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An Assessment of Cyclone-induced Vulnerability and Change in Land Use and Land Cover (LULC) of G-Plot in Patharpratima C. D. Block of South 24 Parganas District, West Bengal

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ABSTRACT

The Sundarban is a region of complex diversities both in terms of its physical and cultural environments. Three very important issues in the Sundarban are poverty, embankment and transport-communication. All of these issues are related to natural calamities. Cyclonic hazards are very common in the Bay of Bengal, as it severely damages lives and properties in the region. The principal objective of this study is to assess cyclone induced vulnerability and change in land utilization pattern in a coastal location of the humid tropics, for which G-Plot of the Indian Sundarban has been selected as the case study area. Both primary and secondary data have been used to analyse the same using quantitative as well as qualitative methods. Field survey was conducted by administering semi-structured questionnaires among 10 households from each mouzas of G-Plot, thus totalling 90 households for the entire area were randomly surveyed. With the adverse effects of mostly the cyclones, the nature of land use and land cover has changed significantly in the area. Out of 5 land cover features, the amount of area under mangrove and non-mangrove land (area covered by all the natural vegetation except mangrove trees) has decreased, while fallow land, water body and sandbar have increased. Settlement is one of the most important land uses, and it is found to be decreasing in the southern part of G-plot, but it has been increasing in the northern part, which can be a testimony of cyclonic effects. Based on vulnerability indices, this study indicates that the mouzas located in the southern portion of G-plot are highly vulnerable to cyclonic hazards compared to its northern counterpart.

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Introduction:

Cyclone is a natural hazard that occurs almost in every year in the coastal regions of India and brings substantial damages to lives and property (Ganesh et al., 2016). Tropical cyclone is a storm characterized by a low-pressure system usually with a diameter of 80 - 400 km. It normally occursin the Arabian Sea as well as in the Bay of Bengal between 6° N to 20° N of latitudes. The centre or eye of the storm is a small area of about 20 km across but if it is strong it can sometimes be 30-40 km, and round it whirl winds of tremendous force to the extent of 120 to 280 km$^{-hr.}$ or more is found. This high speed wind is capable of causing severe destructions to the region of its prevalence (Ghoraiet al., 2017; Islam &Hasan, 2015). The cyclones mostly occur in the northern part of the Indian Ocean, including the Bay of Bengal and the Arabian Sea, with five to six occurring per year, on the average; and out of these two to three can be very severe cyclonic events (Niyas et al., 2009), which are normally associated huge potential for damages (Nayaket al.,2014). Cyclone-induced storm surge and ingression of sea water into the low-lying coastal areas cause heavy floods, erodes beaches, and breach the embankments, damage

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agricultural fields, and due to inundation soils become saline (Ali, 1996; Alam & Dominey-Howes, 2015; Ranaet al., 2018).

In India, there are nearly 84 coastal districts in 13 coastal States and Union Territories frequently affected by tropical cyclones (Suma & Balaram, 2014). It is pertinent to mention here that in the past few decades these coastal areas have witnessed significant urbanization and industrialization leading to huge concentration of population and thereby increase in the vulnerability of the local people. The term 'vulnerability' with reference to climatology is defined as the character, magnitude and rate of climatic variations to which a system is exposed, its sensitivity, adaptive capacity and resilience (IPCC, 2007), which depend on different indicators like physical, social and cultural setup (Bahinipati, 2014; Brooks et al., 2005) or economic, human and infrastructure components (Bhattacharya & Das, 2007) of the concerned area.

2. Selection of the Study Area:

Approximately 25 percent of Indian population live within 50 km of the country's coastline (Ganesh et al., 2016). Considering the cyclone vulnerability map of India, the southern part of West Bengal is the most vulnerable; and G-Plot, an island, which is located (Fig. 1) in the southern part of Patharpratima C.D. Block of South 24 Parganas district may be considered as one of the worst risks zone for cyclonic hazards. Embankments were made to stop ingression of flood water from the adjacent rivers and creeks, so that it does not get sediments from the adjoining rivers/ creeks. If at any time the embankments break, the entire G Plot will be inundated. The area being situated in the southern part of the Ganga delta is characterised by tropical monsoon climatic and associated with the mangrove forests. The annual rainfall in the area varies between 150 and 200 cm, while temperature ranges between 20 and 35°C (IMD: Kolkata, 2018). Soil type is mostly alluvial with about 5% sand, 70% silt and 5% clay. Major problem for productive agriculture in the area Is because of occasional inundation lands by brackish water due to natural calamities, thereby make soil saline and less productive (Chakraborty & Adhikary, 2014).

3. Objectives of the Study:

The principal objective of this study is to assess cyclone induced vulnerability and change in land utilization pattern in a coastal location of the humid tropics for which G Plot of the Indian part of Sundarban region has been selected as the study area. Specific objectives of this study are listed as under:

i. To discuss about the frequency, track and intensity of the cyclones occurring in the region, and their consequences leading to vulnerability of the area selected.

