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Assessing tropical cyclone impacts in coastal Bangladesh: A change detection analysis on cyclone Bulbul using geospatial analysis and remote sensing techniques

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ABSTRACT

The coastal regions of Bangladesh are highly susceptible to the impacts of tropical cyclones, which frequently pose substantial challenges for disaster management. This research aimed to analyze the immediate consequences of significant catastrophic disasters imposed on coastal regions using geospatial techniques. Cloud-free satellite images and a support vector machine learning algorithm were utilized to examine the outcomes of Land Use and Land Cover (LULC) in the pre- and post-cyclone phase for assessing disaster impact. This study found that after the cyclone Bulbul, 45.08 km^2 of land features were changed. It also showed agriculture, bare land, dense vegetation, and settlement areas have decreased by about 4.75 km^2, 5.55 km^2, 4.56 km^2, and 7.72 km^2, respectively. Instead, the body of water grew at a terrible rate of 22.49 km^2 in areas turned into water body areas. Cyclone made a considerable impact by increasing the waterbody in this study area by flooding, mainly the southern portion, due to the changing process of land characteristics, which increases (waterbody) and reduces (agricultural, dense vegetation, barren land, settlement areas). The accuracy of the analysis was supported by the kappa coefficient. The results underscore the vulnerability of the coastal region and emphasize the need for effective post-cyclone recovery strategies. The study hamper valuable insights into the dynamic changes in the landscape following a cyclone, shedding light on the socio-economic and environmental implications. Further research is recommended to explore the long-term impacts of cyclones on coastal ecosystems and communities, considering the changing climate patterns.

1. Introduction

Bangladesh, located along the Bay of Bengal, frequently experiences significant impacts from tropical cyclones that sweep across its extensive coastlines. These events pose recurrent challenges and necessitate vigilant preparedness and response efforts [1–4]. The nation typically faces a tropical storm approximately once every three years [5]. Tropical cyclones, characterized by high winds, flash floods, and heavy rainfalls, represent a considerable threat to coastal regions worldwide, causing substantial economic and ecological damage [6,7]. The most significant impacts of these natural disasters are often include casualties, infrastructure damage, and communication system interruptions [8–10]. Furthermore, these cyclones contribute significantly to fatalities, with their severity surpassing any other natural calamity [11–13]. Over the last two centuries, tropical cyclones have resulted in approximately 1.9 million fatalities

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globally [8,14]. Between 1968 and 2010, an average of 88 tropical storms occurred annually across the globe [15,16]. With climate change causing global temperature increases and sea level rises the pattern and intensity of such storms are expected to shift [11,14]. In this context, tropical cyclones hampers the economy and ecology and can potentially disrupt natural habitats due to violent thunderstorms, tidal waves, and heavy rainfalls [17]. The following briefly summarizes the estimated number of deaths in Bangladesh caused by cyclones:1970 showed 300,000 fatalities, 1988 had 5704.0 deaths, 1991 spotted 138,866.0 deaths, 2007 witnessed 4234.0 deaths, and 2009 observed 190.0 deaths [18,19]. Bangladesh is struck by 1 % of all cyclones worldwide, yet it suffers 53 % of all cyclone-related deaths worldwide [18].

Coastal regions globally experience recurrent flooding due to these catastrophic natural disasters [3,8]. South Asia, particularly Bangladesh, is highly vulnerable due to its topographical characteristics, population density, and the frequency of cyclonic events [4,11,20–22]. Cyclones substantially threaten these regions' agricultural practices, causing significant reductions in seasonal crop production and impacting the livelihoods of coastal communities [10,23]. Evaluating community vulnerability and implementing efficient post-cyclone recovery strategies necessitates a comprehensive analysis of cyclone impacts. This coastal region's community experiences cyclones yearly [24], which damage the (Water Quality Index/Irrigation Water Quality Index) ratio of coastal groundwater by intruding the saltwater in the coastal aquifers [2,25,26,26,27][21]. described the effects of environmental change in Patharghata subdistrict (230 km^2), where geospatial approaches were used to generate both temporal and non-spatial additional information. Several authors [1,5,28] recognized the Land Use and Land Cover (LULC) where wetland evolution and ecology are shifting rapidly in these coastal areas, which has been detected using geospatial methods and Landsat images. Most of the time, cyclones affect LULC, which damages the actual ecosystems and needs extended periods to return to its previous condition after the hurricane. Natural disasters cause significant atmospheric trouble, reducing the provision of coastal ecological services [9,10,18].

Over the last 20 years, several authors have used remote sensing and other geospatial techniques to identify changes in LULC in the coastal regions of Bangladesh [1,3,7,21,29]. GIS, remote sensing (RS) were integrated to map possible freshwater sites in the eastern Chad region of Waddai [30]. Data on impoverishment, danger of flooding, and LULC change were correlated to determine the effects on Bangladesh's the coastline [6,31]. A significant component of geography-related technology is RS, and current advances in this field have been essential in advancing geospatial techniques[1][4,20]. Researchers [7,18,19] have extensively used risk modelling to anticipate future impacts of tropical cyclones under warming scenarios. Cyclone Bulbul, one of the longest-lasting transnational cyclones in the history of Bangladesh, hit on 9 November 2019, affecting 14 coastal districts and impacting an estimated 0.73 million people, detailing the severity of potential threats [32] This cyclone being different in nature in terms of landfall, severity, casualty it is important to analyze the impact of such tropical cyclones and it can open the window of future research by comparing various durational and categorical tropical storms and find out the growth rate of crops and vegetation (agriculture) in the transition period between two cyclones which makes landfall in similar seasons. Therefore, a thorough analysis of the impact of tropical cyclones is imperative for implementing effective post-cyclone recovery strategies. Additionally, storm surge models incorporating geospatial analysis of storm surge impact are crucial to these evaluations. Satellite imaging is a reliable, feasible, and economical way to analyze tropical storm damage across regions [33,34].

