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Original Article

Soil Nutrient Status, Water Quality, and Cropping Pattern in the Southwest Coastal Region of Bangladesh in a Changing Climate

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ABSTRACT: *Extreme climatic events, including cyclones and tidal flooding, occur recurrently in the southern and southwestern regions of Bangladesh. Cyclonic storm surges and tidal flooding increase soil and water salinity, leading to a decline in soil nutrient status and limiting crop growth and yield. Consequently, there is a critical need to assess the agronomic potential of salinity-affected soils. In this context, the present study was designed to evaluate soil and water nutrient status and cropping patterns in the southwestern region of Bangladesh in 2021. Both soil and water salinity in the study location were highest in April. The soil salinity was observed to be highest at 15.1 dS m^{-1} at Kaliganj upazila of Satkhira district, and the highest water salinity of 26.6 dS m^{-1} was at Batiaghata upazila of Khulna district. The soils of the study locations were low in organic matter content, except in Batiaghata upazila of Khulna district, where the topsoil contained 1.91% organic matter. Total N was found to be low in the study locations. The highest exchangeable Na of 2.2 m.e. 100 g-1 soil was recorded in Batiaghata upazila. The K was estimated to be highest at 0.33 m.e.100 g^{-1} soil in Batiaghata upazila of Khulna district, and the highest available P of 10.89 µgg-1 soil was found in Tala upazila of Satkhira district. Surface water (river or canal) in the study area was of poor quality for irrigation use. In the study area, the main cropping pattern was transplanted aman-fallow-fallow, along with shrimp. The results of this study have the potential to inform strategies to increase agricultural productivity in land areas affected by salinity.*

KEYWORDS: *Climate, Coastal, Nutrient, Salinity, Soil.*

1. INTRODUCTION

The coastal area of Bangladesh covers about 20% of the country and 30% of the net cultivable area. The coastal and offshore area (2.85 million ha) includes tidal areas, estuaries, and river floodplains in the south along the Bay of Bengal, which are vulnerable to climate change due to their geographical position, dense population, and dependence on rivers and agriculture. Major impacts are cyclones, sea level rise, coastal erosion, drought, extreme heat, and river floods. Cyclones and storm surges are common annual or recurrent events during the pre-monsoon and monsoon periods along Bangladesh's coastal belt, due to its geographic location. Over the last 30 years (1990-2020), Bangladesh experienced about 228 extreme events, including cyclones Sidr and Aila, which contributed significantly to soil and water salinization in the coastal region. According to Rahman *et al*. (2017), Cyclone Sidr hit the coastal areas in 2007 with a five-meter sea surge, and millions of people were affected; approximately one million tons of rice crop were washed out, and they also reported that Cyclone Aila hit Bangladesh in 2009 and it caused total damage of US 270 million. The magnitude and extent of salinity have increased following Aila and Sidr, resulting in the degradation of soil fertility and productivity in the southwest coastal part of Bangladesh. In Bangladesh, nearly 4,641,060 people in coastal areas are exposed to the threat of cyclones, ranking 6th among the 89 countries analyzed (Hassan, 2016).

Soil and water resources are essential to life on Earth, having a serious bearing on food and water security, biodiversity, climate, and human well-being (McBratney et al., 2014; Bannari and Al-Ali, 2020). The impacts of soil and water salinization are major issues for Bangladesh, posing a significant threat to food security. The severity of soil and water salinity is increasing over time in a changing climate and is seriously affecting crop productivity. Salinity is a major limiting factor for crop growth and yield. Salinity creates an unfavorable environmental and hydrological condition, restricting normal crop production year-round. The most common effects are nutrient imbalance, low osmotic potential and toxicity of Na^{+} and Cl^{-}, resulting in plant growth inhibition or death (Azipour *et al* 2010 and Aslam *et al*., 2011).