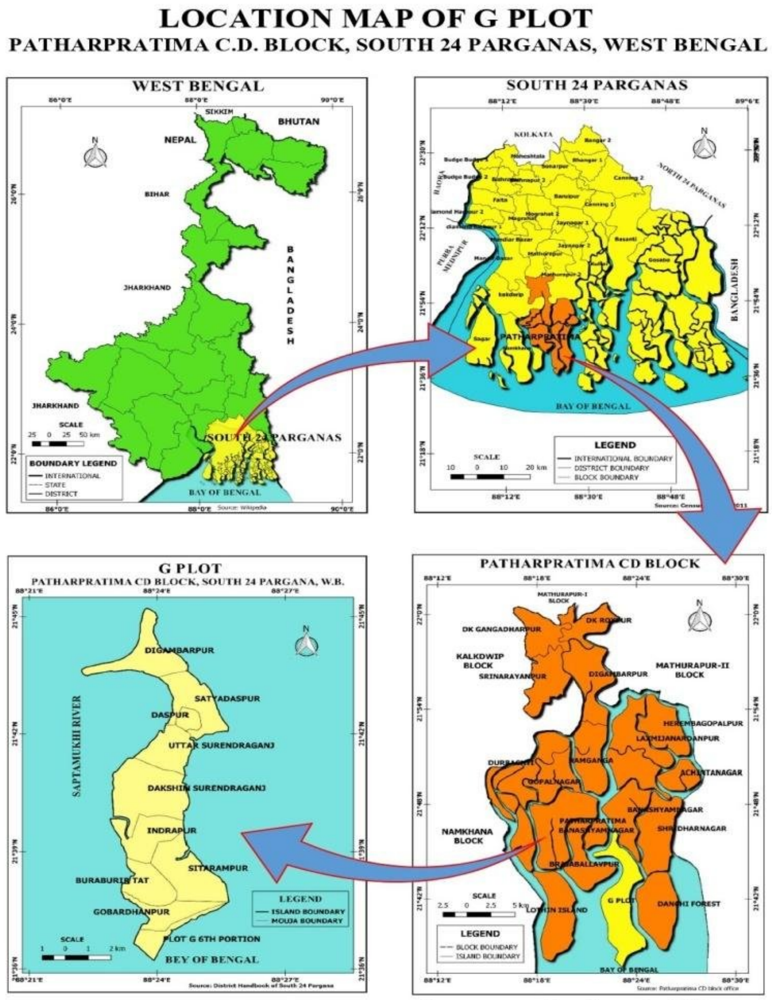
ii. To assess the nature of cyclone-induced vulnerability, and the impact of cyclones on land use and land cover in the study area.

4. Database and Methodology:

This research work is based on both primary and secondary data, and their analysis has been done by using both quantitative (statistical) and qualitative methods (Rana et al., 2018). Field survey was done randomly by administering semi-structured questionnaires among 10 households from each mouza of G-Plot, thus totalling 90 households for the entire area. Observation and photographic evidences along with discussion with the local people, who have significant experience about their localities, have been made to capture the physical and cultural environments, visible impacts of the cyclones and cyclone relief shelters. Secondary data have beencollected from disaster management report ofBlock Disaster Management Office (BDMO); and status of agriculture and embankmentsare based on reports of the Department of Agriculture, and the Department of Irrigation and Water ways, Government of West Bengal respectively. Vulnerability, as a function of exposure, sensitivity and adaptive capacity is estimated on the basis of a number of proxy indicators (Bahinipati, 2014). These indicators have been selected from the existing vulnerability studies (Bhattacharya & Das, 2007; Bahinipati, 2014), field survey and available secondary data at the mouza and block levels. Usually there are two ways to analyse such indicators, namely: (i) Giving equal weightage to each indicator; and (ii) assigning a weight to each indicator with the help of expert judgement (Deressa et al., 2008) (Table 1). Equal weightage to each indicator has been given in the present analysis (Table 2), as the appropriateness of giving separate weightage is still dubious since there is no tested standard weighting method is available so far. Since the indicators are measured in different units, normalization has been done in order to aggregate the indicators of vulnerability indices for obtaining a single value (Eq. 1: O'Brienet al.,2004), as follows:

$$\text{Index } X_{ij} = \left[\frac{(X_{ij} - \text{Min } X_i)}{(\text{Max } X_{ij} - \text{Min } X_i)} \right] \text{ ...... (1)}$$

Where, index X_{ij} is the index value (i.e. 0 to 1) of the indicator for village j, X_{ij} represents the value of



Source: prepared by author, using QGIS

Fig. 1 : Location Map of the Study Area

the *i*th indicator for the district, and the Max X_i and Min X_i manifest the maximum and minimum values of the *i*th indicator of the entire village. After standardization of all the proxy indicators, the components and determinants of vulnerability and the aggregate vulnerability indices are calculated on the basis of the given formula (Eq. 2: O'Brienet al.,2004).

$$M = \frac{[\sum_{i=1}^{n} \text{Index } X_{ij}]}{n} \quad .... (2)$$

Where, M_j is the components or determinants of vulnerability (i.e. exposure, sensitivity and adaptive capacity) denoting the aggregate vulnerability index; Index $X_{ij}$is the index value of the *i*th indicator for the village *j*, and *n* is the number of indicators considered to represent M_j. After getting the values of exposure, sensitivity, and adaptive capacity indices, vulnerability index is calculated (Eq. 3: Leichenkoet al.,2004*)*.

