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Research Article

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Intrusion of surface water salinity in the Western Coastal belt of Bangladesh

Ishtiaq Ahmed[1], Md. Nurul Kadir[1], Md. Hafez Ahmed[2]

[1]Research Associate, Institute of Water and Flood Management, BUET, Dhaka-1000, Bangladesh
[2]Graduate Student, Stockholm University, Sweden

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Abstract

South-West zone of Bangladesh is located in a position very susceptible to water resources related issues and climate change. The South-West region of Bangladesh is a low lying delta with a complex crisscross river system. From last few decades surface water salinity intrusion in the South–West zone in our country has become one of the major concerns. The entire river system of the South-West region is susceptible to extravagant saline water intrusion from the sea with high tide especially during dry season. This problem is exacerbated by decrease of upstream flow due to Farrakka barrage, sea level rise, expansion of shrimp farms and CEP (Coastal Embankment Project) implemented during the 1960s. These facts will lead us to acute problems like decrease in farming lands, increase in groundwater salinity and soil salinity, increased food insecurities, strong scarcity of safe drinking water and loss of biodiversity. This paper evaluates the trend of change in the surface water salinity from the year 2001 to 2008 and analyzes the reasons behind this change. Surface water salinity data source is BWDB. ArcMap 10.1 is used for this purpose combining with analytical analysis and geostatistical analysis. This paper shows increasing trend of surface water salinity majorly due to decrease in upstream fresh water flow rather than the climate change phenomenon.

Keywords: Salinity intrusion, GIS, Geostatistical analysis, Climate change, Fresh water

*Corresponding author: ishtiaq.iwfm@gmail.com, mnkseum@gmail.com, hafez.iwfm@gmail.com

Introduction

In all Coastal regions of Bangladesh, saline water advances and retreats on a daily, fortnightly and seasonal basis. The first two movements are in response to the diurnal and spring-neap tidal cycles, whilst the third is a response to the huge seasonal variation in fresh water flows in the estuaries. There is a zone of continuous transition between fresh water and open-sea salt water. The ecology and land use pattern of coastal regions is adapted to the normal movement of the saline front, and along most of the coast, an equilibrium regime has been established. However the regime has been affected significantly in the Southwest by the reduction in flows into the Ganges distributaries, especially the Gorai, and to a lesser extent, the Meghna estuary, in response to major freshwater withdrawals from the dry season flows of the Ganges. The effect has been particularly severe in the greater Khulna. Climate change phenomenon more aggravates the problem due to the rise of sea level. The main focus of this study is to identify the main reason and to establish a strong relationship with the driving fact.

Methodology

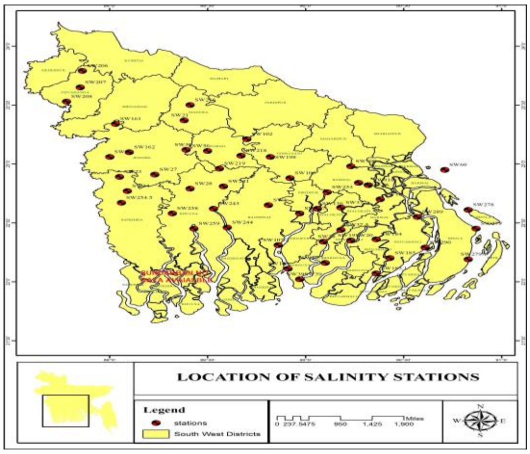
Study area

The South West zone of Bangladesh comprises of 21 districts and have very complex river network along with other water bodies like Beel, Wetlands and Khals. Mainly this zone can be divided into two parts, the coastal zone and the non-coastal zone. Among 21 districts 7 districts are in direct interaction with Bay of Bengal and can be classified as Coastal zone of South-West part of Bangladesh. Other 14 districts situated in non-coastal zone (Table 1). There is Physical, climatic and geomorphic difference between this districts.

Table 1: List of Districts, based on coastal and non-coastal zone.

Name of the Districts (Noncoastal)	Name of the Districts (coastal)
Khustia, Meherpur, Jessore, Narail, Magura, Jhenaihdah, Chuadanga, Rajbari, Faridpur, Gopalgonj, Madaripur, Shariatpur, Barisal, Jhalokati	Khulna, Satkhira, Bagerhat, Barguna, Pirojpur, Patuakhali, Bhola

In this Study area up to 2008 there are 70 Salinity Stations but due to lack of data and Latitude Longitude value only 52 stations were taken under consideration. Using Arc map 10.1 the exact location of the stations were pointed out precisely and presented in a form of map (Figure 1). This map not only shows the stations but also represent the whole study are.



