Original Research Article

IMPACT OF CLIMATE CHANGE AND GANGES DISACHARGE ON THE SALINITY OF THE PASSUR RIVER, SOUTHWESTERN BANGLADESH

ABSTRACT

The present paper embodies the possible impacts of climate change and upstream discharge on the Passur River water at Mongla point of Khulna division, south-western part of Bangladesh. The secondary data have been gathered from different sources and are analyzed to understand the aforementioned situation. To establish the relationship, the long-term salinity data (1962-2015) has been taken into account as dependent variable with other climatic variables' viz., temperature, rainfall, river discharge, tide level and also sea level change. Salinity of the Passur River increased persistently at a rate of 0.13 ppt/year since 1962 to 2015. Dramatically increased changes have been audited after the construction of Farakka barrage (1975), which apparently increased from 0.35 ppt to 7.05 ppt in 2015. A linear increasing relation has been observed in salinity with both the temperature and the height of sea level. Notwithstanding the inconsistency of rainfall data, an inverse relation also noticed between salinity and rainfall, i.e., salinity increase with the decrease in rainfall. The relation between freshwater discharge at the Hardinge Bridge Point of the Ganges River and subsequent salinity in the Passur River has been compared which establish that the long-term gradual and abrupt decrease in discharge has a direct impact on the increasing trend of the salinity of this River. On the basis of foregoing results and observations, an attempt has been made to generate a linear equation that may predict the future scenarios of the salinity, temperature and sea levels for 2050. Nevertheless, a minor disparity in data of various parameters, it may be concluded that the salinity, temperature and the position of sea level will be increased significantly in the near future. On the basis of the present findings, an immediate measure has to be taken to overcome the possible adverse impacts of inevitable climate change.

Keywords: South-western region of Bangladesh, river salinity, climate change impacts, sea level rise, Ganges discharge, Farakka diversion, coastal vulnerability

1. INTRODUCTION

Bangladesh, being a deltaic coastal country, is likely to be one of the most vulnerable countries in the world to salinity problem and consequent upon National Geographic, in the coming decades, Bangladesh ranks first as the nation most vulnerable to the impacts of Climate Change. From the past few decades, salinity encroachment in the coastal rivers has become a key concern in our country. The Passur River (feed from the Gorai River which itself is a tributary of the Ganges River) is one of the major freshwater suppliers in the southern part. The river which is placed after the Meghna in size in the deltaic region is an important river route and was active and carried sufficient water but now experiences severe drainage shortage in the dry season. Moreover, this river undergoes marked tidal influences, its water is saline throughout the year but during the lean period, the concentration of salt is high [5].The coastal belt of Bangladesh is characterized by excessive chloride concentration which exceeds the WHO drinking water standard (250 mg/L) and is unsuitable for drinking and even for irrigation [Md. Mahadi Hasan, GeoBangla; 2015]. For these reasons, the Passur River is chosen for this work.

With the diversion of freshwater in the upstream boundary, salinity has been started to accelerate sharply over the period of time in the coastal zone of Bangladesh. The level of river salinity was below 1 ppt in this part prior to 1975 where at present the level of river salinity remains above 20 ppt during the dry season [24]. In particular, salinity ingress is likely to be more acute in the future for two reasons: a) freshwater flows from rivers in the Himalayas are predicted to decrease during the dry season and, b) the sea level will gradually rise [35]. The decreased flow into the Ganges distributaries, especially in the Gorai, has an adverse effect in the Southwest part, particularly in the greater Khulna and climate change aggravates the problem by sea level rising [14]. There is robust evidence that sea levels have risen as a result of climate change based on observation from tidal gauges, paleo-indicators and satellite measurements [Department of Environment and Energy, Australian Government]. This critical factor makes deltaic regions particularly vulnerable [25].Sea level rise is caused by two processes: thermal expansion (ocean water expanding as it heats up) and additional water flow into the oceans from the ice that melts on the polar region. Both these processes are currently being observed [Dr. Joshua et al., 2016]. In the coastal regions, sea level rise results saline water intrusion in the estuaries and into the groundwater which governs the availability of freshwater when the upstream flow is low. The effects are exacerbated by greater evaporation and evapotranspiration of freshwater as temperatures increase [Saleemul Huq and Jessica Ayers; 2008].

According to a report of Intergovernmental Panel on Climate Change; 2007, by the year 2050 temperature will increase more than 1.8°C and sea level will rise about 32 cm than the present. As a result, more than 20% of southern Bangladesh will engulf with saline water [9]. Under such an alarming situation, it is most necessary to determine the magnitude of salinity encroachment due to climate change and to come forward to save the natural environment as well as people of South Western Bangladesh.

In this project work, an attempt has been taken to assess how salinity of Passur River is governed by the volume of upstream freshwater discharge at Hardinge Bridge, local rainfall of Khulna, the strong tidal currents and sea level rise at Hiron Point, Bangladesh.

The specific objectives of the present study are

1. To determine the salinity levels.
2. To determine the relationship between climate change variables (temperature, rainfall), sea level rise and tidal effects with the salinity of Passur River water.
3. To establish a relation between Passur water salinity and upstream freshwater discharge from the Ganges.
4. To delineate the future projections of salinity encroachment, sea level and temperature.
5. To find out a possible solution to overcome the problems related to salinity.

2. MATERIAL AND METHODS

The study area is located in the southwest region of Bangladesh within the Bagerhat district of Khulna division (Map 2.1). Mongla is known as the second biggest seaport of the country. The study area borders Rampal Upazila on the north, the Bay of Bengal on the south, Morrelganj and Sarankhola Upazilas on the east and Dacope Upazila on the west. Mongla is located 48 km from the city of Khulna and lies 62 km north of the Bay of Bengal coastline. The distance of Mongla from Hiron Point is 76.7 km.

