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IMPACT OF SEA LEVEL RISE ON MANGROVE VEGETATION OF SUNDARBAN TIGER RESERVE

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Abstract- The Sundarbans mangrove ecosystem in the deltaic complex of the Rivers Ganga, Brahmaputra and Meghna is shared between Bangladesh (62%) and India (38%) and is the world's largest coastal wetland. The total area of Indian Sundarbans region is about 9630 sq. km., comprising 102 islands, out of which, 54 are inhabitated with a population of more than 4 million (2011 census) and the rest of 48 islands are Reserved Forest with mangrove vegetation. A lot of studies have been carried out to explore the impact of global warming and sea level rise on the Sundarbans estuary. Most of the available studies have predicted fast submergence of the islands of the estuary in near future, thus leading to vanishing of Sundarbans mangrove forest and threatening the livelihood of the forest-fringe villagers. No detailed study had been done to measure the impact of global warming on the mangrove vegetations of Sundarban Tiger Reserve. A time series study of island dynamics and mangrove density, over a period of 15 years reveals that increased salinity due to SLR will lead to faster conversion of dense mangrove vegetation into more salt-tolerant open mangrove forest, rather than the loss of land through inundation, which will pose imminent danger to the population of Big Cat in this unique mangrove eco-system.

Keywords- Sea level rise, Sundarbans, Sunderland Tiger Reserve, dense mangrove, open mangrove, erosion and accretion, threat to Bengal tiger, climate change.

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Introduction

The total area of Indian Sundarbans region is about 9630 sq. km., out of which the Reserve Forest occupies nearly 4260 sq. km. At present, out of 102 islands of the Sundarbans region, 54 are inhabitated with a population of more than 4 million (2011 census), spread over 1093 mouzas. The region is spread over two administrative districts, namely South 24-Parganas (13 blocks) and North 24-Parganas (6 blocks) [1].

A close network of rivers, channels and creeks intersects the whole area, which has resulted in formation of innumerable islands. The main rivers of the Reserve are Kalindi, Raimangal, Harinbhanga, Jhilla, Kapura, Gomdi, Bidya, Matla, Gosaba & Gona.

Sundarbans delta is very dynamic. The origin of Sundarbans is very recent and it is the only alluvial plain of lower Bengal raised by the deposition of sediments formed due to water erosions [10]. Mangrove and mangrove associates, which are salt-loving plants constitute the dominant vegetation type of the area.

There has been premature reclamation of land in the region from 1883 onwards, with more than 3500 km. of earthen embankments protecting the settlements in the region. Most of the reclaimed areas, guarded by the embankments, are lying at lower depth than the riverbeds. The aquifer of potable water lies at a depth of about 350M from the ground level and in many islands no sweet water (non-saline) is found making life of inhabitants difficult.

Sundarban Tiger Reserve (STR) had been carved out of Indian Sundarbans mangrove, in the year 1973, with the objective of conserving the threatened species of Bengal tiger *(Panthera tigris)* along with its associated ecosystem comprised of mangrove flora and fauna. It is located in the Southern-most part of the state West Bengal in the districts North and South 24-Parganas. It lies between latitude $21^0 31'$ & $22^0 31'$ North and Longitude $88^0 10'$ & $89^0 51'$ East. STR bounded by fringe villages along the northern boundary, Bay of Bengal on the South, territorial division South 24-Pargana on the West and Bangladesh on the east separated by Raimangal and Kalindi rivers [1,14].

Total area of the Reserve is 2585 sq. km. out of which 362.40 sq. km. area belongs to Sajnekhali Wildlife Sanctuary, 1330.10 sq. km. area under Sundarban National Park and area of the Reserved Forest is 892.43 sq. km.

Global importance of Sundarban Tiger Reserve are highlighted below [14]:

a. It is one of the first nine tiger reserves in India, declared under Project Tiger scheme in the year 1973.
b. National Park area of the reserve is a Natural "World Heritage Site" of UNESCO, declared in the year 1987.
c. It is a part of Sundarban Global Biosphere Reserve, declared by UNESCO in the year 2001.
d. It constitutes over 60% of the total mangrove forest area in the entire county and has 90% of the total Indian mangrove species.
e. It is the only tiger reserve containing mangrove landscape of the country.
f. Besides tiger, STR is a home of a large number of endangered and globally threatened species like Fishing Cat (*Felis viverrina*), Estuarine Crocodile (*Crocodylus porosus*), Gangetic Dolphin (*Platanista gangetica*), Irrawady Dolphin (*Oracella brevirostris*), King Cobra (*Ophiophagus hannah*), Water Monitor Lizard (*Varanus salvator*).
g. It harbours significant population of River Terrapin (*Batagar baska*) and provides the nesting ground of Olive Ridley Turtle (*Lepidochelys olivacea*), Green Sea Turtle (*Chelonia mydas*) and Hawksbill Turtle (*Eretmochelys imbricata*).
h. It is also very rich in aquatic/ estuarine avi-fauna.
i. The mangrove forests act as a natural shelterbelt and protect the hinterland

from natural calamities.

The total plant species are grouped into 59 families, 101 genera and 140 species. These comprise of true mangroves or major elements, minor elements of mangroves or/and mangrove associates, back mangrove trees and shrubs, non- halophytic non-mangrove associates in the area, halophytic herbs, shrubs & weeds and epiphytic & parasitic plants [14].