$$V_i = [(E_i + S_i) - A_i] \quad .... (4)$$

Where, V_i is the vulnerability index of each village with its E_i being the exposure, S_i is sensitivity index and A_i describing adaptive capacity index, while is the corresponding village. Thus, by using the formula we have calculated the indices of exposure, sensitivity and adaptive capacity to find out the overall vulnerability index of different mouzas of G-Plot. We have prepared the indices with the help of corresponding values ranked chronologically. Weather data have been collected from IMD Kolkata, and world weather online portal, Cyclone e-Atlas of IMD, NOAA historical hurricane track, and www.indiawaterportal.org etc. Relevant base maps have been collected from the Office of the BDO, Patharpratima C. D. Block, Eastern Regional Office of the Survey of India, Office of the Director, National Atlas & Thematic mapping Organization (NATMO), District Handbook of South 24 Parganas (2018), and Google Earth pro (2018). The confusion matrix and F1-score have used to assess the agreement of LULC identification results for a more reliable assessment (Yao, J et al. 2019). The reference data derived from other LULC products, and it can provide a more global accuracy assessment than using a statistically design sample. The diagonal elements in the matrix represent the number of correctly classified pixels of each class, i.e. the number of pixels with a certain class name of 2008 land use map that actually obtained the same class name during 2018 classification. The off-diagonal elements represent change pixels or the change of classification, in this Confusion Matrix authors have found the accuracy, reliability, average accuracy and overall accuracy. Q-GIS software and MS- Excel and MS-Word 2013 versions have been used for preparation of the different thematic maps.

5. Results and Discussion

5.1 Distribution of Temperature and Rainfall

It is observed that the lowest mean monthly temperature is recorded in the month of January and December (less than 20°C) and the maximum of it in the month of May and June (above 30°C). Fig. 2 also reveals that the lowest mean monthly rainfall has been recorded in the month of December and January (<10mm), whereas the highest one occurring in July and August (>160 cm) (IMD Kolkata, 2019).The annual total rainfall and temperature profile represent typically moist subtropical climate (the Gangetic type).

5.2 Seasonal and Annual Variability of Rainfall

Distribution of the rainfall is highly skewed, much of it concentrated in the monsoon months. Mean, standard deviation (SD) and coefficient of variation (CV) of rainfall for the year 2018 shows that mean monthly rainfall is higher in monsoon season (as already stated), but SD and CV are lowest compared to the other seasons (Fig. 3). In the post monsoon season mean monthly rainfall is lower than the monsoon season, but SD is higher than mean; and CV is the highest in comparison with other seasons indicating huge inequality in distribution of seasonal rainfall.

5.3 Frequency of Cyclones over the District of South 24 Parganas

In the pre-monsoon season, itis observed that, frequency of cyclones is less over the Bay of Bengal (BoB) for the period 2000 to 2018 (Fig. 4), compared to the post- monsoon season (mainly in October and November). Thus, the post-monsoon seasonis more vulnerable to cyclonic hazards, and as after the monsoon season soil and land is fully saturated the situation favours water logging and occasional floods. It is clear (Fig: 6) that the highest numbers of Depressions (D), Cyclones (CS) and Severe Cyclones (SCS) arefound in the post-monsoon season (Sep- Oct), the second highest frequencyin the pre-monsoon season over the district of South 24 Parganas and adjoining areas during the period 2000 to 2018. So, the post-monsoon season is identified as the vulnerable season due to the effect of cyclones. In winter season, cyclones are very rare in the BoB region. Moreover, out of 25 cyclones occurring in this period in the region, almost 68% turned to become severe (Fig. 5).

5.4 Relation between Weather Parameters and Frequencies of Cyclones

Sudden strong blast of wind is called gust (Shaw et al., 1979). It is observed (Fig. 7) that there is a more or less positive relation between temperature and frequency cyclones as is exemplified from the monthly distribution of temperature profiles and occurrences of the cyclones during the study period. The high temperature and highest frequency of cyclones have been recorded in the May over the Sundarban region, but the highest number of monthly distributions of cyclone generates in the October (24) from 2008-2018 (Fig. 4) over BoB. Meteorologically high temperature over the northern part of the enclosed sea surface of the BoB is favourable for genesis of cyclonic storms (IMD Website: Cyclone Page, FAQ: 2018). Besides, the lowest air pressure is observed during the months of May to August and the highest number of cyclones is also observed in the May (Fig. 11). In the monsoon months due to the high speed of horizontal winds, leading to strong vertical sheer reduces the chance of occurrence of cyclones and instead depressions and deep depressions are formed (IMD, 2018). In the winter season the air pressure is higher, and along with low temperatures and strong surface winds formation of cyclone is uncommon in this region.

When large section of a rotating wind accelerates its speed rapidly it is called gust (Shaw et al., 1979). It is found that the mean monthly gust speed is higher in the month of May and October (Fig. 8) compared to other months, and so the vulnerability from cyclonic effects and corresponding damage potentiality is also high in these months. Although humidity is higher in the monsoon and the post-monsoon seasons (Fig: 9), cyclones are not quite common in the monsoon months, due to the reason as already been explained.

The highest rainfall occurs in the monsoon season (Jun-Aug) and the lowest rainfall is recorded in the

