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Environmental Change of Trans International Boundary Indo-Bangladesh Border of Sundarban Ichamati River Catchment Area Using Geoinformatics Techniques, West Bengal, India

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Abstract:

The West Bengal part of the Ganges-Brahmaputra delta, popularly known as the Sundarban delta, is a system where intricate estuarine and coastal processes are influenced by adjacent marine, terrestrial and meteorological systems and the dynamic interface amongst the three, being the center of population growth, coastal sea, ponds/wetlands, estuarine Islands in this area are to sustain the negative impact caused by society's commercial, recreational, and residential activities. Additionally, natural forcing like sea level rise or climate change is a prime issue of concern for this vulnerable tract. Presently, this deltaic system is facing degradation due to natural and anthropogenic causes. Degradation of this littoral tract is manifested in terms of frequent embankment failures, submergence & flooding, beach erosion, siltation within embankment, saline water intrusion in the agricultural field etc. The present study demonstrates the potential of Geospatial and statistical technique for monitoring the climate changes of eastern part of Indian Sundarban, India since such kind of changes stand as a testimony for the past and present coastal environment. In the present study, multi resolution and multi temporal satellite images of Landsat have been utilized to demarcate climate change of weather data between 1990 to 2013. The Statistical techniques called as linear regression and regression coefficient have been used for find out the change rate during the period of 1990 to 2013 weather change and environment impact assessment of the study area. Finally, an attempt has been made to find out any interactive relationship between the climates changes in the concerned area.

Keywords: Climate Change, Environment Impact Assessment, Natural Disaster Aila, Environment Change

1.0. Introduction:

In the eastern side of the Bhagirathi / Hooghly River the only major river is the Ichamati River which is a link between the 'Nadia group of rivers' (viz. Jalangi, Mathabhanga, Churni etc.) in the north and Sundarban in the south. The Ichamati river, a spill channel of Mathabhanaga river, originating from Majdia (krishnaganj block) Nadia District, India and Bangladesh (for a short distance) enters into the 24 Parganas (north) District at Baghda block .subsequently, the Ichamati river flowing through eastern part of the 24 Parganas (north & south) Districts ultimately debouches in the Raimangal river vis-a-vis the Bay of Bengal .The Ichamati river could be subdivided into two segments on the basis of the river morphology:

Upper stretch: Brand off point from Mathabhanga River at Majdia, krishnaganj Block, Nadia District (Photo-) and beri/ Swarupnagar, 24 Parganas (N) district. In this stretch the river is moribund in nature with high sinuosity and serpentine meanders exhibiting numerous abandoned scrolls/oxbow lakes. In this part, the river is practically not receiving upper part flowing excepting in rainy season.

Lower segment: From Beri/Swarupnagar to Bay of Bengal. In this portion, the channel width gradually increases as semidiurnal tidal flow exists. In this stretch, Jamuna River is a tributary to the Ichamati River and joins at Tibi, 24 Parganas (N). The lower most part of the river is funnel shaped.

2. Objectives of the study area:

The study mainly focuses on Rainfall, Temperature, Humidity, Solar Radiation and Wind Speed between 1990 to 2013. The salinity condition and its impact on habitat, forest and agriculture will be modeled for the study. Again impact of Aila in the Environment will also be considered. Finding out the Land Use and Land Cover of the study area to justify the climatic condition and finally environmental management plan (EMP), relief and rehabilitation plan will be formulated to mitigate the condition.

3.0 Topography and Physiographic:

This tract of the Sundarbans has fallen under Ganga delta and is very dynamic; delta formation here is very rapid .This resulted in uneven thickness and width of the surface and horizon, but the morpho-logical nature of entire Sundarban is more or less uniform. This tract of Sundarbans is of quite recent in origin; these are only the alluvial plain of lower Bangal, reside (6m-9m above MSL)by the deposition of sediments formed due to water erosion of the Himalayas. The processes have been assisted by tides from the sea face. It is assumed that about 6000-7000 years back, entire Sundarbans was under the sea. By pollen analytical studies and studying the peat soil it was claimed that the present metropolis of Calcutta was under the mangrove swamps of Sundarbans only 5000 years back, Chakrabarti (1987). The Bay of Bengal along with the network spreading along arms Like the Rivers Saptamukhi, Thakuran, Baratala, Matla and Gosaba are the chief sources of saline water and form this brackishwater the estuary. The river Hooghly in the western part and Ichamati, Bidya and Haribhanga of the eastern part are the tributaries of the Holy Ganga which carry mostly fresh water for this Hooghly-Raimangal estuary .During the spring tide, the water level reaches up to 8m above the MSL but in the solar phases the normal height reach up to 5m above MSL .During the high tide periods larger area are inundated and flooded with brackish water ; while low tides expose vast area, covered either by the dense mangroves or halophyteic herbs, shrubs and trees, flat river–banks and sand dunes, without any forest formation and characterization of wetlands.

3.1 Study Area:

The location of Western Sundarbans (Study Area) of Indian part is between22^0 to 22^0-56$^/$ N and 88^{0-} 41$^/$to 89^0-23$^/$ E. Indian Sundarbans is covering the area of south-eastern part of both North-South 24 Parganas. The sub-division is bounded on the North 24 District on the East by Sadar and Basirhat sub-division the north and west consist of alluvial land, which is fairly well raised; on the south and east, where the delta is in a less advanced stage of growth, there is a network of tidal creeks winding their way to the sea through numerous islands and morasses. In this area are included of the Sundarbans, the Eastern fringe of which has been reclaimed, or partially reclaimed lands are called. The principal River is the Ichamati or Jamuna. There are three towns, viz., Basirhat (the Head quarters), Blocks of Baduria, Hasnabad, Haroa, Minakhan, Hingalgang, Sandeshkhali and Taki.