The animals that once existed in Sundarbans and have become extinct over a period of time include Javan Rhinoceros, wild buffalo, swamp deer, barking deer etc. Apart from tiger, the secondary predators found are fishing cat, jungle cat, leopard cat etc. Other major species found are spotted deer, wild boar, gangetic dolphin, irrawady dolphin, estuarine crocodile, water monitor lizard, olive ridley turtle, hawksbill turtle, king cobra, python, monocellate cobra, banded krait, russels viper etc**.**

Wildlife of the mangrove forests helps in maintaining ecological balance as the plants and animals are directly interdependent on each other. The tiger on the land and crocodiles in the water are the two top consumer groups of animal in this eco-system. Their presence is very much necessary to keep in control the ecological flow by the sustained growth of other species. The birds, mammals, reptiles, fishes and micro organisms associated with the mangroves represent characteristics of this estuarine Sundarbans [14].

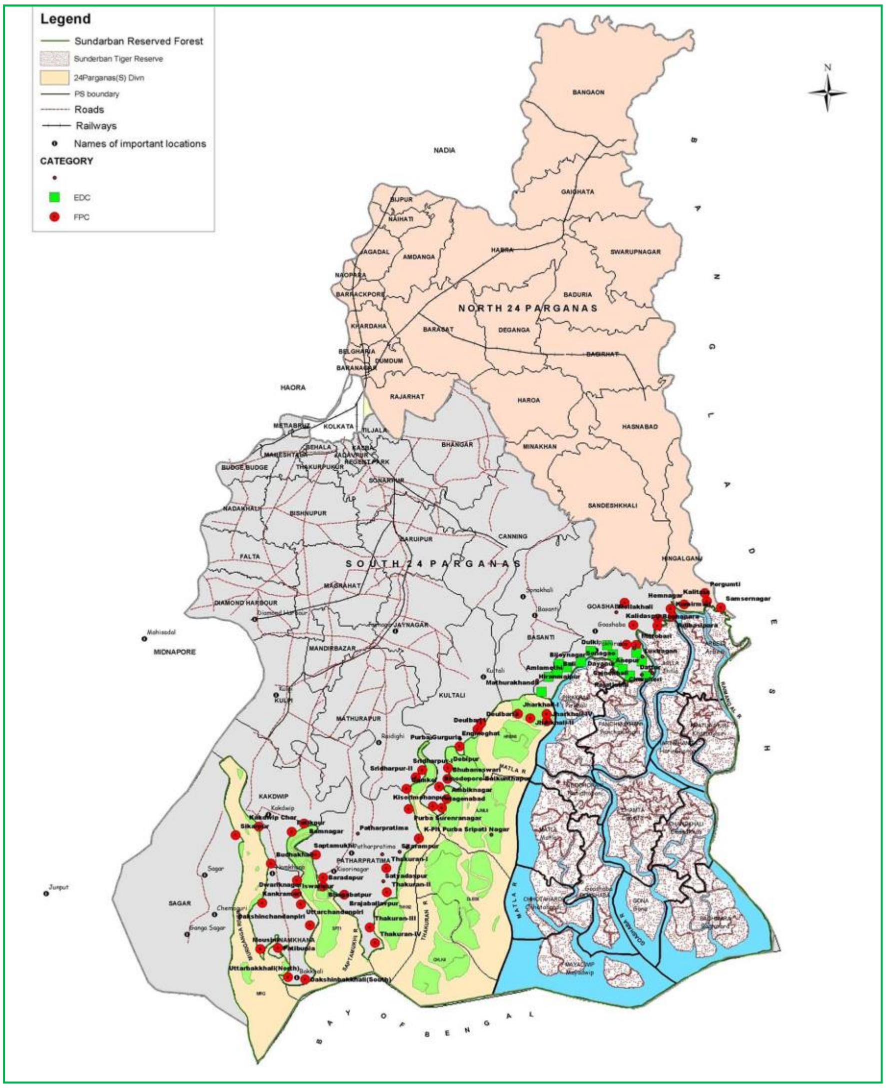
Background of study

Major Conspicuous Changes that have been noted in the Habitat since inception of the Tiger Reserve are as follows [14]**:**

1. Exponential increase in the fringe population leading to increased pressure on the natural sources.
2. Many of the upstream rivers have silted up which is becoming a problem in navigation of watercrafts.
3. Purbasha Island which was the southern most island has disappeared in the sea.
4. A continuous cycle of erosion and deposition has led to decrease in the area of certain blocks and compartments and increase in the area of others. The accretion is more on the southern side and the erosion more on the northern side.

According to a recent report, published by NASA in August 2015, Global sea level has risen about 3 millimeters (0.1 inch) a year since 1993. Seas around the world have risen an average of nearly 3 inches (8 centimetres) since 1992. In 2013, the United Nations Intergovernmental Panel on Climate Change issued an assessment based on a consensus of international researchers that stated global sea levels would likely rise from 1 to 3 feet (0.3 to 0.9 meter) by the end of the century. However, new research available since the 2013 IPCC report suggest that the actual rise, if the present trend continues, may be still higher than the highest predicted range [18].

Sea level rise due to climate change is threatening the biodiversity, flora and fauna of the Sundarban. While tigers are a highly adaptable species, the Sundarbans ecosystem has become an isolated one, facing the potential habitat loss due to sea level rise. A study on the predicted impact of sea level rise on Bangladesh Sundarbans and the associated impact on the tiger population, has focussed on the loss of estuarine land and inundation of mangroves due to the projected sea level rise [7].



Map showing Indian Sundarbans in the district of South 254 Parganas, W. Bengal

Hazra et al, in their research paper on impact of sea level rise on Indian Sundarbans, published in 2002, had concluded that the sea level rise has a dominant influence on coastal erosion. Results from the study area of Sagar island, which is located in the extreme western part of Indian Sundarbans, have established the linkage between the erosion-accretion rate with the rise and fall of relative mean sea level. The authors had further concluded that the mangrove forest cover was predicted to diminish further along with the degradation of existing species combination [2,4,6].

