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EXPLORING THE STATE OF SOIL CHEMICAL PROPERTIES LINKED TO SALINITY IN SOUTH-CENTRAL COAST BANGLADESH

K. K. A Ansari *, A. K. Azad and M. M. Rahman
Environmental Science Discipline, Khulna University, Khulna-9208
*Corresponding author's email: khairulmes@yahoo.com

ABSTRACT

It is well known that soil is the basic media for agriculture, on which crop yield is mostly depended; hence the study analyzed nine important soil nutrients collected from 32 specified locations in Barishal and Patuakhali districts (16 from Barishal and 16 from patuakhali) during the period of 2017 to 2019. The soil nutrients were measured in Khulna University Environmental Science Discipline Laboratory, Khulna. The pH values ranged 6.7 to 7.8 in Barishal district. In Patuakhali district, pH ranged 5.8-7.3, which proved the quite acidity in soil. The detected EC values in Barishal were below 1 in most of the cases. On the other hand, the soil EC measured as 0.06-7.1 ds/m in Patuakhali district. About half of the samples confirmed the desired OM with the values 0.91-2.53% OM in Barishal district. Other remaining samples did not ensure the desired value fallen up to 0.91%. The values of OM were higher OM in Patuakhali district ranged as 0.91-2.53%. The total N content in the soil was generally very low to low, ranging from 0.053-0.168 and 0.053-0.129% in Barishal and Patuakhali districts, respectively. In surface soil, the available phosphorus (P) content ranged from (5.75 to 11 µg/g) with the mean values 8.879 µg/g in Barishal district, while the average P value was 7,400 µg/g varied as 4.29-13.16 µg/g in Patuakhali district. The K values obtained confirmed the sufficient K values both in Barishal and Patuakhali districts compared to std. values for FRG (2012). The study detected the amount of S as 11.01-94.98 µg/g in Barishal district, but 12.44 -172.39 µg/g in Patuakhali. The extreme level of S was measured due to frequent handling S containing chemicals/materials in the rural coastal agricultural fields of Bangladesh. The analyzed Zn amount recorded as 0.31-0.66 µg/g in Barishal districts, which confirmed the lower Zn, whereas, optimum (0.10-1.65 µg/g) in Patuakhali district. The detected B status confirmed the enough B contents in Patuakahli soil.

Key words: Salinity, chemical properties, central-coast.

Introduction

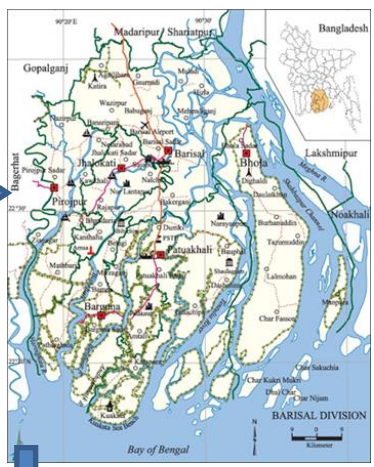
Various types of environmental issues and problems are hindering the development of coastal livelihood of Bangladesh. Salinity is one of them, which is expected to aggravate by climate change and sea level rise and eventually affect food production. Bangladesh has 147,570 km^2 land area that includes 710 km coastal line along the Bay of Bengal (BBS, 2003). In Bangladesh about 0.883 million hectares of the arable lands, which constitutes about 52.8 percent of the net cultivable area in 64 Upazilas of 13 districts, are affected by varying degrees of soil salinity (Karim *et al*., 1990). A recent study indicates that the salinity affected area has increased from 8,330 km^2 in 1973 to 10,560 km^2 in 2009 (SRDI, 2010). Tidal flooding occurs during wet season (June-October), direct inundation by saline water and upward on lateral movement of saline ground water during the dry season (November-May) (Haque, 2006). In addition, cyclone and tidal surge is accelerating this problem (Abedin, 2010). In the coastal areas of Bangladesh, saline water is used for irrigation which reduces the growth of most agricultural crops (Murtaza *et al*., 2006). Salinity is causing decline in soil productivity and crop yield which results in severe degradation of bio-environment and ecology as well as responsible for low cropping intensity in coastal area (Rahman and Ahsan, 2001). Rice (*Oryza sativa* L. spp. *indica)* is one of the five main carbohydrate crops responsible for feeding the world's population including Asian countries and more than 3 billion people which comprises 50%-80% of their daily calorie intake from rice (Khush, 2005). Rice has previously been reported as salt susceptible in both seedling (Munns and Tester, 2008), and reproductive stages (Moradi and Ismail, 2007) leading to a reduction of more than 50% in yield when exposed to 6.65 dSm^{-1} EC (Zeng and Shannon, 2000). Ali

