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Impact of Water and Soil Salinity on Coastal Agriculture in Bangladesh: Insights and Mitigation Strategies

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ABSTRACT

Salinity intrusion is one of the major problems in coastal regions in Bangladesh which affects crop production and livelihood. This study examines the impact of salinity intrusion from the Pasur River on soil quality and agricultural productivity in the coastal region of Bangladesh. For this study, both water and soil collections and field surveys were carried out in seven unions that are directly impacted by the river in Dacope and Mongla Upazilas. Physicochemical analyses of water and soil samples revealed significant variations in salinity levels, with higher concentrations observed in southern regions' spatial distribution. A strong positive relationship between water and soil salinity indicates a direct influence of river salinity on soil quality from the Pearson correlation analysis. Survey data from 240 respondents, predominantly farmers, corroborated these results, with widespread recognition of salinity's detrimental effects on crop yields, especially rice. So, smaller farms focus on vegetables, medium on rice, and larger ones on high-value crops like watermelon. Mitigation strategies such as freshwater irrigation, drainage systems, and salt-tolerant crop cultivation were identified as potential remedies. Additionally, experts suggested implementing sluice gates to control saltwater intrusion from tributary rivers like Chila Khal. These results emphasize the immediate requirement for proactive actions to reduce the negative effects of salt-induced soil degradation and ensure sustainable agricultural practices in the vulnerable region.

INTRODUCTION

Worldwide, Salinity is becoming a rising issue in offshore regions, resulting from saltwater infiltration into freshwater sources (USGS, 2018). This infiltration originates from a complicated interaction between natural and human-caused causes (Shahid *et al.*, 2018). The main natural factors regarded as tidal inundation and evaporation contribute to the issue, and, on the other hand, human activity such as dam construction and deforestation can worsen the problem (Majeed & Muhammad, 2019). The cumulative impacts of these factors result in the deterioration of soil quality (Bidalia *et al.*, 2019), the disturbance of ecosystems (Stavi *et al.*, 2021), and the endangerment of coastal populations (USEPA, 2024). Bangladesh encounters a distinctive predicament in its expansive coastline area. The fertility and the agricultural production of this region largely rely on the Ganges, Brahmaputra, and Meghna rivers, which are at risk due to increasing levels of salt (Lam *et al.*, 2021). This phenomenon is driven by a conjunction of multiple reasons such as increasing sea levels resulting in the inland movement of saltwater (Michael, 2024), whilst decreased freshwater flow from rivers weakens the natural defense against the invasion of saltwater (Mills *et al.*, 2021). In addition, the over-extraction of groundwater can worsen the problem (Li *et al.*, 2020).

The effects of salt in Bangladesh are severe. The presence of saltwater in soil disrupts the complex balance of nutrients, leading them to be washed out and badly altering

their composition (Rahman *et al.*, 2014). Furthermore, it limits the natural microbial populations that are essential for nutrient cycling and decomposition (Dong *et al.*, 2022). As a result, arable land is threatened, rendering it unsuitable for traditional crops such as rice (Ahmed & Haider, 2014). Soil quality decline is directly associated with a significant drop in agricultural yields (Miah *et al.*, 2020), which leads to crop failure and threatens food security (Lam *et al.*, 2021) as well as the livelihoods of many coastal farmers. Salinity intrusion is more than just an environmental issue; it is also a societal emergency. Saline water renders soil unsuited for cultivation, lowering agricultural output and farmer income (Miah *et al.*, 2020; Islam, 2021). This tendency harms food supply stability, resulting in economic vulnerability and inadequate nutrition in households (Guimbeau *et al.*, 2022). Freshwater scarcity also affects the supply of clean drinking water (Nahian *et al.*, 2018), exacerbating the health and livelihood challenges that these already vulnerable people face (Das *et al.*, 2019).

Existing literature highlights the significant impact of river salinity on soil quality and agricultural livelihoods in coastal Bangladesh (Fahim & Afrin, 2023). Rasel *et al.* (2013) mentioned in their study that Salinity in Bangladesh affects crop production by creating an unfavorable environment and hydrological situation due to tidal flooding, direct inundation by saline water, and upward or lateral movement of saline groundwater during the dry season (April to May) and affecting crops

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at critical growth stages, reducing yield and potentially causing a total loss. Tessema *et al.* (2022) found that soil and irrigation water salinity significantly impact crops and agricultural communities in Ethiopia and leads to poorer agricultural production, food insecurity, and poverty. The study highlights the need for better soil and water management to prevent irreversible salinity levels, thereby enhancing the country's agricultural production capacity. Rising salinity due to climate change threatens food security (Lam *et al.*, 2021; Hossen *et al.*, 2022). This multifaceted problem impacts food production in coastal areas, including crops livestock, and aquaculture (Gain, 2007; Lam *et al.*, 2021; Salehin *et al.*, 2018). The causes are complex, and influenced by climate variability, river water dynamics, and human activities (Salehin *et al.*, 2018). To mitigate these threats, researchers propose adaptation strategies like water management (Rahman & Rahman, 2022), salinity-tolerant crops, and improved land management (Shammi *et al.*, 2020). Additionally, frameworks have been developed to assess vulnerability to salinity and other climate-related stressors (Hoque *et al.*, 2019). However, despite the extensive literature on salinity intrusion, there remain gaps, particularly in localized studies focusing on specific regions such as the Sundarbans. These gaps can be addressed by examining the impact of salinity intrusion from the Pasur River on soil quality and agricultural productivity in the coastal region. By conducting comprehensive field surveys and

analyses, research can provide valuable insights into the spatial distribution of salinity levels and their direct relationship with soil quality. Moreover, through farmer surveys, research can find the detrimental effects of salinity on crop yields and identify tailored adaptation strategies for the coastal region.