Most of the agricultural land in the southwestern coastal belt remains uncultivated during the dry season due to increasing salinity and the unavailability of high-quality irrigation water. It is important to consider the impact of salinity on soil and water, as they are closely linked and mutually influence one another in natural systems. Information is limited on agricultural soils, mostly on nutrient properties of soil and water quality, as well as cropping patterns in the southwest of Bangladesh.

Systematic studies could play a significant role in developing crop production strategies for a wide range of agroecological conditions. Therefore, the present study has been designed to analyze current soil nutrients, water quality and cropping patterns to generate information for sustainable crop production, which can help researchers and governments take initiatives, particularly in the agricultural sector.

2. MATERIALS AND METHODS

This study was conducted at Gutudia mouza of Dumuria upazila and Jalma mouza of Batiaghata upazila in Khulna district (Fig. 1), and at Zalalpur mouza of Tala upazila and Moutala mouza of Kaliganj upazila in Satkhira district (Fig. 2) to evaluate electrical conductivity and various chemical properties of soil and water. Two rivers, viz. Kazibacha River of Batiaghata upazila, Kapataksha River of Tala upazila and two canals, viz. The Sholmari canal in Dumuria upazila and the Sheali canal in Kaliganj upazila were selected for the study. Based on the Soil Salinity Mapping Unit (SRDI, 2010), one mouza of each upazila representing strongly to moderately saline conditions was selected to collect soil samples for the study. Soil samples were collected from three sampling sites of a selected mouza. The three sampling sites were located within a cultivable field of about 1000 sq m and were about 250 m apart. The sampling sites remained fallow during the study period. Soil and water samples were collected at 15-day intervals from 15 January 2021 to 30 June 2021. The samples were analyzed for chemical properties at the regional laboratories of the Soil Resource Development Institute (SRDI) in Jashore and Jhenaidah, and at the SRDI central laboratory in Dhaka. The studied soil properties included pH, organic matter, total N, exchangeable Na and K, available P, S, and B, and the water properties studied included pH, Ca, Mg, and Na. Mean data on soil and water salinity were illustrated in graphs, which facilitated better comprehension of topsoil salinity patterns and water quality, as well as the cropping patterns of the four studied locations. An informal interview collected data on cropping patterns. The sample size was 50, and a random sampling technique was used to collect the data. Salinity data are presented in bar and line charts using Microsoft Excel. Cropping pattern data were summarized and presented as percentages.

