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ASSESSMENT OF SOIL SALINITY AND HEAVY METAL CONTAMINATION IN AGRICULTURAL ZONES FROM BARISHAL TOWARDS BARGUNA, BANGLADESH

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ABSTRACT

In certain regions of Bangladesh, salinity negatively impacts the physical and chemical characteristics of the soil. To achieve the study's goals, samples were taken from agricultural locations, and soil sampling was examined using a random sampling technique at 0–13 cm depth. The research's findings demonstrated that the study area's salinity was rising daily, which impacted vegetation and crops based on the salt level. In the districts of Barishal, Jhalokathi, Patuakhali, and Barguna, the research was carried out to ascertain the saline state of the soil in the following areas: Kather Ghor, Runshi, Parshivpur, Mahishkata, Subidhkhali, Gorua, Bodorkhali, and Lobongola. Therefore, the current study suggests a significant management strategy to lower salinity at Parshivpur (794 µS/cm), Mahishkata (578 µS/cm), Bodorkhali (751 µS/cm), and Lobongola (762 µS/cm) regions. Furthermore, at every station in the research region, the mercury levels were higher than the FAO's permissible limit; Subidhkhali had the highest value, while Bodorkhali had the lowest. Because heavy metals are bad for agricultural productivity, the levels of Cd at Parshivpur, Mahiskata, Bodorkhali, Lobongola, and Subidhkhali were higher than the WHO's allowable limit. The range of EC (µS/cm) for the soils was 498 to 762, indicating moderate to high salinity. The levels of total K, Na, Mg, Ca, Fe, Cr, Cd, Hg, Pb, and Zn were medium to low, and the amount of salt that had accumulated was moderate to low. Given the current state of our nation's soil salinity, more implementations and coordination of the relevant policies should be required for particular consideration in decision-making.

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KEYWORDS

Soil Salinity, Electrical Conductivity (EC), Heavy Metals, Minerals, pH, Agriculture, Bangladesh.


INTRODUCTION

Soil Salinity has a significant impact on agriculture everywhere in the world. (Machado & Serralheiro, 2017).Soil salinity is a significant global issue, with approximately 1 billion hectares of land affected, 30% of which is due to human-induced salinization (Hopmans et al., 2021). Research reveals that 11.73 million square kilometers have been salt-affected in the last 40 years – an area 20% bigger than the US. But the continents with the highest salt-affected areas are Asia (particularly China, Kazakhstan, and Iran), Africa, and Australia. The research also found that Brazil, Peru, and Sudan have the highest annual rate of increase in soil salinity.Although existing research agreed that salt-affected areas are expanding, these new findings suggest that the total area of salt-affected soils has been highly variable, showing both decreasing and increasing trends on both national and continental scales. (cosmosmagazine.com, 2020, December 16). This has led to a decrease in global soil organic carbon stocks by 2100 (Raj Setia, 2013).

The impact of salinity on soil and plant properties has been well-documented, with detrimental effects on soil physio-chemical and biological characteristics, plant metabolism, and the abundance and distribution of soil microbes and organisms (Singh, 2009). The historical perspective of soil salinity highlights the long-standing nature of the problem, with various causes such as flooding, over-irrigation, seepage, and silting (Shabbir A. Shahid, Soil Salinity: Historical Perspectives and a World Overview of the Problem, 2018). A report depicts the spatio-temporal distribution of soil salinity, represented as soil EC classes over Central Asia in 1990, 2000, 2010, and 2018. (Measho, May 2022).

Bangladesh's coastline region is home to 28% of its population and 20% of its land area (Islam M. , 2004). The most significant chemical factor in coastal areas of Bangladesh is salinity.In addition to depleting fertile land, salinity also reduced company production, decreased agricultural output, and damaged infrastructure(Bhaban 2019). With the drying of the soil in the coastal area throughout the winter, salinity intensity, and severity are increasing.20% of irrigated land is affected by soil salinity, which also severely lowers crop production(Qadir et al., 2014). Salinity is the key factor affecting the land and water in coastal areas(Ahmed et al., 2014). Bangladesh's coastal regions have experienced a rise in the rate of saline intrusion. According to a comparison of the salt-affected area from 1973 to 2009, around 0.223 million ha (26.7%) of new land had salinity-related problems throughout the previous 40 years(Biswas et al). In coastal areas, the pH of the soil ranges from 6.0 to 8.4(Haque, 2018). Bangladesh's coastal zone has a gross area of 144,085 hectares and a net cropped area of 83,416 hectares (Islam,2006.). According to (FAO, 2003), soil salinity makes the environment unfavorable for tree growth.Crop yield, crop intensity, agricultural output levels, and people's quality of life are all significantly lower than they are in other regions of the nation(Haque, 2018).

Bangladesh's coastal areas will have a net 0.5 million decline in rice output as a result of a 0.3 m rise in sea level (Bank, 2000).Due to the salt being diluted in the root zone of the standing crop, the severity of salinity is lessened during the wet monsoon(Khanam et al., 2020).Rising salinity levels in waterlogged areas, several species of shrubs, herbs, and grass that are utilized for fuel or other domestic purposes are continuously lost(Khanom, 2016). Soil salinity is thought to be mostly to blame for decreased farming intensity in the coastal area, which is necessary to ensure the effect of salt intrusion on trees. (Abedin et al., 2012). Although there had been numerous research on soil salinity, none had yet been done to determine the salt level of agricultural soil in the districts of Barishal, Barguna, and Patuakhali. But below, in the areas listed below, is an overview of a few related studies on soil salinity.

Soil salinity in Bangladesh, particularly in the coastal areas, is a significant threat to agriculture and livelihood. The total affected land has increased over the years, with 53% of the coastal areas being affected (Haque S. A., 2006). The causes of salinity intrusion include geographical location, river flow, polder management, sea level rise, and shrimp culture (Mahmuduzzaman, 2014).