This study seeks to close this gap by looking into how river water salinity impacts adjacent soil quality, ultimately affecting agricultural output and the economic well-being of coastal communities. Furthermore, the research will investigate and assess various mitigation techniques for preserving soil fertility and agricultural viability in this tough climate. This study provides critical insights into a significant issue affecting Bangladesh's coastal communities. It seeks to fill a research gap by explicitly investigating the relationship between increased river salinity, soil degradation, and agricultural livelihoods. Understanding the combined impact is critical for devising effective solutions to maintain soil fertility, food security, and economic well-being for these vulnerable communities.

MATERIALS AND METHODS

Study Area

For this research, we selected the Chalna, Bajua, Lauduv, and Banishanta unions of Dacope Upazila of the Khulna District and; Burirdanga, Chila, and Chandpai unions of Mongla Upazila of the Bagherhat District, in Khulna

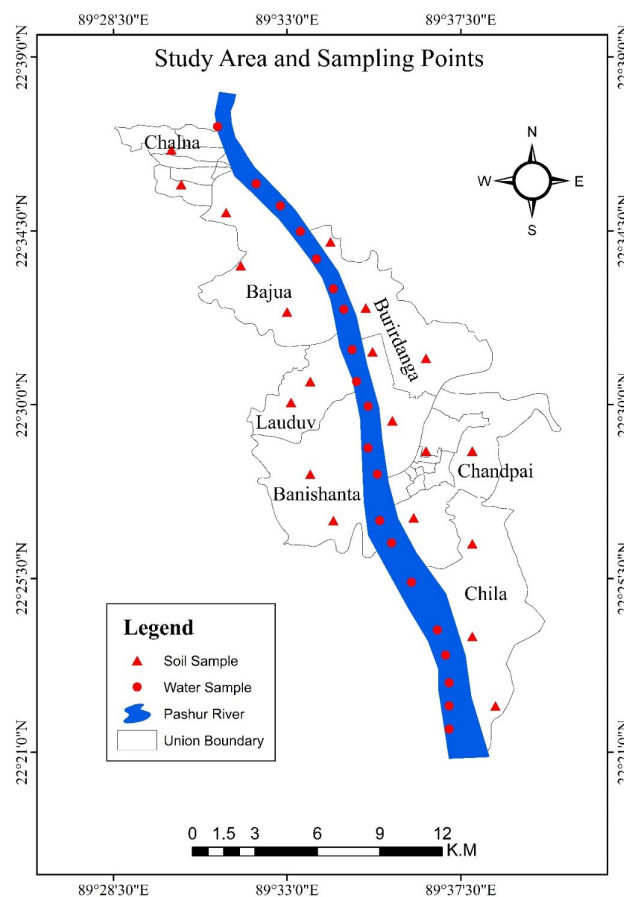


Figure 1: Study area and sampling points

Division which are directly associated with the Pasur River. The Pasur River is situated at 89°30'0" E and 21°45'0" N and it is the biggest river in the Sundarban (Mangrove Forest) region with a length of 131 kilometers north of the Bay of Bengal and 55 kilometers south of Khulna City (Islam *et al.*, 2022). The Sundarbans region, where the Pashur River flows, faces increasing salinity intrusion due to sea level rise and tidal influence, and the surrounding lands are fertile and intensively cultivated, making them susceptible to salinity-induced degradation (Haque & Reza, 2017). The study area and the soil and water sampling location are shown in Figure 1.

Data Collection

Soil and Water Data

To assess the salinity levels of the Pasur River a total of 20 water samples were collected North to South direction

from the river and 20 soil samples were also collected from the surrounding regions to observe the impact of the water salinity and physicochemical parameters. From the Dacope upazila total of 9 soil samples were collected from Chalna (2), Bajua (3), Lauduv (2), and Banishanta (2) union respectively. From the Mongla Upazila, 11 soil samples were collected from Burundanga (3), Chila (3), and Chandpai (5) union respectively.

Survey Data

Along with the field data, a semi-structured questionnaire survey was also conducted. A total of 240 respondents were purposively selected who are mostly associated with farming in those areas from where the soil and water data were collected. The demographic information of the respondents is mentioned in Table 1.

