Ecology and management of natural resources of the island, Nijhum Dwip in Bangladesh

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Dedicated

To

My Beloved Parents, Husband and Daughters

CERTIFICATE

*This to certify that the research work presented in this thesis entitled **"Ecology and management of natural resources of the island, Nijhum Dwip in Bangladesh"** submitted by Nazma Ph.D. fellow bearing Reg. No. 56/2014-2015 was carried out under our direct supervision in the Ecology, Environment and Natural Resource Laboratory, Department of Botany, University of Dhaka. This is further to certify that it is an original work and approved as to the style and content for the partial fulfillment for the award of Doctor of philosophy in Botany.*

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Abstract

The present study has been carried out to estimate the land cover and land area change over the last forty years, determination of productivity and carrying capacity of a coastal island for management, food security and livelihood earning and physico-chemical properties of soil and mineral nutrients of leaf of different mangrove species in Coastal Island namely Nijhum Dwip. Nijhum Dwip is situated in the Noakhali district in Bangladesh. The area is about 14050 ha. The islands are managed by Forest department by planting of trees in this area with species such as *Sonneratia apetala* Buch.-Ham (Keora), *Avicennia officinalis* L. (Bain) and *Ceriops decandra* (Griff.) Ding Hou (Goran) since 1972. Forest department introduced deer in Nijhum Dwip and other coastal islands which is fed on the *Porteresia coarctata* (Roxb) (locally known as Uri grass) and leaves of *Sonneratia apetala* Buch.-Ham.plants. This helped in the rapid buildup of new ecosystems in the coastal areas. But the rapid growth in number of deer and ban on killing them created an ecosystem service problem in this area. Carrying capacity was determined of an area of the Dwip to people exact number of deer the island can support. Soil and leaf samples were collected during four field visits i.e. 2013, 2014, 2015 and 2016 from six locations (six quadrats of 25x25 meter) of the Nijhum Dwip. Four soil samples (which contain upper and lower layers) from each quadrat i.e. total forty eight soil and four leaf samples of plants (Keora, Goran, Bain and Hargoza) from each quadrat were collected. Then these forty eight soil samples and twenty four leaf samples were analyzed in Ecology and Environment Laboratory, MS Laboratory of Department of Botany, Soil Chemistry Laboratory of Soil, Water and Environment Departments, CARS of Dhaka University and Bangladesh Council of Scientific and Industrial Research (BCSIR) laboratory. The mean value of some important soil variables such as moisture, pH, salinity, conductivity, organic carbon, nitrogen and

phosphorus are 42.413 ± 5.58 %, 7.686 ± 0.53, 11.583 ± 2.203 ‰, 12.52 ± 4.28 mS/cm, 0.481 ± 0.221 %, 0.670 ± 0.118 % and 0.0130 ± 0.0154 % respectively in 2013. In 2014 and 2015, the values of moisture and salinity were in decreasing trend but organic carbon and nitrogen showed in increasing trend which represents the good condition of the island. In 2016, the mean value of moisture, pH, salinity, conductivity, organic carbon, nitrogen and phosphorus are 22.090 ± 3.808 %, 6.70 ± 1.233, 3.259 ± 2.270 ‰, 8.296 ± 2.541 mS/cm, 1.372 ± 0.480 %, 1.874 ± 0.302 % and 0.017 ± 9.01. The values of organic carbon and nitrogen in 2016 were more than that of 2013 which indicates that Nijhum Dwip is good for vegetation. The values of heavy metals of soil (Na, K, Ca, Pb, Mg, Fe, Mn, and Zn) were also determined of the samples. In 2013, the value of Na, K, Pb, Mn, Mg, Fe, Ca and Zn were 44.05 ± 11.45 µg/g, 41.84 ± 10.16µg/g, 0.493 ± 0.160 µg/g , 180.74 ± 49.02 µg/g, 229.4 ± 90.7 µg/g, 7297.8 ± 677.1 µg/g, 299.4 ± 90.9 µg/g and 188.81 ± 56.57 µg/g respectively. The value of Na, K, Pb, Mn, Mg, Fe, Ca and Zn in 2014 and 2015 showed fluctuating tendency and the mean value of Na, K, Pb, Mn, Mg, Fe, Ca and Zn in 2016 were 54.04 ± 17.97 µg/g, 24.81 ± 8.43 µg/g, 0.328 ± 0.07 µg/g, 394.3 ± 82.2 µg/g, 819.1 ± 186.9 µg/g, 10074 ± 720 µg/g, 1239.8 ± 440.1 µg/g and 325.18 ± 56.84 µg/g. All the heavy metals in 2016 showed increasing trend except K and Pb in comparison to the values of 2013. Principle component analysis (PCA) was carried out of the values of different variables of soils in different years. The mean value of different mineral nutrients of leaf samples has the other mangrove species throughout the study period. N content of leaves of four species was calculated in four sampling times. *Avicennia officinalis* maintain a higher amount N content in the leaves during 2013 than those of others species and the chronological order was as *A. officinalis> S. apetala> C. decandra> A. ilicifolius*. In *C. decandra*, N maintained negative significant correlation with Pb (r = - 0.918, p = 0.028), Ca (p = 0.044, r = - 0.889). In 2016 the chronological order of the N content of leaves were as *A. officinalis*> *A. ilicifolius* > *C. decandra* > *S. apetala*. N maintained very strong negative significant correlation with Mn (r = -0.906, p = 0.034) in *A. ilicifolius*. Highest total P content was found in leaves of *S. apetala* throughout the study period. In 2013, the P content of leaves was in the following chronological order: *S. apetala*> *A. officinalis*> *C. decandra* > *A. ilicifolius* and the P content of leaves during 2016 was as *S. apetala*> *C. decandra*> *A. ilicifolius*> *A. officinalis.* There were variations found in lead content in different mangrove species studied**.** *Avicennia officinalis* showed highest concentration of lead during most of the study period except 2016 when highest value was found in *A. ilicifolius.* Magnesium content in the leaves of *A. officinalis* was found to be lowest in most of the cases where the value was higher in *S. apetala* in all cases except 2013. In carrying capacity for this island forage demand of the particular species of livestock (here spotted deer is considered with body weight of female is considered to be 45 kg and that of male 65 kg) is about 328.5 kg/y and 474.5 kg/y for female and male spotted deer respectively. These values showed that if we plan to have only female in the herd then the number will be 2341 and 3600 in 2014 and 2015 respectively and if only male is used then the number will be 1700 and 2500 in 2015 respectively. If we use 50:50 of female and male then the number will half in either case. But in case of commercial carrying capacity, i.e. meat is the goal, and then male spotted dear with higher body weight might be preferable to the authority. The present study will provide present status of land area and land cover, carrying capacity and mineral nutrients soil and leaf of Nijhum Dwip for its better management.

1.1 Introduction

Ecology is the scientific learning of the distributions, abundance and associations of organisms and their connections with the environment (Burke and Lauenroth 2002). Ecology deals with the plant and animal populations, plant and animal societies and ecosystems. Ecosystems define the web or set-up of relatives among creatures at different rulers of association. Since ecology states to any form of biodiversity, ecologists study entirety from tiny bacteria's part in nutrient recycling to the belongings of tropical rain forest on the Earth's atmosphere. The discipline of ecology originated from the natural sciences in the late 19th century. Ecology is not equal with environment, environmentalism, or environmental science. Ecology is thoroughly connected to the disciplines of physiology, evolution, genetics and actions.

Like many of the natural sciences, a theoretical accepting of ecology is established in the broader details of education, including:

- life procedures explaining adaptations,
- circulation and plenty of creatures,
- the undertaking of materials and energy through active populations,
- the successional growth of ecosystems, and
- the plenty and distribution of biodiversity in context of the environment (Jaafari *et al.* 2014)

Ecosystem service area starts at the most vital level. Through photosynthesis by bacteria, algae, plankton, and plants, atmospheric oxygen is generally -produced and continued by ecosystems and their basic classes, permitting individuals and innumerable other oxygen-dependent organisms to endure. Oxygen also permits the atmosphere to clean itself via the corrosion of mixtures such as carbon monoxide (Sodhi *et al*. 2007).

Through these sequences, the planet's climate, ecosystems, and beings are strongly connected. Variations in one element can have severe effects on another as showed by the properties of deforestation on climatic variation (Phat *et al*. 2004).

One of the greatest vigorous and speedy facilities of ecosystems, particularly of forests, rivers and wetlands, is the provisioning and parameter of water properties. These facilities offer a massive variety of assistances from divine to life-saving showed by the grouping of hydrologic facilities into five broad classes (Braman *et al.* 2007), development of extractive water supply, progress of tributary water supply, water damage alleviation, running of water-related cultural amenities, and water-associated supportive rest area. Although 71% of the globe is enclosed by water, maximum of this is seawater unfit for consumption or agriculture (Postel *et al.*1996). Fresh water not protected away in glaciers and icecaps establish 0.77% of the planet water (Shiklomanov 1993).

Coastal zone, the main area of oceanic assets and the 'golden area' in marine social-economic improvements, implements and important part in local and national finances of adjacent states and areas (Ketchum 1972). Modern natural calamities all over the place in the world comprising the flood in New York from super storm 'Sandy' and severe Typhoon 'Vicente' that hit Hong Kong should have drawn global attention to coastal area disasters (Parker 1999). The coastal area can be demarcated as the group of land and next to ocean space (water and submerged land) in which terrestrial progressions and land practices directly touch oceanic routes and uses, and vice versa (Hassan 2013). Really, because of the relations between land and ocean, an extremely multipart ecological system dwells at this zone (Webb 2009). They are sensitive to several inner or outer factors that could bring great change to the whole system, as well as prompting urban infrastructures, marine assets and human health. This consequence in coastal zone studies to be extremely multipart and interdisciplinary. The difficulty is that this concern is still increasing with progress in exploitation technology, marine logistics and human lifestyle (Curtin and Prellezo 2010).

Coastal zone is always an area touched by hazards, natural and human-induced (Chowdhury *et al.* 1998). Beside the most well-known natural disasters typically like earthquake, tropical cyclones and tsunamis, the human-tempted oil spill, red tide and water pollution are also of excessive environmental concern now (Hossain 2003). Allowing for the great concentration of vast cities and core cost-effective hearts situated within coastal area, if we do not gain actions concerning the coastal environmental security and sustainable development, the concerns can be disastrous (Blanco 2006).

Mangroves are the greatest noticeable searing ecosystem emerging in the coastal areas where geomorphologic, sedimentary and oceanographic developments have organized landscape growth (Filho and Costa 2006). There is an troubled but long connection existed between the coast with man but the coastal plains and low-lying river basin have been spaces for social development during the course of the past of social presences (Wolanski *et al*. 2006). About 60% of the world's inhabitants is existing immediate to the coast (Lindeboom 2002) at present. There has been a shift in the role of coast towards human benefit that include from food and security provider to industrial and commercial development which have been more recently moved towards leisure and conservation. The coast make available rich natural conditions (Van der Zwiep 1991) and different nice-looking and culturally significant landscapes are located in these greatly multipart areas. Because of excessive biological production (Blaber *et al*. 2000) and valuable environment facility and functions (Costanza *et al*. 1997) the coastal zones of the world are experiencing pressure from anthropological activities.

The coastal resources of Bangladesh have been exploited extensively since long without the prerequisite understanding of the basic functional ecological systems. The management of these resources is also very limited. The protection and conservation of the coastal areas and their surroundings are principal of all good ecological and environmental reputation. It involves in abundance awareness of ecosystem functioning (Ducrotoy and Elliott 2006) and significant studies are also required in order to determining ecosystem degradation as a result of anthropogenic activities (Olenin and Ducrotoy 2006) and other animals' actions and natural calamities. Bangladesh has coast area of about 20,000 km^2. About 24 million or 22% of the population is existing there (Hossain 2001) and they are directly or indirectly dependent on the assets of this planted forest. Further, it helps in protecting the lives and settlements during the cyclones and coastal tides. Therefore, the management and safety of these irreplaceable but vulnerable natural resources is particularly important. The effective management of marine resources requires significant financial investment, strong capacity building including employment of appropriate and experience staff and acceptance and cooperation by the local communities which could be developed within a management framework built on sound scientific information on the structure and function of the ecosystems specially the biology and ecology of the target species. Airborne and orbital remotely sensed data has been comprehensively used for coastal modification monitoring. Aerial photograph (Lucas *et al*. 2002), Thematic Mapper (TM) Landsat, HRV SPOT and high-resolution sensors (Ramsey *et al*. 1998), are suitable bases of optical data for coastal geomorphic applications (Filho and Costa 2006). Guiding principle expressed based on ground level data on the natural resources, stakeholders' estimation and current methods such as Satellite images Geographic Information Systems (GIS) are essential for the actual and sustainable management of any reserve (Ahmed *et al.* 2011, 2018, Ali *et al*. 2013, Giri *et* *al*. 2007). Nevertheless, there is an absence of policy strategies for the controlling of the natural assets of the coastal ecosystems of Bangladesh.

Nijhum Dwip is located in the district named Noakhali. The area of the Dwip (char) is about 14050 ha. The population of this area is about three thousand. The natural resources are managed by Forest department in planting of trees in this area with species such as *Sonneratia apetala* Buch.-Ham. (Keora, local name), *Avicennia officinalis* (Forssk.) Vierh (Bain, local name), *Ceriops decandra* (Griff.) Ding Hou (Goran, local name) since and *Acanthus ilicifolius* L (Hargoza, local name) 1972. Forest department introduced deer in Nijhum Dwip and other coastal islands which is fed on the Uri-gash (*Porteresia coarctata*) and leaves of Keora plants. This helped in the rapid build in of new ecosystems in the coastal areas. But the rapid growth in number of deer and ban on killing has created ecosystem services problems in these areas. For proper management of resources of these islands, assessments of resources available are required that will help in sound and effective policy guidelines formulation.

The general objective of the present work was to study the current status of nutrient of soil and plants and productivity of Nijhum Dwip to propose the proper management policy of the Dwip.

The specific objective of the present study was to

1. monitor the changes in land and forest resources of Nijhum Dwip over a period of time by using Geographic Information Systems (GIS) and Remote Sensing (RS) technique.
2. explore nutrient resources of soil and plant of the study area.
3. effects of plantation on the soil physico-chemical properties.
4. study of the ´´carrying capacity´´ of the studied area.