The Barisal division in Bangladesh faces significant challenges related to soil salinity. The effects of salinity on soil and crop yield have been observed in the coastal areas of Bangladesh, including Barisal (Mahmud, 2010). Remote sensing has been used to map and monitor soil salinity in other regions, providing a potential method for assessing the total soil salinity condition in Barishl (Akhtar Abbas, 2013). However, more specific research is needed to directly address the total soil salinity condition in the Barisal division. (Kashif Solangi, 2019).The coastal areas of Barisal, Jalokathi, Patuakhali, and Barguna districts in Bangladesh are significantly affected by soil salinity, with an increase in affected land from 0.833 to 1.056 million hectares between 1973 and 2009 (Mohammed Shawkhatuzamman S. R., 2023). Remote sensing and GIS techniques have been used to assess soil salinity in Barguna Sadar Upazila, but the effectiveness of these methods is still being explored (Billal Hossen, 2022). Studies in the Patuakhali district have found that the topsoil is particularly sensitive to salt stress, with some villages being seriously affected by salinity (Sabnaj Khanam, 2020).As a result, the water quality in the Payra River, Bishkhali River, and Bighai River has decreased due to siltation and increasing salinity, posing a threat to the ecosystems. (SRDI, . Saline Soils of Bangladesh, Soil Resource Development Institute (SRDI), SRMAF, 2010).

The total condition of soil pH worldwide varies significantly, with factors such as agricultural use, soil type, and depth influencing the phosphate regime and overall pH levels (M. Vasbieva, 2021) (Ping, 2003). Soil pH has been found to influence the chemistry, dynamics, and biological availability of phosphorus, with inorganic phosphorus being particularly affected by pH levels (Benjamin L Turner, 2013). In the red soil region of South China, for example, soil pH decreased from 5.66 to 4.74 between 1982 and 2018, before increasing to 4.96 (Yuye Shen, 2021) (Subhadip Saha, 2021). These findings highlight the complex and dynamic nature of soil pH in Asian soils and the need for sustainable management practices.

The pH of the soil in Bangladesh varies across different regions and is influenced by factors such as parent materials and physiography (K. Egashira, 2003).In unfavorable ecosystems, the soil is generally low in nutrients, with pH ranging from slightly acidic to neutral (P. Saha, 2016). The fertility status of most soils is low to very low, with 65.7% being acidic and 25.7% alkaline (N. Shil, 2016). However, specific data on the total condition of pH in Bangladesh soil is not provided in these studies. The presence of organic matter and saline water can influence the transformation of inorganic phosphorus in the soil (Sabnaj Khanam, 2020) (B. Regmi, 2004). In Muzaffargarh district, Punjab, Pakistan, the majority of soil samples had a pH between 8.5 and 9.0, indicating alkaline soil (Zeeshan Akram, 2014). (K. Egashira, 2003) found that the phosphorus status of paddy soils, a key component of agricultural land in Bangladesh, varied significantly based on physiography. This suggests a potential impact on the levels of dissolved oxygen and total dissolved solids. Similarly, (S. Islam, 2006) highlighted the contamination of agricultural soil by arsenic, which can affect the overall soil quality and potentially impact the levels of dissolved oxygen and total dissolved solids. (Bhuiya, 1987) emphasized the importance of organic matter in soil, which can also influence these levels. (A. A. Zabir) further discussed the impact of wastewater irrigation on major nutrient status in soil, (Guo-li Liao, 2008). The Lublin coal mining region in Poland also showed increased heavy metal concentrations with higher silt-clay fraction and organic carbon content (Tadeusz Filipek, 1990). These findings underscore the widespread and varied impact of human activities on soil heavy metal contamination.

A review of heavy metal contamination in Asian agricultural land found that farmland soil in many Asian countries, including China, is polluted with heavy metals, posing a risk to human health (Md. Abul Kashem, 1999). This is particularly evident in industrial zones, where the pollution level of heavy metals such as Cu, Zn, Pb, and Cd is high. A range of studies have assessed the mineral and heavy metal content in Bangladesh soil. (M. Akter, 2013) found varying levels of organic matter, mineral nutrients, and heavy metals in different regions, with heavy metal contamination not significantly observed. Similarly (K. Begum, 2014)identified high levels of heavy metal pollution, particularly from Cd and Cu, in the soils of Bogra city. These studies collectively indicate a complex and varied picture of mineral and heavy metal content in Bangladesh soil, with significant contamination in some areas.

In Barisal, the highest concentrations of heavy metals were found near a textile industry, with a decrease in pollution levels as distance from the industry increased (M. Begum, Heavy metal contents in soils affected by industrial activities in a southern district of Bangladesh, 2016). However, a study in the northern part of Bangladesh found significant enrichment of heavy metals in coal mine-affected agricultural soils, (Mohammad A H Bhuiyan, Heavy metal pollution of coal mine-affected agricultural soils in the northern part of Bangladesh, 2010). These findings suggest that the presence of heavy metals in the soil is influenced by industrial and mining activities. The soil in the Barishal and Barguna districts of Bangladesh has been found to have varying levels of organic matter, mineral nutrients, and heavy metals (Akhtar Abbas, 2013)

The objective of the subsequent case study is to fill in some of the remaining knowledge gaps regarding the current saline state of agricultural soil in the districts of Barishal, Barguna, and Patuakhali. Thus, it aims to study to explore soil salinity and heavy metal status from Barishal to Barguna district and to investigate soil salinity variation from inland towards the sea as well as to analyze the effects of salt on the chemical properties of soil in various locations in the Barishal, Barguna, and Patuakhali districts.

The southern part of Bangladesh, including the Barishal and Barguna districts, has also been found to have heavy metal pollution in coal mine-affected agricultural soils. After reviewing all the papers related to my paper I found that no work has been done specifically in these areas regarding soil salinity. Soil salinity has been a great concern in recent years in Bangladesh. That’s why this research will be effective in the assessment of soil salinity in the southern part of Bangladesh.

