pixels is then compared to ground reference data. The Kappa analysis method is employed for accuracy evaluation. The independent multivariate method known as Kappa Coefficient analysis is used to determine the overall accurateness of the maker and contributors, and even the Kappa predictive performance. The class-wise area of the January 1999 (before Super Cyclone) and January 2018 (before Titli Cyclone) images has been estimated after accuracy assessment and adjustment. No accuracy assessment has been made because the change shows temporary variation of LULC before and after the cyclone hazard. Formula of accuracy assessment shown below

Accuracy Assessment Formula

$$\text{User Accuracy} = \frac{\text{Number of Correctly Classified Pixels in Each Category}}{\text{Total Number of Classified Pixel in that Category (The Row Total)}} x100$$

$$\text{Produser Accuracy} = \frac{\text{Number of Correctly Classified Pixels in Each Category}}{\text{Total Number of Reference Pixels in that Category (The Column Total)}} x100$$

$$\text{Kappa Coefficient(T)} = \frac{(\text{TS x TCS}) - \sum(\text{Column Total x Row Total})}{\text{TS}^2 - \sum(\text{Column Total} - \text{Row Total})} x100$$

Where, TS= Total Sample and TCS= Total Corrected Sample

4. Results and Discussion

4.1 Land Use and Land Cover Mapping and Change Detection:

4.1.1. Vegetation and Mangrove:

The Bhadrak District has 7 blocks, 1370 villages, and a geographic area of 2505 square kilometers. In 2011, there were 15, 06,337 people living there, compared to 13, 33,749 in 2001. Small trees, deep scrub, and plantation areas make up the vegetation. Mangroves are the best example of an ecotone since they are found in the transition zone between land and water. Mangroves are tiny trees or bushes that grow in brackish or salty coastal waters. The district's western portion and eastern coastline region are covered in vegetation and mangroves, respectively. In January 1999, prior to the super storm (Fig. 3), roughly 55753.72 Hectares, or 23 percent of the district's entire geographic area, were covered by flora and mangroves (Table 2); however, by October 1999, after the hurricane, only about 21 percent remained (Fig. 4 & Table 3). The vegetation and mangrove area in the year 2018 before the Titli cyclone was 20350.23 Hectares, or 8%, (Fig.7 & Table 5) and it became 20268.47 Hectares after the storm in the month of October 2018 (Table 6 & Fig. 8). During Yaas cyclone in the year 2021 in the month of January before the cyclone the vegetation and mangrove has been recorded 16350.23 Ha i.e 6% of the total area but after the cyclone in the month of May this land cover types has been observed as 15690.53 Ha (Table 8,9,10 & Fig. 11 &12).

4.1.2. River, Water Body and Inundation Area:

Streams, lakes, canals, tanks, and reservoirs are among the natural and man-made water features found in the water bodies. The River and Water Body in January 1999,

before the Super Cyclone, was 638.30 Hectares, or 1%, but in October, after the Cyclone, it increased to 43113.70 Hectares, or 18% (Fig. 3, 4 & Table 2 &3).So in the year 1999 during the super cyclone period a drastic change in the water body has been recorded due to high intensity cyclone. During the month of January 2018 before Titli cyclone 725.13 Hectares i.e. 1% river and water body was recorded but in the month of October 2018 after Titli cyclone river and water body has turned into 35150.28 Hectares i.e. 4% of the total area (Fig. 7,8 & Table 5,6). In the year 2021 before Yaas cyclone the LULC type's river and water body has recorded as 725 Ha but after the cyclone due to heavy rainfall 21814.50 Ha. i.e. 9% of the area has been inundated (Table 8,9,10 & Fig. 11 &12).

4.1.3. Cultivated Area:

Cultivation is the primary activity of an area like Bhadrak district. In the recent year cultivated area occupied 73 % of the total area of the district. 130676.41 Hectares i.e. 53% of cultivated area was recorded before super cyclone 1999 (Fig. 3but it become 91192.95 Hectares i.e. 37% after the cyclone due to flood inundation in the respective land (Fig. 4). In the year 2018 before and the after cyclone the cultivated land has been calculated as 166720.57 Hectares i.e. 68% and 153973.94 Hectares i.e. 63% respectively (Fig. 7,8 & Table 5,6). During Yaas cyclone 2021 before the cyclone in the month of January the cultivated land has been identified as 180620.67 Ha. i.e. 73% of the total area of Bhadrak district (3.10 &3.11). But after the cyclone the scenario has been abruptly changed due to drastic rainfall and the area is recorded as 157031.50 Ha. i.e. 64% (Table 8,9,10 & Fig. 11 &12).