Several research articles have thoroughly analyzed the current approaches for assessing coastline risk[4,5,35]. Most of the models that have been carried out have applications on both a regional and global level. Disaster experts, however, generally acknowledge that carrying out coastline risk evaluations at the local level is helpful in precisely determining the nature of the danger and in determining which risk management techniques are most suitable[1,21,36] has shown that, while there is no possibility of a pre-post change in a cyclone, tracking alterations of LULC in mangrove forest regions is achieved through remote sensing and GIS approaches. In local-scale techniques, the distinctive qualities of a particular region are taken into consideration [4,37] has indicated the practical significance since regional variations in climatic and socioeconomic factors may significantly alter the catastrophe risks a given neighborhood might experience. Satellite images were analyzed to determine land cover changes in the Shyamnagar region of Bangladesh throughout the thirteen-year study period (1999–2012) [38].

This research focused on Cyclone Bulbul, a Category-2 cyclone that made landfall along the coasts of West Bengal, India, and subsequently Bangladesh on November 9, 2019. With an approximate duration of 36 hours, Cyclone Bulbul was one of the most protracted transnational cyclones in Bangladesh in the last 52 years [39,40]. The cyclone affected 0.73 million people, displaced over two million residents, caused twelve deaths, and led to significant agricultural losses. This study aimed to identify the changes in LULC in the pre- and post-cyclone phases in the southwestern region of Bangladesh and assess the impact in this study area.

1.1. Study area

This study focuses on Patharghata, a subdistrict in the Barguna district of Bangladesh recognized as one of the most cyclone-prone coastlines in the region. It is situated within the geographical coordinates of 22°14′ to 22°58′ N latitude and 89°53′ to 90°05′ E longitudes [21] Fig. 1(a–d). This subdistrict borders Mathbaria and Bamna to the northeast and southwest, Barguna Sadar and the Bishkhali River to the east and west, and the Bay of Bengal to the north Fig. 1(a–d). It comprises seven unions and 43 villages [21]. This study area has a standard altitude of around 8 m above the ocean level [21] [41]. The area is traversed by three primary rivers: Bishkhali, Haringhata, and Baleshwar. Patharghata has a tropical climate characterized by a standard yearly ambient temperature of 26.0 °C and a typical yearly precipitation of 2410 mm [42]. Precipitation occurs consistently over most of the year's duration [43]. The region offers a range of environmental assets such as woods, farmland, fishing grounds, salt, and promising opportunities for ecotourism and other forms of economy [4,5,7]. A comparatively impoverished people live along the seaside to be near both physical and financial assets that contribute to their sources of income (fishing, farming, forestry, and ecotourism) [43].

This area has faced several coastal catastrophes during the last three decades [44] [15,20]. A tidal bore on November 12, 1971, and a tornado on September 17, 2006, caused regional calamities. Tropical cyclones Sidr (2007), Aila (2009), and Mahasen (2013)