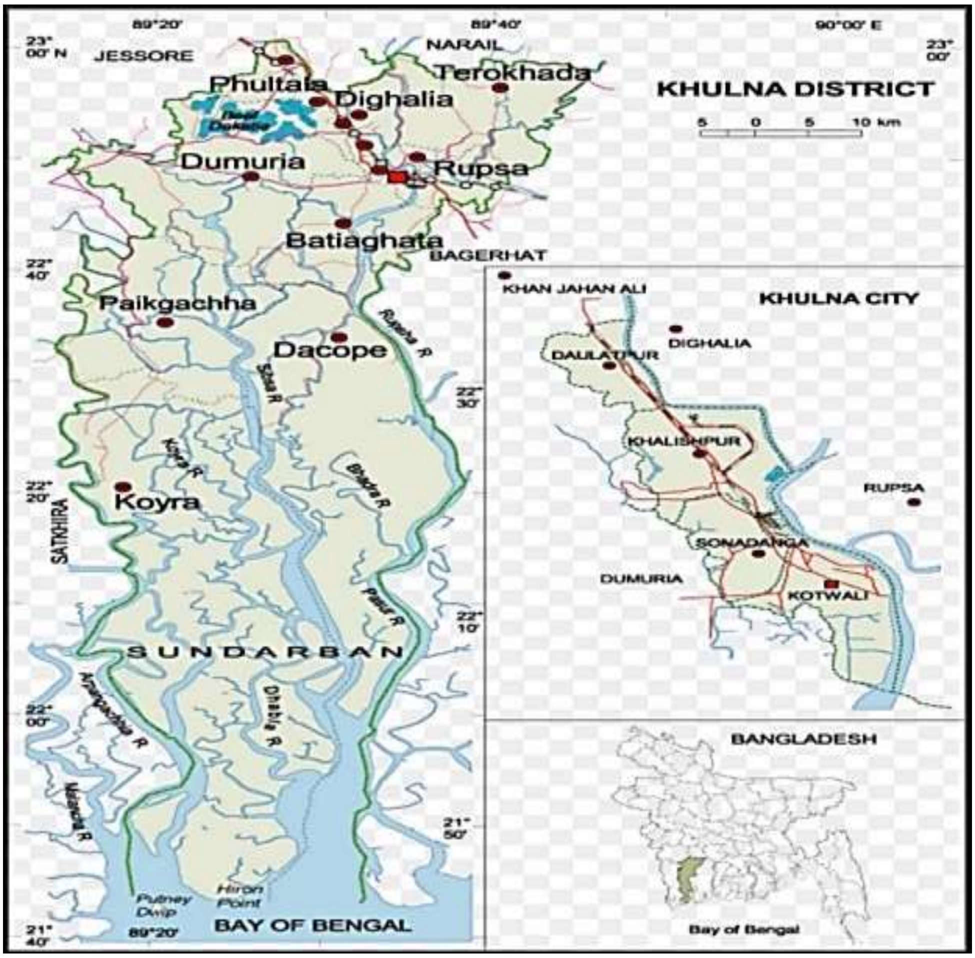

FIGURE 1 Study Area of Khulna District

FIGURE 2 Study Area of Satkhira District

3. RESULTS AND DISCUSSION

3.1. SALINITY OF SOIL AND WATER

Soil and water salinity increased in March and April in the study area. The average intensity of soil salinity was highest at 15.05 dS m^{-1} at Kaliganj in April (Fig. 2), and the average intensity of water salinity was also highest at 26.56 dS m^{-1} in April at Batiaghata among the four studied locations (Fig. 3). Water salinity was found lowest in June at Dumuria, Batiaghata, Tala and Kaliganj upazilas. Soil salinity was also recorded lowest in June at the four studied locations. The average soil salinity was higher in March and April, and salinity concentrations fell due to early rainfall in May and June. The present results are similar to those of various researchers (Hossain et al., 2012; Mahmuduzzaman et al., 2014; and Hasan et al., 2019) who have investigated the impact of salinity intrusion in coastal areas. It may result from climate change impacts in coastal areas, where land comes into contact with seawater due to continuous inundation during high tides, seawater intrusion through cracks, and, in some cases, cyclone-induced storm surges. During the dry season, low flow of fresh water from upstream causes salinity to develop in these areas. The river/canal water in the study area was found to be extremely saline during the dry season and unsuitable for irrigation of any crop. It is also reported that salt concentration in water with an EC of more than 2 dS m-1 in fine-textured soils often creates salinity problems for crop production (SRDI, 2010).