Data

Data used in this study was collected from BWDB. Salinity analysis of water samples collected from 52 stations (From 2001-2008) of South-Western part of Bangladesh is being performed through South-Western measurement division, BWDB. Out of this for 51 stations water samples are collected at high and low water levels during new moon, full moon and mid of moon. For stations at Khulna water samples are collected from Rupsa-Passur river at every high and low water levels from 1st January to 31st May and November, December and June water samples are collected at high and low water levels during new moon, full moon and mid-off moon. Measuring unit is in EC (Electric Conductivity). Here EC is converted to more commonly Water Salinity unit ds/m or mmhos/cm using relation among EC and ds/m.

EC (mmhos/cm or dS/m) x 640 = TDS (mg/l or ppm)

Interpolation Method

The interpolation methods used in this study were performed by Arc Map 10.1. Spatial Analyst and Geo-statistical Analyst is an extension to the Arcgis desktop that provides a powerful suite of tools for spatial data exploration and surface generation using sophisticated statistical methods. Geo-statistical Analyst provides two groups of interpolation techniques: deterministic and Geo-statistical. From the applied methods by evaluating RMS value it has been seen that Kriging method is best (less RMS value means more accurate result). But using this method the situation on the central upper part is not interpolated correctly. Interestingly it is also seen that in IDW method Sundarbon areas are projected with low value as per following the algorithm of the IDW method but this result is not also reflecting the real scenario. Spline is fitting better but if we subtract the Sundarbon area in Natural Neighbor method and interpolate, it gives a quiet convincing result. So after evaluating all available interpolation method Natural Neighbor Method is selected.

Saline Water Classification, Discharge and SLR

In Bangladesh Major Surface water using sector is Agriculture .So in this study saline water classification based on irrigation requirement defined by Food and Agriculture organization of the United Nations has been followed (Table 2).

Table 2: Irrigation Water Quality requirement

Hazad	TDS(ppm or mg/L)	ds/m or mmhos/cm
None	<500	<0.75
light	500-1000	0.75-1.5
Moderate	1000-2000	1.5-3.0
Severe	>2000	>3.0

Then total area is interpolated with four range of salinity (0ds/m-.75ds/m, .75ds/m-1.5ds/m, 1.5ds/m-3ds/m, >3ds/m).This operation has been carried out for 8 consecutive years starting from 2001 to 2008 (Figure 2). South West Estuary of Bangladesh is basically divided into three estuary systems named Western Estuary System (WES), Central Estuary System (CES) and Eastern Estuary System (EES). Form the GIS based surface water salinity analysis it's clear that CES and EES is not under the coverage of severe surface water salinity zone. So for the analysis of discharge, focus is given to the source of fresh water contributor of the WES part. In the extensive complex river network of south west region Gorai and Arial Khan River are main contributors for the WES part. Here for Gorai Discharge Station SW99 and for Arial Khan Discharge Station SW4A's Three months Dry period Average Discharge (March-May) taken in to account staring from 2000-2001 to 2007-2008. Different organization had different SLR projection for different duration of time. Here mean of five organization Altimetry data sets (CU, NOAA, GSFC, AVISO and CSIRO) is used to show trend of change of SLR.

Results and discussion

Surface water salinity risk area

It has been observed that surface water salinity is increasing with increase of time. Using logical expression surface water salinity risk map is produced for each year. This map divide the total interpolated area in two zones, severe risk zone (Deep Color) and non-severe risk zone (Light Color) (Figure 3). Area of the severe risk zones are calculated in sq. km.