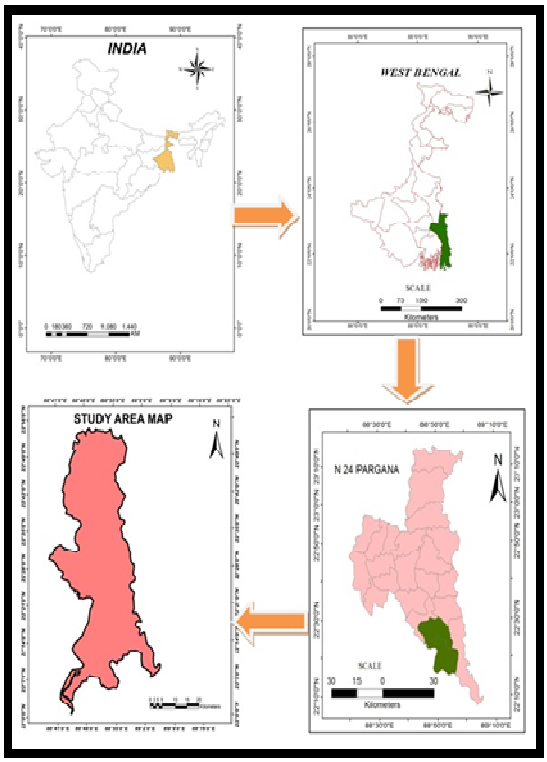


Fig.1. Location Maps

3.2. Climate Condition: The climatic conditions of the region are large similar to the climate of the costal parts of the West Bengal. A tropical monsoon type of climate can be experienced and the main seasons are summer, winter and monsoon. Summers are warm and temperatures can go beyond the 40 degrees Celsius mark. Monsoons receive constant rainfall and most tourist activities are suspended during this period. Winters are mild and many tourists travel to the place during this period. The

summer season starts in the month of March and extends till the end of May. Temperatures can reach a maximum of around 41 degrees Celsius during this period in the region. Humidity is also high and this makes it uncomfortable during the day. The temperature can be expected to drop to around 20 degree Celsius during the summer season. The monsoon rains start in the month of June and end in the month of September. Precipitation is constant during this period and visiting might be difficult. The post monsoon months are neither hot not cold and this is the start of the tourist season. The annual average rainfall is about 1800-1900 mm which mainly occurs in rainy season. Winter season is from December to February and temperatures range from a minimum of 10 degrees to a maximum of 30 degrees Celsius. The peak tourist season is from October to March.

4.0 Result and Discussion

4.1 Land Use and Land Cover of the Study Area:

The study area has some shortcoming in modification of cropping pattern due to heavy saline soil texture, strong drainage and more importantly lack adequate irrigation facilities. For that, the study is characterized with over generalized monotonous cropping sequence dominated paddy. It unfortunate that the main paddy crop Aman crop has to depend on unpredictable monsoon rainfall. During the Rabi-season very small is devoted to Boro cultivation. Among oilseeds, mustard dominates in cropping and in recent year a little space has also been given to sunflowers.

4.2 Normalized Difference Vegetation Index:

In ETM+ image of study area NDVI modeler to detect the greenness of the area. It is clearly shown the high range in deep mangrove forest area of Hingalgang and also in domestic area where vegetation are founded. Medium range is also representing the plantation area of Caning and Gusaba region. And first two classes are not classified as vegetation coverage so no vegetation coverage found in different type of wetland and water content area (Bay of Bengal).

