EFFECT OF SALINITY ON SOIL PROPERTIES OF COASTAL AREAS IN BANGLADESH

RAJA MD. MASUM

DEPARTMENT OF

AGROFORESTRY & ENVIRONMENTAL SCIENCE

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

DECEMBER 2015

EFFECT OF SALINITY ON SOIL PROPERTIES OF COASTAL AREAS IN BANGLADESH

RAJA MD. MASUM

REGISTRATION NO. 14-06351

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE

IN

AGROFORESTRY & ENVIRONMENTAL SCIENCE

SEMESTER: JULY-DECEMBER, 2015

Approved by:

…………………………………………….
Prof. Dr. Nazmun Naher
Supervisor
Department of
Agroforestry & Environmental Science
Sher-e-Bangla Agricultural University
Dhaka

……………………………………….
Prof. Dr. Alok Kumar Paul
Co-Supervisor
Department of Soil science
Sher-e-Bangla Agricultural University
Dhaka

……………………………………………
Dr. Ferzana Islam
Chairman
Examination Committee

CERTIFICATE

*This is to certify that the thesis entitled "***EFFECT OF SALINITY ON SOIL PROPERTIES OF COASTAL AREAS IN BANGLADESH***" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***AGROFORESTRY & ENVIRONMENTAL SCIENCE,*** *embodies the results of a piece of bona fide research work carried out* ***RAJA MD. MASUM,*** *Registration. No.* ***14-06351*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information as has been availed of during the course of this investigation has duly been acknowledged.

....

Dated: December 2015

Place: Dhaka, Bangladesh

Prof. Dr. Nazmun Naher
Supervisor
Department of
Agroforestry & Environmental Science
Sher-e-Bangla Agricultural
University Dhaka

Dedicated to –

MY BELOVED

PARENTS

ACKNOWLEDGEMENTS

All praises to Almighty Allah, the Supreme Ruler of the universe who enables the author to complete this present piece of work.

The author would like to express his heartfelt gratitude to his research supervisor, ***Prof. Dr. Nazmun Naher,*** *Department of Agroforestry & Environmental Science, Sher-e-Bangla Agricultural University, Dhaka-1207, for her constant supervision and encouragement during his research work and guidance in preparation of manuscript of the thesis.*

Deepest sense of gratitude and profound appreciation to ***Dr. Ferzana Islam,*** *chairmen of Department of Agroforestry & Environmental Science, Sher-e-Bangla Agricultural University, Dhaka-1207.*

The author sincerely expresses his heartiest respect to his co-supervisor, ***Prof. Dr. Alok Kumar Paul,*** *Sher-e-Bangla Agricultural University Dhaka Dept. of Soil Scientist from, for constant encouragement, cordial suggestions, constructive criticisms and valuable advice during the research period and preparing the thesis.*

The author would like to express his deepest respect and boundless gratitude to all the respected teachers of the Department of Agroforestry & Environmental Science, Sher-e-Bangla Agricultural University, Dhaka-1207, for the valuable teaching, sympathetic co-operation and inspirations throughout the course of this study and suggestions and encouragement to research work. The author would like to express his cordial thanks to the departmental and field staffs for their active help during the experimental period.

At last but not the least, the Author feels indebtedness to his beloved parents whose sacrifice, inspiration, encouragement and continuous blessing paved the way to his higher education.

Dated: December 2015 ***The Author***

EFFECT OF SALINITY ON SOIL PROPERTIES OF COASTAL AREAS IN BANGLADESH

ABSTRACT

A field study was conducted to determine the impacts of salinity on soil properties at Babuganj, Bakerganj, Gournadi and Kalapara upazila during the period of July to September 2016. Soil sampling was done by random sampling method at 0-50cm and 50-100cm depth. Salinity has a detrimental effect on soil physical and chemical properties. The dominant soil textural classes in the saline areas are silty clay. The soils pH of the surface horizon is slightly lower than those of the subsoil and sub stratums. Cation Exchange Capacity (CEC) of all these soils varies from 12.83 to 20.92meq/100 g soil. Electrical conductivity (EC) of all these soil varies from 1.23 dS/m to 6.6 dS/m at Babuganj, Bakergnaj and Gournadi and moderately saline at Kalapara. The organic matter content is medium to high (0.62 to 1.6)% at Kalapara and Bakerganj, pretty low (0.39 to 1.03)% at Babuganj and Gournadi. Nutrient deficiencies for total nitrogen were quite dominant in the study area. Exchangeable sodium, potassium, calcium and magnesium were in high level. The dominant water soluble anions were Cl^- and SO_4^{2-}. The amount of accumulated salt was found higher at the surface and decreases with depth.

TABLE OF CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

AEZ	Agro- Ecological Zone
AAS	Atomic Absorption spectrophotometer
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BRRI	Bangladesh Rice Research Institute
CEC	Cation exchange capacity
CZPo	Coastal zone of policy
cm	Centimeter
CV	Coefficient of Variance
^{0}C	Degree Centigrade
Ca	Calcium
Cu	Cuper
$CuSO_4$ $5H_2O$	Copper sulphet pentahydrate
CH_3COONH_4	Ammonium acetate
DTPA	Di-ethylene Triamine Penta Acetic acid
dS/m	Dessisimen per meter
ESP	Exchangeable Sodium Percentage
Ex Na	Exchangeable sodium
Ex K	Exchangeable potassium
Ex Ca	Exchangeable calcium
Ex Mg	Exchangeable magnesium
et al.	And others
EC	Electrical conductivity
FAO	Food and Agriculture Organization
g	Gram (s)
H_2SO_4	Sulphuric acid
H_3BO_3	Boric acid
hr	Hour(s)
K_2O	Potassium Oxide

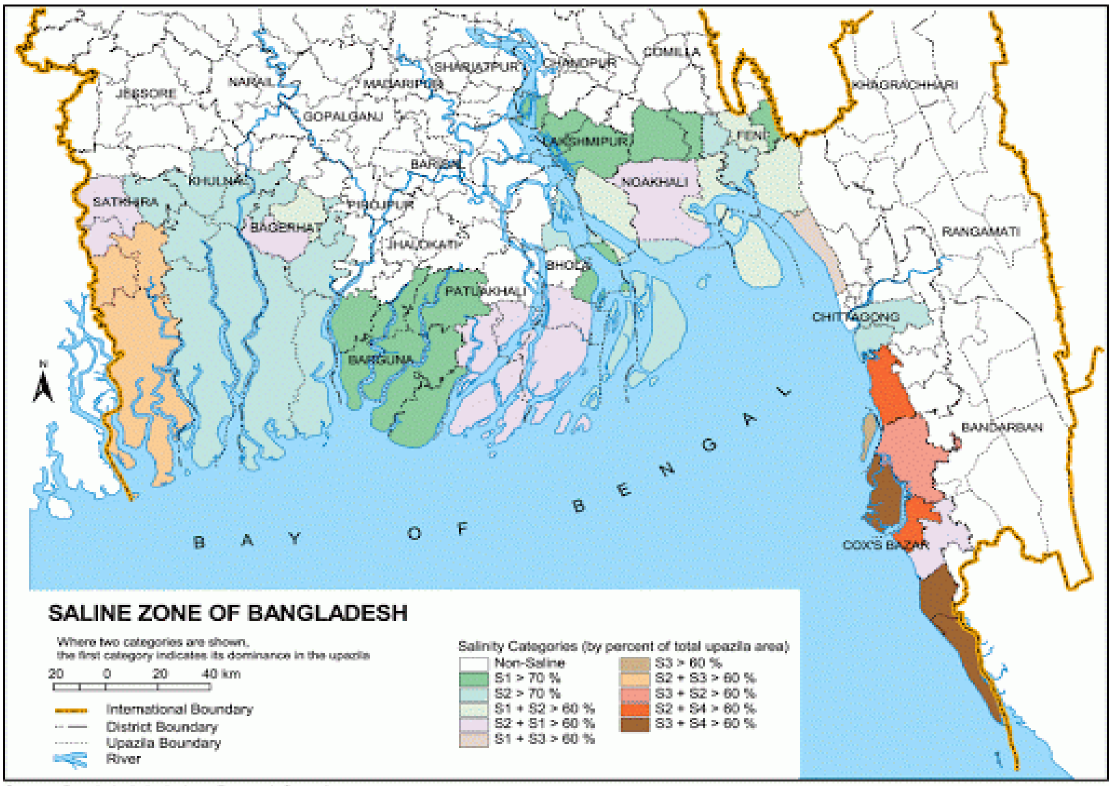
Kg	Kilogram (s)
m	Meter
m^2	Meter squares
Mm	Millimeter
Mha	Mega hectare
Meq	Milli equivalent
Max	Maximum
Min	Minimum
Mg	Magnesium
N	Nitrogen
NaOH	Sodium hydroxide
NaCl	Sodium chloride
No.	Number
NS	Non significant
%	Percentage
OM	Organic Matter
pH	Negative Logarithm of hydrogen ion concentration
P_2O_5	Phosphorus Penta Oxide
K_2SO_4	Potassium sulphet
S	Sulphur
STD	Standard deviation
SAU	Sher-e- Bangla Agricultural University
SRDI	Soil Resources Development Institute
t ha^{-1}	Ton per hectare
USDA	United Nations Department of agriculture
Wt.	Weight

CHAPTER I

INTRODUCTION

Salinity being a major problem is worldwide. Bangladesh is experienced with this problem and the southern part of the country also affected by salinity. The coastal region covers almost 29,000 km^2 or about 20% of the country. Coastal areas of Bangladesh cover more than 30% of the cultivable lands of the country (Islam, 2006). About 53% of the coastal areas are affected by salinity (Haque, 2006).According to the coastal zone policy (CZPo, 2005) of the Government of Bangladesh, 19 districts out of 64 are in the coastal zone covering a total of 147 upazilas of the country. Central coastal zone extends from Feni river estuary to the eastern corner of the Sundarbans, covering Noakhali, Barisal, Bhola and Patuakhali districts. The zone receives a large volume of discharge from the Ganges-Bhrahmputra-Meghna river system, forming high volume of silty deposition. More than 70% of the sediment load of the region is silt; with an additional 10% sand (Allison *et al*., 2003). In Bangladesh, salinization is one of the major natural hazards hampering crop production. The coastal saline are lies about 1.5 to 11.8 meters above mean sea level. The Ganges River meander flood plain systems are standing higher than the adjoining tidal lands. The tidal flood plain has a distinctive, almost level landscape crossed by innumerable interconnecting tidal rivers and creeks. The estuarine islands are constantly changing shape and position as result of river erosion and new alluvial deposition. The lands of coastal area become saline as it comes in contact with sea water by continuous inundation during high tides and ingress of sea water through cracks and sometimes cyclone induced storm surge. The severity of salinity is increasing in the coastal area during winter with the drying of soil (Naher *et al.*, 2011). During rabi season large area remain fallow due to lack of irrigation water and higher level of salinity. Again the coastal belts remain inundated with range of 60 cm to 80 cm from May to September limiting the cultivation of crops except some local rice varieties, covering 60% of total cultivated land (Karim *et al.*, 1998).

Soil with an electrical conductivity of saturation extracts above $4dSm^{-1}$ is called saline soil. The proportions of cations and anions in the natural soil water solution are a function of soil type, climate and land use. The concentration and relative proportions of these salts play a critical role in the salinity hazard of soil. Salinity can have a flocculating effect on soils, causing fine particles to bind together into aggregates. When high concentrations of sodium affect a soil, the subsequent loss of structure reduces the hydraulic conductivity, or rate at which water moves through a soil (Shainberg and Letey, 1984; Hanson *et al.*, 1999).Salinity became a serious problem for agriculture all over the world. (Charman and Murphy, 2000).On a global scale, nearly 40% of the earth`s land surface is potentially endangered by salinity problems. Salinity areas are increasing day by day. It is the measure of all the salts dissolved in the water and measured in parts per thousand (ppt or %). The average ocean salinity is 35ppt and average river water salinity is 0.5ppt or less. High salinity has an impact on people and Industries reliant on water from the river murray. It can also negatively affect plant growth and yields. The severity of salinity problem in Bangladesh increases with the desiccation of the soil. It affects crops depending on degree of salinity at the critical stages of growth, which reduces yield and in severe cases total yield is lost. Soil reaction values (pH) in coastal regions range from 6.0-8.4 (Haque, 2006 and Naher *et al.*, 2011). The organic matter content of the soils is also pretty low (1.0-1.5%) (Karim *et al.*, 1982). Nutrient deficiencies of N and P are quite dominant in saline soils. Micro-nutrients, such as Cu and Zn are widespread. During the wet monsoon the severity of salinity is reduced due to dilution of the salt in the root-zone of the standing crop. Salinity distributions in the coastal region of Bangladesh vary location to location. The costal zones of Bangladesh affected by different levels of salinity have been presented in Figure 1.



Source: Bangladesh Agriculture Research Council

Figure 1. Saline zone of Bangladesh (BARC, 2009)

Both water and soil salinity along the coast will be increased with the rise in sea level, destroying normal characteristics of coastal soil and water. Salinity causes unfavorable environmental and hydrological situation restricting the normal crop production throughout the year. Salinity problem received very little attention in the past, but due to increased demand for growing more food to feed the booming population of the country, it has become imperative to explore the potentials of these lands. So the present study was conducted to know the following objective(s):

1. To determine the salinity level at Babuganj, Bakerganj, Gournadi and Kalapara saline areas;
2. To study the physical and chemical properties of soils of these saline areas;
3. To study the effect of salinity on physico-chemical properties of saline soil.

CHAPTER II

REVIEW OF LITERATURE

This chapter has presented a comprehensive review of literature related to the saline soil.

2.1 Salt affected soils

Al-Busaidi (2014) reported thaton elemental nitrogen losses from soil concluded that losses were likely to be highest under alternate aerobic and anaerobic conditions, a situation exactly met within sodic soils.

Carson *et al*. (2009) reported that a disturbed balance in the uptake and composition of major nutrients is bound to influence the plant composition of micronutrients. Besides the generally known toxic effects of boron there is a need to understand better the behavior of Fe, Mn, Zn, Cu, etc., in relation to soil salinity particularly with a view to establishing limiting values so far only developed for normal soils.

Fallovo *et al.* (2009) reported that the soil chemical properties, especial nutritional disorders that is, decreased or increased solubility and availabilities of essential nutrients caused by the presence of excessive accumulations of specific ions and/or salts such as Na^+, HCO_3^-, CO_3^{2-}, SO_3^{2-}, or NaCl and Na_2SO_4.In salty soils, toxicity is due to the uptake of too many specific ions, often Na^+ and/or Cl^-, sometimes Mg^{2+} or others. High levels of exchangeable sodium and accompanying high pH of sodic soils affect the transformations and availability of several essential plant nutrients (Chinnusamy *et al*., 2005).

Farifteh *et al.* (2006) reported Soil salinity is a critical environmental problem in many countries around the world. This problem has deleterious impact on soil fertility which in turns reduces the soil productivity. Ghafoor *et al*. (2008); Murtaza *et al.* (2009) reported that salt affected soils can have major effect on soil physical properties, especial on the structure of soils. Soil structure, or the arrangement of soil particles, is critical in affecting permeability and infiltration. If a soil has high quantities of Na^+ and the ECe is low, soil permeability, hydraulic conductivity, and the infiltration rate are decreased due to swelling and dispersion of clays and slaking of aggregates.

Aydin *et al.* (2004) found that salt affected soils are characterized by accumulation of soluble salts: cations such as calcium, magnesium and sodium, and anions such as carbonate, sulfate and chloride. Abrol and Yadav (1988); Szabolcs (1989) reported that salt affected soils cover a range of soils defined as saline, saline-sodic, and sodic.

Keshavarz *et al*. (2004) reported that application of judicious quantities of P-fertilizers in saline soils helps to improve crop yields by directly providing phosphorus and by decreasing the absorption of toxic elements like Cl. On moderately saline soils, the application of potassium fertilizers may increase the crop yields either by directly supplying K or by improving its balance with respect to Na, Ca and Mg. However under high salinity conditions it is difficult to exclude Na effectively from the plant by use of K-fertilizers.

Szabolcs (1989); Oldeman *et al*. (1991) as reported that over 10% of the world's land is salt affected and the total global area of saline soils is 397 million ha and that of sodic soils is 434 million ha of the current 230 million ha of irrigated land, 45 million ha (19.5%) are salt affected soils and of the almost 1500 million ha of dry land agriculture, 32 million (2.1%) are salt affected soils to varying degrees by human-induced processes.

2.2. Origin and form

Minhas and Sharma (2003) reported that soil salinity problems can occur naturally (primary salinization), or as a result of human activities (secondary salinization).