(2005) investigated the loss of rice production in a village of Satkhira district (a salinity affected area) where loss of rice production was 69% in the year of 1985 to 2003.Coastal districts are vulnerable to cyclones, tidal surges, tidal and flash flood and other natural calamities (BBS, 2001). The paddy field also becomes saline because it contacts with the sea water and continues to be inundated during high tides and ingress of sea water through river and creeks in Barishal and Patuakhali area. Farmers are changing agricultural practices and reducing crop cultivation. The objectives of this study were to determine the level of soil salinity and assessing current soil fertility status of paddy fields and recommend some measures to reduce salinization process to improve soil fertility status in eight unions of Barishal and Patuakhali district of Bangladesh. Intensive researches on soil salinity have reported the adverse effects of salinity on the physical and chemical properties of soils and on plant growth and yield (Kahlown and Azam, 2003). But there is limited research on the relationship between soil salinity and physico-chemical properties of paddy field soils and prediction their effects. This study attempted to focus to fill that research gap.

Materials and Methods

Study area: Soil analysis-related studies were conducted to investigate the quality and salinity of top soil (0-15 cm) at Barishal and Patuakhali coastal districts of Bangladesh during the period of 2017-2019. The identified sites are shown in Figs. 1-4.

Bangladesh Map



Barishal Divisional Map

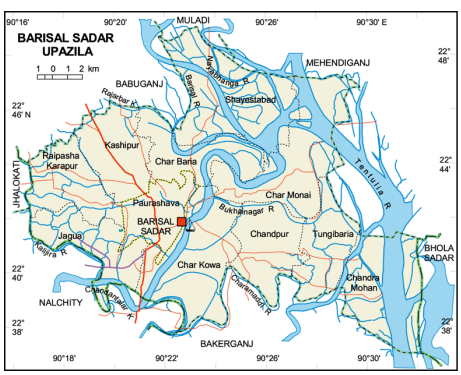


Fig. 1. Map of Barishal Sadar Upazila

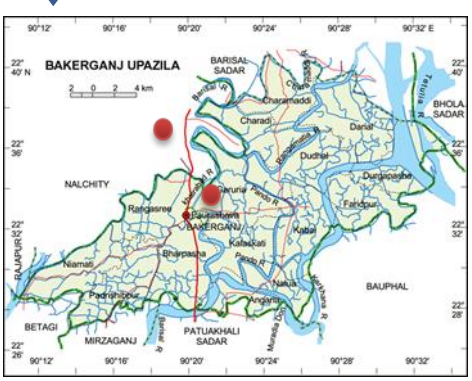


Fig. 2. Map of Bakergonj Upazila

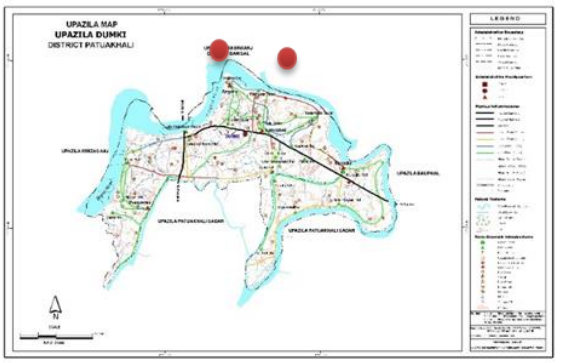


Fig. 3.Map of Dumki Upazila

Fig. 4 .Map of Kalapara Upazila

Soil Sampling: The sample was scraped from top to bottom using an auger. Each sample was placed separately on brown paper and the contents of each brown paper were thoroughly mixed. The sample was placed in a sealed polyethylene bag and labeled with the date of collection, location, and code number of the soil sample. The samples were then transported to the Khulna University Environmental Science Laboratory in Khulna. In the lab, samples (about 500 g for each one) were stored in a clean, cool, dry place for further physical and chemical analysis.