Ecology is as "The economy of nature the study of the total associations of the animal both to its non-living and its living environment; including, above all, its friendly and unfriendly relations with those animals and plants with which it comes directly or indirectly into connection in a word, ecology is the study of all those multipart interrelationships stated to by Darwin as the situations of the disturbance for survival (Dodson *et. al.* 1998). In other words, "Ecology is the study of the communication among living things and their environment" (Sutton and Anderson 2004). An essential part of this association is the adaptation that these beings make to their environment. Adaptation in man is the method by which he makes actual use of dynamic ends of the energy maturing in his habitat (Durham 1976). Man's communication with his environment in terms of economic relations, assets, geographical links, social arrangement and inter-cultural powers, etc. has been altering through the ages (Bhasin 1989). Neither man nor the environment is measured as static or constant

Management of Natural Resources

Agarwal (1987) stated 'natural resource management' as "forecasting and management of capitals so as to protect their sensible use and stability of supply while continuing and improving their superiority, value and multiplicity". Natural resource management is an imperative subject that touches us all. Everyone's well-being, indeed livings, depends directly and indirectly on natural resources. The science of natural resource management is established on the environmentally completely old-style wisdom of planters and its role to expanding productivity. Traditional principles which are workable in nature essential to be related with values of modem schemes. Ecology should start with ancient evidence as they are established technology for natural resources management. In a real sense, every culture is the result of people's determine to continue and their challenges to enhance the use of obtainable resources i.e. soil, water and vegetation (Mishra1987

The chief courses of natural resources according to Howe (1979) are agricultural land; forest land and its several yields and services; natural land areas conserved for aesthetic, amusing or scientific purposes; the fresh and salt water fisheries; mineral resources comprising fuels and non-fuels; renewable non-mineral energy bases of solar, tidal, wind and geothermal schemes; water resources; and the waste-assimilative volumes of all portions of the location. More commonly, natural assets decline into four categories: basic natural resources such as land, water and air; natural resource merchandises such as timber and fish; environmental amenities such as clean air and scenic views; and ecological methods such as pollution, soil erosion, groundwater recharge and species regeneration (Kerr and Swarup 1997). Some authors select to categorize resources into biotic or living resources, e.g., forest, agriculture, fish and wildlife, and abiotic or non-living resources, e.g. land, water, minerals etc.

According to Sharma (1992), assets may be categorized into the following types: Based on Continual utility, some assets are drained quickly, whereas others last for a long epoch. Thus, subject on the accessibility of assets, throughout our constant use. A resource may be renewable (inexhaustible) assets that can be repeated along with their utilization and are always obtainable for use like forests. However, development of some assets like iron ore, coal and mineral oil takes several thousand years. Once they are used in unlimited ways they cannot be easily switched. Therefore, if misused at large scale, they will diminish fast. Hence, such resources are called non-renewable resources or exhaustible resources. For definite capitals there is no final use, as they can be used constantly such resources are known as recurring resources. Based on origin on the basis of their origin, resources may be biotic (organic) or abiotic (inorganic). Biotic resources are found from the biosphere e.g. forest, wildlife, crops, coal, mineral oil, etc. resources composed of non-living inorganic matter are called abiotic resources, e.g., land, water, minerals, etc.

Properties are the bases of both security and opulence; they are the fundamentals of power and wealth, they disturb man's purpose in war and peace alike (Zimmerman 1951). The altering purposes and service of resources can be recognized to socio-cultural and technological development. Modernization, lack of actual forecasting, population growth and other forms of utilization have played a key role in the scarcity of natural resources. The value of land as a capital asset cannot be highlighted enough.

Land is non-reproducible, but in aggregation with water and forests, it is predicted to see most of our needs on constant basis (Satapathy 2000). His study showed that India's productive land base had been lessening owing to social, economic, and political causes taking priority over respects of land fitness. Studies by Tiwari and Singh (1995), Singh and Ghose (2000), Iyengar and Shukla (2000) and Satapathy (2000) had barbed out that there was severe difficulties of land decay in the Northeastern region due to human interference which have transported about a deterioration in the yield capacity of land and this has caused a deterioration in soil productivity, worsening in vegetative cover, degeneration of resources, pollution of air and ground water and has finally led to resource crisis. There is a fascinating need for appropriate supervision of the Common Property Land Resources (CPLRs) in India (Iyengar and Shukla 2000) and eco-restoration of polluted land (Tiwari and Singh 1995).

Soil conservation performs tend to slow down these pollution practices and rise soil productivity. Therefore, to complete sound supervision of degraded soil, one has to implement appropriate soil, nutrient, and water management performs (Singh and Ghose 2000). The water condition situation calls for a supportable development taking into account technical, economic, social, environmental, and institutional factors. Developments have even been obligated to shift from the region where water became lacking in amount, inferior in quality and irregular in behavior (Mahajan 1989). Khulbe’s (1989) study on the Kamaun Himalaya had brought to light the fact that corrupted situations of most of the breaking point are limiting features for the development of the region and can be spoken only by the execution of short and long term approaches for suitable development of micro and macro watersheds.

There is a need for appropriate water resource management which would require irrigation management, flood management, water supply facilities, hydro-power, industrial condition and other uses. A sound and active water management method in the Northeast may come to the save of the neighboring countries as well (Mitra 1999). Consumption of water resources for diverse purposes - irrigation, hydro-power generation, flood control, transportation and environmental security and the need for a correct legal framework for water reserve management. Gadgil *et .al.* (1993) stated that due to the letdown of pure legal safety biodiversity conservation, it became necessary to search for answers in the old conservation and resource management methods based on native knowledge and local communities. Folke and Berkes (1995) reflected ancient ecological knowledge as opposite from precise knowledge in being moral, properly based spiritual, natural and complete and having a huge social context. But Gadgil and Berkes (1991) stated that in compare to the traditional ecological view of nature found in original societies, modem scientific management, with its roots in the useful and unequal worldview, adopts humans have colony over nature. Maikhuri *et. al.* (1998) narrated that there is a requirement for scientific assessment of traditional conservation observes as all traditional practices may not be the best choices in the present day world. Workable economies surely cannot persist in the new situations. Monetary economy is gradually becoming an attraction to the traditional people too. This line of whispered has been well emphasized in the works of McNeely (1988) where he has tried to start the relationship between inducements and management and Wells *et. al.* (1992) who preached that the Integrated Conservation Development Project (ICDP) tried to use this method of motivations and management and calculated to assimilate conservation with the social and economic wants of the local people. Dobriyal *et. al.* (1997) statements subjects on how traditional awareness and management practices have obliged as the basis of clews for many pharmaceutical improvements but local publics have not been able to benefit from such original budding. Posey (1990) guessed that less than 0.001 percent of the market value of plant-based medicines have been refunded to original peoples from whom much of the creative knowledge came. Gadgil (1998) advises value addition to biodiversity by construction volume of local groups and financial inputs should be planned as a national biodiversity conservation fund, which should be logically assigned to local people. Boojh (1992) advocated that the approach for management should aim at the conservation of flora and fauna in their natural environment in order to ensure and continue their existence and this has assisted in bolstering the fact that old-style knowledge of supervision holds true even today. There is an essential to reserve these networks using positive old-style managing performs properly combined with modem management methods. There has to be a continuous strength to increase consciousness at all levels of the culture both about strategies and regulations and the essential to manage the properties therein on sustainable ideologies as Misra (1992) had quite barbed out that the effect of development, upgrading and the conforming exploitative nature of humans on their environment has taken about a extreme consequence on the situation and the principles of a society.

There is vital necessity for different thinking in the management of natural assets as there is a percentage of concern about the corrosion of local knowledge. Gadgil (1998) points this to the loss of communal device over wealth and Gupta (1997) charged it on oblivious state schemes which have reserved over the resources. The use of forest properties for industrial expansion need not be viewed as a total evil. The permission of local knowledge specialists will need building bridges between the brilliance in formal and informal discipline (Gupta 1999).

Remote sensing as a tool for detecting the changes

Different parts of the coastal ecosystems e.g. wetlands and coral reefs are subjected to global warming and thus the rise in sea-level (SLR) that are thought to have long term consequences which are again aggravated with the anthropogenic activities (Klemas 2011). IPCC (2007) predicted the sea level rise (SLR) may accelerate in future which may be up to 0.59 m by 2100. Remote sensing are used to map a variety of ecosystem patterns and processes correlated with vegetation type (Gould 2000). There are many changes in land cover and land area change. It was found changes in land-use in the past 34 years of Nachole upazila Digital analysis(Ali *et al.* 2018). It had been shown that in 1983, there was only 2,829.6 hectares of Garden area and in 2016; it was increased to 29,314.5 hectares revealed from the Satellite image. They found that Garden area in 2016 is more than ten times higher than that of in 1983. From the image analysis they found water bodies area in 1983 was 9,358 hectares and in 2016 it was increased to 10,115.8 hectares which was 757.8 hectares higher than that of in 1983 by Ali *et al.* (2018).

Ali *et al.* (2017) reported the changes in land-use in the past 40 years in a Coastal island, St. Martin Island of Bangladesh. The data obtained from the Satellite images showed that in 1975, there was only 21.59 hectares of settlement and in 2015, it is increased to 93.85 hectares. They found that settlement area in 2015 is more than four times higher than that of in1975. But it was rapidly increased in between 1984 and 2010 and the figure rose to around 38.49 and 76.14 hectares respectively. The total settlement area was increased by 37.65 hectares between 1984 and 2010. Total vegetation area in 1984 was 94.33 hectare, but it reduced to 39.12 hectares by the year 2015. Therefore, the total decreased vegetation area found 55.21 hectares. They found from the analysis settlement area is increased but Vegetation 55.21 hectares, Water bodies 24.54 hectares and sand area55.48 hectares were decreased respectively from 1975 to 2015. The physico-chemical properties of soil have been changed in different times.

Spatio-temporal variation of the soil

The common physico-chemical parameters of soil like moisture, pH, conductivity, salinity, Carbon, Nitrogen, phosphorus and heavy metals of soils such as Sodium, Potassium, Lead, Manganese, Magnesium, Iron, Calcium and Zinc of offshore islands and level of pollution have been studied by several workers (Karim 1994, Khan *et al.* 1998, Hossain 2001, Ahmed *et al.* 2010a, 2011, Ataullah *et al.* 2017, 2018, Ghani *et al.* 2013) .Char Tamaruddin of Noakhali district is a coastal island planted with the mangrove species was found to be rather homogenous in respect to soil quality. Das (2012) found that the mean value of soil moisture in that char was 39.45 % where the minimum value was 30.34% and maximum value was 44.74 %. Ataullah *et al. (*2017) reported that the overall mean of the soil moisture of SMF was 25.701% with minimum value 11.23% and maximum 44.9%. The soils of the coastal islands were found to be slightly acidic to moderately alkaline in nature. It has been found that the soil of Char Tamaruddin, to be neutral to slightly alkaline in nature (Das (2012). Ataullah *et al. (*2017) found that overall mean of the soil pH of SMF was 7.34 with minimum value 6.2 and maximum 8.6. It had been found that the soil of different islands at Buragauranga river estuary as affected by different tidal regimes in Patuakhali district, Bangladesh were neutral to moderately alkaline (Ahmed *et al.* 2010a). Soil pH of other mangrove ecosystems located in Southeast coast of China, were found to be highly acidic that ranged from 2.6 - 6.9 (Lin *et al.* 1987). This acidity may be partly due to oxidation of FeS_2 and FeS to H_2SO_4 (Holmer *et al.* 1994) and resulted from decomposition of mangrove litter (Lacerda*et al.* 1995). Various kinds of organic acids are derived from hydrolysis of tannin in mangrove plants and breakdown of organic matter. Seawater has a strong buffering capacity which helps to neutralize acidic pH (Wakushima *et al.* 1994).

The changeability of the mangrove forest in terms of soil salinity had been detected all over the world. In some forests the salinity values are found to be more than 30 ‰ (Sukardjo 1994, Moreno and Calderon 2011). Das *et al.* (2012) and Ataullah *et al.*(2017) have studied the salinity value of 14.99 ‰ in Char Tamaruddin and mean of the soil salinity 7.79 ‰ with minimum value 2.061 ‰ and maximum 24.256 ‰ in SMF respectively. It is also obvious that under high salinity levels mangrove biomass manufacture and holding are badly strange that influence vegetation in mangrove forest (Lin and Sternberg 1993, Suwa *et al.* 2009). The effect of soil salinity on the biochemical components of some mangrove species hydroponically have been studied by Parida *et al.* (2008). Das (2012) found that the mean value of the soil electrical conductivity of Char Tamaruddin was 322.8 µS/cm, the minimum value was 275.0 µS/cm and maximum value was 410.0 µS/cm. Mean of the soil conductivity of SMF was 12.17 mS/cm with minimum value 3.22 mS/cm and maximum 37.9 mS/cm is reported by Ataullah *et al.* (2017). It has been found that soil electrical conductivity in different islands at Buragauranga river estuary, Rangabali, Patuakhali, Bangladesh as affected by different tidal regimes were ranged from 3-16 mS/cm (Ahmed *et al.* 2010*a*). Das(2012) found the total Nitrogen of Char Tamaruddin differ from 0.056 % to 0.13 % where Ataullah *et al.* (2017) reported the minimum value 0.667 % and maximum 4.567 % with mean of the soil N of SMF was 1.719 %. These N absorptions demolish within the series of other mangroves in the geographical region (Jagtap 1987, Tam *et al.* 1995). The variations of total N in mangrove soils were associated to nutrient reliefs from litter breakdown which was affected by regularity and plenty of tidal glowing. Mangrove soil nutrient solicitations are supposed to imitate many biogeochemical factors, counting litter gathering and corrosion, plant uptake, tidal flushing, leaching and anthropogenic inputs.

Because of these encouragements, it is difficult to define the trend of temporal differences in soil nitrogen contented. It was found negative significant correlation of total N with pH and organic matter by Tam and Wong (1998). Phosphorus in various mangrove forests have been reported by several works where they have comparatively little amount (Tam and Wong 1998, Boto and Wellington 1984) than (Ahmed *et al.* 2010a) recorded about 10 times more P content (0.276 - 0.638%) in their studies in different chars of coastal area of Bangladesh. Mean of the soil P of SMF was 0.022 % with minimum value 0.000052% and maximum 0.0956 % was reported by Ataullah *et al* (2017). Das (2012) found that mean value of total P in Char Tamaruddin 0.05% with minimum value was 0.025% and maximum value was 0.056%.

Different heavy metals contents such as Na, K, Pb, Mn, Mg, Fe, Ca and Zn of mangrove wetland ecosystems have drawn attention of scientists throughout the world. Sodium is the active cation in aquatic environment. If the content of Na exceeds 278 mg/kg (IAEA), it is considered that soil is contaminated. Ataullah *et al.* (2018) found that Na content of SMF ranged from 3.50 – 2600 ppm and the mean values of soil Na of upper and lower layers of oligohaline zone were 164 mg/kg and 243.3 mg/kg, mesohaline zone were 259.4 mg/kg and 135 mg/kg, polyhaline zone were 276.2 mg/kg and 237.4 mg/kg respectively. Ahmed *et al.* (2010a) stated 0.431 – 2.23% Na in a coastal island at Rangabali Upazilla of Patuakhali district of Bangladesh. Ghani *et al.* (2013) have investigated the levels and the distribution of heavy metals in surface sediments of Abu-Qir Bay and the Eastern Harbour of Alexandria, Egypt and also assessed the level of pollution using several pollution indices. Other authors have assessed pollution status of soil by studying enrichment factors (Aprile and Bouvy 2008), the geoaccumulation index (I*geo*) (Abrahim and Parker 2008), contamination factor (Cp) (Davaulter and Rognerud 2001), the potential ecological risk factor and index (Hakanson 1980)

Foliar nutrient dynamics of different mangrove species

The mangrove leaves are appropriate funders to the nutrient association of the mangrove ecosystem (Bandaranayake 2002). It is recognized that mangrove leaves encompass satisfactory numbers of minerals, vitamins and amino acids, which are significant for the advance and food of marine beings and livestock. Mangrove flora shows a dynamic part in the progress of litter which is expended by several estuarine and marine detritus individuals and mangrove plants make greater food due to their great salt and iodine relaxed (Bandaranayake 1998). An insufficient other classes are specifically *Ceriops decandra and Avicennia officinalis* which rise lightly in the coastal chars, while *A. ilicifolius* is invading the chars seriously.

