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Investigation of soil and water salinity, its effect on crop production and adaptation strategy

H. M. Rasel[1]*, M. R. Hasan[2], B. Ahmed[1] and M. S. U. Miah[1]

[1]Department of Civil Engineering, Rajshahi University of Engineering and Technology, Rajshahi, Bangladesh.
[2]Institute of Environmental Science, University of Rajshahi, Bangladesh.

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Bangladesh is a deltaic country with total area of 147,570 km^2. The major part (80%) of the country consists of alluvial sediments deposited by the river Ganges, Brahmaputra, Tista, Jamuna, Meghna and their tributaries. The coastal region covers almost 29,000 sq. km or about 20% of the country. Moreover, the coastal areas of Bangladesh cover more than 30% of the cultivable lands of the country. About 53% of the coastal areas are affected by salinity. Agricultural land use in these areas is very poor, which is much lower than a country's average cropping intensity. Salinity causes unfavorable environment and hydrological situation that restrict the normal crop production throughout the year. The factors which contribute significantly to the development of saline soil are, tidal flooding during wet season (June to October), direct inundation by saline water, and upward or lateral movement of saline ground water during dry season (November to May). The severity of salinity problem in Bangladesh increases with the desiccation of the soil. It affects crops depending on degree of salinity at the critical stages of growth, which reduces yield and in severe cases total yield is lost. Therefore, it is very important to investigate the present scenario of soil and water affected by salinity on crop production of the study area. It is found from the study area named south-western zone of Bangladesh (selected eight sites of seven Upazila under greater Khulna district) that salinity level increased in April to May and decreased in October to November in every year. It has effect on crop yield in dry season due to increased salinity level. If Ganges water supply has increased in dry season, it reduces the salinity effect in crop production in Khulna. Rainfall also reduces the surfaces soil salinity.

Key words: Salinity, coastal region, cultivable lands, cropping intensity, salinity adaptability

INTRODUCTION

The coastal area covers about 20% of the total area of Bangladesh which is 147,570 km^2 the country and over 30% of the net is cultivable area. It extends inside up to 150 km from the coast. Out of 2.85 million hectares of the coastal and offshore areas, about 0.83 million hectares are arable lands, which cover over 30% of the total cultivable lands of Bangladesh. A part of the coastal area, the Sundarbans, is a reserve natural mangrove forest covering about 4,500 km^2. The remaining part of the coastal area is used in agricultural purpose. The cultivable areas in coastal districts are affected with varying degrees of soil and water salinity. The coastal and offshore area of Bangladesh includes tidal, estuaries and river floodplains in the south along the Bay of Bengal. Agricultural land use in these areas is very poor, which is roughly 50% of the country's average. Salinity causes unfavorable environment and hydrological situation that restrict normal crop production throughout the year.

The freshly deposited alluviums from upstream in the coastal areas of Bangladesh become saline as it comes in contact with the sea water and continues to be inundated during high tides and ingress of sea water

*Corresponding author. E-mail: hmrruet@yahoo.com.

through creeks. The factors which contribute significantly to the development of saline soils include, tidal flooding during wet season (June to October), direct inundation by saline or brackish water and upward or lateral movement of saline ground water during dry season (November to May). The main goal of this research is to achieve the following specific objectives: sought to investigate soil and water salinity condition in south-western zone of Bangladesh as well as the effect of salinity on crop production and unveiling a possible solution for reducing these effects.

People in the southwest region are highly dependent on the natural resource base in sustaining their livelihoods. Agriculture and fishery are important economic sectors, employing a large proportion of the population, and aquaculture is increasingly being pursued as an alternative livelihood option for rural households (Islam, 2003). Major agricultural crops include rice, betel leaves, fruits and vegetables, mustard and oilseeds, coconut and sugarcane. The region is densely populated, and most farm families cultivate the scarce land resources intensively, resulting in land degradation and reduced productivity. This situation is compounded by increasing salinity and water logging which further reduces potential cultivating land by increasing salinity and water logging, further reducing the availability of cultivable land. Fishing provides employment to a large number of families, on a full or part-time basis. In addition to its contribution to the major economic sectors, the natural resource base provides coastal people with materials for building houses, cooking fuel, raw materials for handicrafts, etc. It is clear that people in this region are highly vulnerable to water disaster. Moreover the water disasters which have always plagued Bangladesh due to its natural setting, impacts of anthropogenic interventions are creating further challenges to the country's sustainable development. The predicted impacts of water disaster will only increase the difficulties coastal people face in securing their livelihoods, maintaining health and safety, and achieving sustainable development.