Table 1: Demographic information of the respondents

Variables	N	Percentage (%)
Age		
<20	0	0
20-30	20	8.33
31-40	80	33.33
41-50	64	26.67
>50	76	31.67
Gender		
Male	232	96.67
Female	8	3.33
Others	0	0
Occupation		
Farmer	176	73.33
Businessman	20	8.33
Fisherman	32	13.33
Employee	8	3.33
Day-Labor	4	1.67
Family Members		
<3	12	5
3-7	204	85
8-11	16	6.67
>11	8	3.33
Earning Members in Family		
<2	196	81.67
3-6	44	18.33
7-10	0	0
>10	0	0
Source of Income		
Farming	176	73.33
Business	20	8.33
Fishing	32	13.33
Employee	8	3.33

Day-Labor	4	1.67
Education		
Illiterate	110	45.83
Primary	67	27.92
SSC	34	14.17
HSC	21	8.75
Graduate	8	3.33
Farming Experience		
5-10	13	5.41
11-15	25	10.42
16-20	85	35.42
>20	117	48.75

Data Analysis

Physicochemical Parameter Analysis

To assess the salinity levels of Pashur River collected water samples were analyzed using OHAUS-Water Analysis Meters & Electrodes (AQUASEARCHER™ AB23EC Bench Meter). Other Physicochemical parameter of these water samples was analyzed using CLEAN CON30 Tester. On the other hand, measuring soil salinity on the field at a high sampling density is rather costly and time-consuming (Das *et al.*, 2020). Also, the relationship between EC and soil salinity is a bit complicated because

other factors such as soil texture, water content, and bulk density can influence measuring EC (Rhoades *et al.*, 1976; Banton *et al.*, 1997). Collected soil samples were air-dried for 2 hours, exposed to sunlight, and thoroughly crushed. Soil salinity was measured in the laboratory by determining the EC of a 1:10 soil and distilled water suspension using the 1:10 weight-to-volume method. EC was measured after 1 hour of settling using the OHAUS-Conductivity Tester-Bench Cond Meter ST3100C-F. Additionally, other Physicochemical parameters and soil nutrients were analyzed using the methods listed in Table

Table 2: Methods and equipment used in analyzing physicochemical parameters and soil nutrients

Parameters	Materials/Equipment	Methods of Extraction
OC	Titration	Wet oxidation method
N2	Digestion & Distillation Unit	Kjeldahl method
K	Flame photometer	Ammonium Acetate Extraction
Ca	Atomic Absorption Spectrophotometer	Ammonium Acetate Extraction (Atomic Absorption/Emission Spectrophotometric Method)
Mg	Atomic Absorption Spectrophotometer	Ammonium Acetate Extraction (Atomic Absorption/Emission Spectrophotometric Method)
P	Spectrophotometer	Modified Olsen's method for Neutral & Calcareous Soil/ Bray and Kurtz Method for Acidic Soil
S	Spectrophotometer	Calcium Dihydrogen Phosphate Extraction (Turbidimetric method)
B	Spectrophotometer	Calcium Chloride Extraction
Cu	Atomic Absorption Spectrophotometer	DTPA Extraction
Zn	Atomic Absorption Spectrophotometer	DTPA Extraction
Fe	Atomic Absorption Spectrophotometer	DTPA Extraction
Mn	Atomic Absorption Spectrophotometer	DTPA Extraction

2.

Correlation Analysis

A Pearson Correlation and heatmap were used to measure and show the interrelationships between soil and water parameters. Also, it was used to identify the effect of the water salinity of the Pasur River on the soil of the surrounding areas in SPSS V26. Pearson's Correlation coefficient (r) is a measure of the strength and direction

of association that exists between two variables measured on at least an interval scale (LibGuides, 2023). Heat maps, which apply colors to the cell experiences, enable the further visualization of data displayed in tables. material is presented more visibly and readers can rapidly recognize the material of interest by changing the colors or color saturation (In & Lee, 2017). The Pearson correlation coefficient, whose value ranges from - 1 to 1 (Hossain *et*

al., 2023). There exists a negative correlation between two variables when the coefficient's absolute value is higher, and a positive correlation when the coefficient's absolute value is bigger (Yang *et al.*, 2021). With the intensity of the r-value, the color gradient of the heatmap varies.

Spatial Interpolation

A spatial interpolation was used in ArcGIS 10.8 to estimate values at un-sampled locations. It is a fundamental technique used in geospatial analysis to estimate values at un-sampled locations based on known data points (Khouni *et al.*, 2021). It plays a crucial role in various fields such as environmental science, agriculture, hydrology, and urban planning (Jin & Heap, 2011). There are several interpolation methods exist. For this study, we use the Inverse Distance Weighting (IDW) method. It is a widely used spatial interpolation method that uses the deterministic method to compute the value at an unknown location by averaging the values from nearby known sample points (Lu & Wong, 2008). It assigns weights inversely proportional to the distance between the unknown point and the known data points (ESRI, 2024). A more general expression of this method is (Li *et al.*, 2019):

$$z = \frac{\sum_{i=1}^n w_i z_i}{\sum_{i=1}^n w_i} \quad (1)$$

where

- z is the interpolated value
- z_i is the ith sample value
- n is the total number of known points used in interpolation
- w_i is the weighting factor that can be calculated by, w_i = 1 / (d^{p1} / 0_i)
- where
- d_{0_i} represents the data-to-unknown distance
- p1 is generally a non-negative coefficient used to adjust the relative influence of the distance d_{0_i} to the calculation process.

RESULTS AND DISCUSSION

Physicochemical Properties of Water and Soil Samples Show Signs of Variation Despite Favorable Soil Conditions

Tables 3 and 4 present data on the Pashur River's water quality and the surrounding area's soil quality. The Pashur River water quality, the Electrical Conductivity (EC) demonstrates a significant variance between the minimum and maximum values of 2.48 and 28.6 with an average of 20.16. The pH stays almost the same between 6.64 and 7.85, whereas on average, it is 7.66. The patterns for the other two variables, Temperature, and TDS are similar. The soil quality data shows a less restricted range of values in contrast to the river water. The low EC values show that the water quality of the river is relatively good, though there is still some variation. Soil pH can be from 5.6 to 7.8. It is the measure of acidity and alkalinity. Moisture content is very much variable, where the average is 42.5%, but the range varies from 17% to 72%. Organic matter content is moderate and of rather stable properties. Nitrogen (N₂), Potassium (K), and Calcium (Ca) elements are present in different levels but the ranges are within the acceptable ranges for soil. On the other hand, some elements such as Zinc (Zn) have an unbelievably high standard deviation that implies a significant variation in the samples determined.