Table 3: Surface Water Salinity Risk Area

Year	**2001**	**2002**	**2003**	**2004**
Risk area(sq. Km*10^3)	11.125	12.469	12.776	13.817
Year	**2005**	**2006**	**2007**	**2009**
Risk area(sq. Km*10^3)	14.939	16.941	17.231	17.542

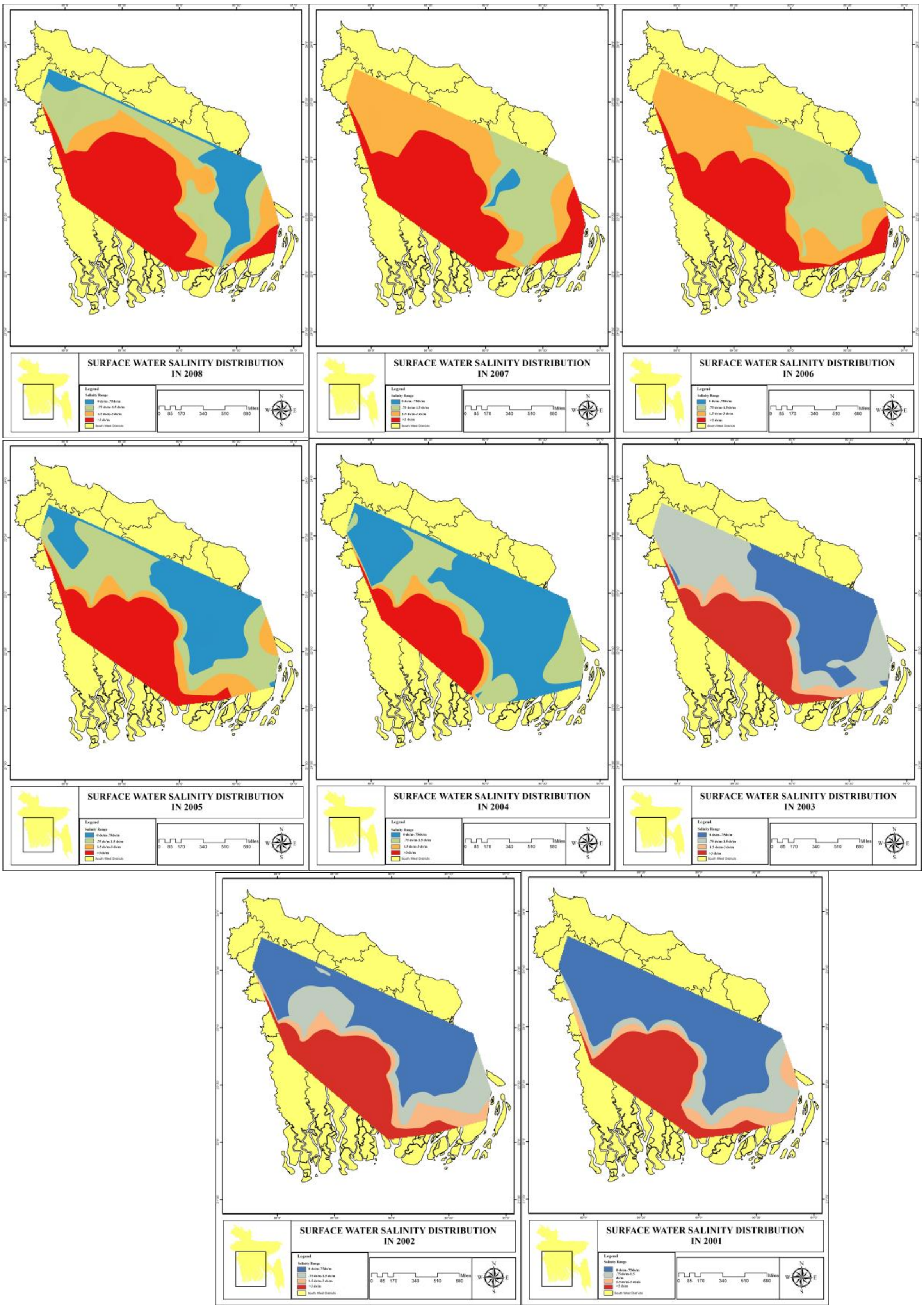


Fig 2: Surface Water Salinity Distibution in Different Year.