Tang *et al.* (2018) have tried to find out the patterns of plant carbon, nitrogen, and phosphorus concentration in relation to productivity in China's terrestrial ecosystems. Sherman *et al.* (1998) reported that N content of the leaves of some mangrove species were nearly similar such as 0.80 ± 0.06% in the leaves of *Rhizophora* sp., 1.01 ± 0.13% in the leaves of *Laguncularia* sp. and 1.10 ± 0.20% in the leaves of *Avicennia* sp. Sterner and Elser (2002) have demonstrated that the concentrations of N and P in plant tissues are crucial in controlling some ecological processes, such as grazing, parasitism, and decomposition. Higher level exposed to salinity have induced different morphological, physiological and biochemical changes in plant bodies that might be related to excess of ions and deficit in water (Greenway and Munns 1980; Maskri *et al.* 2010).

Productivity and carrying capacity of the island

From the viewing platform of vegetation, livestock, wildlife and economic return, correct stocking rate selection is the maximum important of all grazing administration conclusions. Since the beginning of technical administration initial in the twentieth century this has been the highest basic toughest immolating the network and range controllers and definite approaches to this difficult were usually till the late 1980s (Holechek 1988, Toxel and White 1989). Information in stocking rate consequences on specific portions or collections have been recognized to be most important and it is commonly accepted that there is no additional for it. However, methods now accessible will give sound valuation of providing rates for regions (Holechek *et al.* 1995)

Rafay *et al.* (2016) have studied the grass productivity and carrying capacity of the Cholistan desert rangelands, Southern Panjab, Pakistan. For the rangeland managers it is of great importance to measure biomass as it presents a quantitative evaluation of dry matter production over a period of time (Scholes and Baker 1993). An insight about utilization of key forage species by grazing animals is obtained by measuring the biomass (Alemayehu 2006). The quality and productivity of rangeland forages varies tremendously on which the desert regions rangelands livestock production depends entirely, with high abundance of herbage during wet or rainy season as compared to dry season scarcity of feeds (Otsyina *et al.* 1997). Previous records showed that the livestock feed requirements also disturbed the balance of the range carrying capacity (Gammon 1984). Hersom (2010) reported that several factors such as animal body weight, stage of production, forage quantity, quality and availability, and ecological conditions had an effect on dry matter intake by grazing ruminants. Although some studies focused on the productivity and carrying capacity of different rangelands (Workman and MacPherson 1973, Gammon 1984, Hersom 2010, Rafay *et al.* 2016), but no such data existed on the productivity and hence the carrying capacity of offshore islands.

So, the administration and safety of these matchless but threatened natural resources of the coastal regions are vigorous. However, the authentic management of coastal assets desires substantial monetary investment, strong capacity building including engagement of appropriate and knowledge staff and acceptance and support by the local populations which could be recognized within a management framework built on complete scientific suggestion on the structure and function of the ecosystems specially the biology and ecology (i.e. distribution and adaptation) of the goal classes. Over all, measures surrounded created on ground level figures on the natural properties, stakeholders' view and current procedures such as Satellite images, Geographic Information Systems (GIS) (Ahmed *et al.* 2010, 2011, Ali *et al.* 2013, Giri *et al.* 2007) are prerequisite for the actual and workable management of any means. However, there is an absence of strategy procedures for the monitoring of the natural resources of the coastal environments of Bangladesh. So, it is very important to focus on the coastal area to understand the ecology of the coastal part.

2.1 Introduction

Vegetation may be well-defined as an accumulation of plants budding together in a specific place and may be considered either by its element species or by the arrangement of structural and functional features that describe the presence or appearance of plants (Moore 1986). In the improvement of Plant Ecology as in the growth of other natural sciences, the early periods were concerned mostly with qualitative explanation. With growing awareness mostly qualitative descriptions were concentrated more detailed through the use of mathematical measurements and guides. Now, Remote Sensing (RS) and Geographic Information Systems (GIS) are providing new tools for advanced ecosystem management (Wilkie and Finn 1996). Remote sensing could play an important and effective role in assessment and monitoring of any forest cover dynamics. Remote Sensing provides information quickly and efficiently. The use of RS data offers many advantages including availability of low-cost or free satellite data, availability of historical satellite data. In addition, recent advances in the hardware and software used for processing a large volume of satellite data has helped increase the usefulness of satellite data. Use of satellite imagery for change detection is a convenient approach to obtaining accurate information on forest vegetation change because change detection is a major application in digital image processing (Dengsheng 2004). This study investigated the changes in vegetation cover in the past 40 years in the Nijhum Dwip, HatiaUpazila, and Noakhali district of the central coastal area of Bangladesh.

2.2 Materials and Methods

Satellite images have been analyzed to answer the research questions and fulfill the objectives of the study. Images have been obtained from the United States Geological Survey (USGS). Four sets of satellite images dated 1973, 1989, 2010 and 2015 have been used for the analyses. The mosaicing method was applied to fill those gaps. For minimizing the differences in the Digital Number (DN) value of each pixel, radiometric correction procedure was applied. Then ground control points were collected to register these four images. The root mean square error (RMSE) was 0.3. Supervised classification with a maximum likelihood algorithm was applied for image classification. Later, four classified images were used for change detection.

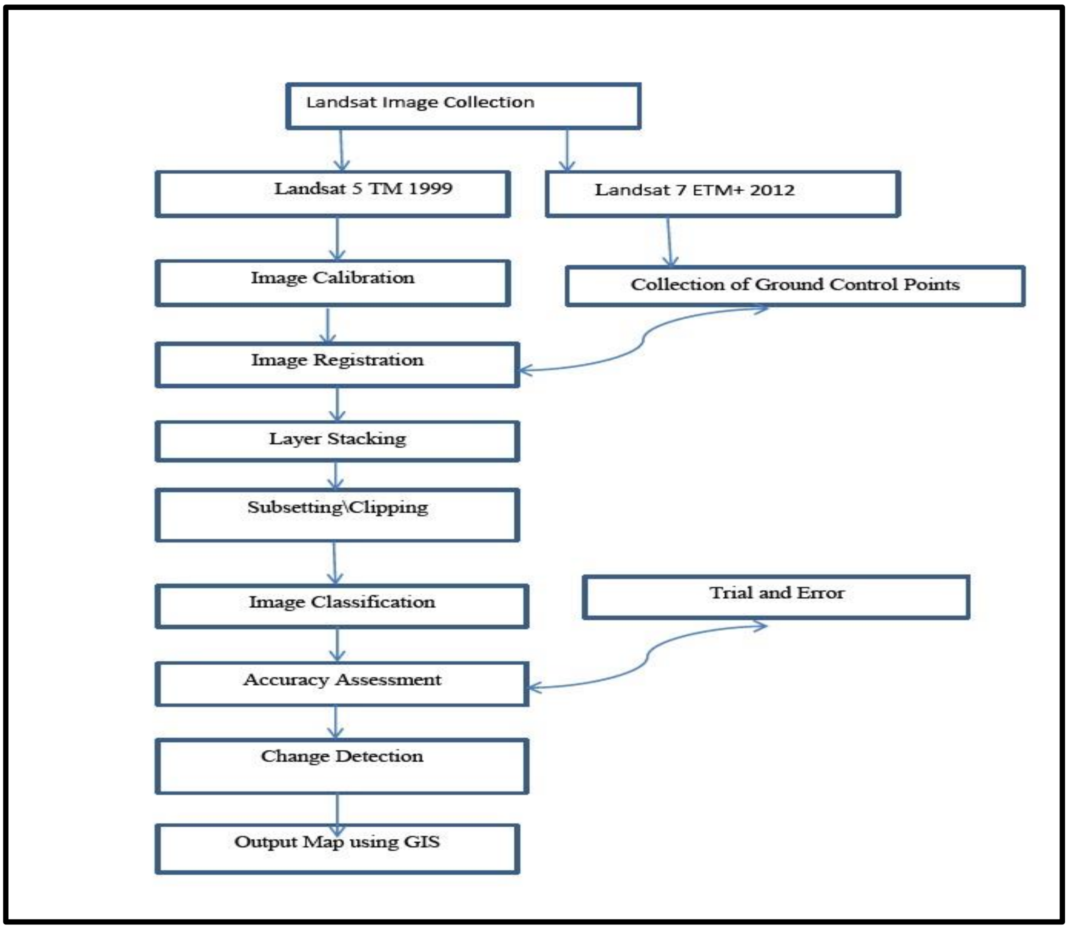

Fig 2.1Image Analysis Processing

2.2.1 Image calibration

Image calibration is achieved by placing the calibration marks on two points that are a known distance apart and entering the actual distance spanned by the points in centimeters. Calibration was recycled to make an image for consequent data taking out and inquiry (Jongmans 2001). Size amounts from a digital image were calibrated by imaging objects with a famous size. Pixel strength is a measure for the composition of the imaged object and can be calibrated by imaging objects with known composition. Methods depend on the type of material and imaging technique. We discuss color calibration as color is one of the most widely used types of data in image analysis. Filtering was performed on an image to remove artifacts that are unrelated to the object of study. The challenge is to find the best filter, one that removes all noise with minimum change to the actual information in the image. Techniques to remove the effects caused by uneven illumination during imaging and methods to filter camera related noise have been described. Image processing involves modification or enhancement of the image in such a way that the required numerical data can be extracted more easily. Processing methods that are drawn include brink finding, subdivision, and handing out of double images (Henderiks and Brabec 2002).

2.2.2 Image registration

Image registration is the procedure of arranging two or more images in a line of the same scene. This process encompasses titling one image as the reference (also called the reference image or the fixed image) and applying geometric transformations to the other images so that they align with the reference. Images can be misaligned for a variety of reasons. Commonly, the images are captured under variable conditions that can change camera perspective. Misalignment can also be the result of lens and sensor distortions or differences between capture devices. Registration is the determination of a geometrical transformation that aligns points in one view of an object with corresponding points in another view of that object or another object. The term “view” is generally used to include a three-dimensional image, a two-dimensional image, or the physical arrangement of an object in space. Difference between images is introduced due to different imaging condition such that yields highest similarity between the input and the reference images. Image registration geometrically aligns two images the reference image and input image. Image registration is a crucial step in all image analysis tasks in which the final information is gained from the combination of various data sources like in image fusion, change detection, and multichannel image restoration. Typically, registration is essential in remote sensing multispectral grouping, environmental checking, variation recognition and image merging weather conditions forecasting, forming super-resolution pictures and assimilating data into geographic information systems (GIS) (Zitova 2003)

2.2.3 Layer stacking:

Layer stacking is a process for combining multiple images into a single image. In order to do that the images should have the same extent (number of rows and number of columns) which means to resample other bands which have different spatial resolution to the target resolution in Fig. 2.2. In other words, all images/bands should have same spatial resolution to be able to perform layer stacking. However, combining images/bands will increase the final stacked image size and consequently will increase the processing time later. Layers are used in digital image editing to separate different elements of an image.

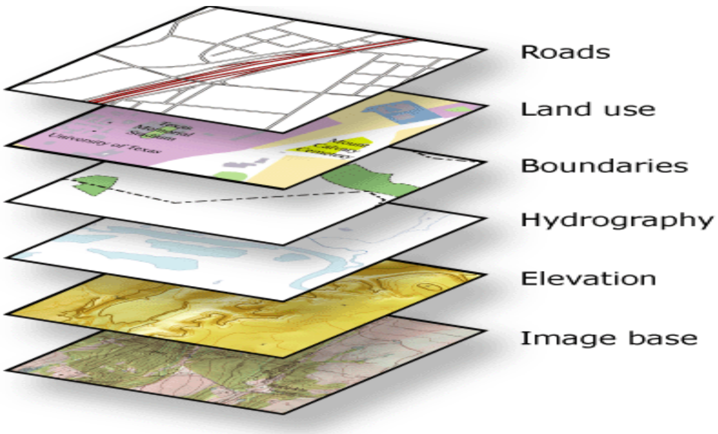

Fig: 2.2 Layer stacking

There are different kinds of layers and not all of them exist in all programs. They represent a part of a picture either as pixels or as modification instructions. They are stacked on top of each other and depending on the order determine the appearance of the final picture.

2.2.4 Clipping and subsetting:

Clipping and subsetting data are actual methods of working with large data sets. In research and testing situations want to create subsets of a large data base. By working with small representative areas can reduce processing times or can use file subsets to test an image process. Clipping is the process by which a subset of the raster dataset is created. Clipping removes data outside the area of interest reducing the file size and improving the processing time for many operations. This video goes over the process of clipping raster data to a polygon area of interest

2.2.5 Image classification:

Image classification refers to the task of extracting information classes from a multiband raster image. The resulting raster from image classification can be used to create thematic maps. Depending on the interaction between the analyst and the computer during classification, there are two types of classification: supervised and unsupervised.

2.2.6 Accuracy Assessment

Accuracy assessment is the procedure of quantification of the reliability of a classified image. It allows the user to assess the data suitability for the particular application. Moreover it allows the producer to learn more about errors in data and to improve the process of classification. Integration of geographical information derived from remote sensing has led to the requirement for increased knowledge of errors and their contribution to the overall quality of the final map. During image processing and the process of classification remotely sensed data are affected by both positional and thematic errors. This chapter has focused on discussion of the assessment of thematic errors of the classified Landsat data, which occur due to the mislabeling of pixels into land cover classes. Classification changes among remotely sensed and reference records ascend for assemble of details (Davis and Simmonett 1991):

(i) Misregistration of satellite data to the cartographic coordinate system.

(ii) Misregistration of reference data to the cartographic coordinate system.

(iii) Spectral confusion between information classes for training and test data.

(iv) In appropriate classification algorithm.

(v) Poor definition of information class for training and test data.

(vi) Information classes containing several spectral classes.

(vii) Sub pixel variations causing mixed pixel and boundary effect.

Understanding the above factors can lead to refinement of the classification approach and improvements in the quality of classification. Analysis of overall classification performance and analysis of performance by the classes will be used to evaluate the contribution of these factors. Accuracy analysis of this study is especially focusing towards a statement about the errors for individual cover classes. Statistically complete methods to establish sample size and sampling strategy are essential to make valid valuations of ordering accuracy for landscapes of changing three-dimensional diversity (Congalton 1991). Considering the most recognized sampling approaches, random sampling was selected and implemented for evaluation of the accuracy of land cover map derived from Landsat imagery.