METHODOLOGY

The total area of the Barguna District is 1939.39 km2. It borders the Patuakhali district to the east. 1831.31 sq km make up the Barguna District (barisal division), which is situated between latitudes 21°48' and 22°29' north and 89°52' and 90°22' east (https://en.wikipedia.org/wiki/Barguna, 2023). Due to the various rivers that cut through the Barisal Division, it was given the moniker Dhan-Nodi-Khal, Ei tine Barishal (https://en.banglapedia.org/index.php/Barisal_Division, 2023). The Patuakhali District is bounded to the north by the Barisal District, to the south by the Bay of Bengal and the Barguna District, to the east by the Tetulia River and the Bhola District, and to the west by the Barisal District. (https://en.banglapedia.org/index.php/Patuakhali_District, 2023).

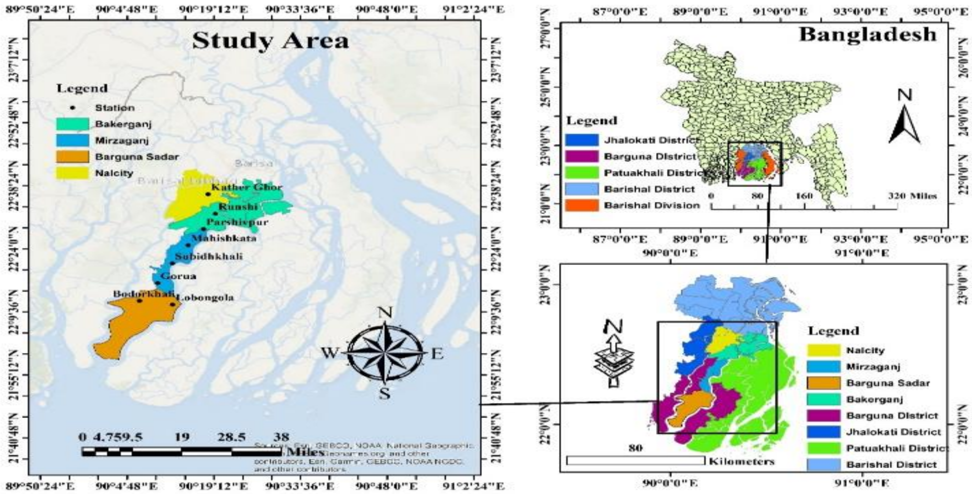

Figure 1: Showing the locale of the study area

Sampling point

Eight soil samples were gathered from the districts of Barishal, Patuakhali, and Barguna. The whole study conducted in the districts of Barguna, Barishal, and Patuakhali is based on field data that was gathered from several sites and bolstered by secondary data from the study region.

Data Collection And Processing

Direct soil sample collection from the Barguna, Patuakhali, and Barishal areas provided the primary data. The Barishal region, which is close to the Kritonkhola River, is where the three soil samples were taken. However, two soil samples were taken from the Barguna region, and three were taken from the Patuakhali area, which is close to the Payra River.Samples of soil were taken from each site at three different soil depths: 0–15 cm, 15–30 cm, and 30-45 cm. Table 1 provides the sampling location's global positioning system (GPS) reading. An auger was used to gather soil samples from each site. The collected soil samples were carried to the laboratory, air dried, broken down large macro aggregates, ground, and passed through a 2-mm sieve to remove weeds and stubbles from the soil. Soil is collected by composite sampling. Chemical analysis of the soil sample was done after Acid Digestion in the laboratory of the Bangladesh Rice Research Institute and Barishal University CDM Science Laboratory. Chemical analysis was done for electrical conductivity, pH, TDS, DO, Ca, Mg, Na, Pb, Zn, Hg, Fe, Cd, Cr, potassium, and contents following standard methods(using ICP-OES, BRRI).

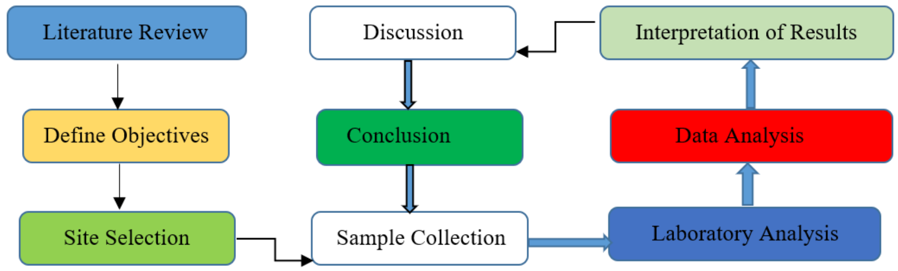

Figure 2: Methodological Workflow of the Present Study

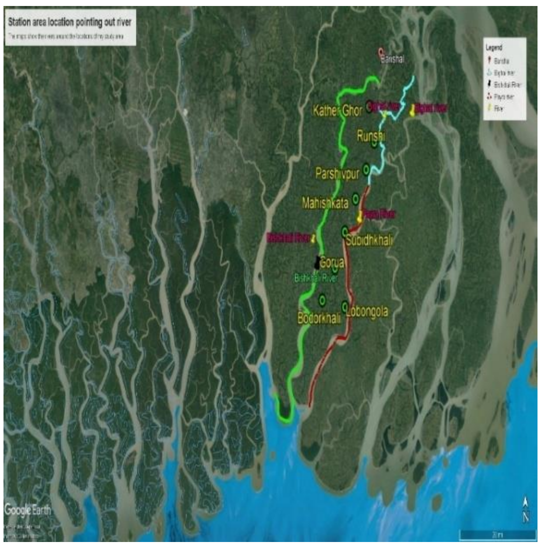

Figure 3: Showing the River point of the study area

The secondary data was mainly collected from the forest, agriculture, soil, and water-related sectors of the study area in Barguna, Barishal, and Patuakhali district, and all other literature was collected from published sources available in the books, national and international journals, publications newspapers, web sites and others published and unpublished documents of Government and non-Government. Pre-testing of the sample collection technique was done in Barishal and the final field study was done on 22 February 2023. The collected information was compiled to make a meaningful paper. In the course of compilation, sincere advice from my supervisor was taken from time to time. After sorting information, data are then analyzed and compiled sequentially and systematically. SPSS version 10.0 has been used to analyze the collected data.

RESULTS

The research work was accomplished to determine the soil salinity of the coastal area in the Barguna, Patuakhali, and Barishal districts. Some of the data have been presented and expressed in table(s) and others in figures for the case of discussion, comparison, and understanding. The analysis of the variance of data with respect to all the parameters has been shown in the Appendix. The results of each parameter have been discussed and are possible.