Coram *et al*. (2001) found that the water table rises, salts stored within the soil profile are mobilized and carried toward the soil surface, resulting in salinization. At least 2.5 million hectares (5% of cultivated land) are currently affected by dry land salinity and approximately 5.7 million hectares of Australian farmland have a high salinity risk. This could rise to 12 million hectares (22%) in 50 years. Yeo (1999) found that Soils affected by secondary salinization account for about 76 Mha of 1.5 Mha cropped land, including 56Mha of 280 Mha irrigated lands in Australia.

Abrol and Yadav (1988) found that salt affected soils are more extensive in arid and semi-arid regions compared to humid regions. However, the occurrence of saline soils is not limited to arid environments. Salt affected soils can be found in the tropical regions of Africa and Latin America, and in all continents and under almost all climatic conditions.

Russell (1989) reported that in addition, salts can come from vegetation growing on salt affected soils. Up to one quarter of plant dry weight is ash, and the large proportion of the ash may be soluble salts. Almost 200 kg ha^{-1} of salts is brought annually to soil surface by vegetation. Although small compared to amounts of salts added by irrigation, plants can contribute to the accumulation of salts in the top soil over long periods of time. The area affected by salts is expected to increase over time due to water shortage, and adoption of agricultural practices such as the use of wastewater in irrigation or over fertilization with absence or installation of inefficient drainage systems.

Szabolcs (1989) showed that the phenomenon of primary salinization affects about 1.3 Gha out of the global land area of 13.4 Gha. Bertrand *et al*. (2003) reported that secondary salinization, the gradual buildup of salt in previously salt-free topsoil, occurs in irrigated areas as salt is introduced into the soil with every round of irrigation. Part of the salt is leached below the root zone, but parts remain in it. In Australia, the dry climate is the background of widespread salinity.

2.3. Characteristics of salt affected soils

Salinity and sodicity are major soil problems leading to the deterioration of soil fertility. The occurrence of each can change the properties of soils, but these two main groups of salt affected soils differ not only in the chemical characteristics, but also in the physical and biological properties.

2.3.1. Soil Physical Properties

Srivastava *et al*. (2014) reported that generally, soil physical properties (bulk density, soil aggregate stability, available water content, hydraulic conductivity and soil water retention potential) affected and also limiting root growth in the salt affected soils in the case of sodic soil.

Akhter *et al*. (2004) reported that the physical properties of soils determine their adaptability to cultivation and the level of biological activity that can be supported by the soil. Soil physical properties also largely determine the soil's water and air supplying capacity to plants. Many soil physical properties change with changes in farmlands and its management such as intensity of cultivation, the instrument used and the nature of the land under cultivation, irrigation water quality and management, rendering the soil less permeable and more susceptible to formation salt affected soil under irrigation farmland.

2.3.1.1. Soil texture

Rogobete *et al*. (2013) reported that the fluvisols have large pores and large soil texture, the solute transport to soil surface that forms salt crust higher than vertisols have very fine pores and smaller soil texture.

Naher *et al.* (2011) reported that saline soil has a detrimental effect upon soil physical and chemical properties. The dominant soil textural classes that occur in the saline areas of Bangladesh (Assauni and Kalapara) are siltyclay.

Leal *et al*. (2009) reported that sandy soils can withstand higher salinity irrigation water because more dissolved salts will be removed from the root zone by leaching. Another important aspect of soil texture has to do with surface area. Because of their tiny size, a given volume of clay particles has far more surface area than the same volume of a larger sized particle. This simply means that clay soils are at a greater risk than course textured soils for excess sodium to bind to them and cause dispersion.

Goldshleger *et al.* (2001) reported that after rainfall or irrigation, the optical properties of soil with different clay content vary as they retain water to a different extent which results in confusion of spectral signatures between low or medium salt affected soil and non-affected soil.

Ghafoor *et al*. (2004) reported that generally, soil texture is very useful indicator of physical properties like soil porosity and workability. It influences air and water movement and is important for irrigation management and soil salinity and sodicity.

2.3.1.2. Bulk and particle densities

Muhammad *et al*. (2002); Barik *et al*. (2011) reported that the bulk density increase with increase salinity and especially sodicity this due to soil compaction increase dispersive action of exchangeable sodium on soil colloids and altering the pore size distribution and decrease the total volume of soil. He also reported that this increase in bulk density due to high salinity and especially sodicity affected available water and porosity and thus it may strongly influence permeability, drainage rate and penetration by roots.

Hussein *et al*. (2010) reported that the effect of saline water on bulk density and mechanical strength of soil compared to that irrigated regularly by fresh water, values of bulk density and penetration resistance were increased by 0.27 and 24.0%; 0.65 and 27.24%; and 2.15 and 32.89% that of control by using fresh water alternating with saline water 2000, 4000, 6000 ppm, respectively. Generally, any factor that influences soil pore space was also affect the bulk density.

Muhammad *et al*. (2002); Srivastava *et al*. (2014); reported that the bulk density, particle density and porosity are affected by clay, silt, and salts content and also by organic matter.

2.3.2. Soil Chemical Properties

Allotey *et al*. (2008) reported that soil chemical fertility refers to chemical properties and processes important to plant growth and environment. Determinants of soil chemical quality include soil organic matter content, total nitrogen (N), soil reaction (pH), salt content of soil (ECe), cation exchange capacity (CEC), exchangeable bases, and plant available nutrient reserves. Soil and crop variables explained more than 70% of the variance in soil quality among agricultural histories. The edaphic indicators that showed the greatest change from pristine conditions were organic C, N, P, Mg, K, B, Ca, and Zn contents and cation exchange capacity.

Swarp (2004) reported that the attributes include, soil reaction, salinity, aeration status, organic matter content, cation exchange capacity, status of plant nutrients, concentrations of potentially toxic elements, and possibly the most important attribute, the capacity of the soil to buffer against change. However, the final selection will depend upon the function under consideration of sensitive to changes.

2.3.2.1. Electrical conductivity (EC) as soil salinity

Naher *et al.* (2011) conducted an experiment in two salt affected soil of Bangladesh and found that the ECe value ranged from2.4 to 3.4 dS/m at Asasuni and 3.1 to 4.0 dS/m at Kalapara.

Nurul *et al.* (2009) studied on suitability assessment of water and soil salinity for boro cultivation in coastal region of Barisal and found that the salinity of Khalisakhali river water varied from 0.14- 0.87 dSm^{-1} during December to April and also reported that the soil salinity at Bakergonj and Khalisakhali was 0.69- 1.8 dSm^{-1} from December to April.

Rengasamy (2006) found that increasing the salinity of the soil solution has a positive effect on soil aggregation and stabilization, it can damage soil structure with increasing Na+ concentration in the soil solution and accumulation on clay particles causing sodicity.

SRDI (2003) reported that soil salinity level of south of Khulna and Bagerhat towns ranged between 8 to $15dSm^{-1}$ during the low flow season. It is also reported that several sub-districts (such as Kachua, Mollahat, and Rultali) south of the Sundarban known to be non-saline in the pre-Farakka period have begun to develop soil salinity during the low flow seasons of 1980s. SRDI (2005) reported that soil salinity in the crop yields ranged from 4.5-8.5 dSm^{-1} and fallow lands with that are relatively more saline ranged from 5.5-15.5 dSm^{-1}.

Bhattacharya *et al*. (1994) observed that the ECe values ranged from 1.8 to 17.0 dSm^{-1} and also observed that the organic carbon value ranged from 0.5 to 1.5 gm/kg. Sahoo *et al*. (1995) conducted an experiment in the Sundarban Mangrove soil and found that the ECe value ranged from 1.36 to 11.47. Anonymous (2001) reported that in coastal area of Bangladesh, tidal water intrusion and drought condition, during rice growing season increased the salinity level and EC may develop up to 5 to 30 m mohs / cm.

SRDI (1993a) reported that the ECe value ranged between 0.44 to 6.4 m mohs/cm in the salt affected Rupsa Thana of Khulna District. SRDI (1993 b), reported that the ECe value ranged between 0.54 to 10.2 dSm^{-1} in the salt affected Sathkhira Sadar Soils of Bangladesh.

Rahman (1987) conducted an experiment in two salt affected soil of Bangladesh and found that the ECe value ranged from 1.2 to 11.1 m mohs/ cm at different depth. More *et al*. (1987) reported that the ECe of the salt affected soil ranging from 0.84 to 39.20 m mohs/ cm in Maharashtra soil. Anwar (1993) observed that the ECe value varied from 3.25 to 12.36dSm^{-1} in two salt affected areas of Patuakhali and Barguna District of Bangladesh and the level of salinity increased with the advancement towards the coast of Bay of Bengal.

George and Wren (1985) reported that salinity is generally expressed in deciSiemens/meter (dS/m) or millimohs/centimetre (mhos cm^{-1}). Siemens per meter equals 0.1 mhos cnil. The ratio of the electrical current density to the electric field in the soil is expressed as the reciprocal value of its resistivity in mhos cm^{-1} (or cm^{-1}) of soil extract or paste and generally refers to the salt/solute content of the soil. The non-saline and low-, moderate- and high-salinity categories are identical to those used by EC1:5 rangesare calculated using a conversion factor selected for every soil texture.

Russell (1961) showed that in sodic soils, carbonate and bicarbonate are the principal anions and Na^+ is the dominant cation. Sodicity is based on Na^+ concentration relative to other cations (i.e. Ca^{2+}, Mg^{2+}, K^+, NH_4^+) adsorbed to soil particles on the exchange complex.

USDA (1954) reported that in salt affected soils, soluble salts consisting of chlorides and sulphates of sodium, calcium and magnesium are present in high concentrations leading to an increase in electrical conductivity (EC). According to the classification of U.S. Salinity Laboratory soils (saturated paste) with an electrical conductivity (EC) greater than 4 deciSiemens/meter (dS/m) are saline. In Australia, a classification was proposed to describe the level of salinity in soils based on the values of electrical conductivity in the soil saturation extract (abbreviated ECe), or in the 1:5 extract (EC1:5).

2.3.2.2 pH

Mariangela and Francesco (2015) reported that generally, the degree and nature of soil reaction influenced by different anthropogenic and natural activities including leaching of exchangeable bases, decomposition of organic materials, application of commercial fertilizers and other farming practices.

Mahmood *et al*. (2013) reported that the pH of soil solutions has a profound effect on element solubility and availability of a given nutrient in soils. The processes of mineral dissolution and also adsorption at alkaline functional groups are dependent on pH, in addition to the fact that action exchange capacity depends on pH. Alkaline soils are often associated with nutrient excess of the base cations Ca, Mg, K and Na and base anion Cl^- and SO_4^{-2} and also at pH > 8.2 excess carbonate and bicarbonate. Trace element cations and Na are often present at high enough concentrations to cause toxicity to plants in alkaline soils. Alkaline soils are associated with deficiencies of trace element nutrients, in particular Fe and Zn, and also deficiencies of P.

Akram *et al*. (2011) reported that salt-affected soil, pH inhibits water and nutrient uptake although there is sufficient quantity of them in soil.

Naher *et al*. (2011) reported that the pH value of the topsoil at Asasuniupazila in satkhira district of Bangladesh ranged from 5.39 to 6.02 i.e. the soils were slightly acidic to acidic in reaction. In 50-100 cm depth in this area the pH ranged from 6.7 – 6.85 which is nearly neutral. At Kalapara upazila in patuakhali district of Bangladesh the pH values in 50 – 100 cm deep is 5.9 to 6.20 which is slightly acidic. The pH ranged of the soils from 50 -100 cm deep was 6.49 and 7.2, and from 100 – 150 cm deep was 7.2 – 8.1 which is strongly alkaline.

Rengasamy (2010) report shows the pH of soil–water suspension is greater than the filtered extracts for high land soil. In alkaline sodic soils the pH of a 1:5 suspension is usually from one-half to one pH unit higher than that of a saturated soil paste or a soil suspension prepared by using $CaCl_2$.

Jones (2003); Qadir *et al.* (2007) reported that descriptive terms commonly associated with certain ranges in pH are extremely acidic (pH < 4.5), very strongly acidic (pH 4.5-5.0), strongly acidic (pH 5.1-5.5), moderately acidic (pH 5.6-6.0), slightly acid (pH 6.1-6.5), neutral (pH 6.6-7.3), slightly alkaline (pH 7.4- 7.8), moderately alkaline (pH 7.9-8.4), strongly alkaline (pH 8.5-9.0), and very strongly alkaline (pH > 9.1).

Bertrand *et al*. (2003) found that in acidic soils, P is generally bound to hydrous oxides of Fe^{3+} and Al^{3+} and is gradually converted into crystalline Fe^{3+} and Al^{3+}phosphates but its solubility increases with increasing soil pH.

Rengasamy (2010) reported that the electrical conductivity (ECe) measurement identifies soils, which are potentially saline. These salts contain the cations Na^{+}, Ca^{2+} and Mg^{2+} and the anions Cl^{-}, SO_4^{2-}, HCO_3^{-}, and CO_3^{2-} which can be weathered from minerals and accumulate in the soil solution in areas where the precipitation is too low to provide leaching. Excessive accumulation of soluble salts convert to salt affected soils and the process leading to accumulation of salts are common in arid and semi-arid regions where rainfall amount is insufficient to leach soluble salts.

Samadi and Gilkes (1998) reported that in contrast, in neutral, calcareous and alkaline soils, P precipitates with calcium in stable forms of Ca-P and is gradually converted into soluble hydroxyapatite or fluroapatite minerals. The solubility of Ca-P increases with decreasing soil pH.

Anwar (1993) observed that the pH of Patuakhali and Barguna Districts of Bangladesh varied from 6.21 to 7.88 and at some locations increased with the soil depth. SRDI (1999) reported that the pH value varied from 5.7 to 7.7 in salt affected Sathkhira Soil while values varied from.6:66 to7:47 in Bangladesh and that Ghosgaon Series.

Chowdhuri (1992) observed that the pH of Old Brahmaputra Floodplain Soil ranged from 6.02 to 7.1.Prafitt, (1978) reported that the highest phosphorus (P) availability occurs at the pH 6-7 while at higher or lower pH availability of P decreases. White (1980) reported that the Phosphorus reacts with $A1^{3+}$, Fe^{3+} and Ca^{2+} on the surface area of the clay minerals.

Prafitt (1978) showed that calcareous soils fix P in the form of Ca-P and hydroxyl apatite on the surfaces of carbonate minerals. Ryan *et al*. (1985) found that due to the greater surface area to volume ratio, small particles of carbonates sorb more P than large particles.

Brammer and Brinkman (1977) concluded that the increase of pH with depth is a common feature in the seasonally flooded soil of Bangladesh. In an observation of salt affected soils of Bangladesh. Rahman (1978) stated that the pH value ranged between 6.7 to 7.9 and 6.7 to 7.8. Dube and Shama (1987) stated that the pH value ranged between 8.2 to 8.3 and 8.0 to 8.5 at two highly saline areas of Gujarat (India).

Ponnamperuma (1972) observed that when an aerobic soil was submerged, its pH decreased during first few days, reached a minimum and then increased to a fairly stable value of 6.7 to 7.2 a few weeks later in a 1:1 soil water suspension. He reported that the overall effect of flooding is an increase in pH of most acid mineral soil which was due to the reaction of Fe_3^+ and a decrease in pH alkaline soil which was due to CO_2 accumulation.

2.3.2.3. Organic matter and total nitrogen

Kizildag *et al.* (2013) reported that the organic carbon and total nitrogen values were found to be low compared with non-saline soils and it is possible to conclude that nitrogen mineralization of saline soils can be affected by the composition of different plants.

Naher *et al*. (2011) reported that topsoil organic status in all the horizons ranges from medium to high at Asasuni upazila in satkhira district of Bangladesh range is 0.85 to 2.8% and 0.55 to 1.89% at Kalapara upazila in Patuakhali district of Bangladesh. Top soil organic matter content in almost all the soils collected from Kalapara upazila are found very low mainly due to the lower topographic position of the soils. Organic matter content gradually decreases with depth followed by increasing trend due to the presence of buried mineral and organic horizons.

Arunakumara and Walpola (2010); (2011) reported that the importance of increased soil OM or soil organic carbon is its effect on improving soil physical properties, conserving water, and increasing available nutrients. However, this critically important soil component is strongly influenced by natural and anthropogenic factors. These practices adversely affected the soil organic carbon pool and strongly impacting global warming and climate change (Kumar, 2013). Salinity and sodicity decrease the plant productive and consequently reduce the organic matter input, also affect the active of microorganisms and therefore can change organic matter decomposition rate.

Pattersion (2006) reported that the proportions of cations and anions in the natural soil water solution are a function of soil type, climate and land use. Portch and Islam (1984) also found that 100% of the soils studied were deficient in available nitrogen, which was similar to the present findings.

Zaman and Bakri (2003) reported that Bangladesh has 3 million hectares of land affected by salinity, mainly in the coastal and south-east districts, with ECe values ranging between 4 and 16 dS/m.