2.2.7 Change detection

Change detection in RS is a method of understanding how a given area has changed between two or more time periods. Change detection is helpful for understanding the change in forest coverage, ice sheets, and land area. Change detection involves comparing changes between images (landsat, Quickbird or Ikonos) taken over different time periods that cover the exact same geographic area. There is considerable interest in the use of remote sensing to study thematic change such as land cover dynamics. This ascends chiefly through the significance of land cover variation within the bigger field of ecological change (Skole 1994). Many approaches of change finding have been used to identify land cover variation (Lambin and Ehrlich 1997, Mas 1999, Singh 1989) but by far, the most popular has been the use of post classification comparison methods. A variety of factors influence the accuracy of land covers change products. With the popular post grouping assessment approaches basic subjects are the precisions of the constituent classifications as well as more delicate issues related with the devices and data preprocessing methods used together with the principal locations at the times of image acquirement (e.g atmospheric assets, observing geometry etc.) (Khorram 1999). In mapping land area and land cover change, the difficulties noted above in near to the recording of data sets and boundaries are usually overblown (Khorram 1999, Roy 2000). Error in the specific groupings may also be jumbled with variation (Khorram 1999). This can be problematic to permit for or learning principally as the position of borders among classes at each distinct time dated may be undefined (De Groeve and Lowell 2001) and there may be no information on the spatial distribution of accuracy for the classifications used. Consequently, any changes experimented over time may not be attributable only, if at all, to actual variation on the earth. As a result of these and other subjects, the appraisal of the precision of a variation product is a significantly more tough and challenging task than the calculation of the precision of a single image cataloging (Congalton and Green 1999). With no standard method to the calculation of the precision of a change product, it has been common to adjust the standard confusion matrix to produce a change finding confusion matrix. The origins of this variation detection confusion matrix signify individual from/to class change states (Congalton and Green 1999, Khorram 1999). As a result, the dimensions of the matrix are much larger than the basic confusion matrix used to assess the accuracy of the single date classifications depicting the land cover classes of interest; each dimension of the change detection confusion matrix is the square of the number of classes involved. Obtaining the sample of data to use in the building of the change finding confusion matrix can, however, be tough. Often, for example, some of the modification states are uncommon, confusing the sampling method (Biging*et al.* 1999, Khorram 1999). Perhaps a more significant problem is that these methods are suitable only for use with predictable hard classifications. This, however, limits the change detection to indicate where a conversion of land cover seems to have happened. Although land cover changes are important, they are only one component of land cover change. Subtle transformations, land cover modifications will be in appropriately represented by conventional post classification comparison methods of change detection. In Fig. 2.3, Fig. 2.4, Fig. 2.5, Fig. 2.6 imge, change of vegetation cover and land area in different times has been shown. Through ARC GIS (10.5) software, change of Nijhum Dwip in the map (Fig. 2.7, Fig. 2.8, Fig. 2.9, and Fig. 2.10) has been detected in different times.

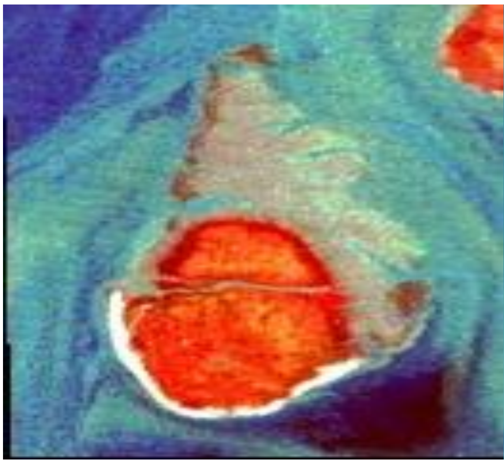

Fig: 2.3 Satellite image of Nijhum Dwip (1973)

Fig: 2.4 Satellite image of Nijhum Dwip (1989)

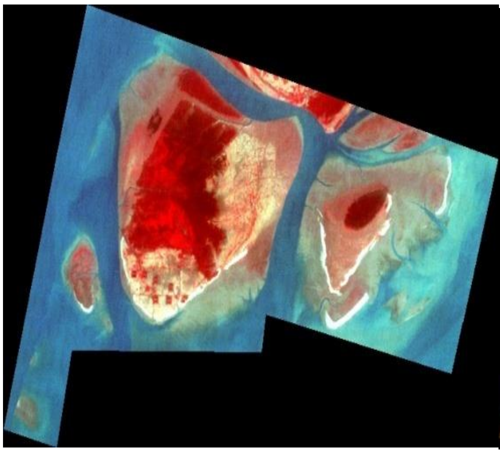

Fig: 2.5 Satellite image of Nijhum Dwip (2010)

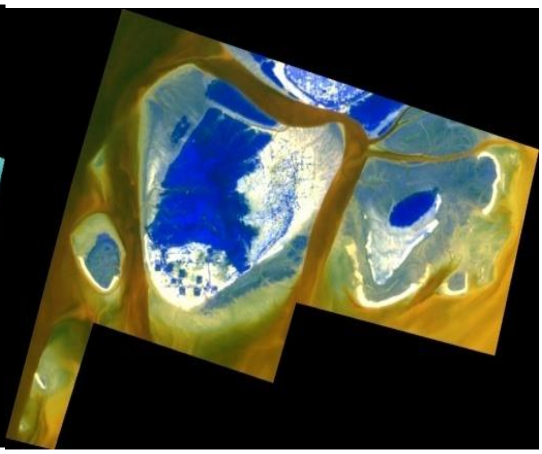

Fig: 2.6 Satellite image of Nijhum Dwip (2015)

Source: SPARRSO

Fig. 2.7 **Map of Nijhum Dwip during 1973 (using ArcGIS 10.5 software)**

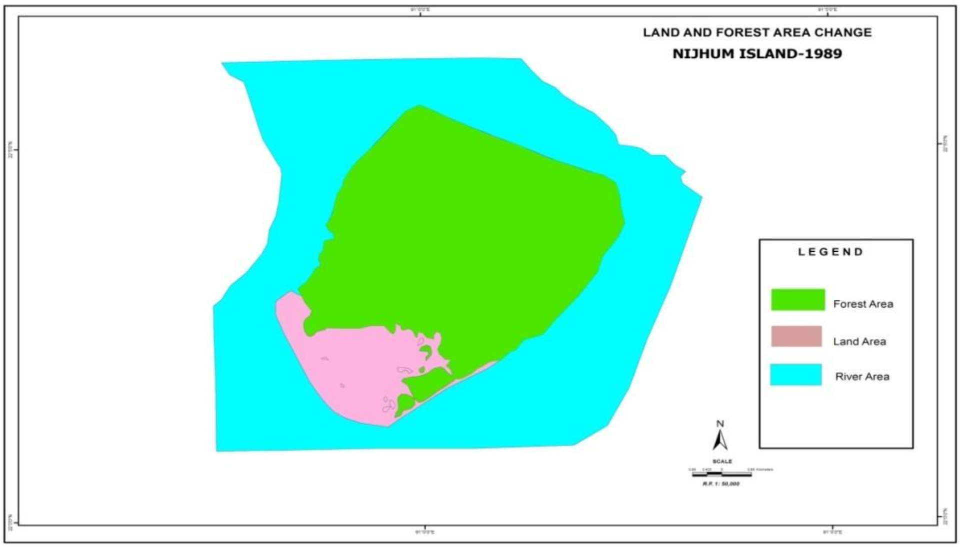

Fig. 2.8 **Map of Nijhum Dwip during 1989 (using ArcGIS 10.5 Software)**

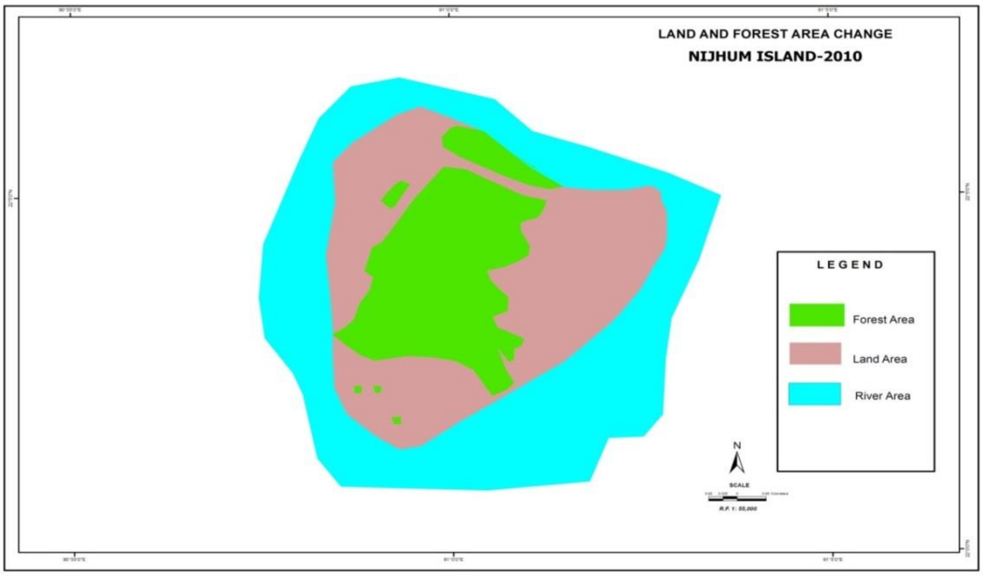

Fig. 2.9 **Map of Nijhum Dwip during 2010 (using ArcGIS 10.5 software)**

Fig. 2.10 **Map of Nijhum Dwip during 2015(using ArcGIS 10.5 software)**

2.3 Results and discussion

From the satellite image analysis, it is evident that very significant land and forest area have changed through RS and GIS software in the study area within the last forty years i.e. from 1973 to 2015. In 1973, 1989, 2010 and 2015 the land area was 1168.56, 2956.52, 1756.58 and 2399.91 ha (Table 2.1). From 1973 to 2015 the land area of Nijhum Dwip has been increased but in 2010 the area has been decreased. The forest cover has also been changed which was 2720.93, 5576.37, 4803.40 and 5225.04 ha (Table 2.2) in those time respectively. But in 2010 the forest covers showed decreasing value due to natural disasters (Ayla). In this way we can calculate area and vegetation cover of other coastal island of Bangladesh or of the world.

Table 2.1: Forest covers change

Year	**Area (Ha)**
1973	1168.56
1989	2956.52
2010	1756.58
2015	2399.91

Table 2.2: Land area change

Year	**Area (Ha)**
1973	2720.93
1989	5576.37
2010	4803.40
2015	5225.04

During field visits a focus was laid on the identification of land area and vegetation area changed. Attention was also given to find out if there have been changes of forest cover in the study area and the reasons behind the changes. Man-made causes are affecting the sustainability of forest products and land area. The natural causes are also affecting the study area. Flooding causes erosion along the banks of the courses of the river almost every year. It is urgent to protect the forest and people settling in the region from probably upcoming natural disasters like cyclones tsunami. Lack of proper management of the mangrove forest resources results in serious consequences not only locally but also concerns Bangladesh as a whole. Among the causes of change natural ones cannot be controlled fully, while man-made causes may be controlled more effectively. This would result in a decrease of change in forest in the course of time. Remote Sensing and GIS provides a great potential to monitor the forest. It also offers the possibility to monitor large regions and to study changes in the entire ecosystem over space and time.

Ali *et al.* (2017) reported the changes in land-use in the past 40 years in Coastal island, St. Martin Island of Bangladesh. The data found from the Satellite image presented that in 1975, there was only 21.59 hectares of settlement and in 2015, it is increased to 93.85 hectares. They established that settlement area in 2015 is more than four times higher than that of in1975. But it was quickly improved in between 1984 and 2010 and the figure rose to around 38.49 and 76.14 hectares respectively. The total settlement area was increased by 37.65 hectares between 1984 and 2010. Total vegetation area in 1984 was 94.33 hectare, but it reduced to 39.12 hectares by the year 2015.Therefore, the total reduced vegetation area found 55.21 hectares. So we found from the analysis settlement area is improved but Vegetation 55.21 hectares, Water bodies 24.54 hectares and sand area55.48 hectares were declined respectively from 1975 to 2015.

In another study, Ali *et al.* (2013) identified both the accretion and erosion patterns by formulating a paleographic map of the Manpura island during a span of 37 years (1973-2010). Considerable changes have happened in the northern shore of the island. Total of 3.0 km of the land from top northern part of the island was battered away throughout the period of 37 years. During the period, the island lost land along 500 meters laterally along the entire east side and about 800 meters of land was dropped into the sea along the North West half of the island. The island also lost 400 hectares f the land in its southern extremely over the said ancient era.

Ali *et al.* (2018) studied changes in land-use in the past 34 years of Nachole upazila of Chapai Nababgonj district by digital analysis. The satellite images showed that in 1983, there was only 2,829.6 hectares of garden area and in 2016; it is increased to 29,314.5 hectares. They found that Garden area in 2016 is more than ten times higher than that of in 1983. From the Image analysis they found water bodies area in 1983 was 9,358 hectares and in 2016 it is increased to 10,115.8 hectares which is 757.8 hectares higher than that of in 1983.

3.1 Introduction

Mangroves are vital intertidal steamy and subtropical ecosystem establish along protected estuarine coasts. This ecosystem is considered by its extraordinary production, multiplicity, and exceptional zonation of abundant plant and animal populations (Odum and Heald 1972). These extremely dynamic ecosystems distribute a large volume of organic substance and provided detrital nutrition chains in neighboring waters, coastal fisheries and aquaculture (Odum and Heald 1972). Many ecological features comprising climate, geomorphology, hydrodynamics and soil features regulated the arrangement and task of mangrove ecosystems. Between all the biotic features, edaphic variables, in certain soil nutrient position, are the maximum straight reins on the mangrove ecosystems (Boto and Wellington 1984). The accessibility of nutrients to mangrove plant assembly is organized by the softened and particulate nutrient assemblages in mangrove soils (Tam and Wong 1998). These assemblages are controlled by the tidal accumulation and altitude, quality redox position and microscopic actions of soils, plant species, receipt, litter association and decomposition (Steinke and Ward 1988, Holmer *et al.* 1994, Lacerda *et al.* 1995). Therefore, nutrient condition of soils differs suggestively among mangrove ecosystems of dissimilar terrestrial places**.**

Micro inconsistency of soil goods at the scale of singular small mangrove strip (less than 1 ha in size) has also been stated (Sylla *et al.* 1995, Tam *et al.* 1995). Great seasonal difference in soil nutrients could also be because of flood statement of nutrient amusing deposit in the course of the summer (wet) seasons. On the other hand, absorptions of nutrients and organic matter collected in soil are prejudiced by anthropogenic actions such as sewage discharge and waste dumping. As in other marshlands, mangrove ecosystems are gifted of absorbent nutrients from wastewater and perform as bowls for nitrogen and phosphorus (Tam and Wong 1995). It has been recommended that N and P content of soils can be recycled as a replacement record of nutrient loadings in bays and lakes (Khan and Brush 1994). Studies on soil nutrient absorption and their availability are mostly concentrated on tropical mangrove ecosystem soils in spite of their significance in the supervision of mangrove ecosystems.