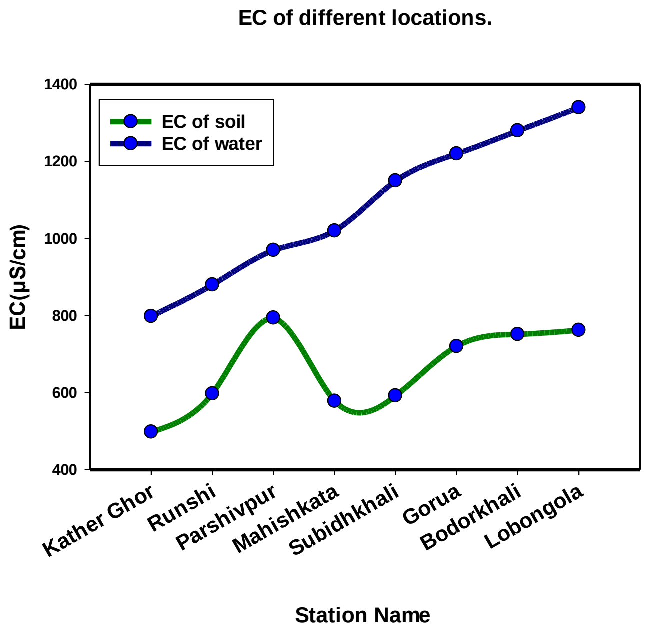

Figure 4: EC of different locations

EC of agricultural soils at Kather ghor varies 398 to 400 µs cm-1. In Runshi EC varies from 442 to 450 µs cm-1 and in South Parshivpuri EC of soil were 794 µs cm-1. EC of all these agricultural soils varies from 498 to 794 µS/cm which expresses the medium status of salinity according to the (Landon, 2014) reported that Bangladesh has 3 million hectares of land affected by salinity, mainly in the coastal and south-east districts, with EC values ranging between 750-2250 µS/cm. The highest EC value was found at Parsivhpur (EC = 794 µS/cm) and the lowest value was recorded at Katherghor (EC = 498 µS/cm). The highest EC value of the region indicated that the area is slightly salinity-affected.The value of EC gradually increased to 794 at Parsivhpur but suddenly it declined at Mahiskata which is 578 µS/cm.The reason behind this fluctuation can be the distance from the river water source as Parsivhpur is close to the river Bighai and Mahiskata is slightly far from the river point. Then subidhkhali has higher salinity as it is also close to river Payra. Consequently, it increased in amount ranging from 578 to 762.

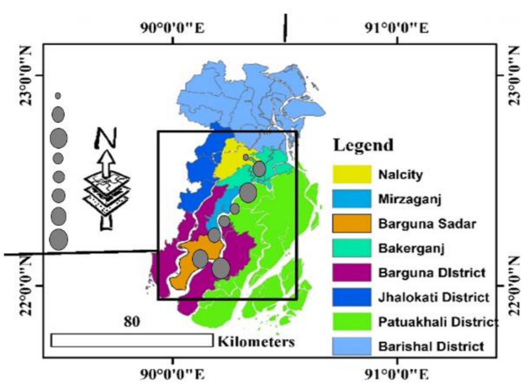

Figure 5: soil salinity flux across to the south central coastal zone of Bangladesh

*Remarks: This sign ⬤ indicates the trend of soil salinity flux across to the south central coastal zone of Bangladesh

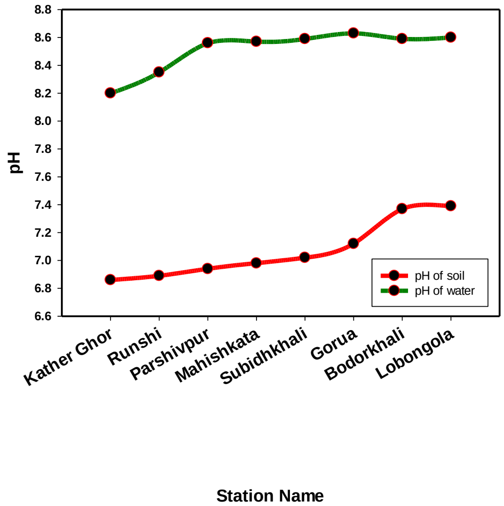

Figure 6: PH of different locations

At Parshivpur, the pH values were 6.94 which is slightly acidic according to USDA. The pH value of the agricultural soil at lobongola ranged from 7.4-7.8 pH range are slightly alkaline according to USDA. Overall, the PH values of study areas are neutral and slightly alkaline. (Haque S. A., 2006) reported that the soil reaction values (pH) range from 6.0-8.4 in coastal areas of Bangladesh with the exception of Chittagong and Patuakhali where the pH values range from 5.0-7.8. He also found that most of the soils are moderate to strongly alkaline. Although there is an adequate supply of water and nutrients in the soil,found that salt-affected soil's pH limits water and nutrient uptake. (Akhtar Abbas, 2013).(Benjamin L Turner, 2013) investigated the impacts of salinity on crop agriculture in south-central coastal zone of Bangladesh and found pH level 7.99.The ideal range of pH in soil is 5.5 to 7.5 because most of the plant nutrients are available in this stage. In the current study area, most of the soil was alkaline (pH > 7.5).

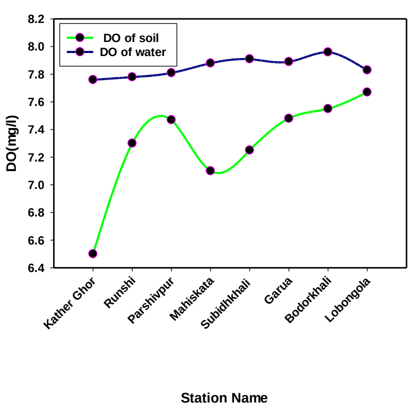

Figure 7: DO of different locations.