Loveland and Webb (2003) reported that generally, there is considerable concern that if soil OM or soil organic carbon concentrations in soils are allowed to decrease too much, the productive capacity of agriculture will be then compromised by deterioration in soil physical properties and by impairment of soil nutrient cycling mechanisms. Soil OM contributes positively to soil fertility, soil tilth, crop production, and overall soil sustainability.

Sahoo *et al.* (1995) conducted and experiment in the sundarban mangrove Soil and found that the organic carbon value decreased with depth in all the profile with its content ranging from 0.29 to 1.89%.Marschner and Termaat (1995) reported that Soil with an electrical conductivity of saturation extracts above $4dSm^{-1}$ is called saline soil.

Panaullah (1993) reported that the degree of salinity varies widely with area and season, depending on a availability of fresh water, intensity of tidal flooding and nature of movement of saline ground water. Soil salinity shows an upward trend in February and reaches a maximum level in April- May.

Leeper and Uren (1993) reported that high salinity levels may cause soil inorganic fractions to coagulate but the concentration of salt may cause the organic colloids to disperse and drain from the soil profile. Saline seeps are often colored with dispersed organic colloids. Robert and Patterson (2006) reported that when sodium salts reach high levels the soils may disperse and the soil pores become blocked with the subsequent capture of the colloids.

Rengasamy and Olsson (1993) reported that physical blocking of the soil pores cannot be reversed chemically and the permeability of the effluent application area will be reduced. Hanson *et al.* (1999) reported that Calcium and magnesium compete for the exchange sites occupied by sodium so that increased calcium and magnesium concentrations reduce the amount of sodium that will be bound to soil particles**.**

Karim *et al*. (1990) found that the organic matter content ranged between 0.10 to 1.00 and 1.15 to 2.27% in two salt affected soils of Bangladesh. SRDI(1993) reported that the organic carbon values varied from 0.40 to 2.54% in the salt affected Rupsa Thana Soil of Khulna District. Anwar (1993) found that the organic carbon percentage ranged between 0.51 to 0.64 in two salt affected areas of Patuakhali and Barguna districts of Bangladesh and the high value was obtained at surface soil.

2.3.2.4. Cation exchange capacity (CEC)

Girma *et al.* (2012) reported that the depletion of CEC is a serious threat to agricultural production and food security; it leads to soil degradation and nutrient depletion, a decline in agricultural and biomass productivity and poor environmental quality.

Naher *et al.* (2011) reported that the cation exchange capacity of soils of different horizons varies from 12.8 to 27.2 meq/100 g soil and 12.4 to 21.0 meq/100 g soil at Asasuni upazila in Satkhira district and Kalapara upazila in Patuakhali district of Bangladesh respectively. CEC of all these soils varies from 12.7 to 27.2 meq/100 g soil expressing medium to high status. The high CEC values of these soils denote the comparatively high chemical activity of soil.

Dohrmann (2006) reported that cation exchange capacity (CEC) of the soil is the ability of the soil solid phase to attract or store and exchange cationic nutrients with the soil solution and render them available to plants through exchange reactions.

Pansu and Gautheyrou (2006) showed that CEC is highly correlated with organic OM content of the soil, which is in turn, is affected by different soil management practices such as intensive cultivation, fertilization, and changes in land use. Besides, due to intensity of human action, there was a drastic loss of CEC in the surface than in the subsurface layers in soils of Senbat watershed, western Ethiopia (Nega and Heluf, 2013). Generally, processes that affect texture (such as clay) and OM due to land use changes also affect CEC of soil.

Aweke (2005) reported that in his research result on major soils of some dry land areas of north-east Ethiopia, stated that the highest CEC value (56.70 cmolcg-1) was recorded in the surface layer of Kobo EutricVertisols and can be considered very high for tropical soils.

Sopher and Baird (1982) reported CEC is an important parameter of soil because it gives an indication of the type of clay minerals present in the soil, soil's capacity to retain nutrients against leaching, determines how often and how much gypsum must be applied, and determines how plant nutrients other than gypsum can be applied and assessing their fertility and environmental behavior. Generally, the chemical activity of the soil depends on its CEC. The CEC is strongly affected by the nature and amount of mineral and organic colloids present in the soil. Soils with large amounts of clay and OM have higher CEC than sandy soils low in OM.

2.3.2.5 Cations and anions

Tisdale *et al.* (1993) mentioned that $A1^{3+}$ and Fe^{3+} precipitate P in acid soils whereas in alkaline soils P is precipitated with Ca^{2+} and Mg^{2+} and is generally sparingly soluble.

White (1980) reported that high concentrations of Zn^{2+} also enhance P adsorption whereas high concentrations of selenite and arsenate decrease P adsorption in soils with goethite.

Prafitt (1978) found that phosphorus can be replaced by other anions such as SO_4^{2-}, SO_3^{2-}, $HCO_3^-$and polybasic organic anions.

2.3.2.6. Exchangeable bases and percentage base saturation

Awdenegest (2013) showed that PBS of soils also indicate the degree of leaching and evaporation of exchangeable bases from surface and sub-surface and in arid area higher percentage base saturation because of higher evaporation than leaching. Therefore, this characteristic is extensively used in soil classification, soil fertility appraisal, and mineral nutrition studies.

Wondimagegne and Abere (2012) reported that the exchange complex is dominated by Ca^{2+} followed by Na^{+}, $Mg^{2+}$and K^{+} in both Vertisols and Fluvisols of Amibara irrigation cotton farm land. Rashad and Dultz (2007) reported Also, single-charged Na has lower clay-binding ability then double-charged Ca (or Mg), which in turn is not as strongly hydrated as Na.

Gabrijel *et al.* (2011) reported exchangeable bases include Ca, Mg, K and Na. These basic cations are loosely (depending on the nature and conditions of the soil) attached to the edge of the clay particles or to the soil OM (exchange sites) and are in equilibrium with the concentration of cations in the soil solution. The order/distribution of exchangeable basic cations in most agricultural soil is generally $Ca^{2+}> Mg^{2+}> K^{+}> Na^{+}$ with a pH of 5.8 or more.

Naher *et al.* (2011) reported that the sodium hazard is expressed as ESP. It ranged from 2.31 % to 3.04% at Asasuni upazila in Satkhira district which is acceptable (< 10%) and it is intermediate (10-35%) at Kalapara upazila in Patuakhali district of Bangladesh, i.e. 9.55% to 13.05%.

Freire (2009) reported that the dispersion of the clay particles caused by substitution of the calcium (Ca^{+2}) and magnesium (Mg^{+2}) ions present in the complex by sodium (Na^{+}), resulting in an increase in soil sodicity, that is, in the exchangeable sodium percentage (ESP), which, in the last instance, is the main factor responsible for the deterioration of the physical properties of salt-affected soils (sodic, or alkaline, and saline-sodic).

Haque (2006) reported that magnesium has synergistic effect of plant uptake of Na as well as antagonistic effect on the uptake of Ca and K. Havlin *et al.* (2010) reported that the percentage of the CEC that is satisfied by the base forming cations is termed as percentage base saturation (PBS). As a general rule, the degree of base saturation of normal uncultivated soils is higher for arid than for humid region soils. On the other hand, in arid regions, the PBS of soils formed from lime stones or basic igneous rocks is greater than that sandstones or acidic igneous rocks of soils formed from.

Buckland *et al.* (2002) found that in sodic soil, aggregate stability is reduced due to the increase in exchangeable sodium percentage (ESP).

Mesfin (1998) reported that the exchangeable Ca and Mg cations dominate the exchange sites of most soils and contributed higher to the total percent base saturation particularly in Vertisols in Ethiopia. The soils contain variable levels of exchangeable bases, but a general feature is the higher Ca and K saturation of the exchange complex compared to Na and Mg in most of the soils. The Na and Mg saturation saline sodic and sodic soil of the exchange complex is harmful because they destroy the soil physical properties and offset plant nutrition.

2.3.2.7. Sodium absorption ratio

Wondimagegne and Abere (2012) reported that the water in soils is commonly referred to as "soil solution" because it contains various solutes, principally cations such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}) and sodium (Na^{+}), and anions such as sulfate (SO_4^{2-}), chloride (Cl^{-}), carbonate (CO_3^{-2}) and bicarbonate (HCO_3^{-}), which collectively are called soluble salts (Melese and Gemechu, 2010). In MelkaSadi state farm and WARC profiles the anionic preponderance is in the order Cl^{-}> HCO_3^{-}> SO_4 = and Cl^{-}> SO_4 = > HCO_3^{-}, respectively under salt affected soil.

Naher *et al.* (2011) reported that the SAR of a soil extract gives an indication of the level of exchangeable Na+ in comparison with that of Ca+ and Mg+ in soil. The SAR values vary from 1.72-2.22 at Asasuni upazila in Satkhira district and 1.94 to 3.33 at Kalapara upazila in Patuakhali district of Bangladesh. The SAR values of these areas are acceptable (<10).

Melese and Gemechu (2010) reported that generally, result it could be concluded that chloride salts of sodium and calcium and magnesium could be highly soluble salts that contribute for the formation of salt in the soils. The Sodium absorption ratio defines sodicity in terms of the relative concentration of sodium (Na) compared to the sum of calcium (Ca) and magnesium (Mg) ions in a sample.

Gedion (2009) reported that the same manual shows the degree to which this reaction takes place may depend on the properties of calcium and magnesium to sodium in the soil solution that comes in contact with the colloidal soil particles, as well as with the total concentration of these elements. Sodium absorption ratio value tends to be higher at lower depths in saline and saline-sodic soils because of ground water septic tanker of soluble salt.

Pearson and Bauder (2003) reported that the soil clay particles have negative electrical charge attracting a large number of cations. The zone surrounding the cations at the negative charges on soil particles is termed "diffuse double layer." The concentration of cations is high within the diffuse double layer close to the surface of the clay particles, and decreases with distance. Clay particles are subject to forces that can move them together (aggregation) or apart (dispersion).

Qureshi and Barrett-Lennard (1998) reported that in non-sodic soils, the accumulation of salts can affect soil physical properties by causing fine particles to bind together into aggregates. This process is known as flocculation and is beneficial in terms of soil aeration (due to aggregate stabilization when wet), hydraulic conductivity (because soil pores remain open and water readily infiltrates into the soil) and root growth. Dispersion of clay particles occurs when diffuse double layer is distorted by large size of hydrated ions, or due to electrostatic repulsion.

Shainberg (1992) found that the reduction of thickness of diffuse double layer can maintain the clay particles close to each other. When dissolved in water, Na+ ions are larger in size than K^+, and Mg^{2+} is larger than Ca^{2+}. Compared to small cations, large cations in the diffuse double layer push clay particles apart. Gupta and Verma (1983); Rengasamy *et al.* (2003) reported that the structure of the soil is therefore degraded due to a high degree of clay dispersion.

Rengasamy *et al.* (1984) found that the saline soils tend to have sodium adsorption ratios (SAR) less than 13 in their saturation extract and exchangeable sodium percentage (ESP) lower than 15. Sodic soils have SAR greater than 13 in their saturation extract and EC values less than 4 dS m^{-1}.

Richards (1954) reported that the sodicity may also be expressed as sodium adsorption ratio (SAR), which is the concentration of Na+ relative to other cations in soil solution. SAR is approximately equivalent to ESP for saturation extracts, and approximately half the value of ESP for 1:5 soils: water extracts.

CHAPTER III

MATERIALS AND METHODS

3.1. Study area

A field survey was carried out at Babuganj, Bakerganj and Gournadi upazilas in Barisal district and Kalapara is an upazila of Patuakhali district in Barisal Division in Bangladesh. Babuganj is located at 22.8319°N 90.3222°E. Bakerganj at 22.5500°N 90.3389°E. Gournadi at 22.9736°N 90.2306°E. Kalapara at 21.98610N 90.24220E.

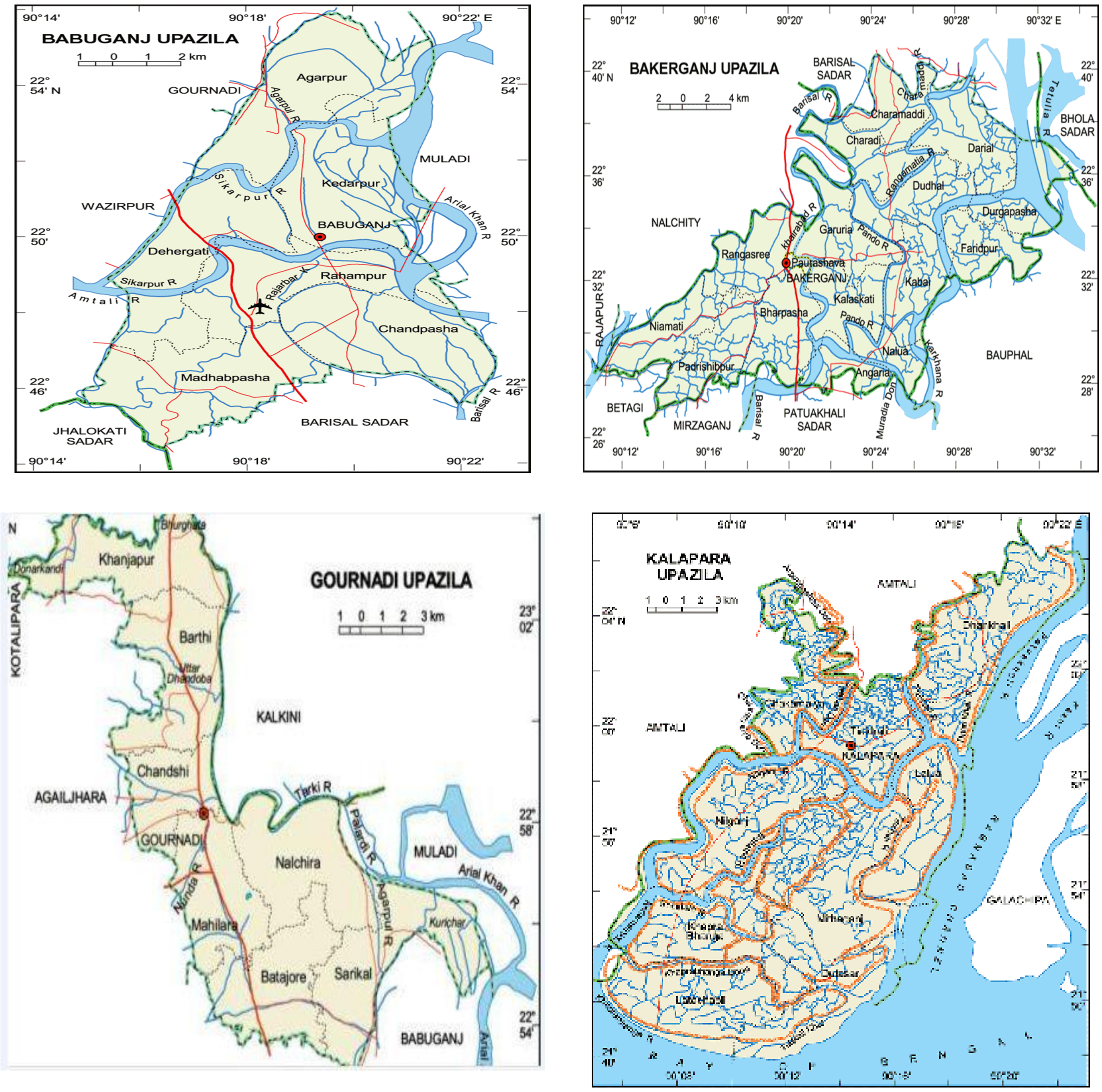


Figure 2. Study areas at Babuganj, Bakerganj and Gournadi upazilas in Barisal district and Kalapara upazila in Patuakhali district of Bangladesh

3.2. Environmental characteristics

3.2.1. Geology and morphology

Bangladesh has a wide range of agro ecological environment due to climate change, physiography, soil and hydrology. The country has a very flat and low topography except in the northeast and southeast regions. About 10% of land is hardly in above the mean sea level (msl) and one-third is under tidal excursions. Salt affected soils in Bangladesh occur in the coastal districts of Khulna, Barisal, Patuakhali, Noakhali, Chittagong and Satkhira. Topographically all these areas are low lying and have elevations mostly less than 8 m above the mean sea level.