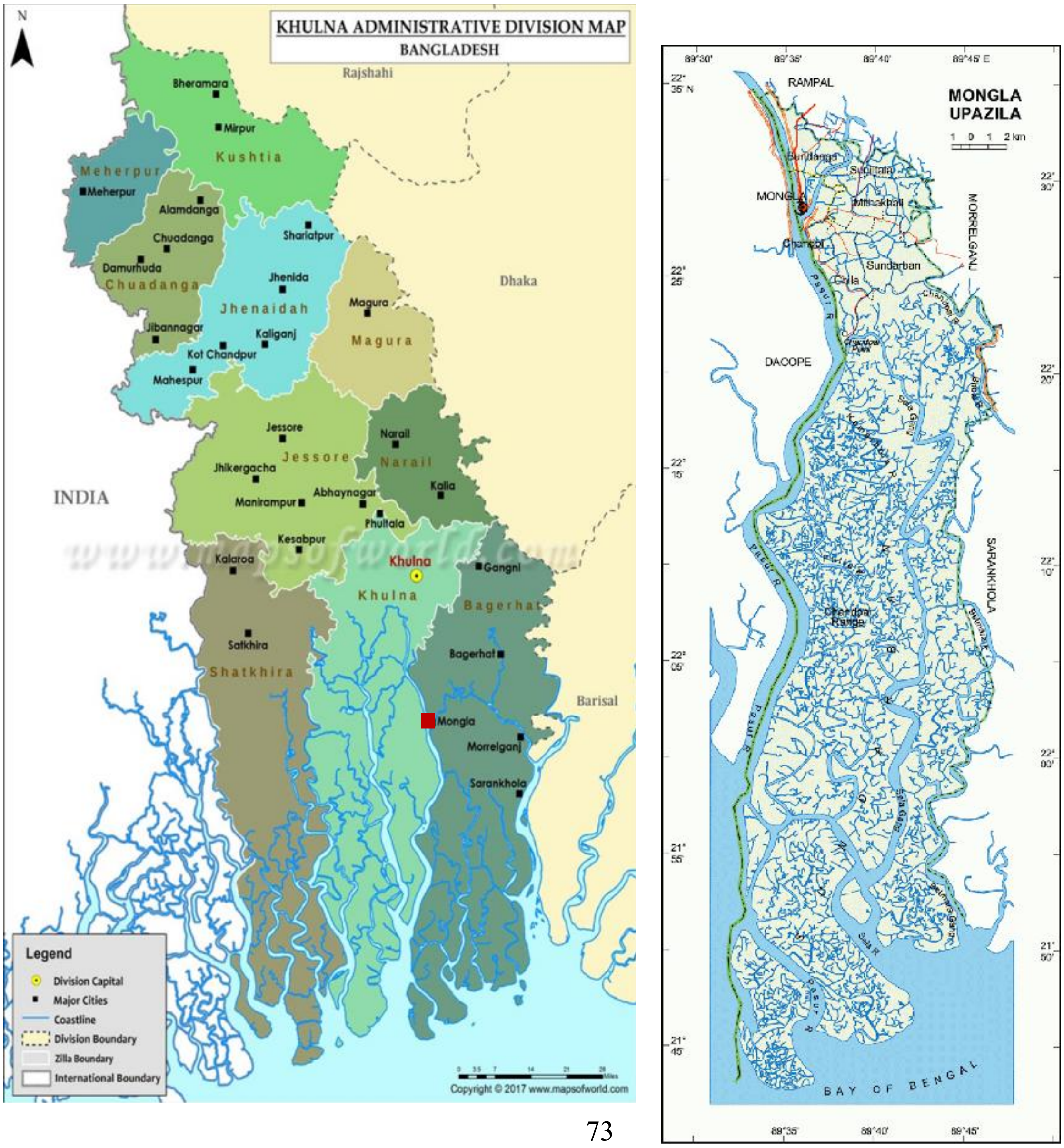


Figure - 2.1: Location map of the study area (Source: Website)

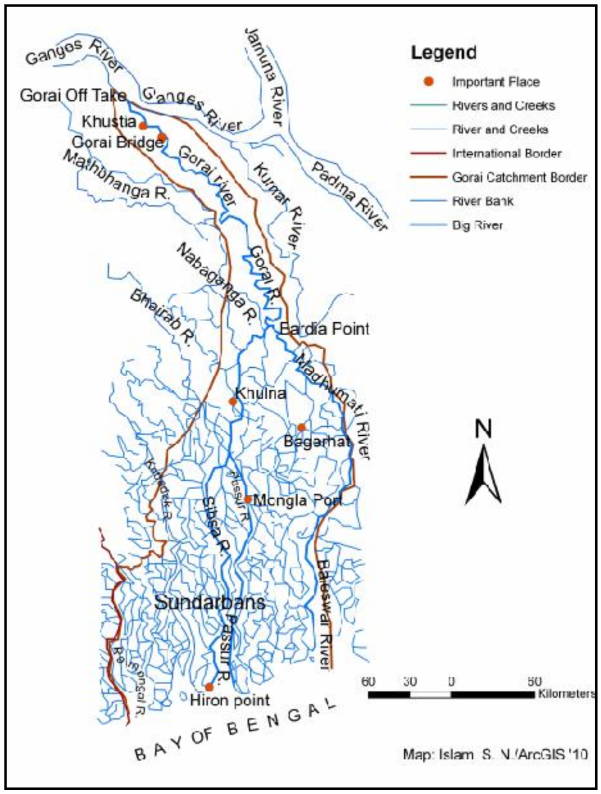


Figure - 2.2: River network map of the southwestern zone of the coastal area (Source: Islam, S.N./ArcGIS '10)

The climatic data (rainfall and temperature of Khulna) has been collected from Bangladesh Water Development Board and different hydrological data has been gathered from various sources to understand the baseline condition; salinity of Passur River at Mongla point from BWDB, Sea water level data of Hiron Point from Bangladesh Tide Gauge, discharge of Ganges River at Hardinge Bridge area from both BWDB and IWM (Institute of Water Modeling) and tidal effect of Passur River from Bangladesh Tidal Chart. Salinity ranges have been estimated from the period of 2016 to 2050.

