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GEOMORPHOLOGICAL STUDY OF SUNDARBANS LAND AND RESOURCES - A STATISTICAL APPROACH FOR CLASSIFICATION AND PREDICTION

[1]Abhinandan Das

[1]Corresponding Author (Department of Humanities and Social Sciences, Indian Institute of Technology Kharagpur, West Bengal 721302, India.

Abstract: The Sundarban is a deltaic complex created by deposition of sediments by the rivers of Ganga and Brahmaputra, forming the world's largest wetland ecosystem. Studies done in the past points out to the changing nature of erosion and accretion process of the Sundarban Islands. This change is brought by many factors which are both natural as well as anthropogenic like storm surges, sea level rise, rainfall patterns, land reclamation for agriculture and settlement, etc. An attempt is made to study the changes of the Sundarban land and resources. The study is confined only to the Indian part of the Sundarban. The analysis is performed to examine the change of area of few selected northern and southern islands of the Sundarban region over time from 1988 to 2016. An attempt is made to study the changes in temporal configuration of the Bhangaduni Island in the said period. Furthermore an attempt is also made to analyze, examine and predict the scenario of the Bhangaduni Island by statistical analysis based on mathematical modeling.

Index Terms - Sundarbans, erosion, accretion, Bhangaduni Island, prediction.

I. INTRODUCTION

The Sundarbans is a natural region in the southern part of Bangladesh and the southern part of the Indian state of West Bengal. It covers a total area of approximately 10,000 square kilometers (3,900 sq mi), majority of which lies in Bangladesh with the remaining part in India. The Sundarban Region in India is located between 21° 32' and 22° 40'N latitude and 88°30'N and 89°00'E longitude(Raha et al 2014). It is surrounded by the river Hooghly on the west, Ichamati-Kalindi-Raimangal on the east, Dampier-Hodges line on the north and the Bay of Bengal on the south. The total area of the Sundarban region in India is about 9630 sq.km(Hazra et al,2002) The two great rivers, Ganges and Brahmaputra meet the Bay of Bengal along India and Bangladesh forming an intertidal zone which is developed by the process of accretion of alluvium deposited by these two river systems over the years(Banerjee et al, 2012)

The Sundarban region comprises of low flat islands and mud banks which is separated by many tidal channels and rivers. This region consists of saline banks, mud flats, mangroves , degraded mangroves, sand banks, creeks, estuaries etc.(Das, 2004) The mangrove forests are very rich in diversity and their root system plays a vital role in preventing the process of erosion caused by sea waves and undertow currents(Ganguly et al 2006). Degraded mangroves are the main outcome of land reclamation for agriculture and settlement that started during the 18th century. The Sundarban region is characterized by river mouths that widen like funnels they approach the bay of Bengal(Raha et al, 2014) The deltaic estuarine coast of the Sundarban is the outcome of the characteristics of the rivers in the region.

The Sundarban estuary is still in the process of formation. The Sundarban islands are being continuously built up by the deposition of the silt carried by the rivers. The shape of the islands keeps on changing as a result of continuous process of erosion and accretion caused by tidal waves and ocean currents. Sundarbans are the only mangrove tiger land of the globe that is presently under threat of severe coastal erosion(Ganguly et al 2006). At present the deltaic system is facing degradation due to natural and anthropogenic factors. Several factors like embankment failures, subsidence and flooding, cyclones, storm surges, beach erosion are increasing the vulnerability of this area.(De, 2002). Furthermore the alarming growth of population in this ecologically sensitive area has become a threat in the recent years.

There were studies conducted by the scientists of Jadavpur university reflecting the changes in the islands of the Sundarban estuary. Their research paper states that "In Sundarbans, a comparison of the former maps (1942,1969) and more recent satellite images (2001,2006) reveals significant amount of land loss in spite of marginal accretion on the sheltered western banks." In our study we attempted to observe the change in shape and area of the islands situated in the northern and southern part of the Sundarbans. An attempt is made to analyze the changes in shape and area of the Bhangaduni island island (south of Sundarbans) and to make a prediction of its shape and area in the comming years. An attempt is also made to predict the areal decrement of the Bhangaduni island by statistical analysis based on mathematical modeling.

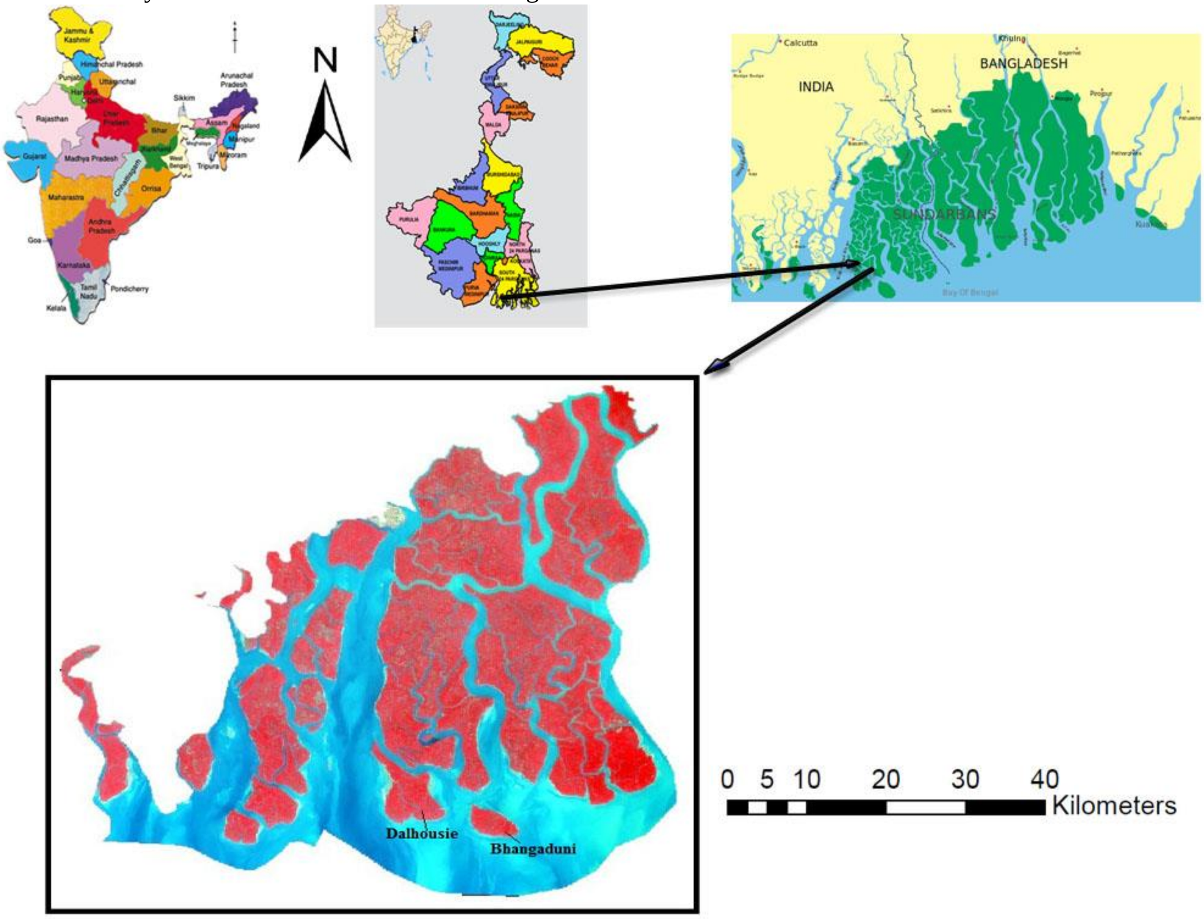


fig: 1 Our study area

II. OBJECTIVE

- **General objective:**

To study the geomorphological changes of the Sundarban islands on a temporal basis.

- **Specific objective:**

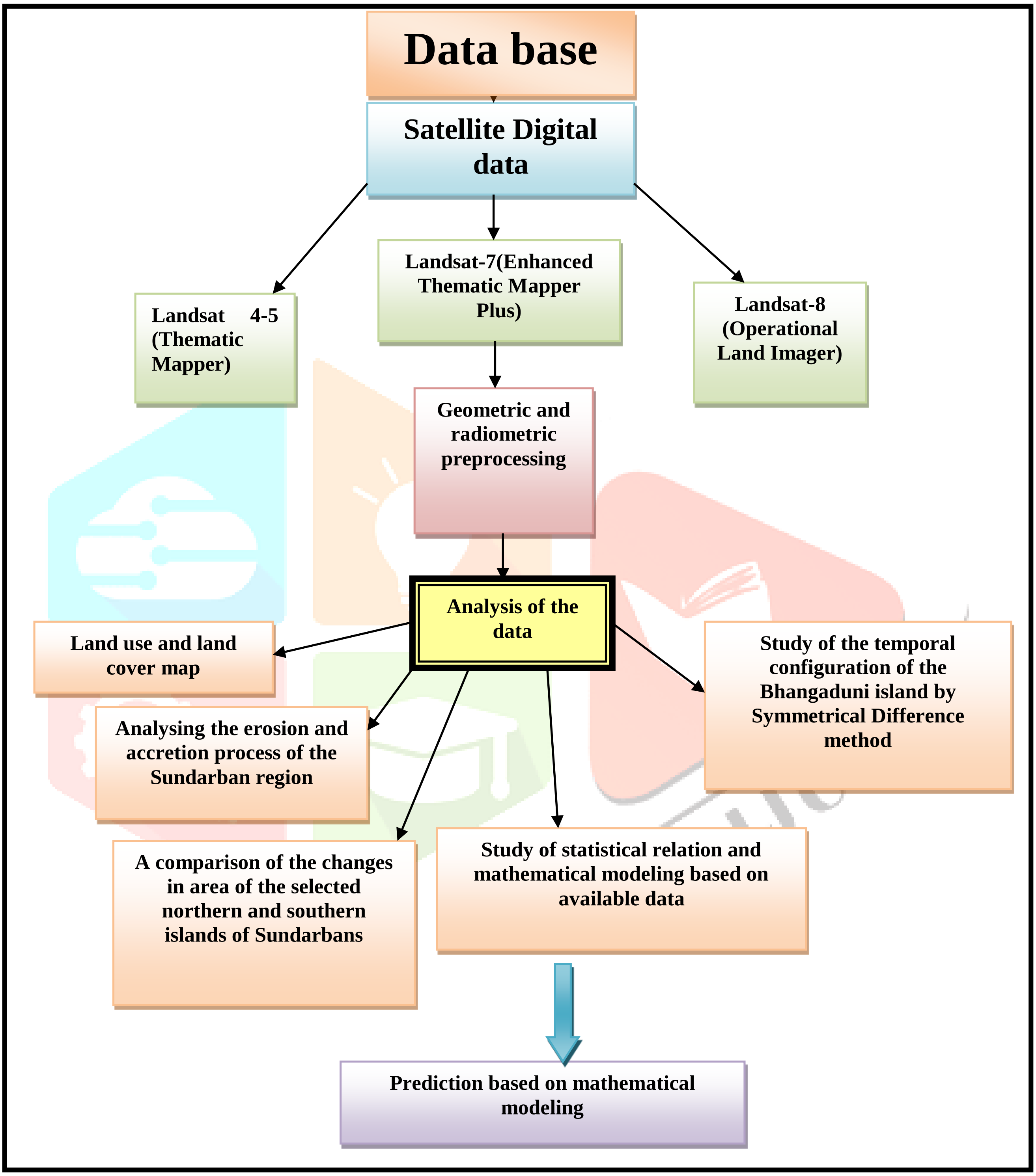
1) To analyse the change of area of the selected northern and southern islands of Sundarbans.

2) To study and analyse the change in area and shape of the Bhangaduni island situated in the southern part of Sundarbans by using Symmetrical Difference method.