Table 1. Different land types of the studied saline areas of Bangladesh

Locations	**High land**	**Medium high land**	**Medium Low land**	**Low land**	**Very low land**
	Hectare				
Babuganj	1360	14248	0	0	0
Bakerganj	3240	39596	0	0	0
Gournadi	2518	15316	0	0	0
Kalapara	2188	37827	0	0	0

Source: salinity problems and crop intensification in the coastal regions of Bangladesh (BARC) 1990

Table 2. Agro ecological regions occurring in the studied saline zonesof Bangladesh

Locations	AEZ Region	AEZ Sub Region	Main Soil	Main Soil General Type
Babuganj	Ganges Tidal Flood Plain	Saline, Non calcareous	Loamy, Clayey	Calcareous Alluvium, Non Calcareous Grey Flood Plain
Bakerganj	Ganges Tidal Flood Plain	Saline, Non calcareous	Loamy, Clayey	Calcareous Alluvium, Non Calcareous Grey Flood Plain
Gournadi	Ganges Tidal Flood Plain	Saline, Non calcareous	Loamy, Clayey	Calcareous Alluvium, Non Calcareous Grey Flood Plain
Kalapara	Ganges Tidal Flood Plain	Saline, Non calcareous	Loamy, Clayey	Calcareous Alluvium, Non Calcareous Grey Flood Plain

Source: salinity problems and crop intensification in the coastal regions of Bangladesh (BARC) 1990

3.2.2. Soil Salinity

Mainly four categories of salinity existing in the coastal saline areas and the range is from S_1 to S_4. The highest area is under S_2 category at Kalapara, and S_1 also at Kalapara. Soil occurring in the coastal areas of Bangladesh shows a wide variation in salinity. Seasonal fluctuation in salinity is also usually very large except for the recent coastal plain areas. Soils are grouped according to salinity classes as in Table 3. They are slightly to moderately saline but during dry season increase in salinity.

Table 3. Distribution and extent of different categories of soil salinity in the studied saline areas of Bangladesh

Locations	Total Area (ha)	Total Saline Area (ha)	Percent of Saline Area	Salinity Categories			
				S_1	S_2	S_3	S_4
				2.1-4 (ds/m)	4.1-8 (ds/m)	8.1-15 (ds/m)	>15 (ds/m)
				Slightly Saline	Moderately Saline	Saline	Strongly Saline
				(Hectares)			
Babuganj	15,247	1470	10	1030	370	70	0
Bakerganj	40,496	3350	9	3080	770	0	0
Gournadi	14,417	2410	17	1930	480	0	0
Kalapara	47,194	34,730	75	4770	10680	7240	7970

Source: Soil salinity in Bangladesh (SRDI) 2010

3.2.3. Agroclimate

Rainfall, wind velocity, relative humidity, evaporation and maximum and minimum temperature data of the study areas (Babuganj, Bakerganj, Gournadi and Kalapara upazila under Barisal and Patuakhali district during the period from July to September 2016) are reported in appendix-1 and appendix-2. Maximum and minimum air temperatures vary from 30.6^0 C to 25.2^0 C. During the monsoon more than 90% of the total precipitation takes place. Total average rainfall is estimated to be maximum 2618 mm at Patuakhali and minimum 2188 mm at Barisal district annually.

3.3. Soils Used

The soil survey was conducted during July-September, 2016. Soil samples were collected from 30 sites at 0.5 km distance and 0-50 cm, 50-100 cm depth by auger. Soil sampling was done by random sampling method. The soil samples were dried at room temperature, crushed, mixed thoroughly, sieved with 2mm sieve and preserved in plastic bags for subsequent laboratory analyses.

3.3.1. Analytical Procedures

Particle-size analysis was carried out by the hydrometer method as outlined by Bouyoucos, (1927). The textural classes were then determined by plotting the results on a triangular diagram designed by Marshall, (1947) following the U.S. Department of Agriculture classification system. The pH was determined by a glass-electrode pH meter in the soil suspension having a soil: water ratio of 1:2.5, after 30-min shaking. The electrical conductivity (EC) was measured by an EC meter in the soil suspension having a soil: water ratio of 1:5, after 30-min shaking. The organic carbon content was determined by the wet oxidation method as outlined by Nelson *et al.,* (1982) and the organic matter content was calculated by multiplying the organic carbon content with a conventional factor of 1.724. The total nitrogen content was determined by the micro-Kjeldhal digestion method. Digestion was made with concentrated H_2SO_4 with addition of catalyst mixture ($K_2SOkuSO_4$ $5H_20$: Se in the ratio of 10:1:0.1). Nitrogen in the digest was estimated by distillation with 40% Na011 followed by titration of the distillate trapped in the H_3B0_3 solution against 0.005M H_2SO_4 (Bremner and Mulvaney, 1982).

Cation exchange capacity (CEC) was determined by the sodium saturation method as described by, Chapman, (1965).Exchangeable calcium, sodium and potassium were extracted from soil using 1 M CH_3COONH_4 and their concentrations in the extract were directly determined by a flame photometer. Exchangeable magnesium was extracted by Diethylene Triamine Penta Acitate (DTPA) solution and its concentration in the extract was determined directly by an atomic absorption spectrophotometer (AAS). Water soluble ion Cl^- was determined by 0.01N $AgNO_3$ titration method and $SO_4^=$ determined by turbidimetric method.

Exchangeable Sodium Percentage (ESP) and Sodium Adsorption Ratio (SAR) were determined by-

$$ESP = \frac{\text{Exchangeable } Na^+}{CEC} \times 100$$

$$SAR = (\text{ sodium}^+ / \text{calcium}^+ + \text{magnesium}^+)/2)^{1/2}$$

3.3.2 Data analysis

Collected data were processed and analyzed by using SPSS-16.0 version software and MS excel 2007. Pearson's product moment correlation coefficient was computed to explore the correlation matrix.

CHAPTER IV

RESULTS AND DISCUSSION

Salinity has an adverse effect on soil physical and chemical properties. Saline soil contains an excess of soluble salts, especially sodium chloride. The proportions of cations and anions in the natural soil water solution are a function of soil type. The physico-chemical properties and salt characteristics of the soils of Babuganj, Bakerganj, Gournadi and Kalapara regions under this study are below:

4.1. Soil physico-chemical properties:

4.1.1 Particle size distribution

Data on the particle-size distribution and the USDA (United States Department of Agriculture) textural class of the soils of studied areas are presented in the Table 4 indicated that soils of Ganges tidal floodplain, silt and clay are the dominant fractions. The dominant soil textural classes that occur in the saline areas of these regions are silty clay. Clay varies from 37%-41% at Babuganj, 38% at Bkaerganj, 37%-39% at Gournadi, 37%-39% at Kalapara and silt from 50%-53% at Babuganj, 52%¬53% at Bakerganj, 52%-53% at Gournadi and 51%-52% at Kalapara respectively in different depths. The clay and silt contents were increased with depth at Babuganj, Gournadi and Kalapara while, sand content was decreased a phenomenon Essoka and Esu, (2001) reported that clay migration by lessivage to produce the process of illuviation. Naher *et al.* (2011) found the same result at Satkhira and Kalapara of Bangladesh.

Table 4. Physical properties of different soils in studied areas of Bangladesh

Locations	Depth (cm)	Particle size distribution (%)			Texture
		Sand	Silt	Clay	
Babuganj	0-50	10	53	37	Silty clay
	50-100	9	50	41	Silty clay
Bakerganj	0-50	10	52	38	Silty clay
	50-100	9	53	38	Silty clay
Gournadi	0-50	10	53	37	Silty clay
	50-100	9	52	39	Silty clay
Kalapara	0-50	12	51	37	Silty clay
	50-100	9	52	39	Siltycaly

4.2. Chemical properties

4.2.1. Soil reaction

(Table 5) The pH value of the topsoil at Babuganj ranged from 7.4-7.7 in 50-100 cm depth. pH ranged from 7.6-7.9 according to USDA which is moderately alkaline. At Bakerganj, the pH values in 0-50 cm depth were 7.4-7.5 in 50-100 cm depth. pH ranged from 7.5- 7.8 which is slightly alkaline. At Gournadi, the pH values in 0-50 cm depth were 8.0-8.2 in 50-100 cm depth. pH ranged from 8.2- 8.8 which is strongly alkaline. At Kalapara, the pH values in 0-50 cm depth were 5.90 to 6.20 which is slightly acidic and in 50-100 cm depth in this area the pH ranged from 6.44 to 7.2 which are neutral. In most of the soils pH value of the surface horizon was slightly lower than those of the subsoil and sub stratums. In most of the soils, pH increased with depth which is similar to the report published by SRDI, 2000 in Borguna district of Bangladesh. The higher pH values of the soils are likely micronutrient deficiency and Phosphate fixation problem. According to Tamhane *et al.* (1970) most of the soil nutrients were available to plants in a pH range from 6.5 to 7.5. The availability of most micronutrients depends on the pH of the soil solution as well as the nature of binding sites on organic and inorganic particle surfaces. In saline and sodic soils, the solubility of micronutrients (e.g. Cu, Fe, Mn, Mo and Zn) is particularly low, and plants grown in these soils often experience deficiencies in these elements (Page *et al.*, 1990) but not in all cases.

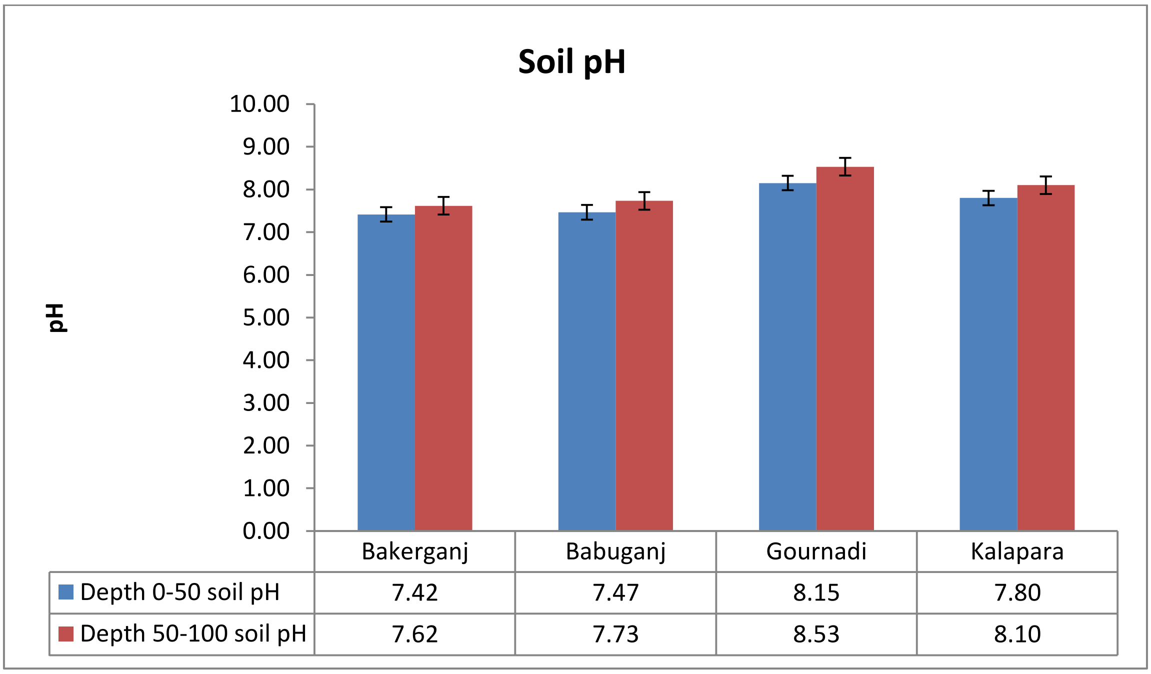


Figure 3. pH values of Babuganj, Bakerganj, Gournadi and Kalapara at different depth

4.2.2. Total nitrogen

The total nitrogen content of the topsoil was generally low to occasionally high ranging from 0.06 to 0.09% at Babugnaj and Bakerganj, 0.09 to 0.1% at Gournadi and 0.07 to 0.09% at Kalapara. The total nitrogen content of the soil from Babuganj and Bakerganj were low to very low level than that of the soils from Gournadi and Kalapara according to the grading of (BARC, 1997). Nitrogen content of the surface horizon was higher than that of subsoil. In almost all the layers, total nitrogen content decreased with depth. The poor nitrogen status of salt affected soil was due to high rates of decomposition of organic matter and inadequate application of organic matter in terms of manure, compost etc. and high volatilization of ammonium nitrogen. Naher *et al.* (2011); Portch and Islam, (1984) also found that 100% of the soils were deficient in available nitrogen, which was similar to the present findings.

4.2.3. Cation exchange capacity (CEC)

Cation Exchange Capacity (CEC) of soils at different horizons varies from 13.2 to 21.8meq/100 gm soil at Babuganj16.6 to 20.8 meq/100 gm soil at Bakerganj14.8 to 21.3 meq/100 gm soil at Gournadi and 12.8 to 21.0 meq/100 gm soil at Kalapara. CEC of all this soils varies from 12.8 to 21.0 meq/100 gm soil expressing medium to high status according to the (BARC, 2012). The CEC values of these soils denoted the comparatively high chemical activity of soil. (Aweke, 2005) in his research result on major soils of some dry land areas of north-east Ethiopia, stated that the highest CEC value (56.70 cmolc kg^{-1}) was recorded in the surface layer of Kobo EutricVertisols and can be considered very high for tropical soils. Naher *et al.* (2011) found 12.8 to 27.2 meq/100 gm soil and 12.8 to 21.0 meq/100 gm soil in Satkhira and Kalapara upazila respectively.

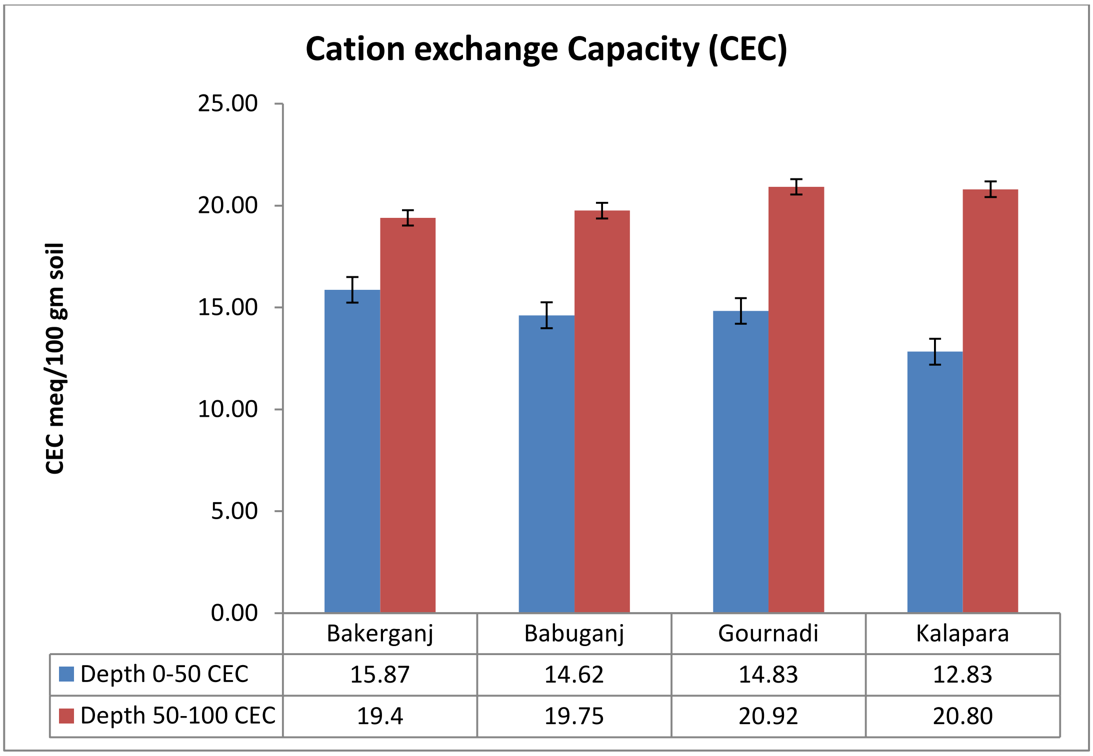


Figure 4. CEC values of Babuganj, Bakerganj, Gournadi and Kalapara at different depths

4.2.4. Organic Matter (OM)

Top soil organic status in all the horizons ranged from medium to high at Asasuni according to the grading of BARC, (1997). From the Table 5 and table 6 organic matter range was 1.0 to 1.12% at Babuganj and Bakerganj and Table 7 and table 8 it is seen that this range was 1.02 to 1.12% at Gournadi and 0.09 to 1.89% at Kalapara. Top soil organic matter content in almost all the soils collected from Kalapara were found very low mainly due to the lower topographic position of the soils. Organic matter content gradually decreases with depth may be due to the presence of buried mineral and organic horizons. Karim *et al.* (1990) found that the organic matter content ranged between 0.10 to 1.00 and 1.15 to 2.27% in two salt affected soils of Bangladesh. SRDI (1993) reported that the organic carbon values varied from 0.40 to 2.54% in the salt affected Rupsa Thana Soil of Khulna District. Naher *et al.* (2011) and Anwar (1993) found that the organic carbon percentage ranged between 0.51 to 0.64 in two salt affected areas of Patuakhali and Barguna Districts of Bangladesh and the high value was obtained at surface soil.