Saline soil

Saline soil contains an excess of soluble salts, especially sodium chloride. In other words, soils that develops under the influence of the electrolyte of sodium salts, with a nearly neutral reaction. Dominant salts are sodium sulphate and sodium chloride, but seldom sodium nitrate, magnesium sulphate, or magnesium chloride. They are non-sodic soils containing soluble salts in such quantities that they interfere with the growth of most crop plants. The pH of the saturated saline soil is usually less than 8.3. These soils are geographically associated with arid, semi-arid, sub-humid and humid areas as well. The estimates indicate that Bangladesh has about 2.8 million ha (Chanratchakool, 2007) of land affected by salinity and poor quality water. The total area includes deltaic floodplains and offshore islands. This comes to about one-fifth of the total areas of Bangladesh and lies around the northern apex of the Bay of Bengal. The saline soils are mainly found in Khulna, Barisal, Patuakhali, Noakhali and Chittagong districts of the coastal and offshore lands (Figure 1). Due to a number of environmental factors the coastal soils are slightly moderately saline on the surface, and highly saline in sub-surface layers and substrata.

METHODOLOGY

Study area

The south western coastal zone is covered by the Sundarbans mangrove forest, covering greater Khulna and part of Patuakhali district. Greater Khulna district consists of nine Upazilas. Out of them four land sites of Jalma (Batiaghata), Krisnanagar (Dumuria), Kismat (Fultola), Bajua (Dakop) and four rivers, viz: Rupsha River (Rupsha), Shailmari River (Koyra), Vadra River (Dakop) and Kazibachha River (Terokhada) were selected as the study sites. These sites were selected to investigate the top soil and river water salinity and their effects on crop production. The study sites are highlighted in Figure 2. The areas lie at 0.9 to 2.1 m above mean sea level. Soil characteristics of the western coastal zone are silty loams or alluvium.

Data collection

The study area was the south western part of Bangladesh more specifically, the Khulna district. In this study, two types of data were collected. The soil and river water salinity data of year 2004 to 2009 for study site was collected from “Soil Resources Development Institute (SRDI, 2009), Khulna” and crop yield data of 2004 to 2009 for Khulna from “Agricultural Extension Institute (AEI, 2009), Khulna”.

Data analysis

From the soil and water salinity data, monthly salinity of 2004 to 2009 was calculated and illustrated in graphs which faciliated better comprehension of top soil salinity pattern of the study area of Jalma (Batiaghata), Krisnanagar (Dumuria), Kismat (Fultola) and Bajua (Dakop) as well as river water salinity pattern of four rivers like Rupsha River (Rupsha), Shailmari River (Koyra), Vadra River (Dakop) and Kazibachha River (Terokhada), under greater Khulna district.

Analysis of topsoil and river water salinities (ECe:ds/m) conditions

Monthly variations of topsoil and river water salinities of the study area in different years are shown in Figures 3 to 6 and 7 to 10, respectively.

IMPACT OF SALINITY OF SOIL AND WATER ON CROP PRODUCTION

Rising of salinity level will decrease agricultural production by unavailability of fresh water and soil degradation. Salinity also decreases the terminative energy and germination rate of some