The variability in water quality parameters reveals natural fluctuations in the river's environment. Despite generally low EC levels indicating adequate water quality, fluctuations imply localized concerns. Soil pH levels within the normal range indicate soil compatibility for various agricultural activities. However, a large variation could affect nutrient availability and plant health (Oshunsanya, 2019). Moderate and consistent organic matter concentration is beneficial for soil fertility and

Table 3: Physicochemical properties of the selected water samples

Sample Number	Latitude	Longitude	EC (ds/m)	pH	TDS (ppt)	Temperature (°C)
1	22.62	89.52	2.68	7.81	12.7	28.2
2	22.59	89.53	2.48	7.82	12.1	29.2
3	22.57	89.55	3.2	7.85	11.9	28.6
4	22.56	89.56	4.3	7.84	12.4	28.9
5	22.55	89.57	12.35	7.37	12.3	28.3
6	22.54	89.57	16.33	6.64	14	27.6
7	22.52	89.57	24.7	7.04	12.5	29.1
8	22.51	89.58	25.9	7.73	12.2	28.7
9	22.5	89.58	24.5	7.68	12.8	27.8
10	22.48	89.58	25	7.75	12.3	28.2
11	22.47	89.589	26.2	7.67	8.13	28.9
12	22.44	89.59	24.6	7.73	6.17	29.3
13	22.42	89.6	24.8	7.68	2.17	28.4
14	22.4	89.61	23.8	7.75	1.62	28.1
15	22.38	89.62	24.2	7.85	1.52	27.8
16	22.37	89.62	28.6	7.8	1.64	29.3

17	22.36	89.62	27.5	7.82	2.05	28.5
18	22.39	89.61	26.8	7.79	2.12	28.8
19	22.45	89.59	28.2	7.77	2.08	29
20	22.58	89.54	27.1	7.81	2.15	29.2

microbial activity (Soothar *et al.*, 2021). However, the large variance in Zinc levels raises concerns regarding potential environmental contamination or uneven distribution of contaminants in the soil (Tolay, 2021). Further work is necessary to understand the underlying causes and consequences of these findings.

Correlation between Water and Soil Parameters Helps Understanding the Connection between Water and Soil Parameters

The correlation matrix is crucial to the assessment of relations between water and soil factors observed in the

dataset. Based on the water sample, the EC and TDS are positively correlated showing that an increase in one leads to the other, most likely due to more ions being dissolved, which increments both measures (Fig. 2). The negative correlation at a moderate level indicates that some dissolved solids can affect the pH, but the exact types present determine the degree of this effect. The weak positive or negative correlations between temperature and the other parameters (EC, pH, and TDS), indicate an insignificant association, and temperature seems to have a slightly larger influence on EC. In summary, the data proves a strong connection between EC and