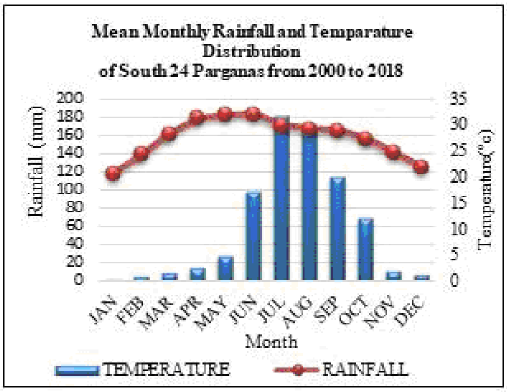


Fig. 2

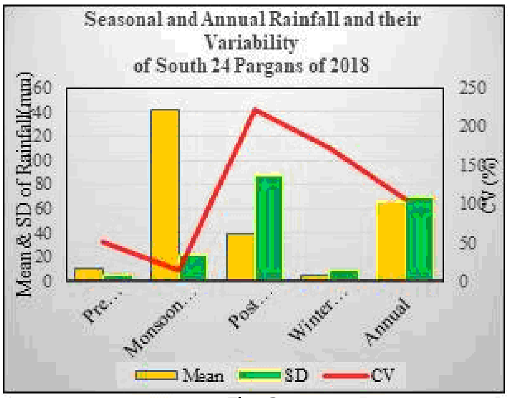


Fig. 3

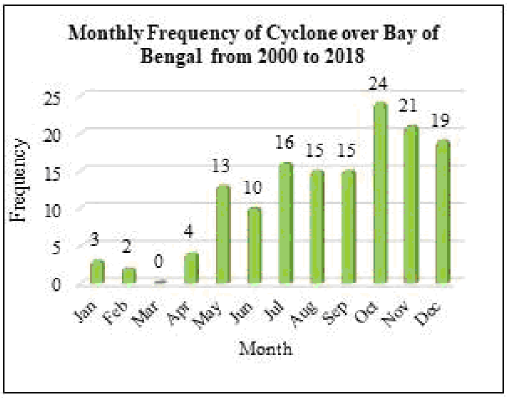


Fig. 4

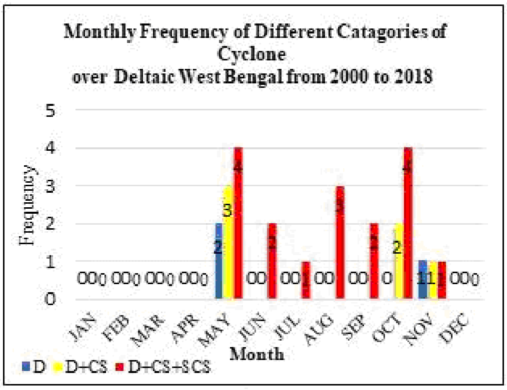


Fig. 5

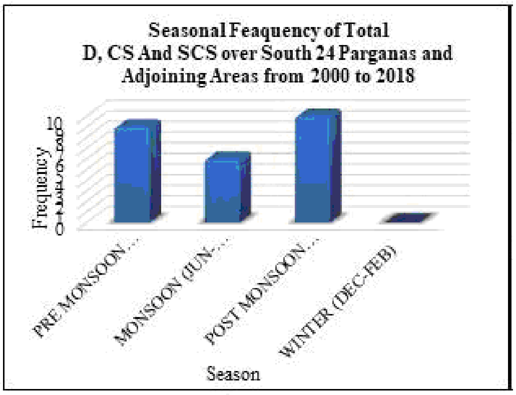


Fig. 6

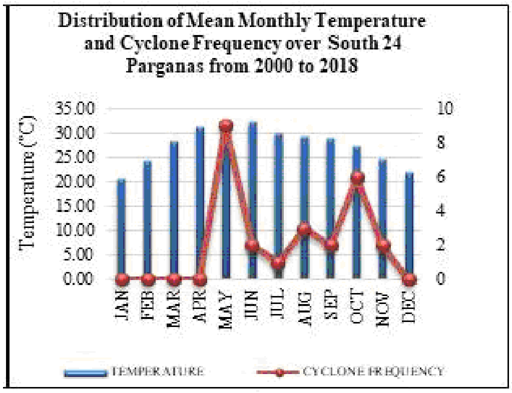


Fig. 7

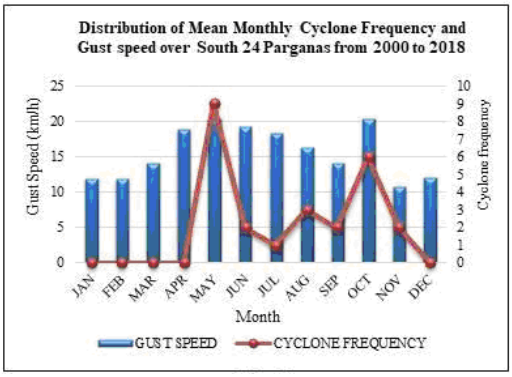


Fig. 8

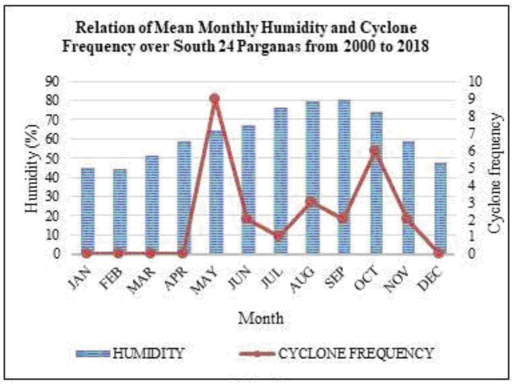


Fig. 9

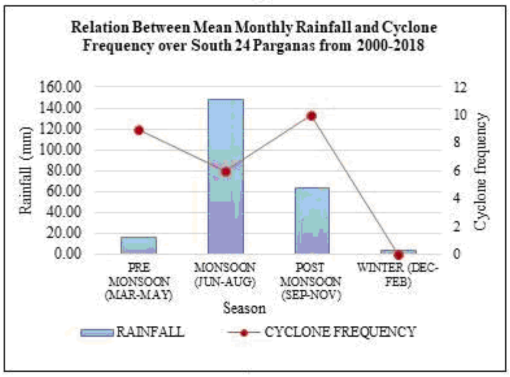


Fig. 10

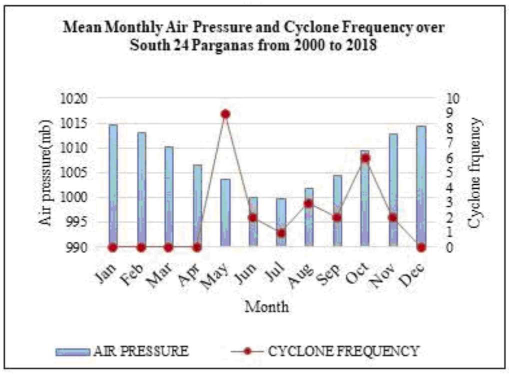


Fig. 11

*Sourcwe:*www.worldweatheronline.com & Cyclone e-Atlas, IMD, 2019

winter season (Dec-Feb). But, the relation between frequency of cyclones and amount of rainfall is not established (Fig. 10) as the monsoon months are usually devoid of cyclonic storms. However, in some occasions due to cyclones rainfall may be very intense amounting to significant quantity even during the pre and post monsoon months. In the pre-monsoon season cyclonic rainfall is often helpful for agriculture, if the storm and associated storm surge do not devastate the standing crops already there in the fields. But in the post-monsoon season excessive rainfall from cyclones create floods damaging the matured crops yet to be harvested casing vulnerable situation in the region.

5.5 Determinants and Indicators of Vulnerability

Among the vulnerability indices (Table 2) and their determinants (Table 1) for the study area, a high SD is found in the case of vulnerability (4.685) compared to exposure (1.956), sensitivity (1.269) and adaptive capacity (1.759). The average score of vulnerability (6.944) is also higher than exposure (5.928), sensitivity (6.059) and adaptive capacity (5.079). This suggests that variation of vulnerability level is higher across all the mouzas of G Plot in respect to exposure, sensitivity and adaptive capacity. Most of the mouzas become