3) To study the areal and coastal shrinkage and angular shift of the centroid of the Sundarban Islands- A statistical approach to study of Tigers Den as example

III. METHODOLOGY

Chart: 1 Flow chart for the methodology used for our study



Landsat series of imageries were obtained from online sources like Glovis and USGS Earth explorer websites for the years 1988, 1995, 1999, 2001, 2006, 2011 and 2016. These images were atmospherically corrected by using Atcor software. The data for these years were collected from Landsat 4-5(TM), Landsat-7(ETM+) and Landsat-8(OLI) sensors. All these images are used at a spatial resolution of 30m. The images are georeferenced and registered, the subsets of which are used to create a standard FCC. A supervised classification has been done to obtain classes like mangroves, saline bank, mudflat, degraded mangroves and waterbody in ArcGis 10.3.1 platform.

An analysis is made regarding the amount of erosion and accretion of the Sundarban region in the above mentioned years. A separate comparison of changes in area of the northern and southern islands are made with respect to the years 1988, 1995, 1999, 2001, 2006, 2011 and 2016. A separate analysis of the changes in the area of Bhangaduni island has been made in the above mentioned time periods by using the Symmetrical difference method in ArcGis platform. Furthermore an attempt has also been made to predict the changes in shape and configuration of the Bhangaduni island.

Softwares used: ArcGis 10.3.1, Matlab 2014b, Erdas Imagine 9.2 and Microsoft Office Excel 2007

IV. ANALYSIS

After obtaining the Landsat images for the above mentioned years an attempt is made to analyse the dynamic changes in shape, area and temporal configuration of the Sundarban islands. An attempt is also being made to predict the changes in temporal configuration and geometry of the Bhangaduni island situated in the southernmost part of the Sundarbans. The process of Sundarban erosion has been studied by several scientists. In all of their studies it was found that the erosion process associated with the Sundarban islands is related to several factors like ocean currents, tidal erosion, storm surges, man induced land use and land cover changes after reclamation, global rise of sea level, etc. Thus it is a result of these factors and therefore it is very difficult to point out any single factor or factors responsible for erosion. Thus an attempt is made to make a comparative study of the changes in area of the northern and southern islands of the Sundarbans, change in area and temporal configuration of the Bhangaduni island and moreover an attempt is also made regarding the prediction of the temporal configuration and geometry of the Bhangaduni island.

1) Erosion and accretion process of the Sundarban region

At first an analysis is made regarding the erosion and accretion process of the Sundarban islands. The erosion is mainly attributed to the factors like ocean currents, storm surges, tidal wave erosion, etc. Recent studies has revealed several incidences of erosion and accretion of the Sundarban islands. In our study we have analysed the process of erosion and accretion for the entire study area considered as shown in the figure below.

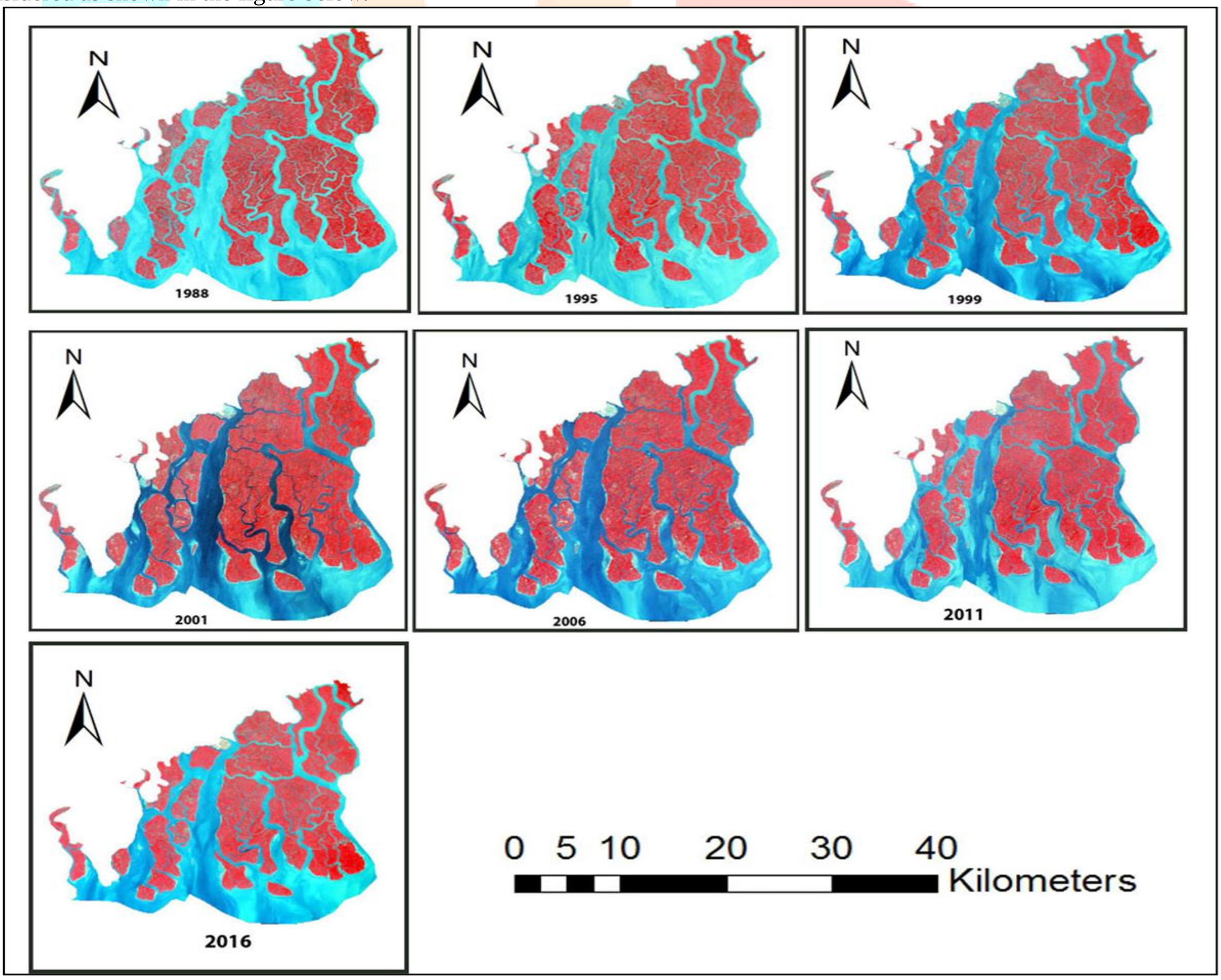


Fig: 2 Study area considered for analysing the erosion and accretion process of the Sundarbans

2) **The analysis of erosion and accretion process of our study area reveals some important facts**

table:1 Erosion and accretion of the Sundarbans

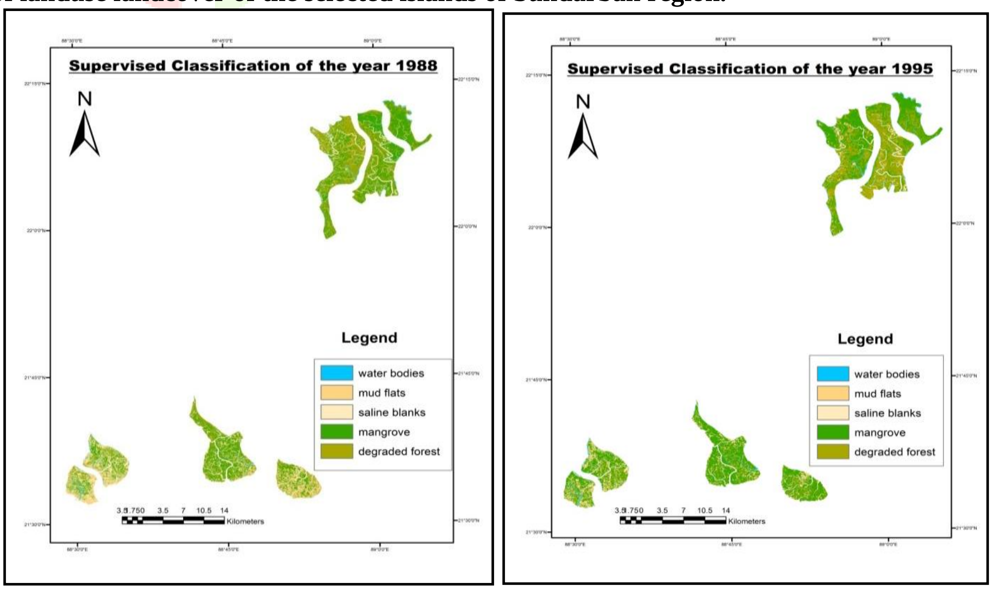
Years	Erosion(Sq.km)	Accretion(Sq.km)
1988 and 1995	96.97	10.03
1995 and 1999	233.39	46.35
1999 and 2006	53.16	525.46
2006 and 2011	41.54	15.49
2011 and 2016	68.35	10.91

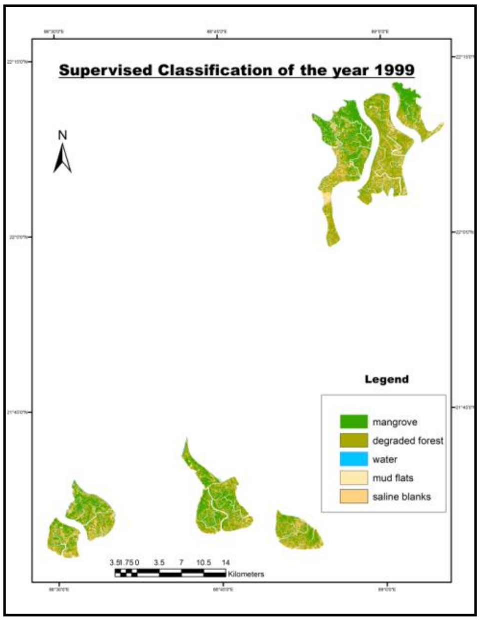
It is clear from the above table that the amount of erosion and accretion has been different in different time periods. The erosion-accretion values were obtained with respect to the years of 1988 and 1995, 1995 and 1999, 1999 and 2006, 2006 and 2011 and 2011 and 2016. It is found that the amount of erosion is greater than accretion for most of the years except 1999 and 2006, where the accretion amount found to be greater than erosion. The amount of erosion is the highest in between 1995 and 1999 i.e. 233.39 Sq.km. Similarly the amount of erosion is the highest in between 1999 and 2006 i.e. 525.46 Sq.km. But in general the overall trend shows an increaing rate of erosion over the years.
The process of erosion and accretion is of highly dynamic in nature. There are host of factors responsible for these processes like ocean currents, tidal characteristics, storm surges, global rise of sea level temperature, supply of sediments, etc. Thus it is very difficult to point out any particular factor or factors responsible for these processes. It is also a fact that the mangrove cover plays a vital role in preventing the process of erosion over the years. The degradation of the mangroves over the last few decades by human settlement and other anthropogenic activies have been giving great impetus to the process of erosion over the years.
Thus siutable steps and sustainable land management practises are very much essential to reduce the rate of erosion of the Sundarban islands. The phenomenon of global warming and seal level rise is a serious threat to the existence of small islands throughout the world including the Sundarban islands. Just a slight rise in the sea level can cause large scale deltaic subsidence.
Thereby it can be said that appropriate steps are needed to be taken to check the coastal erosion of the Sundarban islands. Mangrove forests play a vital role in protecting the natural leeves and the inter tidal point bars of the rivers. The occurances of cyclones greatly affects the mangroves by wind damage, storm surge and sedimentation. The sediments carried by storm surges gets deposited on the forest floor causing plant mortality by affecting their root and soil gas exchange. It also affects the seed germination of the mangroves. Thus if the mangroves are continously affected by these processes the vulnerability of the Sundarban islands to erosion gets further increased over time period.