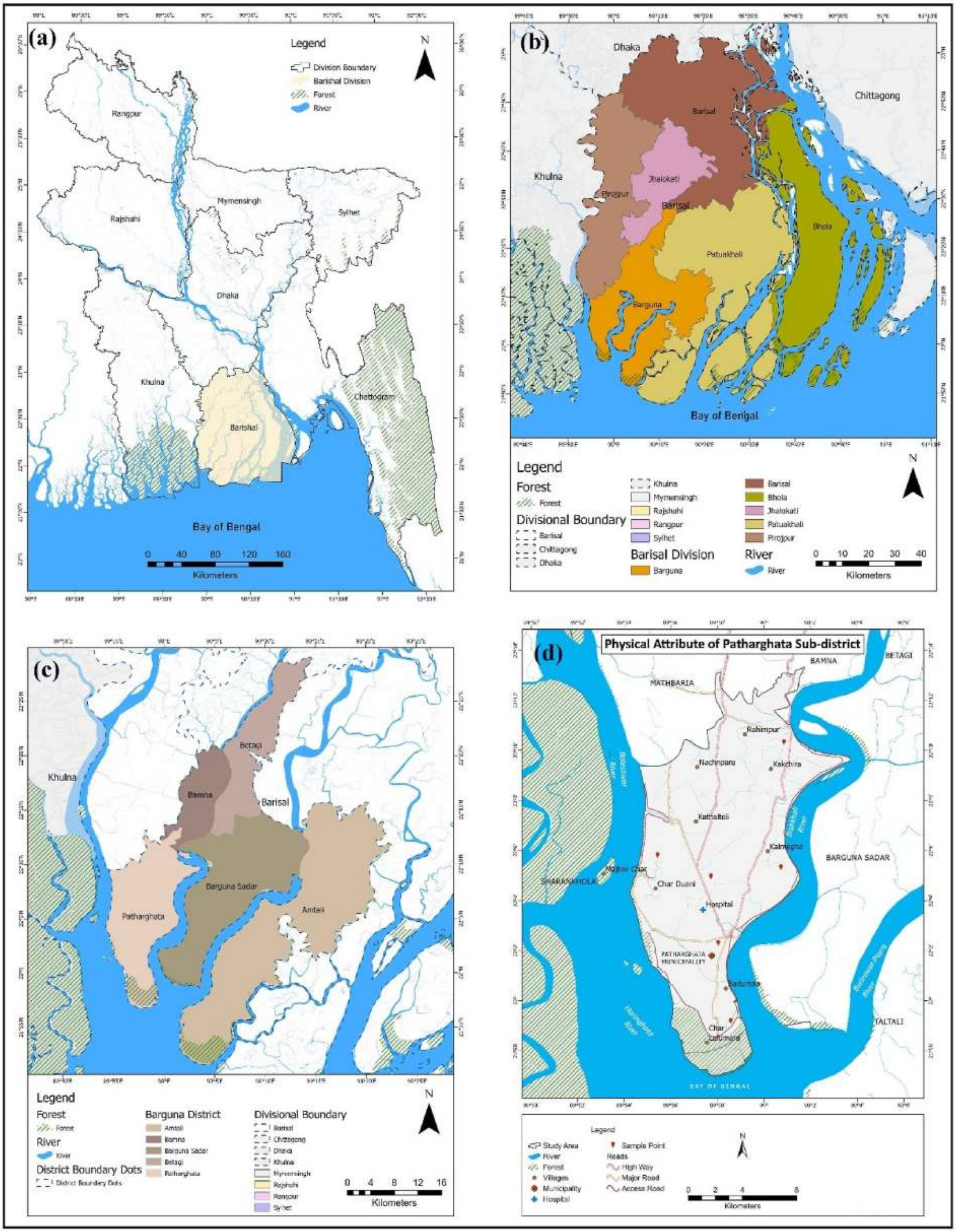

Fig. 1. Study area map (a) Bangladesh; (b) Barisal Division; (c) Barguna District; (d) Patharghata Subdistrict.

also killed and devastated local people [22]. Other than tropical cyclones, rising water levels and coastal erosion are significant issues. The salinity of intrusion, extensive flooding, persistent water retention, watercourse siltation, and subsidence are frequent in this coastal area [24]; [45]. Characterized by its low-lying topography with little topographical relief, the coastline of Bangladesh, and its offshore islands are particularly vulnerable. Less than 3 m separate the coast from the mean sea level, making it susceptible to the extensive astronomical tides frequent along the coastline [42]. During the cyclonic storms, the rise in water can potentially reach at alarming heights. As a result, the Patharghata coastal region experiences numerous catastrophic events each year, including floods, cyclones, storm surges, saltwater intrusion, and riverbank erosion Fig. 1(a–d). These events have profound implications, causing significant disruptions to human lives, damaging infrastructure, displacing populations, and altering local lives [24]. Natural disasters in the area substantially threaten individuals' well-being, economic stability, residential infrastructure, and overall health [45].

2. Materials and methods

2.1. Data acquisition

Additional analysis will provide a deeper understanding of the issue. Quantitative data from satellite images, such as Landsat and sentinel images from the USGS Earth Explorer have been used to classify LULC. The USGS Earth Explorer platform allows users to search for available images within a specified date range, with filters for necessary image specifications like cloud coverage. Landsat 8 OLI/TIRS Collection-2 Level-1 aided cloud-free images for the study area (Table 1).

2.2. Satellite image processing

Several methods were combined in this study to analyze the effects of tropical cyclones. Cloud-free satellite images taken before and after the cyclone were assessed. Using pre- and post-cyclone Landsat-8 satellite imagery, machine learning technique Support Vector Machine (SVM) was used to derive spatial information of selected artificial and natural features categorized by types of land cover and land use [11,38]. SVM has been used for supervised LULC classification, helping to highlight vegetation damage effects. The objective was to highlight the cyclone's impact in terms of damage or loss through the quantification of land use and land cover features area in statistical units [31]. Overall methodological structure in this study has been shown in Fig. 2.

2.3. LULC classification

Following a physical visit to the study area, Landsat imagery from satellites is classified into five LULC classes by several authors [46,47] classes: (a) Agriculture (agriculture/lower green areas/agricultural); (b) Built-up (residential/communicating roads/shores/playgrounds/industry); (c) Bare land; (d) Dense vegetation (forest, mangroves); (e) Waterbody. In ArcGIS Pro, SVM technique has been implemented in the categorizing process to classify the satellite images. SVM algorithm is an extensively utilized, advanced, and dependable classification method. It is also suitable for complicated.

Table 1
Properties of datasets used in this study.

Year	Data Acquired (DD/MM/YYYY)	Geometric attribute	Sensor	Application	Resolution
2019	November 07, 2019	Level-1	Landsat 8 OLI/TIRS Collection-2 Level-1	Classification	30m
2019	November 23, 2019	Level-1	Landsat 8 OLI/TIRS Collection-2 Level-1	Classification	30m
2019	November 28, 2019	Level-1C	Sentinel-2A	Validation	10m