In another study [13], it has been observed that the southern islands of STR facing the Bay of Bengal e.g. Baghmara, Chandkhali, Gona, Mayadwip have shown considerable loss of land between 1986 to 2009 due to tidal erosion whereas the islands in central and northern STR i.e. Harinbhanga, Netidopani, Chamta has shown little erosion or accretion. This has been attributed to the high tidal currents duly impacted by sea level rise. The loss of discharge of fresh water due to blocade of river Bidyadhari in central Sundarban, which forms the eastern bouandry of Sundarban Tiger Reserve allows the tidal currents from Bay of Bengal to strike the western Sundarban Tiger Reserve islands unchallenged by the upstream fresh water flow.

A study on Bangladesh Sundarbans had shown that the coastline had lost around 170 sq km of land area during the 37 years of study period from 1973 to 2010 [8].

However, other than the published papers on impact of sea level rise on the human population in coastal/ estuarine zones and erosion/ accretions of the islands in the estuary [10,11], no detailed study or data was available to measure the changes that have occurred in the mangrove forests of Sundarban Tiger Reserve over the last few decades.

The present study is the first of its kind to (i) map, monitor and predict the comparative changes in densities of mangrove forests in the Southern, Central and Northern parts of Sundarban Tiger Reserve, (ii) a comparative study of mangrove vegetational changes in Western and Eastern sectors of STR as well as (iii) study the progressive changes in the mangrove vegetation of the Sundarban Tiger Reserve as a whole.

Materials and Methods

For a difficult and highly inaccessible terrain like Sundarbans estuary, satellite imagery from the Indian Remote Sensing satellites are found to be the most cost-effective mode of real-time mapping of the Sundarbans estuary as well as mangrove vegetation over a very large area[12,16]. Digital satellite data covering the entire Indian Sundarbans were procured from NRSC, Hyderabad. For the period Dec 2001, imageries were obtained from IRS 1D satellites and the data pertaining to the period Dec 2005, Dec 2009, Dec 2010 and Dec 2014 were AWiFS data from IRS P6 satellites.

ERDAS Imagine Image processing software, version 2014 was used for Image geometric correction, with reference to earlier registered Images of Sundarbans, and subset of Sundarban Tiger Reserve, within the South 24 Parganas district were generated for each year. The small portion of mangrove forest of STR, around 8 sq km, belonging to North 24 Parganas part of STR, were left out due to non availability of data for the said part in all the reference years.

For Each set of image of STR, further subsets were generated as North East, North West, Central East, Central west, South East and South West. The objective was to compare the relative changes of mangrove density and erosion/ accretion/ submergence status in the six different spatial regions of STR due to the impact of sea level rise on Sundarbans mangroves.

Sub-sets/ Zones	STR N-E region	STR N-W region	STR C-E region	STR C-W region	STR South region
Forest Blocks	Jhila, Arbesi, Khatuajhuri, Harinbhanga	Pirkhali, Panchamukhani	Chamta, Chandkhali, Gona, Baghmara	Matla, Netidhopani, Chotohardi, Goashaba	Mayadwip

STR Zones	North	Central	South
Forest Blocks	Jhila, Arbesi, Khatuajhuri, Harinbhanga, Pirkhali, Pancmukhani	Chamta, Chandkhali, Gona, Baghmara, Matla, Netidhopani, Choto-hardi, Goashaba	Mayadwip

STR Zones	Eastern sector	Western sector
Forest Blocks	Jhila, Arbesi, Khatuajhuri, Harinbhanga, Chamta, Chandkhali, Gona, Baghmara	Pirkhali, Pancmukhani, Matla, Netidhopani, Choto-hardi, Goashaba, Mayadwip

Each of the standard FCC subset was then classified using "Unsupervised classification technology" available in ERDAS software, into Dense mangrove, open mangrove, Mudflat and water. The protocol followed were Standard deviation 2, no of classes 25 and no of iterations were 25. On the basis of field knowledge and Ground Truth Verification, final density wise classification was carried out. Mangrove vegetations with canopy density more than 40% was classified as Dense mangrove and those with density less than 40% was classified as open mangroves. Mudflats included the saline blanks, inter-tidal zones as well as shallow creeks/ channels within the forest areas, devoid of vegetation.

The data were then compared and merged with the classified data obtained by Sundarban Biosphere Reserve from 1986 onwards [3]. The data for the period 1986 and 1989 were from the IRS 1B satellites with resolution of 72m X 72m, and the data set for the period 1999 was from the satellite IRS 1C with resolution of 36m X 36m.

Graphs were plotted for the dense mangrove, open mangrove, mud flats and total land area vis--a-vis year of monitoring, for different regions of STR as well as for the entire STR area. Correlation equations and correlation coefficients were calculated for each plotted graph.

Graphs were generated for different regions of STR to find out the degree of correlation of density classes of mangrove vegetation with progressive time.

Results and discussions

The classified data have been analyzed for the period of 28 years, from 1986 to 2014 for monitoring of land area [Fig-2], and from 2001 to 2014 for monitoring the changes in mangrove vegetation density.

The data for the period 2010 is for the post Aila period. The cyclone Aila had struck Sundarbans and adjoining areas in middle of May 2009 and had caused massive devastations in the island-villages adjoining the Sundarbans Reserved mangrove forest. There had been large scale damages to the embankments, surrounding the villages, resulting into inundation of hundreds of sq. kilometres of habitation areas in Sundarbans. However, there had not been any scientific and quantitative assessment of impact of this Aila storm on the mangrove vegetations and the Reserved Forests of Sundarbans.