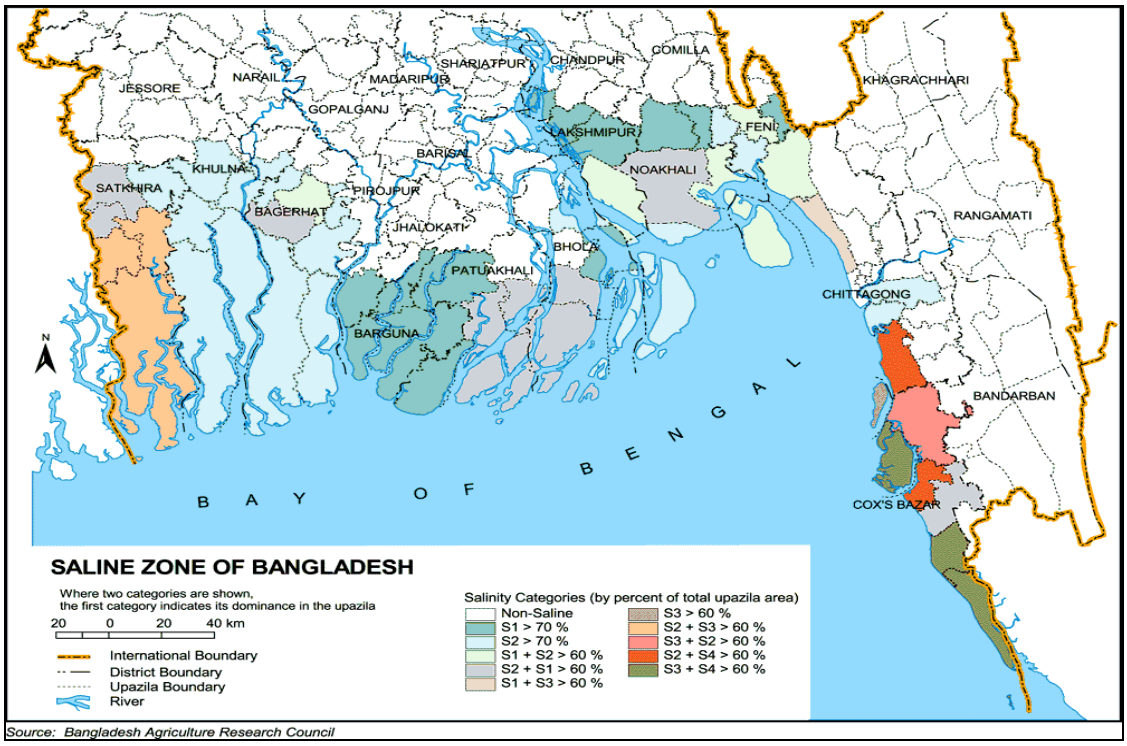

Figure 1. Saline Zone of Bangladesh.

plants (Rashid et al., 2004; Ashraf et al., 2002). Ali (2005) investigated the loss of rice production in a village of Satkhira district and found that rice production in 2003 was 1,151 metric tons less than the year 1985, corresponding to a loss of 69%. The production rate of different types of crops in different Upazila in Khulna districts is shown from Figures 11 to 14.