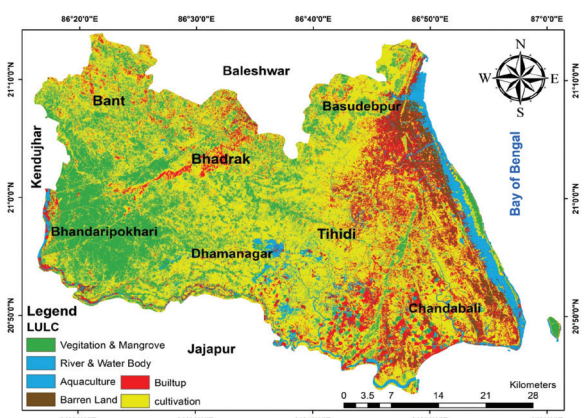

Figure 3 Land use and Land cover Map (Before super cyclone 1999)

Table 2: Land use & Land Cover and Kappa Coefficient Statistics of the year 1999

SL. NO	Land use & Land Cover 1999 January			Kappa Coefficient 85%	
	LULC TYPES	Area in Hectares	Percentage	User Accuracy %	Producer Accuracy %
1	Aquaculture	17032.92	7%	100	50
2	Barren Land	9960.71	4%	85.71	100
3	Built-up	31034.98	13%	80	100
4	Cultivation	130676.41	53%	87.50	77.77
5	River & Water Body	638.30	0%	100	100
6	Vegetation & Mangrove	55753.72	23%	83.33	90.90
Grand Total		**245097.03**	**100%**	**Overall Accuracy-87.5%**	

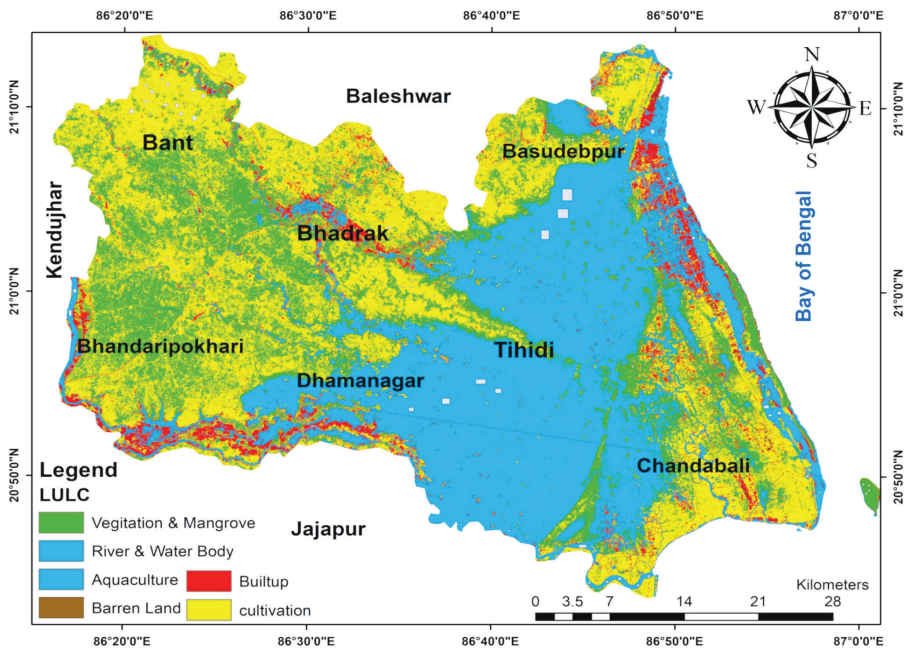

Figure 4 Land use and Land cover Map (After super cyclone 1999)

Table 3: Land use & Land Cover of the year 1999 (After Cyclone)

SL. NO.	Land use & Land cover 1999 October		
	LULC TYPES	Area In Hectares	Percentage
1	Aquaculture	28908.46	11%
2	Barren Land	1265.02	1%
3	Built-up	29770.40	12%
4	Cultivation	91192.95	37%
5	River & Water Body Inundation	638.30	<1%
6	Inundation	42475.40	+17.30%
7	Vegetation & Mangrove	50901.13	21%
	Grand Total	**245151.66**	**100%**