Increasing the conception of soil superiority may help to categorize the soil management researches the required for environmentally, socially, and economically workable development. The concept of soil superiority has been advised by several authors (Lal 1991, Granatstein and Bezdicek 1992, Sanders 1992, Karlen *et al.* 1992) as an instrument for evaluating long-term sustainability of soil at local, regional, national, and international levels. This study analyses the soil quality of Nijhum Dwip of Hatiya Upazila of Noakhali district as exaggerated by altered natural and man-made disturbance.

3.2 MATERIALS AND METHODS

3.2.1: Geography of the coastal region of Bangladesh

Bangladesh is a very flat with low topography deltaic plain shaped by the three mighty rivers – the Ganges (Padma), Brahmaputra and the Meghna (GBM) that organized one of the biggest river schemes in the world. Massive amount of the water and sediments are passed by these rivers to the Bay of Bengal, where the situations of the Bay lead in the vibrant activities such as coastal destruction, land accretion and other activities (Ali 1999). With Bay of Bengal in the south of the country and the Himalaya in the north of the country, the two conflicting locations consequence in theatrical weather conditions characterized by the monsoons, cyclones, storm surges, floods and droughts.

The coastal zone of the country is around 710 km long (latitude 21-23 degree N and longitude 89-93 E (Siddiqi 2001) with various ecosystems. These ecosystems offer conservation standards such as bays, coral reef, beaches, island and mangroves that cares environment for many plants along with fish and wildlife. These coastal zones could be distinctly divided into three distinct areas: central, the western and eastern coastal zone (Fig. 3.1). The eastern coastal region is untaken by the presence of sea beach, coral islands, hilly cover and is the steadiest zone. The central zone is introduced by the releases of the three mighty rivers- the Ganges or Padma, the Brahmaputra, and the Meghna (GBM) and is an area of constant process of accretion and erosion that prepared the area most vigorous among the 3 Zones (Ali 1999). Tropical cyclones and storm rushes this area and the area are much esteemed to such calamities. The western part is categorized by various criss-crossed channels and creeks, low and flat topography and covered chiefly of semi dynamic delta. This zone is also known as Ganges tidal plain where Sundarban mangrove forests are located. An oceanic gap named "Swatch of No Ground" is existing at 25 km south of the western coast (Ali 1999). The coastal zone is prolonged along the Bay of Bengal from the entrance of the river Raimangal in the west to the mouth of the river Teknaf (Siddiqi 2001) which contain the greater districts of Chittagong, Noakhali, Barisal, Patuakhali and estuaries and islands near the continental.

3.2.2 Climate:

Tropical oceanic environment conquers in the coastal regions of Bangladesh (Hossain 2001). In summer, the mean temperature in the coastal parts differs between 19° C in winter and 29° C. The amount of rainfall changes from about 3,000 mm in the west, down to 2,300 mm in the center and as high as 4,000mm in the east. Heavy precipitation happens in the months of July to September throughout the rainy season when rainfall volume to around 80% of the whole yearly precipitation (Siddiqi 2001)

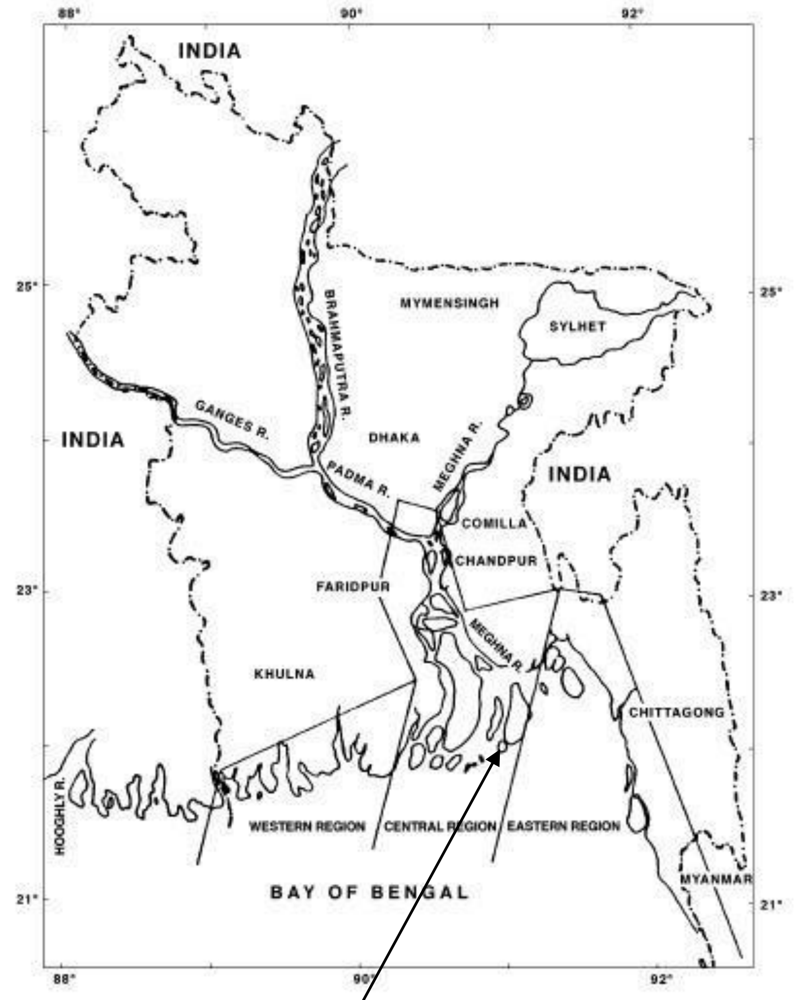

Fig.3.1 Map of Bangladesh showing coastal area and the major river system

Study area

(Source: Ali 1999)

3.2.3 Study area

A segment of the coast was studied at the Nijhum Dwip of Hatia Upazila (22º00′ and 22º35′ N and 90º58′ and 91º14′ E) of Noakhali District to get a view of the ecological conditions of this artificial forest and coastal zone of Bangladesh (Fig.3.2).

Figure 3.2 Study area and sampling locations

3.2.4: Collection of soil samples

Soil samples were collected during four field visits times in 2013, 2014, 2015 and 2016 from six locations of the Nijhum Dwip to study the physical and chemical parameters of the soils. Four samples from each location (two samples from each replicates, from two depths, 0 – 15 and 15 – 30 cm) were collected with the help of augur and kept in air tight polythene bags.Then these forty eight samples had been analyzed in Ecology and Environment Laboratory, MS laboratory of Department of Botany; Soil Chemistry Laboratory, Department of Soil, Water and Environment, CARS of Dhaka University and Bangladesh Council of Scientific and Industrial Research (BCSIR) lab to find out various physical and chemical properties of soil.

3.2.5 Soil analysis

3.2.5.1 Determination of soil moisture content

For the determination of soil moisture content, 10g fresh soil was taken into a cup made up of aluminum foil and then kept in an oven at 104^{0}C temperatures for 24 hours. Soil moisture content was determined by the following formula:

Soil moisture content (%) = $\frac{F - D}{F} \times 100$

Where, F = weight of fresh soil

D= weight of dry soil.

3.2.5.2 Soil pH:

Soil pH was recorded within 24 hours after collection from the field. Soil pH was determined in suspension with distilled water (1:2.5, w:v). 20 gm soil was taken in a beaker and then 50 ml distilled water was added to make a suspension by shaking well. The suspension was kept for a while for settling down of the particles. The pH meter (Hanna pH meter, pHeP) was calibrated with known pH (7.01). Then, the pH values were recorded for the soil samples.

3.2.5.3 Soil Salinity:

Soil salinity was recorded in the laboratory within 24 hours after collection from the field. Soil salinity was determined in suspension with distilled water (1:2.5, w:v) by hand refractrometer (model-Vee Gee STX-3). 20 gm soil was taken in a beaker and then 50 ml distilled water was added to make a suspension by shaking well. The suspension was kept for a while for settling down of the particles. The salinity meter was calibrated with known salinity. Then, the salinity values were recorded for each of the soil sample and the values were multiplied by a factor 2.5.

3.2.5.4 Soil electrical conductivity:

Soil conductivity was recorded in the laboratory within 24 hours after collection from the field. Soil conductivity was determined in suspension with distilled water (5:1, v:w) by Electrical conductivity meter (Aqua Lytic CD 22). 20 gm soil was taken in a beaker and then 100 ml distilled water was added to make a suspension by shaking well. The suspension was kept for a while for settling down of the particles. The conductivity meter was calibrated with known conductivity. Then, the conductivity values were recorded in triplicate replications for each of the soil sample.

3.2.5.5 Total N, P, and OC: Total N of the soil was determined by the modified Kjeldahl method (1883) as described by Jackson (1973). Phosphorus content of the digest was determined by vanadomolybdophosphoric yellow color method in nitric acid system as described by (Jackson 1973). OC (%) was determined by Walkley and Black method (1934). These parameters were determined at the Soil Chemistry Laboratory of Soil, Water and Environment Department, University of Dhaka.

3.2.5.6 Water soluble Na, K and total Ca, Mg, Fe, Mn, Zn and Pb : 1g air dried soil sample was digested with nitric acid-perchloric acid mixture (2:1) (Piper 1950). Water soluble Na and K was determined by flame photometry at the MS laboratory, Department of Botany. Total Ca, Mg, Fe, Mn, Zn were determinate at the Centre for Advanced Research in Sciences, University of Dhaka with the help of atomic absorption spectrophotometer and in BCSIR Laboratory.

3.3: Statistical analysis

In the present studies 15 variables of soil were analyzed. To compare soil variables between the locations, one-way ANOVA was performed using Minitab 14 software. Pearson's correlations were calculated for soil variables. Principles component analysis was done using Minitab 14 software.

3.4: Result & Discussion

Physical and chemical properties of soil

The study Dwip was found to be rather homogenous in respect to soil quality in 2013.The physical and -chemical properties of the soil of Nijhum Dwip during the study period have been shown in different tables (Table 3.1 – 3.76)

3.4.1 Soil moisture

Physico-chemical properties, descriptive statistics, One-Way and Two-way ANOVA and correlation matrix of different variables of soil samples studied during 2013 are given in the Table 3.1.a, 3.1.b, 3.2, 3.3-3.9 ; 3.10 – 3.12 ; 3.13 - 3.19 respectively.

3.4.1.1 (2013)

The mean of soil moisture of upper layer was 41.99 % and lower layer was 42.84 % (Table - 3.2). The overall mean value of soil moisture in the Dwip was 42.41 % where the minimum value was 32.90 % and maximum value was 60.60 % (Table - 3.9). Moisture maintained significant positive correlation with N ($r = 0.196$, $p = 0.021$), P ($r = 0.332$, $p = 0.004$) and negative correlation with Fe ($r = -0.335$, $p = 0.020$) (Table - 3.19). It has been found that moisture content of soils in 2013 and was highest during the study period (Fig. 3.3)

In the location-1, the mean value of upper layers was 40.05 % and lower was 38.60 % (Table - 3.1a). The overall mean value of soil moisture was 39.33 % where the minimum value was 34.40 % and maximum value was 44.40 % (Table - 3.3). In case of location-2, the mean value of upper layers was 43.60 % and lower was 43.97 % (Table - 3.1a).The mean value of soil moisture was 43.79 % where the minimum value was 39.90 % and maximum value was 51.60 % (Table - 3.4). Here moisture maintained significant very strong negative correlation with Fe (r = -0.804, p = 0.016) (Table - 3.14). In case of location-3, the mean value of upper layers was 41.75 % and lower was 41.250 % (Table - 3.1a). The mean value of soil moisture was 41.50 % where the minimum value was 32.90 % and maximum value was 51.10 % (Table - 3.5). In this area moisture maintained significant positive very strong correlation with Mn (r = -0.77, p = 0.023) (Table - 3.15). In the location-4, the mean value of upper layers was 41.77 % and lower was 46.50 % (Table - 3.1a). The mean value of soil moisture was 44.14 % where the minimum value was 34.50 % and maximum value was 60.60 % (Table - 3.6). Here, moisture maintained significant positive strong correlation with OC (r = 0.730, p = 0.040), N (r = 0.743, p = 0.035) and negative strong correlation with P (r = -0.719, p = 0.045) (Table - 3.16). In the location-5, the mean value of upper layers was 42.80 % and lower was 40.40 % (Table - 3.1 a). The mean value of soil moisture was 41.60 % where the minimum value was 35.00 % and maximum value was 50.50 % (Table - 3.7). In this area, moisture maintained significant very strong positive correlation with N (r = 0.814, p = 0.3.34), P (r = 0.910, p = 0.002) (Table - 3.17). In the location-6, the mean value of upper layers was 41.950 % and lower was 46.30 % (Table - 3.1a).The mean value of soil moisture was 44.13 % where the minimum value was 37.50 % and maximum value was 50.50 % (Table - 3.8).

3.4.1.2 (2014)

Descriptive statistics, One-Way and Two-way ANOVA and correlation matrix of different variables of soil samples studied during 2014 are given in the Table 3.20 a, 3.20.b, 3.21; 3.22-3.28 ; 3.29 – 3.31 ; 3.32-3.38 respectively. It has been found that moisture content of soils decreased during the study period in 2014 (Fig. 3.3)

The study Dwip showed very high variation in respect to soil moisture content among the locations in 2014. The mean of soil moisture of upper layers was 28.64 % and lower was 32.24 % (Table - 3.21). The mean value of soil moisture in the Dwip was 30.44 % where the minimum value was 5.40 % and maximum value was 77.20 % (Table - 3.28). Moisture maintained significant negative correlation with Na (r = -0.376, p = 0.009) (Table - 3.38).

In the location-1,the mean value of soil moisture of upper layers was 40.20 % and lower was 26.00 % (Table - 3.20 a).The mean value of soil moisture was 33.10 % where the minimum value was 8.20 % and maximum value was 67.90 % (Table - 3.22). In location-2, the mean of upper layers was 22.97 % and lower was 33.17 % (Table - 3.20a). The mean value of soil moisture was 28.08 % where the minimum value was 18.40 % and maximum value was 38.90 % (Table - 3.23). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.045) (Table - 3.29). In case of location-3, the mean of upper layers was 17.50 % and lower was 32.65 % (Table - 3.20 a). The mean value of soil moisture was 25.08 % where the minimum value was 10.00 % and maximum value was 49.40 % (Table - 3.24). Here moisture maintained significant positive correlation with Mn (r = 0.794, p = 0.018) (Table - 3.34). In the location-4, the mean of upper layers was 52.25 % and lower was 34.18 % (Table - 3.20 a). The mean value of soil moisture was 43.21 % where the minimum value was 14.90 % and maximum value was 77.20 % (Table - 3.25). In this area, moisture maintained significant very strong positive correlation with pH (r = 0.904, p = 0.002), salinity (r= 0.843, p = 0.009) (Table - 3.35). In the location- 5, the mean of upper layers was 19.28 % and lower was 40.10 % (Table - 3.20 a). The mean value of soil moisture was 29.69 % where the minimum value was 5.40 % and maximum value was 67.90 % (Table - 3.26). Moisture maintained significant very strong positive correlation with Zn (r = 0.800, p = 0.017) (Table - 3.36) in this area. In the locatin-6, the mean of upper layers was 19.62 % and lower was27.32 % (Table - 3.20a).The mean value of soil moisture was 23.48 % where the minimum value was 16.00 % and maximum value was 35.80 % (Table - 3.27). One-Way ANOVA showed that there was no significant difference between upper and lower layer of soil moisture except location-2 (Table - 3.29).