Salinity adaptation strategy

Worsening sea water storm surges and over use of irrigation have left fields, wells and ponds in parts of southern Bangladesh too salty to grow crops, leading to a growing exodus of farmers from the region. During Cyclones Sidr and Aila, in 2007 and 2009 respectively, sea water was driven into ponds and rivers in Khulna, Bagerhat and Satkhira districts in southern Bangladesh, and some fields remained flooded by sea water long enough to raise levels of salinity in the soil and in underground aquifers used for irrigation. If we can control natural disasters then we can control salinity level. Now farmers on hundreds of thousands of acres in the region are watching their rice crops wither and die before reaching maturity. In some cases, farmers have sown rice plants several times in a season but seen none survive. Binoy Singh, a farmer in Surigati village in Bagerhat district, recently lost nearly his entire 10-acre rice crop to salt contamination. Severe storm surges and sea level rise linked to climate change, as well as over use of irrigation, threaten to make soil salinity a worsening problem across broad areas of southern Bangladesh, a vast and heavily populated river delta region that sits barely above sea level. In the Tala, Debhata and Kaliganj sub-districts under Satkhira district, salinity in wells 70 to 80 feet deep is now 10 times higher than the tolerable limit for rice cultivation, researchers say. This poses a grave threat to food security in southern Bangladesh, and is causing farmers to relocate in search of other work to feed their families. Institute researchers are installing wells in some of the worst hit areas in an attempt to find out whether there is water suitable for irrigation still available deeper underground. In many areas, farmers now have to dig wells at least 500 ft deep to get water that is safe for irrigation. Earlier, such water was available at 200 to 250 ft. Over the last 25 years, sea water from the Bay of Bengal has pushed 40 km inland throughout underground aquifers, replacing fresh water. Topsoil salinity in cropped lands came down to 4.0 ds/m or less at least one month earlier than fallow lands. Such a low salinity level opened up an opportunity to grow modern rice varieties (whether salt - tolerant or not) in the wet season. Taking advantage of rainfall, much earlier than the present cropping schedule offered a yield advantage of about 1.5 t/ha over the present productive level. Slightly saline groundwater was used to irrigate dry season crops. Of all the crops grown only sesame responded positively to irrigation. Yields were not significantly different for any crop between irrigated and rain-fed conditions mostly because about 60 mm rainfall occurred at the pod formation stage of crops, a week after irrigation. Although groundwater was slightly saline, it reduced topsoil salinity when used to irrigate dry season crops. Therefore groundwater can be used to irrigate profitable non-rice crops in the dry season. The marginal rate of return indicated that sesame and mungbean were highly profitable in saline soil environments, but mungbean grown under rainfed conditions maximized farmer's income from dry season cropping. The deepest water table was within 1.0 to 1.5 m below ground surface at both locations. The aquifer was fully recharged and the water table remained either above or close to the soil surface from the last week of June to the first week of December.

DISCUSSION

Out of 2.85 million hectares of coastal and off-shore land, about 1.5 million hectares have been affected by varying

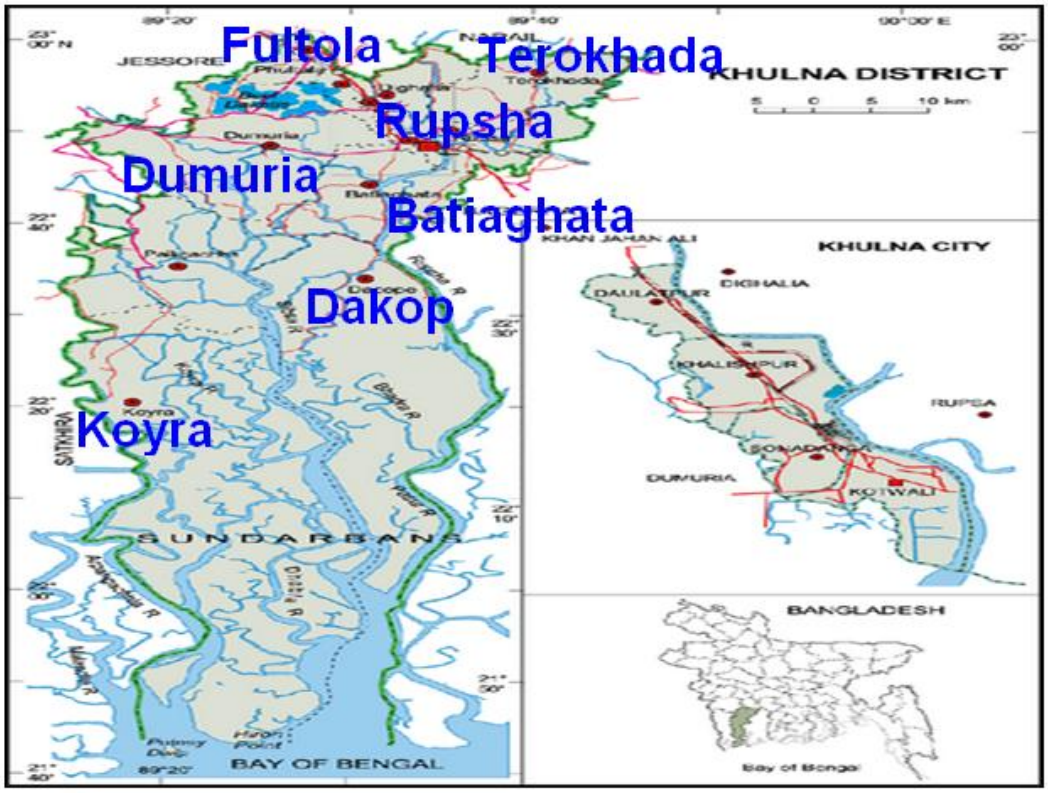

Figure 2. Map showing the study area of South West Zone of Bangladesh (Highlighted zone).