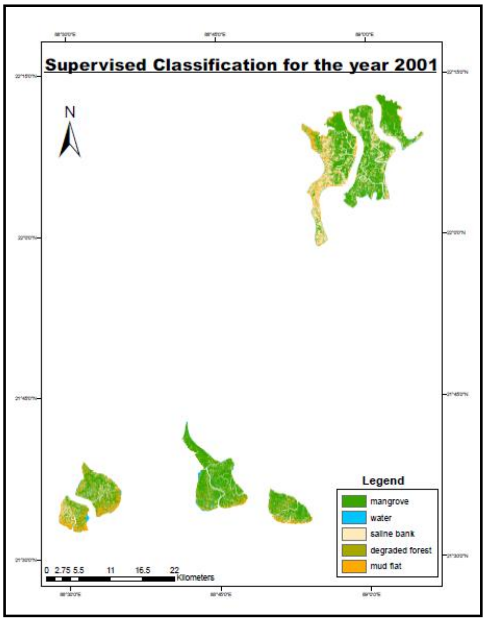
3) **Landuse and landcover scenario of selected northern and southern islands of the Sundarban region**

A supervised classification has been done to analyse the land use and land cover scenario of the selected islands of the Sundarban region. It is very important to analyse the areal extent of the mangroves in comparison to the other land use types as it plays a vital role in preventing the coastal erosion of these islands. The landuse and landcover types as of the selected northern and southern islands of the Sundarban region has been analysed by using supervised classification technique. The five major classes of landuse as derived by the classification are: mangroves, saline banks, mudflats, degraded forest and water bodies. The classification points out to the varying degree of mangroves coverage in the temporal scale. The highest coverage of the mangroves are found in the years of 1995 and 2001 i.e. an areal coverage of 251 and 298 Sq.km respectively. But the mangrove coverage has faced a sharp reduction in 2016 to a meagre value of 121.55 Sq.km. And in the same year the areal coverage of the degraded forest rose significantly to a value of 155.65 Sq.km at the cost of the mangroves. Thus this makes the islands of the Sundarban region more susceptible to coastal erosion.

Fig: 3 Condition of landuse landcover of the selected islands of Sundarban region.




Supervised Classification of the year 1999
N
Legend
mangrove
degraded forest
water
mud flats
saline blanks
Kilometers


Supervised Classification for the year 2001
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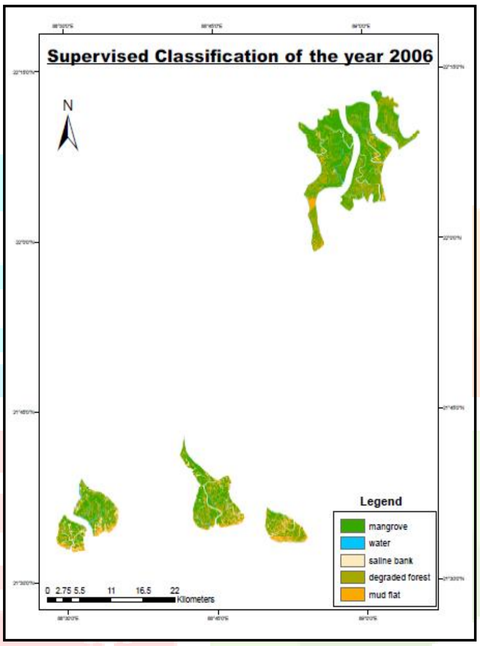
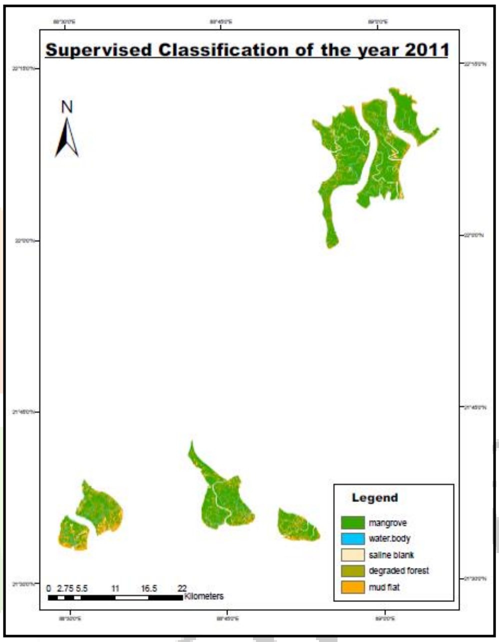
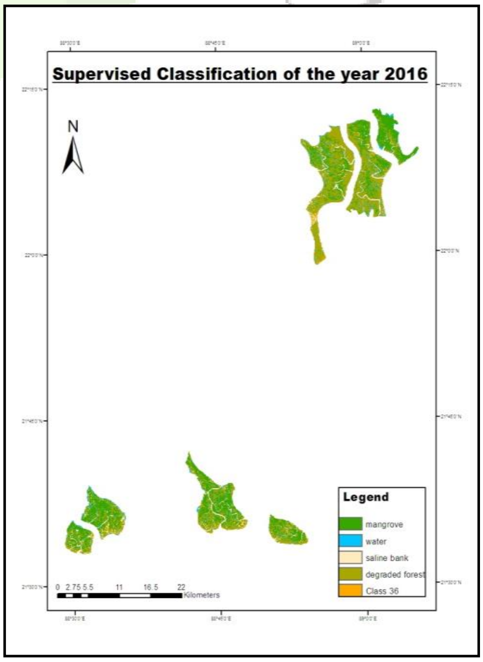
Legend
mangrove
water
saline bank
degraded forest
mud flat
0 2.75 5.5 11 16.5 22
Kilometers


Supervised Classification of the year 2006
N
Legend
mangrove
water
saline bank
degraded forest
mud flat
0 2.75 5.5 11 16.5 22
Kilometers


Supervised Classification of the year 2011
N
Legend
mangrove
water.body
saline blank
degraded forest
mud flat
0 2.75 5.5 11 16.5 22
Kilometers


Supervised Classification of the year 2016
N
Legend
mangrove
water
saline bank
degraded forest
Class 36
Kilometers

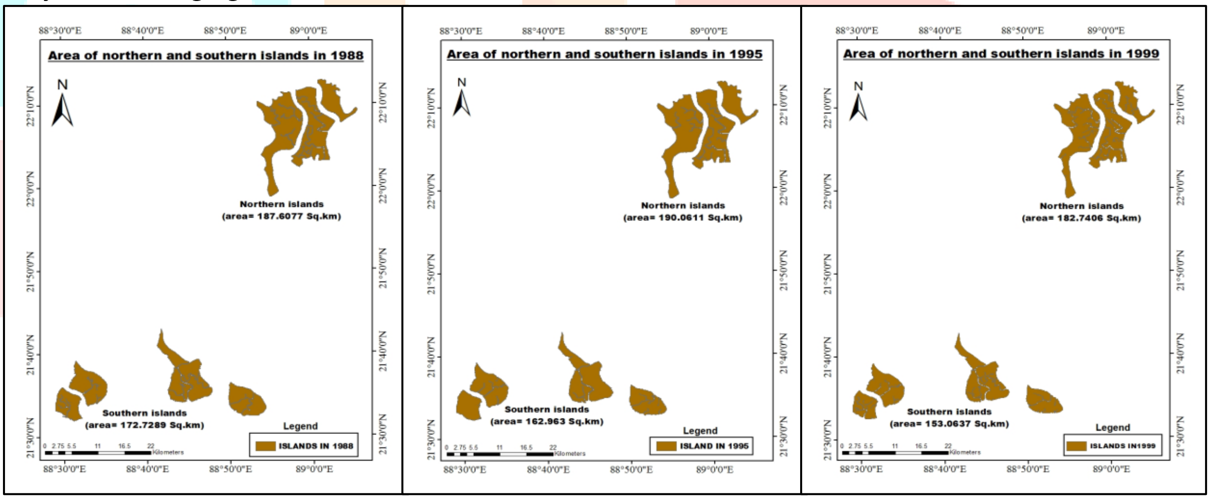
The reduction of the mangroves can be induced by the factors which are both natural as well as anthropogenic. Natural factors like storm surges, coastal erosion, etc are the dominating factors while anthropogenic factors like land reclamation for agriculture and settlement plays a pivotal role in accelerating the process of erosion and land degradation. Thus these factors increases the vulnerability of these islands to erosion.

Table: 2 Area of different classes of landcover types of the selected northern and southern islands of the Sundarban region.

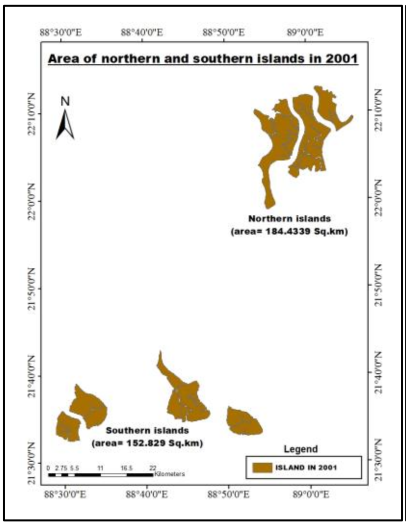
Year	Area in Sq.km				
	mangrove	water	saline bank	degraded forest	mud flat
1988	146.1978	6.4215	58.1454	110.1429	39.429
1995	251.0043	29.4705	206.9091	112.9036	60.39
1999	180.7686	8.37	20.1969	107.5131	36.1755
2001	298.7715	40.8033	291.3525	73.8864	183.3534
2006	181.017	8.9748	20.9691	69.1497	57.4479
2011	222.5673	6.9984	15.426	27.6057	56.9034
2016	121.5495	18.567	7.4304	155.6577	8.0091

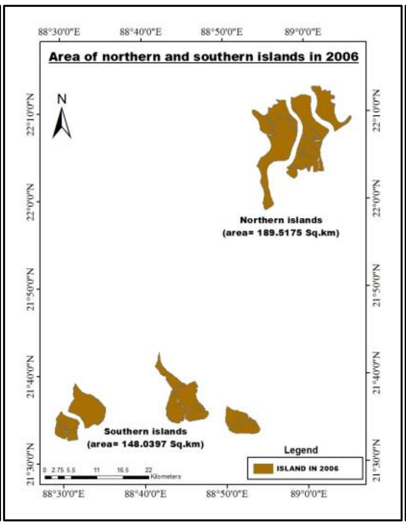
4) A COMPARISON OF THE CHANGES IN AREA OF THE SELECTED NORTHERN AND SOUTHERN ISLANDS OF SUNDARBANS

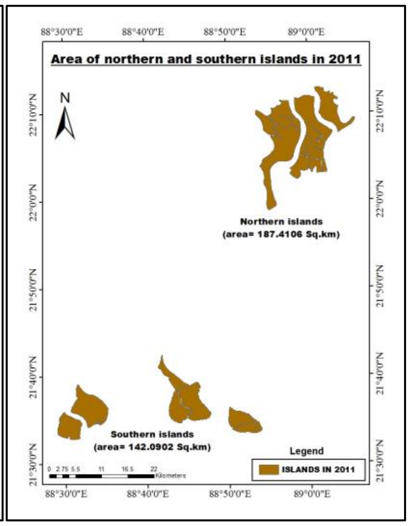
It is a fact that the rate erosion is different in the northern and southern part of the Sundarbans. Thereby the shape and temporal configuration of these islands ought to be different in different time scales. It is also seen that the effect of erosion is highly pronounced in the southern part of the Sundarbans compared to its northern part. This is due to effect of ocean currents, tidal activities, strom surges which is mostly pronounced in the southern part. Therefore the erosion is much higher over the southern islands like Bhangaduni, Balucheri, Dalhousie, Jambudwip, Dhanchi, etc. so these islands have suffered areal reduction over the years. This fact is analysed by the following figures.



