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# ANALYSIS OF SEA LEVEL RISE AND ITS IMPACT ON COASTAL WETLANDS OF INDIA

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**Abstract**

Many studies across the globe has predicted the rise in the Sea level as a result of the global warming caused by the rising concentration of the atmospheric carbon diooxide, methane, carbon mono oxide and chlorofluorocarbons. The paper aims at analyzing the sea level data from the nine-tide gauge monitoring stations across the country. The most significant and direct impact of the sea level rise may be the shoreline retreat and the loss of the coastal wetland as a result of the inundation of the low land. We attempt to find the time trend of the sea level rise and document the positive, significant and increasing trend for the majority of the monitoring stations in India. Total wetland loss along the nine coastal states under different possible scenario and the under projected and estimated trend scenario is evaluated.

**Key words**: Global Warming, Sea Level Rise, Coastal wetlands, Impact Analysis.

## Introduction:

This Paper aims at analyzing the sea level data, collected from the tidal gauze stations across the India and finds the alarming trend near few hotspots of the Indian coast such as Calcutta, Mangalore, Vishakhapatnam and Diamond harbour.

Global sea level trends have generally been estimated by combining the trends at tidal stations around the world. A serious concern over the rising sea level was attempted in the early 1975 when Cesare Emiliani at the University of Miami reported measuring deep-sea cores that showed a shockingly rapid rise of sea level. Mercer (1997) was first among the few who concerned that most climate expert's assumption that ice sheet changes would take many centuries was wrong.

These records suggest that during the last century, worldwide sea level has risen 10 to 25 cm[+]. The global warming of the last century2 later attributed such behavior. Different studies of the sea level rise have projected the significant rise in the global mean sea level (Table 1).

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+ Barnett, 1984; Peltier and Tushingham, 1989

This rise in the sea level was later explained by the Intergovernmental panel of Climate Change+. IPCC found that there are four major factors related to this phenomenon. Thermal expansion of the oceans, melting of the mountain glaciers and small ice caps, melting of the Greenland ice sheet and the rapid breakdown of the edge of the Antarctic ice sheet are the possible factors for the global sea level rise.

UNEP (1989) has identified India among the 27 countries that are most vulnerable to sea level rise. India has a coastline that stretches about 5422 kms on the mainland and exhibits most of the known geomorphologic features of coastal zones. We attempt to find the time trend of the rising mean sea level, measured at the nine tidal gauge stations spread in six states along the Indian coast. The worst hits are the Calcutta, diamond harbour in West Bengal; Kandla in Gujarat then again Haldia in west Bengal. One of the interesting results is the study of Mangalore station in Karnataka. Prior to 1980 the sea level falls and a negative time trend is estimated, after the year 1980 a significant positive time trend is estimated. For one of the monitoring station Sager, we have observed the negative time trend.

The impact of global warming-induced sea level has great significance to India due to its extensive low-lying densely populated coastal zone. We observe the direct Impact of the

India has 7,516 km of coastline, of which the mainland accounts for 5,422 km, Lakshadweep Islands coast extends for 132 km and the Andaman and Nicobar Islands extends for 1,962 km+ (Table 2). Major loss of wetlands is projected in the states Gujarat, West Bengal and Karnataka by the possible sea level rise. We compute the loss in wetland under different possible scenario and under the present situation if the current trend continues in the next century.

## Literature Survey

Cesare Emiliani at the University of Miami took a serious concern over the rising sea level in the year 1975 and reported that measuring deep-sea cores showed a shockingly rapid rise of sea level. Mercer (1997) concerned that most climate expert's assumption that ice sheet changes would take many centuries was wrong.

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+ IPCC 2001: The scientific Basis

the sea level rise on the inundation of the coastal wetlands and this will reduce the mangrove cover and coral reefs along the coast. India has a rich variety of wetland habitats. According to Earth trends 2001, India coast maintains 28 Mangrove species out of the 70 found in the world, 12 out of 58 Sea grass species in the world. According to the space application center ISRO, Total coastal wetlands area in India is 40230 Sq Km.

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+ Ministry of Environment and forestry, India

Global sea level trends have generally been estimated by combining the trends at tidal stations around the world. These records suggest that during the last century, worldwide sea level has risen 10 to 25 cm (4 to 10 in) (Barnett, 1984; Peltier and Tushingham, 1989), much of which has been attributed to the global warming of the last century (Gornitz et al., 1982; Meier, 1984).