3. RESULTS AND DISCUSSION

3.1 Salinity of the Passur River

Spread and intensity of salinization in the coastal regime is a threatening issue for the recent time. Salinity data of the Passur River system at Mongla point has investigated both for before and after declination of Ganges River. It expresses a sturdy association between salinity-river discharge and salinity-rainfall in the Passur River but others are not much strongly related. The amount of precipitation and force of upland freshwater through the Gorai-Madhumati maintains the salinity condition of the southwestern part by opposes away the saltwater front. It has been observed that river water salinity augmentation occurs with the increase of time. The salinity trend was tolerant (from 0.11 ppt to 0.35 ppt) at Passur-Mongla point until 1975 just before the construction of the Farakka Barrage (Fig-3.1.1). The Ganges outflow during the lean (January-May) period has been reduced more than a quarter since the commissioning of the Farraka Barrage in the Ganges River which is outside of Bangladesh. This acute shortage of fresh water in the southwest region lead to instant salinity intrusion and eventually in 2015, salinity was 7.05 ppt. This observation clearly affirmed the potential contribution of rainfall and river discharge over the vast southern areas of Bangladesh.

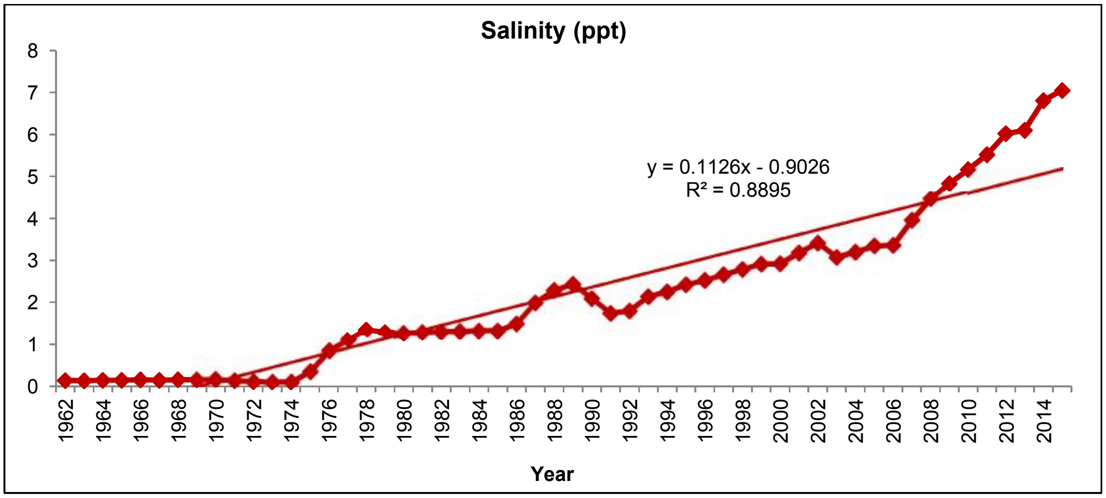


Figure - 3.1.1: Historical Salinity of the Passur River at Mongla (From 1962 to 2015)

The line graph delineates the amount of salinity of the Passur River at Mongla point for more than five decades since 1962 (Fig- 3.1.1). The straight line equation y=0.112x-0.902 shows that salinity increase with time and a high correlation coefficient R^2=0.889 indicates a fitted line for salinity values since its value is near 1. Here, the positive slope means the value of y increases as the value of x increases.

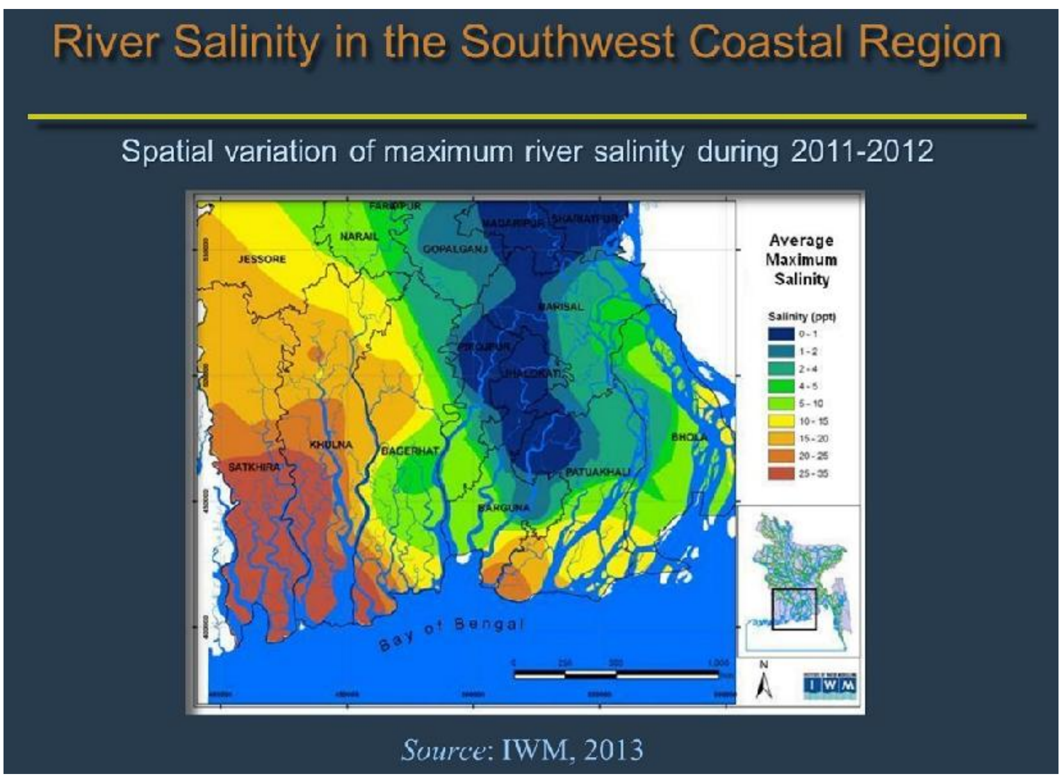


Figure - 3.1.2: Salinity of Coastal Rivers (Source: IWM)