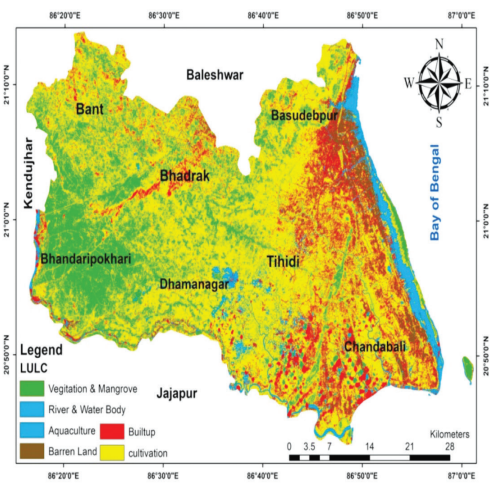

Figure 5 Before Cyclone

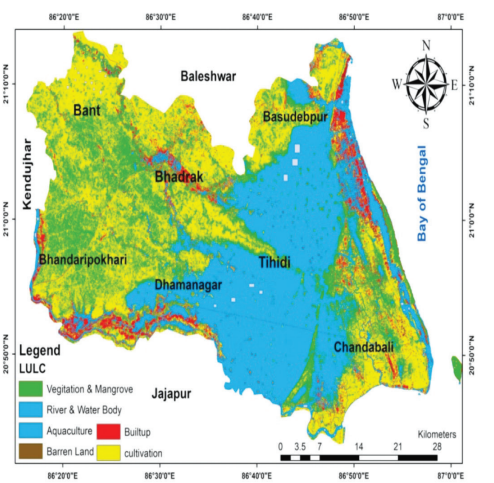

Figure 6 After Cyclone

Table 4: LULC Change Detection Before and After Super Cyclone 1999

SL. NO	LULC TYPES	Area In Hectares January 1999	Area In Hectares October 1999	Area change In Hectares	Percentage Change
1	Aquaculture	17032.92	28908.46	11875.54	4%
2	Barren Land	9960.71	1265.02	- 8695.69	- 3.5%
3	Built-up	31034.98	29770.40	-1264.58	-1%
4	Cultivation	130676.41	91192.95	-39483.46	-17%
5	River & Water Body	638.30	638.30	0	0
6	inundation	0	42475.40	42475.40	+17.30%
7	Vegetation & Mangrove	55753.72	50901.13	-4852.59	-2%

4.1.4. Barren Land:

Land where no human activity has occurred is referred to as barren land. This group includes dry, stony areas, salt-affected areas, scrubby areas, sand areas, and sheet rock areas. Such lands are formed on the basis of soil physical and chemical properties, climate, rainfall, and regional environmental conditions. Before the cyclone in 1999, there were 9960.71 Hectares (or 4% of the area) of barren land (Fig. 3 Table 2); after the cyclone, just 1265.02 Hectares (or 1%) remained (Table 3 & Fig. 4).In the year 2018 before the cyclone the barren land area was 2640.20 Hectares but after cyclone it becomes 2636.64 Hectares (Fig. 7, 8 & Table 5, 6). In the year 2021 the barren land becomes 1525.08 Ha. i.e. < 1% of the study area. But in the month of May 2021 after Yaas cyclone there is a significant decrease in the barren land due to cyclone induce flood and the area recoded as 1006.03 Ha (Table 8,9,10 & Fig. 11 &12).

4.1.5. Built-up Area:

Built-up land is defined as that which is covered by a structure or building. The research region contains both built-up and rural areas as well as minor industries, governmental, educational, and industrial buildings. The built-up area, before and after the 1999 super storm was 31034.98 Hectares, or 13 percent, and 29770.40 Hectares, or 12 percent (Fig. 3,4 & Table 2,3). In the year 2018 the built-up has been recorded as 35175.15

Hectares and 35150.28 Hectares before and after the cyclone respectively (Fig. 7, 8 & Table 5, 6). Due to increase in population in the city area in the recent year 2021 before the cyclone Yaas the built up area has been recorded as 36352.35 Ha. i.e. 15% of the total study area (Fig. 11 & Table8). But after the cyclone the built up area which is situated in the low lying area has been inundated due to heavy rainfall and 32054.16 Ha i.e. 13% built up area has been calculated in Bhadrak district (Fig. 12 & Table 9).

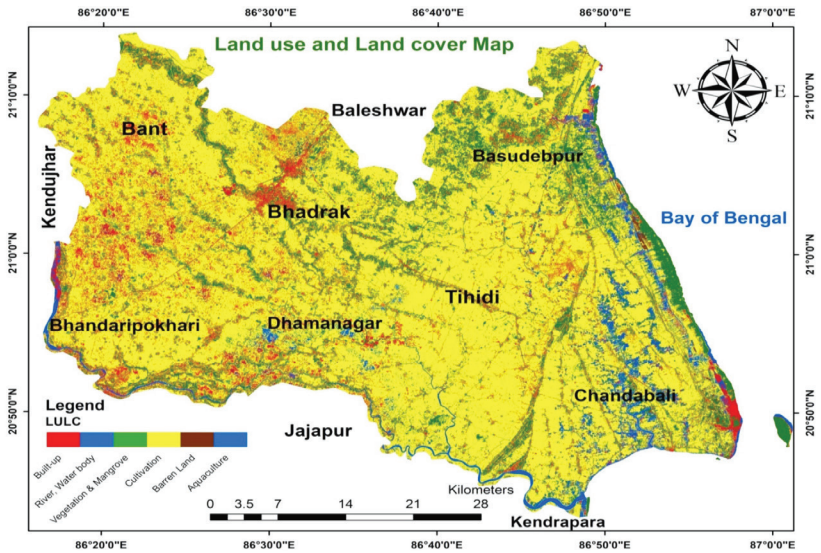

Figure 7 Land use and Land cover Map (Before Cyclone Titli 2018)