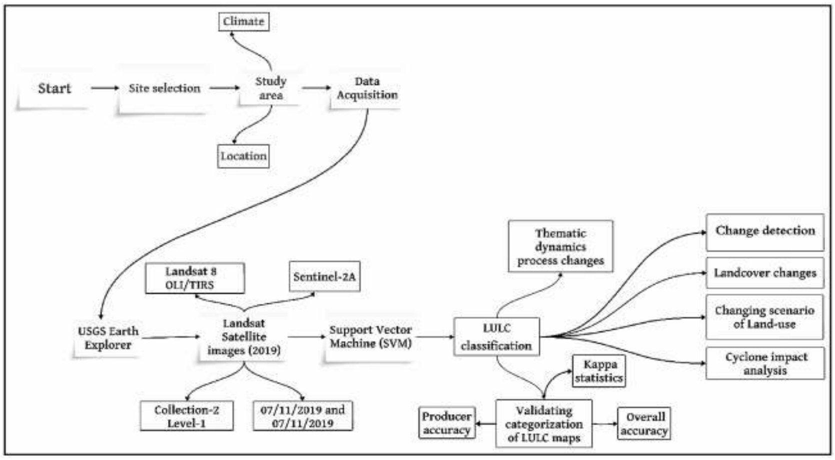

Fig. 2. Methodological Flow chart to help understand the analysis process.

2.4. Change of thematic dynamics process

Evaluating each image thematically makes it feasible to forecast thematic variations in this case. In here, mapping is displayed the differences between the two classified LULC outcome. The thematic shift of the pixels dictated the alterations in them. The images gathered after the disaster would provide a distinct spectrum combined with the images obtained before the incidents. Changing characteristics were monitored in this study, and ArcGIS software was utilized to generate the class modifications. This tool would provide a concept of the shifting patterns of land-cover change to a particular extent across different classes [4,11,20]. This research would only look at subclasses that are relevant to shift.

2.5. Validating categorization of LULC maps

The random assortment of one-third of the regarded sites was used in the validation procedure. Pre-post-categorized images were also subjected to accuracy analysis based on validating reference points. The correctness of the categorized pictures has been evaluated in terms of producer accuracy, overall accuracy, and Kappa statistics. The producer accuracy, overall accuracy, and kappa statistics equations represent [1,44,48] some of the most effective quantitative measures for classifying satellite images, and they are explained below:

$$\text{Overall Accuracy} = \frac{\text{Total corrected categorized pixels (diagonals)}}{\text{The total referencing pixels}} * 100 \quad \text{(i)}$$

$$\text{Producer Accuracy} = \frac{\text{Number of pixels identified properly per category}}{\text{Maximum referenced pixels per categories (column total)}} * 100 \quad \text{(ii)}$$

$$\text{Kappa Coefficient} = \frac{\text{Total number of Sample} * \text{Total number of corrected sample} - \sum (\text{col.tot} * \text{row.tot})}{(\text{Total number of samples})\,2 - \sum (\text{col.tot} * \text{row.tot})} * 100 \quad \text{(iii)}$$

3. Results and discussion

3.1. Classification accuracy

Table 2 provides an accurate classification of each class before displaying the result. It is an assessment of the accuracy of the cyclone categorization both before and after the disaster. There was a lack of precision in the settlements because of the low resolution of the satellite image. Thus, it was difficult to pick out individual pixels. In terms of the correctness of the whole, the accuracies of the other classes are quite high.

The classification accuracy was analyzed for the recent image before and after the cyclone of Bulbul in this study area with an overall accuracy of 95.06 % and 94.54 % (Table 2). On the other hand, the kappa coefficient was found to be 0.9361 and 0.9093, respectively. The convergent criteria for Kappa statistics were specified by Ref. [49] as follows: undesirable when Kappa <0.4, fair when $0.4 <$ Kappa <0.7, and outstanding when $K > 0.75$. In light of this, the classification of LULC used in this investigation indicates superior (Table 2). This implies that the level of agreement between the frequencies of the classified images and reference data is substantial, which also shows that the accuracy of the classified images is strong. This investigation's findings agree with those of [50,51], who revealed an acceptable overall accuracy of 86.6 % and 87.1 %, respectively. This study area's overall accuracy is also compatible with their findings. As a result, the Kappa statistical analysis of this analysis demonstrated a high degree of concordance for the most recently categorized image and the overall accuracy allowed range of the following LULC adjustments investigation [50].

3.2. Change detection analysis on LULC

Table 3 and Fig. 3 summarizes the changes identified per Land cover class of different areas before and after the cyclone. Comparison of pre-and post-cyclone images provided an overview of land cover changes. Five main categories of LULC were identified for the pre-post of the cyclone Bulbul (Table 3). These types were settlement, dense vegetation, bare land, agricultural, and waterbody (Fig. 3). shows the series of changes in this area: Dense vegetation < Agriculture < Bare land < Settlements < Waterbody. It has been found that most of the site has been sifted on waterbody areas. It can be inferred from the changes in settlement agriculture (crops) sustained significant damage.

Table 2
Summary of classification accuracies of pre- and post-cyclone of classified images.

Class	Before-cyclone		After-cyclone	
	User accuracy (%)	Producer accuracy (%)	User accuracy (%)	Producer accuracy (%)
Settlements	94.54	98.18	88.06	93.56
Dense vegetation	93.48	88.52	97.9	99.02
Agriculture	97.06	99.95	99.01	87.03
Waterbody	99.48	92.67	92.08	94.63
Bare land	97.96	88.78	90.8	98.45
Overall accuracy	95.06 %		94.54 %	
Kappa coefficient	0.9361		0.9093	

Table 3
Total area per cover class before and after the cyclone and amount of area changed.