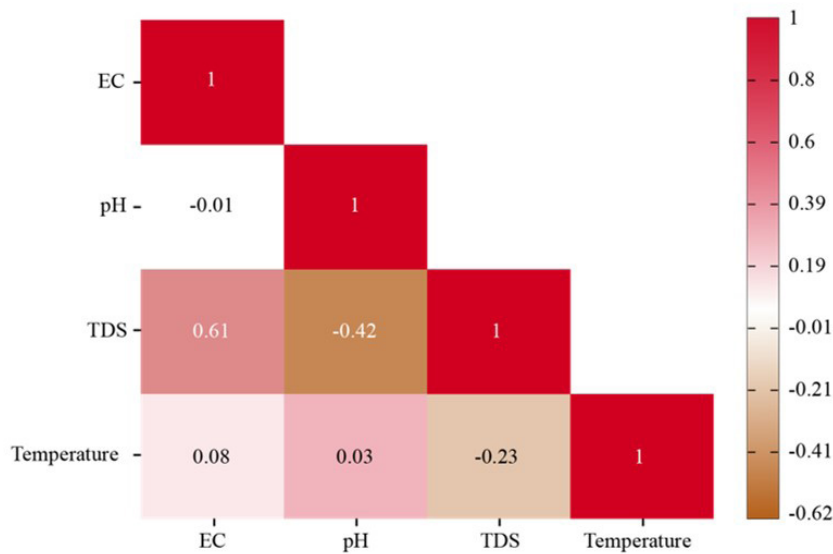


Figure 2: Correlation heatmap of the water sample parameter

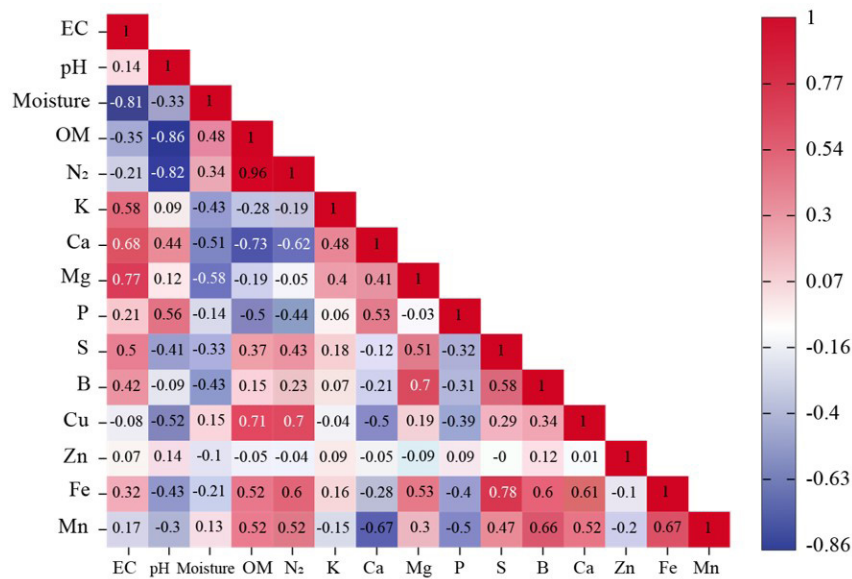


Figure 3: Correlation heatmap of the soil sample parameter

TDS, though relationships between other parameters are not evident. Out of the parameters in soil samples, electrical conductivity (EC) is the strongest and positively correlates with the concentrations of calcium (Ca) and magnesium (Mg), hence higher EC values are linked to the presence of greater amounts of Ca and Mg. Besides that, EC displays a slight positive relationship with pH and phosphorus (P) which implies that soil pH and phosphorus levels are likely to be elevated as well as electrical conductivity (Fig. 3). On the other side, a direct, significant/strong, negative correlation is observed between EC and moisture, meaning that the higher the moisture content, the lower the EC value.

pH is positively correlated with most nutrients but to a lesser extent when compared to Ca and Mg. Here, OM has been found to have the strongest positive correlations with nitrogen (N₂) and phosphorus, indicating that higher concentrations of OM are associated with increased levels of these nutrients. In addition, N₂ has strong positive correlations with organic matter and P and moderate positive correlations with Mg and Ca. Thus, the correlation matrix depicts the interrelationships between multiple soil characteristics, indicating how alterations in one variable affect the others, and provides critical information for the development of soil management and agricultural methods.

Table 4: Physicochemical properties of the selected soil samples

Sample Number	Latitude	Longitude	EC	pH	Moisture	OM	N ₂	K	Ca	Mg	P	S	B	Cu	Zn	Fe	Mn
			ds/m		(%)	Percentage	meq/100g soil	µg/g soil									
1	22.61	89.5	10.2	6.21	37	2.74	0.16	0.83	14.51	6.55	6.6	221.43	0.97	4.96	0.88	46.54	29.74
2	22.59	89.5	8.56	7.32	41	1.86	0.09	0.97	13.01	6.38	2.72	208.35	1.15	4.59	0.52	47.07	38.9
3	22.58	89.52	13.7	6.86	38	2.27	0.11	0.66	16.23	6.6	17.3	298.18	1.12	4.84	1.3	11.15	8.39
4	22.56	89.53	6.67	7.01	67	2.68	0.13	0.58	11.85	6.26	13.5	225.22	0.56	4.64	1	25.12	37.47
5	22.54	89.55	4.37	5.1	72	3.65	0.18	0.7	7.78	5.99	3.19	115.25	0.76	8.42	1.25	103.45	29.33
6	22.51	89.56	12.82	4.6	39	3.37	0.16	0.71	12.7	7.64	1.89	453.92	1.16	7.29	1.91	118.19	36.62
7	22.49	89.54	6.88	5.65	67	2.55	0.12	0.64	13.28	7.44	2.18	250.06	1.19	4.68	1.97	32.65	38.44
8	22.47	89.56	9.87	5.3	56	3.16	0.15	0.71	9.13	5.94	3.99	167.48	1.44	5.52	1.85	74.21	38.87
9	22.45	89.57	13.4	7.2	26	1.76	0.1	0.9	22.73	6.86	15.9	40.59	0.38	3.79	0.52	37.17	6.09
10	22.37	89.64	21.02	6.8	17	1.72	0.1	1.05	30.69	10.38	10.6	210.75	1.43	5.62	1.6	19.75	5.91
11	22.4	89.63	12.53	7.3	52	1.9	0.11	0.85	27.57	7.19	25.9	71.53	0.16	4.84	0.81	37.1	5.05
12	22.44	89.63	15.99	7.1	43	1.72	0.1	0.95	27.75	9.37	9.8	132.15	1.02	3.31	0.65	23.48	5.59
13	22.45	89.6	10.5	7.6	32	1.81	0.10	0.38	18.79	7.99	10.6	55.11	1.64	4.47	0.66	26.7	25.1