3.2 Tidal Effect and Salinity of Passur

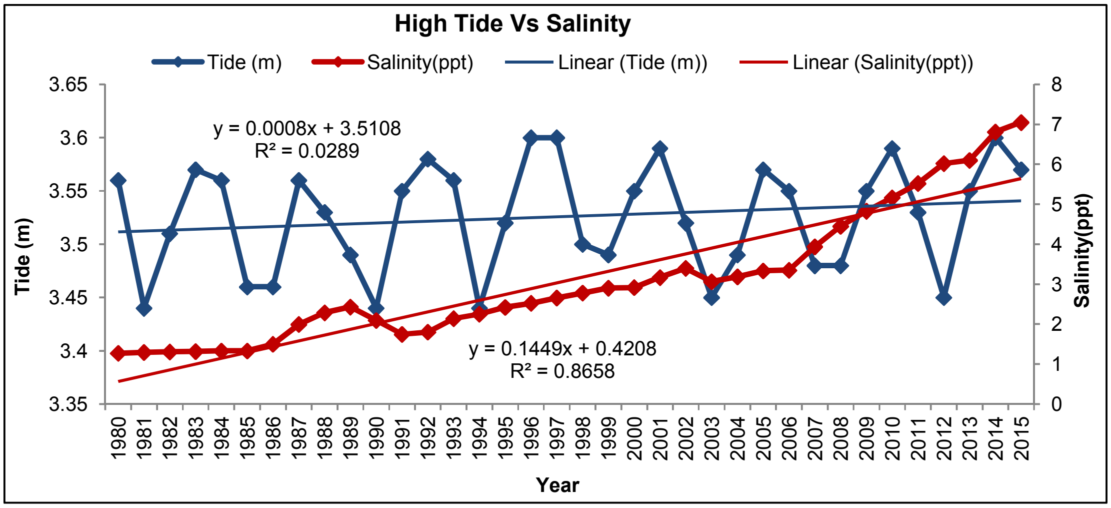


Figure – 3.2.1: Yearly High Tide versus Salinity at Passur River (From 1980 to 2015)

Monthly Tidal Effect and Salinity Relationship:

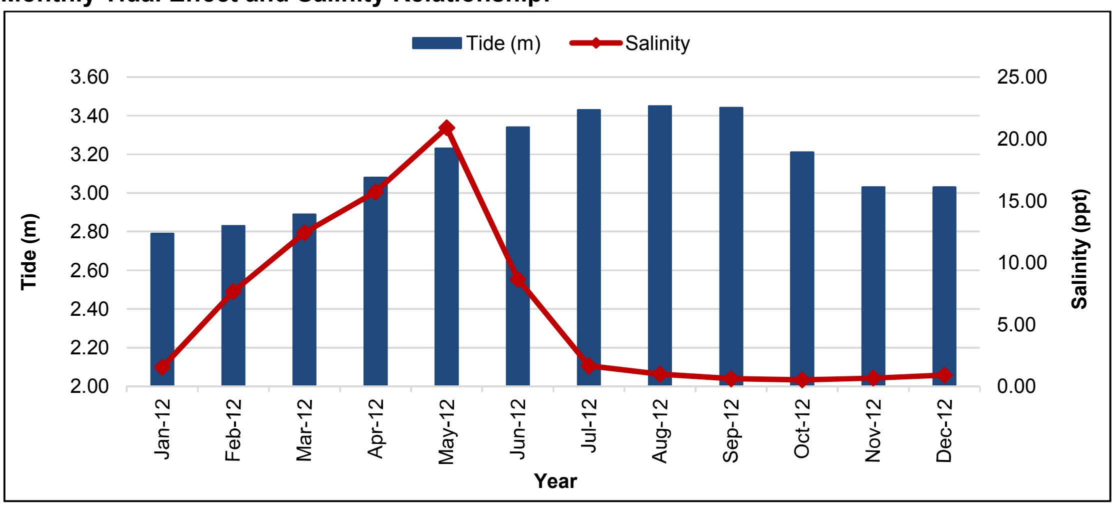


Figure – 3.2.2: Monthly Maximum High Tide versus Salinity Relationship (For the Year 2012)

The double line graph in the figure (3.2.1) gives information about the yearly tidal activity of the Passur River over a time span of 35 years, starting from 1980 which depicts a slight increase in high tide. The Passur is a tidal river of the south-west region of Bangladesh. The Bay of Bengal functions as an origin of salinity in the coastal estuaries. This coastal area lies at 0.9 to 2.1 meter above mean sea level which suffers seriously from tidal flooding. Salt intrudes into the Passur River from the ocean through tidal effects, mixes with fresh water and makes it saline.

And the other figure (3.2.2) represents the relationship between salinity and monthly high tide in 2012. The annual relation between high tide and salinity gives evidence that higher salinity (up to 20 ppt) starts to increase from the month of January and reaches its peak in the month of May and though the magnitude of the tide was high, with the advent of monsoon it starts to recede.