IPCC Projections of global average sea level rise from 1990 to 2100, using a range of AOGCMs following the IS92a scenario (including the direct effect of sulphate aerosol emissions), lie in the range 0.11 to 0.77 m. According to the IPCC four factors are responsible for rise in the sea level. The main contributions to this sea level rise has been a thermal expansion of 0.11 to 0.43 m, a glacier contribution of 0.01 to 0.23 m, a Greenland contribution of -0.02 to 0.09 m and an Antarctic contribution of -0.17 to +0.02 m.

A study by Diksha Aggarwal and Murari Lal, "Vulnerability of Indian Coastline To Sea Level Rise" for the Centre for Atmospheric Sciences, Indian Institute of Technology Delhi does the simulation studies based on the four AOGCM models and find the future projections for the Indian coasts are lower than the IPCC projections but still significant. A mean sea level rise of between 15 and 38 cm is projected by the mid- 21st century along India's coast.

In a series of studies using the tide-gauge records at five coastal locations of Bombay, Cochin, Calcutta, Kandla, and Sagar Island by Das and Radhakrishna, "Trends and Pole Tide in Indian Tide gauge Records" ( In Proceedings of the Indian Academy of Sciences, Earth and Planetary Sciences 1993) have reported an increase in sea level. The trend appears to be higher on the eastern coast compared to the western coast. The average sea level rise for India has been reported as 2.5 mm/year since the 1950s.

Sea level rise affects the beaches and they are subject to increased erosion as sea level rises. Given the historical frequency and severity of coastal storms, any rise in sea level will greatly increase the extent of damage within the coastal zone. As sea level rises, coastal ecosystems are subject to flooding. This may result in the loss of biological diversity for example, fisheries and also creates serious consequences for marine ecosystems. With rising sea level the Salinization of water supplies may take place. But sea level rise has a direct impact on the coastal wetland.

In an attempt to find the possible impact of the projected sea level rise on the coastal wetland , "Sea Level Rise And Wetland Loss: An Overview", A study be James D. Titus for the U.S. Environmental Protection Agency emphasizes that the rising sea level can disrupt the wetlands, can cause flooding in the coastal states, erosion, and saltwater intrusion. Other findings are that Sea level rise increases the frequency and/or duration of tidal flooding throughout a salt marsh. After that marshy grass drowns and marsh soil erodes and hence portions of the high marsh become low marsh. Thus coastal wetlands are the worst hit.
Another study for the U.S. Environmental Protection Agency by John S. Hoffman, "Projecting future sea level rise Methodology, estimates to the year 2100, and research

needs", generates the projections of the sea level rise based on the scientific constituents, mainly atmospheric composition, climate, oceans, and the cryosphere. Hoffman estimates the major impacts of the sea level change and uses "the Braunn theory of sea level rise" as a cause of shore erosion from the journal of geology, 75, 76-92.
A study by the Asian Development Bank (ADB), "Climate Change in Asia" conducted the vulnerability assessment of the sea level rise for the India's costal Zone. GIS analysis, based on the topographic maps and socio economic data estimated the economic cost assuming the one-meter rise in the sea level. Due to land loss, population displacement, economic loss and impact on the forestry, total economic cost of one-meter sea level rise in the year 1994 was estimates to 71292 million dollar.

## Data:

Annual mean value of sea level data for nine tidal gauze[+] stations has been collected from the database of the Permanent Service for Mean Sea Level (PSMSL). PSMSL contains annual mean values of sea level from almost 2000 tide gauge stations around the world. The PSMSL receives annual mean values of sea level from almost 200 national authorities, distributed around the world, responsible for sea level monitoring in each country or region. Indian authority is the director, survey of India, geodetic & research branch Dehradoon.

PSMSL is based at the Proudman Oceanographic Laboratory, Merseyside, United Kingdom and is a member of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS) established by the International Council for Science (Earlier, The International Council of Scientific Unions-ICSU). The U.K. Natural Environment Research Council supports it by FAGS, Intergovernmental Oceanographic Commission (IOC) and.

Coastal wetland area statistics has been taken from the Space Applications Centre[+] (SAC) that has mapped coastal wetlands of India in 1998 and has classified them in different categories. A total of 3960 sites of coastal wetlands are mapped, covering a total extent of 40,230 sq. km. These wetlands are distributed in nine states and four Union Territories.

Coastal length and other statistics are taken from the ministry of Environment and forestry, India.

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+ tide gauge, an instrument that automatically records water levels at fixed intervals of time,

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+ Garg, J. K., T.S. Singh and TVR Murthy, 1998 "Coastal Wetlands of India Nation-wide wetland mapping project" For Space Application Center (ISRO).