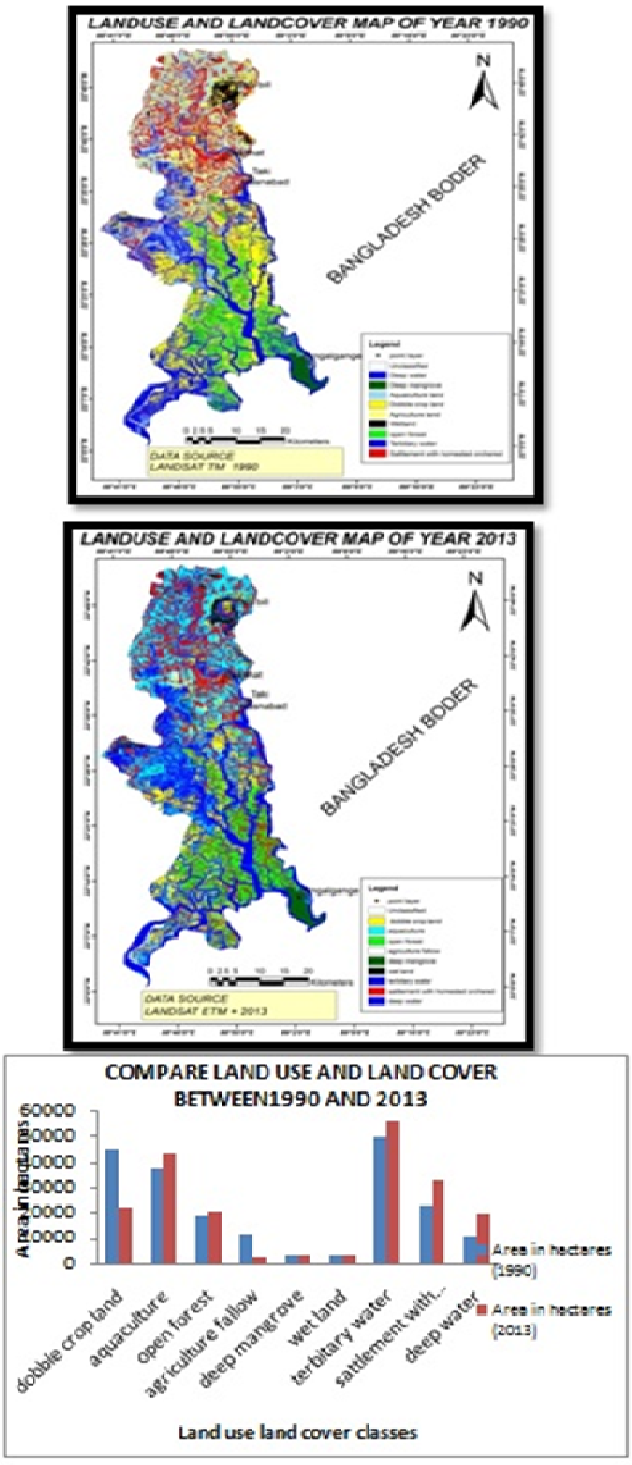


Fig. 2. Land Use Land Cover Maps & Compare Land Use Land Cover Maps

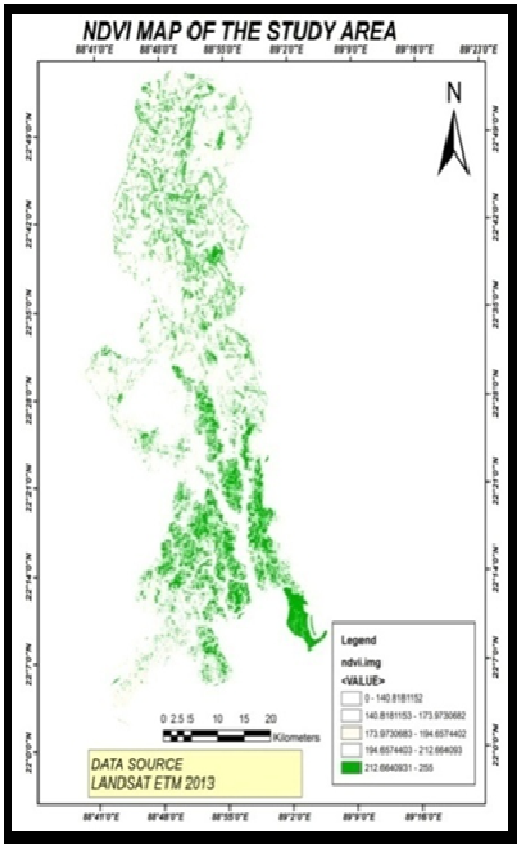


Fig.3: NDVI Maps

4.3 Normalized Difference Water Index (NDWI):

Applying NDWI on study area to delineate open water feature and enhance their presence in remotely-sensed digital imagery. The NDWI makes use of reflected near-infrared radiation and visible green light to enhance the presence of such features while eliminating the presence of soil and terrestrial vegetation features. It is suggested that the NDWI may also provide researchers with turbidity estimations of water bodies using remotely-sensed digital data. After using NDWI on ETM+ digital imagery of study area it is clearly shown the open water in part of eastern Sundarban. In this index the range 0.147286 -1(2013) and 0.164179-0.65217 (1990) indicates the highly open water features. In this area 1990 to 2013 of Sandeshkhali and Bashirhat II area are very increase 0.3478 % of water level. These areas are very increase of fishery zone a socio economic development.

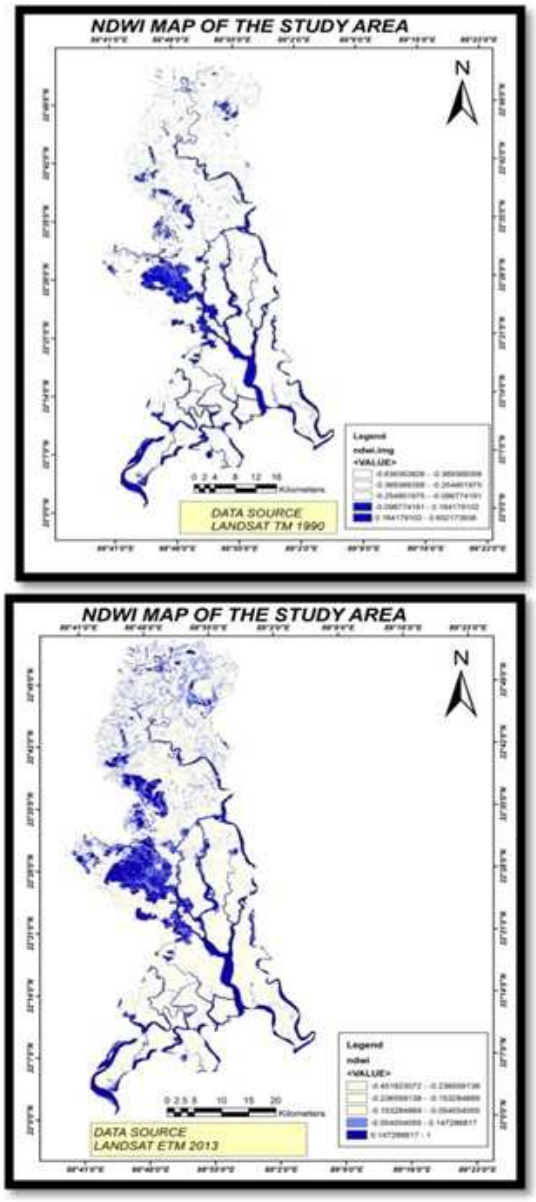
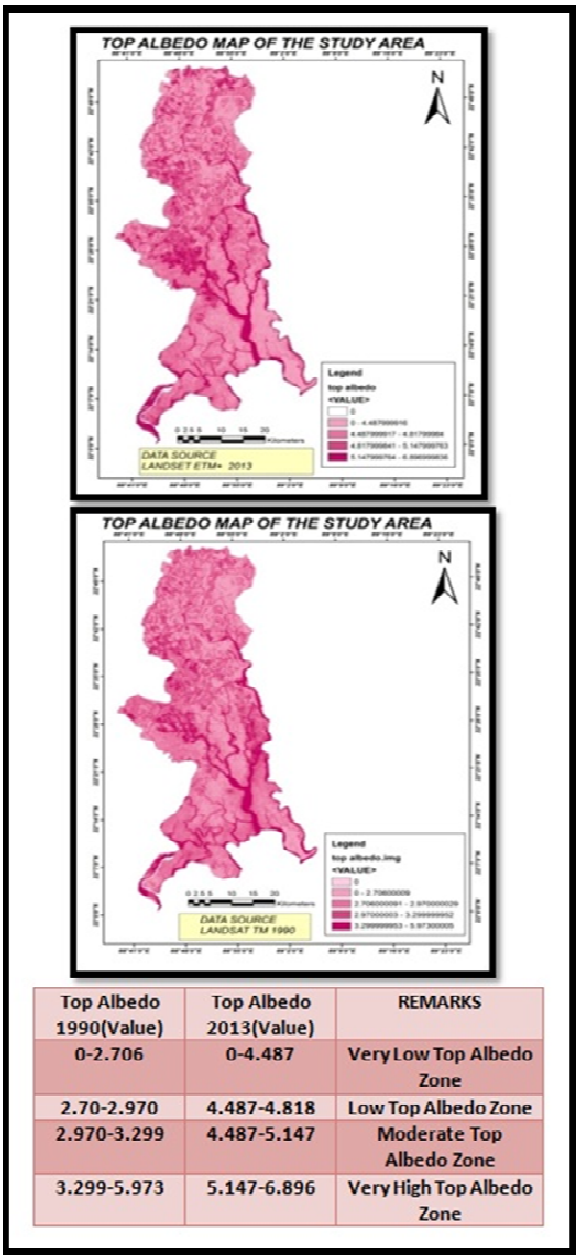


Fig.4. NDWI Maps

4.4 Albedo at the Top of the Atmosphere (α_{toa}):

Estimate the earth's radiation budget at the top of the atmosphere (α_{toa}) from satellite-measured radiances, it is necessary to account for the finite geometry of the earth and recognize that the earth is a solid body surrounded by a translucent atmosphere of finite thickness that attenuates solar radiation differently at different heights. As a result, in order to account for all of the reflected solar and emitted thermal radiation from the planet by direct integration of satellite-measured radiances, the measurement viewing geometry must be defined at

a reference level well above the earth's surface (e.g., 100 km). This ensures that all radiation contributions, including radiation escaping the planet along slant paths above the earth's tangent point, are accounted for.