In the present study, whenever the data for the year 2010 was included for monitoring and analysing the trends of land area and mangrove vegetation, the correlations were not very strong [Fig-3-8, 19, 20]. But if the data period of 2010 (post-Aila) was left out of the analysis, the regression equations were much more consistent and predictive and the changes had a strong correlation [Fig 9-18, 21, 22]. Due to the Aila cyclonic storm in May 2009, major parts of Sundarbans mangrove forests, specially the North western and central western region, were severely affected by the cyclonic storm, temporarily causing degradation of dense mangrove forests into open type. One inference from the data sets, regarding the impact of Aila on the mangrove vegetation of Sundarbans, is the large scale inundation of the islands of the Tiger Reserve leading to temporary but abrupt increase of salinity of the otherwise densely vegetated islands. However, with passage of time, as the immediate impact of Aila had subsided, the natural mangrove vegetation had resuscitated to a large extent.

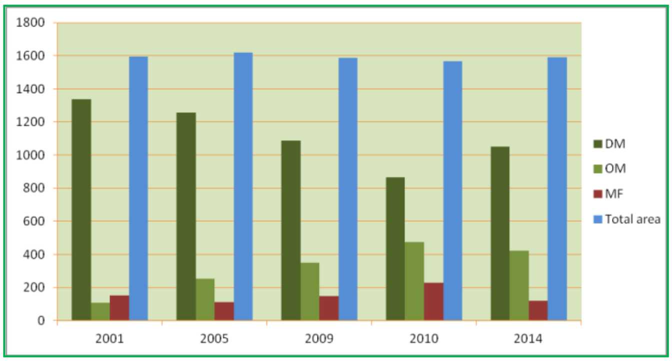


Fig-1 Graphical representation of Dense Mangrove (DM), Open Mangrove (OPM), Mudflat (MF) for the Year: 2001, 2005, 2009, 2010 and 2014. X-axis: Yera; Y-axis: Areal extent

Graphs in Fig 2 to 22 below have been plotted with areal extent (along Y-axis) against Year of observation (along X-axis)

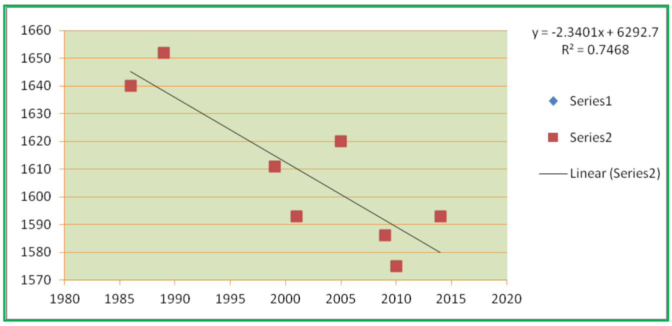


Fig-2 Trend line showing total land area of STR (Y-axis) against progressive time (X-axis) for the period 1986 – 2014

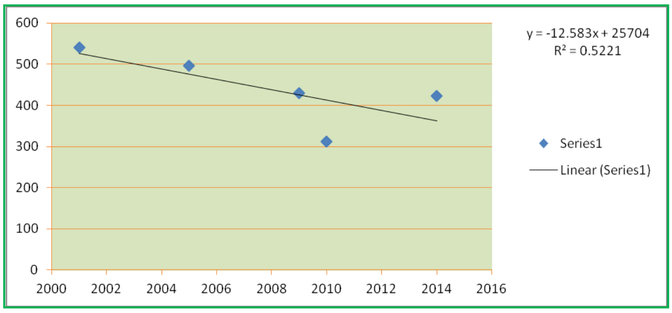


Fig-3 Trend line showing gradual reduction of area of dense mangrove (Y-axis) (including data for post-Aila period) in Northern part of STR over time (X-axis)

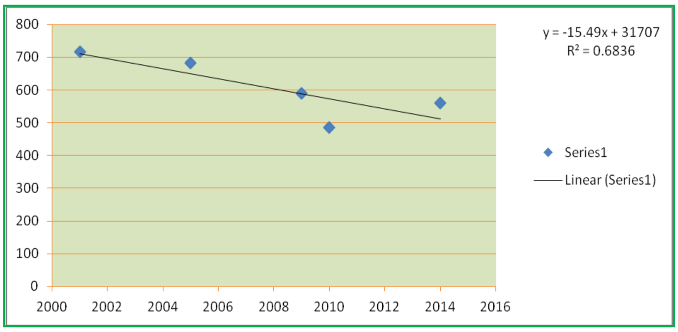


Fig-4 Trend line showing gradual reduction of area of dense mangrove (including data for post-Aila period) in Central part of STR

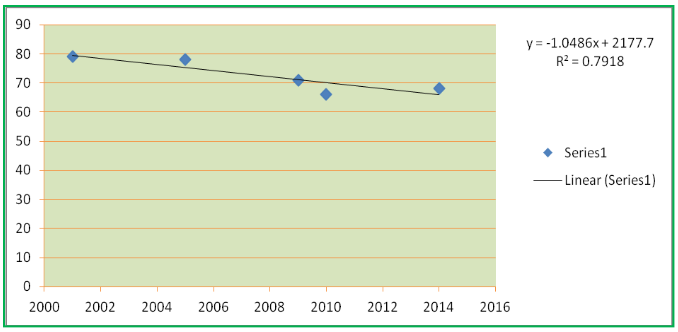


Fig-5 Trend line showing gradual reduction of dense mangrove (including data for post-Aila period) in Southern part of STR

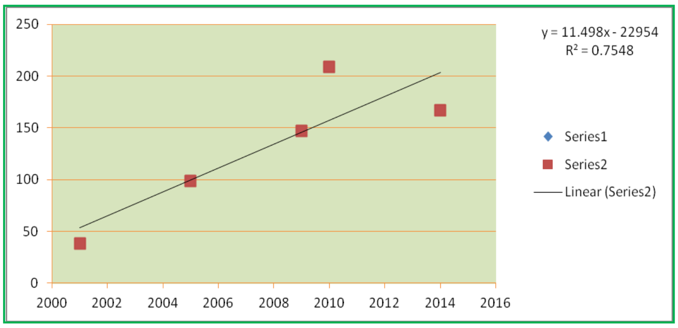


Fig-6 Trend line showing gradual increase of open mangrove (including data for post-Aila period) in Northern part of STR