## The Model:

This study uses the spline interpolation for the missing or irregular time series means sea level data. Statistical method that is employed here is the calculation of the sea level trend. If MSL is the mean sea level and the TIME is the year identification variable then the regression equation that yield the trend is

$$MSL = a + bTIME + U$$

Where "a" is the intercept of the equation and the "b" is the slope (trend). This exercise is repeated for the data from all the nine monitoring stations of the country.

Coastal wetlands areas for all coastal states from the GIS imaginary of the space application center, ISRO are used here. Length of the coastal states is taken from the website of ministry of environment and forestry, India. Arithmetical calculation is done to find the width of the coastal wetland from the area and the length of the coast.

The consolidated Freshwater and Wetlands Conservation Programme (FWCP) by a wildlife conservation organization, WWF-India has been doing the wetland management of the east of Calcutta wetlands and the Vembanad - Kol wetland system in the kerela[+]. The height definition on the two sites differs so we take the assumption that all area above one meter of the sea is to define as the coastal wetland.
Area to be undaunted due to possible sea level rise in different projection is calculated. And finally we calculate the possible wetland loss due to the estimated trend in the next 100 years.

## Empirical results:

This section has two subsections. The first one deals with the descriptive statistics of the data. The estimation results are given in the second subsection.

**Descriptive Statistics:**

Descriptive statistics of the mean sea level is listed in (Table 3). It contains mean, maximum and minimum value of the MSL along with the standard deviation. We have different number of observation for the different monitoring station. Mean sea level data for Mumbai has been observed for hundred and eighteen years where as we have only 26 observation for the Haldia in West Bengal. A very huge variation on the Calcutta coast has been observed whereas least variation is observed for the Mangalore coast in Karnataka.

**Estimation results:**

The trend statistics (Table3) reveals the three out of our monitoring stations in west Bengal has been reported a very significant and positive trend (Table 4). If the trend

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East Calcutta Wetlands - West Bengal, Elevation - 2 m GTS
Vembanad - Kol Wetland – Kerala Elevation - 0.6 - 2.2 m below MSL

continues then the approximately 832 mm sea will rise in the Calcutta and cause the damage to 2100 $km^2$ of coastal wetland whereas total coastal wetlands in west Bengal are 3604 $km^2$. Gujarat is richest in the coastal wetlands and maintains approximately 60 percent of the total coastal wetland of the India (Table 5). The maximum loss of coastal wetland is projected for the Gujarat and it is approximately 8453 $km^2$ out of the total 25083 $km^2$ (Table 6 and 7).

## Conclusion:

"Wetland" is a term used for all of the different kinds of wet habitats where the land is wet for some period of time each year but not necessarily permanently wet. This loss in the coastal wetlands will harm the biological diversity of flora and fauna and productivity of wetland systems.

The Ramsar Convention+ had highlighted the wetland ecosystems as the starting point of all integrated water management strategies. Sustainability can be ensured only by maintaining the health of wetlands which are the sources of freshwater, besides being sources of livelihood to rural population.

This alarming level of the rising sea level if continues in the next century then it will cause not only land loss but also a very huge population living near the coastal cities will have to be displaced. There may be the loss to the existing road network near the sea as three mega national highways in India passes near the coast. The salinity prevention along with the managing biological species and flood protection structures should be the immediate cause of concern to the policy makers.

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+ The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources.

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## Tables:

Table 1: Different estimates of mean global sea level rise

| **Author** | (Cm/Century) | Method |
|---|---|---|
| Thorarinsson (1940) | | Cryologic Aspects |
| Gutenberg (1941) | 11 ± 8 | 1937 (many stations) |
| Kuenen (1950) | 1214 | 1942 Different Methods |
| Lisitzin (1958) | 11.2±3.6 | Sea Level (six stations) |
| Fairbridge and Krebs | 12 | 1900 1950 (selected stations) |
| Emery (1980) | 30 | 1935-1975 (selected stations) |
| Gornitz et al. (1982) | 12 | 1880-1980 (many stations) |
| Klige(1982) | 15 | 1900-1975 (many stations) |
| Barnett (1984) | 14.3± 1.4 | 1881-1980 (many stations) |
| Barnett (1984) | 22.7±2.3 | 1930-1980 (many stations) |

Table 2: State-wise Length of Coastline+

| **States** | **Coastal Length (km)/ Number of Islands** |
|---|---|
| Gujarat | 1663 |
| Maharashtra and Goa | 720 |
| Karnataka | 290 |
| Kerala | 560 |
| Tamil Nadu and Pondicherry | 1050 |
| Andhra Pradesh | 930 |
| Orissa | 450 |
| West Bengal | 200 |
| Lakshadweep Island | 37 Islands |
| Andaman and Nicobar Islands | 348 Islands |

+ Source: Oil Pollution and the Marine Environment, Ministry of Environment & Forest.