Sample analysis: In analyzing the physicochemical properties of soil, a variety of standard methods were used, and many sophisticated instruments were used. The used instruments and followed methods to be analyzed the pH, Electrical conductivity (EC), organic matter (OM), total nitrogen (N), available phosphorus (P), available potassium (K), sulphur (S), zinc (Zn) and boron (B) are illustrated in Table 1.

Table 1. The Name of parameter, unit, method and instrument name for soil quality analysis

Parameters	Unit	Method/ Instrument	Instrument name
pH		Glass Electrode pH Meter	Potentiometric Method
EC	ds/m	EC Meter	EC Meter Electrode, Filter paper,
OM	%	Tyrin's methods	Filter paper, Conical Flask and others
TN	%	Digestion, distillation and titration	Burette, Pipette, Conical Flask and others
P	mg/g	Molybdophosphoric yellow colour method	Spectrophotometer
K	meq/100g	Flame Emission Spectroscopic Method	Flame photometer
S	mg/g	Turbidimetric Method	Spectrophotometer
Zn	mg/g	Smart Analyzer	Spectro Analytical Instrument GmbH
B	mg/g	Smart Analyzer	Spectro Analytical Instrument GmbH

Data processing and analysis: Analyzed data and information were classified and interpreted in MS Word and Excel, 2010 and SPSS-20 with the help of various analytical methods and computer programs according to the purpose.

Correlation analysis for soil parameters: To explore the relationship among the soil quality parameters, Pearson Correlation Co-efficient (r) was calculated. A probability level of five percent (0.05) was used to reject a null hypothesis.

Results and Discussion

pH: Soil pH was measured firstly in this experiment; actually Soil pH is the main factor controlling the availability of nutrients in the soil. Generally, the availability of macronutrients increases in higher pH, whereas lower pH increases the availability of micronutrients except Mo (FRG, 2012). The ideal range of

pH in soil is 6.00 to 6.50, because most of the plants nutrients are available in this stage (Vossen, 2012), but the soil pH of the present study ranged 6.7 to 7.8 (Table 2) in Barishal district, which proved the slightly alkaline in soil of Barishal district. This was due to saline water intrusion in locality but the situation is not alarming, where much care is highly recommended to mage the excess saline water intrusion in agricultural field. In case of Patuakhali, pH ranged 5.8-7.3, which proved the quite acidity in soil. This is exception for Patuakhali as the site is closest to the Bay of Bengal, where there is more possibility of alkanity. The situation was due to availability of soil nutrient especially P, where the positive relations between pH and P is highly recognized (FRG, 2012).

Table 2. Soil Chemical Properties at Barishal District

Location/ Union	PH	EC (ds/m)	OM (%)	TN (%)	P (mg/g)	K (meq/ 100g)	S (mg/g)	Zn (mg/g)	B (mg/g)
Charmonai-1	7.8	0.8	1.05	0.061	9.66	0.12	36.99	0.39	0.50
Charmonai-2	7.7	0.7	1.11	0.071	9.11	0.14	37.01	0.36	0.56
Charmonai-3	7.6	0.9	2.46	0.143	10.65	0.15	35.43	0.33	0.34
Charmonai-4	7.5	1.0	2.33	0.168	10.23	0.16	33.82	0.32	0.32
Charkawa-1	7.8	0.8	0.91	0.053	6.27	0.14	12.41	0.42	0.35
Charkawa-2	7.3	0.9	1.02	0.072	6.29	0.13	13.11	0.48	0.36
Charkawa-3	7.4	0.8	2.53	0.147	9.17	0.21	52.58	0.39	0.67
Charkawa-4	7.5	1.1	2.47	0.166	8.99	0.19	53.08	0.52	0.72
Rongosree-1	7.4	0.7	0.98	0.057	10.20	0.20	11.26	0.39	0.29
Rongosree-2	7.2	0.9	1.03	0.062	11.00	0.21	11.01	0.44	0.33
Rongosree-3	7.1	1.2	1.90	0.110	9.44	0.19	73.72	0.59	0.73
Rongosree-4	7.0	1.0	1.88	0.119	10.01	0.17	72.19	0.49	0.71
Bharpasa-1	7.3	0.8	0.91	0.053	5.75	0.14	22.16	0.31	0.38
Bharpasa-2	7.4	0.7	1.15	0.099	6.09	0.16	21.99	0.37	0.45
Bharpasa-3	6.7	0.8	2.18	0.126	9.42	0.30	94.98	0.58	0.56
Bharpasa-4	6.8	0.9	2.53	0.201	9.79	0.40	94.01	0.66	0.55
Mean	7.343	0.875	1.652	0.106	8.879	0.188	42.234	0.44	0.488
SD	0.324	0.143	0.681	0.047	1.746	0.071	28.557	0.104	0.157