Class	Area Before Cyclone (km^2)	Area After Cyclone (km^2)	Change(km^2)
Agriculture	90.0978	85.3417	4.7561
Bare land	25.6027	20.0511	5.5515
Dense vegetation	74.2198	69.656	4.5637
Settlements	24.8715	17.146	7.7254
Waterbody	11.1513	33.6494	−22.4924

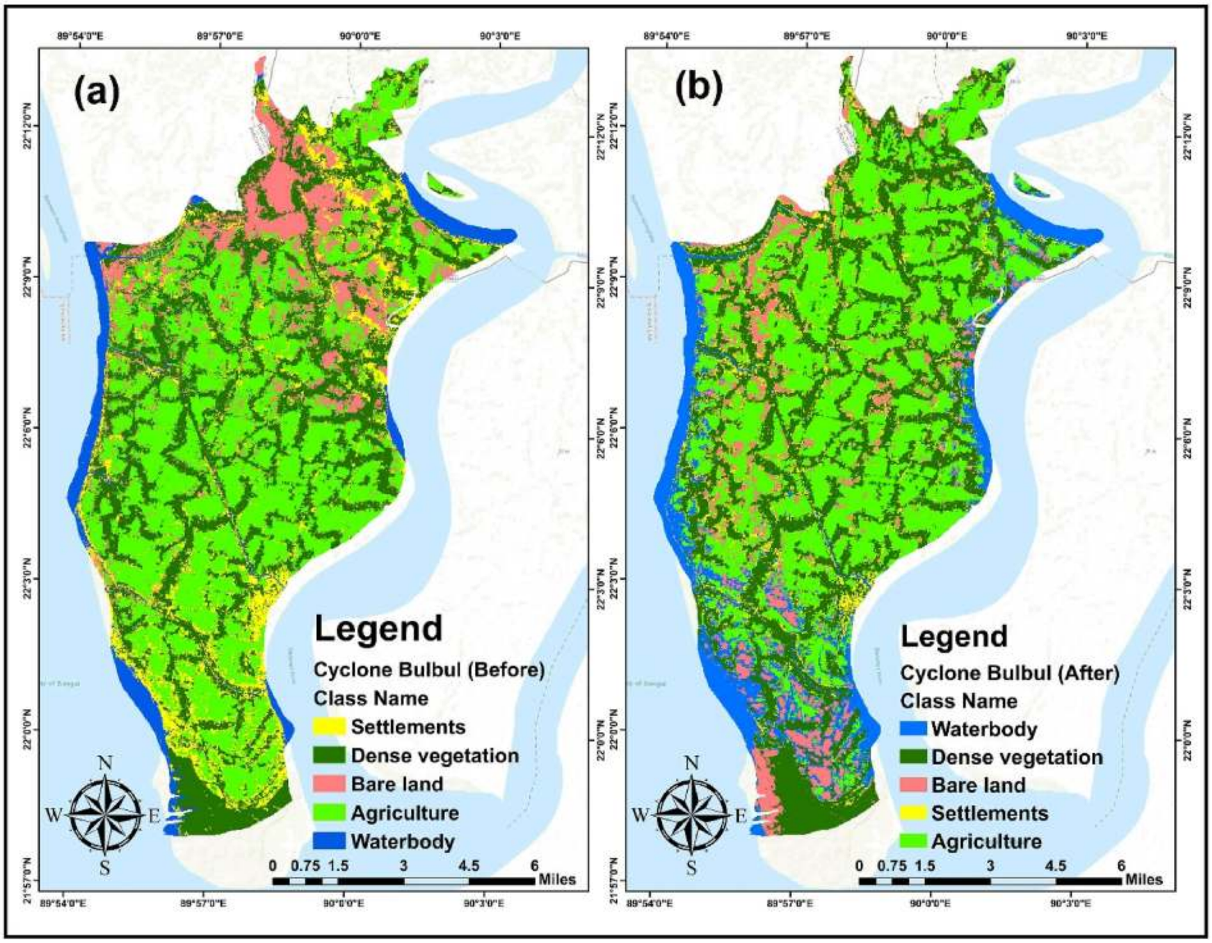

Fig. 3. LULC classification map of pre-cyclone and post-cyclone of Bulbul.

The findings revealed that the total land area of the region under investigation was 225.9431 km^2 (Table 3). The summary of the area coverage and percentage of each LULC during the two periods, covering both before and after the cyclone Bulbul, can be seen in Table 3. According to the LULC categorization on Fig. 3 of the TM 2019 before the cyclone image, most of the research area comprised dense vegetation and agricultural land, comprising a total area of 74.2198 km^2 and 90.0978 km^2 and, equivalent to nearly 60 % of the site. The bare land and settlements were 25.6027 km^2 and 24.8715 km^2, respectively. In comparison, the waterbody of cover accounted for 11.1534 km^2 of the district's total land area (Table 3 and Fig. 3). Similarly, after the cyclone, agriculture and dense vegetation—which together occupy an area of 85.3417 km^2 and 69.656 km^2 —accounted for the most significant portion of LULC across all classes. The total area of 20.0511 km^2 and 17.1466 km^2 were covered by bare land and settlement, respectively. Waterbody regions, which comprise 33.6494 km^2, were the subject of the most recent aerial surveillance (Table 3 and Fig. 3).