Table 3: Descriptive statistics of the mean sea level of the monitoring station.

| Monitoring Station (MSL) | **Maximum** | **Mean** | **Minimum** | **OBS** | **Std Dev** |
|---|---|---|---|---|---|
| Calcutta | 7380 | 7023.94 | 6698 | 67 | 187.819 |
| Cochin | 7010.07 | 6931.98 | 6846 | 58 | 40.4324 |
| Diamond Harbour | 7170 | 7017.41 | 6838 | 49 | 95.9907 |
| Haldia | 7105 | 7032.23 | 6918 | 26 | 44.1156 |
| Kandla | 7055 | 6959.53 | 6695 | 47 | 69.0857 |
| Manglore_prior_1980 | 7018.29 | 6962.88 | 6919 | 24 | 27.5276 |
| Manglore_after_1980 | 7140.98 | 7072.43 | 7028 | 20 | 32.0805 |
| Mumbai | 7115 | 7020.58 | 6937 | 113 | 38.8899 |
| Vishakapattam | 7149 | 7072.11 | 6990 | 58 | 33.99 |
| Sager | 7028 | 6863.91 | 6641 | 49 | 108.459 |

Table 4: Estimated trend of the rising mean sea level (MM/Year).

| State | Hot Spot | Trend (MM/100Year) By 2100 |
|---|---|---|
| West Bengal | Calcutta | 832.317 |
| | Diamond Harbour | 583.58 |
| | Haldia | 332 |
| | Sager | (-405.5) |
| Maharashtra | Mumbai | 78 |
| Gujarat | kandla | 337 |
| Andhra Pradesh | Vishakapattam | 52 |
| Karnataka | Mangalore | (-149 before 1978) |
| | | 256(after 1978) |
| Kerela | Cochin | 125 |

Table 5: Width of the coastal wetlands

| State | Coastal length (KM) | Wetland area($KM^2$) | Width ( Km) |
|---|---|---|---|
| Gujarat | 1663 | 25083 | 15.08 |
| Maharashtra & Goa | 720 | 545 | 0.76 |
| Karnataka | 290 | 1800 | 6.20 |
| Kerala | 560 | 424 | 0.76 |
| Tamil Nadu & Pondichery | 1050 | 3987 | 3.8 |
| Andhra Pradesh | 930 | 1855 | 1.99 |
| Orissa | 450 | 1854 | 4.12 |
| West Bengal | 200 | 3604 | 18.02 |
| Andaman & Nicobar | 348 Islands | 1078 | NA |

Table 6: Loss in the coastal wetland ($Km^2$) in different possible scenario

| **If Sea level Rises by.** | 0.1( M) | 0.2( M) | 0.3( M) | 0.4( M) | 0.5( M) |
|---|---|---|---|---|---|
| Gujarat | 2508.3 | 5016.6 | 7524.9 | 10033.2 | 12541.5 |
| Maharashtra & Goa | 54.5 | 109 | 163.5 | 218 | 272.5 |
| Karnataka | 180 | 360 | 540 | 720 | 900 |
| Kerala | 42.4 | 84.8 | 127.2 | 169.6 | 212 |
| Tamil Nadu & Pondichery | 398.7 | 797.4 | 1196.1 | 1594.8 | 1993.5 |
| Andhra Pradesh | 185.5 | 371 | 556.5 | 742 | 927.5 |
| Orissa | 185.4 | 370.8 | 556.2 | 741.6 | 927 |
| West Bengal | 360.4 | 720.8 | 1081.2 | 1441.6 | 1802 |
| TOTAL | 3915.2 | 7830.4 | 11745.6 | 15660.8 | 19576 |

Table 7: Loss in the coastal wetland
(if the present trend continues in the next 100 years)

| | Projected rise in sea level(M) | Loss in Wetland Area ( $Km^2$) |
|---|---|---|
| Gujarat | 0.337 | 8452.971 |
| Maharashtra & Goa | 0.072 | 39.24 |
| Karnataka | 0.256 | 460.8 |
| Kerala | 0.125 | 53 |
| Tamil Nadu & Pondichery | 0.0361 | 143.9307 |
| Andhra Pradesh | 0.052 | 96.46 |
| Orissa | 0.012 | 22.248 |
| West Bengal | 0.582632333 | 2099.806929 |
| **Total** | | **11368.45663** |