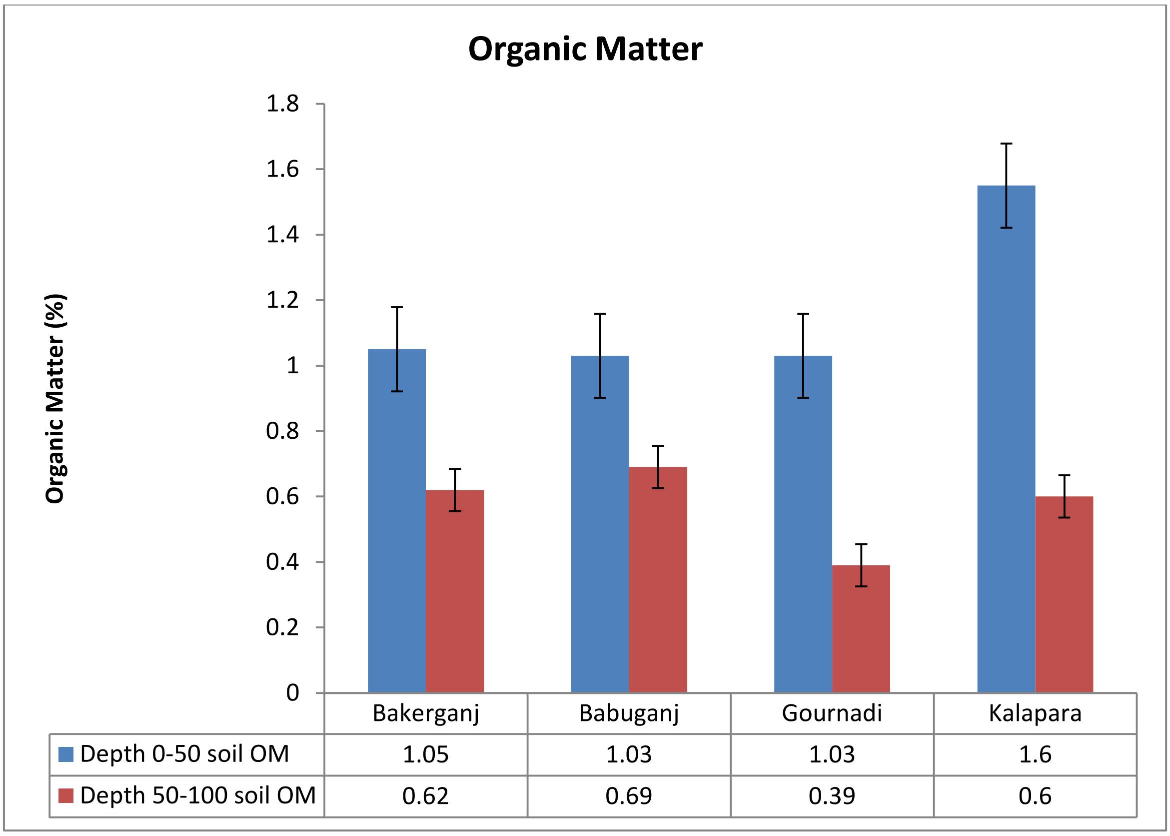


Figure 5. Organic matter (%) of Babuganj, Bakerganj, Gournadi and Kalapara at different depths

Table 5. Physico-Chemical properties of soil collected from Babuganj

Location	**Sample No.**	**Soil layer depth (cm)**	**p^H**	**Total N (%)**	**CEC meq/100 mg soil**	**Organic matter (%)**
Babuganj	1	0-50	7.40	0.08	13.20	1.12
		50-100	7.80	0.07	18.20	0.63
	2	0-50	7.70	0.09	14.30	1.02
		50-100	7.90	0.08	21.80	0.60
	3	0-50	7.40	0.07	16.20	1.00
		50-100	7.60	0.06	18.20	0.60
Average			7.63	0.08	16.98	0.83
STD			0.21	0.01	3.10	0.24
CV (%)			2.8	12.5	18.26	28.91
Average (BARC, 2005; SRDI, 2000)			**5.6- 8.4**	**0.27-0.36**	**7.6-15**	**1.8-3.4**

Table 6. Physico-Chemical properties of soil collected from Bakerganj

Location	**Sample No.**	**Soil layer depth (cm)**	**p^H**	**Total N (%)**	**CEC meq/ 100 mg soil**	**Organic matter (%)**
Bakerganj	1	0-50	7.4	0.09	17.2	1.02
		50-100	7.5	0.07	20.8	0.60
	2	0-50	7.4	0.08	16.6	1.12
		50-100	7.8	0.06	19.6	0.63
	3	0-50	7.5	0.09	17.3	1.0
		50-100	7.7	0.08	18.2	0.60
Average			7.6	0.07	18.28	0.83
STD			0.16	0.01	1.62	0.24
CV (%)			2.10	14.28	8.86	28.92
Average (BARC, 2005; SRDI, 2000)			**5.6- 8.4**	**0.27-0.36**	**7.6-15**	**1.8-3.4**

Table 7. Physico-Chemical properties of soil collected from Gournadi

Location	**Sample No.**	**Soil layer depth (cm)**	**p^H**	**Total N(%)**	**CEC meq/ 100 mg soil**	**Organic matter (%)**
Gournadi	1	0-50	8.0	0.10	16.2	1.12
		50-100	8.2	0.16	20.2	0.70
	2	0-50	8.1	0.09	14.8	1.05
		50-100	8.5	0.05	19.6	0.68
	3	0-50	8.2	0.10	17.9	1.02
		50-100	8.8	0.06	21.3	0.73
Average			8.3	0.09	18.33	0.88
STD			0.29	0.04	2.49	0.20
CV (%)			3.49	44.44	13.58	22.73
Average (BARC, 2005; SRDI, 2000)			**5.6- 8.4**	**0.27-0.36**	**7.6-15**	**1.8-3.4**

Table 8. Physico-Chemical properties of soil collected from Kalapara

Location	Sample No.	Soil layer depth (cm)	p^H	Total N(%)	CEC meq/ 100 mg soil	Organic Matter (%)
Kalapara	1	0-50	6.20	0.09	12.8	0.90
		50-100	6.44	0.08	20.80	0.62
	2	0-50	5.92	0.08	12.70	1.87
		50-100	6.49	0.07	20.60	0.58
	3	0-50	5.90	0.09	13.0	1.89
		50-100	7.20	0.08	21.0	0.60
Average			6.36	0.08	16.82	1.07
STD			0.48	0.007	4.37	0.63
CV (%)			7.55	8.75	25.98	58.88
Average (BARC, 2005; SRDI, 2000)			**5.6- 8.4**	**0.27-0.36**	**7.6-15**	**1.8-3.4**

4.3. Salt characteristics

Soils in the saline areas of Bangladesh show a wide variation in salinity. Seasonal fluctuation in salinity was also usually very high. The salinity of these areas was slightly too moderately saline but during dry season, the salinity increases. The degree of salinity varied widely with area and season, depending on the availability of fresh water, intensity of tidal flooding and nature of movement of saline ground water. Soil salinity shows an upward trend in February and reaches a maximum level in April- May (Panaullah, 1993). The amount of accumulated salt is found higher at the surface horizon. It decreases with depth and then increases again. Soil salinity usually referred to in terms of ECe (in units of dSm^{-1}) and this value can be used to predict soil structure stability in relation to irrigation water quality and the sodium adsorption ratio. Electrical conductivity of almost all the soils decreased with depth and then increased again due to influence of saline ground water. The higher ECe value found at the surface horizon followed by decrease with depth can be attributed to flooding with saline water or accumulation of salts through upward capillary movement of saline ground water.

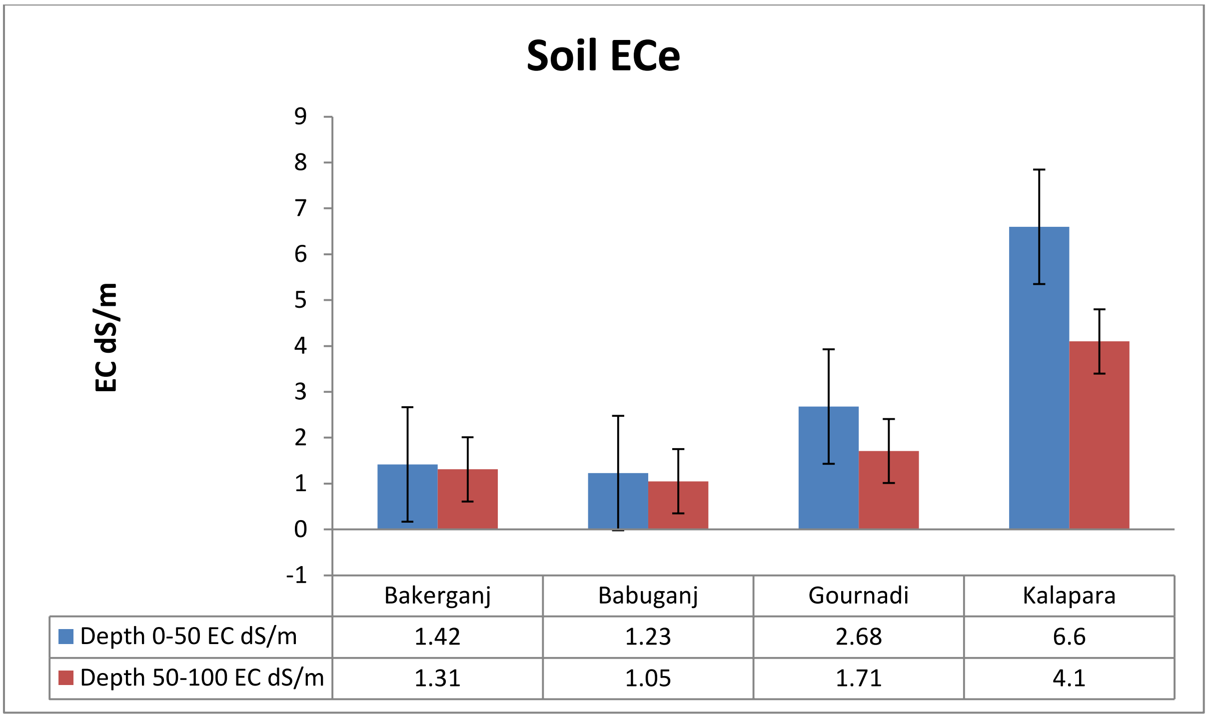


Figure 6. EC values of Babuganj, Bakerganj, Gournadi and Kalapara at different depths

Soil salinity of different horizons normally ranged from 1.05 to 1.23dS/m at Babuganj, 1.31 to 1.42 dS/m at Bakerganj which is non saline. But at Gournadi it was 1.78 to 2.68 dS/m which denotes very slightly saline according to Bookess Tropical Soil Mannal, 1991. At Kalapara the ECe ranged from 4.1 to 6.6dS/m which is under slightly saline. It means that the totat salt content in this soil is 0.15-0.35%. Zaman and Bakri (2003) reported that Bangladesh has 3 million hectares of land affected by salinity, mainly in the coastal and south-east districts, with ECe values ranging between 4 and 16 dS/m. high salinity levels may cause soil inorganic fractions to coagulate but the concentration of salt may cause the organic colloids to disperse and drain from the soil profile. Saline seeps are often colored with dispersed organic colloids (Leeper and Uren, 1993).

Table 9. Salt characteristics of soil of Babuganj, Bakergang, Gournadi and Kalapara

Locations	Depth cm	EC dS/m	CEC meq/100g	Exchangeable Cationsmeq/100g				Watersoluble ions meq/L		ESP	SAR
				Na	K	Ca	Mg	Cl^-	SO_4		
Babuganj	0-50	1.23	14.6	1.25	0.68	5.78	4.42	2.10	3.20	7.88	1.52
	50-00	1.05	19.7	2.1	1	10.5	7.3	2.30	3.50	10.82	1.93
Bakerganj	0-50	1.42	15.8	1.2	0.7	6.1	3.98	1.7	3.70	8.21	1.44
	50-00	1.31	19.4	2.3	1.35	9.98	7.7	1.9	3.90	11.64	1.99
Gournadi	0-50	2.68	14.4	1.63	0.67	6.53	4.38	1.8	3.60	10.99	1.52
	50-00	1.71	20.9	2.15	1	10.63	7.48	2.1	4.10	10.28	1.95
Kalapara	0-50	6.6	12.8	1.67	0.57	6.73	4.47	1.5	3.50	13.05	1.94
	50-00	4.1	20.8	2.20	1.10	10.75	7.75	1.6	3.80	10.58	2.32

4.3.1. Exchangeable sodium content

The exchangeable sodium contents of the soils of Babuganj, Bakerganj, Gournadi and Kalapara at different soil depths have been presented in Table-9. It was observed that the exchangeable sodium content for Babuganj varied from 1.25 to 2.1meq/100 gm soils,1.2 to 2.3 meq/100 gm soils at Bakerganj, 1.63 to 2.15meq/100 gm soils at Gournadi and Kalapara varied from 1.67 to 2.2 meq/100 gm soils. When sodium salts reach at high levels the soils may disperse and the soil pores become blocked with the subsequent capture of the colloids (Robert, 2006). Such physical blocking of the soil pores cannot be reversed chemically and the permeability of the effluent application area will be reduced (Rengasamy and Olsson, 1993). Basically, attractive forces which bind clay particles together are disrupted when too many sodium ions get between the clay particles. When such separation occurs, repulsive forces begin to dominate, and the soil disperses (Hanson *el al.,* 1999; Buckman and Brady, 1967; Frenkel *et al.,* 1978; Saskatchewan, 1987; Western Fertilizer Handbook, 1995). Dispersion of clay particles causes plugging of soil pores. Upon repeated wetting and drying and associated dispersion, soils reform and solidify into an almost cement-like soil with little or no structure, depending on the sodium concentration and clay type (Frenkel *et al.*, 1978; Buckman and Brady, 1967; Hanson *et al.,* 1999; Henderson, 1981; Miller and Donahue, 1995; Saskatchewan, 1987).

4.3.2. Exchangeable potassium content

The exchangeable potassium content of the soils of Babuganj, Bakerganj, Gournadi and Kalapara varied mainly based on the clay content. At Babuganj this range was 0.68 to 1.0 meq/100gm soil, 0.7 to 1.35meq/100 gm soil at Bakerganj, 0.67 to 1.0 meq/100 gm soil at Gournadi and at Kalapara it was 0.57 to 1.10 meq/100gm soil. All of these ranges were very high. Naher *et. al.* (2011) found that the exchangeable potassium content of the soils of Asasuni ranged from 0.45 to 1.45 meq/100gm soil and at Kalapara it was 0.57 to 1.10 meq/100gm soil.

4.3.3. Exchangeable calcium content

The exchangeable calcium contents of the soils for Babuganj were 5.78 to 10.5meq/100gm soil, and 6.1 to 9.98 meq/100 gm soil at Bakerganj, 6.53 to 10.63 meq/100 gm soils at Gournadi and for Kalapara, ranged from 6.73 to 10.75 meq/100gm soil. It is seen that the exchangeable calcium content at Babuganj, Bakerganj and Gournadiis medium to very high, and at Kalapara, the range is high to very high. The simillar results showed at Asasuni was medium to very high, and at Kalapara, the range was high to very high (BARC, 2005) and Naher *et al.* (2011).

4.3.4. Exchangeable magnesium content

Exchangeable magnesium content of these areas was in the very high level (Table 9). At Babuganj this range was 4.42 to 7.3 meq/100gm soil, 3.98 to 7.7 meq/100 gm soil at Bakerganj, 4.38 to 7.48 meq/100 gm soil at Gournadi and at Kalapara it was ranged from 4.47 to 7.85 meq/ 100gm soil. Naher *et. al.* (2011) found that the Exchangeable magnesium content of Asasuni ranged from 4.0 to 6.0 meq/100gmsoil and from 4.47 to 7.85 meq/ 100gm soil at Kalapara.

4.3.5. Water soluble ions

From the Table 9it was shown that the water soluble ions $Cl^-$and $SO_4^=$ was ranged from 2.10 to 2.30 meq/L and 3.20 to 3.50 meq/L at Babuganj, 1.7 to 1.9 meq/L and 3.70 to 3.90 meq/L at Bakerganj, 1.8 to 2.10 meq/L and 3.60 to 4.10 meq/L at Gournadi and 1.5 to 1.6 meq/L and 3.50 to 3.80 meq/L at Kalapara. The amount of accumulated salt is found higher at the surface horizon. It decreases with depth and then increases again. The physical separation of soil particles results in sufficient distance between individual soil particles such that repulsive forces between like molecules exceed bonding forces and dispersion occurs. Naher *et al.* (2011) found the same result at Asasuni and Kalapara upazila respectively.