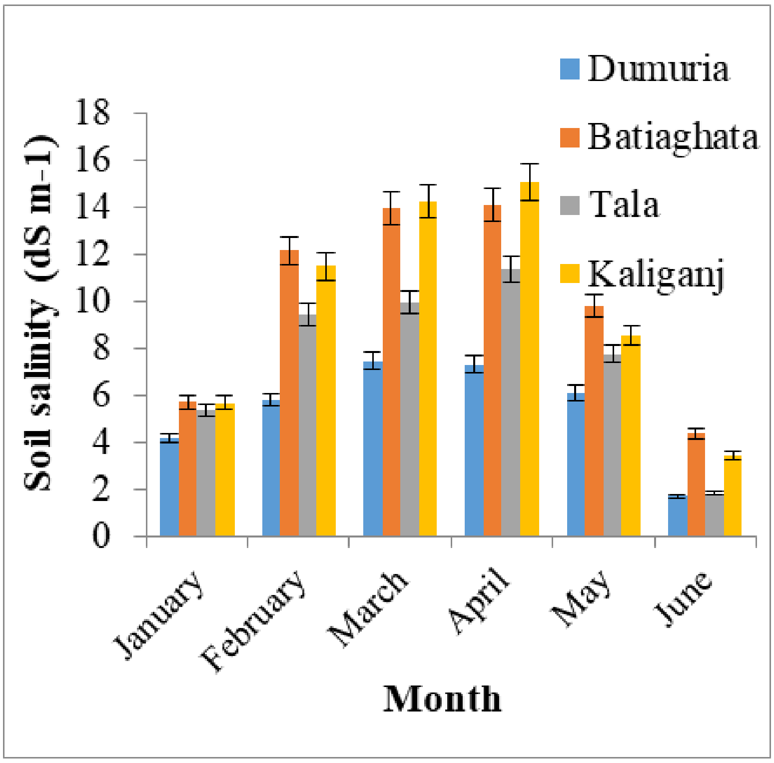

FIGURE 3 **Salinity Levels of Soil of the Study Area**

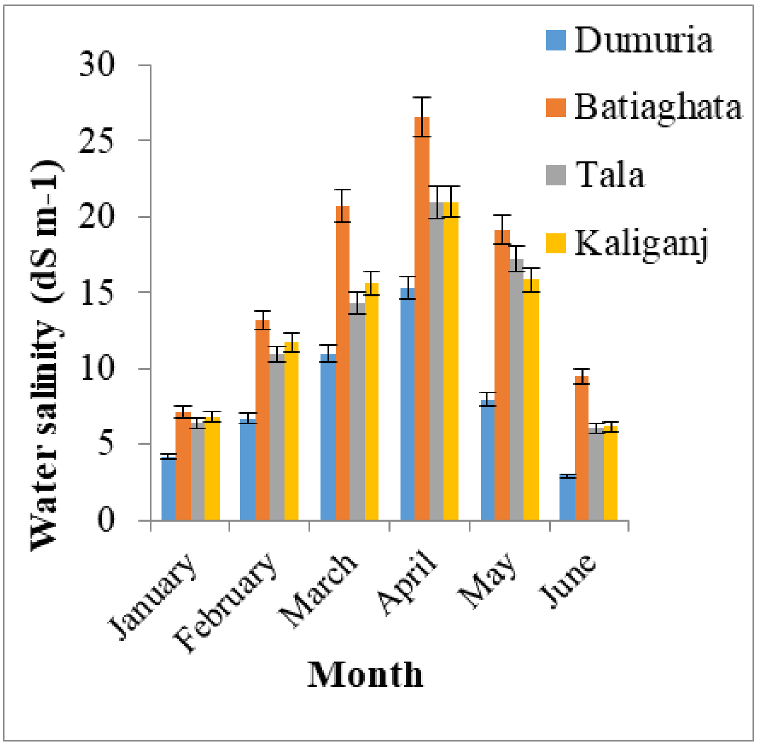

FIGURE 4 **Salinity Levels of Water of the Study Area**

3.2. CHEMICAL CHARACTERISTICS OF SOIL

Soil fertility is an important factor for crop production. In general, Bangladesh's coastal regions are low in soil fertility. The soil pH values in the study area were near neutral, ranging from 7.05 to 7.30 (Table 1), and were considered nearly neutral (FAO, 2008). Organic matter content of the topsoil of the study area was found to be in the low to medium category. It was low at Dumuria (1.34%) and Kaliganj upazila (1.58%), and medium at Batiaghata (1.91%) and Tala upazila (1.79%) (Table 1). Masum *et al. (*2017) also reported low organic matter content in their study, indicating poor physical condition of the coastal soils and the need for additional fertilizers and manures for successful crop production (Jamil *et al*., 2020). Total N was very low at all locations except Batiaghata, where it was in the low-level category at 0.15% (Table 1). The highest amount of exchangeable Na of 2.2 m.e.100 g^{-1} soil was recorded at Batiaghata upazila, and the 2^{nd} highest Na of 2.1 m.e.100 g^{-1} soil was at Kaliganj upazila. Na was estimated at 1.4 m.e.100 g^{-1} soil at Dumuria upazila, while the lowest amount of Na of 0.91 m.e.100 g^{-1} soil was observed at Tala upazila (Table 1). The available K was observed in the high category at Dumuria (0.31 m.e. 100 g^{-1} soil), Tala (0.28 m.e. 100 g^{-1} soil), Batiaghata (0.33 m.e. 100 g^{-1} soil) and Kaliganj upazila (0.32 m.e. 100 g^{-1} soil). Available P was observed to be very low at Kaliganj (6.98 µg g^{-1} soil), low at Tala (10.89 µg g^{-1}), Dumuria (8.95 µg g^{-1}), and Batiaghata upazila (8.53 µg g-1). S content was found in the medium category, and B content was observed in the high category at all locations. The agrochemical properties of the study area's soil are consistent with the previous results of Masum *et al*. (2017).

TABLE 1 Chemical Characteristics of Soils of the Study Area

Location	pH	OM	Total N	Na	K	P	S	B