The results showed that the research region saw several LULC variations during certain pre- and post-cyclone phases. The findings demonstrated that at that time, the waterbody region in the research area considerably grew and gained influence. On the other hand, a more significant portion of the land covered by settlements had dropped dramatically and changed into different LULC zones. Furthermore, an increasing amount of land was abandoned and deteriorated. It was discovered that the growth of farmed and densely vegetated areas at the cost of grazing land and forest cover was compatible with LULC trends previously documented [12,22,33,37]. According to [18]; [32], a considerable amount of mangrove forest was lost in many regions, particularly in Bangladesh, in the 1960s compared to the total amount of forest cover the rate was high. In addition to natural calamities, the local population makes more use of the nearby forest since they rely on it for their financial security rather than the remote forest. The rise in lodging options, such as small-scale businesses and communication networks, is to be anticipated in terms of the built-up area. Due to the research area's location and downstream of rivers [8,31], caused constant erosion during this cyclone period and over the years and the water area grew over time. Findings from studies [7,8,21,40] in several coastal regions of Bangladesh were likewise in line with this analysis. It is also compatible with research by Ref. [4,7,40], who found that during the past few decades of cyclones, agricultural and settlement land decreased where water bodies increased. By modifying land structures, transportation, and execution, this cyclone directly or indirectly impacts the changing climate, affecting the LULC and the environment [3,20].

3.3. Landcover changes

The technique known as Thematic Change Dynamics is responsible for the thematic shifts that have occurred in the region (Fig. 4). Table 4 showed that there had been five different kinds of land cover where waterbody areas changed at higher rates, particularly around 22.4924 km^2 by changing. It also indicated a significant effect, which is around 201.702 % impact that is found by waterbody in the overall land. (Fig. 5 and Table 4). It had observed by several authors [20]; [12,20] that that when a cyclone (like Bulbul) moves

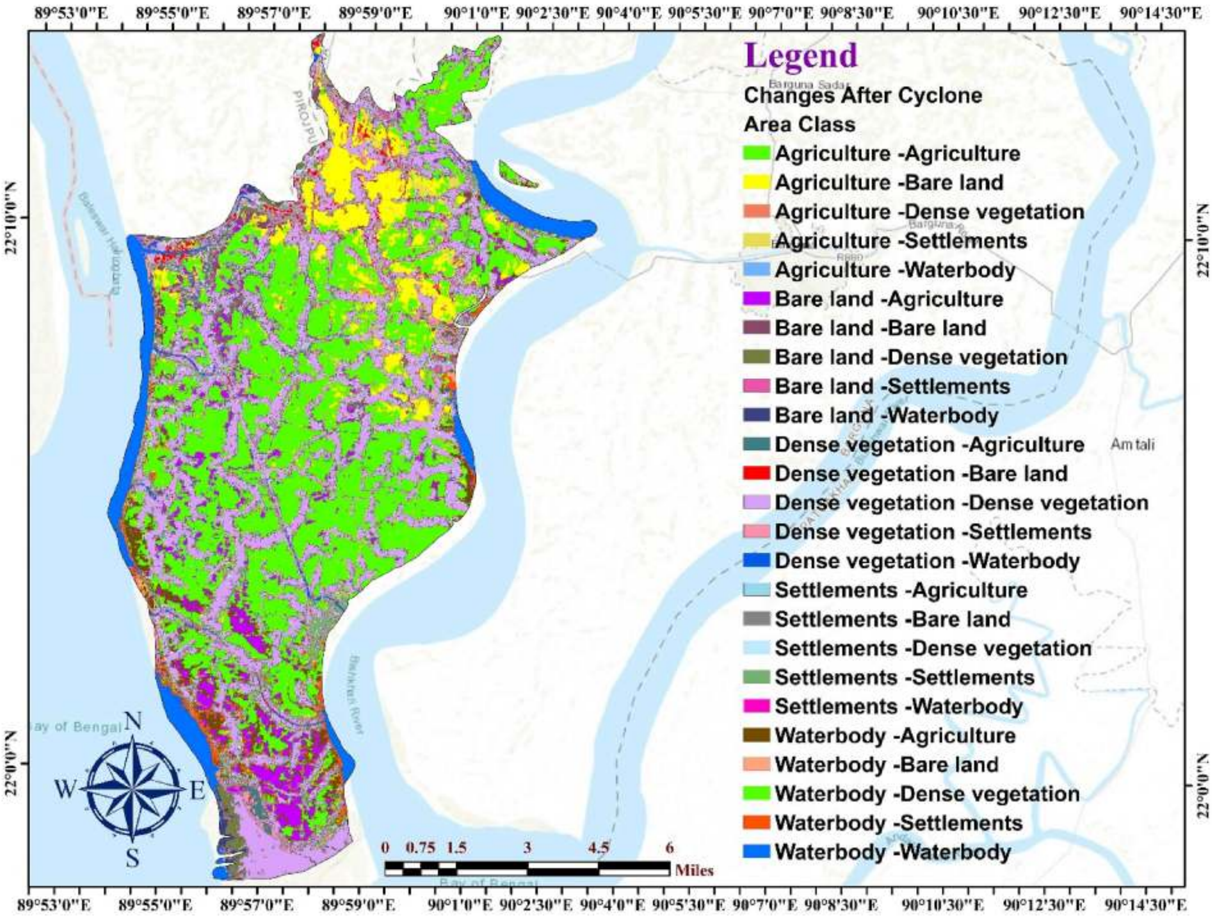

Fig. 4. The changes before and after the cyclone in the study area by thematic process.

Table 4
Cyclone impact statistics on land cover and land usage.