3.3 Temperature and Salinity

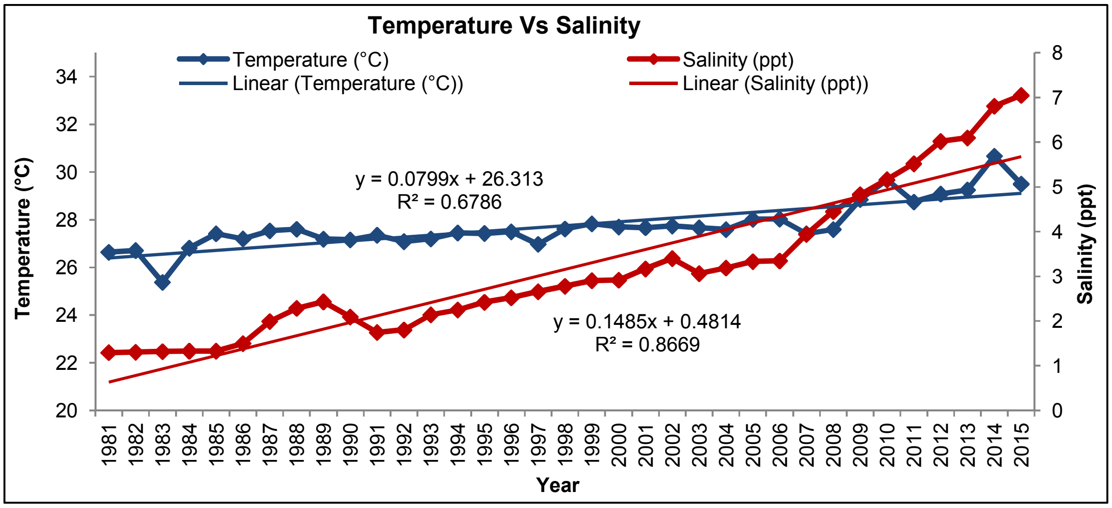


Figure – 3.3: Historical Average Temperature of Khulna versus Salinity of the Passur River (From 1981 to 2015)

The above figure compares salinity with temperature data. With a minimal fluctuation, the overall trend line of temperature shows an increasing pattern. The straight line equation y=0.079x+26.31 (for temperature) shows the relationship between the dependent and independent variables with a correlation coefficient R^2=0.689 which indicates a moderately fitted line.

According to the figure, it is obvious that a relation exists between local temperature and the salinity of the Passur River. In both cases, the positive intercept value indicates that both have been increased simultaneously. In 1981, salinity was 1.30 ppt and temperature was 26.64^{0}C and within the next 34 years, salinity and temperature were 7.05 ppt and 29.50^{0}C respectively.

Actually, rapid enhancement of the salinization process caused by climate change through sea level rise and increased evaporation from higher temperature. Evaporation starts increasing from February and attains its peak in May when maximum temperature occurs.

3.4 Rainfall and Salinity

Rainfall is considered to be a climatic factor which immensely controls the state of salinity. Historical rainfall analysis indicates that over the period rainfall pattern has changed both in magnitude and distribution, providing possible evidence of climate change which influences salinity. Moreover, it is proven that salinity occurs due to the lack of frequent rainfall and the degradation of river flow in the dry season, which is also dominated by rainfall runoff. However, both rainfall and evaporation affect the volume of salt but they do not change the amount of salt.

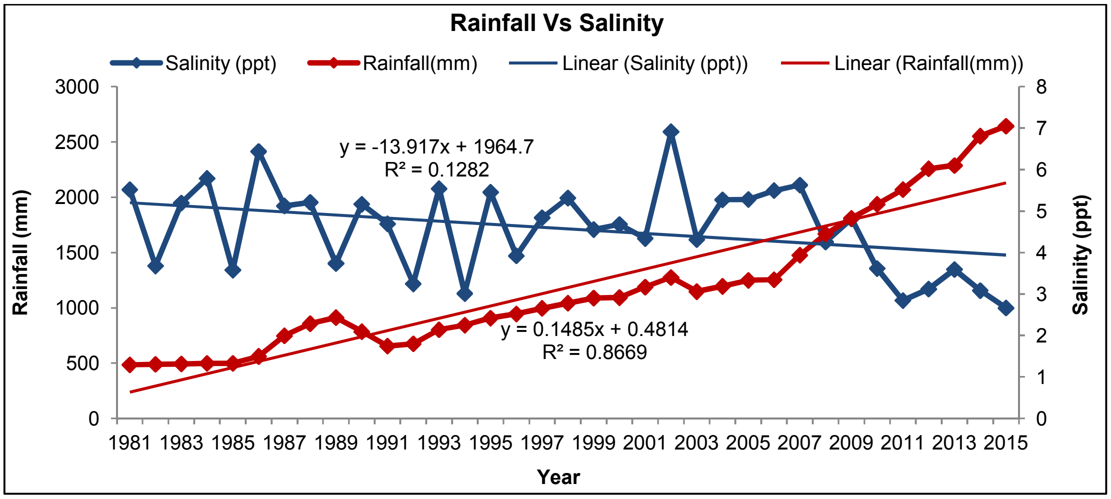


Figure -3.4.1: Annual Rainfall of Khulna versus Salinity of the Passur River (From 1981 to 2015)

The trend line of annual rainfall implies a decreasing tendency. However, the rainfall in Khulna fluctuated significantly from 1981 to 2009 and from then it reduced steeply. Here, the equation is -13.91x+1924 with an R squared value 0.128 that indicates a weak correlation between the dependent and independent variables because the value of R^2 is near 0. The negative value of slope indicates that the value of y decreases as the value of x increases.

Monthly Rainfall and Salinity Relationship:

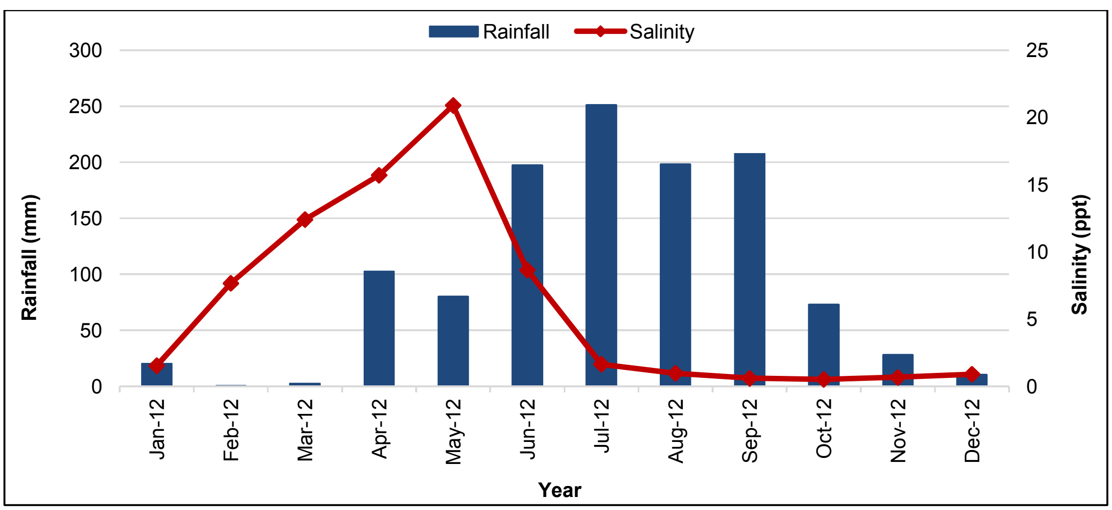


Figure – 3.4.2: Monthly Local Rainfall versus Salinity Relationship (For the Year 2012)