Top Albedo 1990(Value)	Top Albedo 2013(Value)	REMARKS
0-2.706	0-4.487	Very Low Top Albedo Zone
2.70-2.970	4.487-4.818	Low Top Albedo Zone
2.970-3.299	4.487-5.147	Moderate Top Albedo Zone
3.299-5.973	5.147-6.896	Very High Top Albedo Zone

Fig.5. Top Albedo Maps

The albedo at the top of the atmosphere (α_{toa}) is computed as follows:

$$(\alpha_{toa}) = \sum (\omega\lambda \times \rho\lambda)$$

$\rho\lambda$ = Reflectivity

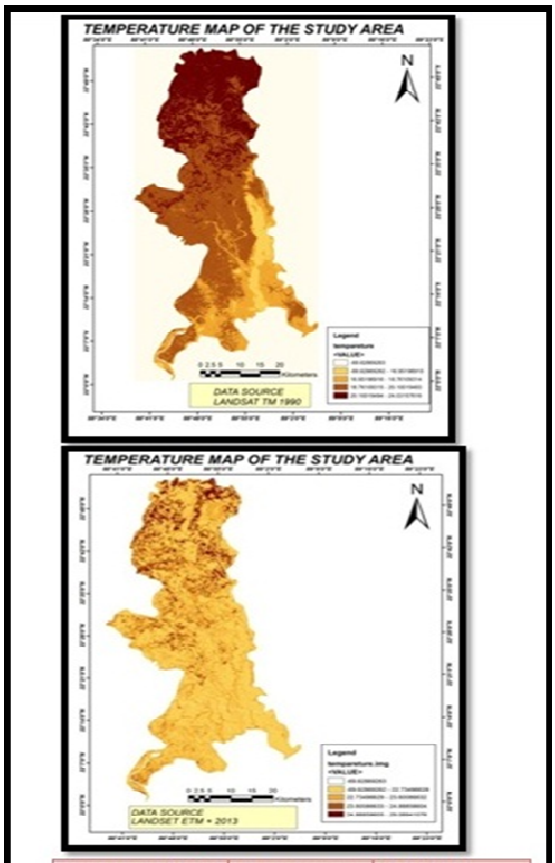
$\omega\lambda$ = weighting coefficient for each band

Weighting coefficient ($\omega\lambda$) for each band computed as follows:

$$\omega\lambda = \frac{ESUN_{\lambda}}{\sum ESUN_{\lambda}}$$

Values for the Weighting coefficient ($\omega\lambda$) for each band are given in annexure C

3.5 Surface Water Temperatures of the Study



Temperature1990 (Value °C) 28 Feb	Temperature 2013(Value°C) 28Feb	REMARKS
0-16.951	0-22.734	Very Low Temperature zone
16.951-18.761	22.734-23.600	Low Temperature zone
18.761-20.100	23.600-24.885	Moderate Temperature zone
20.100-24.031	24.888-29.089	High Temperature zone

Area:

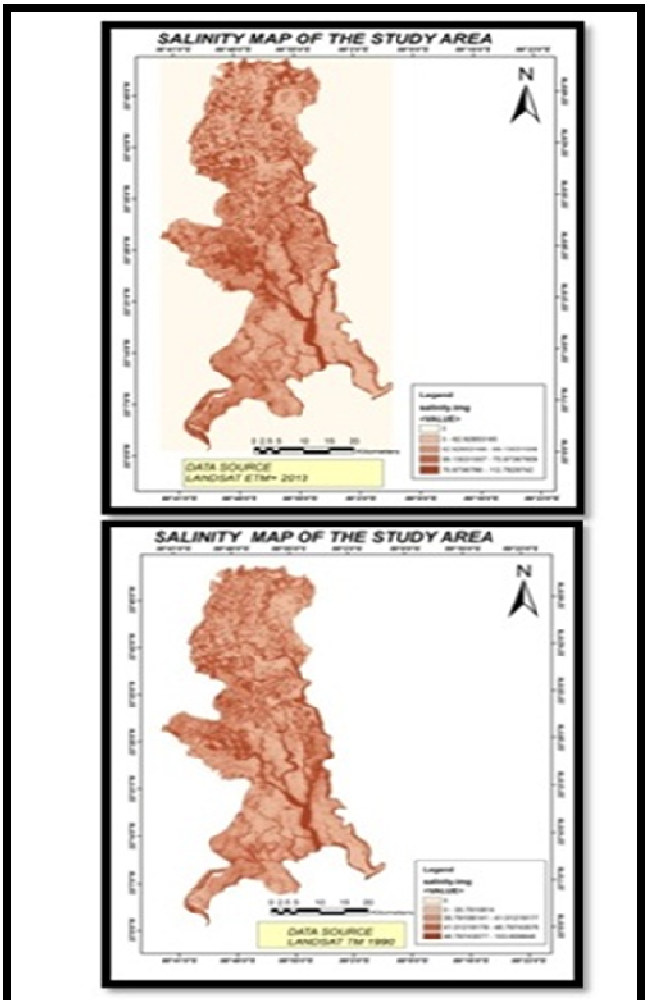
Fig. 6. Temperature Maps

The surface water temperatures in Sundarban have shown significant rising trends for both pre-monsoon and monsoon periods. Quantitatively, these temperatures have risen by 5.78% in the western sector and by 4.30% in the eastern sector over the past 23years (1990-2013). In another study, the annual composite surface temperature of Sundarban region during the period 1990-2013 varied from 22.734 °C in the year 1990 to 29.089 °C in the year 2013. This observed rate is found to be in conformity with the estimation by Landsat Temperature Map (2013), which estimates a decadal rate of about 0.2 °C to 0.9 °C. Rising surface temperature is directly related with the increased frequency and severity of cyclonic storms and depression in the Bay of Bengal. It is also reported that increasing trend in SST may result in changes to the chemical composition of sea water, leading to increased acidification & decreased dissolved Oxygen level.