vulnerable because of high exposure and sensitivity and low adaptive capacity. This implies that exposure, sensitivity, and adaptive capacity are vital component for assessment of vulnerability. For example, in Gobardhanpur mouza/ village there are higher exposure (8.373) and sensitivity (7.407) and lower adaptive capacity (3.434), and therefore, vulnerability value is high (12.346) with the second rank (high) vulnerability. Daspur has lower exposure (3.554) and sensitivity (4.315) and higher adaptive capacity (7.242) making it a less vulnerable village with rank 10^{th} (vulnerable value being 0.627).

Table 1. Choice of Indicators for the Vulnerability Assessment (Deressa et al., 2008)

Determinants of Vulnerability	Proxy indicators	Expected Sign
Hazard and Exposure	Percentage of people affected	+
	No of livestock death	+
	Percentage of house damaged	+
	Damage to crop lands (ha)	+
	Costal length (km)	+
	Distance of house from the sea/ river	-
	Share of village population to total population of G Plot	+
	Population density	+
Sensitivity	Percentage of female population	+
	Percentage of children (less than 6 year)	+
	Percentage of old people (more than 60 year)	+
	Percentage of cultivator	+
	Percentage of agricultural labourers	+
	Percentage of net sown area	+
	Cropping pattern	-
	Percentage of families below poverty level	+
Adaptive Capacity	Percentage of people employed	-
	Total area covered by irrigation (ha)	-
	Income in Rs.	-
	House type	-
	Literacy rate (in %)	-
	Female literacy rate (%)	-
	Percentage of households electrified	-
	Total length of roads (in km)	-
	No. of non-govt. medical amenities available	-

Note: ' + ' means increasing vulnerability, and ' - ' means decreasing vulnerability(Bahinipati, 2014)

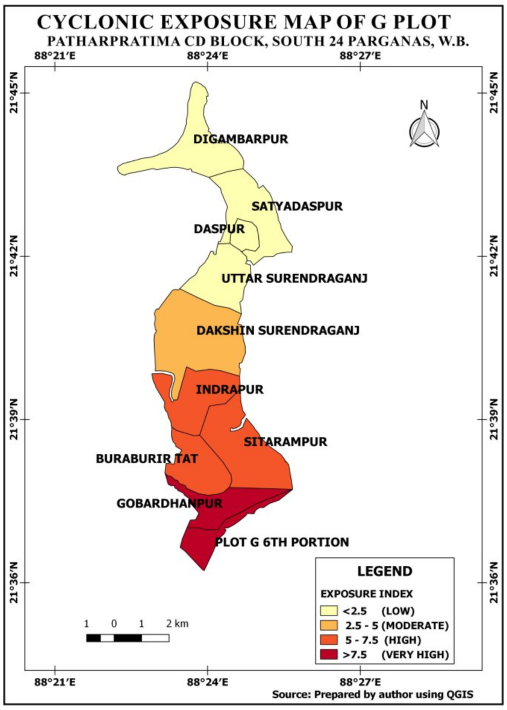
5.6 *Changes in land use and land cover (LULC) between 2008 and 2018*