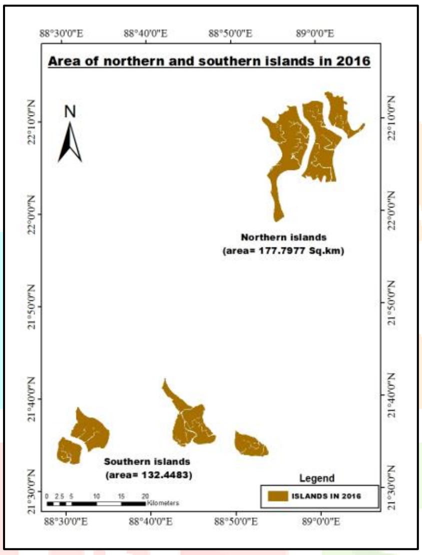
1988 1995 1999







2001 2006 2011



2016

Years	area of northern islands(Sq.km	area of southern islands(Sq.km)
1988	187.6077	172.7289
1995	190.0611	162.963
1999	182.7406	153.0637
2001	184.4339	152.829
2006	189.5175	148.0397
2011	187.4106	142.0902
2016	177.7977	132.4483

Table: 3 Temporal change of area of northern and southern islands of the Sundarbans.

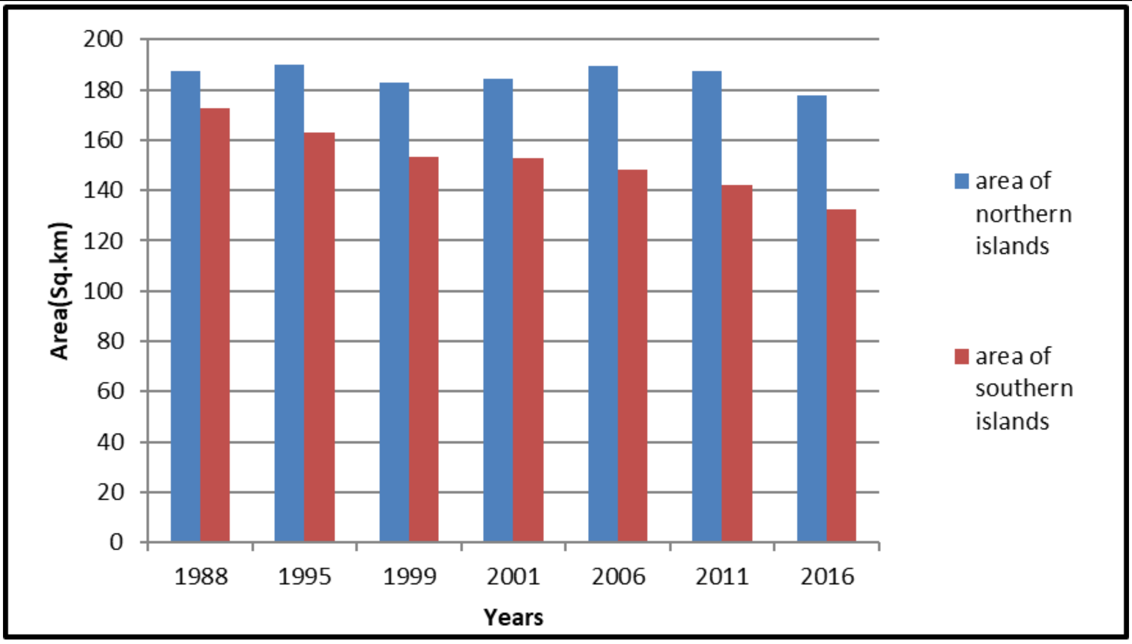


Fig: 5 Temporal change of area of northern and southern islands of the Sundarbans.

It is clear from above figures that the area of the Sundarban islands has changed over the years. The northern and southern Islands have experienced a loss of area. But the loss is far greater in the southern islands compared to the northern islands.

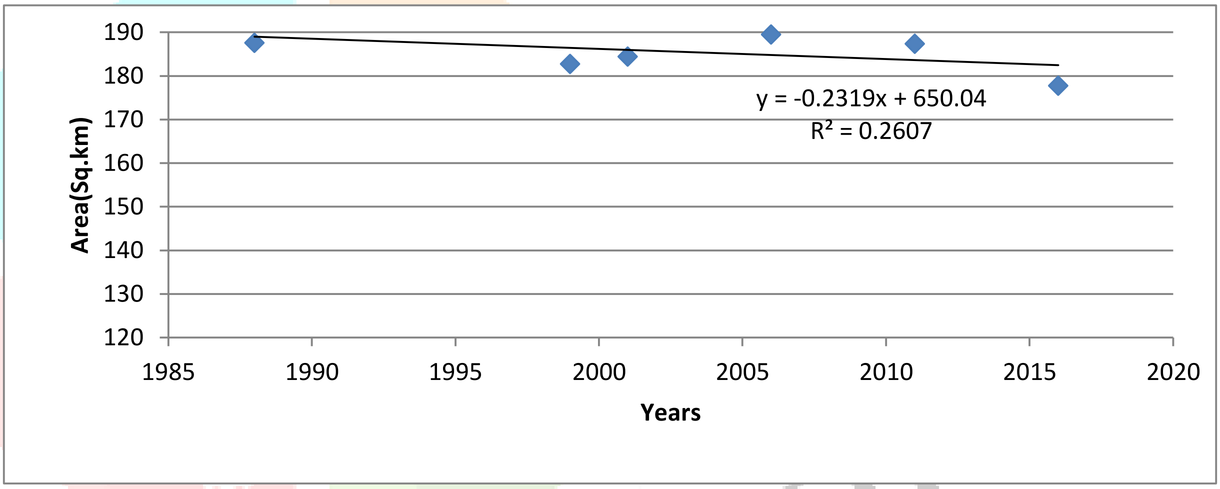


Fig: 6 Regression line showing the rate of decrease in area of the northern islands of the Sundarbans

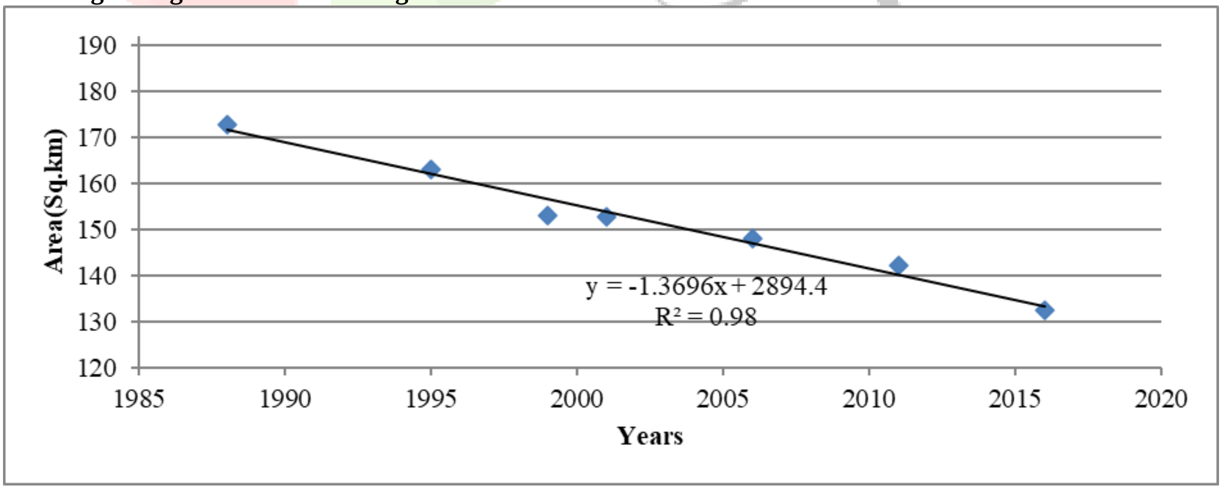


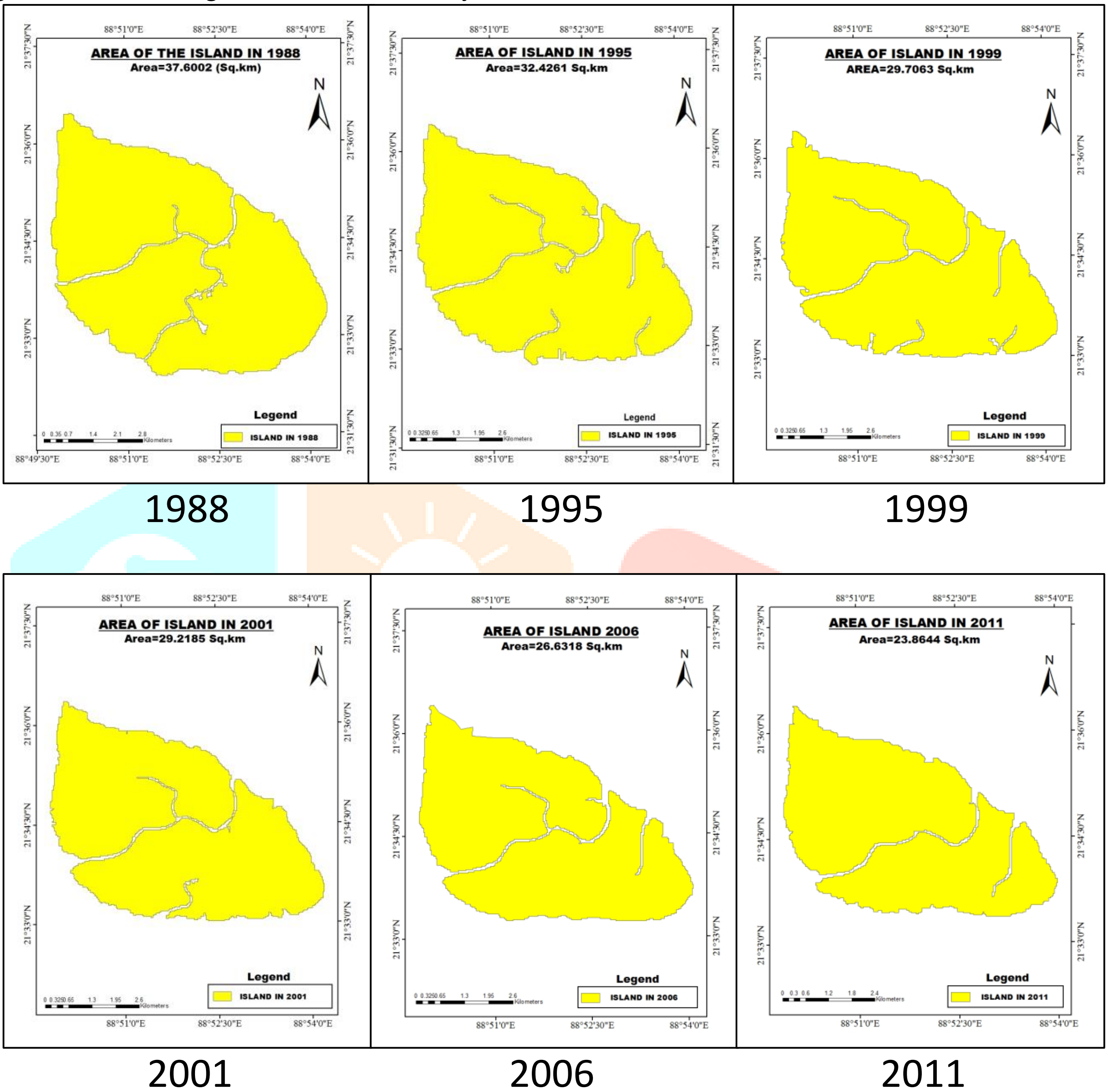
Fig: 7 Regression line showing the rate of decrease in area of the southern islands of the Sundarbans

It is clear from the above regression lines that the rate of decrease of area of the southern islands is more rapid as compared to the northern islands. The steeper slope of the regression line confirms this fact. This is due to openness of the southern islands to the erosional processes caused by ocean currents, tidal activities, etc. these islands are also affected greatly by storm surges. The area of these islands are expected to decrease further in future. The area of the islands like Bhangaduni, Jambudwip, Dhanchi, Dalhousie, etc has decreased rapidly in the past few decades which has been confirmed my many studies. So these facts revealed that the erosional processes are more active in the southern part of the Sundarbans.