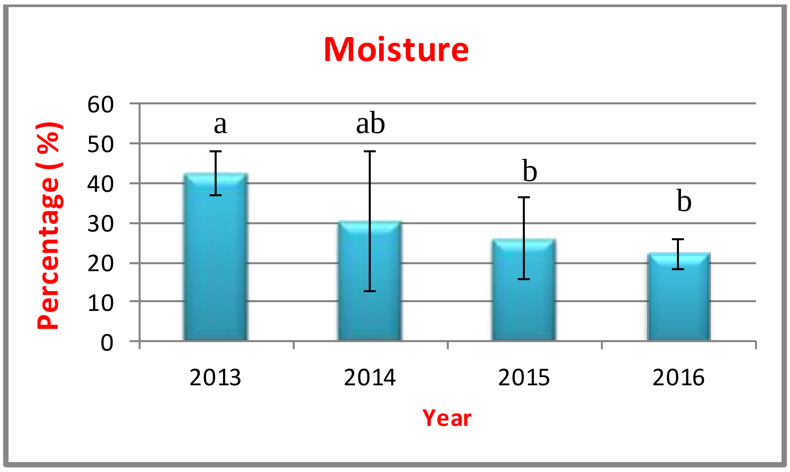

Fig-3.3 Overall mean and standard deviation of moisture content of the study area from 2013 to 2016. Different letters at the top of bars indicate that they are significantly different at 5% level, some letters indicate that they are not significantly different.

3.4.1.3 (2015)

Descriptive statistics, One-Way and Two-way ANOVA and correlation matrix of different variables of soil samples in the period of 2015 are given in the Table 3.39.1a, 3.39.1b, 3.40; 3.41-3.47 ; 3.48 – 3.50 ; 3.51-3.57 respectively. Moisture content of soils slightly decreased in 2015than 2014 (Fig. 3.3)

The mean of upper layers was 26.88 % and lower was 25.10 % (Table - 3.40). The mean value of soil moisture in the Dwip was 25.99 % where the minimum value was 11.00 % and maximum value was 57.00 % (Table - 3.47).

In location-1, mean of upper layers was 21.52 % and lower was 31.02 % (Table - 3.39.1a). The mean value of soil moisture was 26.28 % where the minimum value was 20.00 % and maximum value was 46.70 % (Table - 3.41). In case of location-2, mean of upper layers was 25.97 % and lower was17.75 % (Table - 3.39.1a).The mean value of soil moisture in the location-2 was 21.86 % where the minimum value was 12.10 % and maximum value was 39.90 % (Table - 3.42). In location-3, mean of upper layers was 27.02 % and lower was 21.90 % (Table - 3.39.1a). The mean value of soil moisture was 24.46 % where the minimum value was 15.00 % and maximum value was 33.50 % (Table - 3.43). In this location moisture maintained significant positive correlation with Ca ($r = 0.773$, $p = 0.025$) (Table - 3.53). In the location-4, mean of upper layers was 24.45 % and lower was 21.07 % (Table - 3.39.1a). The mean value of soil moisture was 22.76 % where the minimum value was 11.00 % and maximum value was 39.30 % (Table - 3.44). In this area, moisture maintained significant positive correlation with pH ($r = 0.733$, $p = 0.039$), Pb ($r = 0.753$, $p = 0.031$), Zn($r = 0.723$, $p = 0.043$) and negative correlation with Fe ($r = -0.845$, $p = 0.008$) (Table - 3.54). In location-5, mean of upper layers was 24.35 % and lower was 25.35 % (Table -3.39.1a).The mean value of soil moisture was 24.85 % where the minimum value was 13.20 % and maximum value was 48.10 % (Table - 3.45). Here, moisture maintained significant positive correlation with p ($r = 0.810$, $p = 0.001$), Fe ($r = 0.819$, $p = 0.013$) (Table - 3.55). In the location-6, mean of upper layers was 37.95 % and lower was 33.53 % (Table - 3.39.1a).The mean value of soil moisture in the location-6,was 35.74 % where the minimum value was 18.90 % and maximum value was 57.00 % (Table - 3.46). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.027) (Table - 3.49).

3.4.1.4 (2016)

In 2016, Descriptive statistics, One-Way and Two-way ANOVA and correlation matrix of different variables of soil samples studied are given in the Table 3.58.1a, 3.58.1b, 3.59; 3.60-3.66 ; 3.67 – 3.69 ; 3.70-3.76 respectively. Moisture content of soils slightly decreased in 2015than 2014 (Fig. 3.3). It has been found that moisture content of soils was lowest during the study period 2016 (Fig. 3.3)

The study island was found to be rather homogenous in respect to soil moisture content. The mean of upper layers was 32.24 % and lower was 28.64 % (Table - 3.59). The mean value of soil moisture in the Dwip was 22.09 % where the minimum value was 10.20 % and maximum value was 28.00 % (Table - 3.66). Location and layer showed significance interaction in case of soil moisture (P = 0.015) lyr (P = 0.000) (Table - 3.69). Moisture maintained significant positive correlation with Mg (r = 0.287, p = 0.048) and negative correlation with pH (r = -0.480, p = 0.001), N (r = -0.407, p = 0.004), Zn (r = -0.355, p = 0.013) (Table - 3.76).

In the location-1, the mean of upper layers was 23.22 % and lower was 16.77 % (Table - 3.58.1a).The mean value of soil moisture in location-1 was 20.00 % where the minimum value was 10.20 % and maximum value was 27.90 % (Table – 3.60). Moisture maintained negative positive correlation with pH (r = -0.756, p = 0.030) (Table - 3.70) in location-1. In case of location-2, the mean of upper layers was 25.12 % and lower was 23.40 % (Table - 3.58.1a). The mean value of soil moisture in the location-2 was 24.26 % where the minimum value was 21.00 % and maximum value was 28.00 % (Table - 3.61). Here, moisture maintained significant negative correlation with N (r = -0.825, p =

0.012), Zn (r = -0.778, p = 0.023) (Table - 3.71). In location-3, the mean value of upper layers was 24.00 % and lower was 21.00 % (Table - 3.58.1a). The mean value of soil moisture in the location was 22.63 % where the minimum value was 21.00 % and maximum value was 26.00 % (Table - 3.62). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.039) (Table - 3.67). Moisture maintained positive correlation with conductivity (r = 0.712, p = 0.047), K (r = 0.735, p = 0.038) (Table - 3.72) in this area-3. In location-4, the mean of upper layers was 23.80 % and lower was 16.47 % (Table - 3.58.1a).The mean value of soil moisture in the location-4 was 20.14 % where the minimum value was 11.00 % and maximum value was 27.00 % (Table - 3.63). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.048) (Table - 3.67). In this area, moisture maintained positive correlation with Con (r = 0.819, p = 0.013) (Table - 3.73). The mean of upper layers was 25.750 % and lower was 22.250 % (Table - 3.58.1a) in the location-5. The mean value of soil moisture in the location-5, was 24.00 % where the minimum value was 21.00 % and maximum value was 27.00 % (Table - 3.64). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.004) (Table - 3.67). Here, moisture maintained positive correlation with Conductivity (r = 0.921, p = 0.001), salinity (r = 0.861, p = 0.006), Mg (r = 0.744, p = 0.034) and negative correlation with pH (r = -0.755, p = 0.03), Fe (r =- 0.837, p = 0.010) (Table - 3.74). In location-6, the mean of upper layers was 22.55 % and lower was 20.47 % (Table - 3.58.1a).The mean value of soil moisture in the location-6 .was 21.51 % where the minimum value was 17.00 % and maximum value was 25.00 % (Table - 3.65). In this area, moisture maintained positive correlation with Mg (r = 0.756, p = 0.030) (Table - 3.75).

A coastal island named Char Tamaruddin of Noakhali district planted with the mangrove species was found to be rather homogenous in respect to soil quality. The mean value of soil moisture in that char was 39.45 % where the minimum value was 30.34 % and maximum value was 44.74 % (Das 2012) and Overall mean of the soil moisture of SMF was 25.701 % with minimum value 11.23 % and maximum 44.9 % (Ataullah *et al.* 2017).

3.4.2 Soil pH

3.4.2.1 (2013)

The soil of the study Dwip was found to be slightly acidic to moderately alkaline in nature. The mean of upper layers was 7.56 and lower was 7.8 (Table - 3.2). Overall mean of the soil pH of Nijhum Dwip was 7.6 with minimum value 6.5 and maximum 9.3 (Table - 3.9). Layer showed significance interaction in case of soil pH (P = 0.002, F = 3.84) (Table - 3.12).

In the location-1, the mean value of upper layers was 7.20 and lower was 7.4 (Table - 3.1a). Overall mean of the soil pH was 7.31 with minimum value 7.00 and maximum 7.13 (Table - 3.3). Mean value of the soil pH of location-2 of upper layers was found to be neutral 7.00 and lower was 7.26 (Table- 3.1a). Mean of the soil pH of was 7.13 with minimum value 6.5and maximum value 7.45 (Table - 3.4). In the location-3, the soil was found to be more alkaline than those of the other locations and the mean value of upper layers was 8.01 and lower was 8.15 (Table - 3.1a). Mean value of the soil pH was 8.08 with minimum value 7.8 and maximum 8.4 (Table - 3.5). Here, pH maintained significant positive correlation with K (r = 0.795, p = 0.3.38), Mn (r = 0.772, p = 0.025), Mg (r = 0.742, p = 0.035) (Table - 3.15). In the location-4, the mean value of upper layers was 7.75 and lower was 8.39 (Table - 3.1a). Mean of the soil pH was 7.9 with minimum value 7.5 and maximum 8.4 (Table - 3.6). In this area, pH maintained significant negative correlation with P (r = -0.776, p = 0.024) (Table - 3.16). In case of location-5, the mean of upper layers was 7.82 and lower was 7.95 (Table - 3.1a). Mean of the soil pH was 7.8 with minimum value 7.0 and maximum 9.3 (Table - 3.7). In location-6, the mean of upper layers was 7.57 and lower was 8.00 (Table - 3.1a). Mean of the soil pH of location-6 was 7.7 with minimum value 7.0 and maximum 8.3 (Table - 3.8). One-Way ANOVA showed that there was no significant difference between upper and lower layers in pH all location (one to six).

3.4.2.2 (2014)

During 2014 the soil of the studied Dwip was found to be neutral to slightly acidic in nature. The mean of upper layers was 7.13 and lower layer was 7.18 (Table - 3.21). Overall mean of the soil pH of Nijhum Dwip was 7.16 with minimum value 5.350 and maximum 8.30 (Table - 3.28). Two way ANOVA showed that there was significant effects on locations (P = 0.000) and interaction (F = 0.013) (Table - 3.31). pH maintained significant negative correlation with K (r = --0.454, p = 0.001) and significant positive correlation with Pb (r = 0.407, p = 0.004),Mn (r = 0.168, p = 0.038),Mg (r = 0.403, p = 0.005) (Table - 3.38).

In the location-1, the mean of upper layers was 7.85 and lower was 6.95 (Table - 3.20a). pH decreased during 2014 than 2013 and became slightly acidic. Mean of the soil pH was 7.85 with minimum value 7.20 and maximum 8.3 (Table - 3.22). pH maintained significant positive correlation with Pb (r = 0.708, p = 0.049) (Table- 3.32). In location-2, the mean of upper layers was 7.60 and lower was 7.45 (Table - 3.20a). Mean of the soil pH was 7.52 with minimum value 7.10 and maximum 7.90 (Table - 3.23). pH maintained significant positive correlation with Na (r = 0.708, p = 0.045) (Table - 3.33) in this area. In location-3, the mean of upper layers was 6.47 and lower was 7.27 (Table

- 3.20a). Mean of the soil pH of location-3 was 6.87 with minimum value 6.10 and maximum 7.50 (Table - 3.24). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.006) (Table - 3.29) in location-3. Here pH maintained significant negative correlation with Conductivity (r = -0.789, p = 0.020) (Table - 3.34). In case of location-4, the mean of upper layers was 7.62 and lower was7.45 (Table - 3.20 a).Mean of the soil pH was 7.53 with minimum value 7.30 and maximum 7.9 (Table - 3.25). In this area, pH maintained significant very strong positive correlation with salinity(r = 0.843, p = 0.000) and very strong negative correlation with Mn (, r = -0.854, p = 0.007) Mg (r = -0.843, p = 0.010) (Table - 3.35).In the location-5, the mean of upper layers was 7.40 and lower was 7.47 (Table - 3.20 a). Mean of the soil pH was 7.4 with minimum value 7.1 and maximum 7.7 (Table - 3.26). In location-6, the mean of upper layers was 5.85 and lower was 5.63 (Table - 3.20 a).Mean of the soil pH was 5.74 with minimum value 5.3 and maximum 6.2 (Table - 3.27). There was no significant difference between upper and lower layer (P = 0.006) (Table - 3.29) except location-3.

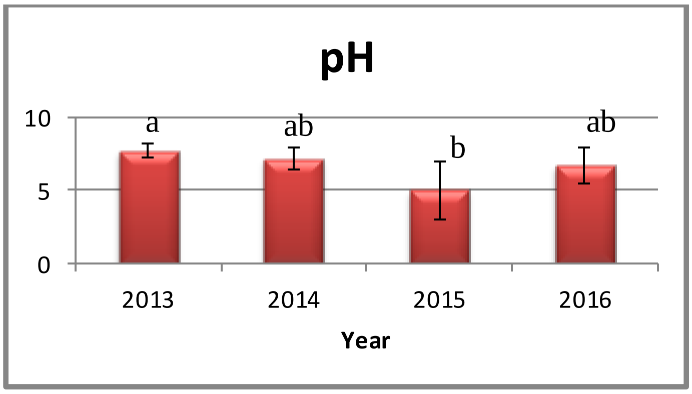

Fig – 3.4 Overall mean and standard deviation of soil pH content of the study area from 2013 to 2016.

3.4.2.3 (2015)

The soil of the study island showed gradual decreasing in pH and was found to be highly acidic to neutral in nature. High variation was observed in pH of soil of different locations. The mean of upper layers was 5.12 and lower was 4.83 (Table - 3.40). Overall mean of the soil pH of Nijhum Dwip was 4.98 with minimum value 2.00 and maximum 9.8 (Table - 3.47). Two way ANOVA showed that there was significant effects on locations (P = 0.000) (Table - 3.50). pH maintained strongly significant positive correlation with Conductivity (r = 0.491, p = 0.000) (Table - 3.57).