The research areas' respective Dos were 6.50 in Kather Ghor and 7.30 at Runshi, which was a good amount. However, it went from 6.91 at Bodorkhali to 7.47 in Parsivhpur, 7.10 and 7.15 at Subidhkhali and Garua, and finally 7.53 at Lobongola, which was a favorable number for crop output. Diffusion and aeration, photosynthesis, respiration, and breakdown all continuously impact dissolved oxygen concentrations.

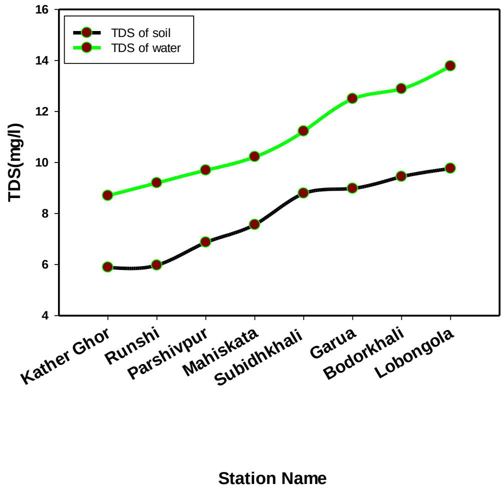

Figure 8: TDS of the water and agricultural soil of different locations.

The highest amount of TDS was found at Lobongola in Barguna District which was 2.99. The amount of TDS was increased gradually from Katherghor to Lobongola. Human activities such as agriculture, irrigation, water use, industry processes, and mining can increase the TDS level.

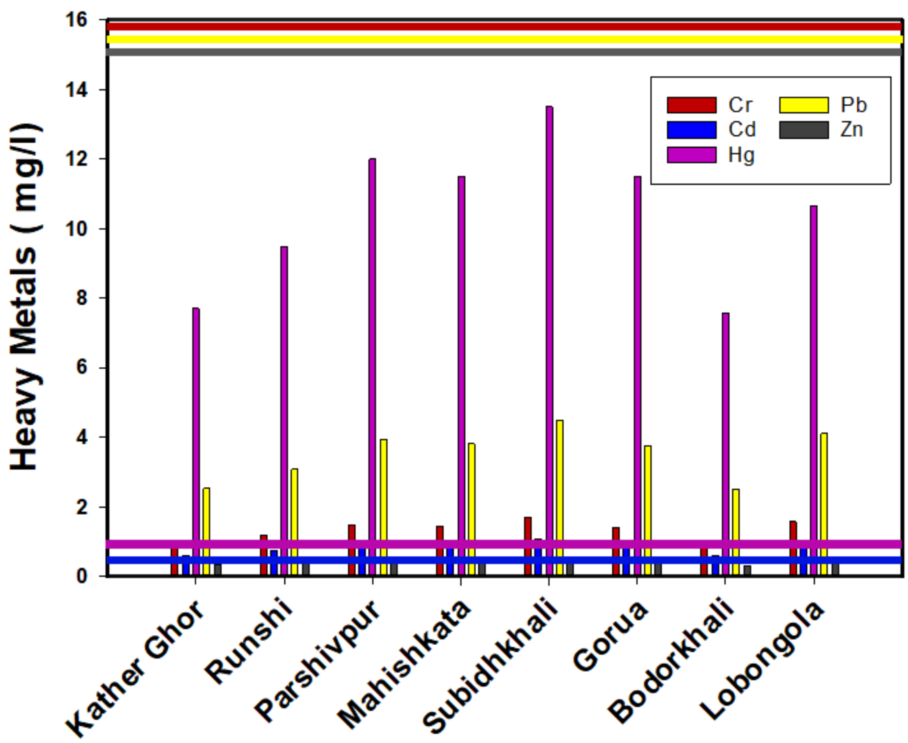

Figure 9: Soil heavy metals of different agricultural areas of different locations

Remarks: The horizontal color bar indicates the respective standard element of the minerals as well as same colour indicates the same element. The unit of the elements is in mg/l.

The amount of Cd was highest in Subidhkhali and lowest in Bodorkhali and that was 1.07 mg/l and 0.61 mg/l, while the permissible limit of calcium in soil is 0.8 mg/l. So, the amount of Cd contained in the soil of Subidhkhali at Patuakhali crossed the allowable limit of Cd in the soil. But the amount in Katherghor was also good although it is the lowest in amount. The amount of Hg was highest in Subidhkhali and Parshivpur and lowest in Kather ghor and Bodorkhali was 13.5 mg/l, 12.00 mg/l, and 7.70 mg/l, the amount looks so high than the standard range. The standard limit of Mercury in soil is 1.00 mg/l. The rate of Cr in Subidhkhali was 1.68 mg/l which was the highest among the collected samples. For Zn and Pb the amount of highest and lowest is the same which is at Patuakhali and Brishal which was 4.50 mg/l and 2.53 mg/l. The permissible of Lead in soil is 85 mg/l. Considering the industries the overall value of heavy metals in the agricultural soil is Hg>Pb>Cr>Cd>Zn.The amount of Hg passed beyond the permissible limit of FAO at every station of the investigation area among them the highest value was at Subidhkhali and the lowest at Bodorkhali.

Soil Minerals From Different Agricultural Areas Of Different Locations

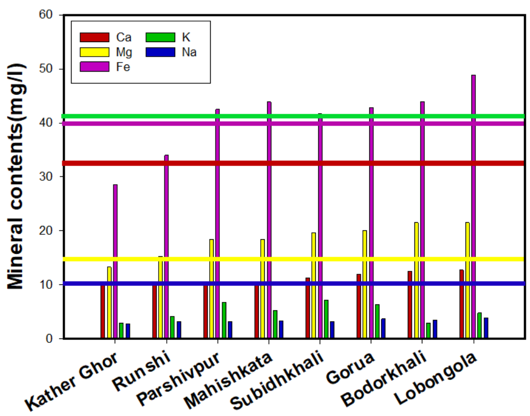

Figure 10: Soil minerals of different agricultural areas of different locations

Remarks: The horizontal color bar indicates the respective standard element of the minerals as well as same colour indicates the same element. The unit of the elements is in mg/l.