The combination of line and bar graph illustrates an opposed relationship of salinity with local rainfall over a period of 12 months. The Passur River is mainly fed by local rainfall and spill from the Ganges. A simple relationship has developed from the figure of the annual rainfall versus salinity of the Passur River which pointed at a strong converse correlation between salinity and local rainfall. The analysis represents that a decrease in salinity of the Passur River was caused by the heavy rainfall. In the dry season when rainfall fluctuated between 0.3 mm and 80 mm, salinity was higher than 20 ppt and during the monsoon, with the increase in rainfall and rising river stages, salinity level dropped down sharply. As a result, in the wet period, the distribution of salinity near the shore area is lower than the lean period. In an average 75% to 80% of the annual rainfall occur during the monsoon period with steady rain whereas about 10% to 15 % rainfall occur during both the summer and winter period.

3.5 Sea Level and Salinity

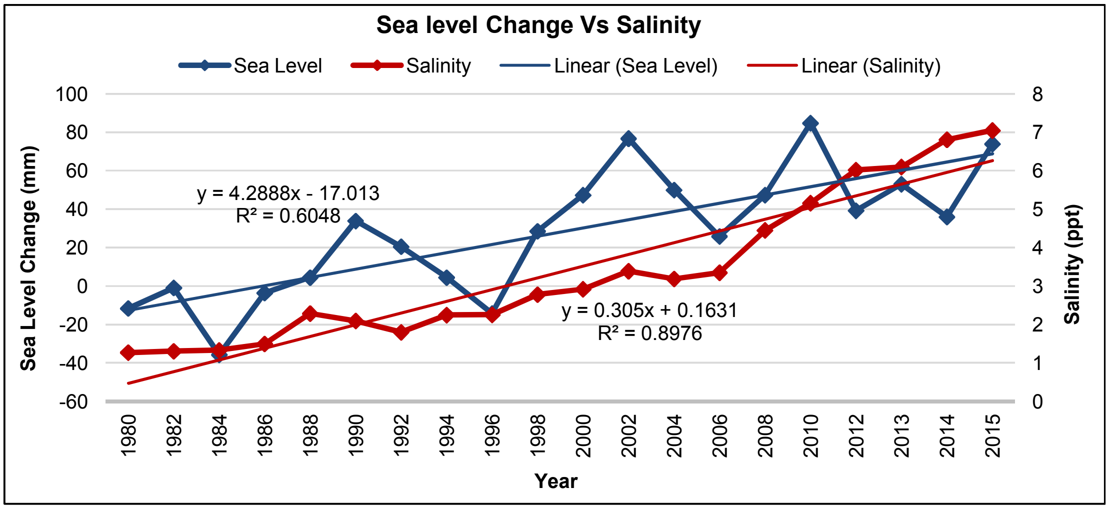


Figure – 3.5: Sea level change at Hiron Point versus Salinity of the Passur River (From 1980 to 2015)

From the above figure, it is apparent that salinity has a direct and drastic relationship with sea level change. The height of sea level at Hiron Point increased markedly from 1980. The straight line equation y= 4.288x-17.01 (for sea level) shows the relationship between the dependent and the independent variables with a correlation coefficient R^2= 0.604, which depicts a considerable congruence for the sea level values. As sea level increases, saline water started to penetrate in coastal rivers being drained by tidal flow.

3.6 Ganges Discharge and Salinity

The southwestern region has been strongly invaded by the reduced flows of the Ganges because rivers of this area originated largely from this mighty river. The average flow in the Ganges at Hardinge Bridge (inside Bangladesh) in the pre-Farakka period was 11,690 m^3/sec (Fig-3.6.1). The minimum flow takes place in March to May and currently, with the drainage failure, it gets down to few hundred m^3/s. This clearly exhibits some irregular flow direction which has given rise to the level of river salinity in the coastal belt of Bangladesh. This figure clearly shows how average salinity at south-west region of Bangladesh started to increase based on upstream diversion. The absence of freshwater force approves the salinity to encroach farther inland.

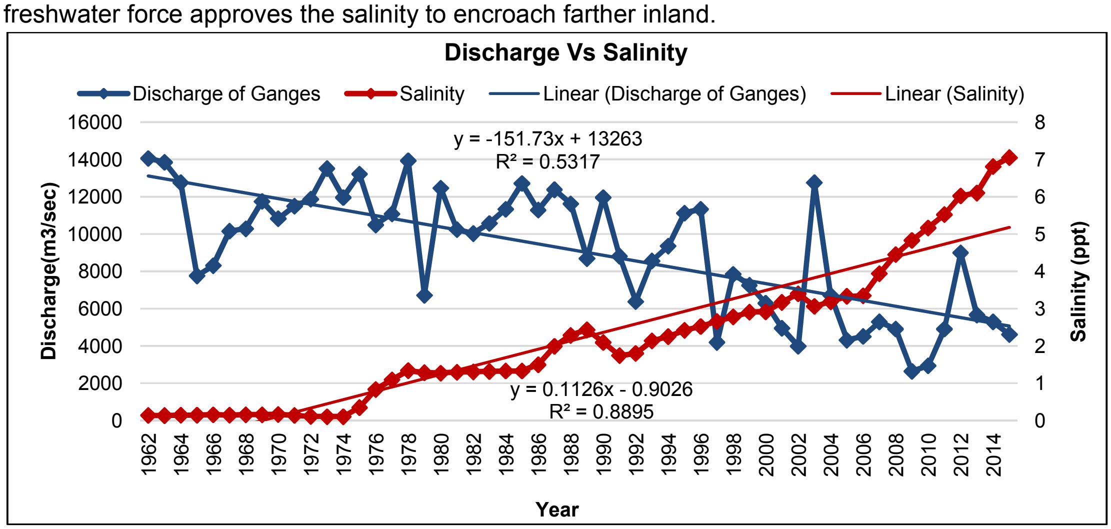


Figure-3.6.1: Average Discharge of the Ganges at Hardinge Bridge versus Salinity of the Passur River (From 1962 to 2015)