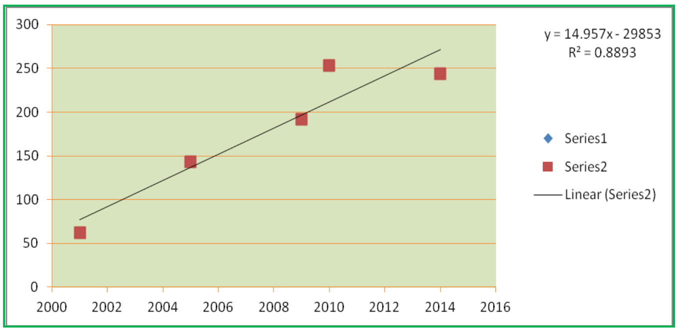


Fig-7 Trend line showing gradual increase of open mangrove (including data for post-Aila period) in Central part of STR

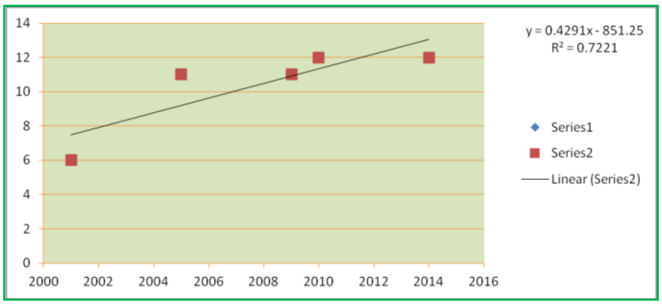


Fig-8 Trend line showing gradual increase of open mangrove (including data for post-Aila period) in Southern part of STR

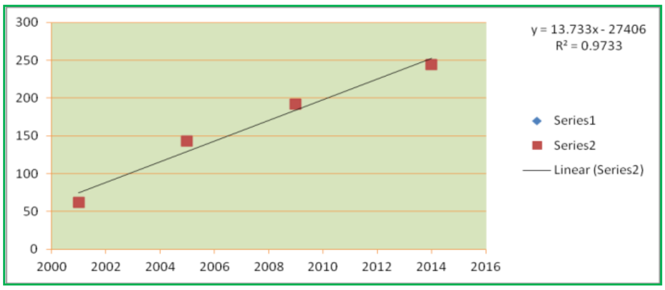


Fig-13 Trend line showing gradual increase of open mangrove in Central part of STR

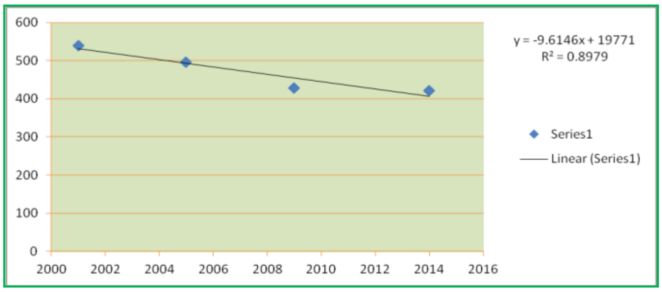


Fig- 9 Trend line showing gradual decrease of dense mangrove in Northern part of STR

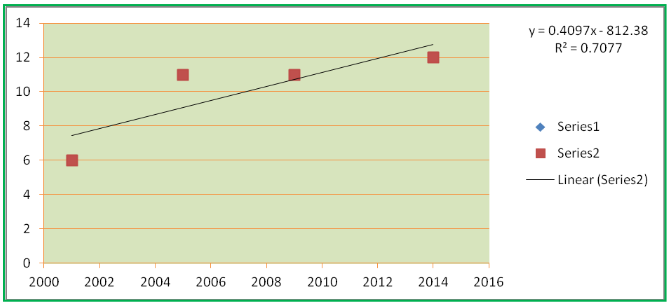


Fig-14 Trend line showing gradual increase of open mangrove in Southern part of STR

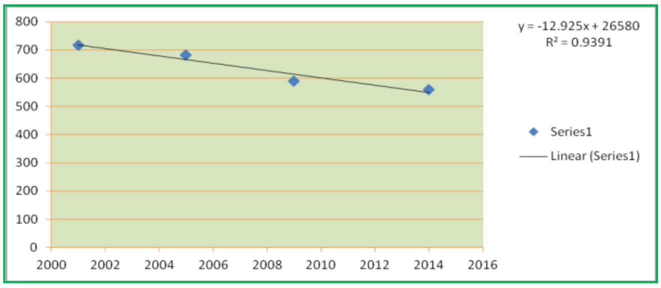


Fig-10 Trend line showing gradual decrease of dense mangrove in Central part of STR

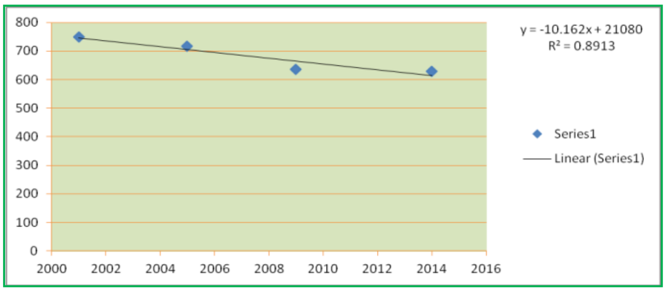


Fig-15 Trend line showing gradual decrease of dense mangrove in Eastern part of STR