Table 3. Soil Chemical Properties at Patuakhali District

Location/ Union	PH	EC (ds/m)	OM (%)	TN (%)	P (mg/g)	K (meq/ 100g)	S (mg/g)	Zn (mg/g)	B (mg/g)
Pangasia-1	7.3	1.2	1.19	0.069	5.58	0.25	55.20	0.47	0.74
Pangasia-2	7.1	1.32	1.11	0.071	6.11	0.31	53.12	0.42	0.73
Pangasia-3	7.2	0.06	1.40	0.081	13.16	0.23	27.32	0.28	0.68
Pangasia-4	7.2	0.09	1.51	0.099	12.22	0.27	28.11	0.32	0.66
Angaria-1	6.4	1.7	1.97	0.114	4.29	0.30	14.90	0.47	1.15
Angaria-2	6.6	1.75	2.09	0.111	5.01	0.35	15.02	0.41	1.13
Angaria-3	7.2	0.7	0.91	0.053	4.29	0.35	13.92	0.10	1.15
Angaria-4	7.1	0.9	1.01	0.066	4.92	0.30	12.44	0.16	1.14
Tiakhali-1	6.5	6.8	1.90	0.110	12.40	0.46	172.39	1.62	1.06
Tiakhali-2	6.6	7.1	2.00	0.118	11.38	0.38	172.01	1.65	1.11
Tiakhali-3	6.7	4.7	1.05	0.061	6.30	0.54	130.09	0.42	1.55
Tiakhali-4	6.5	5.1	1.10	0.077	6.55	0.61	124.92	0.43	1.47
Nilgonj-1	5.8	5.5	2.11	0.122	5.30	0.27	107.49	1.30	1.65
Nilgonj-2	5.9	6.1	2.55	0.129	5.28	0.34	105.99	1.36	1.71
Nilgonj-3	6.9	4.9	1.33	0.077	7.85	0.33	89.17	0.42	1.43
Nilgonj-4	7.01	5.2	1.41	0.069	7.77	0.29	90.55	0.49	1.50
Mean	6.750	3.32	1.54	0.089	7.400	0.348	75.79	0.645	1.178
SD	0.459	2.547	0.494	0.02	3.104	0.104	56.016	0.517	0.349

EC: EC is another important factor giving a measure of the strength of the ions in the soil. There is a high correlation between better crop yield and the prevailing electrical conductivity (EC) including soil texture, cation exchange capacity (CEC), drainage conditions, organic matter level, salinity and soil characteristics. Plants are adversely affected both physically and chemically by excess salts in some soils and by high levels of exchangeable sodium in others. Hence the study measured the EC collecting soil samples from sixteen different sites of Barishal district and the findings are shown in Table 2. The detected EC values were below 1 in most of the cases. Only 4 samples showed the EC higher than upto 1.2ds/m. But all values confirmed the non-saline soils in the sampling areas of Barishal district. It is very positive sense for safely growing the agricultural crops without facing any hazards of salinity in Barishal district. On the other hand the soil EC measured as 0.06-7.1 ds/m in Patuakhali district. Amongst the sixteen soil samples collected from the different sites of Patuakhali district, four samples showed the EC values below 1, whereas four samples gave the values within 1-2 ds/m. These eight samples i.e. 50% soil samples (collected from Dumki upazila) confirmed the non-saline sate in the study areas of Patuakhali district accordingly the standard values of EC as stated by Smith and Doran (1996). The soil samples collected from Kalapara upazila showed the EC vales within the range of 4.72 to 7.1 ds/m, which confirmed the moderately salinity having the hazards for crop production (Smith and Doran, 1996). The above fluctuations in salinity were due to the location and protection measures against intrusion of saline water in places where Kalapara upazila was suffering seriously from salinity while producing crops.