Table 5: Land use & Land Cover and Kappa Coefficient Statistics of the year 2018

SL. NO	Land use & Land cover January 2018			Kappa Coefficient Statistics 86%	
	LULC TYPES	Area in Hectares	Percentage	User Accuracy %	Producer Accuracy %
1	Aquaculture	19538.14	8%	90.30	70.50
2	Barren Land	2640.20	1%	87	90
3	Built-up	35175.15	13%	83.20	97
4	Cultivation	166720.57	68%	89	85
5	River &Water Body	725.13	<1%	100	100
6	Vegetation & Mangrove	20350.23	8%	85	84.30
Grand Total		**245149.42**	**100%**	**Overall Accuracy-89%**	

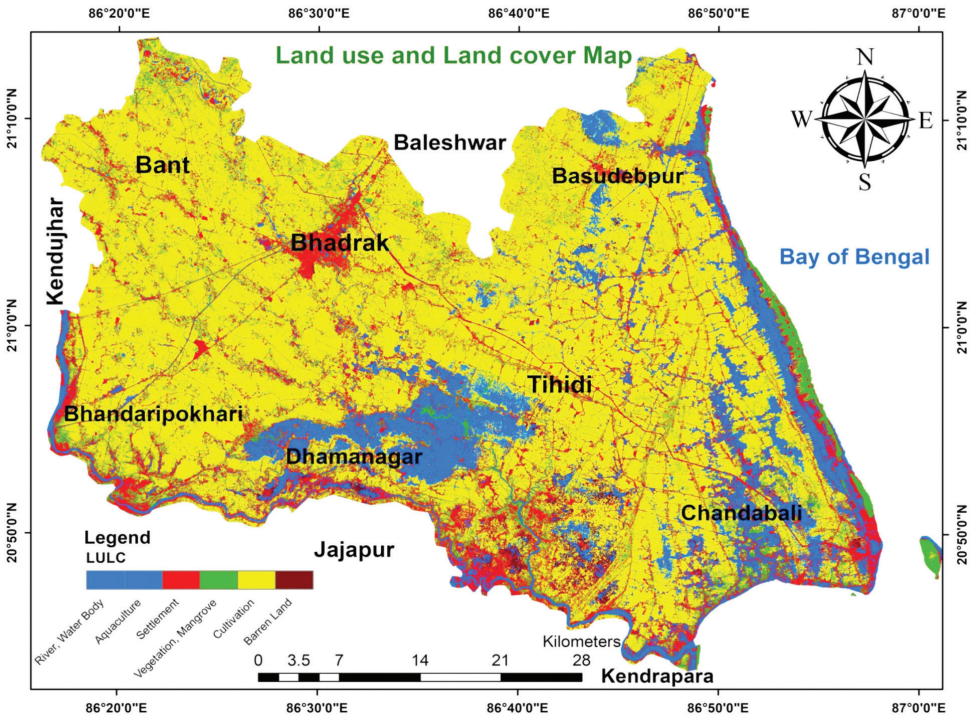

Figure 8 Land use and Land cover (After Cyclone Titli 2018)

Table 6: LULC Change Detection After Super Cyclone 2018

SL. NO	After Titli Cyclone 2018		
	LULC Types	Area in Hectares	Percentage
1	Aquaculture	23281.06	9%
2	Barren Land	2636.64	1%
3	Built-up	35150.28	13%
4	Cultivation	153973.94	63%
5	River, Water Body	725.13	<1%
6	Inundation	9113.90	+4%
7	Vegetation, Mangrove	20268.47	8%
Grand Total		245149.42	100%