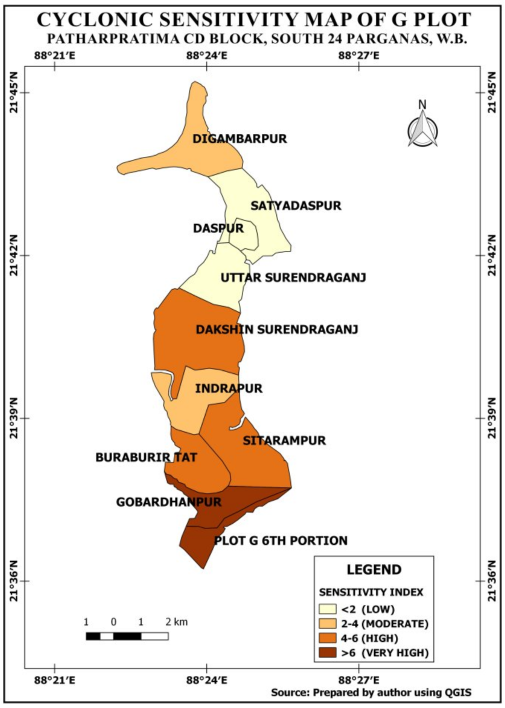
With the adverse effects of mostly cyclones, landuse and landcover pattern have changed significantly in the study area (Fig. 13). Out of 5 landcover features, the area under mangrove and non-mangrove land has decreased from 982.52 hectare (ha) in 2008 to 524.21 ha in 2018 (Table 3), whereas fallow land has increased from 347.85 ha to 749.12 ha, water body from 108.52 ha in 2008 to 115.85 ha in 2018. Forest is concentrated mostly in the periphery, and it is reducing due to land erosion by cyclone-induced storm surge along with unscientific construction embankment. Settlement is one of the most important landuses, and it is found to be decreasing in the southern part of G-plot (reduced from 142.59 to 185.92 ha during 2008-18), but it is increasing in the northern part of it, where land erosion is almost negligible. Out of 6 landuse features agricultural land has been decreasing. Using the support of governments metalled (pacca) road, un-metalled (kachha) road, earthen embankments and concrete embankments have been increasing to ease transport and protect the settlements (Table 4). Therefore, the impacts of cyclones are quite visible in the overall physical landscape of G-Plot.

Table 2. Village/ Mouza wise Vulnerability Indices

Name of Village/ Mouza	Exposure	Rank	Sensitivity	Rank	Adaptive capacity	Rank	Vulnerability	Rank
Digambarpur	4.770	7	6.091	6	7.385	1	3.476	8
Satyadaspur	3.409	10	4.422	9	5.210	6	2.621	9
Daspur	3.554	9	4.315	10	7.242	2	0.627	10
Uttar Surendraganj	4.218	8	4.980	8	5.568	4	3.631	7
Daksin Surendraganj	5.553	6	6.423	5	5.331	5	6.646	6
Indrapur	6.370	5	6.770	3	5.749	3	7.391	4
Sitarampur	6.665	4	5.750	7	5.165	7	7.250	5
Buraburir Tat	7.410	3	6.542	4	4.349	8	9.602	3
Gobardhanpur	8.373	2	7.407	2	3.434	9	12.346	2
Plot G 6Th Portion	8.953	1	8.256	1	1.358	10	15.851	1
Min. Value	3.409		4.315		1.358		0.627	
Max. Value	8.953		8.256		7.385		15.851	
Mean	5.928		6.095		5.079		6.944	
SD	1.956		1.269		1.759		4.685	

Computed by the authors, 2019





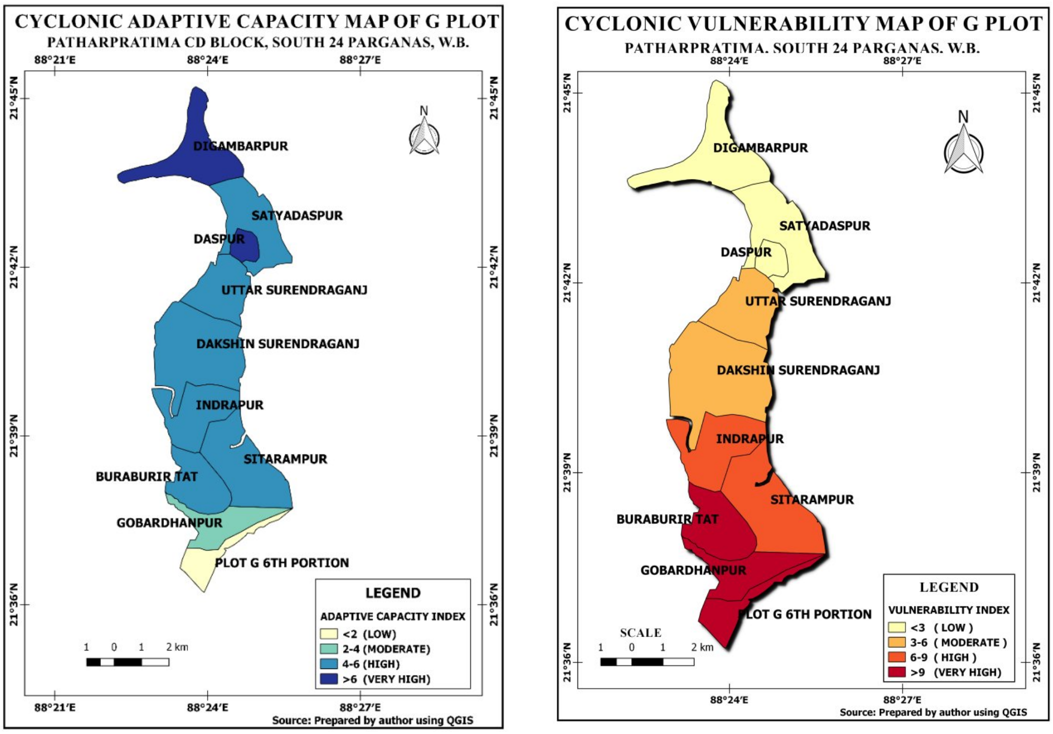


Fig. 12: Cyclonic exposure, sensitivity, adaptive capacity and vulnerability in G Plot