Class	Change (Sq km)	Total impact of the area (%)
Agriculture	4.7561	5.278819239
Bare land	5.5515	21.68325997
Dense vegetation	4.5637	6.148898272
Settlements	7.7254	31.06125485
Waterbody	22.4924	201.7020437
Total	45.0891	265.874276

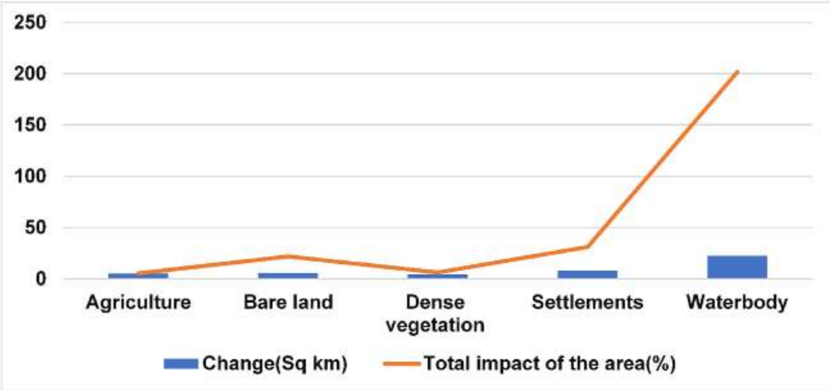

Fig. 5. Area of impact based on before and after the cyclone on the main land.

across a coastal area, the whole settlement area is affected by seawater (tide, flood). According to Fig. 5, about 7.72 km^2 of settlement areas land have been sifted or damaged by cyclone Bulbul, which is comparable to the region the authors identify on [4,50].

When the cyclone was moving through this coastal region of Bangladesh [8,13], indicated that a significant amount of seawater had made its way into this region. Fig. 5 depicts the overall changes in different areas of this study areas. To illustrate the changes that have occurred in different parts of the land, various mixes of colors are used. The shift between earlier and later in the catastrophe illustrates differences between the pre-disaster and post-disaster states. Every color symbolizes a different class shift that occurs while moving from one kind of land cover to another. Early and post-classified images were studied to understand the variations throughout the first and subsequent periods.

3.4. Changing scenario of land-use

For the purpose of this classification study, the statistical representation of the outcomes of class change throughout the initial and post-disaster periods occurs (Fig. 5). A significant amount of change has been seen in the water body, which is 22.4924 km^2, and in the settlement areas, which are 7.7254 km^2. It has been identified that most of the time, when cyclones run through this area, a significant percentage of settlement areas are converted into waterbody areas after the cyclone [13,19,20,38]. The location of this research region may be described as a heavily vegetated coastal area characterized by mangrove forests. This forest area experienced damage by every cyclone, and the study also revealed that the size of (4.5637 km^2) noticed a reduction. The bare land and agriculture change in the study area has been identified as the same ratio of 4.7561 km^2 and 5.5515 km^2, respectively (Table 4). The overall statistics revealed that most LULC classes have covered water areas. Again, the figure indicated that the south coastal part of this study area was found on a high-water body and several areas of dense vegetation land sifted in bare land [1,4,12,18]. also mentioned the 2007–2009 (Sidr-Ayla) cyclone severely devastated mangrove forests and other densely vegetated regions as it moved across Bangladesh's coastal region.

3.5. Cyclone impact analysis

The change detection analysis provides a very clear picture of the total changes between two time period and opens the door to further study into the effect that the impact had on the study area (Fig. 4). The cyclone made landfall on November 09, 2019, and the interval between the analyzed photographs and the event was thirteen days. Therefore, the impact percentages are not precise, but it does give an accurate picture of the whole. Each class type is affected in this situation, and these effects are portrayed from a distinct point of view. The final result consists of the results of 'area of impact' which is generated on the basis of pre– and post–cyclone conditions and in terms of total study area is affected has also been shown (Table 4 and Fig. 5). Results indicate that 265.70 % of the study area is affected due to cyclone Bulbul on its main land. This is the overall impact percentage of vegetation, waterbody, land, and other infrastructures (Fig. 6). The Patharghata union is characterized by the confluence of three rivers and the Bay of Bengal. Parts of the land are submerged during the monsoon season, while the coastal areas remain dry during the dry season.

Settlements encompass a broad range of human-made structures, including but not limited to houses, schools, madrasas, and markets. Image analysis conducted both pre- and post-cyclone revealed that the cyclone affected or damaged only about 7.752 km^2 areas of land of this category due to wind damage or destruction (Fig. 4). The relatively small impacted area was attributed in part to the limitations of the low-resolution satellite imagery used, as well as the fact that the study region is predominantly vegetated rather than constructed. However, this accounted for nearly 31.061 % of the total damage in the study area (Table 4 and Fig. 5). Fig. 6 also indicated that most of the settlement area has been converted into other zones. High seawater intrusion and higher wind with the tide at a significant rate damaged the settlement areas during the cyclone that is indicated by several authors [14]; [20,36]. High seawater intrusion and higher wind with the tide at a significant rate damaged the settlement areas during the cyclone that is indicated by several authors [14]; [20,36]. Similar research indicates [52,53] that " cyclone FANI" impacted ecosystems and agricultural land more than the built-up regions.