5) **TEMPORAL CONFIGURATION OF THE BHANGADUNI ISLAND**

An analysis of the change of area of Bhangaduni island situated at the southernmost part of the Sundarbans has been made corresponding to the years of 1988, 1995, 1999, 2001, 2006, 2011 and 2016. The amount of areal change has been calculated by using the Symmetrical Difference method. It is found that the amount of area of the Bhangaduni island has declined over the years which indicate that this island has undergone significant amount of erosion over the years. The temporal configuration of the island itself shows that in comparison to 1988 (when the area of the island was the highest), its area has declined significantly over the years in 1995, 1999, 2001, 2006, 2011, 2016.

Fig: 8 Area of the Bhangaduni island in different years



The areal decline is clearly evident from the above area diagrams of the island. The comparison with 1988 shows the change in both shape and area of the island in the above mentioned years. The temporal configuration of the island gives a clear insight into the changes mentioned above.

The symmetrical difference diagram shows more clearly the part and the area of the island lost due to the process of erosion. The symmetrical difference has been calculated for the years 1995, 1999, 2001, 2006, 2011 and 2016 by considering 1988 as the base year. It is clearly evident that the highest symmetrical difference has been found in between the years of 1988 and 2016. It thus can be concluded that the decrease of areal extent of the Bhangaduni Island is evident and is going to decrease further in the upcoming years.

The area of the island was the highest in 1988 i.e. 37.6 Sq.km which has declined to 21.3 Sq.km in 2016. This reduction can be attributed to several factors like sea-level rise consequent upon global rise in temperature, melting of glaciers globally, tidal characteristics, severe and continual erosion of these islands caused by storm surges, ocean currents, cyclones, etc. Though it is very difficult to point out any single factor, yet such a reduction is alarming indeed. This scenario is also evident by scatter plot below, where the steep slope of the regression line points out the rapidity of the process of areal loss caused due to erosional processes.

YEARS	AREA OF BHANGADUNI ISLAND(Sq.km)
1988	37.6002
1995	32.4261
1999	29.7063
2001	29.2185
2006	26.6318
2011	23.8644
2016	21.305

Table: 4 Area of Bhangaduni island

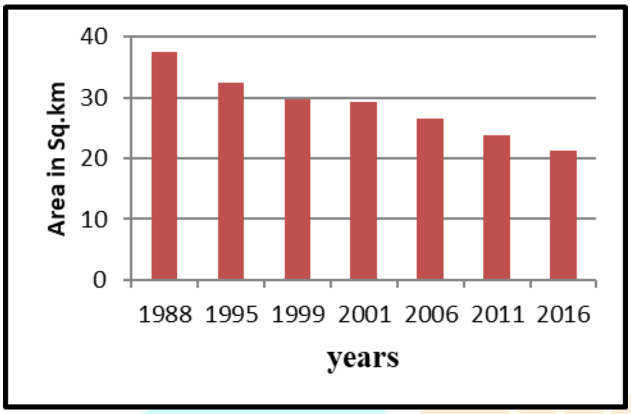


Fig: 9 Reduction of area of Bhangaduni island

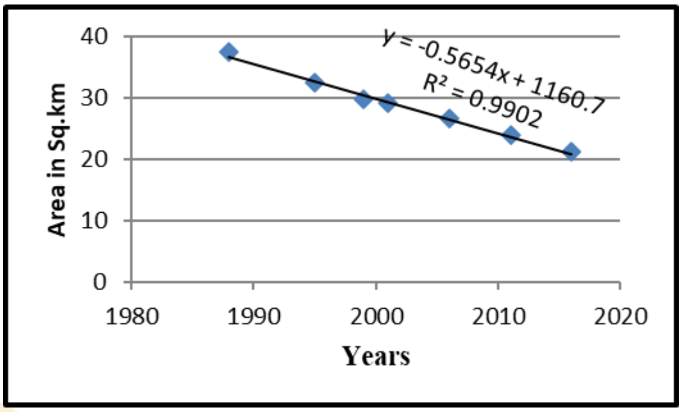


Fig: 10 Rate of decrease in area of Bhangaduni island

Years	Symmetrical Difference(Sq.km)
1988 and 1995	5.8761
1988 and 1999	8.766116
1988 and 2001	9.129155
1988 and 2006	11.591989
1988 and 2011	14.4432
1988 and 2016	16.2952

Table: 5 Symmetrical Difference of the Bhangaduni Island

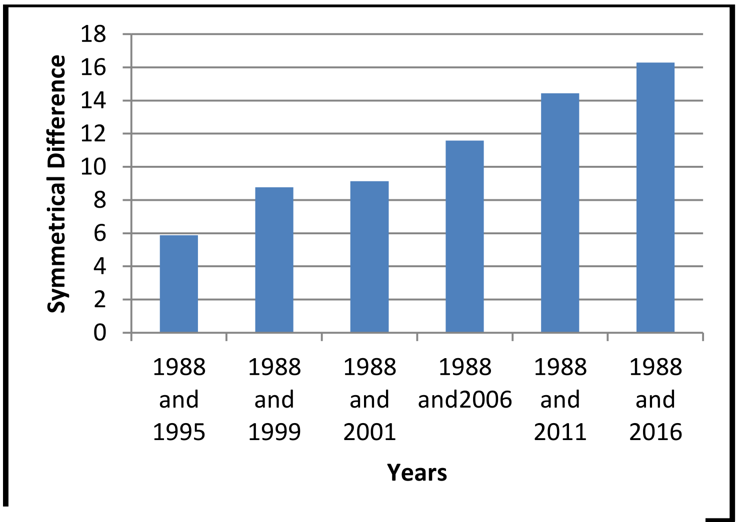


Fig: 11 Symmetrical difference of the Bhangaduni island over the years with 1988 as the base year

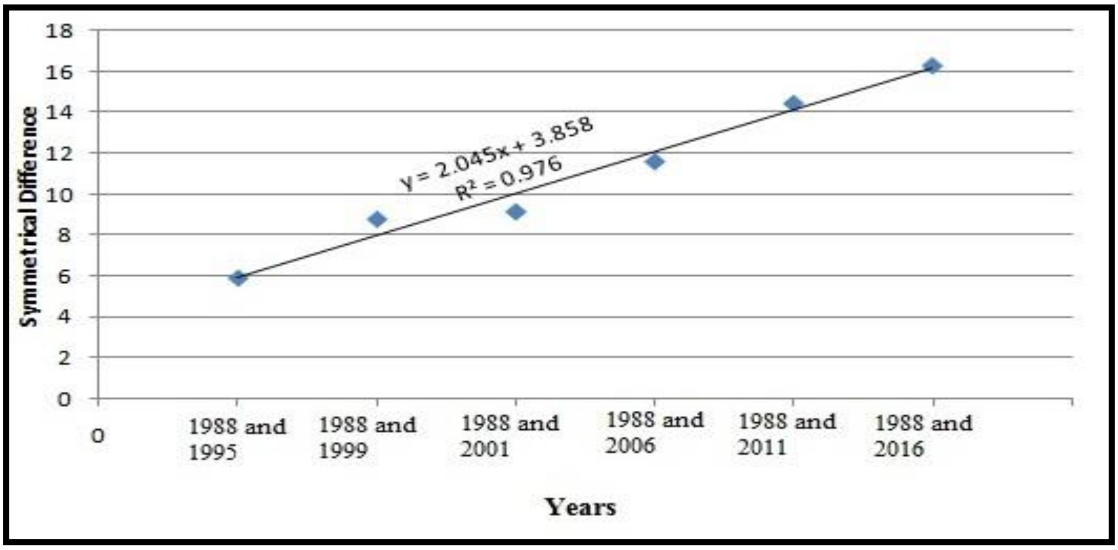


Fig: 12 Regression line showing the increase in symmetrical difference of the Bhandaduni island area over the years in comparison to the year 1988.

From the above figures it is clear that in comparison to the year 1988 the symmetrical difference has increased over the years. This shows the fact that the area of Bhangaduni has decreased over the years compared to 1988. The symmetrical difference between 1988 and 1995 was minimum i.e. 5.8761 Sq.km and it has increased significantly over the years to 16.2952 Sq.km in between 1988 and 2016 which is maximum. Thus the rate of increase of symmetrical difference shows the amount of areal loss of the island in comparison to 1988 as the base year. The steepness of the positively sloped regression line of scatter plot confirms the fact that the increase in symmetrical difference or the amount of areal loss of the island has taken place at a rapid rate with time which is alarming indeed.

5.1) TEMPORAL CONFIGURATION AND SYMMETRICAL DIFFERENCE OF THE BHANGADUNI ISLAND & TIGERS DEN OVER THE YEARS IN COMPARISON TO 1988