20	22.56	89.56	14	7.2	36	2.2	0.12	0.85	16.5	7.5	11	225	1.5	6	70	50	20
19	22.54	89.58	11.5	6.8	40	2.4	0.13	0.78	15.2	7.2	10.5	210	1.3	5	65	45	15
18	22.52	89.61	13.2	6.7	49	2.6	0.14	0.82	16.8	9.1	5.7	198.5	1.2	6.8	1.15	92.7	36.2
17	22.52	89.58	9.5	7.5	38	2.1	0.11	0.68	14.2	7.5	4.8	165.2	0.95	5.7	0.95	74.5	28.6
16	22.49	89.59	11.8	6.9	45	2.3	0.12	0.75	15.6	8.2	5.3	185.7	1.1	6.2	1.05	87.3	33.8
15	22.48	89.61	21.9	5.9	18	2.82	0.16	0.92	18.33	11.8	4.78	892.12	2.61	6.25	2.21	260	56.52
14	22.48	89.63	12.1	7.1	37	2.56	0.14	0.82	10.09	10.62	12.6	220.03	2.67	7.19	0.91	120	72.11

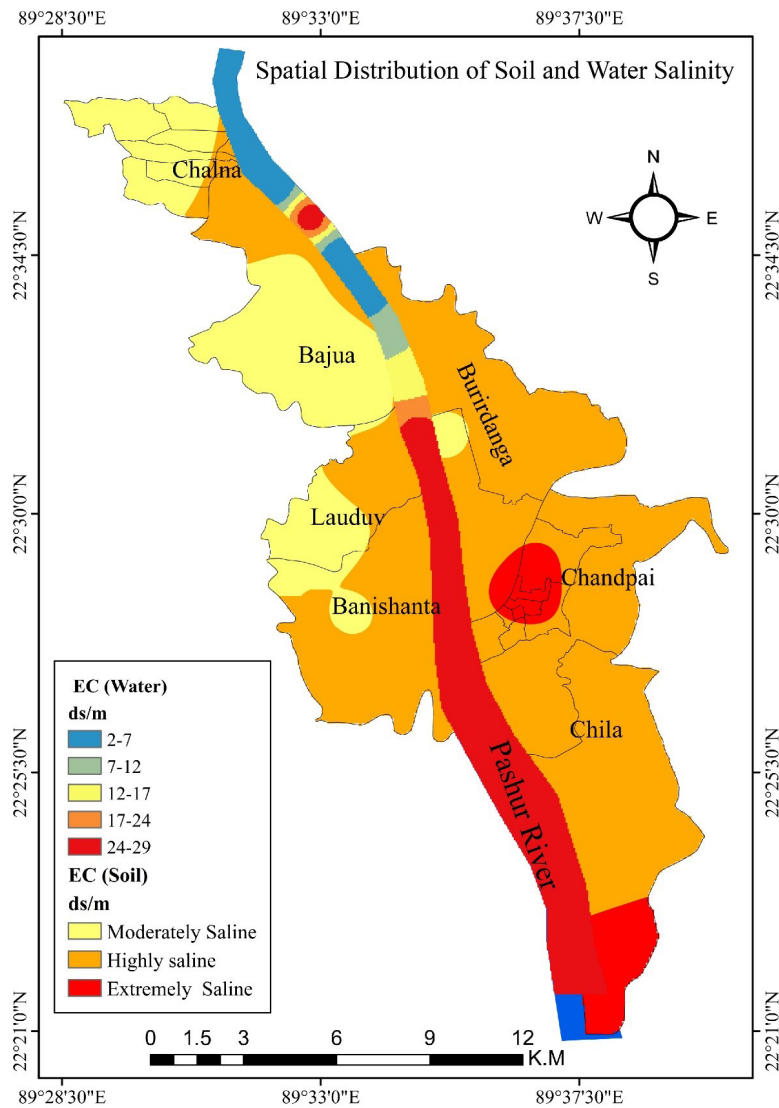


Figure 4: Spatial distribution of soil and water quality

Pashur River Water Gets Saltier Downstream and Same for Nearby Soil

Fig. 4 illustrates the spatial variation and distribution of soil and water samples in the study area. Salinity levels in the water samples range from 2.48 ds/m to 28.6 ds/m, increasing from north to south. Specifically, the Chalna union in Dacope upazila exhibits the minimum salinity levels, while the maximum salinity is observed in the Chila union of Mongla upazila. Generally, coastal areas experience a gradual increase in salinity moving from north to south (Mahmuduzzaman *et al.*, 2014). This is because of saltwater intrusion from the ocean. As ocean water moves inland through rivers and estuaries, it mixes with freshwater. The denser saltwater tends to sink and flow downstream, leading to higher salinity levels in the southern parts of the river system.

Regarding soil samples, the electrical conductivity (EC) values range from 4.32 ds/m to 21.02 ds/m. Notably, Bajua and certain parts of the Lauduv union in Dacope Upazila have comparatively higher EC values. Additionally, the figure indicates that Chalna, Lauduv, and Banishanta unions in Dacope upazila, as well as Burirdanga and some parts of the Chandpai union in Mongla upazila, exhibit

moderate to highly saline conditions. The extreme saline areas are the Chila Union and some parts of the Chandpai Union.

Correlation between Soil and Water Quality Proves the Effect of River Water on the Nearby Soil

Spatial analysis in Fig. 5 reveals a southward increase in both water and soil salinity. This trend suggests a potential influence of water salinity on nearby soil characteristics. Further statistical analysis confirms this relationship, with a strong positive correlation coefficient ($r = 0.78$) between water and soil salinity data.

The associated p-value of less than 0.0001 indicates a statistically significant positive correlation. As saline river water infiltrates the soil, evaporation concentrates the dissolved salts left behind (Zhang *et al.*, 2023). Furthermore, capillary action can draw this salty groundwater upward through the soil where it evaporates at the surface, further increasing soil salinity (Nachshon, 2018). In simpler terms, as water salinity increases, so too does soil salinity, highlighting a potential negative impact of water salinity on the surrounding soil quality within the study area.