From the above bar -chart we can see that the the amount of Ca was highest in Lobongola and lowest in Kather ghor and the amount was 12.78 mg/l and 9.90 mg/l, while the standard limit of calcium in soil is 32 mg/l.So, there is a good amount of Ca contained in the soil of Subidhkhali at Patuakhali.The standard range of sodium in soil is 10 mg/l. Considering the industries the overall value of minerals in the agricultural soil is Fe>Mg>Ca>Na>K.The amount of Mg passed beyond the permissible limit of FAO at every station of the investigation area among them the highest value was at Lobongola and the lowest at Parshivpur.On the one hand, a good amount of mineral content is good for soil and crop production as well.

Table 1: Correlation matrix between the characteristics of the agricultural soil

	PH	EC(µS/cm)	TDS(k Ω.cm)	DO(mg/l)
PH	1			
EC(µS/cm)	0.650127	1		
TDS(k Ω.cm)	-0.16396	-0.6196971	1	
DO(mg/L)	0.309598	0.68912253	-0.37094685	1

Table 2: Pearson Correlation matrix between the characteristics

	Ca	Cd	Cr	Fe	Hg	K	Mg	Na	Pb	Zn
Ca	1									
Cd	0.233756	1								
Cr	0.217229	0.99858	1							
Fe	0.753497	0.622671	0.605795	1						
Hg	0.026888	0.928177	0.941651	0.467044	1					
K	0.010949	0.849767	0.870594	0.417079	0.970967	1				
Mg	0.890027	0.470712	0.458667	0.939195	0.340538	0.323788	1			
Na	0.883948	0.391942	0.383235	0.831116	0.187976	0.17189	0.845663	1		
Pb	0.196498	0.995142	0.997976	0.595164	0.958372	0.897289	0.451712	0.357826	1	
Zn	0.137003	0.982007	0.980202	0.516855	0.892625	0.813623	0.33715	0.327841	0.973264	1

The correlation matrix between the characteristics of the agricultural soil is determined in the present study which is collected from Kather Ghor, Runshi, Parshivpur, Mahiskata, Subidhkhali, Gorua, Bodorkhali, and Lobongola.Total Pb showed a significant positive relationship with Zn. (Naher, 2011) studied the correlation matrix for physical and chemical properties of soil in these areas. The study proposes measuring effects carefully and implying appropriate change even though the salinity level is advantageous for rice to protect the interior coast from suffering like external coastal districts.

Remarks = Unit of the elements is in mg/l. ** and * mean correlation significant at the 0.01 and 0.05 levels, When the coefficient =+1 there is a perfectly positive linear equation. Mg: total Mg content, Fe: total Fe content, Ec: electrical conductivity, Ca; total Ca content, K: total K content, Cr; total Cr content, Cd; total Cd content Zn; total Zn content, Pb; total Pb content, Hg; total Hg content, Na; total Na content.

Regression Analysis

The regression results are as follows:

$$y= \beta_0+\beta_1 x_1+ \beta_2 x_2+\cdots+\beta_k x_k+\epsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

$$y=\beta_0+\beta_1 x+\epsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

Fe=14.0024+0.9984Ca+0.5479Mg+0.4567Hg\{Fe} = 14.0024 + 0.9984 \{Ca} + 0.5479 \{Mg} + 0.4567 \{Hg}

Hypothesis Testing

For each coefficient (β1, β2, β3\beta_1, \beta_2, \beta_3), we perform hypothesis testing:

Null Hypothesis (H0):

Since all p-values are less than 0.05, we reject the null hypothesis for each coefficient. This means that Ca, Mg, and Hg are significant predictors of Fe levels.

The regression model explains 87.5% of the variability in Fe levels (R-squared = 0.875). This analysis provides insights into how Ca, Mg, and Hg levels influence Fe levels in the soil.

Independent t-test

The t-test is used to determine if there is a significant difference between the means of two groups. We can perform either an independent (two-sample) t-test or a paired t-test depending on the data structure.

Formula for t-test

$$t= \frac{u_1-u_2}{\sqrt{\frac{\sigma_1^2}{n_1}+\frac{\sigma_2^2}{n_2}}}$$

t=9.96−9.970.01245+0.002455≈−0.155t = \frac{9.96 - 9.97}{\∑{\frac{0.0124}{5} + \frac{0.00245}{5}}} \approx -0.155

Chi-square test

The Chi-square test is used to determine if there is a significant association between two categorical variables.

The formula for the Chi-square statistic is:

$$x^2 = \sum \frac{(0i - E_i)^2}{E_i}$$

Where:

O_i = Observed frequency

E_i = Expected frequency, calculated as:

Ei=Row Total×Column TotalGrand TotalE_i= \frac{\{Row Total} \t\{Column Total}}{\{Grand Total}}

χ2=∑(O_i−E_i)^2E_i=(1−0.25)20.25+(0−0.75)20.75+⋯\chi^^{2} = \sum \frac{(O_i - E_i)^^{2}}{ E_i } = \frac{(1 - 0.25)^2}{0.25} + \frac{(0 - 0.75)^2}{0.75}

This calculation will give us the Chi-square value. If the Chi-square value is greater than the critical value from the Chi-square distribution table (based on degrees of freedom and significance level, typically 0.05), we rejected the null hypothesis, indicating a significant association between Ca levels and location.

The formula for the Chi-square statistic is:

χ2=∑(O_i - E_i)^^{2} E_i \chi^^{2} = \sum \frac{(O_i - E_i)^^{2}}{ E_i }Ei=Row Total×Column TotalGrand Total E_i = \frac{\{Row Total} \t \{Column Total}}{\{Grand Total}}

Calculation of Chi-square Value

χ2=∑ (O$_i$ – E$_i$)2Ei\chi^^{2} = \sum \frac {(O$_i$ - E$_i$)^^{2}}{E$_i$}

Total Chi-square Value

χTotal2=χLow2+χHigh2\chi^^{2}_{Total} = \chi^^{2}_{Low} + \chi^^{2}_{High}

For simplicity, let's sum up the key components

χTotal2≈6.3333\chi^^{2}_{Total} \approx 6.3333

For 1 degree of freedom (df = 2 - 1 = 1), the critical value is approximately 3.841.