4.5 Salinity of the Study Area:

Salinity in the Sundarbans is highly dependent on the volume of freshwater coming from the upstream. The variation is subject to the nature of tide in the area. Annual pattern of salinity changes inside the Sundarbans is also related with the changes of freshwater flow from upstream rivers. The peak salinity was found to be about 10 ppt in 1990 and 11 ppt 2013 and the minimum salinity during post monsoon was found. Salinity in eastern boundary areas is influenced by the Bidhadhari River; salinity in this part is almost zero throughout the monsoon. Salinity at northern and north central parts is also influenced by fresh water flow of the Raimangal River which is originated from the Ichamati River. Salinity remains almost zero during monsoon due to large discharge of the Matla River and starts to increase steadily from the post monsoon period. Salinity in the southern part of the Bay remains less than 1.5 ppt during monsoon and starts to increase. Salinity in the western part is not reduced to low salinity range even during monsoon periods; salinity increases at a steady rate during dry periods. The adverse effects of increased salinity on the ecosystem of the Sundarbans are manifested in the dying of tops of Sundari trees, retrogression of forest types, slow forest growth, and reduced productivity of forest sites. There can be total wash out during cyclonic and storm surges. (Mondal et al. 2014)

During such occasion, the river water rushes into the Islands and ruins almost everything within minutes and incurs irreparable loss of assets, lives and livelihoods of the people. The adverse effects of increased salinity on the ecosystem of the Sundarbans are manifested in the dying of tops of Sundari trees, retrogression of forest types, slow forest growth, and reduced productivity of forest sites and agriculture.



Salinity 1990(Value)	Salinity 2013(Value)	Remarks
0-35.791	0-62.928	Very Low Salinity zone
35.791-41.012	62.928-69.130	Low Salinity zone
41.012-46.797	69.130-75.973	Moderate Salinity zone
46.797-103-609	75.973-112.782	High Salinity zone

Fig.7. Salinity Maps

4.6. Climate Change and Effect of the Study Area:
The Intergovernmental Panel on Climate Change (IPCC) projected that the state of tropical forest ecosystems is likely to get worse due to climate change. West Bengal and Bangladesh being in the tropical region, different physical effects of climate change including increased temperature and precipitation, increased salinity and extreme weather events such as floods, cyclones and droughts will have profound negative impacts on its forests.

The Sundarbans is already affected by climate change, importantly from increasing salinity and extreme weather events like tropical cyclones. Some researchers predict that top dying of Sundari trees is likely to be the consequence of slow increase of salinity over a long period of time. Salinity increase also affects the species combination and regular succession patterns in the Sundarbans as some non-woody shrubs and bushes replace the tree species, reducing the forest productivity and habitat quality for valuable wildlife. World Wildlife Fund for Nature Conservation (WWF) estimates that due to sea level rise, nearly 7 500 hectares of mangrove forest in the Sundarbans is projected to be flooded. Many studies have shown that tropical cyclones destroy the mangrove forests to a large extent. For instance, in the recent past, cyclone Sider has destroyed one-third of the Sundarbans.

A recent study (Mitra et al. 2009) showed that surface water temperature has been rising at the rate of 0.5 degree Celsius per decade over the past three decades in the Sundarbans, eight times the rate of global warming rate of 0.06 degree Celsius per decade that makes the Sundarbans one of the worst climate change hotspots on the globe. The study found a change of 1.5 degrees Celsius from 1980 to 2007, indicating a clear challenge to the survival of flora and fauna in this forest. IPCC documented a temperature increase rate of 0.2 degree Celsius per decade in the Indian Ocean during 1970-99 (IPCC 2007). The study by Mitra et al. (2009) also looked into the variations in dissolved oxygen, pH level, transparency and water quality in order to determine the impact of global warming on the ecosystem of the Sundarbans. The surface water pH over the past 30 years has reduced in the region, thus increasing acidification. The variations in salinity and increased temperature are thought to be the reasons for observed variation in pH and dissolved oxygen. The concentration of dissolved oxygen in some parts of the Sundarbans showed a decreasing trend. Depletion in dissolved oxygen can cause major shifts in the ecological habitation in the region. Rising temperature could also be one of the reasons for decreasing dissolved oxygen in the Sundarbans.

Global warming will accelerate the process of erosion in coastal and estuarine zones either through increased summer flow from the glaciers or by increased tide penetration due to sea level rise. Erosion and sedimentation processes, along with subsequent churning action, increase the saturation of suspended solids, (Banerjee, J 2013) thus decreasing the transparency. The reduced transparency affects the growth and survival of phytoplankton, the small microscopic plants in the oceans that produce three-fourths of the earth's oxygen supply. Damage to this community may adversely affect the food chain in this mangrove-dominated deltaic complex, which is the nursery and breeding ground of aquatic live. B K Chand, R K Trivedi, S K Dubey and M M Beg (2012).

4.7. Weather Change between 1990-2013:
SRAD: Daily Insolation Incident on a Horizontal Surface (MJ/m^2/day)
T2M: Average Air Temperature at 2 m Above the Surface of The Earth (degrees C)
TMIN: Minimum Air Temperature at 2 m Above the Surface of The Earth (degrees C)
TMAX: Maximum Air Temperature at 2 m Above the Surface of The Earth (degrees C)
RH2M: Relative Humidity at 2 m (%)
TDEW: Dew/Frost Point Temperature at 2 m (degrees C)
RAIN: Average Precipitation (mm/day)
WIND: Wind Speed at 10 m above the Surface of the Earth (m/s)

The meteorological conditions, including temperature precipitation and wind that characteristically prevail in a particular region: the long-term average of weather. The changes of various items of climate from the year 1990 to 2013 are described in earlier figures. According to the daily Insolation Incident on a Horizontal Surface Change (SARD) diagram, the maximum value of daily Insolation Incident on a Horizontal Surface change (SARD) in the year 2010 and The minimum value of SARD in the year 2013. By Maximum Air Temperature at 2 m Above the Surface of the Earth (T-MAX) diagram, the maximum value of Maximum

Air Temperature at 2 m Above the Surface of the Earth (T-MAX) is in the year 2007. And the minimum temperature is in the year 2003. In Minimum Air Temperature at 2 m Above the Surface of the Earth (T-MIN) diagram, the minimum value of Minimum Air Temperature at 2 m Above the Surface of the Earth (T-MIN) in the year 2009 is 26.352 degree and the maximum value of T-MIN in the year 1997 is 23.875 degree approximately. In year basis average rainfall diagram, the maximum percentage of rainfall in the year 2005 and 1999 is 7.40 mm/day and 7.33 mm/day respectively and the minimum percentage of rainfall in the year 2010 is 4.33 mm/ day.