The above figure demonstrates a comparison in the amount of freshwater discharge from the Ganges River and salinity of the Passur River. Here, the straight line equation y=-151.7+13263 (for discharge) evidently shows the relationship between the dependent and the independent variables where the negative value of slope clearly indicates that the discharge is declining as the time has passed. The value of R squared (0.531) is moderately correlative. It can be seen that the apparent variations in the river salinity are linked with the alterations in river flow volume. In previous years, salinity concentration was normal of the rivers that receive a freshwater input but currently this flow dropped down at a dreadful rate.

Monthly Discharge of Ganges and Salinity Relationship:

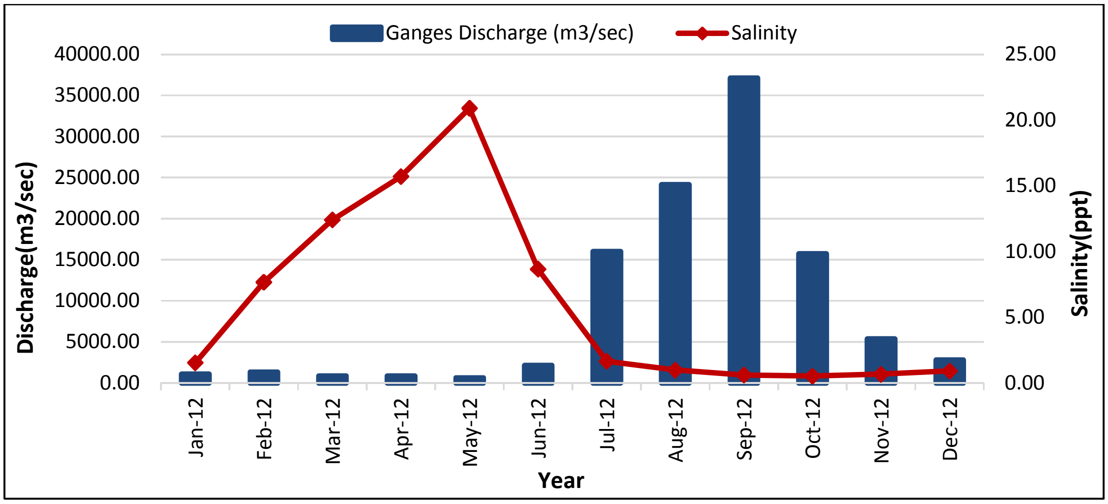


Figure – 3.6.2: Monthly Ganges Discharge versus Salinity Relationship (For the Year 2012)

The monthly distribution of salinity and discharge has shown how discharge conflicted with salinity throughout the year of 2012. As the salinity level in Passur River is greatly influenced by the upstream river discharge, mainly Ganges River, they both maintain a strong relationship. It can be seen that in the first month of 2012, salinity level stood at 1.54 ppt then it started to rise almost linearly to reach about 20.9 ppt in May. The upward trend was suddenly broken and fell dramatically over the next two months when salinity was 0.98 ppt. The number plateaued between 0.61 and 0.91 ppt from September to December.

To sum up, it is well observed that when flow of fresh water was ceased, the salinity of Passur River at Mongla was high and from June, discharge increased as a result salinity levels were at the minimum because freshwater forced the saline water to back the ocean.

3.7: Future Projections: Up to the year 2050

Future Projections of Salinity of the Passur River, Temperature and Sea Level Rise in Southwest Coastal Area for 2050:

3.7.1 Projection for Salinity

For salinity, the equation of trend line is y=0.112x-0.902. Assume 1962-2015 as the baseline year, we can project the salinity of Passur River for 2050 from the equation;

y = 0.112*88-0.902 = 8.954 (Here, the difference between 1962 and 2050 is 88 years)

The future (2050) salinity may reach near 9 ppt where present (2015) salinity is 7.05 ppt.

So, there is a possibility that the salinity of Passur river at Mongla will increase at 8.954 ppt with a correlation coefficient 0.889, that is mesohaline or moderately saline.

3.7.2 Projection for Temperature

For temperature, the straight line equation is y=0.079+26.31. Assume 1981-2015 as the baseline year, we can project the temperature for 2050 from the equation;

y= 0.079*69+26.31 = 31.76 (Here, the difference between 1981 and 2050 is 69 years)

The future (2050) temperature may reach above 31^{0}C where present (2015) temperature is 29.5^{0}C.

So, there is a possibility that temperature of Khulna will increase to 31.76^{0}C with a correlation coefficient 0.678.