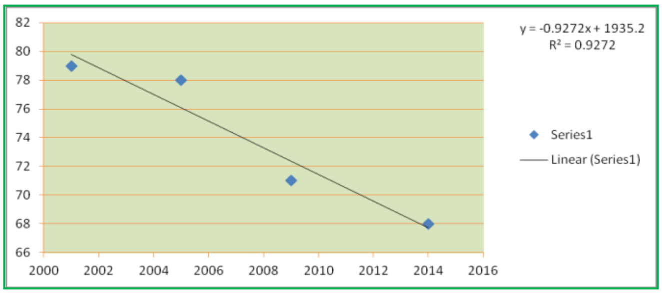


Fig-11 Trend line showing gradual decrease of dense mangrove in Southern part of STR

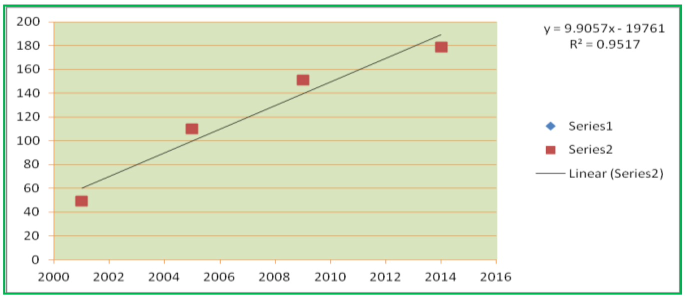


Fig-16 Trend line showing gradual increase of open mangrove in Eastern part of STR

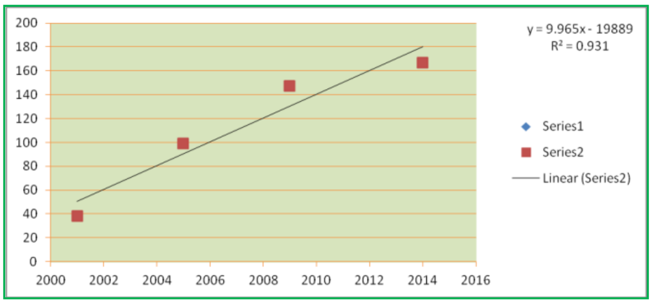


Fig-12 Trend line showing gradual increase of open mangrove in Northern part of STR

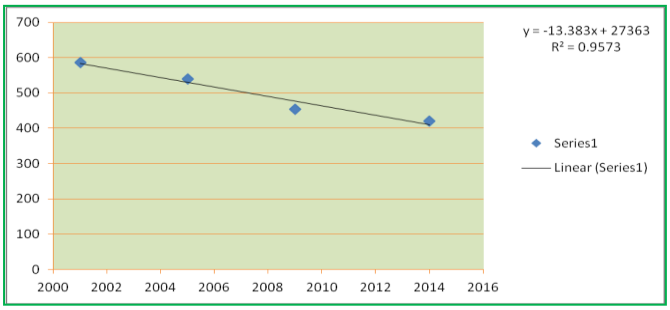


Fig-17 Trend line showing gradual decrease of dense mangrove in Western part of STR

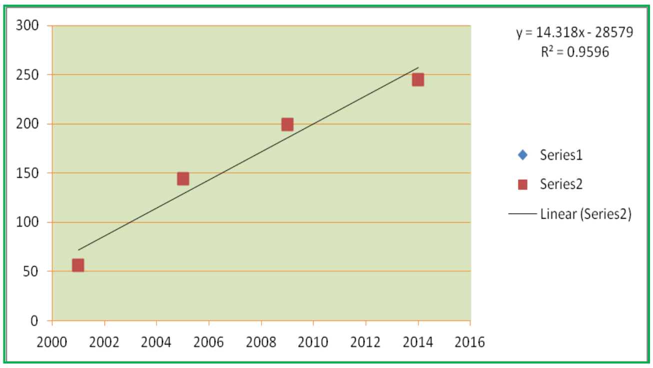


Fig-18 Trend line showing gradual increase of open mangrove in Western part of STR

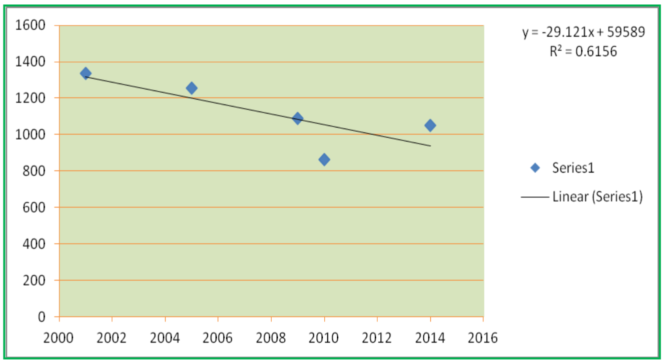


Fig-19 Trend line showing gradual decrease of dense mangrove in STR (incl. Post-Aila data)

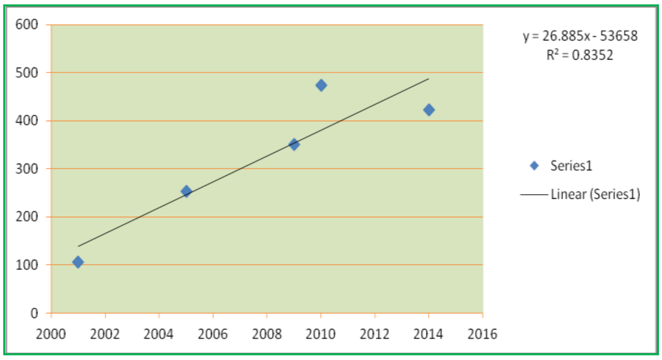


Fig-20 Trend line showing gradual increase of open mangrove in STR (incl. Post-Aila data)