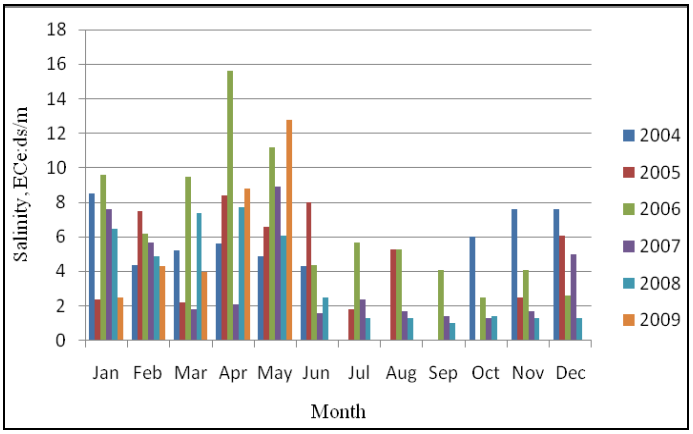

Figure 3. Monthly variation of top soil salinity rate in different years at Jalma **(**Batiaghata Upazila), Khulna.

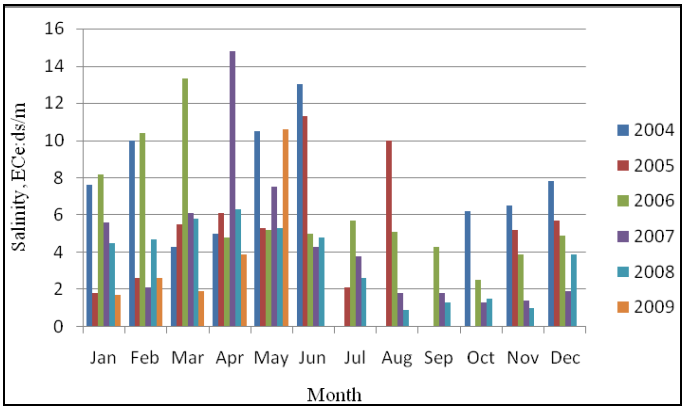

Figure 4. Monthly variation of top soil salinity rate in different years at Krisnanagar **(**Dumuria Upazila), Khulna.

degrees of salinity. The coastal saline soils are distributed unevenly in 64 thanas of 13 districts, covering portions of 8 agro-ecological zones (AEZ) of the country. The larger portions of saline land fall in the districts of Shatkhira, Khulna, Bagerhat. Large fluctuations in salinity level sever time are observed at almost all sites in these regions. The common trend is an increase in salinity with time, from November to December and March to April, until the onset of the monsoon rains. The electrical conductivities (ECs) of the soil and water were lowest in July to November and highest in January to May at all sites. Soil salinity, at any time, is maximum in the surface layers (0 to 15 cm), the salinity gradient being vertically downwards. Subsoil salinity is usually much lower than topsoil salinity. Moderately to strongly saline under groundwater is found within 1 to 2 m below the soil surface at all locations in the dry season. The spatial and

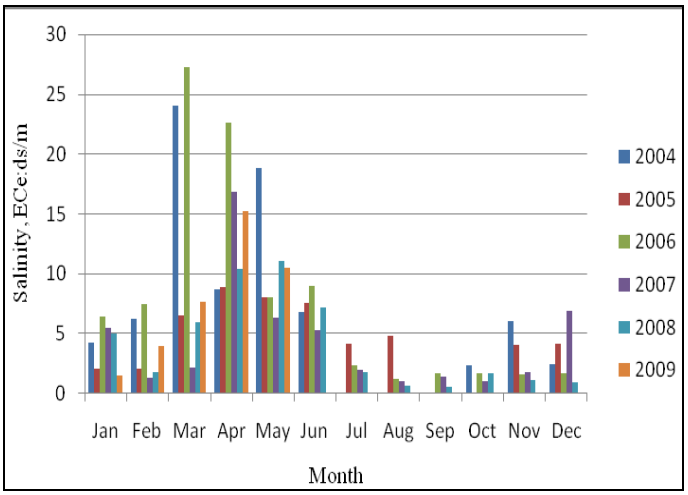

Figure 5. Monthly variation of top soil salinity rate in different years at Kismat (Fultola Upazila), Khulna.