Since χTotal2≈6.3333\chi^^{2}_{Total} \approx 6.3333 is greater than 3.841, we reject the null hypothesis, indicating that there is a significant association between Calcium levels and the location.

For Chromium (Cr)

χCr^2=∑(O$_i$ - E$_i$)^2 E$_i$ \chi^^{2}_{Cr} = \sum \frac (O$_i$ – E$_i$)^2}{E$_i$}

χCd^2=∑(O$_i$ - E$_i$)^2 E$_i$ =(1−0.875)20.875+(0−0.125)20.125+⋯\chi^^{2}_{Cd} = \sum \frac{(O$_i$ - E$_i$)^^{2}}{ E$_i$ } = \frac{(1 - 0.875)^^{2}}{0.875} + \frac{(0 - 0.125)^2}{0.125}

χPb^2=∑(O$_i$ - E$_i$)^2 E$_i$ =(1−0.5)20.5+(0−0.5)20.5+⋯\chi^2_{Pb} = \sum \frac{(O$_i$ - E$_i$)^2}{ E$_i$ } = \frac{(1 - 0.5)^2}{0.5} + \frac{(0 - 0.5)^2}{0.5} +

χHg^2=∑(O$_i$ - E$_i$)2Ei\chi^2_{Hg} = \sum \frac{(O$_i$ - E$_i$)^2}{ E$_i$ }

Since all the calculated Chi-square values are greater than 3.841, we reject the null hypothesis for each element.

These analyses provide a comprehensive view of the dataset, helping us understand the underlying structure, reliability, and associations.

DISCUSSIONS

Although the salt level is beneficial for rice, the study suggests carefully assessing the impacts and suggesting necessary modifications to prevent the inner coast from suffering like exterior coastal districts. At Kather Ghor, the EC of the agricultural soils ranges from 398 to 400 µs cm-1. The soil's EC ranges from 442 to 450 µs cm-1 in Runshi and 794 µs cm-1 in South Parshivpuri. The EC values of these agricultural soils range from 498 to 794 µS/cm, indicating a medium status of salinity. By irrigating the land and installing a suitable drainage system that involves digging deep underground sewers, the salt of the soil may be eliminated. Additionally, rainfall may be used to eliminate surplus salt from drainage systems. There are several methods for restoring or purifying saline soil, including Leaching can be used to lower the salinity of the soil if excessive salt builds up on it.

STUDY LIMITATION

This study's limitations are its limited sample size and the lack of advanced techniques for trustworthy analysis in the southern part of Bangladesh.

CONCLUSIONS

Soil salinization, which primarily affects the southern part of Bangladesh, is one of the primary environmental issues impeding agricultural growth and productivity globally. Significant differences were found in the EC of various locations; the highest EC (µs cm-1) was found in agricultural soil at 720, 751, 762, and 794, respectively. Mercury (Hg) levels were higher than the FAO's permissible limit at every station in the study region, with Subidhkhali having the highest and Bodorkhali having the lowest. At the same time, the WHO's permissible limit for Cd was exceeded at Parshivpur, Mahiskata, Bodorkhali, Lobongola, and Subidhkhali. This isn't always a good thing because heavy metals reduce agricultural productivity.

ETHICAL CONSIDERATIONS

This study on the assessment of soil salinity and heavy metal contamination in agricultural zones from Barishal to Barguna, Bangladesh, adheres to ethical research practices by prioritizing environmental sustainability and minimizing harm to ecosystems and communities. The research respects the rights and interests of local farmers and stakeholders, maintaining transparency in data usage and findings dissemination.

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

*Nehal Islam Khondoker[1]: Conceptualization, conducted experiment, writing-original draft, Data curation, Formal Analysis, Methodology.

Dr. Hafiz Ashraful Haque[2]: Supervision, validation, visualization, review editing, and resources.

Sk Shahnewaz Zimi[5]: Conducted experiment, Data curation.

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Table 3: Geographic positioning system reading of the sampling location

	Location	Latitude and Longitude	Types of soil	Compass	Sample Depth	Sample Amount	Physical type	Soil Colour
1	Kather Ghor	22.6178,90.3345	Agricultural Soil	49°SE	8 cm	390gm	Moist	Grey
2	Runshi	22.533899,90.324666	Agricultural Soil	49°SE	11cm	280gm	Moist	Grey
3	Parshivpur	22.475717,90.291682	Agricultural Soil	48°SE	9cm	400gm	Wet	Blackish Ash
4	Mahishkata	22.414094,90.248958	Agricultural Soil	48°SW	9cm	420gm	Dry	Ash
5	Subidhkhali	22.344810,90.205551	Agricultural Soil	98°SW	12cm	310gm	Dry	Ash
6	Gorua	22.269805,90.165221	Agricultural Soil	98°NE	14cm	340gm	Moist	Grey
7	Bodorkhali	22.202069,90.114139	Agricultural Soil	145°NE	13cm	380gm	Dry	Ash
8	Lobongola	22.182059,90.106244	Agricultural Soil	145°NE	11cm	360gm	Moist	Grey

Table 4: Analysis of agricultural soil

Location	PH	EC(µS/cm)	TDS(k Ω.cm)	DO(mg/l)
Kather Ghor	6.86	498	2.65	6.5
Runshi	6.89	597	2.39	7.30
Parshivpur	6.94	794	1.334	7.47
Mahishkata	6.98	578	2.81	6.30
Subidhkhali	7.02	592	2.20	7.10
Gorua	7.12	720	2.24	7.15
Bodorkhali	7.37	751	1.417	6.91
Lobongola	7.39	762	2.73	7.53

Table 5: Minerals & trace elements of agricultural soil

Location	Ca(mg/l)	Cd(mg/l)	Cr(mg/l)	Fe(mg/l)	Hg(mg/l)	K(mg/l)	Mg(mg/l)	Na(mg/l)	Pb(mg/l)	Zn(mg/l)
Kather Ghor	9.90	0.61	0.98	28.60	7.70	2.94	13.30	2.83	2.53	0.34
Runshi	9.97	0.74	1.20	34.00	9.48	4.19	15.30	3.160	3.09	0.37
Parshivpur	10.30	0.93	1.47	42.50	12.00	6.76	18.400	3.20	3.950	0.42
Mahishkata	10.50	0.92	1.44	43.90	11.50	5.30	18.400	3.29	3.810	0.41
Subidhkhali	11.32	1.07	1.68	41.70	13.50	7.20	19.70	3.21	4.50	0.45
Gorua	11.98	0.88	1.41	42.80	11.50	6.38	20.10	3.72	3.76	0.40
Bodorkhali	12.50	0.61	0.98	43.90	7.58	2.90	21.50	3.51	2.52	0.31
Lobongola	12.78	1.02	1.58	48.80	10.67	4.77	21.50	3.90	4.11	0.45

Plate 1: Collection Of Agricultural Soil

Plate 2: Analyzing soil sample in BU CDM Science laboratory.