4.4. Correlation matrix

The correlation matrix for physical and chemical properties determined in the present study of Babuganj is given in the Table 10. It was found that the clay content was the most fundamental property to control chemical properties of soils at Babuganj. Organic matter showed significant negative relationship with CEC. Exchangeable Na, K, Ca and Mg showed mostly significant negative relationship with OM. Exchangeable Ca Showed significant positive relationship with pH and mostly significant positive relationship with Exchangeable K Mg. Naher *et al.* (2011) found the same result at Kalapara and Asasuni.

10. Correlation matrix between soil physical and chemical properties of Babuganj

	Clay	pH	N	CEC	OM	EC	Ex Na	Ex k	EX Ca	Ex Mg
Clay	1									
pH	0.411	1								
N	0.135	0.185	1							
CEC	-0.159	0.727	-0.341	1						
OM	-0.186	-0.724	0.53	-.893*	1					
EC	.930**	0.465	-0.2	0.087	-0.458	1				
Ex Na	0.589	0.732	-0.221	0.488	-0.729	0.732	1			
Ex K	0.189	0.59	-0.652	.835*	-.964**	0.489	0.606	1		
Ex Ca	0.256	0.724	-0.496	.857*	-.984**	0.502	0.679	.968**	1	
Ex Mg	0.295	0.7	-0.531	.826*	-.983**	0.547	0.703	.973**	.997**	1

Remarks = ** and * mean correlation significant at the 0.01 and 0.05 levels, respectively (2-tailed). Clay: clay percentage, N: total N content, CEC: cation exchange capacity, OM: organic matter content, Ec: electrical conductivity, Ex Na: exchangeable Na content, Ex K: exchangeable K content, Ex Ca: exchangeable Ca content, Ex Mg: exchangeable Mg content.

The correlation matrix for physical and chemical properties determined in the present study of Bakerganj is given in the Table 11. It was found that the clay content was the most fundamental property to control chemical properties of soils at Bakerganj. OM showed significant positive relationship with Clay and N and significant negative relationship with pH and CEC. Electrical Conductivity (EC) showed significant positive relationship with OM and significant negative relationship with pH. Exchangeable Na, K, Ca, Mg showed significant negative relationship with OM. Naher *et al.* (2011) found the same result at Kalapara and Asasuni.

11. Correlation matrix between soil physical and chemical properties of Bakerganj

	Clay	pH	N	CEC	OM	EC	Ex Na	Ex k	EX Ca	Ex Mg
Clay	1									
pH	-0.43	1								
N	0.363	-0.677	1							
CEC	-0.525	0.494	-0.764	1						
OM	0.769	-0.769	0.696	-.859*	1					
EC	0.309	-0.692	0.373	-0.682	0.774	1				
Ex Na	-0.703	.856*	-.866*	0.79	-.934**	-0.608	1			
Ex K	-0.66	.828*	-.908*	.820*	-.917*	-0.585	.995**	1		
Ex Ca	-0.682	0.798	-0.808	.884*	-.982**	-0.744	.964**	.961**	1	
Ex Mg	-0.792	0.746	-0.797	.857*	-.975**	-0.63	.971**	.964**	.982**	1

Remarks = ** and * mean correlation significant at the 0.01 and 0.05 levels, respectively (2-tailed). Clay: clay percentage, N: total N content, CEC: cation exchange capacity, OM: organic matter content, Ec: electrical conductivity, Ex Na: exchangeable Na content, Ex K: exchangeable K content, Ex Ca: exchangeable Ca content, Ex Mg: exchangeable Mg content.

The correlation matrix for physical and chemical properties determined in the present study of Gournadi is given in the Table 12. It was found that the clay content was the most fundamental property to control chemical properties of soils at Gournadi. CEC showed significant positive relationship with Clay and pH and OM showed significant negative relationship with clay and CEC. Exchangeable Na, K, Ca and Mg showed significant negative relationship with OM.

12. Correlation matrix between soil physical and chemical properties of Gournadi

	Clay	pH	N	CEC	OM	EC	Ex Na	Ex k	EX Ca	Ex Mg
Clay	1									
pH	0.62	1								
N	-0.005	-0.564	1							
CEC	0.692	0.795	-0.42	1						
OM	-0.656	-0.73	0.579	-.883*	1					
EC	-0.53	-0.474	-0.025	-.849*	0.65	1				
Ex Na	.822*	0.642	-0.266	0.79	-.921**	-0.65	1			
Ex K	0.8	.880*	-0.506	.826*	-.917**	-0.525	.914*	1		
Ex Ca	0.733	0.721	-0.451	.862*	-.984**	-0.672	.973**	.938**	1	
Ex Mg	.829*	0.693	-0.405	.859*	-.960**	-0.641	.973**	.934**	.978**	1

Remarks = ** and * mean correlation significant at the 0.01 and 0.05 levels, respectively (2-tailed). Clay: clay percentage, N: total N content, CEC: cation exchange capacity, OM: organic matter content, Ec: electrical conductivity, Ex Na: exchangeable Na content, Ex K: exchangeable K content, Ex Ca: exchangeable Ca content, Ex Mg: exchangeable Mg content

The correlation matrix for physical and chemical properties determined in the present study of Kalapara is given in the Table 13. It was found that the clay content was the most fundamental property to control chemical properties of soils at Kalapara. OM showed significant negative relationship with pH and CEC. Exchangeable Na, K, Ca and Mg showed significant positive relationship with OM.

13. Correlation matrix between soil physical and chemical properties of Kalapara

	Clay	pH	N	CEC	OM	EC	Ex Na	Ex k	EX Ca	Ex Mg
Clay	1									
pH	-0.766	1								
N	0.188	-0.413	1							
CEC	-0.531	.812*	-0.707	1						
OM	0.576	-0.785	0.476	-.821*	1					
EC	-0.519	0.13	0.005	0.075	0.279	1				
Ex Na	-0.465	.868*	-0.695	.964**	-0.801	-0.038	1			
Ex K	0.089	-0.189	-0.404	0.382	-0.133	0.179	0.167	1		
Ex Ca	-0.542	.868*	-0.592	.982**	-0.811	0.07	.974**	0.264	1	
Ex Mg	-0.539	0.726	-0.71	.981**	-.822*	0.102	.896*	0.52	.936**	1

Remarks = ** and * mean correlation significant at the 0.01 and 0.05 levels, respectively (2-tailed). Clay: clay percentage, N: total N content, CEC: cation exchange capacity, OM: organic matter content, Ec: electrical conductivity, Ex Na: exchangeable Na content, Ex K: exchangeable K content, Ex Ca: exchangeable Ca content, Ex Mg: exchangeable Mg content.

4.5. Exchangeable Sodium Percentage (ESP)

Exchangeable Sodium Percentage has been used as a parameter for assessing the severity of salinity problem. The sodium hazard is expressed as ESP. It ranged from 7.88% to 10.82% at Babuganj, 8.21% to 11.64% at Bakerganj,10.28% to 10.99% at Gournadi and 9.55% to 13.05% at Kalapara which were intermediate but acceptable is (< 10%). In sodic soil, aggregate stability is reduced due to the increase in exchangeable sodium percentage (ESP) (Buckland *et al.*, 2002).

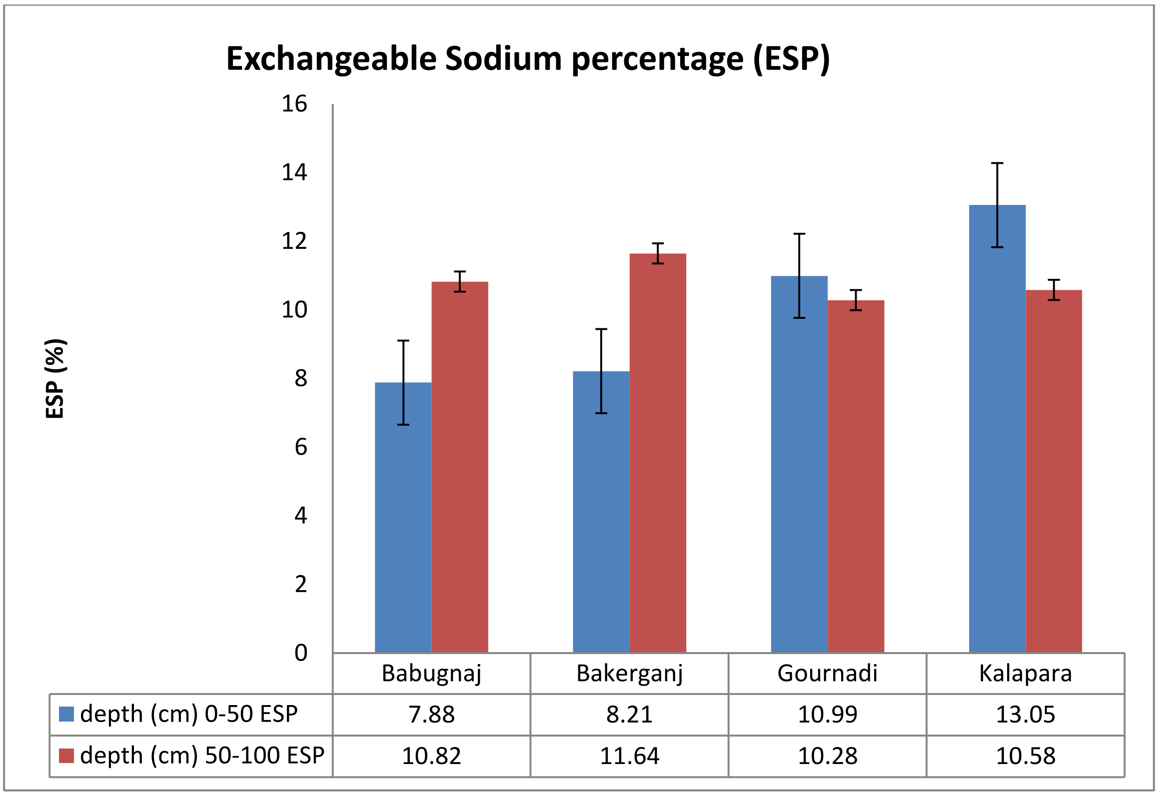


Figure 7. ESP of Babuganj, Bakerganj, Gournadi and Kalapara at different depths

4.6. Sodium Adsorption Ratio (SAR)

The sodium hazard is denoted by the sodium adsorption ratio. The SAR of a soil extract gives an indication of the level of exchangeable Na^+ in comparison with those of Ca^+ and Mg^+ in soil. The SAR value varies from 1.52 to 1.93 at Babuganj, 1.44 t0 1.99 at Bakerganj, 1.52 to 1.95 at Gournadi and 1.94 to 3.33 at Kalapara upazila. The saline soils tend to have sodium adsorption ratios (SAR) less than 13 in their saturation extract and exchangeable sodium percentage (ESP) lower than 15. Sodic soils have SAR greater than 13 in their saturation extract and EC values less than 4 dS m^{-1}(Rengasamy *et al.*, 1984). The SAR values of these areas are acceptable (<10) during the study period.

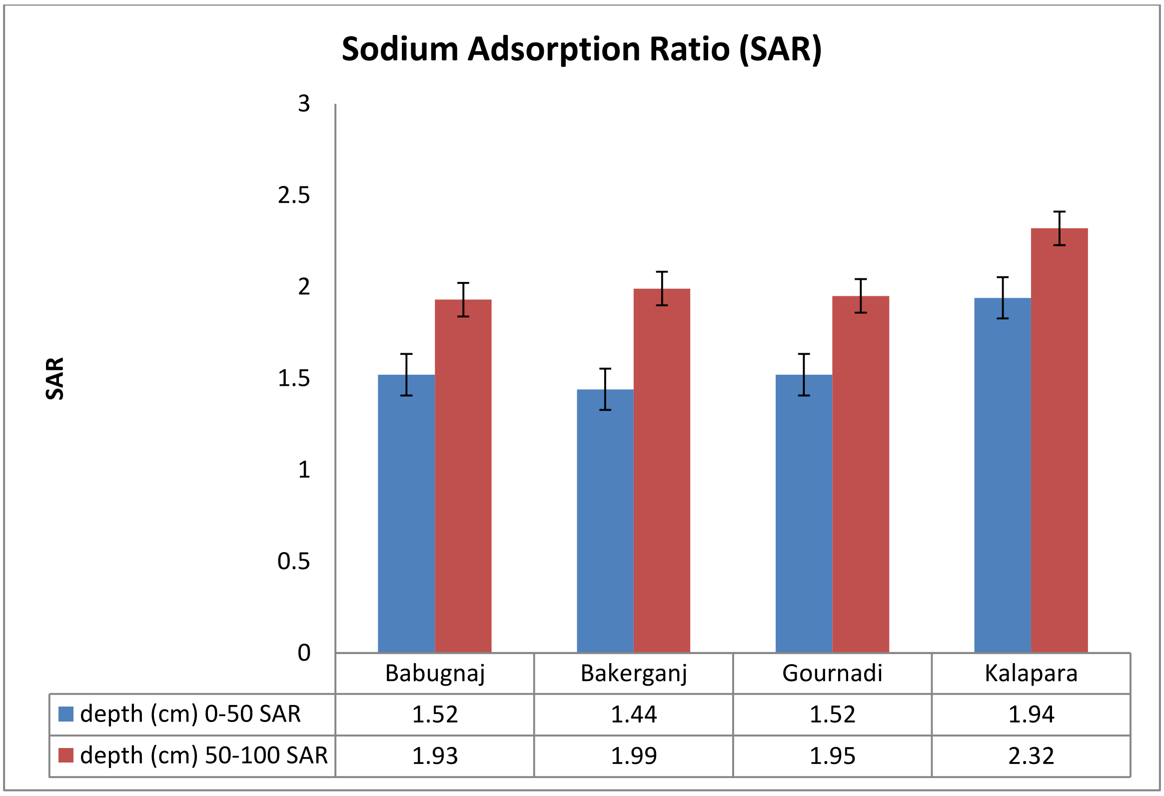


Figure 8. SAR (%) of Babuganj, Bakerganj, Gournadi and Kalapara at different depths

CHAPTER V

SUMMARY AND CONCLUSION

A field survey was carried out at Babuganj, Bakerganj and Gournadi upazilas in Barisal district and Kalapara upazila of Patuakhali district in Barisal Division in Bangladesh.

It was found that there are mainly four categories of salinity existing in the coastal saline areas and the range is from S_1 to S_4. The highest area is under S_2 category and S_1 at Kalapara. Soil occurring in the coastal areas of Bangladesh shows a wide variation in salinity.

From the data on the particle-size distribution and the USDA textural class of the soils it was found that Clay varies from 37%-41% at Babuganj, 38% at Bkaerganj, 37%-39% at Gournadi, 37%-39% at Kalapara and silt from 50%-53% at Babuganj, 52%¬53% at Bakerganj, 52%-53% at Gournadi and 51%-52% at Kalapara respectively at different horizons. The dominant soil textural classes that occur in the saline areas of these regions are silty clay. The clay and silt contents were observed to increase with depth at Bakerganj and Kalapara while, sand content decreased a phenomenon.

The pH value of the top soil at Babuganj ranged from 7.4-7.7 i.e. the soils were slightly alkaline in reaction. In 50-100 cm depth in this area the pH ranged from 7.6- 7.9 which is moderately alkaline. At Bakerganj, the pH values in 0-50 cm depth were 7.4-7.5 i.e. the soils were slightly alkaline in reaction. In 50-100 cm depth in this area the pH ranged from 7.5- 7.8 which is slightly alkaline. At Gournadi, the pH values in 0-50 cm depth were 8.0-8.2 i.e. the soils were moderately alkaline in reaction. In 50-100 cm depth in this area the pH ranged from 8.2- 8.8 which is strongly alkaline. At Kalapara, the pH values in 0-50 cm depth were 5.90 to 6.20 which is slightly acidic.

Soil salinity of different horizons normally ranged from 1.05 to 1.23 dS/m at Babuganj, 1.31 to 1.42 dS/m at Bakerganj, 1.78 to 2.68 dS/m at Gournadi and 3.1 to 4.0 dS/m at Kalapara. In dry season this ranges become 5 to 10 dS/m at Babuganj, Bakerganj, gournadi and Kalapara.

Top soil organic status in all the horizons ranged from medium to high at all regions. And the range was 1.0 to 1.12% at Babuganj and Bakerganj. 1.02 to 1.12% at Gournadi and .09 to 1.89% at Kalapara.

The total nitrogen content of the topsoil was generally low to occasionally high ranging from 0.06 to 0.09% at Babuganj and 0.06 to 0.09% at Bakerganj, 0.09 to 0.1% at Gournadi and 0.07 to 0.09% at Kalapara.