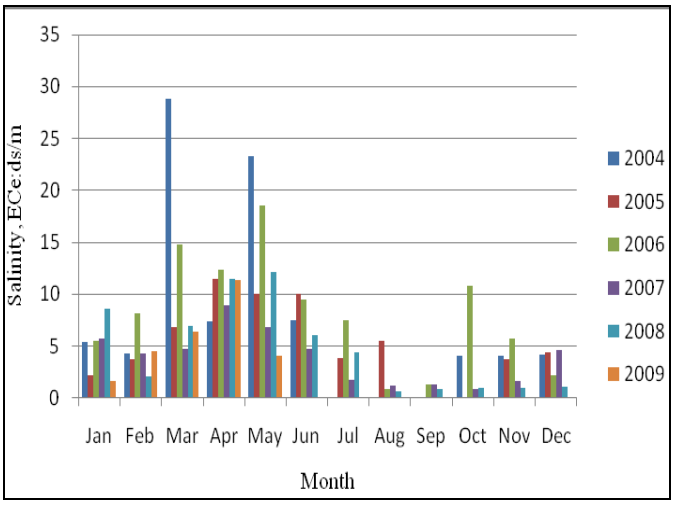

Figure 6. Monthly variation of top soil salinity rate in different years at Bajua (Dakop Upazila), Khulna.

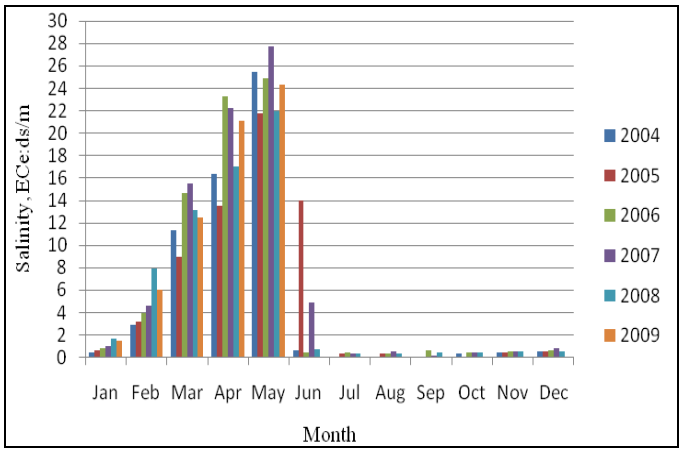

Figure 7. Monthly variation of river water salinity rate in different years at Rupsha River (Rupsha Upazila), Khulna.

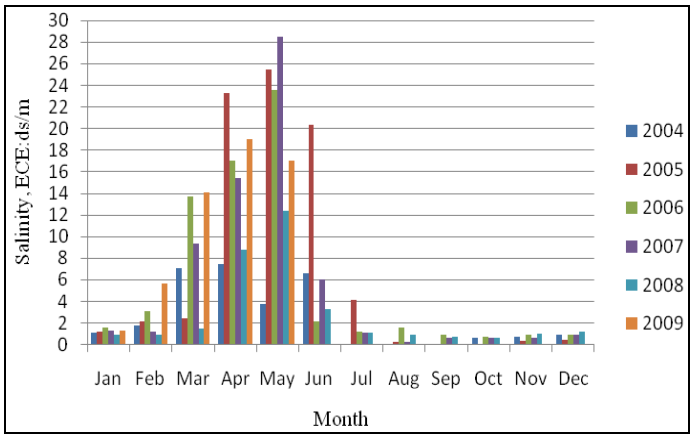

Figure 8. Monthly variation of river water salinity rate in different years at Shailmari River (Koyra Upazila), Khulna.