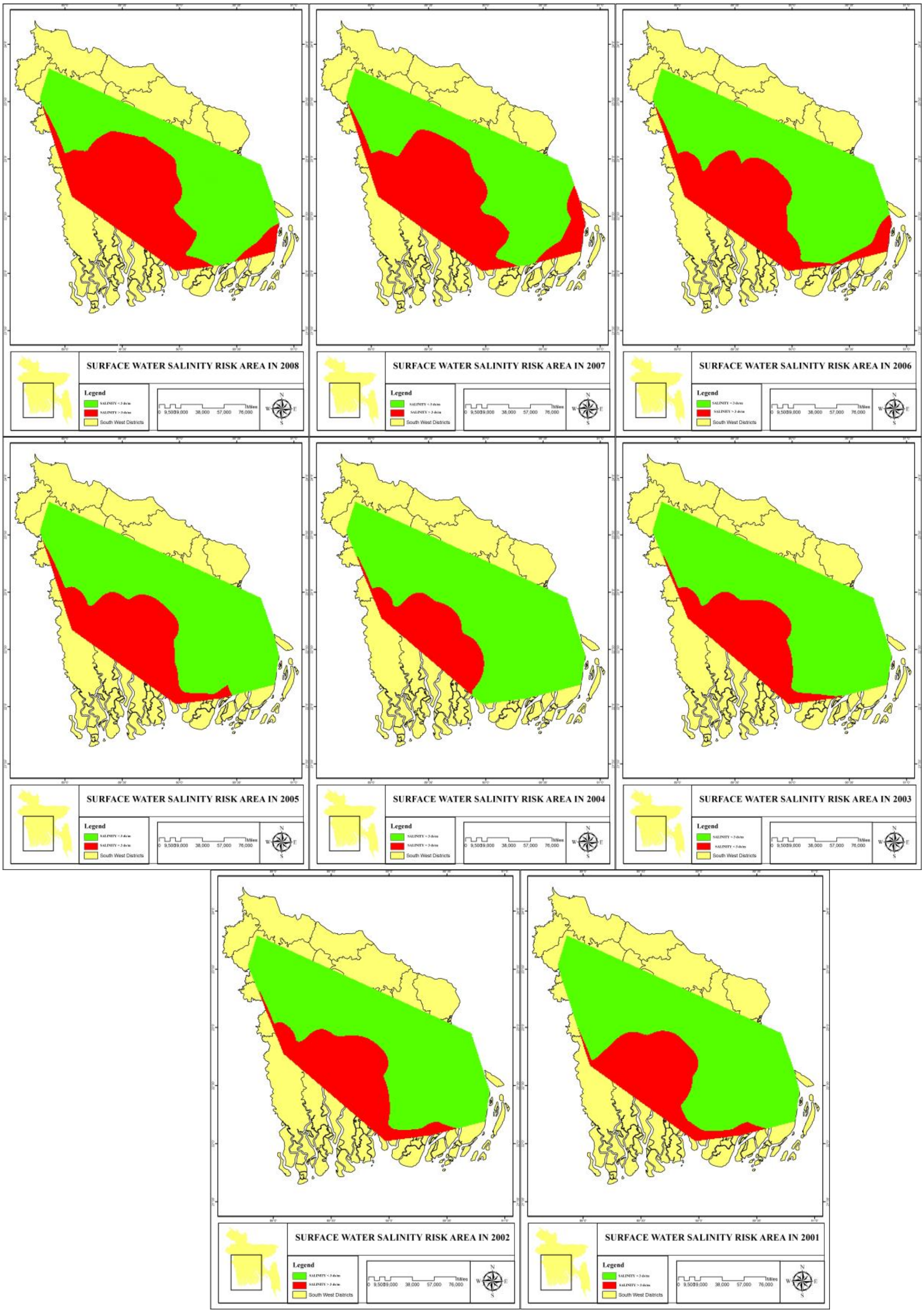


Fig 3: Surface Water Salinity Risk Maps

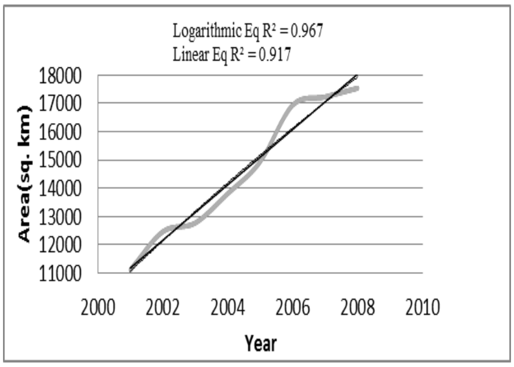


Figure 4: Surface Water Salinity Risk Area vs. Year

In Figure 4 Surface Water Salinity Risk Area Vs. Year is plotted. As Trend line is added for two types of equation (Linear and Logarithmic) results different Regression coefficient value. For Linear equation fitting R2= .917 and for Logarithmic equation fitting R2=.967. This R2 values indicate that Logarithmic profile is more accurate to fit Salinity Risk area changes over the year.