In wind speed diagram, the maximum speed of wind in the year 2013.and the speed is 5.19 m/s. The minimum speed of wind in the year 1997, and the average speed is 3.17 m/s approximately.
In Dew/Frost Point Temperature at 2 m (TDEW) diagram, the highest value of Dew/Frost Point Temperature at 2 m (TDEW) in the year 2012 and the value is 22.53 degree approximately and the lowest value of TDEW in the year 1999 and the value is 20.68 degree approximately.
By Average Air Temperature At 2 m Above The Surface Of The Earth (T2M) diagram, The maximum value of Average Air Temperature At 2 m Above The Surface Of The Earth (T2M) in the year 2010 and 2011 and the value is 27.34 degree and 27.33 degree respectively .the minimum value of T2M in the year 2003 and the value is 25.51 degree.

By the Relative Humidity diagram, the maximum relative humidity in the year 2003 and the value is 77.74 % approximately and the minimum relative humidity in the year 2013 and the value is 72.70 % approximately. So the weather data between 1990-2013 after 23 years of visa-vis Indian Sundarban is oceanic region is world largest mangrove forest. There is several change of study area landform forest, agriculture etc. Naturally eastern part of Indian Sundarban has an ideal tropical monsoon climate with hot rainy humid summers and dry mild winters. Three climate seasons are recognized in the area. These are:

i) Pre-monsoon (February - May)
ii) Monsoon (June - September)
iii) Post monsoon(October - January)

The average rain fall of study area 6.52mm/day (1997-2013) and temperature range 13^{0} c in winter and 35^{0} c in summer. Tropical cyclones variable average wind speed 3.63 m/s is regular phenomena in the Sundarban area. This storm caused a wide spread damaged in Indian Sundarban coastal region and adjoining surrounding areas. After describe of 23 years data are define that there is change of Rain Fall, Temperature, Wind Speed, Relative Humidity etc. The study area are mostly affected of environment, Land Use and Land Cover, Forestry, Agriculture due to cause of climate change.

4.8. Rainfall and Monsoonal Pattern:

Sundarban receives rain mainly from South-West monsoon which generally starts in the middle of June and withdraws during the second week of October. August is the rainiest month which contributes 21 % - 22% of the annual precipitation. The average annual rainfall is 1625 mm but in case of high rainfall year this may increase to 2000mm where as this may drop to 1300mm in exceptionally low rainfall year. The analysis looking at data over a period of 1990-99 have received a slight increase in monsoon (Chand et al, 2012).

4.9. Aila Cyclone:

Cyclone Aila hit the Sundarban in the Indian sub continent near Bay of Bengal on the afternoon of 23-26th May, 2009, with gale-force winds up 120 kmph, and torrential rain. As it crossed over the coastline of South 24 Parganas district in West Bengal, Aila temporarily strengthened to a Category 1 cyclone. Aila ripped through 17 districts in West Bengal, of which South and North 24 Parganas was one of the affected. Storm surges at the coast flooded agricultural areas with saline water. High winds and high tide became a devastating combination. According to UNDMT and media reports, Aila was one of the worst cyclones in decades, in which about 6.3 million people were affected and nearly half a million homes were lost or damaged. (Mondal et al. 2014)

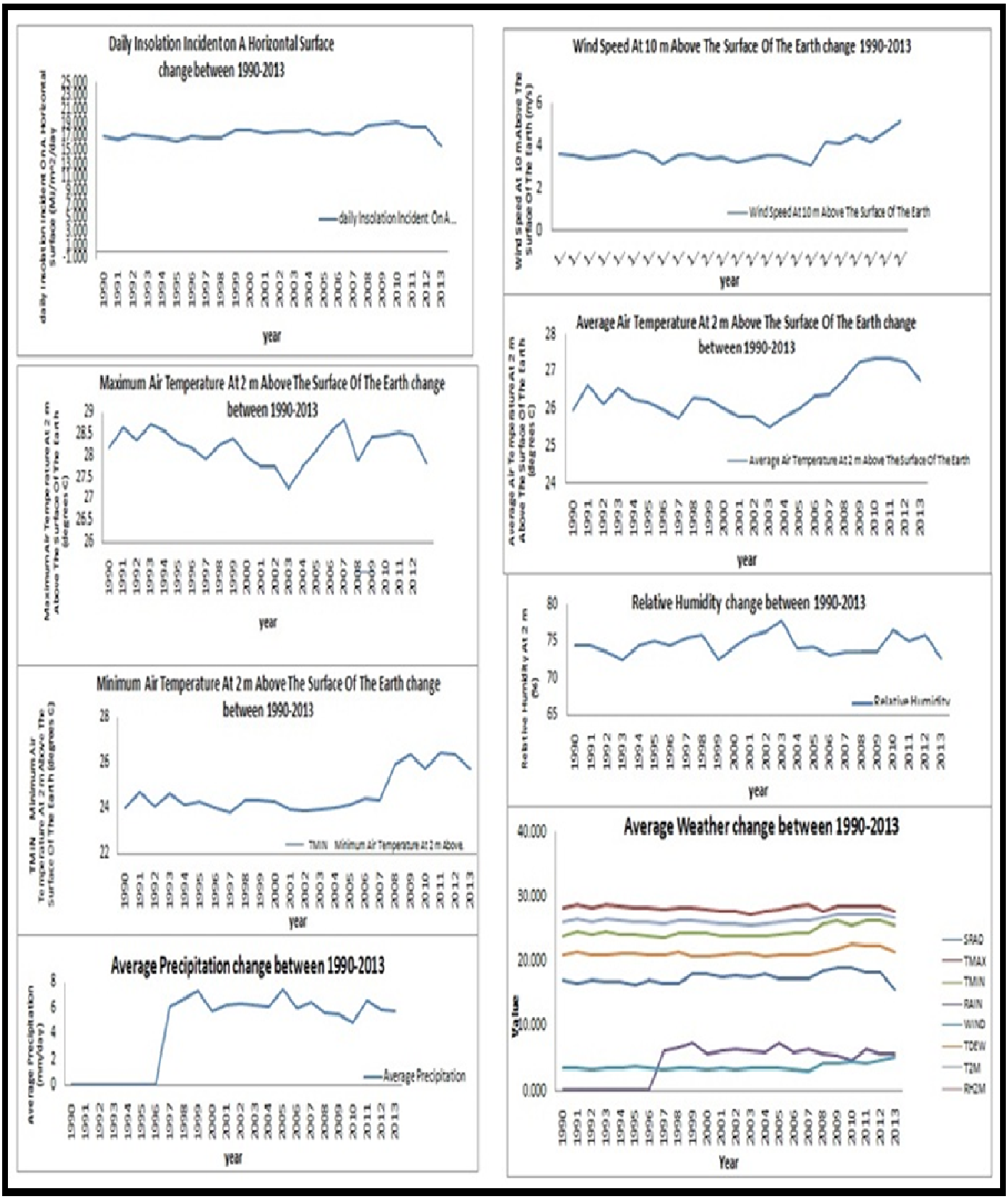


Fig.8. Weather Change between (1990-2013)

4.10 Damage:

The severe cyclonic storm, Aila affected both India and Bangladesh. A brief report on damages due to Aila in these two countries is summarized below.