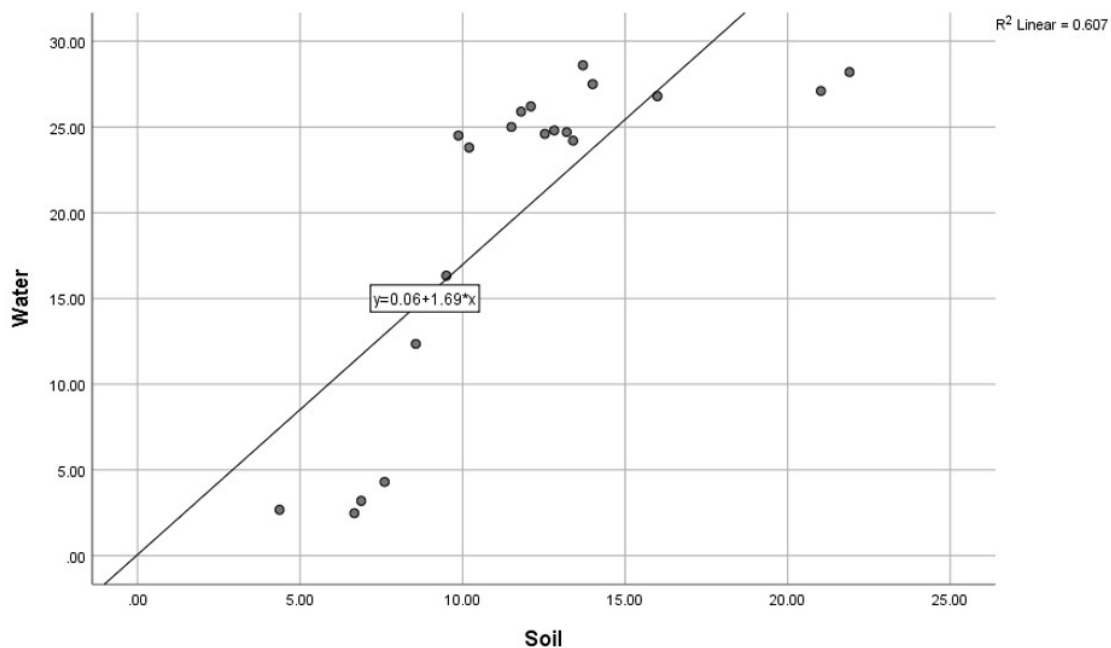


Figure 5: Correlation between soil and water quality

Land Size Affects Farming Choices and Income in Coastal Area

The data reveals a diverse range of landholdings and agricultural practices in the study area. Land size varies considerably, with a significant portion (44% of respondents) owning less than 2 bighas (approximately 0.67 hectares). Despite this, a substantial number (32% of respondents) manage medium-sized plots between 3 and 6 bighas. Interestingly, larger landholdings exceeding 10 bighas are not uncommon (24% of respondents). This pattern likely reflects the economic realities of smaller

landholders needing high-value, quick-growing crops like vegetables to maximize yield on limited space on the other hand, medium-sized farms can dedicate land to rice, ensuring food security while potentially generating a surplus for sale (MJF, 2019; Abedin & Shaw, 2013).

The focus of agriculture also differs based on land size. Smaller landholders (under 2 bighas) primarily cultivate vegetables (53 respondents), while rice remains the dominant crop for medium-sized farms (3-6 bighas) with 68% (51 respondents) dedicating land to it. For those with extensive holdings (over 10 bighas), there's a shift

towards more profitable options like watermelon (57 respondents). This highlights a potential link between land size and crop selection, with farmers adapting their practices to maximize yield and income on the available land. This intensive cultivation allows farmers to leverage the productive potential of the land and potentially increase their overall income (Emran *et al.*, 2021).

The data also suggests that agriculture is practiced throughout the year. While a significant portion (42% of respondents) cultivate crops two to three times annually, a substantial number (38% of respondents) engage in intensive cultivation with four or more cycles per year. Coastal agriculture in Bangladesh is practiced throughout the year, with a significant portion of farmers cultivating crops two to three times annually (Abedin & Shaw, 2013). Income seems to be directly related to the scale of operation and crop selection. Smaller farms generate lower annual earnings per bigha, typically falling within the range of 10,000-20,000 taka. In contrast, medium-sized farms see a significant increase in earnings (21,000-40,000 taka per bigha), and larger landholders cultivating high-value crops like watermelon can potentially earn even more (exceeding 41,000 taka per bigha). This underscores the economic importance of land size and crop selection for coastal farmers. While rice remains a staple crop, there's a clear trend towards high-value options like watermelon, indicating a focus on maximizing profit. The trend of higher income with larger landholdings and high-value crops like watermelon is likely consistent across Bangladesh's coastal regions (UNDP, 2024). This adaptability will likely be crucial for the region's long-term agricultural success, particularly in the face of a changing climate and economic landscape.