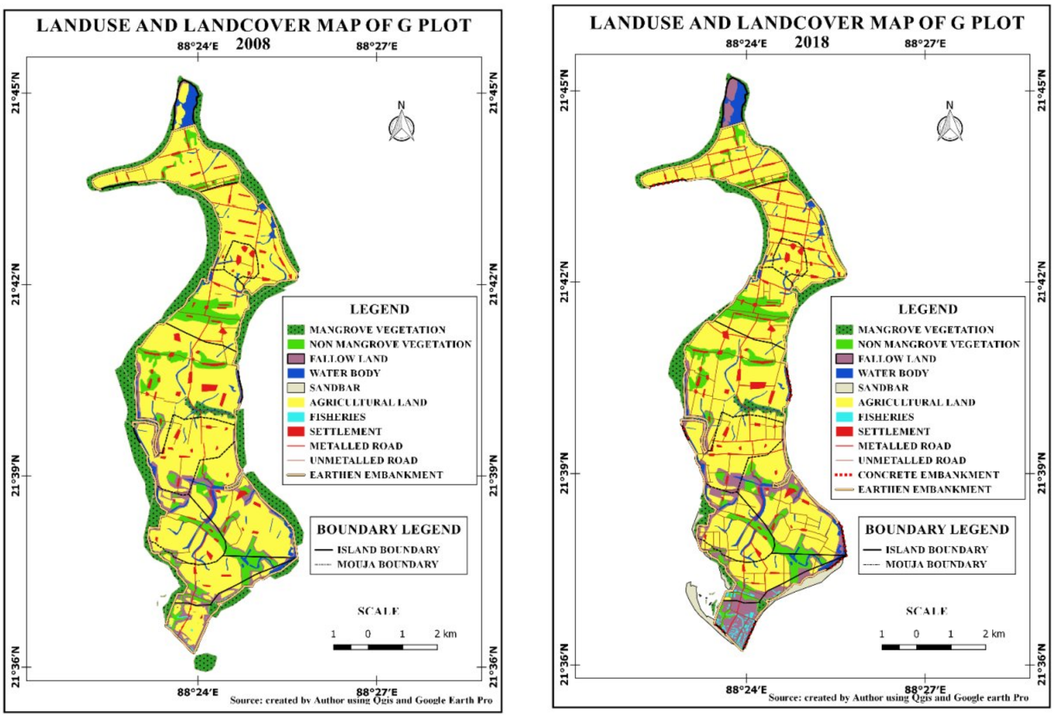


Fig. 13: Changes in land use and land cover in G-Plot for the years 2008 and 2018

Table 3. Change of LULC in G-Plot, Patharpratima C. D. Block (2008 -2018)

Categories of LULC	Area (in ha)	
	2008	2018
Mangrove Vegetation	982.52	524.21
Non- Mangrove Vegetation	627.18	508.59
Fallow Land	347.85	749.12
Water Body	108.52	115.85
Sandbar	25.32	72.86
Agricultural Land	4699.52	3897.25
Fisheries	12.51	52.96
Settlement	142.59	185.92

Source: Computed by the authors using QGIS from Landsat 8 images, 2019

Table 4. Change of road length in G-Plot, Patharpratima C. D. Block (2008 -2018)

Road Type	Length (km)	
	2008	2018
Metalled Road	19.21	27.52
Un-metalled Road	34.41	42.53
Concrete Embankment	0	9.82
Earthen Embankment	12.85	41.12

Source: Computed by the authors using QGIS from Landsat 8 images, 2019

5.7 *LULC identification and accuracy assessment*

The accuracy of classification has been represented in both column and row direction. It is the fraction of pixels of specific landuse classification with regard to all pixels of all the landuse class. For each class represent pixels of 2008 landuse classification (row). The number of pixels of 2018 landuse classification is divided by the total number of pixels of that class of 2008 landuse classification. Here the 'mangrove vegetation' class, the accuracy is 0.68 meaning that approximately 68% of the 'mangrove vegetation' pixels also appear as 'Mangrove Vegetation' pixels in the classified image. In row, reliability presents the reliability of classes in the classified image; it is the fraction of pixels of specific landuse classification with regard to all pixels of all landuse class. In this study area the 'mangrove vegetation' class, the reliability is 0.76 meaning that approximately 76% of the 'mangrove vegetation' pixels in the classified image actually represent 'mangrove vegetation' on the ground. Highest reliability observed on Agriculture landuse pattern 0.94 or 94%, so only 6% landuse is changed and on the other hand lowest accuracy observed on concrete embankment 0.11 or 11%, so 89% landuse is changed. The average accuracyis calculated as the sum of the accuracy figures in column accuracy divided by the number of classes in the test set. Hare average accuracy is 0.68 or 68%. So we can say that 68% landuse is not changed and 32% landuse is changed to other landuse pattern in the study area.The F1- score of reference data in the study area was also represent significant result (Table 6). The identification accuracy of sandbar was higher than mangrove vegetation /settlement/water body/fallow land while the conversion among earthen embankment, unmetalled road land and settlementwas quiet frequently in this study area and the distribution of agricultural land is relatively stable.