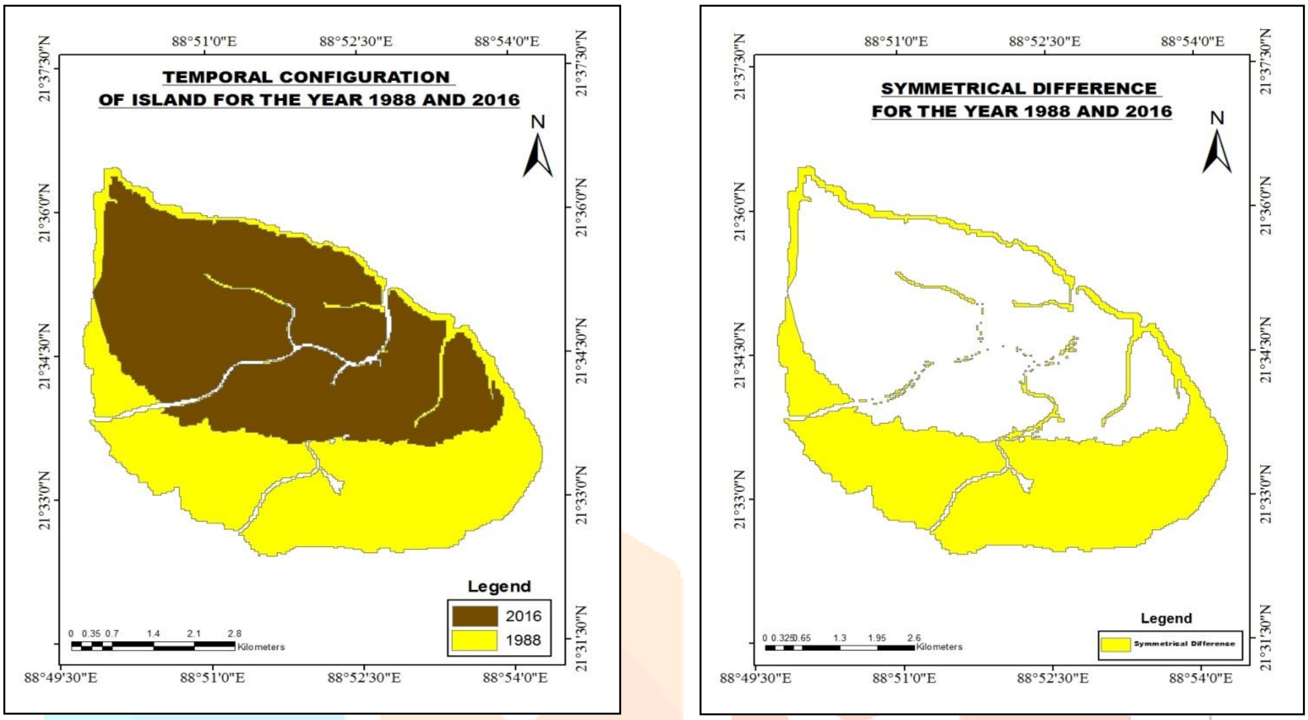


Fig: 13 Comparison between 1988 and 2016

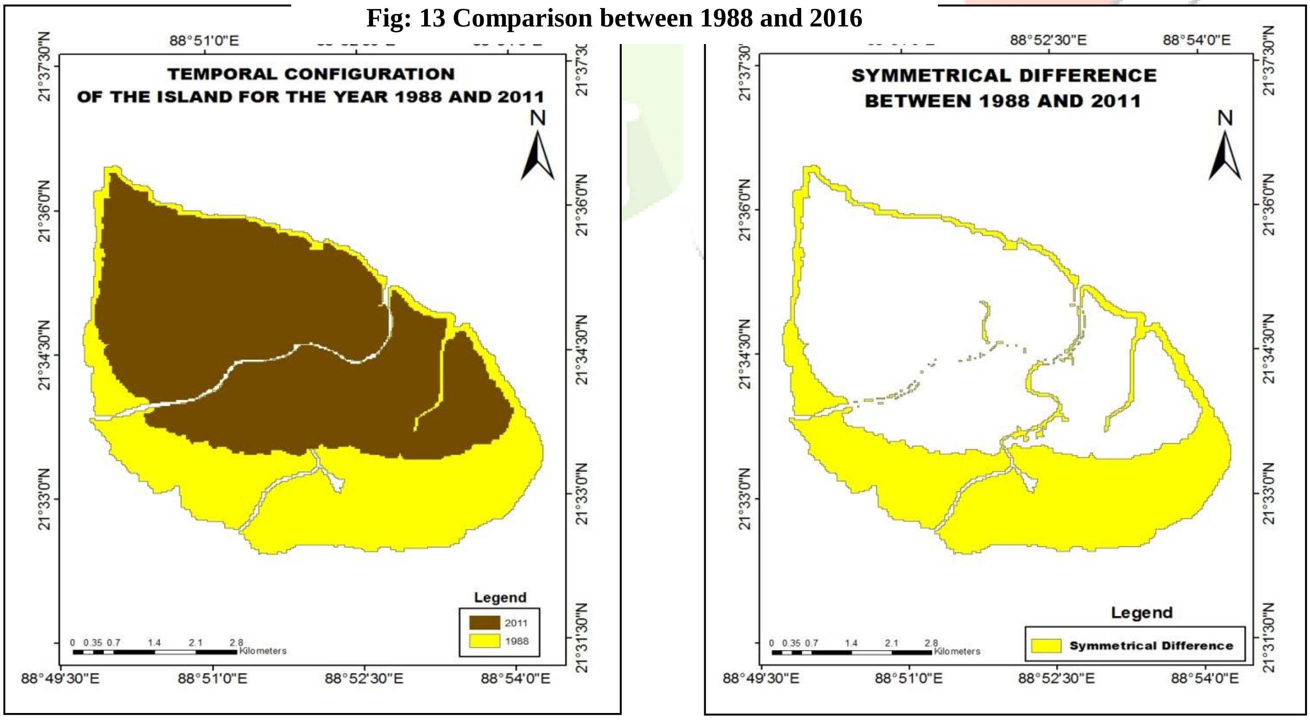


Fig: 14 Comparison between 1988 and 2011

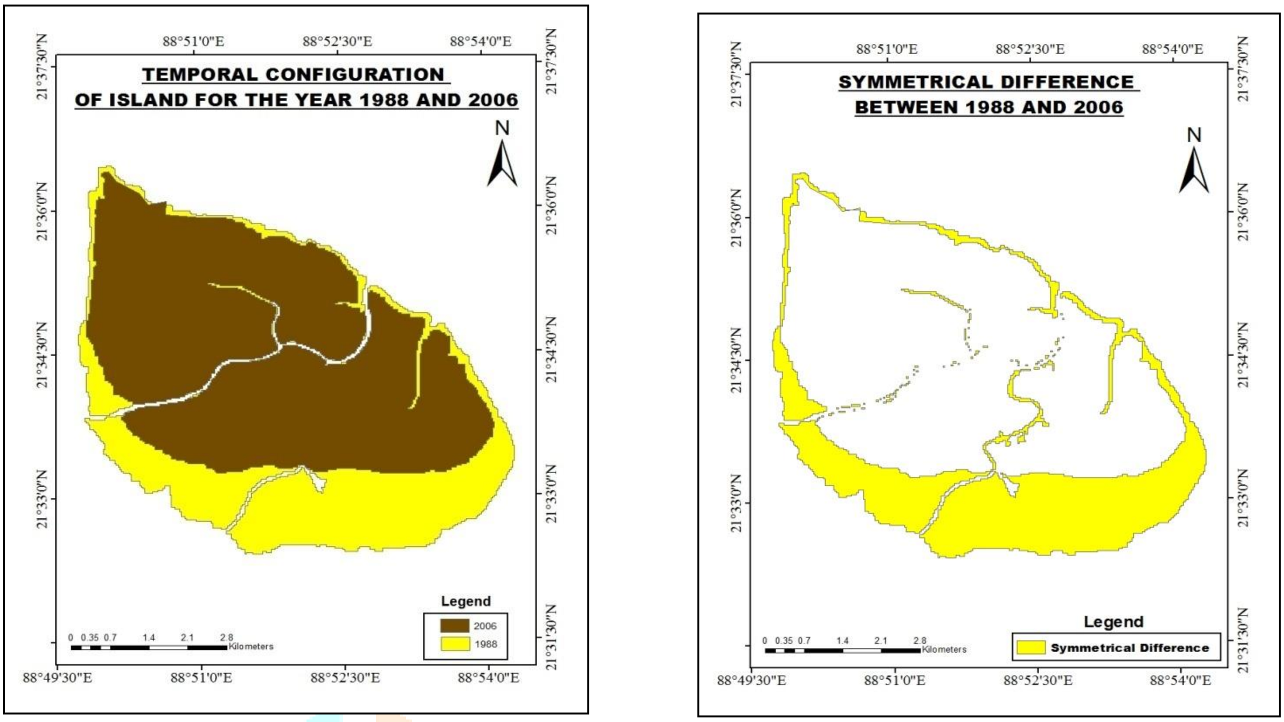


Fig: 15 Comparison between 1988 and 2006

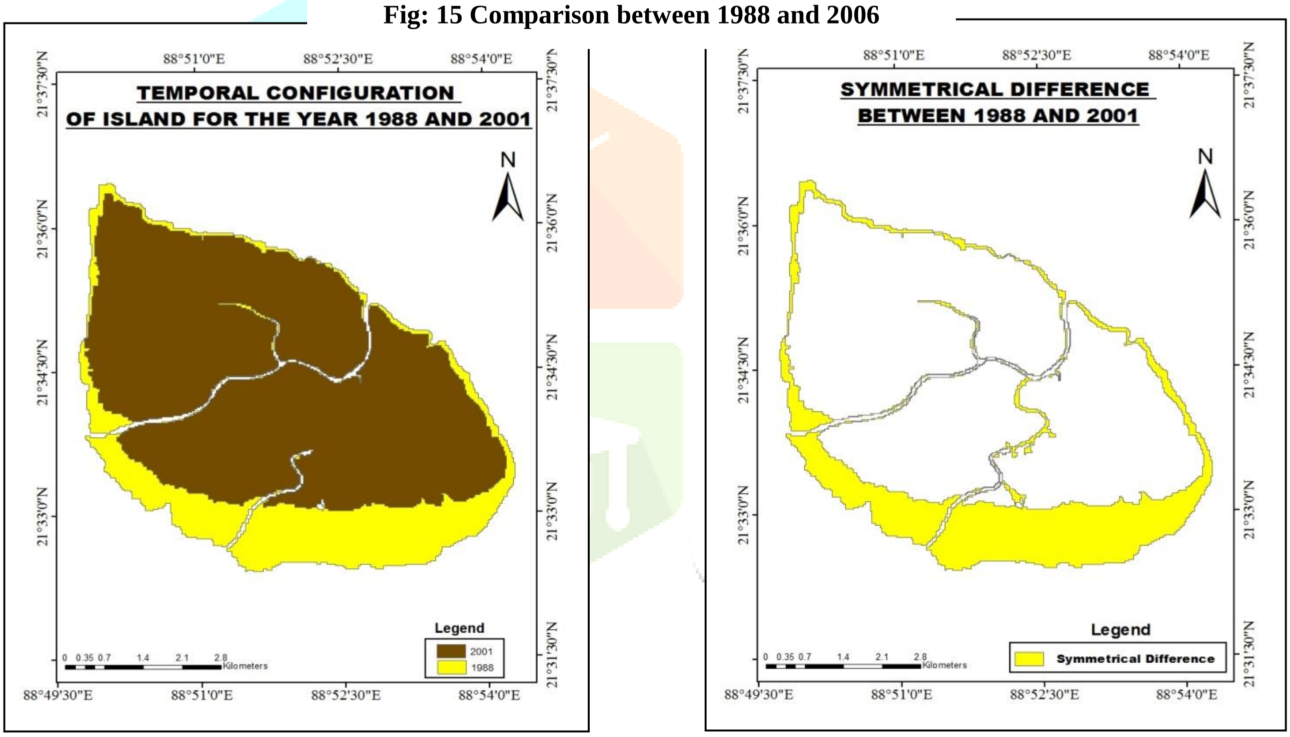


Fig: 16 Comparison between 1988 and 2001

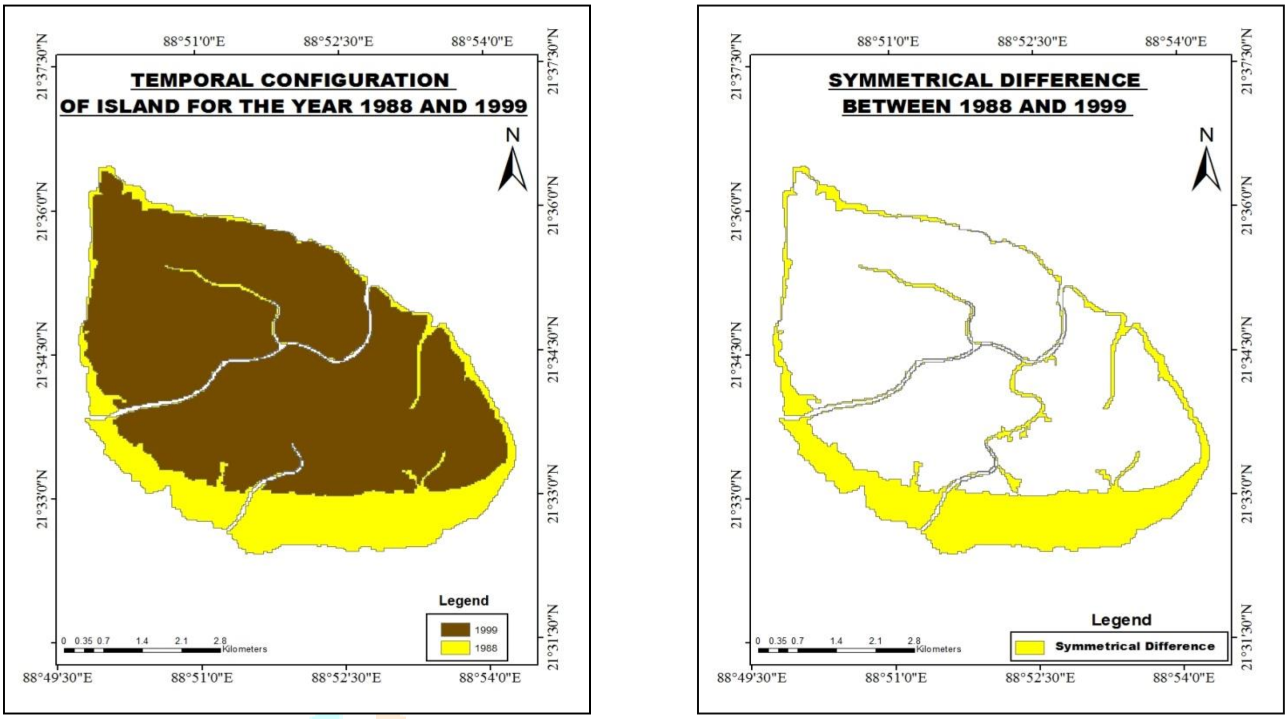


Fig: 17 Comparison between 1988 and 1999

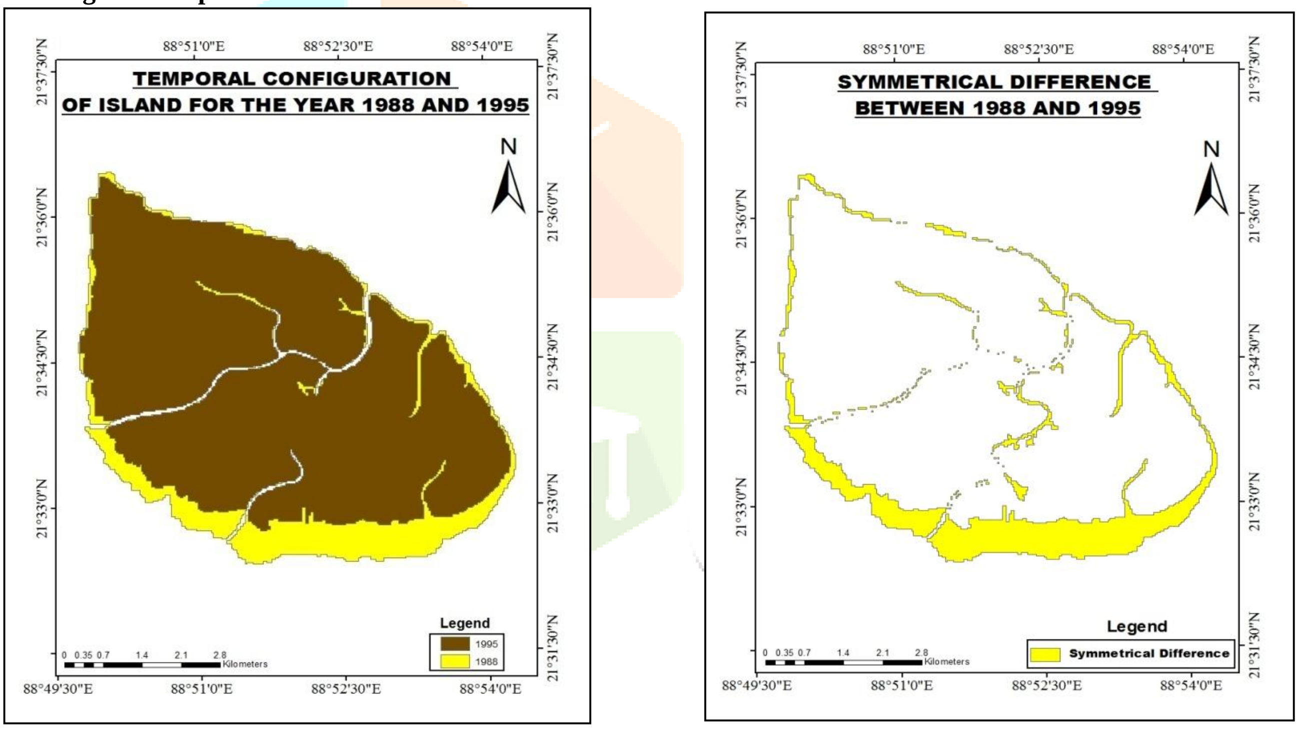


Fig: 18 Comparison between 1988 and 1995

5.2 AN ANALYSIS OF THE AREAL AND COASTAL SHRINKAGE AND ITS CONSEQUENT ANGULAR SHIFT OF THE CENTROID OF TIGERS DEN OVER THE YEARS

Over the years the Bhangaduni Island has suffered coastal shrinkage mainly due to coastal erosion induced by many factors already mentioned above. In this regard the statistical analysis of the Bhangaduni islands reveals many important facts.

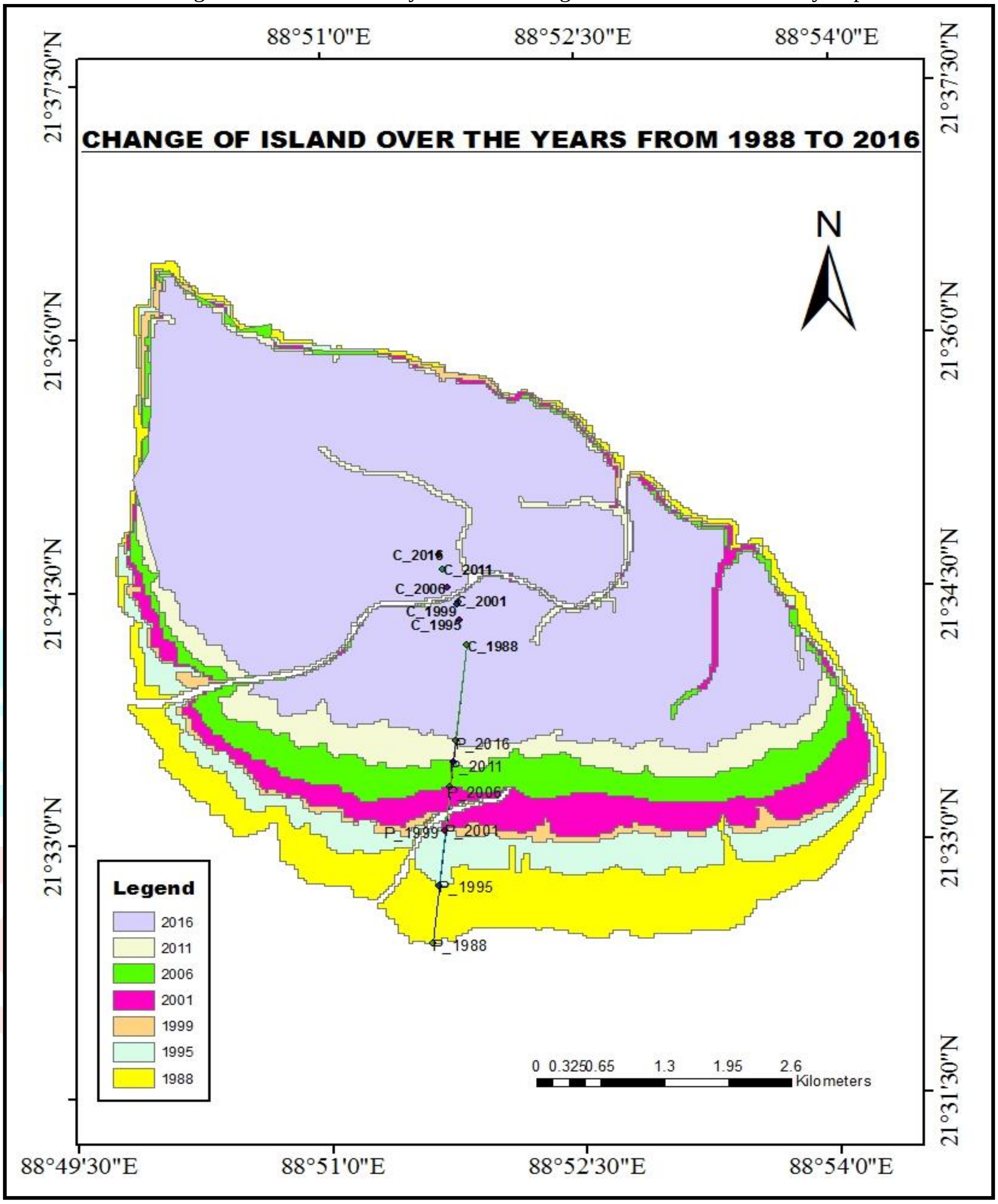


Fig: 19 Angular shift of centroid and a common selected coastal point of the Bhangaduni island over the years.

1. *MATHEMATICAL MODELING FOR THE PREDICTION OF GEOGRAPHICAL EROSION AND ACCRETION*

The data obtained using image processing of Landsat images from 1988 to 2016 as given in Table 1 has been used by two parts. First part has been used for training the data and second part is for testing purpose. Three different studies has been shown which are

1. Delta Overall decrement of the Delta
2. Decrement in the coastal area of the Bhangaduni island.
3. Shift of the centroid from earth origin due to erosion and accretion.