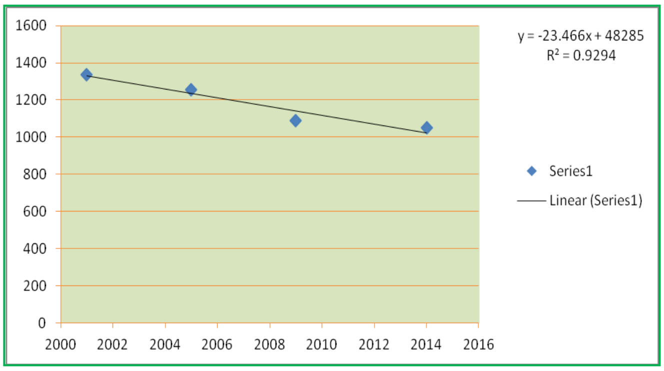


Fig-21 Trend line showing gradual decrease of dense mangrove with time in STR (data excludes Aila period)

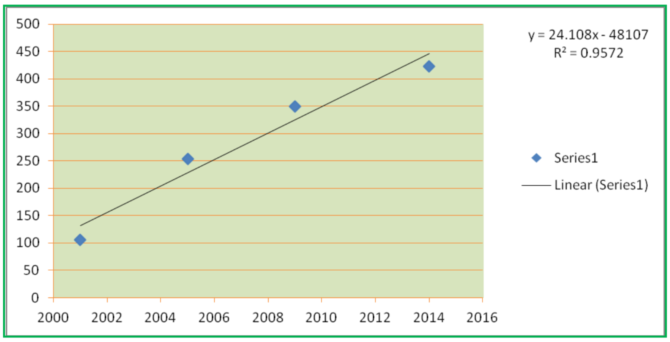
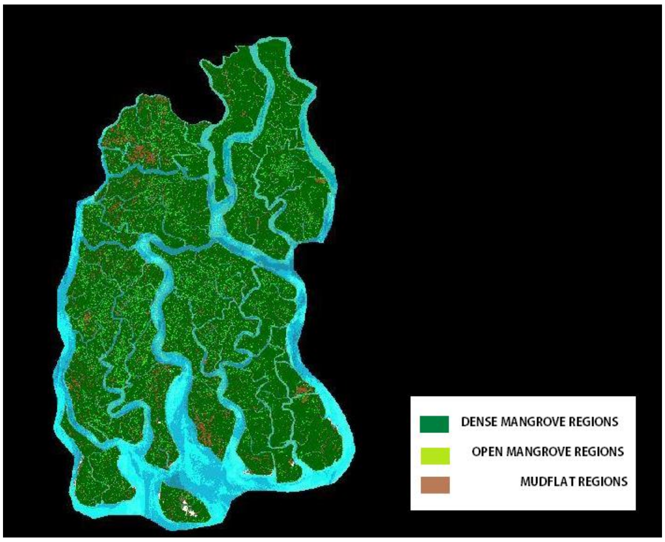


Fig-22 Trend line showing gradual increase of open mangrove with time in STR (data excludes Aila period)

Map-1 Classified imagery of STR for 2014



Map-2 Classified imagery of STR for 2001

On the other hand, time series analysis of total land area, including the dense/ open mangroves and mud flats, over a period of more than three decades have shown that there was moderate correlation between the island areas with progressive time (the land area did not undergo much appreciable changes over the years). Plotting of total land area of STR against year [Fig-2] shows that there has been only 3% reduction in land area in STR from 1986 to 2014. The trend line shows that by 2020, the Sundarban Tiger Reserve will be loosing a total of 75 sq km of the land area from its year 1986 figure. This can be explained by the simultaneous effects of accretion and erosion in this dynamic estuary, which has to a large extent off-set the impact of sea level rise [12,16].

But the most significant results are the gradual and fast natural conversion of dense mangroves into open mangroves over the years. Since the degradation due to biotic factors in the Protected Area is almost nil, the predicted reasons for changes in the vegetation density may be due to the increased salinity within the STR region due to sea level rise9 and the changes in mangrove vegetation pattern due to salinity gradient across the Tiger Reserve[15].

Trend of reduction of dense mangrove with time reveals that the percentage change of dense mangrove in the Northern and Central Sector are around 22% [Table-2,3], whereas the change is around 14% [Table-4] in case of Southern sector. It thus appears that the increase in salinity in the northern and central parts of the Tiger Reserve are much more as compared to the changes in salinity level in the Southern sector.

Comparative study of changes in mangrove densities between Eastern sector and western sectors of Tiger Reserve shows that the changes from dense to open mangroves is less for Eastern sector [Table-11] (around 16%) as compared to western sector [Table-12] (around 28%). The possible reasons may be relatively higher increase of salinity in the western sector of STR, i.e., central portion of Indian Sundarban estuary [9]. This appear to be due to availability of more sweet water in the eastern part of Sundarbans and reduction of fresh water flow in western part of STR due to sedimentation of tidal rivers and reclamation of low lying areas in upper reaches of western part for habitations and aquaculture.

When the data for the dense mangrove vegetation for the entire Tiger Reserve were extrapolated [Fig-21,22], it is found that the total quantum of dense mangrove forest will reduce to half of the year 2001 value by the year 2029, and the entire STR will be taken over by open mangroves by 2058.