Cation exchange capacity of soils of different horizons varies from 13.2 to 21.8 meq/100 gm soil at Babuganj. 16.6 to 20.8 meq/100 gm soil at Bakerganj.14.8 to 21.3 meq/100 gm soil at Gournadi and 12.8 to 21.0 meq/100 gm soil at Kalapara. CEC of all this soils varies from 12.8 to 21.0 meq/100 gm soil expressing medium to high status.

The exchangeable sodium contents of the soils of Babuganj, Bakerganj, Gournadi and Kalapara at different soil depths have been presented in Table-2.9, It was observed that the exchangeable sodium content for Babuganj varied from 1.25 to 2.1 meq/100 gm soils,1.2 to 2.3 meq/100 gm soils at Bakerganj, 1.63 to 2.15 meq/100 gm soils at Gournadi and for Kalapara it varied from 1.67 to 2.2 meq/100 gm soils.

The exchangeable potassium content of the soils of Babuganj, Bakerganj, Gournadi and Kalapara varied mainly based on the clay content. At Babuganj this range was 0.68 to 1.0 meq/100gm soil, 0.7 to 1.35 meq/100 gm soil at Bakerganj, 0.67 to 1.0 meq/100 gmsoil at Gournadi and at Kalapara it was 0.57 to 1.10 meq/100gm soil. These ranges were very high in every the areas.

The exchangeable calcium contents of the soils for Babuganj were 5.78 to 10.5meq/100gm soil, and 6.1 to 9.98 meq/100 gm soil at Bakerganj, 6.53 to 10.63 meq/100 gm soils at Gournadi and for Kalapara, it was 6.73 to 10.75 meq/100gm soil.

Exchangeable magnesium content of the two areas was in the very high level. At Babuganj this range was 4.42 to 7.3meq/100gm soil, 3.98 to 7.7 meq/100 gm soil at Bakerganj, 4.38 to 7.48 meq/100 gm soil at Gournadi and at Kalapara it ranges from 4.47 to 7.85 meq/ 100gm soil.

The correlation matrix for physical and chemical properties revealed that the clay content was the most fundamental property to control chemical properties of soils at Babuganj, Bakerganj, Gournadi and Kalapara. Exchangeable Sodium Percentage ranged from 7.88% to 10.82% at Babuganj, 8.21% to 11.64% at Bakerganj,10.28% to 10.99% at Gournadi and 9.55% to 13.05% at Kalapara. All were intermediate but acceptable is (< 10%).

The Sodium Adsorption Ratio (SAR) value varies from 1.52 to 1.93 at Babuganj, 1.44 t0 1.99 at Bakerganj, 1.52 to 1.95 at Gournadi and 1.94 to 3.33 at Kalaparaupazila. The SAR values of these areas are acceptable (<10) during the study period.

CONCLUSION

Coastal area in Bangladesh constitutes 20% of the country of which about 53% are affected by different degree of salinity. The texture of the study areas were silty clay soil. In these areas Electrical conductivity (EC) varies from 1.23 dS/m to 6.6 dS/m expressing very slightly saline to slightly saline. Cation Exchange Capacity (CEC) of all these soils varies from 12.83 to 20.92 meq/100 g soil expressing medium to high status. The organic matter content is pretty low to medium to high. The higher pH values of the soils are likely to create micronutrient deficiency problem. Hence, soil fertility should be improved based on the results obtained in the present study.

CHAPTER VI

REFERENCES

Abrol, I. P. and Yadav, J. S. P. (1988).Salt-Affected Soils and their Management.FAO Soils Bulletin 39.

Akhter, J., Murray, R.., Mahmood, K., Malik, K.A. and Ahmed, S. (2004). Improvement of degraded physical properties of a saline-sodic soil by reclamation with kallar grass (Leptochloafusca).*J. of Plant and Soil*,**258**: 207–216.

Akram, N. A., Ashraf, M. and Al-Qurainy, F. (2011).Aminolevulinic acid-induced changes in yield and seed-oil characteristics of sunflower (Helianthus annuus L.) plants under salt stress.*Pakistan J. of Bot. Sci.*,**43**:2845-2852.

Al-Busaidi, K.T.S., Buerkert, A. andJoergensen, R.G. (2014). Carbon and nitrogen mineralization at different salinity levels in Omani low organic matter soils. J Arid Environ **100**:106–110.

Allison, M.A., Khan, S.R., Goodbred, J.S.L. and Kuehl, S.A. (2003).Stratigraphic evolution of the late Holocene Ganges–Brahmaputra lower delta plain, Sedimentary Geology 155, pp.317–342

Allotey, D. F. K., Asiamah, R. D., Dedzoe, C. D. and Nyamekye, A. L. (2008).Physico-Chemical Properties of Three Salt-Affected Soils in the Lower Volta Basin and Management Strategies for their Sustainable Utilization.*West AfricanJ.of Appl. Eco.*,**12(3)**:23-29.

Anonymous (2007).Salinity of Sonagazi Soil and Water, Annual Report, BRRI, Sonagazi, Bangladesh.

Anonymous(2001).Salinity of Sonagazi Soil and Water, Annual Report, BRRI, Sonagazi, Bangladesh.

Anwar, M. K. (1993). Evaluation of Some Physico-chemical Characteristics of SalineSoil. M.Sc.(Ag.) Thesis, Dept. Soil Sci., BAU, Mymensingh. pp. 1-79.

Arunakumara, K. K. I. U. and Walpola, B. C. (2010). Effect of salt stress on decomposition of organic matter and nitrogen mineralization in animal manure amended soils. *TheJ. of Agric. Sci.,***51(2)**: 9-18.

Arunakumara, K. K. I. U. and Walpola, B. C. (2011). Carbon and nitrogen mineralization of a plant residue amended soil: The effect of salinity stress. *Bangladesh J. of Sci. and Indus. Res.,***46(1)**: 565-572.

Awdenegest, M., Melku, D. andFantaw, Y. (2013). Land use effects on soil quality indicators: A case study of AboWonsho Southern Ethiopia. Applied and Environmental Soil Science**.;784989**: 1-9.

Aweke, (2005).Modeling the effect of three soil and water conservation practices in Tigray, Ethiopia. Agric. Ecosyst. Environ. **105**, 29–40.

Aydin, A., Turan, M. and Sezen, Y. (2004). Effect of sodium salts on growth and nutrient uptake of spinach (Spinaciaoleracea) and beans (Phaseolus vulgaris). International Soil Congress (ISC) on "Natural Resource Management for Sustainable Development", Erzurum-Turkey, June 7-10.

Barik, K.M., Canbolat, Y., Yanı k, R. and Rafiq, K. (2011). Compressive behavior of soil as affected by aggregate size with Different textures in turkey. *J. of Animal and Plant Sci.,* **21(2)**: 186-192.

Bertrand, I., Holloway, R. E., Armstrong, R. D., McLaughlin, M. J. (2003). Chemical characteristics of phosphorus in alkaline soils from southern Australia.*Australian J. of Soil Res.,***41**: 61-76.

Beutler, A.N. and Centurion, J.F. (2004).Effect of soil compaction in root development and soybean yield.*Brazilian J. of Agric. Res.,***39(3)**: 581–588.

Bhattacharya, T., Srivastra, R., Sharma, J. P. and Shegal, J. L. (1994).Classification of Saline SodicVertisols in the Coastal Plains of Gujarat.*Indian j. Soc. Soil Sci.,***42 (2)**: 306-309.

Bouyoucos, G.J. (1927).The hydrometer as a method for the mechanical analysis of soils. *Soil Sci.*, **23**: 343–353.

Brady, N.C. and Weil, R.R. (2002).The Nature and Properties of Soils.13th ed. Macmillan Publishing Company, Inc. USA.

Brammer, H. and Brinkman, R. (1977). Surface Water Gley Soils in Bangladesh: *Envir. Landf.and Soil Morph. Geodelma*.**17**:91-109.

Brammer, H., Asaduzzaman, M. and Sultana.P. (1993). Effects of climate and sea-level changes on the natural resources of Bangladesh. briefing document No. 3,5-7. Bangladesh UnnayanParishad (BUP), Dhaka.

Buckland, G. D., Bennett, D. R., Mikalson, D. E., de Jong, E., Chang, C. (2002). Soil salinization and sodication from alternate irrigations with saline-sodic water and simulated rain.*Canadian J. of Soil Sci.,***82**: 297-309.

Buckman, H.O. and Brady. N.C.(1967). The nature and properties of soils. The MacMillan Company, New York, New York. 42-46

Carson, J.K., Campbell, L., Rooney, D., Clipson, N. and Gleeson, D. B.(2009). Minerals in soil select distinct bacterial communities in their microhabitats. J. *of FemsMicrobi.Eco.,***67(1)**: 381-388.

Chabra, R., Ringoet, A., Lamberts, D. (1976). Kinetics and interaction of chloride and phosphate absorption by intact tomato plants from a dilute nutrient solution.*Z PflanzenPhysi.,***78**: 253-261.

Charman, P.E.V. and Murphy, B.W. (2000).Soils: *Their properties and management*.Oxford University Press, South Melbourne.pp. 217.

Chinnusamy, V., Jagendorf, A. and Zhu, J.K. (2005).Understanding and improving salt tolerance in plants.*J. of Crop Sci.,* **45**: 437-448.

Chowdhuri, A. H. (1992). To Study The Physical and Chemical Properties of Two AEZ of Bangladesh Under Three Cropping Pattern. M:Sc.(Ag.) *Thesis, Dept. Soil Sci., BAU*,Mymensingh. pp. 1-95.

Coram, J. E., Dyson, P. A., Houlder, P. A. and Evans, W. R. (2001). Australian groudwater flow systems contributing to drylandsalinity.A Bureau of Rural Sciences Project for the National Land and Water Resources Audit's Dryland Salinity Theme.77-90.

Curtin, D., Syers, J. K. and Bolan, N. S. (1993).Phosphate sorption by soil in relation to exchangeable cationcomposition and pH.*Australian J. of Soil Res.*,**31**: 137-149.

CZPo, (2005). Coastal Zone Policy, Ministry of Water Resources, Government of the People's Republic of Bangladesh, Dhaka.

Dohrmann, R. (2006). Cation exchange capacity methodology I: An efficient model for the detection of incorrect cation exchange capacity and exchangeable cation results. *Appl. Clay Sci.*,**34**: 31-37.

Dube. D. D. and Shama, 0. P. (1987).Characteristics and Classification of Coastal Salt Affected Soils.*Indian J. Soc. Soil Sic.*,**41(1)**: 62-66.

Fallovo, C., Rouphael, Y., Rea, E., Battistelli, A. and Colla, G. (2009). Nutrient solution concentration and growing season affect yield and quality of Lactuca sativa L. var. acephala in floating raft culture. *J. of the Sci. of Food and Agric.*,**89**: 1682–1689.

Freire, A., Neves, J. and Pestana, R. (2009).Analysis of recycled aggregates properties for unbound granular asphalt pavement layers.Proceedings of the 11th Conference on Asphalt Pavements, Nagoya, Japan.

Gabrijel, O., Zed, R. and Szilvia, V.(2011). Soil Salinization and Salt Stress in Crop Production, Abiotic Stress in Plants Mechanisms and Adaptations, *J. of Soil Sci.*, **978(2)**: 307-394.

Garcia, C. and Hernandez, T. (1996). Influence of salinity on the biological and biochemical activity if a calciorthird soil. *Plant and Soil* **178**: 255-263.

Gedion, T.(2009).Surface water-Groundwater Interactions and Effects of Irrigation on Water and Soil Resources in the Awash Valley.MSc Thesis, Addis Ababa University. Addis Ababa, Ethiopia.

George, P. R. and Wren, B. A. (1985).Crop tolerance to soil salinity.Department of Agriculture of Western Australia, South Perth.

Ghafoor, A., Murtaza, G., Ahmad, B. and Boers, T.H.M. (2008).Evaluation of amelioration treatments and economic aspects of using saline-sodic water for rice and wheat production on salt-affected soils under arid land conditions.*J. of soil and Irrig.Drai.*,**57**: 424-434.

Ghafoor, A., Qadir M. and Murtaza G. (2004). Salt-Affected Soils: Principles of Management, Allied Book Centre, Urdu Bazar, Lahore, Pakistan.

Gibson, T. S. (1988). Carbohydrate metabolism and phosphorus/salinity interactions in wheat (Triticumaestivum L.).*Plant and Soil***111**: 25-35.

Girma, A., Endalkachew, W. M., and Bakken, L.R. (2012). Carbon and nitrogen mineralization dynamics in different soils of the tropics amended with legume residues and contrasting soil moisture contents. *J. of Bio.andFert.of Soils*,**48**: 51-66.

Goldshleger, N., Ben Dor, E., Benyamini, Y., Agassi, M. and Blumberg, D. (2001). Design and test of a generic cohort model of organic matter decomposition, the SOMKO model. *Globe Ecol. and biogeo.*,**10**: 639 – 660.

Gupta, R. K. and Verma, S. K. (1983).Water behaviour of black clay soil as influenced by degree of sodicity.*Current Agric.*,**7**: 114-121.

Hanson, B.R., Grattan, S.R. and Fulton.A. (1999).*Agricultural salinity and drainage.* Publication 3375:141. Div. of Agriculture and Natural Resources, University of California, Oakland, CA..

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

Hussein, M.M., Abd El-Kader, A.A, Kady, K. A., Youssef, R. A. and Alva, A.K. (2010).Sorghum response to foliar application of phosphorus and potassium with saline water irrigation.*J. of Crop Improvement*, **24**: 324-336.

Islam, M. R.,(2006). Managing Diverse Land Uses in Coastal Bangladesh: Institutional Approaches. In: Hoanh, C. T.; Thong, T. P.; Gowin, J. W. and Hardy, B. (Ed.) Environment and livelihoods in tropical coastal zones, pp. 237-248.

Jones, J. B.(2003). Agronomic Hand Book: management of crops, soils and their fertility. CRC Press, Washington.

Jones, R. C. andUehara, G. (1973).Amorphus coatings on mineral surfaces.*American J. Soil Sci. Soc.*, **37**: 729-798.

Karim, Z., Hussain, S. G. and Ahmed, M. (1990). Salinity Problems and Crop Intensification in the Coastal Region of Bangladesh .Soil publication no. 33, Soils and Irrigation Division BARC, Farmgate, Dhaka, pp.1-22.

Karim, Z., Hussain, S. G. and Ahmed, A. U. (1998). Climate Change Vulnerability of Crop Agriculture", in Huq, S.; Karim, Z.; Asaduzzaman, M. and Mahtab, F. (Eds.), Vulnerability and Adaptation to Climate Change for Bangladesh, Kluwer Academic Publishers, Dordrecht. pp. 39-54.

Keshavarz, P., Norihoseini, M. and Malakouti, M. J. (2004).Effect of Soil Salinity on K Critical Level for Cotton and its Response to Sources and Rates of K Fertilizers. PhD Thesis TarbiatModarres University, Iran.

Kizildag, N., Sagliker, H. and Cengiz, D. (2013). Nitrogen mineralization in some saline soils at Eastern Mediterranean coasts, *Turkey Eurasia J. of Biosci.*,**7**: 95-100.

Kumar, S. (2013). Spatial Soil Toxicity Estimation Methodology for Improving Soil Fertility Using GIS Modeling, *J. of Arid Envir.*,**3(4)**: 613-620.

Leal, R.M., Herpin, A.F., Firme, L.P., Montes, C.R. and Melfi, A.J. (2009).Sodicity and salinity in a Brazilian Oxisols cultivated with sugarcane irrigated with wastewater. *J. of Agric. Water Manag.*,**96 (2)**: 307-316.

Leeper, G.W. and Uren, N.C. (1993). Soil Science: An Introduction. Melbourne University Press.

Loveland, P. and Webb, J. (2003). Is there a critical level of organic matter in the agricultural soils of temperate regions? *A revi.Soil Till. Res.*,**70**: 1–18.

Mahmood, I. A., Arshad, A., Muhammad, A., Armghan, S., Tariq, S., and Fayyaz, H. (2013).Phosphorus Availability in Different Salt-affected Soils as Influenced by Crop Residue Incorporation.*International J. of Agric. and Bio.*,**15(3)**: 472–478.

Manchanda, H. R., Sharma, S. K. and Bhandari, D. K. (1982).Response of barley and wheat to phosphorus in the presence of chloride and sulphate salinity.*Plant and Soil*.,**66**: 233-241.

Mariangela, D. and Francesco, M. (2015).Effectiveness of Organic Wastes as Fertilizers and Amendments in Salt-Affected Soils.*J. of Agric. Sci.*,**5(1)**: 221-230.