Study Part 1: Delta Overall decrement of the Delta

Fig.1_a shows the decrement of overall area of the delta (in KM^2) with time (year).

Using these data into MATLAB 2014b, a nonlinear regression method has been used to study the changes. A quadratic polynomial functions has been fitted with the data as

f(x) = p1*x^2 + p2*x + p3;

Where,

p1 = 0.007257
p2 = -0.792
p3 = 38.06

Goodness of fit:
SSE: 0.9583
R-square: 0.9946
Adjusted R-square: 0.9919
RMSE: 0.4895

The predicted value for the next 20 years are given in the table below:

Table: 6 The predicted value of decrement of the delta area for the next 20 years (2020 to 2035)

Sl. No.	Year	Decrement of Delta Area (in KM^2)
1	2020	19.8269
2	2025	18.4431
3	2030	16.4222
4	2035	14.7641

Study Part 2: Decrement in the coastal area of the Sunderban Island (Tigers Den)

Fig.1_b shows the decrement of costal area from its centroid (in KM) with time (year).

Using these data into MATLAB 2014b, a nonlinear regression method has been used to study the changes. A power exponent functions has been fitted with the data as

f(x) = a*x^b+c

Where,

Coefficients (with 95% confidence bounds):
a = -344.3
b = 0.6125
c = 3656

Goodness of fit:
R-square: 0.989
Adjusted R-square: 0.9834

The predicted value for the next 20 years are given in the table below:

Table: 7 The predicted value of decrement in coastal area for the next 20 years (2020 to 2035)

Sl. No.	Year	Decrement in coastal Area (in KM)
1	2020	724.9258
2	2025	460.3848
3	2030	209.0383
4	2033	63.6703
5	2034	16.0371
6	2035	0