OM: In the present study half of the samples confirmed the desired OM with the values 0.91-2.53% OM in Barishal district. Other samples did not ensured the desired value having the value fallen up to 0.91%. Actually the overall OM status of Bangladesh is not sufficient enough except water logging and coastal areas of Bangladesh. The higher OM in the water logging and coastal areas are due to carrying biomass and deposited over soil in time. The measured OM in Patuakhali also ranged as 0.91-2.53% OM. But comparatively most of the soils of Patuakhali district showed the lower OM than that of Barishal district. So, still there are scope to be increased the OM adding cowdung, compost, FYM etc. in both of the districts due to ensure the sustainable crop production for natural hazards prone coastal areas of Bangladesh.

Total N: Nitrogen is the most important nutrient for crop cultivation in Bangladesh. Still our farmers are pay their great demand for this nutrient as the reaction of N is quickly visible than for other nutrients. The total N content in the soil was generally very low to low, ranging from 0.053-0.168 and 0.053-0.129% in Barishal and Patuakhali districts, respectively (Tables 2-3) compared to std. values for FRG (2012). Only one soil sample collected from the Bharpasha Union in Barishal district showed the medium level of N (0.201%). However, the detected low N content in the study area reveals poor quality of soils, which can be attributed to the low organic matter content of the soils and the prevailing high temperature in the studied coastal areas of Bangladesh. These results came very close to Chowdhury and Islam (2019).

Phosphorus (P): Phosphorus is an important macro element needed for plant nutrition. It participates in metabolic processes such as photosynthesis, energy transfer and synthesis and degradation of carbohydrates. P is found in the soil in organic compounds and in minerals. The available P of various studied soils has been shown in Tables 2-3. In surface soil, the available P content ranged from (5.75 to 11 µg/g) with the mean values 8.879 µg/g in Barishal district, while the average P value was 7,400 µg/g varied as 4.29-13.16 µg/g in Patuakhali district. The results explored that the P status was low to medium in the study areas, except four soil samples in Patuakhali which confirmed the optimal level of P compared to std. values for FRG (2012). This result was supported by Shaibur *et al*. (2017).

Potassium (K): Potassium is an important plant nutrient and is required in large quantities for proper growth and reproduction of plants. K is considered only nitrogen when it comes to nutrients required by plants and is usually considered "quality nutrient." Here, in the present study, K content was found to be 0.12-0.40 meq/100 g with the mean 0.188 meq/100 g in Barishal district, while K varied 0.23-0.61 meq/100g in Patuakhali with the mean 0.348 meq/100g K (Tables 2-3). The K values obtained confirmed the sufficient K values both in Barishal and Patuakhali districts compared to std. values for FRG (2012). This was perhaps a somewhat high pH and OM content in the studied coastal soils in Bangladesh.

Sulfur (S): Sulfur is now recognized worldwide as the fourth major phyto nutrient after N, P and K. S is derived from sulfur-containing minerals present in the parent materials, from which the soil is derived, and from plant and animal residues, or from external additions of element S or its minerals. The study detected S as 11.01-94.98 µg/g with the mean value of 42.23µg/g in Barishal district, on the other hand 12.44 - 172.39 µg/g in Patuakhali having the average value of 75.79µg/g (Tables 2-3). In both cases extreme level of S was measured due to frequent handling S containing chemicals/materials in the rural coastal agricultural fields of Bangladesh.

Zinc (Zn): Zinc is important to ensure early plant growth. Hence the study detected Zn status in the collected soil samples of Barishal and Patuakhali districts, respectively. The analyzed Zn amount recorded as 0.31-0.66 µg/g with the average value of 0.44µg/g in Barishal districts, which confirmed the Zn status below the optimum level. On the other hand, the detected Zn values ranged as 0.10-1.65µg/g having the average value of 0.645µg/g, here only four soil samples showed the Zn level upto optimum level as compared the values with FRG std. The above situations suggested using Zn containing fertilizer to achieve desire yield in the studied coastal areas of Bangladesh.

Boron (B): Boron is a micronutrient that is essential for the growth and health of all crops. It is a component of the plant cell wall and reproductive structure. The study also detected the B amount both in Barishal and Patuakhali districts with the amount of 0.29-0.73 and 0.66-1.71µg/g, respectively. The detected B status confirmed the enough B as compared with the std. values of FRG (2012). It mentioned no B deficiency in the studied samples yet, which ensures the good sign for agricultural production without using B containing fertilizers in the studied central coastal zone of Bangladesh.