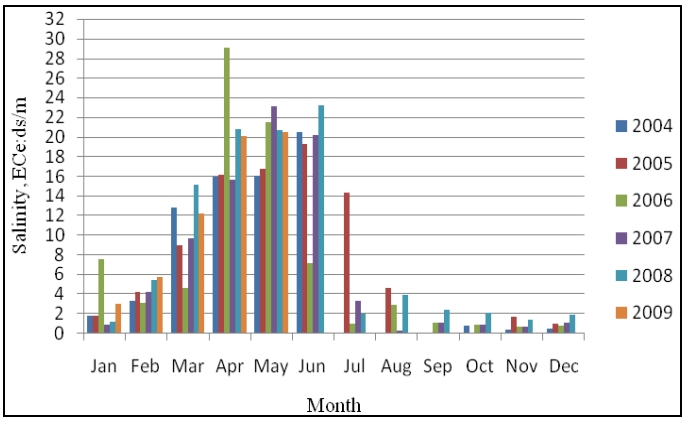

Figure 9. Monthly variation of river water salinity rate in different years at Vadra River, Dakop Upazila, Khulna.

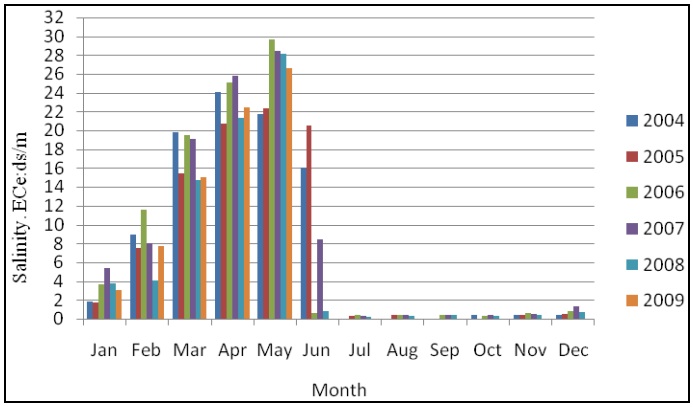

Figure 10. Monthly variation of river water salinity rate in different years at Kazibachha River, Terokhada Upazila, Khulna.

temporal variations in soil salinity indicate the need for independent crop production planning for different locations in the coastal areas. No generalization can be made in this regard.

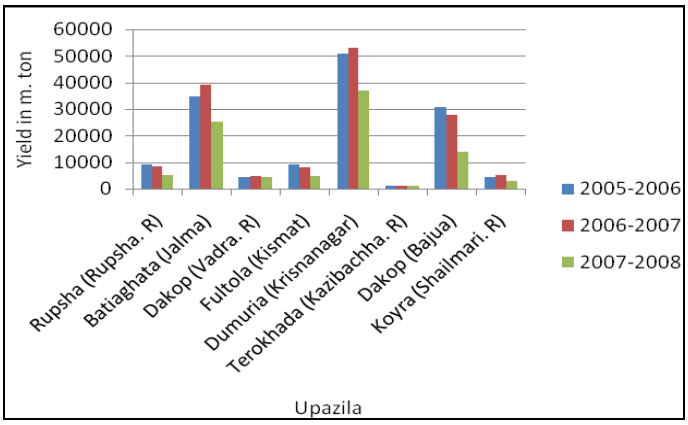

Figure 11. Rupa Aman yield rate at different study sites (Upazilas) in greater Khulna district (in metric ton).

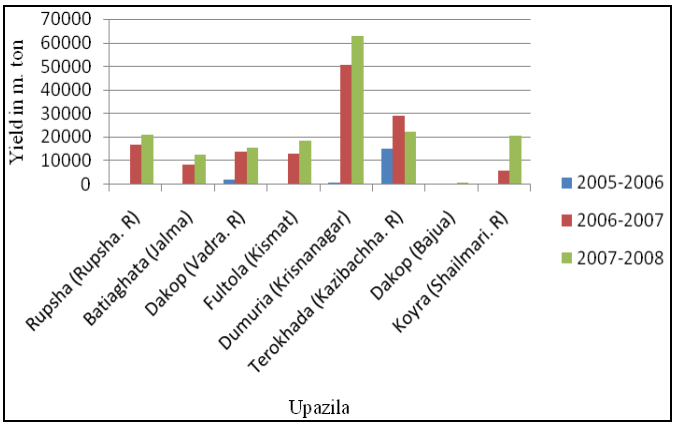

Figure 13. Boro yield rate at different study sites (Upazilas) in greater Khulna district (in metric ton).