Discharge

To Show an increasing trend of decreasing Discharge, Discharge value of both Stations are subtracted from a fixed value (For SW99 its 1000 and for 4A its 200). Figure 5 and 6 also clearly indicate that both station change yield good fit with Logarithmic profile rather than the linear profile.

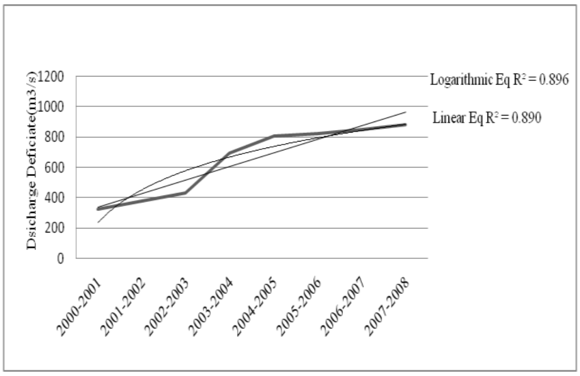


Figure 5: Average Discharge Deficit from fixed value VS. Time Graph for SW4A

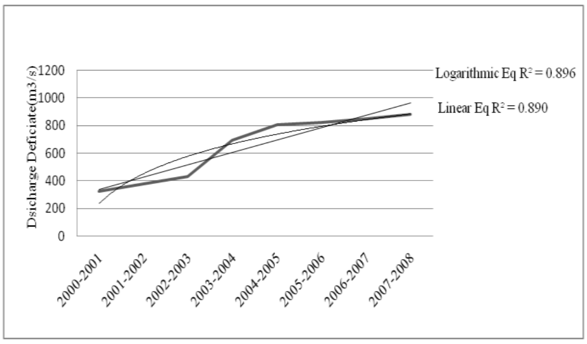


Figure 6: Average Discharge Deficit from fixed Value VS. Time Graph for SW99

Sea level rise

Different organization had different SLR projection for different duration of time. Here mean of five organization Altimetry data sets (CU, NOAA, GSFC, AVISO and CSIRO) is used to show trend of change of SLR (Figure 7).

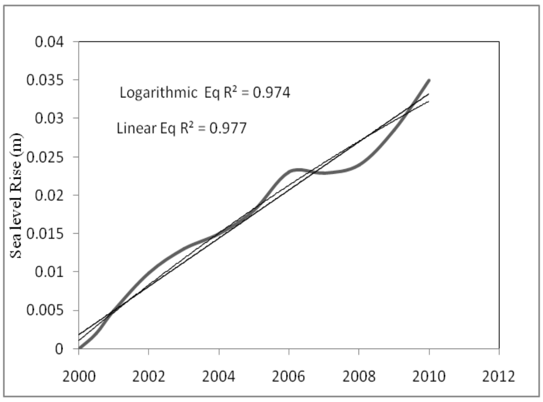


Figure 7: Sea level rise over the time

Interestingly Sea level rise follow a Liner profile (R2=.977) better than Logarithmic profile (R2=.974).
From the above results it is shown that Surface Water Salinity risk area and Discharge profiles are following the same Profile of increase (Logarithmic profile) whereas SLR following a Linear profile. Which strongly relate a relationship between Discharge and Surface Water Salinity and establish it as the key driving factor whereas sea level rise remain secondary driver of Surface water Salinity Intrusion in South West part of Bangladesh.

Conclusions

In the South West part of Bangladesh Salinity Intrusion problem is majorly due to lack of Fresh Water flow from Upstream compared to SLR. So for solution of this problem an Upstream to Downstream approach required rather than Local Approaches. It also shows that as increasing trend of Surface Water Salinity Risk area follow a logarithmic profile, first surface water salinity is increasing very sharply and then will follow a very mild slope pattern. It indicates that if the Estuary systems adjusted themselves with a constant fresh water feed in future, that mild slope of Logarithmic profile will indicate Surface water Salinity intrusion due to SLR and the amount can be quantified separately.

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