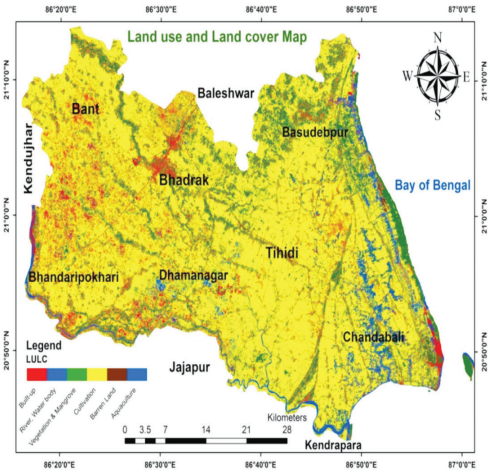

Figure 9 Before Cyclone Titli 2018

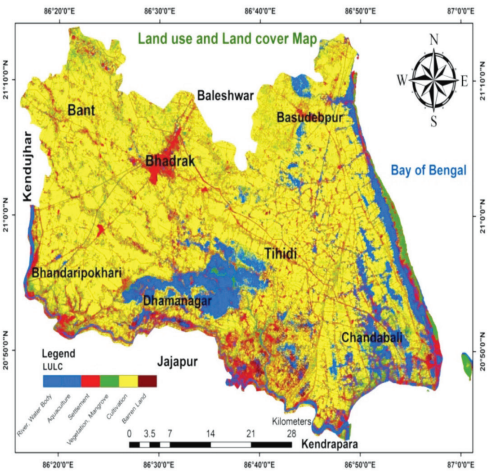

Figure 10 After Cyclone Titli 2018

Table 7: LULC Change Detection Before and After Titli Cyclone 2018

SL. NO	LULC TYPES	Area In Hectares January 2018	Area In Hectares October 2018	Area change In Hectares	Percentage Change
1	Aquaculture	19538.14	23281.06	+3742.92	+1%
2	Barren Land	2640.20	2636.64	- 3.56	0%
3	Built-up	35175.15	35150.28	-4115.30	-2%
4	Cultivation	166720.57	153973.94	-23297.53	-10%
5	River & water Body	725.13	725.13	0	0%
6	inundation	0	+9113.90	+9113.90	+4%
7	Vegetation & Mangrove	20350.23	20268.47	-81.78	0%

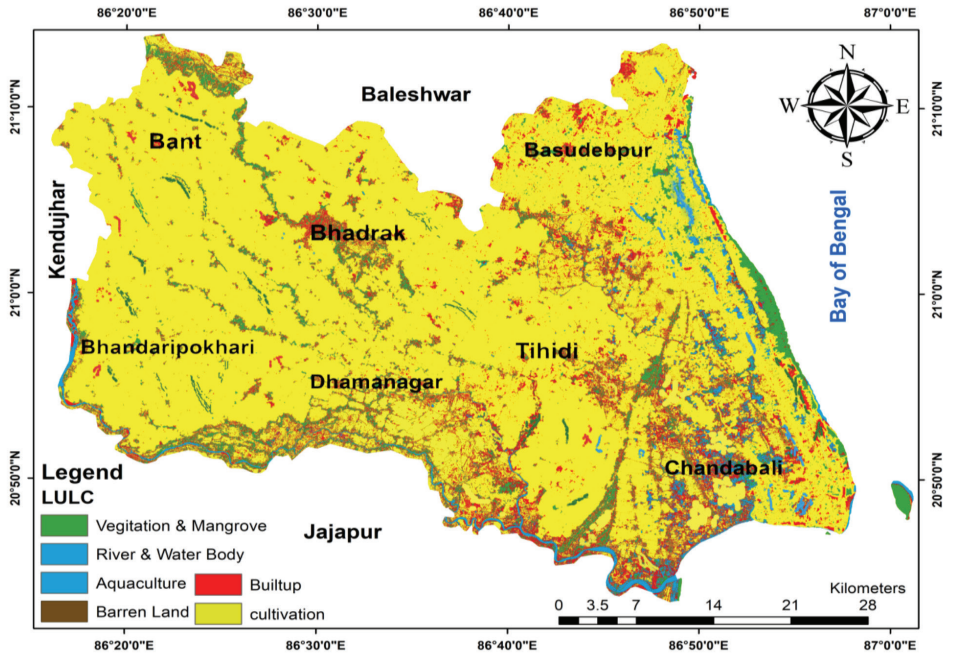

Figure 11 Land use and Land Cover (Before Cyclone Yaas 2021)

Table 8: Land use & Land Cover and Kappa Coefficient Statistics of the year 2021

SL. NO	Land use & Land Cover January 2021			Kappa Co-efficient Statistics 90%	
	LULC TYPES	Area in Hectares	Percentage	User Accuracy %	Producer Accuracy %
1	Aquaculture	15576.02	6%	85.71%	99%
2	Barren Land	1525.08	<1%	78.50%	87.50%
3	Built-up	36352.35	15%	87.75%	89.30%
4	Cultivation	180620.67	73%	85.71%	85.50%
5	River & Water Body	725.13	<1%	100%	100%
6	Vegetation & Mangrove	16350.23	6%	85	84.30
	Grand Total	**245149.42**	**100%**	**Overall Accuracy-89%**	