7. Major findings and Conclusion

The frequency of cyclone is higher in the pre-monsoon season and the highest in the post-monsoon season over the southern part of West Bengal. Mouza-wise estimation of relative vulnerability indices of G-Plot and assignment of vulnerability rank to each mouza according to their vulnerability level with regard to cyclones has been done in this study. It is found that

Table 5. Confusion matrix and indices of agreement between LULC identification results

		2018													
		Mangrove Vegetation	Non-Mangrove Vegetation	Fallow Land	Water Body	Sandbar	Agricultural Land	Fisheries	Settlement	Metalled Road	Unmetalled Road	Concrete Embankment	Earthen Embankment	Total	Accuracy
2008	Mangrove Vegetation	485709	25111	73051	34243	38808	20546	13697	9131	0	0	4566	9131	713993	0.68
	Non-Mangrove Vegetation	8709	381961	23223	10886	5806	21772	14515	258	0	2177	2903	4354	476564	0.80
	Fallow Land	72933	46677	402867	23338	17504	110858	14587	121	0	325	0	256	689465	0.58
	Water Body	1325	958		101104	125	4253	568	95	0	0	0	98	108526	0.93
	Sandbar	3840	3031	2627	1819	47156	2425	1617	56	0	0	0	5052	67623	0.70
	Agricultural Land	60695	39018	6503	15174	13006	3323791	21677	10838	4335	6503	0	10838	3512380	0.95
	Fisheries	0	0	4846.2	11308	0	24231	39400	0	0	0	0	0	79785	0.49
	Settlement	0	3304	8260	0	0	29738	89	130791	53	0	0	0	172235	0.76
	Metalled Road	0	0	0	0	0	763	0	63	16991	6260	0	611	24688	0.69
	Unmetalled Road	0	0	596	0	0	5662	0	0	24	29799	56	1043	37180	0.80
	Concrete Embankment	156	36	65	0	0	143	0	42	56	198	1025	6212	7933	0.13
	Earthen Embankment	1974	2632	3400	0	0	2961	0	0	0	0	452	24412	35832	0.68
	Total	635341	502730	525439	197871	122404	3547142	106149	151395	21460	45262	9002	62008		
	Reliability	0.76	0.76	0.77	0.51	0.39	0.94	0.37	0.86	0.79	0.66	0.11	0.39		

Average Accuracy: 0.68 (68%) Average Reliability: 0.61 (61%) Overall Accuracy: 0.65 (65%)

Source: Computed by the authors

(Fig. 13) the very high cyclone-induced vulnerable mouzas include Gobardhanpur and Buraburirtat because of their exposure and sensitivity are being very high and adaptive capacity being very low. High cyclone-induced vulnerable mouzas comprises Sitarampur, Indrapur, and Dakshin Surendraganj. Relatively low cyclone-induced vulnerable mouzas are Satyadaspur, Daspur and Digambarpur. It may be noted that the frequencies and intensity of cyclones are increasing in the recent times (Cyclone e-Atlas: IMD, 2008), along with increasing cyclone-induced vulnerabilities. On the basis of the vulnerability indices of all the mouzas of G-Plot, the present study has found that the southern portion of G-Plot is highly vulnerable and the northern portion of it is relatively low vulnerable to cyclonic hazards. Gobardhanpur, Buraburirtat and G-Plot's 6th

Table 6. F1-score referred to the LULC Map in the study area

Sl. No.	LULC Class	Accuracy	Reliability	F1 Score
1	Mangrove Vegetation	0.68	0.76	0.72
2	Non-Mangrove Vegetation	0.80	0.76	0.78
3	Fallow Land	0.58	0.77	0.66
4	Water Body	0.93	0.51	0.66
5	Sandbar	0.70	0.39	0.50
6	Agricultural Land	0.95	0.94	0.94
7	Fisheries	0.49	0.37	0.42
8	Settlement	0.76	0.86	0.81
9	Metalled Road	0.69	0.79	0.74
10	Unmetalled Road	0.80	0.66	0.72
11	Concrete Embankment	0.13	0.11	0.12
12	Earthen Embankment	0.68	0.39	0.50

Source: Computed by the authors

portion are very highly vulnerable. Sitarampur, Indrapur, Dakshin Surendraganj are high vulnerable. Digambarpur and Uttar Surendraganj are moderately vulnerable, and Satyadaspur, Daspur, G-Plot's 6th portion are relatively low vulnerable. The last portion is situated in the south-eastern part of G-plot, but vulnerability is the least to human population, as no settlement is found there. The present study also reveals the impact of cyclones on land use of G-Plot, and it has been found that coastal land area, agricultural land and area under mangrove vegetations are reducing; whereas fallow land, water body and are under pisciculture or fish culture have been increasing which is almost as similar as the F1-score in the above table (table-6). So,it is clear that cyclone has negatively impacted on landuse and land cover of the area (in case of pisciculture, it makes the land unproductive for long term).

Cyclone is a natural hazard. We can't stop them in the immediate future with our present scientific understanding and technological set up,but by increasing our consciousness, warning system, adaptive capacity and implementing the mitigation strategies it is possible to reduce the cyclone-induced vulnerability, as successful early warning of some previous cyclones has been claimed to have saved many human lives (Paul, 2009).

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