This analysis indicates that 6.14 % of the changes were observed in the dense vegetation category, with coverage decreasing from 74.21 km^2 to 69.65 km^2 due to cyclone Bulbul (Table 3). This significant change is represented in Fig. 4. When assessed relative to the

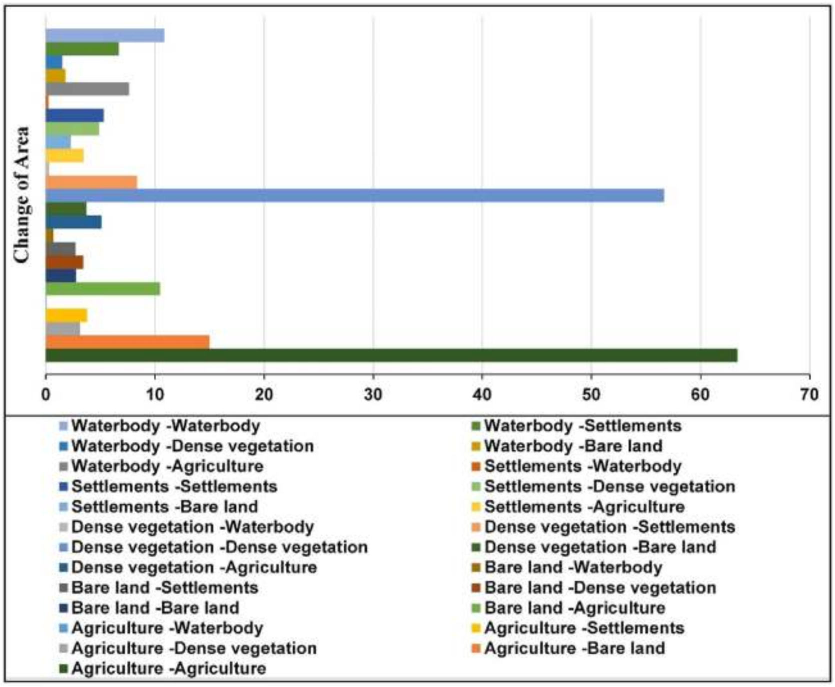

Fig. 6. Area of shifting of the total study area.

entire study area, the decrease the dense vegetation accounted for 4. 5637 km^2 of the overall 6.148 % affected change on the initial area (Table 4 and Fig. 5). Due to the significant repercussions throughout those regions, Satkhira northern part and specific areas of Khulna have seen the most modification [1,6] [11,20]). indicated that storm surges, floods, and cyclones like Bulbul when passed through the investigation and freshwater areas, converted into saltwater-affected areas which damages agricultural production. According to our analysis, the waterbody areas expanded to approximately 11.17 km^2–33.434 km^2 after the cyclone (Table 3). The storm surges were primarily responsible for a 31.09 % increase in waterlogged areas across the overall affected area (Fig. 5 and Table 4). Differential study of crop output demonstrates a clear connection to catastrophic occurrences. Waterbodies and barren terrain have replaced the cultivated land. Like Bulbul, a cyclone of this kind passes across this region and drastically alters agriculture. According to the LULC [54], agricultural areas decreased by 2.94 % in 2007 because of cyclones (Sidr and Aila) in Koyra Upazila and this area is also situated in the same coastal region of this study. In several related research [5,8,36,44,53], the impacted regions saw a sharp reduction in land, with the farmers who live there suffering the most because of land loss or crop damage. Moreover, the land use evolution prediction shows that the most significant notable reduction in vegetation occurred in 1991. Similar investigations from 1991 revealed that a storm inundated low-lying regions to a depth of 6 m [44,52–54].

4. Conclusion

This study analyzed the effects of Cyclone Bulbul on Bangladesh's coastal areas, specifically the Patharghata Subdistrict. This region is highly susceptible to cyclone-related risks, leading to significant losses in human life, agriculture, and other sectors. Annual storms cause severe socioeconomic losses, disproportionately affecting rural inhabitants due to inadequate infrastructure and underdeveloped lands. Cyclones also have a significant negative impact on natural ecosystems and biodiversity, including loss of human life and damage to fishing areas. Measuring the effects at the land level becomes challenging. Using geospatial techniques (GIS and RS), this study demonstrates how cyclones drastically alter both natural and human environments. Landsat satellite images were utilized to understand the intensity and effects on various land use and land cover categories. Despite challenges posed by machine learning and software processing, a close approximation of the cyclone's impact is obtained through images captured before and after the event at a thirteen-day interval. The proportionate effect of the initial land on the study location and following proportions are as follows: agriculture (5.278 %), barren land (21.683 %), dense vegetation (6.148 %), settlements (31.061 %), and waterbodies (201.702 %). The immediate effects of the cyclone included increased water bodies, agricultural damage, and vegetation destruction. Future studies should consider the socioeconomic aspects of vulnerability and develop comprehensive mitigation and adaptation strategies to effectively reduce the challenges posed by these natural disasters. This research contributes to a better understanding of the repercussions of cyclonic disasters worldwide and the specific impacts on the coastal areas of Bangladesh

CRediT authorship contribution statement

M Shahriar Sonet: Conceptualization, Project administration, Data collection, Formal analysis, Data curation, Supervision, Resources, Software, Methodology, Investigation, Writing – original draft, Validation, Writing – review & editing. **Md Yeasir Hasan:** Data collection, Formal analysis, Data curation, Supervision, Resources, Software, Methodology, Investigation, Writing – review & editing. **Salit Chakma:** Project administration, Data collection, Data curation, Supervision, Resources, Software, Methodology, Investigation, Validation, Writing – review & editing. **Abdulla Al Kafy:** Project administration, Data collection, Data curation, Supervision, Resources, Software, Methodology, Investigation, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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