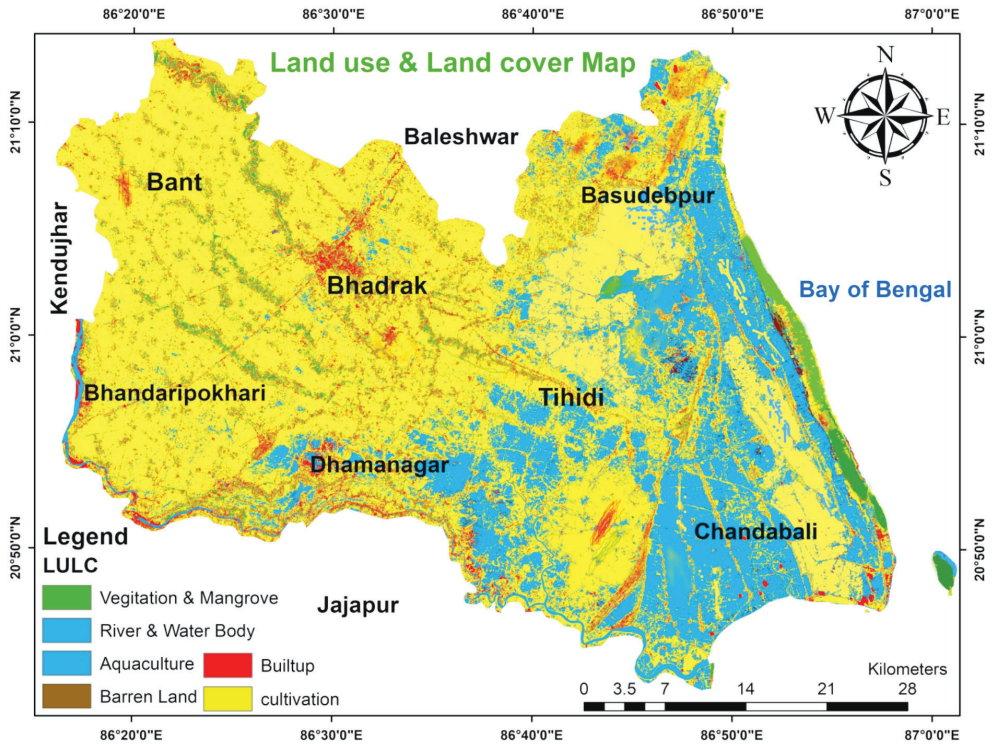

Figure 12 Land use and Land Cover (After Cyclone Yaas 2021)

Table 9: LULC Change Detection Before and After Titli Cyclone 2018

SL. NO	After Yaas Cyclone 2021		
	LULC Types	Area in Hectares	Percentage
1	Aquaculture	16827.15	7%
2	Barren Land	1006.03	<1%
3	Built-up	32054.16	13%
4	Cultivation	157031.50	64%
5	River, Water Body	725.13	<1%
6	Inundation	21814.50	9%
7	Vegetation, Mangrove	15690.53	6%
	Grand Total	**245149.42**	**100%**

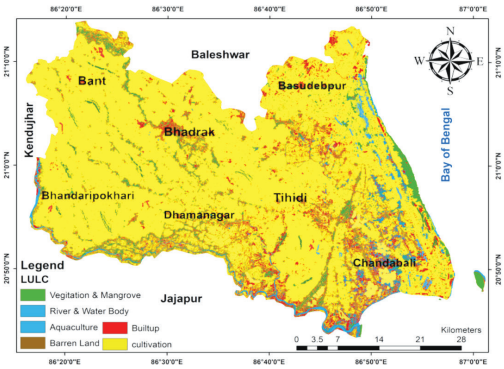

Figure 13 Before Cyclone Yaas 2021

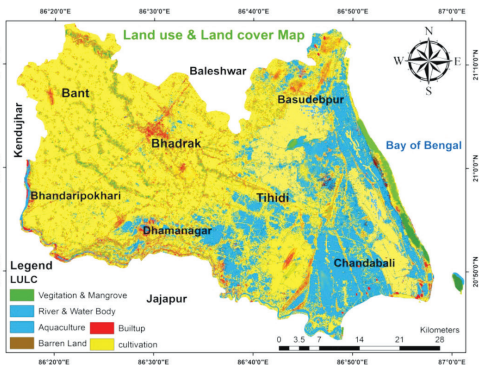

Figure 14 After Cyclone Yaas 2021

Table 10: LULC Change Detection Before and after cyclone Yaas 2021

SL. NO	LULC TYPES	Area In Hectares Before Yaas	Area In Hectares After Yaas	Area change In Hectares	Percent-age Change
1	Aquaculture	15576.02	16827.15	+1251.13	+1%
2	Barren Land	1525.08	1006.03	- 519	-1%
3	Built-up	36352.35	32054.16	-4298.19	-2%
4	Cultivation	180620.67	157031.50	-23589.17	-9%
5	River & water Body	725.13	725.13	0	0%
6	inundation	0	21814.50	+21814.50	+9%
7	Vegetation & Mangrove	16350.23	15690.53	-659.7	-1%