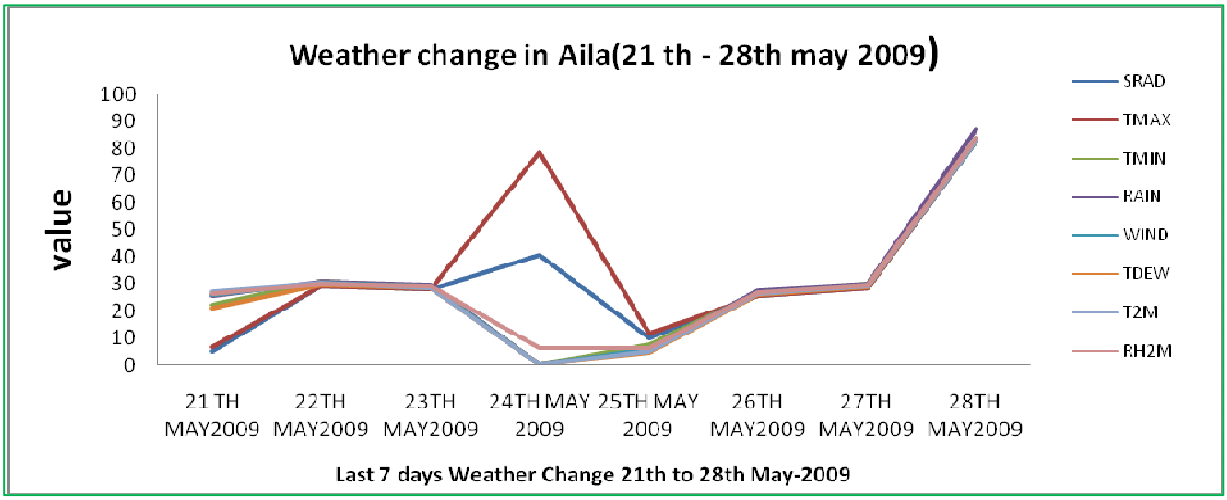


Fig.9. Weather change of Aila of 7 days

and winds peaked at 90 km/h (56 mph). Numerous trees were uprooted and power lines were downed, causing widespread power outages. High waves produced by the storm inundated coastal villages, forcing residents to evacuate to safer areas. However, there is no report of human death in the state. An estimated 1,000 acres of Orissa cropland were affected due to Aila. The remnants of Aila produced gusty winds and heavy rains in Meghalaya between 25 and 26 of May. Rainfall amounts peaked at 213.4 mm and winds reached 60 km/h. Several homes were damaged in the area and power was cut due to fallen trees and power lines. No injuries were reported in the state. Several streets were flooded and some homes were reported to have standing water,(CycloneAila (IMD designation: BOB,02, JTWC designation: 02B).

4.11 Environmental impact of Aila:

Sundarbans meaning "beautiful forest" in Bengali is known as the largest single block of tidal mangrove forest on earth, and a world heritage site. What is less known is that Sundarbans is home to over a million people, who live in a vulnerable environment, with constant threat of rising sea levels, seasonal flooding and water scarcity, diseases and loss of livelihood. Land mass in this delta region is fragmented into thousands of hard-to access Islands. Most of these are below the sea level, ringed by bunds [traditional embankments], to keep the salt water away. While this provides precious land for human habitation, most areas have to do without electricity, motorable roads, or drinking water connections. People use diminishing underground resources to meet some of their drinking water needs, and harvest rainwater in shallow ponds for all other purposes. The Sundarbans, a region was inundated with 6.1 m (20 ft) of water. Dozens of the tigers are feared to have drowned in Aila's storm surge along with deer and crocodiles. Additionally, the forest remains under an estimated 2.4 m (7.9 ft) of water on 27 May according to media reports. The actual impact of Aila on flora and fauna in Sundarbans is being ascertained by various Govt. and non-Govt. agencies.

4.12 Environmental Change:

Environmental change is a major problem of the world. Coastal Environment of Sundarban has been changed on different issues and aspects of environmental change. The extensive farming systems requiring large land areas have contributed most to encroachment of agriculture land and mangrove clearance with increased intrusion of salinity, degradation of land and destabilization of coastal eco-systems impact of shrimp while the others focus on both environmental and social issues. The mainstream literatures argue that shrimp farming in Sundarban has many negative environmental impacts including Stalinization of soil and water, loss of wild and domesticated flora and

fauna, mangrove destruction, change in cropping patterns and species composition. (Mondal et al. 2014)

4.13 Major Threats of the Ecosystem:

Apart from the waste generated by Sundarbans, untreated wastes, domestic waste per day reach the Sundarbans area from the Calcutta Municipal Area.

- Gradual clearance of the forest area has occurred due to the increase in need for fuel wood, construction activities, etc.
- Sundarbans is also highly susceptible to natural disasters. Violent storms occur during the Southwest.
- Monsoon and early post monsoon period, causing severe erosion to the coastal zone.

In the changed situation, the salination of lands and water in the inhabited areas of Sundarban may bring more areas under brackish water aquaculture (*Bheries*) given the decreasing viability of fresh water aquaculture and agriculture sectors, thus presenting an opportunity for this sector to capitalize on the changes posed by climate change. (Mondal et al. 2014)

- Discharge of oil from mechanized boats and oil tanker wash is also increasing. The Hooghly River, which forms the western boundary of the Sundarbans, has been subjected to great stress from increased industrial & domestic sewage pollution.
- Intensive agriculture activities with more and more fertilizer and pesticide along with changed land-use pattern have an impact on the ecosystem.