Correlation studies: The study showed the relationship among the soil characteristics collected from different locations of Barishal district. The relationship was also statistically analyzed, where it was found that there were enough significant variations among pH, OM, Total N, K, S and B (Table 4). Whereas no distinguish relationship was not found for EC, due to less salinity in the studied coastal Barishal district of Bangladesh. The study also analyzed the relationship for soil characteristics in Patuakhali district, where it was found that there were enough significant variations among pH, OM, Total N, S, Zn and B (Table 5). Here somewhat distinguish relationship was found for EC due to prevailing slightly salinity in the studied coastal Patuakhali district of Bangladesh.

Table 4. Pearson Co-relation coefficient for Soil Chemical Properties (SCP) at Barishal District

	pH	EC	OM	TN	P	K	S	Zn	B
pH	1								
EC	-.261 .329	1							
OM	-.358 .173	.504* .047	1						
TN	-.383 .144	.466 .069	.949* .000	1					
P	-.183 .496	.292 .273	.486 .057	.392 .133	1				
K	-.757** .001	.079 .770	.520* .039	.592* .016	.340 .197	1			
S	-.683** .004	.394 .131	.708** .131	.675** .004	.358 .173	.696** .003	1		
Zn	-.716** .002	.466 .069	.370 .158	.410 .115	.176 .515	.730* .001	.733* .001	1	
B	-.320 .227	.458 .074	.489 .055	.423 .103	.154 .568	.252 .346	.734** .001	.547* .001	1

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed).

Table 5. Pearson Co-relation coefficient for Soil Chemical Properties (SCP) at Patuakhali District

	pH	EC	OM	TN	P	K	S	Zn	B
pH	1								
EC	-.665** .005	1							
OM	-.766** .001	.451 .079	1						
TN	-.761** .001	.417 .108	.962** .000	1					
P	.228 .397	.130 .632	.084 .758	.168 .533	1				
K	-.277 .300	.504* .046	-.156* .564	-.104 .700	-.034 .900	1			
S	-.481 .059	.923** .000	.271 .310	.290 .275	.340 .197	.584* .017	1		
Zn	-.684** .003	.789** .000	.728** .001	.742** .001	.299 .261	.151 .578	.774** .000	1	
B	-.704** .002	.696** .003	.292 .272	.190 .480	-.431 .095	.420 .105	.452 .079	.307 .248	1

**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed).

Conclusion

In the present study different aspects of environment was minutely investigated paying great attention in agriculture sector. We know that soil is the basic media for agriculture, on which crop yield is mostly depended, such even the prevailing nutrient of soil is quite enough to ensure demanding yield of many crops. Here we analyzed nine important soil nutrients collected soil from 32 specified locations of Barishal and Patuakhali districts. Sixteen soil samples from each district were collected to know how the soil's ability to grow crops. The soils of the study area are quite fertility for safely crop production except excess S contamination due to frequent handling S containing chemicals/materials in the studied areas.

References

Abedin, M. Z. 2010. Global warming, climate change and impact on agriculture in Bangladesh. 4th National Convention of Krishibid Institute, Bangladesh.

Ahmed, A. 2011. Some of the major environmental problems relating to land use changes in the coastal areas of Bangladesh: A review. *J. Geo. Regio. Plann.*, 4:1-8.

Ali, A. M. S. 2005. Rice to shrimp: Land use/land cover changes and soil degradation in southwestern Bangladesh. *Land Use Policy*, 23(4), 421-435. http://dx.doi.org/10.1016/j.landusepol.2005.02.001.

BBS (Bangladesh Bureau of Statistics). 2001. Statistical year book of Bangladesh. Government of the people's republic of Bangladesh, Dhaka.

BBS (Bangladesh Bureau of Statistics). 2003. Population census 2001. Retrieved April 12, 2012, from http://www.bbs.gov.bd/PageWebMenuContent.aspx?MenuKey=57.

Chowdhury, S. A. R. and Islam, M. 2019. Evaluation of soil health in construction sites of developing coastal areas of Bangladesh. *Bangladesh J. Environ. Sci*., 37:94-97.

FRG (Fertilizer Recommendation Guide), 2012. Bangladesh Agricultural Research Council, Farmgate, New Airport Road, Dhaka-1215.

Haque, S. A. 2006. Salinity problems and crop production in coastal regions of Bangladesh. *Pakistan J. Bot.*, 38(5), 1359-1365.