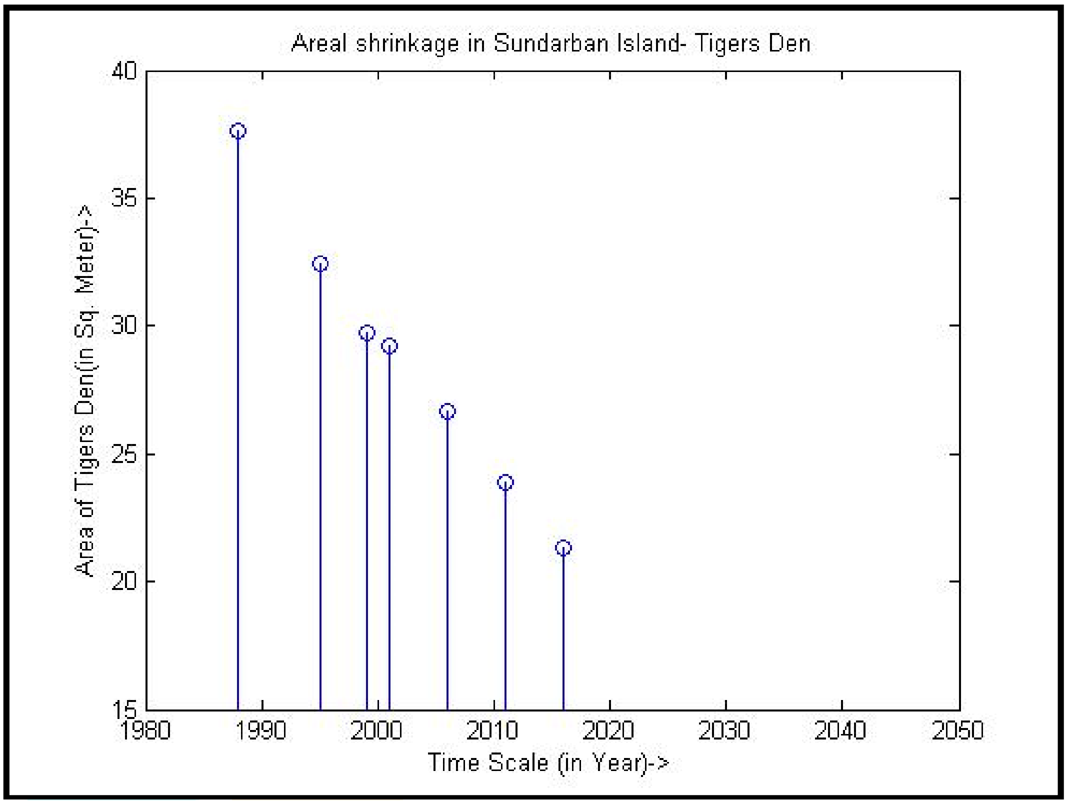


Fig: 20 Areal shrinkage in Sundarban Island (Bhangaduni) - Tigers Den

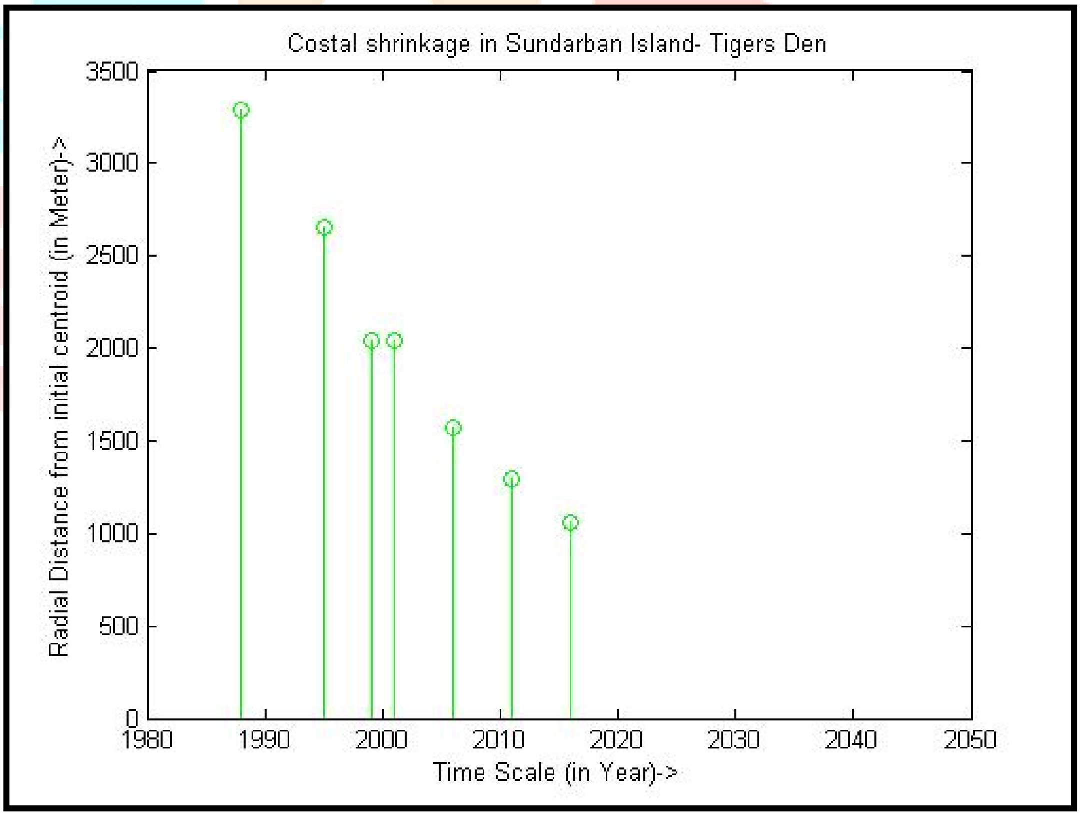


Fig: 21 Coastal shrinkage in Sundarban Island (Bhangaduni)- Tigers Den

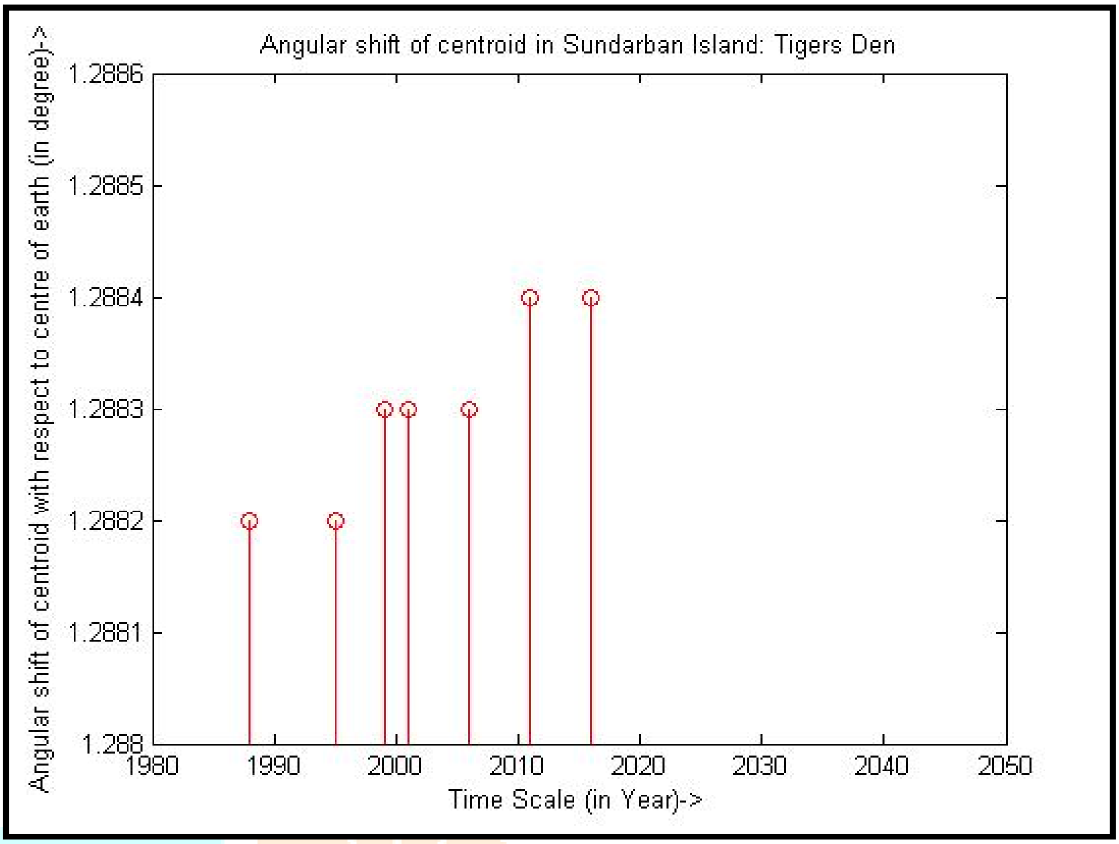


Fig: 22 Angular shift of centroid in Sundarban Island (Bhangaduni)-Tigers Den

v) DISCUSSION

Our analysis clearly points out the changes in temporal configuration of the Sundarban islands that is induced mainly by the process of coastal erosion induced by many factors like rising sea level, storm surges, effect of ocean currents etc. the land cover classification itself indicated that how the areal coverage of the mangroves has fluctuated over the years to eventually decline to a meager value of only 121.55 Sq.km.(table: 2) It is expected that this decline in mangroves coverage will increase the vulnerability of the Sundarban islands to erosion and causing the decrement in area.

The comparison of the changes in area of our selected northern and southern islands of the Sundarbans clearly reveals that the effect of coastal erosion is far greater in the southern islands as compared to the northern islands. This fact is clearer from the steeper slope of the regression line of the southern slope compared to the northern slope (in fig 6 and fig 7). The area of the southern islands got reduced to 132.45 Sq.km in 2016 from 172.72 Sq.km in 1988(table 3). This rate of reduction in area is alarming indeed.

The analysis of the temporal configuration of the Bhangaduni Island (which is one of the southernmost islands of the Sundarbans) reveals the decrement in area over the years from 1988 to 2016. Thus following the overall trend of reduction in area of the southern islands of the Sundarbans as shown earlier. The area of Bhangaduni island has reduced from 37.6 Sq.km in 1988 to 21.305 Sq.km in 2016(table: 4). So its rate of reduction in area is occurring at a rapid rate as indicated by the steep slope of the regression line (fig: 10).

The change in temporal configuration of the Bhangaduni Island is clearer from the Symmetrical Difference analysis of the island over the years. The symmetrical difference analysis helped us to form an accurate idea about the loss of area of the Bhangaduni Island over the years by considering 1988 as the base year. It is clear from table: 5 and fig: 11 that the symmetrical difference between the year 1988 and 2016 was the highest. This indicates that the amount of areal loss due to erosion is also the highest in this time interval. The analysis reveals a tendency of higher values of the symmetrical difference over the years. This trend is also indicated by the steep slope of the regression line drawn for symmetrical difference values over the years (fig 12). Thus the loss of area of the Bhangaduni is very much predictable in near future.

In order to analyze this predictability an attempt is made to fit mathematical models for the prediction of geographical erosion and accretion of the Bhangaduni Island. A nonlinear regression method has been used to study the changes. A quadratic polynomial function has been fitted with the data with Root Mean Square Error of 0.4895. The prediction made by the equation shows the decrement of the delta area. It is observed that the area will get reduced from 19.82 Sq.km in 2020 to 14.76 Sq.km in 2035. Furthermore the prediction made by using the equation shows the decrement in coastal area of the island in future. The outcome of the analysis shows that the area of the Bhangaduni Island will get reduced to 724.92 Sq.km in 2020 and will get further reduced to 460.38 Sq.km in 2025, to 63.67 Sq.km in 2033, to ultimately 0 Sq.km in 2035. Thus the model shows a complete disappearance of the Bhangaduni Island by 2035 which is alarming indeed. Furthermore an analysis is also made regarding the angular shift of the centroid of Bhangaduni Island to examine its true locational shift over the years.

vi) CONCLUSION

The above analyses regarding the changes in area, temporal configuration of the Sundarban islands reveals that erosion has been a single dominant control factor that has caused the areal reduction especially of the southern islands of the Sundarban region over the years. Along with the natural factors like ocean currents, storm surges, anthropogenic factors such as land reclamation for agriculture and settlement has given impetus to the coastal erosion of the Sundarban islands. The change of temporal configuration of the Bhangaduni Island is analyzed by using symmetrical difference method. A statistical study has been done on the Tigers Den Island from 1988 to 2016 for quantitative analysis of the overall areal and coastal region shrinkage. Furthermore the statistical analysis based on the mathematical model also provides for prediction of Tigers Den Island that. Thus it is important to consider this fact and to take appropriate steps towards construction of embankments in the coastal erosion prone areas, creating opportunities for proper sustainable land use practices, afforestation of the degraded areas. To respite from complete erosion of the Island, everyone should take initiative from personal level to global scenario and to minimize it.

vii) CONFLICT OF INTEREST STATEMENT

The present research declares no conflict of interest with anyone.

viii) SOURCE OF FUNDING

The present research declares no source of funding

ix) ACKNOWLEDGEMENT

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