Farmers Feel Salinity Hamper Crops and Livelihood Along Pashur River

Most of the respondents near the river Pashur were related to farming and almost all of them recognized the effects of salinity on crops, indicating widespread recognition of the issue. 70% of them ensured that salinity levels increased mostly during March-June at monsoon time, 20% followed by November-February and least during July-October over the year. Salinity intrusion in Bangladesh is a time-varying event and is minimal during the monsoon (June-October) due to the pushback of the rivers' discharge at the salinity front in estuarine and floodplains (Mahmuduzzaman *et al.*, 2014). Besides this 95% of people agreed with the risk of cropland flooding 0-2 times a year which is also a strong reason for less production in their cropland for saline water intrusion. 65% of people ensured that among all kinds of arable land, riverside lands, and lowland areas are mostly affected by salinity which aligns with the result of Habiba *et al.* (2014). High land and medium-high land are less affected. According to their farming experience, the most common symptoms observed due to salinity are growth problems of crops and dead leaves. Other symptoms include germination problems, dry leaves, and

faded plants. In those areas, rice is the most damaged crop by salinity rather than vegetables and watermelon. This might be due to the specific salt tolerance levels of these crops, with rice being generally less tolerant than vegetables and watermelons (Al-Tamimi *et al.*, 2021). The annual damage of crops is mostly in the range of 21K-50K (76 respondents), followed by 51K-1Lakh (80 respondents). Less frequent are damages under 20K (32 respondents), 1-2Lakh (32 respondents), and over 2Lakh (20 respondents). The majority of respondents (73%) reported that in the absence of salinity issues the expected rice production levels are between 21-30 maund per bigha. Besides this, several natural calamities are responsible for less production of crops like floods, heavy rainfall, drought, flow tide, and river erosion. Among all of them, floods are the most cited natural calamity responsible for reduced crop production clarified by 78% of respondents. As the production rate declines due to salinity and other natural calamities, people in these areas mostly depend on shrimp farming in Gher. From the 1980s, rising seas and storm surges began pushing saltwater over the banks of tidal rivers and ruining crops and this led farmers to flood their paddies with brackish water and stock the briny ponds with black tiger prawn fry (Guardian, 2022). Although salt tolerance plant breeding or the application of alternate irrigation techniques can combat salinity (Afzal *et al.*, 2022) farmers might not be completely informed about the most recent developments. So, the economic situation deteriorates as a result of lower crop yields induced by high soil salinity.

Salty River Water Affecting Farms: Solutions to Consider

The investigation undertaken in the Pashur River region disclosed a clear connection between soil salinity and water salinity. Soil salinity increased in line with water salinity as one proceeded south. This means that saline river water percolates into the soil and collects ions within the soil profile via evaporation and capillary action. The detrimental effects of salinity on Agricultural productivity were readily apparent due to the detrimental effect of salinity as the majority of producers encountered diminished crop yields, with rice being specifically impacted. A variety of solutions can be employed to address this issue. The adoption of freshwater irrigation techniques can effectively decrease the accumulation of salts by diluting their existing state (FAO, 2020). Chila Khal is one of the tributary rivers of Pasur that goes through both the Chila Union and some sections of the Chandpai Union. From the expert opinion, Chilar Khal produces large saline intrusion in various villages in Chila Union, such as Purbo Chila, Moddhoholholdibuniya, Boddhmari Bazar, and Gholer Danga. Similarly, in Chandpai Union, the villages of Dokkhinkainmari and Kalikabari are facing high salt levels. A sluice gate in the mouth of Chilar Khal can reduce the salt problem in those areas. Drainage systems can reduce surplus saline water in locations plagued by salt water, while salt-tolerant crops can provide a sustainable means of production

(FAO, 2020b). The development and adoption of salt-resistant plants may serve as bioremediation to give a sustainable way of mitigating soil salinity (Wang *et al.*, 2020). Furthermore, soil amendments such as gypsum or limestone might boost drainage capacity and reduce the adverse effects of salt on the structure of the soil. Farmers dwelling in the Pashur River region can work towards controlling salinity and enhancing agricultural output by applying the previously listed measures.

CONCLUSION

The investigation found considerable differences in water and soil quality parameters, as well as strong correlations between several variables in the Pashur River basin and their consequences for local agriculture and livelihoods. The EC's geographic distribution demonstrated a southward shift in salt levels in both water and soil samples, indicating that water salinity may influence soil characteristics. This conclusion underlines the need to comprehend and mitigate the consequences of saltwater intrusion on agricultural productivity and coastal communities. The study uncovers variances in land size and crop choices in agriculture, with smaller farms focusing on vegetables, medium farms on rice, and large farms on high-value crops like watermelon, thereby increasing productivity and profitability based on available acreage. The study also showed that salt negatively influenced agricultural production, with rice production dropping considerably.

Farmers in the region confront issues in mitigating soil salinity and improving agricultural production, necessitating the installation of effective mitigation techniques such as freshwater irrigation, drainage systems, salt-tolerant crops, and soil additives to reduce salinity and improve yields. Even though the study gives information on the interconnection between water and soil features in the Pashur River basin, further research is needed on saltwater intrusion mechanics, mitigation effectiveness, and socioeconomic impacts. Collaborative efforts among scientists, policymakers, and communities are crucial for sustainable coastal agriculture. Overall, addressing soil salinity issues in the Pashur River basin will require multidisciplinary study and collaboration among scientists, legislators, and community members to build resilience and sustainability in coastal agriculture systems by better understanding these complex environmental challenges and implementing effective mitigation techniques.

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