In case of location-1, the mean of upper layers was 6.30 and lower was 6.95 (Table - 3.39.1a). Mean of the soil pH was 5.12 with minimum value 3.00 and maximum 7.5 (Table - 3.41). Here, pH maintained significant very strong positive correlation with Pb (r = 0.844, p = 0.008), Mg (r = 0.758, p = 0.029), (Table - 3.51). In the location-2, mean of upper layers was 5.57 and lower was 5.67 (Table - 3.39.1a). Mean of the soil pH was 4.70 with minimum value 2.00 and maximum 6.60 (Table - 3.42). Here, pH maintained significant positive correlation with K (r = 0.760, p = 0.029). In case of location-3, mean of upper layers was 5.75 and lower was 5.40 (Table - 3.39.1a). Mean of the soil pH of location-3 was 5.5 with minimum value 3.10 and maximum 9.20 (Table - 3.43). In the location-4, mean of upper layers was 6.62 and lower was 6.70 (Table - 3.39.1a).Mean of the soil pH of location-4 was 3.66 with minimum value 2.4 and maximum 5.2 (Table - 3.44). In this area, pH maintained significant positive correlation with Mn (r = 0.758, p = 0.029) (Table - 3.54). In the location-5, mean of upper layers was 7.10 and lower was 7.20 (Table - 3.39.1a). Mean of the soil pH of location-5 was 7.15 with minimum value 4.50 and maximum 9.80 (Table - 3.45). In the location-6, mean of upper layers was 7.42 and lower was 3.08 (Table - 3.39.1a). Mean of the soil pH of location-6 was 3.25 with minimum value 2.0 and maximum 4.20 (Table - 3.46). There was no significant difference between upper and lower layers in pH (Table - 3.49).

3.4.2.3 (2016)

The pH of soil during 216 increased slightly**.** The soil of the study island was found to be moderately alkaline to slightly acidic in nature. The mean of upper layers was 7.13 and lower was 7.18 (Table - 3.59). Overall mean of the soil pH of Nijhum Dwip was 6.69 with minimum value 5.10 and maximum 9.05 (Table - 3.66). One-Way ANOVA showed that there was strong significant difference between upper and lower layers (P = 0.000) (Table - 3.67). Location and layer showed significance interaction in case of pH (P = 0.004, F = 4.29) (Table - 3.69). Here, pH maintained significant positive correlation with conductivity (r = 0.343, p = 0.017), salinity (r = 0.446, p = 0.001), Mg (r = 0.303, p = 0.036), Fe (r = 0.301, p = 0.038) (Table - 3.76).

In location-1, the mean of upper layers was 7.43 and lower was 5.35 (Table - 3.58.1a). Mean of the soil pH of location-1 was 6.40 with minimum value 5.20 and maximum 7.75 (Table - 3.59). In the location-2, the mean of upper layers was 5.87 and lower was 7.26 (Table - 3.58.1a). Mean of the soil pH of location-2 was 6.56 with minimum value 5.60 and maximum 7.45 (Table - 3.60). In this case, pH maintained significant positive correlation with P (r = 0.757, p = 0.029), Ca (r = 0.826, p = 0.012) (Table-3.71). The mean of upper layers was 5.67 and lower was 8.10 (Table - 3.58.1a) in the location-3. Mean of the soil pH of location-3 was 6.91 with minimum value 5.50 and maximum 8.4 (Table - 3.61). One-Way ANOVA showed that there was strongly significant difference between upper and lower layers (P = 0.000) (Table - 3.67). In case of location-3, pH maintained significant positive correlation with conductivity (r = 0.823, p = 0.012), K (r = 0.734, p = 0.031) (Table - 3.72). In the location-4, the mean of upper layers was 5.35 and lower was 8.07 (Table - 3.58.1 a). Mean of the soil pH of location-4 was 5.47 with minimum value 5.10 and maximum 8.40 (Table - 3.62). One-Way ANOVA showed that there was strongly significant difference between upper and lower layer (P = 0.000) (Table - 3.67). Here, pH maintained significant very strong negative correlation with conductivity (r = -0.889, p = 0.003), Sal (r = -0.977, p = 0.000) and significant positive correlation with N (r = 0.714, p = 0.047) (Table - 3.73). In the location-5, the mean of upper layers was 5.50 and lower was7.95 (Table - 3.58.1a). Mean of the soil pH of location-5 was 6.72 with minimum value 5.40 and maximum 8.70 (Table - 3.64). One-Way ANOVA showed that there was strongly significant difference between upper and lower layers (P = 0.000) (Table - 3.67). In case of location-5, pH maintained significant very strong negative correlation with conductivity (r = -0.888, p = 0.003), Salinity (r = -0.734, p = 0.038) and very strong positive significant correlation with Ca (r = 0.814, p = 0.014) (Table - 3.74). In location-6, the mean of upper layers was 5.52 and lower was8.18 (Table - 3.58.1 a). Mean of the soil pH of location-6 was 6.85 with minimum value 5.20 and maximum 9.05 (Table - 3.65). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.001) (Table - 3.67) in this locatin. Here, pH maintained significant positive correlation with OC (r = 0.747, p = 0.033), Mn (r = 0.698, p = 0.054) (Table - 3.75).

Das (2012) has found that the soil of a coastal island namely Char Tamarudd, Hatiya, Noakhali to be neutral to slightly alkaline in nature with mean of the soil pH was 7.22 and minimum value of 7.00 and maximum 7.50 and Overall mean of the soil pH of SMF was 7.34 with minimum value 6.2 and maximum 8.6 (Ataullah *et al.* 2017). Ahmed *et al.* (2010a) found pH 6.97 - 8.99 in different islands at Buragauranga river estuary as affected by different tidal regimes in Patuakhali district, Bangladesh. Soil pH of other mangrove ecosystems located in Southeast coast of China, ranged from 2.6 - 6.9 (Lin *et al.* 1987). This acidity may be partly due to oxidation of FeS_2 and FeS to H_2SO_4 (Holmer *et al.* 1994) and resulted from decomposition of mangrove litter (Lacerda *et al.* 1995). Various kinds of organic acids are derived from hydrolysis of tannin in mangrove plants and breakdown of organic matter. Seawater has a strong buffering capacity which helps to neutralize acidic pH (Wakushima *et al.* 1994).We have also found very low pH during 2015 which may be due to the factors explained above.

3.4.3 Soil Salinity

The value of soil salinity was higher in 2013 and it gradually decreased during the study period (Fig. 3.5). The salinity value indicated that the island was mesohaline condition.

3.4.3.1 (2013)

The salinity of the soil of the studied areas showed gradual decrease with time (Fig.3.5). During the sampling year 2013, the mean of salinity of soils upper layers was 12.046 ‰ and lower was11.121 ‰ (Table - 3.2). The average salinity of Nijhum Dwip was from 8.0 – 15.20 ‰ and mean value was 11.5 ‰ (Table - 3.9). Two way ANOVA showed that there was significant effects of layer (P = 0.000) (Table - 3.12). Salinity maintained significant negative correlation with Mg (r = -0.549, p = 0.000) and Pb (r = -0.350, p = 0.015) (Table - 3.19).

In location-1, the mean value of soil salinity upper layers was 9.92 ‰ and lower was 9.3.2 ‰ (Table - 3.1 a). Overall mean of the soil salinity of this location was 9.5 ‰ with minimum value 8.00 ‰ and maximum 12.10 ‰ (Table - 3.3). Here, salinity showed negative correlation with P (r = -0.853, p = 0.007) (Table - 3.13). In the location-2, the mean value of upper layers was 10.40 ‰ and lower was 10.57 ‰ (Table - 3.1a). Mean of the soil salinity was 10.8 ‰ with minimum value 8.20 ‰ and maximum 14.00 ‰ (Table - 3.4). In this area salinity showed negative correlation with Nitrogen (r = -0.761, p = 0.028) (Table - 3.14). In the location-3, the mean of upper layers was 13.55 ‰ and lower was 11.87 ‰ (Table - 3.1a). Mean of the soil salinity was 12.7 ‰ with minimum value 10.0 ‰ and maximum 15.2 ‰ (Table - 3.5). In the location-4, the mean of upper layers was 13.00 ‰ and lower was 11.00 ‰ (Table - 3.1a). Mean of the soil salinity was 12.00 ‰ with minimum value 8.00 ‰ and maximum 14.00 ‰ (Table - 3.6). In case of location-4, salinity maintained significant negative correlation with Mn ($r = -0.519$, $p = 0.002$), Mg ($r = -0.900$, $p = 0.002$), Ca ($r = -0.849$, $p = 0.031$) (Table - 3.16). In the location-5, the mean of upper layers was 10.75 ‰ and lower was 10.35 ‰ (Table - 3.1a). Mean of the soil salinity was 10.50 ‰ with minimum value 8.80 ‰ and maximum 13.00 ‰ (Table - 3.7). Here, salinity maintained significant negative correlation with N ($r = -0.924$, $p = 0.033$) (Table - 3.17). In the location-6, the mean of upper layers was 14.65 ‰ and lower was13.75 ‰ (Table - 3.1a). Mean of the soil salinity was 14.20 ‰ with minimum value 13.20 ‰ and maximum 15.00 ‰ (Table - 3.8). One-Way ANOVA showed that there was significant difference between upper and lower layer ($P = 0.025$) (Table - 3.10). Salinity maintained significant negative correlation with Zn ($r = -0.781$, $p = 0.022$) (Table - 3.18). One-Way ANOVA showed that there was no significant difference between upper and lower layers in salinity all locations except location six.

3.4.3.2 (2014)

During 2014, salinity showed a decreasing tendency in different locations of Nijhum Dwip. High variation was observed in different locations of the Dwip. The mean of upper layers was 7.40 ‰ and lower was 6.88 ‰ (Table - 3.21). Mean value was 7.14 ‰ with minimum value 2.00 ‰ and maximum value 15.10 ‰ (Table - 3.28). Salinity maintained significant negative correlation with Pb ($r = -0.479$, $p = 0.001$) (Table - 3.38).

In the location-1, the mean of upper layers was 7.25 ‰ and lower was 6.55 ‰ (Table - 3.20 a). Mean of the soil salinity was 7.94 ‰ with minimum value 6.68 ‰ and maximum 9.46 ‰ (Table - 3.22). In location-2, the mean of upper layers was 6.90 ‰ and lower was 5.35 ‰ (Table - 3.20 a). Mean of the soil salinity was 6.13 ‰ with minimum value 2.00 ‰ and maximum 15.10 ‰ (Table - 3.23). In this area, salinity maintained significant negative correlation with Zn ($r = 0.734$, $p = 0.038$) (Table - 3.33). In the location-3, the mean of upper layers was 6.7 ‰ and lower was 7.62 ‰ (Table - 3.20 a). Mean of the soil salinity was 7.20 ‰ with minimum value 5.50 ‰ and maximum 8.90 ‰ (Table - 3.24). In location-4, the mean of upper layers was 8.37 ‰ and lower was7.12 ‰ (Table - 3.20 a). Mean of the soil salinity was 7.75 ‰ with minimum value 6.20 ‰ and maximum 11.50 ‰ (Table - 3.25). Here, salinity maintained significant negative correlation with Mn ($r = -0.741$, $p = 0.034$) (Table - 3.35). In the location-5, the mean of upper layer was 7.70 ‰ and lower was 7.00 ‰ (Table - 3.20 a). Mean of the soil salinity of location-5 was 7.37 ‰ with minimum value 6.50 ‰ and maximum 8.60 ‰ (Table - 3.26). In this case, salinity maintained significant negative correlation with Ca ($r = -0.719$, $p = 0.045$) (Table - 3.36). In the location-6, the mean of upper layer was 7.37 ‰ and lower was 7.65 ‰ (Table - 3.20 a). Mean of the soil salinity of location-6 was 7.51 ‰ with minimum value 6.90 ‰ and maximum 8.20 ‰ (Table - 3.27). Here, salinity maintained significant negative correlation with Zn ($r = -0.781$, $p = 0.022$) (Table - 3.37).One-Way ANOVA showed that there was significant difference between upper and lower layer in case of salinity (Table - 3.29).

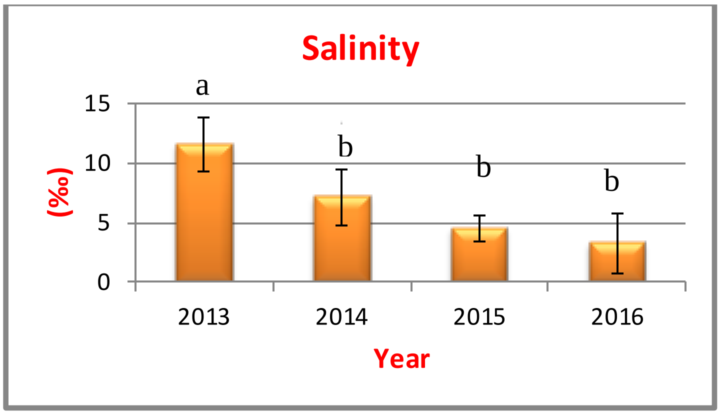

Fig-3.5 Overall mean and standard deviation of soil salinity of the study area from 2013 to 2016.

3.4.3.3 (2015)

The salinity of the soil of the studied areas showed gradual decrease with time (Fig.5 The mean of upper layers was 5.12 ‰ and lower was 4.83 ‰ (Table - 3.40). Salinity of Nijhum Dwip was high which ranged from 2.10 ‰ – 7.80 ‰ and mean value was 4.51 ‰ (Table - 3.47). Location and layer showed significance interaction in case of salinity (P = 0.009, F = 0.367) (Table - 3.50). Salinity maintained negative correlation with P (r = 0.536, p = 0.000), N (r = -0.532, p = 0.000) (Table - 3.57).

The mean values of soil salinity of different locations were more or less similar. In the location-1, mean of upper layers was 5.49 ‰ and lower was 4.91 ‰ (Table - 3.39.1a). Mean of the soil salinity of location-1 was 5.19 ‰ with minimum value 4.40 ‰ and maximum 7.31‰ (Table - 3.41). In the location-2, mean of upper layer was 4.66 ‰ and lower was 4.68 ‰ (Table - 3.39.1a). Mean of the soil salinity of location-2 was 4.67 ‰ with minimum value 3.9 ‰ and maximum 5.13 ‰ (Table - 3.42). In case of lacation-2, salinity maintained significant positive correlation with Pb (p = 0.014, r = 0.812) (Table - 3.52). In the location-3, mean of upper layers was 4.89 ‰ and lower was 4.02 ‰ (Table - 3.39.1a). Mean of the soil salinity of location-3 was 4.45 ‰ with minimum value 3.38 ‰ and maximum 5.88 ‰ (Table - 63). In case of location-3, salinity maintained significant positive correlation with N (r = 0.810, p = 0.015), P(r = 0.730, p = 0.022) (Table - 3.53). In the location-4, mean of upper layers was 4.28 ‰ and lower was 7.73 ‰ (Table - 3.39.1a). Mean of the soil salinity of location-4 was 4.00 ‰ with minimum value 2.80 ‰ and maximum 5.33 ‰ (Table - 3.44). In the location-5, mean of upper layers was 5.91 ‰ and lower was 4.62 ‰ (Table - 3.39.1a). Mean of the soil salinity of location-5 was 5.26 ‰ with minimum value 3.45 ‰ and maximum 7.80 ‰ (Table - 3.45). In case of location-5, salinity maintained significant negative correlation with N (r = -0.921, p = 0.001) (Table - 3.55). The salinity of location-6, which is situated near the river and inundated daily was lowest among the locations. In the location-6, mean of upper layers was 3.91 ‰ and lower was 3.03 ‰ (Table - 3.39.1a). Mean of the soil salinity of location-6 was 3.47 ‰ with minimum value 2.10 ‰ and maximum 4.19 ‰ (Table - 3.46). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.033) (Table - 3.48). In location-6, salinity maintained significant negative correlation with Na (r = -0.725, p = 0.042), Zn (r = -0.827, p = 0.011) and positive correlation Mg (r = 0.747, p = 0.033) (Table - 3.56).