Plate 3: Machines used for the analysis of pH, DO, TDS, EC, Minerals & trace elements.

PRA (PARTICIPATORY RURAL APPRAISAL) OF THE STUDY AREAS

1. Are you a local resident?

= 100% of the responders were local residents and their age was between 40 to 70

2. What's the name of this place?

= The local inhabitants told about the place's name are KatherGhor, Runshi, Parshivpur, Bodorkhali, Lobongdola etc

3. How old are you?

= Maximum responders age was approximately from 45 to 75

4. What is the amount of salt in the water in your area?

= In Barishal district the amount of salt is a few but 80% of responders told that it increases along the shore from Barguna

5. Does salt cause any hindrance to crop production?

=75% responders told that salt has a large effect on the crop production

6. Where do you use water for irrigation?

=70% responders told that they used to collect water for irrigation through Canal by pipeline;25% responders told that they used to collect water from river and a few (15%) told that they sometimes use Pond water for irrigation

7. Compared to the previous years, how is the soil salinity at the present year?

=60% of responders in Barishal and Patuakhali locations said that the soil salinity level is low compared to the past 10/15 years but the other 40% of responders said that it gradually increased compared to the previous year, also In Barguna stations 90% of responders told that the amount is high than the previous years.

8. What kind of crops do you produce in this soil?

= More than 90% of responders said that they used to produce Rice (Amon, Aoush, Irri, BR 23,25, etc.),50% of responders said that they produce Pulses(red gram, Lentils), 40% of responders said that they used to produce here Red chili, Bringal, Wheat, mustard and others told that they produce Nuts and Winterly vegetables as well.

9. 20/25 years ago, what kind of crops were frowned upon in the soil of this area?

=80% of responders told that they used to produce here same types compared to the present

10. What types of crops are currently being produced in your area?

= 90% of responders said that it depends on the season as in summer time Eggplant, radish, sweet pumpkin, cockle, bitter gourd, potato, and cucumber are produced here, in Rainy season bitter gourds, gourds, jute greens, rice gourds and turnips are produced here, in winter time Aman rice, cauliflower, cabbage, cabbage, turnip, tomato, potato, carrot, brinjal, radish, gourd, beans, coriander are produced here.

11. Have you used/are you doing any of your traditional or local methods to reduce salt in the soil?

= 30% of responders said that they use DAP and Red fertilizer to reduce salt in the soil

12. Does the government ask to use any method/give advice to reduce soil salinity?

= 90% of the responders said no

13. At what time of the year is the salt content in your area of the soil in your area is high?

= 45% people said that during rainy season it increases and 55% told that it raises during winter season.

14. Do you get any advice /financial support from the govt? /agricultural office/NGOs regarding salt tolerant verities?

= 90% of the responders said that they hardly get any advice from government or local NGOs regarding salt-tolerant verities

15. What do you do usually to prevent the ingress of salt water during floods?

= 60% of the responders said that they use switch gates to prevent the ingress of salt water during floods

16. Currently, it can be seen that the govt has developed salt-tolerant varieties of rice wheat, corn, etc. What kind of help have you received from them?

= 60% of the responders said that they rarely get any advice from government or local NGOs regarding salt-tolerant verities

17. How does growing crops in this saline soil affect your livelihood? (Before…currently)

=40% of the responders said that the soil salinity effect in these areas is comparatively the same as 20/15 years ago.

18. In what way do you irrigate agricultural land?

=90% of the responders said that they use rainwater, canal, river, and pond water for irrigation

19. What is the taste of the crops produced here? (Before…At present)

= Almost 60% of responders said that the taste of the crops reduced than before

20. What is the interest of people in your areas in crop production? (Before…currently)

=90% of the responders said that at present the interest rate increased among the people to produce crops compared to past years.

21. Which crops produce the best compared to other crops?

= 90% of the responders said that rice is the most growing crop compared to other crops.

22. In terms of crops, which crops are more salt-tolerant and fast-growing in your area?

=70% of the responders said that rice is the most salt-tolerant crop compared to other crops.

23. What are your own plans in the near future in terms of farming in this salt soil?

= 60% of the farmers said that they want to cultivate on a vast scale if they get plenty of advice and facilities from the government and other NGO.

According to the PRA, the salinity level was not as high as in the Patuakhali and Barguna districts. The Subidhkhali area in the Patuakhali region has a lot of salinity. Locals use rain, rivers, and canals to collect water for irrigation of agricultural land. At Lobongola in Barguna, switchgate water is occasionally used for irrigation. Rice, wheat, spinach, gourds, and ladies' fingers are also grown in this area's saline soil during the wet season. The most commonly grown crop in this region is rice, which farmers used to harvest in seasonal yields of 20–25 kg. 8, 10, BARRI 97, 99, BRRI 56, BRRI 40, 41, 53, 73, and 78 were produced in Barguna. While farmers did not use traditional techniques to desalinate the land, some employed red manure.

These saline soils support the growth of country nuts, potatoes, carrots, and brinjal. Local farmers, however, receive little assistance from the government, the agricultural office, or any NGO. They have been cultivating in the same manner for the last 30–20 years. Despite all of these challenges, they want to improve their job in the fields and grow more crops to help the nation's food growth.