		(%)		m.e. 100 g^{-1}		µg g^{-1}		
Gutudia, Dumuria, Khulna	7.15	1.34	0.08	1.4	0.31	8.95	9.57	0.75
Jalma, Batiaghata, Khulna	7.00	1.91	0.15	2.2	0.33	8.53	12.10	0.66
Zalalpur, Tala, Satkhira	7.30	1.79	0.09	0.91	0.28	10.89	9.40	1.16
Moutala, Kaliganj, Satkhira	7.05	1.58	0.07	2.1	0.32	6.98	14.51	0.95

3.3. CHEMICAL CHARACTERISTICS OF WATER

The results of the study presented in Table 2 indicated that the water pH at four locations ranged from 7.6 to 8.6, with the highest pH of 8.6 observed at Batiaghata upazila and the lowest pH of 7.6 at Dumuria upazila. The pH values of 7.7 and 7.8 were estimated in Kaliganj and Tala upazilas, respectively. The estimated Ca of water ranged from 0.12 to 0.19 cmol $L^{-1,}$ with the highest Ca of 0.19 cmol L^{-1} found at Tala upazila and the lowest Ca of 0.12 cmol L^{-1} was recorded at Dumuria upazila. The 2^{nd}-highest Ca of 0.17 cmol L-1 was observed at Kaliganj, which was higher than the Ca estimated at Batiaghata upazila (Table 2). The maximum Mg concentration of 24.2 cmol L-1 was recorded in Tala upazila.

In comparison, the lowest Mg of 24.1 cmol L^{-1} was observed at Kaliganj upazila. The Mg concentration was estimated at 24.14 and 24.2 cmol L-1 in water from Batiaghata and Dumuria upazilas, respectively (Table 2). The data presented in Table 2 also showed that the exchangeable Na in water varied from 8.1 to 12.2 cmol L-1, with the highest Na of 12.2 cmol L-1 recorded at Batiaghata upazila and the 2nd-highest Na of 10.3 cmol L-1 at Tala upazila. The lowest Na concentration, 8.1 cmol L-1, was recorded in Dumuria upazila, which was lower than that recorded at Kaliganj upazila. The chemical properties of soil and water samples were found to be toxic and not suitable for crop production. Similarly, Alam et al. (2017) reported cations, anions, and soil and water conductivity in the Kalapara coastal belt at extremely toxic levels. The intensity and extent of these anions' and cations' toxicity across the southwest coastal region of Bangladesh are increasing with sea level rise, high temperatures, drought and inundation from extreme cyclones.