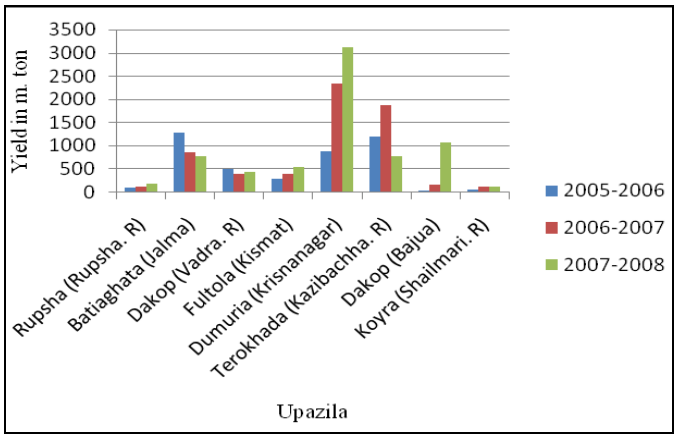

Figure 12. Aman yield rate at different study sites (Upazilas) in greater Khulna district (in metric ton).

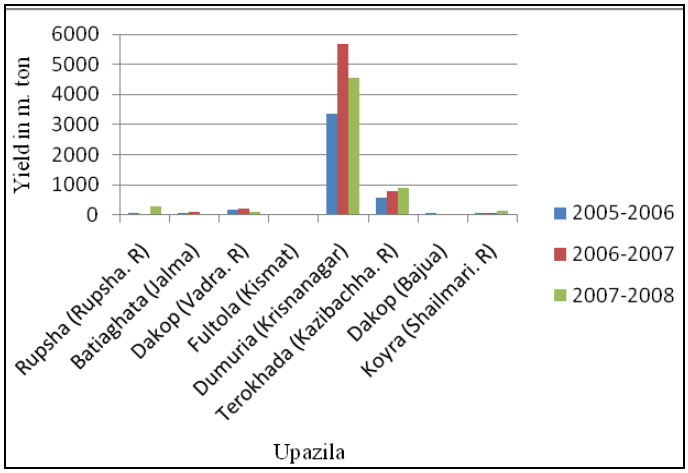

Figure 14. Jute yield rate at different study sites (Upazilas) in greater Khulna district (in metric ton).

Conclusion

It is found that the soil salinity, at any time, is highest in the surface layers (0 to 15 cm), the salinity gradient being vertically downwards. Subsoil salinity is usually much lower than topsoil salinity. Soil salinity indicates the need for independent crop production planning for different locations in the coastal areas. Development and implementation of adaptation policies and taking initiatives for mitigation measures are the right ways to respond to the impacts of rise in salinity levels. From data analysis, it is found that top soil salinity gradually increases from January to May and then it decreases up to December for all (four) sites. Water salinity gradually increases from January to May and then it decreases up to December for all (four) rivers. However, it is found that both top soil and river water are badly affected by salinity for the months of March to May from 2004 to 2009 in all areas studied. The crop production rate decreases in the study area of Dakop, Rupsha, Fultola, and Koyra due to the rising of salinity. In Batiaghata, Dumuria and Terokhada the crop production rate is comparatively high due to presence of low salinity. This research provides some baseline information and understanding with regards to the state of salinity of the study area cope with the salinity adaptability and remedial measure for the lessening of salinity in this region. Development and implementation of adaptation policies and taking initiatives for mitigation measures are the right ways to respond to salinity level rise impacts. More research is indispensable to find solutions to potential problems, in practice and to develop salinity to learnt species for agriculture and fisheries sectors.

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