3.7.3 Projection for Sea Level

For sea level, the straight line equation is y=4.288x-17.01. Assume 1980-2015 as the baseline year, we can project the sea level rise for 2050 from the equation;

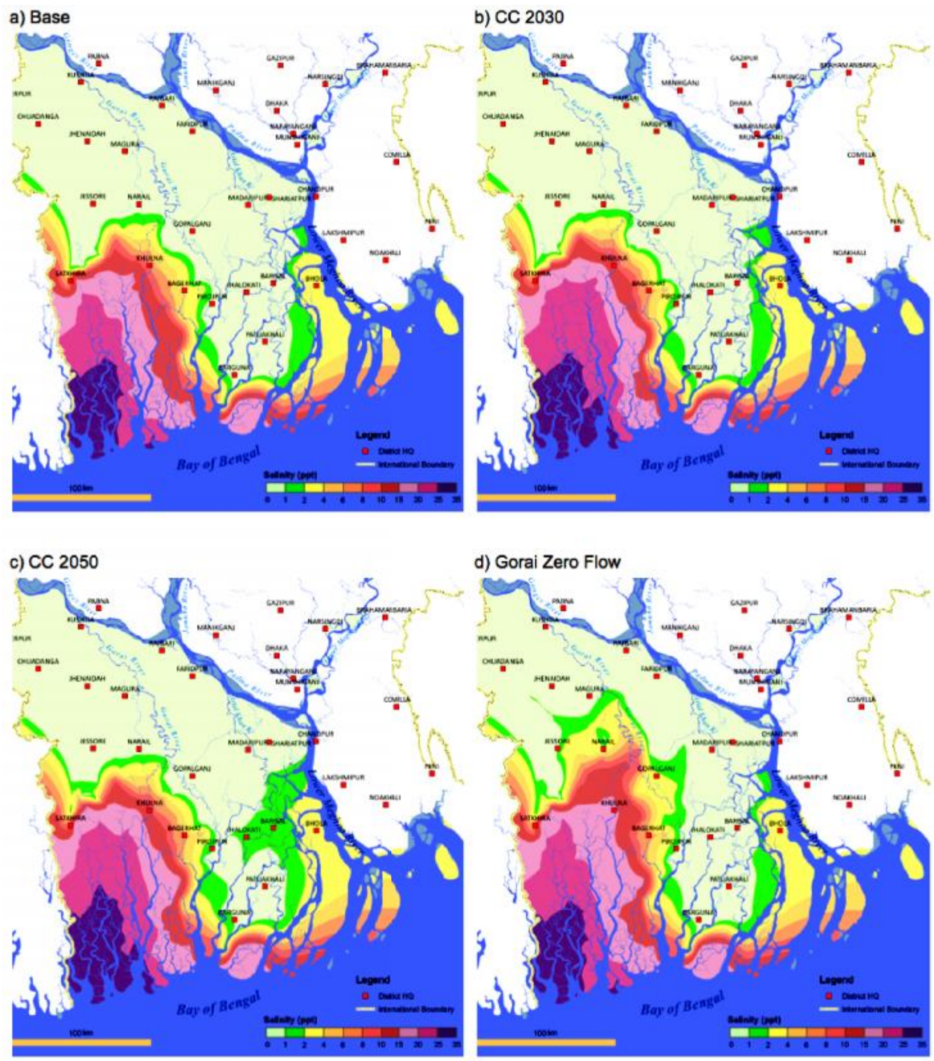
y = 4.288*70-17.01 = 283.15 mm = 28.31 cm (Here, the difference between 1980 and 2050 is 70 years)

The future (2050) level may reach approximately 283 mm where present (2015) sea level is 74.00 mm.

So, there is a possibility that sea level at Hiron Point will rise near 30 cm with a correlation coefficient 0.604.

Table – 3.7: Comparison of Future Projection (2050) of Salinity, Temperature and Sea Level with the Baseline and Present (2015) Scenario

Future Projection for 2050								
Salinity (ppt)			**Temperature (^{0}C)**			**Sea level (mm)**		
Base 1962	Present 2015	Future 2050	Base 1981	Present 2015	Future 2050	Base 1980	Present 2015	Future 2050
0.14	7.05	8.954	26.64	29.50	31.76	-11.61	74.00	283.15



(Baseline Year 2000)

Figure – 3.7: Future Projection of Salinity in the Southern Area (Source: Wahid Palash, Tufts University)

In general, some points are clear from the observation that salinity is constantly increasing in coastal rivers because this area is less elevated from the sea level, scarcity of fresh water discharge and seriously affected on monthly basis by upstream river flow, rainfall and tidal effect. The reduction in the mean monthly discharge of the Passur River is a result of deliberate withdrawal of the Ganges water at Farakka and the environmental impact of this downcast flow is very serious in terms of increased salt-water intrusion in the coastal area which has significant adverse effects on the agriculture and fisheries, infrastructure, forestry, industry, human health and drinking water sectors.

Overall, our findings have reported that climate change phenomenon will cause considerable changes in river salinity in the southwest region of Bangladesh especially during the dry season (November to May) by 2050. According to IWM, for domestic purposes salinity of water should be within 1 ppt and for crop production 4 ppt. But now our river salinity is far beyond that. As a result, requirement of fresh drinking water is becoming a serious issue for the people of coastal areas.

The key visualization of this study is that both climate change and reduction in freshwater inflow from the upstream will convert the present freshwater zones into saline zones and lower saline zones into more saline zones. However, the outcome of the diminishing freshwater flow will be greater than the impact of climate change for the south-western portion.

4. CONCLUSION

The country has already been facing several climatic disasters which are seriously affecting our ecosystems and the socio-economic schemes in the coastal area. In order to diminish their adverse impact, both adaptation and mitigation are needed to be considered as a solution. Adaptation requires to minimizing the negative impacts and hazards caused by sea level rise on living organisms, including human life, property and the environment; on the other hand, mitigation involves global endeavor where the main focus is to impede climate change and sea level rise by emission control. Although Bangladesh ejects an insignificant amount of greenhouse gasses (<0.40%), the problems cannot be overlooked and instant steps should be taken to eliminate its emission.

The study shows that more saline water intrusion will likely to occur during the dry season with the increased sea level rise in the year 2050. If the outflow of exaggerated gases were to keep in a static position, yet it is not likely to control sea level rise properly beyond 2100. With the continuation of SLR, the consequences of extended submersion will accelerate the salinity concentration around coastal areas. Now we should come forward to take some necessary steps such as, emphasize salinity issue in International Forum; more investigation is needed in order to invent salt-resistant crop strains; consider the plants that can grow up in salty soil; storing of additional rainwater for irrigation purposes; develop worldwide awareness about the damage caused by salinity as sea-level is rising; implement standard coastal embankments; the activities like deforestation and carbon emission should be discouraged and finally upland freshwater flow must be increased.

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