TABLE 2 Chemical Characteristics of Water of the Study Area

Locations	pH	Ca (cmol L^{-1})	Mg (cmol L^{-1})	Na (cmol L^{-1})
Sholmari canal, Dumuria, Khulna	7.6	0.12	24.2	8.1
Kazibacha River Batiaghata, Khulna	8.6	0.16	24.1	12.2
Kapataksha River Tala, Satkhira	7.8	0.19	24.2	10.3
Sheali canal Kaliganj, Satkhira	7.7	0.17	24.1	10.0

3.4. CROPPING PATTERN

Rice, sesame, jute, pulses, vegetables, mustard and fruits are cultivated in the studied saline area. The study area of Dumuria was under medium-low land. Fallow –transplanted aman is the most dominant cropping pattern in this area, and 40% of farmers follow this pattern. The fallow–fallow- shrimp mixed transplanted aman pattern is followed by 30% of farmers. A few farmers grow sesame or vegetables during the Kharif season, and 10% of farmers follow the boro–shrimp (fallow) pattern (Table 3). The location Batiaghata was medium-low land. The dominant cropping pattern in this area is fallow–fallow-transplanted aman mixed shrimp, and 74% of farmers in this location practice this pattern. Only 14% of farmers in Batiaghata cultivate watermelon, sesame or vegetables during the rabi season, and 12% practice sole shrimp culture. The fallow–fallow transplanted aman mixed shrimp pattern is practiced by 56% of farmers in the studied area, and the boro-shrimp (fallow) pattern is followed by 30% of farmers. A few farmers are following a mustard/vegetables-fallow-transplanted aman cropping pattern (Table 3). The study area in Kaliganj upazila was medium-low-lying land. Shrimp (fallow) culture is dominant in the study area of Kaliganj upazila. 70% of farmers in Kaliganj upazila are following sole shrimp (fallow) culture. Fallow–fallow-transplanted aman mixed shrimp, as well as boro-shrimp cropping pattern, are also followed in this area. Only 4% of farmers cultivate vegetables or pulse crops, and they follow the vegetables/pulse-fallow-transplanted aman cropping pattern. KGF (2023) reported that the Fallow–T Aman–Fallow is the dominant cropping pattern in the Khulna, Bagerhat and Shatkhira districts, which is also visible in our current study.

TABLE 3 **Current Cropping Pattern in the Study Area**

Study location	Sample size	Cropping pattern	Frequency	Percentage (%)
Upazila-Dumuria (Mouza-Gutudia)	50	i) Fallow-fallow-transplanted aman ii) Fallow-fallow-shrimp mixed transplanted aman iii) Fallow-sesame/vegetables- transplanted aman iv) Boro-shrimp (fallow)	20 15 10 5	40 30 20 10
Upazila-Batighata (Mouza-Jalma)	50	i) Fallow–fallow- transplanted aman mixed shrimp ii) Vegetables / watermelon / sesame-fallow - transplanted aman mixed shrimp iii) Shrimp (fallow)	37 7 6	74 14 12
Upazila-Tala (Mouza-Zalalpur)	50	i) Fallow –fallow-transplanted aman mixed shrimp ii) Boro-shrimp (fallow) iii) Mustard/ vegetables-fallow- transplanted aman	28 15 7	56 30 14
Upazila-Kaliganj (Mouza-Moutala)	50	i) Fallow-fallow- transplanted aman mixed shrimp ii) Shrimp (fallow) iii) Boro-shrimp (fallow) iv) Vegetables/ pulse- fallow-transplanted aman	8 35 5 2	16 70 10 4

4. CONCLUSION

Based on the results of the present study, it is concluded that soil and water salinity were highest in April in Kaliganj and Batiaghata upazilas, respectively. Soil and water salinity were the lowest in June across the studied locations. Available K was in the high category in the soil at both locations, but available P and total N were in the low category; S was medium, and B was in the high category under the study area. The dominant cropping pattern of the study area was fallow–fallow-transplanted aman with mixed shrimp. There is an urgent need to develop a strategy based on soil and water conditions to identify suitable crop varieties and bring fallow saline land under cultivation.

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