4.1.6. Aquaculture:

Fish farming includes the reproduction, beginning to grow, and cultivation of fish, prawn, and native organisms. It is basically aquaculture. On the eastern coast of the Bhadrak district, a large rectangular aquaculture region has been established in year 1999 before and after cyclone the aquaculture area was 17032.92 Hectares i.e. 7% and 28908.46 Hectares i.e. 11% respectively (Fig. 3,4 &Table 2,3). But on the other hand in the year 2018 before and after cyclone the aquaculture area has become 19538.14 Hectares

i.e. 8% and 23281.06 Hectares i.e. 9% respectively (Fig. 7, 8 & Table 5, 6). In the year 2021 during January the aquaculture area has been recoded as 15576.02 Ha. i.e. 6 % (Fig. 11 & Table 8). But in the month of May 2021 after the Yaas cyclone the aquaculture area has been increased by 1% (Fig. 12 & Table 9).The results of the supervised classification between January 1999 and October 1999, January 2018 and October 2018, January 2021 and May 2021, and January 2018 and October 2018 all clearly demonstrate that there is a percentage fluctuation in the land utilization and land cover area (Table 4,7,10).

Additionally, it is determined that the high intensity storm during the super cyclone of 1999 was the cause of the enormous LULC change detection. The study's findings, however, indicate that the Titli cyclone's low strength caused less of a change in the LULC. Huge areas have been inundated recently during the Yaas cyclone in 2021 because of the cyclone's precipitation-inducing precipitation. However, Yaas Cyclone 2021's intensity was considerably lower than that of Super Cyclone 1999

5. Conclusion

The study's findings demonstrate that, because of their good overall quality and moderate spatial resolution, Landsat 7 ETM+ and Sentinel 2A data are certainly suitable for undertaking regional scale I level LULC analyses. The study's methodology can identify regions of cultivation, barren land, aquaculture, vegetation and mangrove, rivers and water bodies, and built-up areas precisely over the full 2505 sq. km. Bhadrak District, which is capable of generalizing pretty effectively. Additionally, it was able to categories the various classes and significant and intermediate characteristics affecting in the investigation of cultivated land, vegetation, mangroves, and river systems from before monsoon (pre) to after monsoon (post) season Variations in land use / land cover are also attributed to variations in the strength of the super cyclone, Titli cyclone, and Yaas cyclone, according to the study. The district's vegetation and mangrove area was around 55753.72 Hectares, or 23 percent, in January 1999 before the super storm, but it was only estimated to be roughly 21 percent of the overall geographic area in October 1999 following the cyclone. The amount of land that was cultivated in 2018 before and after the cyclone was assessed to be 166720.57 hectares, or 68 percent, and 153973.94 hectares, or 63 percent, respectively. The River & Water Body was 638.30 Hectares (1%) in the month of January 1999, before the Super Cyclone, but increased to 43113.70

Hectares (3%) in the month of October, following the Cyclone. But in the month of October after cyclone it become 43113.70 Hectares i.e. 18%. So in the year 1999 during the super cyclone period a drastic change in the water body has been recorded due to high intensity cyclone. In the year 2021 before Yaas cyclone the LULC type's river and water body has recorded as 725 Ha but after the cyclone due to heavy rainfall 21814.50 Ha. i.e. 9% of the area has been inundated. From the above discussion one can easily observed that the eastern and lower part of the study area has been affected the most. Because of low elevation the eastern and lower part of the district has been affected the most. Dhamnagar, Chandabali, Tihidi and Basudebpur block of Bhadrak district were affected heavily. The northern and western part of the study area is safer than the eastern part because the northern part of the study area comprises of high elevation and far away from cyclone landfall area. This research will help to develop effective land utilization and land cover management plans, as well as improved cyclone hazard prevention policies in the study area.

Reference:

1. Barnieh, B.; Jia, L.; Menenti, M.; Zhou, J. Mapping Land Use Land Cover Transitions at Different Spatiotemporal Scales in West Africa. Sustainability 2020, 12, 8565.
2. Castillo, C.R.; Güneralp, ˙I.; Güneralp, B. Influence of changes in developed land and precipitation on hydrology of a coastal Texas watershed. Appl. Geogr. 2014, 47, 154–167.
3. Chaudhary, B.S., Saroha, G.P., and Yadav, M. (2008) Human Induced Land Use Land Cover Changes in Northern Part of Gurgaon District, Haryana, India: Natural Resources Census Concept. Journal HumanEcology,23(3), pp. 243-252.
4. Dada, O.A.; Agbaje, A.O.; Adesina, R.B.; Asiwaju-Bello, Y.A. Effect of coastal land use change on coastline dynamics along the Nigerian Transgressive Mahin mud coast. Ocean Coast. Manag. 2019, 168, 251–264.
5. Fan, D.; Dac Ve, N.; Su, J.; Vuong, B.; Tran Dinh, L. Coastal morphological changes in the Red River Delta under increasing natural and anthropic stresses. Anthr. Coasts 2019, 2, 51–71.
6. Huang, J.; Huang, Y.; Zhang, Z. Coupled effects of natural and anthropogenic controls on seasonal and spatial variations of river water quality during baseflow in a coastal watershed of Southeast China. PLoS ONE 2014, 9, e91528.
7. Huang, J.; Pontius, R.G.; Li, Q.; Zhang, Y. Use of intensity analysis to link patterns with processes of land change from 1986 to 2007 in a coastal watershed of southeast China. Appl. Geogr. 2012, 34, 371–384.
8. Jonathan, M., Meirelles, M.S.P., Berroir, J.P., and Herlin, I. (2007) Regional Scale Land Use/ Land Cover Classification Using Temporal Series of Modis Data. MS/MT. Revista Brasileira de Cartografia, 59, pp. 1-7.
9. Kumari, M.; Das, A.; Sharma, R.; Saikia, S. Change detection analysis using multi temporal satellite data of Poba reserve forest, Assam and Arunachal Pradesh. Int. J. Geomat. Geosci. 2014, 4, 517–527.
10. Lillesand, T.M., and Kiefer, R.W. (2000) Remote Sensing and Image Interpretation. 4th ed. New York, Wiley and Sons.
11. Munoth, P.; Goyal, R. Impacts of land use land cover change on runoff and sediment yield of Upper Tapi River Sub-Basin, India. Int. J. River Basin Manag. 2020, 18, 177–189.
12. Rao, K.N., and Narendra, K. (2006) Mapping and Evaluation of Urban Sprawling in the Mehadrigedda Watershed in Visakhapatnam metropolitan region using Remote Sensing and GIS. Current Science, 91(11), pp. 1552-1557.
13. Rawat, J.S.; Biswas, V.; Kumar, M. Changes in land use/cover using geospatial techniques: A case study of Ramnagar town area, district Nainital, Uttarakhand, India. Egypt. J. Remote Sens. Space Sci. 2013, 16, 111–117.
14. Rawat, J.S.; Kumar, M. Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India. Egypt. J. Remote Sens. Space Sci. 2015, 18, 77–84.
15. Remi, A., Huang, S., Jiren, L., Herve, Y., and Yvew- Louis, D. (2007) Large Scale Land Cover Map Generation based

on low and medium resolution, Envisat ASAR Data, Application of Poyang Lake area (JIANG XI, P.R. China). Proc. Envisat Symposium 2007, April 23-27, 2007, Montreux, Switzerland (ESA SP -636, July 2007).
16. Sugimoto, R.; Kasai, A.; Tait, D.R.; Rihei, T.; Hirai, T.; Asai, K.; Tamura, Y.; Yamashita, Y. Traditional land use effects on nutrient export from watersheds to coastal seas. Nutr. Cycl. Agroecosyst. 2021, 119, 7–21.
17. Wang, S.; Gebru, B.; Lamchin, M.; Kayastha, R.; Lee,W.-K. Land Use and Land Cover Change Detection and Prediction in the Kathmandu District of Nepal Using Remote Sensing and GIS. Sustainability 2020, 12, 3925.
18. Yang, X.; Liu, Z. Using satellite imagery and GIS for land-use and land-cover change mapping in an estuarine watershed. Int. J. Remote Sens. 2005, 26, 5275–5296.
19. Zhao, R.; Chen, Y.; Shi, P.; Zhang, L.; Pan, J.; Zhao, H. Land use and land cover change and driving mechanism in the arid inland river basin: A case study of Tarim River, Xinjiang, China. Environ. Earth Sci. 2013, 68, 591–604.
20. Zhou, P.; Huang, J.; Pontius, R.G.; Hong, H. Land classification and change intensity analysis in a coastal watershed of Southeast China. Sensors 2014, 14, 11640–11658.
21. Zubair, A.O. (2006) Change Detection in Land Use and Land Cover Using Remote Sensing Data and GIS (A case study of Ilorin and its environs in Kwara State). M.Sc Project, Department of Geography, University of Ibaden.
22. Toushif Jaman, K. Dharanirajan, Sohel Rana: Land use and Land cover Change detection and Its Environmental Impact on South Andaman Island, India using Kappa coefficient Statistical Analysis and Geospatial Techniques-International Research Journal of Engineering and Technology (IRJET), Volume: 09 Issue: 04 | Apr 2022.