Hossain, M. A. 2009. Global warming induced sea level rise on soil, land and crop production loss in Bangladesh. SRDI, Ministry of Agriculture, Dhaka, Bangladesh. Retrieved from http://msucares.com/crops/soils/phosphorus.html

Islam, M. S., Razzaque, M. A., Rahman, M. M. and Karim, N. H. 2004. Present and future of agricultural research in Bangladesh (in Bangla). Agriculture in the 21st Century: challenges and possibility (pp. 20-27). Ministry of Agriculture, Dhaka, Bangladesh.

Kahlown, M. A., and Azam, M. 2003. Effect of saline drainage effluent on soil health and crop yield. *Agric. Water Manage*., 62(2), 127-138. http://dx.doi.org/10.1016/s0378-3774(03)00096-9.

Karim, Z., Hossain, S. G. and Ahmed, M. 1990. Salinity problems and crop intensification in the coastal regions of Bangladesh (p. 63).

Khush, G. S. 2005. What it will take to feed 5.0 billion rice consumers in 2030. Plant Mol. Bio., 59(1), 1-6. http://dx.doi.org/10.1007/s11103-005-2159-5.

Liang, Y., Si, J., Nikolic, M., Peng, Y. and Chen, W. 2005. Organic manure stimulates biological activity and barley growth in soil subject to secondary salinization. *Soil Biol. Biochem*., 37(6), 1185-1195. http://dx.doi.org/10.1016/j.soilbio.2004.11.017.

Moradi, F. and Ismail, A. M. 2007. Responses of photosynthesis, chlorophyll fluorescence and ROS-scavenging systems to salt stress during seedling and reproductive stages in Rice. *Annals Bot*., 99(6), 1161-1173. http://dx.doi.org/10.1093/aob/mcm052.

Munns, R. and Tester, M. 2008. Mechanisms of salinity tolerance. *Annu. Rev. Plant Biol.*, 59(1), 651-681. http://dx.doi.org/10.1146/annurev.arplant.59.032607.092911.

Murtaza, G., Ghafoor, A. and Qadir, M. 2006. Irrigation and soil management strategies for using saline-sodic water in a cotton-wheat rotation. *Agric. Water Manage*., 81(1-2), 98-114. http://dx.doi.org/10.1016/j.agwat.2005.03.003.

Qadir, M., Oster, J. D., Schubert, S., Noble, A. D. and Sahrawat, K. L. 2007) Phytoremediation of sodic and saline-sodic soils. *Advances in Agron.*, 96, 197-247. http://dx.doi.org/10.1016/s0065-2113(07)96006-x

Shaibur. M. R., Shamim, A. H. M., Khan, M. H. and Tanzia, F. K. S. 2017. Exploration of soil quality in agricultural perspective at gabura and burigoalini union: Shyamnagar, Satkhira, Bangladesh. *Bangladesh J. Environ. Sci*., Vol. 32, 89-96.

Smith, J. L. and J. W. Doran. 1996. Measurement and use of pH and electrical conductivity for soil quality analysis. P. 169-185 *In* J.W. Doran and A.J. Jones (ed.) Methods for assessing soil quality. Soil Science Society of America Spec. Publ. 49. SSSA, Madison, WI.

SRDI (Soil Resource Development Institute). 2010. Saline Soils of Bangladesh. Ministry of Agriculture, Dhaka, Bangladesh.

Tanji, K. K. 2002. Salinity in the Soil Environment. Salinity: Environment – plants – molecules (pp. 21-51). Kluwer Academic, Dordrecht, The Netherlands. http://dx.doi.org/10.1007/0-306-48155-3_2

Vossen, P. 2012. Changing pH in soil, Santa Rosa; cooperative extension University of California, pp. 1-2.

Wang, Q. Z., Wu, C. H., Xie, B., Liu, Y., and Cui, J. 2012. Model analyzing the antioxidant responses of leaves and roots of switchgrass to NaCl-salinity stress. *Plant Physiol. Biochem.*, 58, 288-296. http://dx.doi.org/10.1016/j.plaphy.2012.06.021

Zeng, L., and Shannon, M. C. 2000. Salinity effects on seedling growth and yield components of rice. *Crop Sci*., 40(4), 996-1003. http://dx.doi.org/10.2135/cropsci2000.404996x.