Table-1 *Changes in Land Area (Dense/ Open/ Mudflats) of STR between 1986 and 2014*

	Forest Blocks	1986	1989	1999	Year of mapping 2001	2005	2009	2010	2014
STR N-E region	Jhila, Arbesi, Khatuajhuri, Harinbhanga	372	375	368	345	349	342	341	344
STR N-W region	Pirkhali, Panchamukhani	289	295	291	291	296	290	287	292
STR C-E region	Chamta, Chandkhali, Gona, Baghmara	524	524	513	515	527	516	514	518
STR C-W region	Matla, Netidhopani, Chotohardi, Goashaba	359	364	355	346	354	350	347	354
STR South	Mayadwip	96	94	84	96	94	88	86	85
STR Total		1640	1652	1611	1593	1620	1586	1575	1593

Table-2 *Changes in Land Area of Northern zone of STR between 2001 and 2014 (DM-Dense mangrove; OPM-Open mangrove; MF-Mudflat)*

STR North	DM (sq.km)	OPM (sq.km)	MF (sq.km)	Total (sq.km)
2001	540	38	58	636
2005	496	99	50	645
2009	429	147	56	632
2010	312	209	107	628
2014	422	167	47	636

Table-3 *Changes in Land Area of Central zone of STR between 2001 and 2014*

STR Central	DM (sq.km)	OPM (sq.km)	MF (sq.km)	Total (sq.km)
2001	716	62	83	861
2005	682	143	56	881
2009	589	192	85	866
2010	486	253	122	861
2014	560	244	68	872

Such rapid changes in vegetation density will be associated with (i) stunted growth of existing species composition and (ii) gradual replacement of less salt tolerant, taller mangrove species with more salt tolerant dwarf species like Phoenix, *Ceriops decandra* etc., [1,4,5]. A recent study conclusively shows that the concentrations of chlorophyll decreased significantly with salinity in *Sonneratia apetala, Avicennia marina, Avicennia officinalis* and *Heritiera fomes*, but for Rhizophora spp. a reverse situation was observed. This species could tolerate high salinity condition. The chlorophyll level also increased significantly with the increase of salinity for the Rhizophora spp., which confirms the adaptation of the species to high salinity related to rising sea level [17].

Table-4 *Changes in Land Area of Southern zone of STR between 2001 and 2014*

STR South	DM (sq.km)	OPM (sq.km)	MF (sq.km)	Total (sq.km)
2001	79	6	11	96
2005	78	11	5	94
2009	71	11	6	88
2010	66	12	8	86
2014	68	12	5	85

Table-5 *Changes in Land Area of STR between 2001 and 2014*

Total STR	DM (sq.km)	OPM (sq.km)	MF (sq.km)	Total area (sq.km)
2001	1335	106	152	1593
2005	1256	253	110	1620
2009	1089	350	147	1586
2010	864	474	230	1575
2014	1050	423	118	1593

Such vegetational changes in Sundarban Tiger Reserve will have impact on the wild fauna which are dependent on the mangrove vegetations. One of the major prey species which is going to be directly affected are the spotted dear, in turn affecting the tiger population dependant on the prey base.

Increased salinity of the mangrove forest floor will also affect the eco-system of the tiger, forcing them to move towards the less saline zones, in search of more abundant prey base.

Table-6 *Mangroves of STR North East*

STR NE	DM	OM	Total
2001	308	18	326
2005	292	39	331
2009	267	52	319
2014	269	55	324

Table-7 *Mangroves of STR North West*

STR NW	DM	OM	Total
2001	232	20	252
2005	205	60	265
2009	163	95	258
2014	152	112	264

Table-8 *Mangroves of STR Central East*

STR CE	DM	OM	Total
2001	441	31	472
2005	425	71	496
2009	369	99	468
2014	359	124	483

Table-9 *Mangroves of STR Central West*

STR CW	DM	OM	Total
2001	275	30	305
2005	257	73	330
2009	220	90	310
2014	201	121	322

Table-10 *Mangroves of STR South*

STR South	DM	OM	Total
2001	79	6	85
2005	78	11	89
2009	71	11	82
2014	68	12	80

One obvious impact of the observed trend shall be an enhanced human-tiger conflict in Sundarban Tiger Reserve. The increase of salinity and loss of land shall result in depletion of species like *Sonneratia apetala*, adversely affecting the spotted deer population thus lessening the availability of prey for tigers and leading to more frequent tiger straying to adjoining island-villages in search of easy food like domestic cattle. The impact of salinity on mangroves has been proved conclusively in lowering of mangrove biomass and replacement of low salinity tolerant mangrove species with that of high salinity tolerant mangrove species which are not the preferred food for herbivores, [13].

Table-11 *Mangroves of STR East*

STR East	DM	OM	Total
2001	749	49	798
2005	717	110	827
2009	636	151	787
2014	628	179	807

Table-12 *Mangroves of STR West*

STR West	DM	OM	Total
2001	586	56	642
2005	540	144	684
2009	454	199	653
2014	421	245	666

Conclusion

The present study conclusively shows that the rate of net loss of island area due to the sea level rise, as predicted by the researchers till now, is less significant as compared to the impact of increasing salinity on the mangrove vegetation of Sundarban Tiger Reserve. Though the southern most islands of Mayadwip block are directly impacted with the ocean current, yet the rate of net erosion of land area in this southern zone is much less as compared to net loss of land in the central and northern parts of the Tiger Reserve. This is due to the higher rate of accretion due to sediment flow with the ocean current and its deposition on the islands during high tides. The most important outcome of the result is the fact of faster degradation of mangrove vegetation in the northern/ central zones of the Tiger Reserve, as well as, faster degradation of mangrove density in the western sector of STR. The study also predicts that most of the dense mangrove forest will degrade into less dense, open mangrove forest by the turn of 2050. The study also predicts an enhanced human-wildlife conflict threatening the long term conservation of the highly endangered Bengal tiger population in the world's largest delta The study, thus, indicates a real-time threat to this Tiger Reserve, due to global warming, and calls for more pro-active action towards conservation of the Bengal Tiger and its ecosystem in Indian Sundarbans.

Author's Contribution and Conflict of Interests

Dr. A.K. Raha is the prime backbone of the manuscript. The other authors helped in collecting secondary data and information on Indian Sundarbans. The authors do not have any conflict of interest.

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