Marshall, T.J. (1947).*Mechanical composition of soils in relation to field description of texture*. Commonwealth of Australia,Council for Scientific and IndustrialResearch, Bulletin 224, Melbourne(Australia). pp. 20.

Melese, M. and Gemechu, S.(2010).Manual for Soil, Plant and Water Analytical Methods.Jije Analytical Survice Laboratory. Addis Ababa, Ethiopia.

Mesfin, A.(1998).Nature and management of Ethiopian soils.Alemaya University of Agriculture. Ethiopia.

Minhas, P. S. and Sharma, 0.P. (2003).Management of soil salinity and alkalinity problems in India. (Crop production in saline environments: global and integrative perspectives). *J. of Crop Prod.*,**7**: 181-230.

More, S. A.,Shinde, J. S. and Malewar, G. U. (1987). Studies on Salt Affected Soils of Puma Commend. *J. Maharashtra Agric. Univ.*,**12 (2)**: 145-146.

Muhammad, S. S., Anwar, H. and Abdul, R. (2002). Effect of salt on bulk density, particle density and porosity of different soil series, *Asia J. of plant sci.*,**5(1)**: 5-6.

Mulugeta, L.(2004). Effects of land use changes on soil quality and native flora degradation and restoration in the highlands of Ethiopia: Implication for sustainable land management. PhD Thesis, Uppsala University, Swedish.

Naher, N., Uddin, M. K. and Alam, A. K. M. M. (2011).Impacts of salinity on soil properties of coastal areas in Bangladesh**,** *Agrivita*.**33(2)**.

Nega, E. and Gikidan, H. (2012). Land use changes and their effects on physical and chemical properties in Senbat sub-watershed, western Ethiopia, *J. of Agric. and Bio. Sci.*,**8(3)**: 206-212.

Nelson, D.W. and Sommers.L.E. (1982). Total carbon, organic carbon, and organic matter. In: Methods of Soil Analysis, Part 2, 2nd ed., A.L. Page et al., Ed. Agronomy. **9:**961-1010. Am. *Soc. of Agron*., Inc. Madison, WI.

Nurul, H.,Sattar, A. and Saleque, M. A. (2009). Suitability Assessment of Water and Soil Salinity for Boro Cultivation in Coastal Region of Barisa.Paper Presented in Thursday Seminar at BRRI, Gazipur on 25 June, 2009.

Okalebo, J.R., Gathua,K.W. andWomer, P.L.(2002). Laboratory methods of soil and plant analyses: a working manual, 2nd Ed. TSBF–CIAT and SACRED Africa, Kenya.

Oldeman, L. R., Hakkeling, R. T. A. andSombroek, W. G. (1991).Second revised edition.World map of the status of human-induced soil degradation.An explanatory note.International Soil Reference and Information Center (ISRIC), Wageningen.

Olsen, S.R., Cole, C.V., Watanabe, F.S. andDean, A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Department of Agriculture Circ.,929.

Page, A. L. (1982).Method of Soil Analysis.Part ii, 2nd ed. Amer. *Soc. Agron*.Wisconsis, U.S.A.

Panaullah, G. (1993). Soil salinity and associated problems in connection with crop production in the coastal regions of Bangladesh. Proceedings of the workshop on, 'Coastal salinity and crop production in Bangladesh', February 17, 1993, Bangladesh Rice Research Institute publication p..1-30.

Pansu, M and Gautheyrou, V. (2006). Handbook of Soil Analysis: mineralogical, organic and inorganic methods. Springer-Verlag, Berlin, Germany.

Parfitt, R. L. (1978). Anion adsorption by soils and soil minerals.*Adv. in Agron.,* **30**: 1-50.

Pathak, H. and Rao, D. L. N. (1996).Carbon and nitrogen mineralization from added organic matterin saline and alkali soils.*Soil Bio.andBioch.,***30**: 695¬702.

Patterson, R.A. (1994). On-site treatment and disposal of septic tank effluent.PhD thesis.*Depart.Resource.Engg.& and Agronomy & Soil Sci. Uni.*New England. Armidale.

Patterson, R.A. (2000). Wastewater Quality Relationships with Reuse Options in Proceedings of 1st World Water Congress of the International Water Association.7 July 2000. Paris France Conference Preprint Book 8, pp 205-212.

Pearson, K. E. (2004).The basic effects of salinity and sodicity effects on soil physical properties. http://waterqualityMontana.edu/docs/methane/basics_highlight.shtml

Pearson, K. E. andBauder, J. W. (2003).The basics of salinity and sodicity effects on soil physical properties. The Department of Land Resources and Environmental Sciences, Water Quality & Irrigation Management, MSU Bozman.

Petersen, L. and Shireen.S.(2001). Soil and water salinity in the coastal area of Bangladesh. SRDI,.15-18.

Pierre, H.(1997). Relationship between porosity, electrical conductivity, and cation exchange capacity in Barbados wedge sediments, Proceedings of the Ocean Drilling Program, *Sci. Resu.*,**156**: 35-42.

Ponnamperuma, F. N. (1972). The Chemistry of Submerged Soils.*Adv. Agron.***24**: 29-96.

Portch, S. and Islam, M. S. (1984). Nutrient status of some important agricultural soils of Bangladesh. In "Proceedings of the International Symposium on Soil Test Crop Response Correlation Studies", *Bangladesh Agricultural Research Council and Soil Science Society of Bangladesh*, Dhaka (Bangladesh),. 97–106

Qadir, M., Sharma, B.R., Bruggeman, A., Choukr-Allah, R., and Karajeh, F. (2007).Nonconventional water resources and opportunities for water augmentation to achieve food security in water scarce countries.*J. of Agric. Water Manag.*,**87**: 2-22.

Quirk, J.P. and Schofi, E. (1955).The effect of electrolyte concentration on soil permability.*J. Soil Sci.*, **6,** 163-173

Qureshi, R. H. and Barrett-Lennard, E. G. (1998). Saline agriculture for irrigated land in Pakistan: A handbook. *Australian Centre for Inter. Agric. Res. (ACIAR)*, Canberra, Australia.

Rahman, M. S. (1987). Some Physico-chemical properties of Two Major Salt Affected Soil of Bangladesh.*Bangladesh, J. Agril*: **12(2)**: 113-120.

Rashad, M. and Dultz, S. (2007).Decision Factors of Clay Dispersion in Alluvial Soils of the Nile River Delta – A Study on Surface Charge Properties. *American-Eurasian J. of Agric. and Envir. Sci.*, **2 (3)**, 213-219.

Rayment, G.E. and Higginson, F.R. (1992).Australian Laboratory Handbook for Soil and Water Chemical Methods.Inkata Press. Melbourne ix Rengasamy, P and Olsson, K.A. 1993.Irrigation and Sodicity.Aust. *J. Soil Res*. 1993.**31**:821-37.

Rengasamy, P. (2006). World salinisation with emphasis on Australia.*J. of Experi.Bota.*,**57**: 1017-1023.

Rengasamy, P. (2006).World salinization with emphasis on Australia.*J. of experi.Bota.*,**57**: 10-17.

Rengasamy, P. (2010). Soil processes affecting crop production in salt affected soils. *Functi.plant Bio.*,**37(3)**: 613-620.

Rengasamy, P., Chittleborough, D. and Helyar, K. (2003).Root-zone constraints and plant-based solutions for dryland salinity.*Plant and Soil*., **257**: 249-260.

Rengasamy, P., Greene, R. S. B., Ford, G. W. and Mehanni, A. H. (1984). Identification of dispersive behaviour and the management of red-brown earths.*Australian J. of Soil Res.*,**22**: 413-431.

Richards, L. A. (1954). Diagnosis and improvement of saline and alkali soils. USDA Agricultural Handbook No. 60 *United States Depart.of Agric.*, Washington DC, USA.

Rietz, D. N. and Haynes, R. J. (2003). Effects of irrigation induced salinity and sodicity on soil microbial activity. Soil Biology and Biochemistry **35**: 845-854.

Rogobete, G., Tarau D., Dicu, D.and Bertici, R. (2013). Capillarity and solute transport in swelling and shrinking soils. Soil Forming Factors and Processes from the Temperate Zone **12(2)**: 53-59.

Russell, E. J. (1961). Soil conditions and plant growth. London, UK., Longmans.

Russell, N. J. (1989). Mini-review: Adaptive modifications in membranes of Halotolerant and Halophilic microorganisms. *J. of Bioenerg.andBiomembr.*,**21**: 93-113.

Ryan, M.G. and Covington, W.W. (1986).The effect of a prescribed burn in ponderosa pine on inorganic nitrogen concentrations of mineral soil.*US Dep. Agric.*

For.Serv., Rocky Mount.For. Range Exp. Stn., Fort Collins, CO, Res. Note RM-464, 5 pp.

Ryden, J. C., Syers, J. K. and McLaughlin, J. R. (1977). Effects of ionic strength on chemisorption and potential-determining sorption of phosphate by soils.*J. of Soil Sci.,* **28**: 62-71.

Sahoo, A. K., Saho, K. D. and Gupta, S. K. (1995). Organic Carbon Status in the Sunderban Mangrove Soils, *Indian J. Soc. Soil Sci.,***43(2)**: 265-267.

Samadi, A. and Gilkes, R. J. (1998).Forms of phosphorus in virgin and fertilised calcareous soils of Western Australia.*Australian J. of Soil Res.,***36**: 585-601.

Sarig, S., Fliessbach, A. and Steinberger, Y. (1996). Microbial biomass reflects the nitrogen and phosphorus economy of halophytes grown in salt desert soil. *Bio.andFerti. of Soils* **21**: 128-130.

Saskatchewan W. C.(1987). "Irrigation water quality - soil compatibility: Guidelines for irrigation in Saskatchewan." Saskatchewan Water Corporation..60

Shainberg, I. (1992). Chemical and mineralogical components of crusting. In Sumner, M. E. and Stewart, B. A. (ed) Soil crusting, chemical and physical processes. Advances in Soil Science, Lewis Publishers, Boca Raton.

Sharpley, A. N., Meisinger, J. J., Power, J. F. and Suarez, D. L. (1992). Root extraction of nutrients asociated with long-term soil management. In: Stewart, B. (Ed.), *Adv. in Soil Sci.,***19**: 151-217.

Sopher, C.D. and Baird, J.V.(1982).Soils and Soil Management.2nd Edition.Prentice Hall Career and Technology, Englewood Cliffs, New Jersy.

SRDI (Soil Resource Development Institute). (2003). SoilSalinity in Bangladesh.Government of the People's Republic of Bangladesh.

SRDI.(2005). Reconnaissance Soil Survey Reports of Different Districts of Bangladesh. Govr.of Bangladesh, Farmgate, Dhaka.

SRDI.(1993). Land and Soil Resource Utilization (in Begali).Thana Nirdeshika Series SatkhiraSadar. Soil Resource Development Institute, Dhaka, Bangladesh. pp. 52-60.

SRDI.(1999). Land and Soil Resource Utilization (in Begali).Thana Nirdeshika Series SatkhiraSadar. Soil Resource Development Institute, Dhaka, Bangladesh. pp. 51-61.

Srivastava, P.K., Gupta, M., Pandey, A., Pandey, V., Singh, N., and Tewari, S.K. (2014). Effects of sodicity induced changes in soil physical properties on paddy root growth. *J. of Plant Soil Envir.*,**60(4)**: 165–169.

Swarp, A. (2004). Chemistry of sodic soils and management. pp. 7-52. In: Advances in Sodic Land Reclamation Int. Conf. Feb. 9–14. on Sustainable Management of Sodic Lands, Lucknow. Adelaida, Australia.

Szabolcs, I. (1989). Salt-Affected Soils. Boca Raton: CRC Press Incorporation 274-290.

Tamhane, R. V., Motiramani, D. P., and Bali, Y. P. (1970).Soils; their chemistry and fertility in Tropical Asia.Prentice Hall of India Private Ltd. Pp 475.

Tisdale, S.L., Nelson, W.L. Beaton, J.D. and Havlin, J.L.(1993).Soil acidity and basicity.p.364-404. In Soil fertility and fertilizers. 5th ed. Macmillan Publ., New York.

Tracy, S.R., Black, C.R., Roberts, J.A. and Mooney, S.J. (2011). Soil compaction: A review of past and present techniques for investigating effects on root growth. *J. of the Sci. of Food and Agric.*,**91**: 1528–1537.

USDA.(1954). Origin and nature of saline and alkali soils.London, UK, Longmans.Classification of salt-affected soils.London, UK, Longmans.

Velazquez, E., Lavelleb, P. and Andradec, M. (2007).General indicator of soil quality (GISQ), a multifunctional indicator of soil quality.*J. of Soil Bio.andBioch.,***39**: 3066–3080.

White, R. E. (1980). Retention and release of phosphate by soil and soil constituents. In: Soils and Agriculture, ed. Tinker, P. B 71-114. *Blackwell Sci. Publication*, Oxford.

Wondimagegne, C. and Abere, M.(2012). Selected Physical and Chemical Characteristics of Soils of the Middle Awash Irrigated Farm. *Ethiopia J. of Agric. Sci.*,**22**:127-142.

Yeo, A. (1999). Predicting the interaction between the effects of salinity and climate change on crop plants.*Scienti.Hortic.*,**78**: 159-174.

Zaman, T.M. and Bakri, D.A. (2003).Dry land salinity and rising water table in the Mulyan Creek Catchment, Australia. The University of Sydney Orange Leeds Parade, Orange, NSW 2800, Australia. p.23-27.

Appendices

Appendix-I. Monthly average temperature, wind speed, Relative humidity, Total rain fall and Evaporation of experimental site during the period from July to September 2016 at Barisal district.

Temperature	July	August	September	Annually
Mean.max(C)	30.3	30.1	30	
Mean.min(C)	25.2	25.5	25.3	
Mean (C)	27.75	27.8	27.65	26.35
Wind speed(Km/h)	7.1	7.52	3.10	
Humidity(%)	92	86	85	
Rainfall(mm)	458	332	283	2188
Evaporation(mm)	71.3	64.7	65.8	

Source: Meteorological station, Barisal

Appendix-II. Monthly average temperature, wind speed, Relative humidity, Total rain fall and Evaporation of experimental site during the period from July to September 2016 at Kalapara.

Temperature	July	August	September	Annually
Mean.max(C)	30.6	30.3	30	
Mean.min(C)	25.6	25.7	25.6	
Mean (C)	28.1	28	27.8	26.08
Wind speed(Km/h)	7.3	7.82	3.15	
Humidity(%)	94	88	88	
Rainfall(mm)	575	425	325	2618
Evaporation(mm)	72.4	65.6	68.7	

Source: Meteorological station, Kalapara

Appendix-III. Soil salinity classes on the basis of Electrical conductivity (dS/m)

Soil salinity class	EC (dS/m)	Effects on crop plants
Non-saline	0 – 2	Salinity effects negligible
Slightly saline	2 – 4	Yields of sensitive crops may be restricted
Moderately saline	4 – 8	Yields of many crops are restricted
Strongly saline	8 – 16	Only tolerant crops yield satisfactorily
Very strongly saline	> 16	Only very tolerant crops yield satisfactorily

Source: Bookess Tropical Soil Mannal, 1991

Appendix-IV. Classification of land type

F0 (Highland)	Land which is above normal flood-level
F1 (Medium Highland)	Land which is normally flooded up to about 90 cm deep during the flood season
F2 (Medium Lowland)	Land which is normally flooded between 90 and 180 cm deep during the flood season
F3 (Lowland)	Land which is normally flooded between 180 and 300 cm deep during the flood season
F4 (Very Lowland)	Land which is normally flooded deeper than 300 cm deep during the flood season

Source: soil salinity in Bangladesh, 2000

Appendix V. Classification of soil on the basis of pH

Denomination	pH range
Ultra acidic	< 3.5
Extremely acidic	3.5–4.4
Very strongly acidic	4.5–5.0
Strongly acidic	5.1–5.5
Moderately acidic	5.6–6.0
Slightly acidic	6.1–6.5
Neutral	6.6–7.3
Slightly alkaline	7.4–7.8
Moderately alkaline	7.9–8.4
Strongly alkaline	8.5–9.0
Very strongly alkaline	> 9.0

Source: BARC, 2012

Appendix VI. Classification of soil on the basis of Organic Matter (OM)

Class	Range (%)
Very low	< 1
low	1.0-1.7
Medium	1.8-3.4
High	3.5-5.5
Very high	> 5.5

Source: BARC, 2012

Appendix VII. Classification of soil on the basis of CEC

Class	Range (%)
Very low	< 3
low	3-7.5
Medium	7.6-15
High	16-30
Very high	> 30

Source: BARC, 2012

PLATES

Plate 1. Soil collection from Babuganj, Bakerganj, Gouranadi and Kalapara upazila

Plate 2. Analyzing soil sample in SAU soil science laboratory