4.14 Major Findings in the Study Area:

- **Climate change-** Increases sea temperatures, cyclones and storm surges.
- **Habitat loss-** Through wetlands reclamation for agriculture, urban and tourism development.
- **Nutrient loading** -From nitrogen, phosphorous and other chemicals mostly from agriculture but also from poorly treated domestic waste, affecting inland and coastal wetlands and causing excessive algal growth and the resulting reduction in other species.
- **Siltation** in coastal areas is occured from the outflow of rivers. Too much siltation, through agriculture, deforestation, etc, is a serious problem.
- **Pollution-** from urban, industrial and agricultural waste are flowing into coastal waters and is poisoning animals and plants in the study area.
- **Mangrove loss-** Deforestation, human settlement, conversion of agricultural land into prawn fisheries, uses of mangroves as fuel wood are the major problems of losing mangrove swamps. (Mondal et al. 2014)

5.0 Conclusions:

The study area is a part of Sundarban, contributing the sustenance of life as well as safety of living being of the area. The climate change is the fallout of exaggerated interventions in the name of development and is horrifying the nature, including the Sundarbans. Increase in salinity intrusion due to anticipated sea level rise is one of the major threats to the Sundari trees, which are already under threat due to increased salinity levels. Majority of the negative impacts in the study area aggravate during dry periods when the flow of the Raimangal River, the main feeder of the water bodies of the area falls drastically. Subsequently, the Ichamati River flowing through eastern part of the 24 Parganas (north & south) Districts ultimately debouches in the Raimangal River vis-a-vis the Bay of Bengal.

Evidences of weather data between 1990 to 2013 and the analysis of this data substantiate the climate change and its major impact in the study area. Increase in air and water temperature, rise in wind velocity and sea level rise enhanced erosion of land, amplification in frequency and intensity of extreme weather events like cyclone and storm *etc.* in the area. These are putting enormous stresses on both biotic and abiotic condition and livelihood of the people of the study area. Sea levels are rising faster than the global average and high intensity events such as severe cyclones and tidal surges are becoming more frequent in the area. In this context, adoption of climate-resilient agriculture including animal husbandry and fishery as an adaptation strategy will help in meeting the food security of the area in changing climate.

References:

1) Banerjee, J Marine Sci Res Development 2013, S11: Decadal Change in the Surface Water Salinity Profile of Indian
2) B K Chand, R K Trivedi, S K Dubey and M M Beg (2012): Aquaculture in of Changing Climate Sundarban.
3) Chakrabarti, Parthasarathi (1987): Quaternary Geology and Geomorphology of Hooghly Estuary, Dist. 24 –Parganas, West Bengal.

Unpublished Final Report of Geological Survey of India for FS 1984-85 and 85-86.

4) Chakrabarti PS (1998) Changing courses of Ganga, Ganga-Padma River, System, West Bengal, India-RS data usage in user orientation, River Behavior and Control, Journal of River Research Institute, Ganges River at Hardinge Bridge and Gorai River at Gorai Railway Bridge, Dhaka.
5) Climate Change: (2013) the Physical Science Basis. IPCC.
6) Cyclone
   Aila (IMD designation: BOB,02, JTWC designatio n: 02B, also known as Severe Cyclonic Storm Aila)
7) Das, M. K. and Sahu, S. K. (2012). Impact and adaptation of inland fisheries to climate change with special reference to West Bengal. In: CIFRI Compendium on Sundarban, Retrospect and prospects., CIFRI, Barrackpore, Kolkata
8) Dr. (Mrs.) Sushma Panigrahy(2010) NATIONAL WETLAND ATLAS GOA, Sponsored by -Ministry of Environment and Forests, Government of India (As a part of the project on National Wetland Inventory and Assessment, NWIA)
9) Danda, A. A. (2007). Surviving in the Sundrabans: Threats and responses. PhD thesis. University of Twente, Netherlands
10) Hazra, S. (2003). Vulnerability Assessment in a Climate Change Scenario: A Pilot Study on Ecologically sensitive Sundarban Island System, West Bengal. Technical Report, MOEF, Govt. of India.
11) Islam SN, Gnauck A (2008) Mangrove wetland ecosystem in Ganges Brahmaputra delta in Bangladesh. Front Earth Sci China 2: 439-448.
12) Institute Of Water Modeling (IWM). 2003. Sundarban Biodiversity Conservation Project. Surface Water Modeling Final Report. Dhaka Bangladesh
13) Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change: The Physical Science Basis, Report of Working Group I, 'assesses the current scientific knowledge of the natural and human drivers of climate change, observed changes in climate, the ability of science to attribute changes to different causes, and projections for future climate change'
14) IPCC (2007). Climate Change 2007: Synthesis report. In: Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
15) Islam, S. 2007. Healing of the Sundarbans following Sidr, The Daily Star, 28 December, Dhaka
16) Khondker, S.A. (1996), Development issues of Bangladesh: Bangladesh's economy, environment and the Farakka Barrage, University Press Limited, Dhaka.
17) Khan, M.A. 2006. Depletion of forest cover portends climatic disaster. The Daily Star, Dhaka
18) Master Plan Organisation (MPO) 1986. Chapter 7: Salinity. Pages 7-1–7-33 in National water plan, Vol. 1. MPO, Dhaka.
19) Mitra A, Ghosh PB, Choudhury A (1987) A marine bivalve Crassostrea cacullata can be used as an indicator species of marine pollution. Proceedings of National Seminar on Estuarine Management 177-180.
20) Mitra A, Choudhury A, Yusuf Ali Zamaddar (1992) Effects of heavy metals on benthic molluscan communities in Hooghly estuary. Proceedings of the Zoological Society 45: 481-496
21) Mondal, I, Bandyopadhyay, J, (2014): Coastal Zone Mapping through Geospatial Technology for Resource Management of Indian Sundarban, West Bengal, India, International Journal of Remote Sensing Applications Volume 4 Issue 2, June 2014.
22) Mitra, A., Gangopadhyay, A., Dube, A., Schmidt André, C. K. and Banerjee, K. (2009). Observed changes in water mass properties in the Indian Sundarbans (northwestern Bay of Bengal) during 1980–2007. Current Science, Vol. 97, No. 10.
23) Mishra, S. (2002). Climatic trends in West Bengal. Indian Journal of Landscape systems and Ecological studies, Vol.14, No.1.
24) Mishra, S. (2010). 'Abar Kharar Kabale Paschim Banga'. Saar Samachar, Oct-Dec. Vol. 48, No. 3.
25) Water Resources Planning Organization (WARPO). 2002. National Options for the Ganges Dependent Area, Final Report, Volume 1, Main Report, Water Management Plan Project, Ministry of Water Resources, Government of the People's Republic of Bangladesh, Dhaka.