3.4.3.4 (2016)

The mean of upper layers was 4.40 ‰ and lower was 3.89 (Table - 3.59). Salinity of Nijhum Dwip decreased in 2016 which ranged from 1.06 - 5.47 ‰ and mean value was 3.26 ‰ (Table - 3.66). Two way ANOVA showed that there was significant effects of locations (P =0.003) and layer (P = 0.001) (Table - 3.69).

In the location-1, the mean of upper layers was 5.75 ‰ and lower was 2.75 ‰ (Table - 3.58.1a). Mean of the soil salinity of location-1 was 4.25 ‰ with minimum value 1.00 ‰ and maximum 10.00 ‰ (Table - 3.59). In case of location -1, Salinity maintained significant positive correlation with Oc (r = 0.756, p = 0.030), Fe (r = 0.712, p = 0.048) and negative correlation with Ca(r = -0.715, p = 0.046) (Table - 3.70). In the location-2, the mean of upper layer was 2.450 ‰ and lower was1.35 ‰ (Table - 3.58.1a). Mean of the soil salinity of location-2, was 1.90 ‰ with minimum value 1.32 ‰ and maximum 4.50 ‰ (Table - 3.60). In case of location -2, salinity showed negative correlation with P (r = -0.764, p = 0.027) (Table - 3.71). In the location-3, the mean of upper layers was 3.50 ‰ and lower was 2.33 ‰ (Table - 3.58 a). Mean of the soil salinity of location-3 was 2.87 ‰ with minimum value 2.00 ‰ and maximum 5.00 ‰ (Table - 3.61). Salinity maintained significant positive correlation with Pb (r = 0.811, p = 0.015) (Table - 3.72). In the location-4, the mean of upper layers was 4.75 ‰ and lower was 1.50 ‰ (Table - 3.58.1a). Mean of the soil salinity of location-4 was 3.12 ‰ with minimum value 1.00 ‰ and maximum 5.00 ‰ (Table - 3.63). One-Way ANOVA showed that there was strongly significant difference between upper and lower layer (P = 0.000) (Table - 3.67). In case of location-4, salinity maintained significant negative correlation with N (r = 0.705, p = 0.051) (Table - 3.73). In the location-5, the mean of upper layers was 3.00 ‰ and lower was 0.750 ‰ (Table - 3.58.1a). Mean of the soil salinity of location-5 was 1.87 ‰ with minimum value 1.25 ‰ and maximum 5.00 ‰ (Table - 3.64). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.024) (Table - 3.67). In case of location-5, salinity maintained significant positive correlation with Mg (r = 0.833, p = 0.010) (Table - 3.74). In the location-6, the mean of upper layers was 7.00 ‰ and lower was 4.50 ‰ (Table - 3.58 a). Mean of the soil salinity of location-6 was 5.75 ‰ with minimum value 2.00 ‰ and maximum 9.50 ‰ (Table - 3.65). In case of location-6, salinity maintained significant positive correlation with Pb (r = 0.794, p = 0.019) (Table - 3.75).

The variability of the mangrove forest in terms of soil salinity is observed all over the world. In some forests the salinity values are obtained more than 30 ‰ (Sukardjo 1994, Moreno and Calderon 2011). However, the salinity value of 14.99 ‰ was also observed by Das *et al.* (2012) and mean of the soil salinity of SMF was 7.79 ‰ with minimum value 2.061 ‰ and maximum 24.256 ‰ (Ataullah *et al.* 2017). Comparatively lowest amount of salinity in this area height be due to the inundation of the Nijhum Dwip by the less saline water of the Meghna River flowing beside the Dwip. Mangrove vegetation is more luxuriant in lower salinities (Kathiresan *et al.* 1996) and experimental evidence indicates that at high salinity, mangroves spend more energy to maintain water balance and ion concentration rather than for primary production and growth. It is also evident that under high salinity levels mangrove biomass production and retention are adversely affected that influence vegetation in mangrove forest (Lin and Sternberg 1993, Suwa *et al.* 2009). In other mangrove soils such as in the Northern Australian Mangrove Forest, salinity was found to be 30-50 ‰ (Boto and Wellington 1984). Soil salinity decreased with increasing distance from the tidal coast. Naidoo and Raiman (1982) reported soil salinity to be related with extent of tidal inundation and seepage in the mangrove soils of Sipingo and Mgeni, South Africa. Salinization leads to a partial or total loss of the productive capacity of a soil, because of degradation of its chemical and physical properties.

3.4.4 Soil conductivity

The value of soil conductivity was high in 2013 and it was gradually decreased during the study period (Fig 3.6).

3.4.4.1 (2013)

The mean value of upper layers was 13.37 mS/cm and lower layer was 11.67 mS/cm (Table - 3.2). Mean of the soil conductivity of was 12.52 mS/cm with minimum value 5.95 mS/cm and maximum 26.25 mS/cm (Table - 3.9).

In the location-1, the mean of upper layers was 14.35 mS/cm and lower was 9.95 mS/cm (Table - 3.1a). Mean of the soil conductivity was 12.15 mS/cm with the minimum value 6.0 mS/cm and maximum 20.05 mS/cm (Table - 3.3). In case of location-2, the mean of upper layers was 16.27 mS/cm and lower was 11.205 mS/cm (Table - 3.1a). Mean of the soil conductivity was 13.65 mS/cm with minimum value 7.95 mS/cm and maximum 26 mS/cm (Table - 3.4). In this area, conductivity maintained very strong significant positive correlation with Na ($r = 0.812$, $p = 0.014$) (Table - 3.14). In the location-3, the mean of upper layers was 10.15 mS/cm and lower was 10.66 mS/cm (Table - 3.1a). Mean of the soil conductivity was 10.4 mS/cm with minimum value 6.2 mS/cm and with maximum value 16.9 mS/cm (Table - 3.5). Here, conductivity maintained very strong significant positive correlation with Mn ($r = 0.852$, $p = 0.007$) (Table - 3.15). In the location-4, the mean of upper layers was 15.21 mS/cm and lower was 14.9 mS/cm (Table - 3.1a). Mean of the soil conductivity was 13.5 mS/cm with minimum value 7.1 mS/cm and with maximum value 19 mS/cm (Table - 3.6). In the location-5, the mean of upper layers was 10.83 mS/cm and lower was 14.48 mS/cm (Table - 3.1a). Mean of the soil conductivity was 12.5 mS/cm with minimum value 6.4 mS/cm and with maximum value 17.25 mS/cm (Table - 3.7). In case of location-5, conductivity maintained significant positive correlation with Mn (r = 0.618,p = 0.049) (Table - 3.17). In the location-6, the mean of upper layers was 13.35 mS/cm and lower was 9.00 mS/cm (Table - 3.1 a). Mean of the soil conductivity was 6.45 mS/cm with minimum value 3.16 mS/cm and with maximum value 13.47 mS/cm (Table - 3.8). In this location, conductivity maintained strong significant positive correlation with Salinity (r = 0.727, p = 0.041) and negative correlation with Pb (p = 0.037, r = -0.736) (Table - 3.18). There was no significant difference between upper and lower layers in conductivity all location which has been shown through One-Way ANOVA (Table - 3.10).

3.4.4.2 (2014)

The values of soil conductivity in 2014 were comparatively lower than those of 2013 (Fig .3.6).

The mean of upper layers was 16.92 mS/cm and lower was 14.82 mS/cm (Table - 3.21). Mean of the soil conductivity was 17.60 mS/cm with minimum value 5.00 mS/cm and maximum 30.20 mS/cm ((Table - 3.28). Two way ANOVA showed that there was significant effects on locations (P = 0.004) layer (P = 0.022) and interaction (P = 0.040) (Table - 3.31). Conductivity maintained weak significant negative correlation with Mn (r = -0.300, p = 0.037) (Table - 3.38).

In location-1, the mean of upper layers was 8.46 mS/cm and lower was 7.25 mS/cm (Table - 3.20a). Mean of the soil conductivity was 13.80 mS/cm with minimum value 6.00 mS/cm and maximum 26.00 mS/cm (Table - 3.22). Conductivity maintained significant negative correlation with Mn (r = -0.822, p = 0.012) (Table - 3.32). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.015) (Table - 3.29). In case oflocation-2, the mean of uppers layer was 8.350 mS/cm and lower was 9.450 mS/cm (Table - 3.20a). Mean of the soil conductivity was 8.90 mS/cm with minimum value7.30 mS/cm and maximum 13.50 mS/cm (Table - 3.23). In the location-3, the mean of upper layers was 6.44 mS/cm and lower was 5.31mS/cm (Table - 3.20a). Mean of the soil conductivity of location-3 was 5.8 mS/cm with minimum value 5.0 mS/cm and with maximum value 6.80 mS/cm (Table - 3.24). In thelocation-4, the mean of upper layers was 9.17 mS/cm and lower was 6.20 mS/cm (Table - 3.20a). Mean of the soil conductivity of location-4 was 7.69 mS/cm with minimum value 5.16 mS/cm and with maximum value 12.03 mS/cm (Table - 3.25). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.028) (Table - 3.29). In thelocation-5, the mean of upper layers was 10.02 mS/cm and lower was 7.25mS/cm (Table - 3.20a). Mean of the soil conductivity of location-5 was 8.64 mS/cm with minimum value 6.6 mS/cm and with maximum value 11.8 mS/cm (Table - 3.26). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.021) (Table - 3.29). Inlocation-6, the mean of upper layers was 8.16 mS/cm and lower was 9.02 mS/cm (Table - 3.20a). Mean of the soil conductivity of location-6 was 8.5 mS/cm with minimum value 7.29 mS/cm and with maximum value 13.50 mS/cm (Table - 3.27). Here, conductivity maintained strong significant positive correlation with Salinity (r = 0.727, p = 0.041) and strong negative correlation with Pb (r = -0.736, p = 0.037) (Table - 3.36).

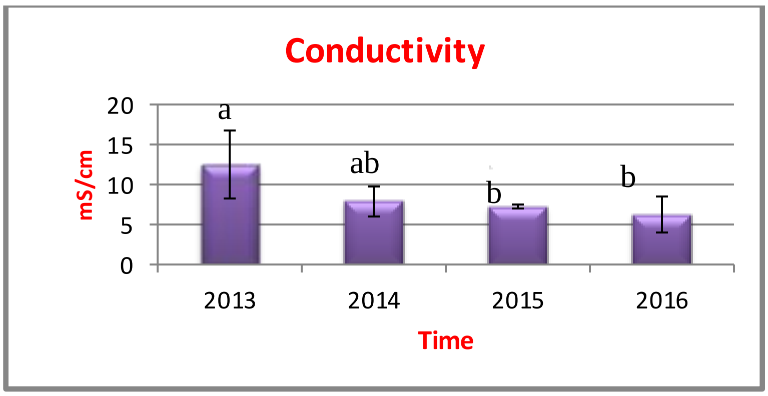

Fig- 3.6 Overall mean and standard deviation of conductivity the study area from 2013 to 2016.

3.4.4.3 (2015)

The mean of upper layers was 7.24 mS/cm and lower was 7.16 mS/cm (Table - 3.40). Mean of the soil conductivity of was 7.20 mS/cm with minimum value 6.50 mS/cm and maximum 8.10 mS/cm (Table - 3.47). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.027) (Table - 3.49). Two way ANOVA showed that there was significant effects on locations (P = 0.002) and lyr (P = 0.012) (Table - 3.50). Conductivity maintained significant positive weak correlation with OC (r = 0.303, p = 0.036), Mg (r = 0.308, p = 0.033), (Table - 3.57).

In location-1, the mean of upper layers was 7.20 mS/cm and lower was 7.20 mS/cm (Table - 3.39.1a). Mean of the soil conductivity of location-1, was 7.20 mS/cm with minimum value 7.00 mS/cm and maximum 7.30 mS/cm (Table - 3.41). In this area, conductivity maintained significant negative correlation with salinity (r =- 0.797, p = 0.018) (Table - 3.51). In the location-2, mean of upper layers was 7.17 mS/cm and lower was 7.22 mS/cm (Table - 3.39. a). Mean of the soil conductivity of location-2 was 7.20 mS/cm with minimum value 7.00 mS/cm and maximum 7.50 mS/cm (Table - 3.42). Here, conductivity maintained significant negative moderate correlation with Mn (r = -0.563, p = 0.053) (Table - 3.52). In case of location-3, mean of upper layers was 7.10 mS/cm and lower was7.20 mS/cm (Table - 3.39.1a). Mean of the soil conductivity of location-3 was 7.15mS/cm with minimum value 7.0 mS/cm and with maximum value 7.30 mS/cm (Table –3.43). Conductivity maintained significant positive strong correlation with Na (r = 0.711, p = 0.048) (Table - 3.53) in location-3. The mean of upper layers was 7.15 mS/cm and lower was7.30 mS/cm (Table - 3.39.1a) of location-4. Mean of the soil conductivity of this area was 7.22 mS/cm with minimum value 7.0 mS/cm and with maximum value 7.50 mS/cm (Table - 3.44). Here, conductivity maintained significant negative very strong correlation with salinity (r = -0.843, p =

0.009) (Table - 3.54). In the location-5, mean of upper layers was 7.17 mS/cm and lower was 6.92mS/cm (Table - 3.39.1a). Mean of the soil conductivity of location-5 was7.05 mS/cm with minimum value 6.50 mS/cm and with maximum value 3.45 mS/cm (Table - 3.45). In the location-6, mean of upper layers was 7.65 mS/cm and lower was 7.12 mS/cm (Table - 3.39.1a). Mean of the soil conductivity of location-6 was 7.38mS/cm with minimum value 6.90 mS/cm and with maximum value 8.10 mS/cm (Table - 3.46). In case of lacation-6, conductivity maintained significant positive correlation with salinity (r = 0.806, p = 0.016,) (Table - 3.56).

3.4.4.4 (2016)

The mean values of upper layers was 8.46 mS/cm and lower was 7.41 mS/cm (Table - 3.59). Mean of the soil conductivity of was 3.25 mS/cm with minimum value 1.06 mS/cm and maximum 13.47 mS/cm (Table - 3.66). Two way ANOVA showed that there was significant effects on locations (P =0.007) lyr (P = 0.000) (Table - 3.69).

In location-1, the mean of upper layers was 22.51 mS/cm and lower was 13.01 mS/cm (Table - 3.58.1a). Mean of the soil conductivity of location-1 was 17.65 mS/cm with minimum value 10.6 mS/cm and maximum 35.2 mS/cm (Table - 3.60). In this area, conductivity maintained significant very strong positive correlation with salinity (r = 0.915, p = 0.000), OC (r = 0.779, p = 0.023), Mg (r = 0.716, p = 0.046), Fe (r = 0.778, p = 0.023) and significant negative strong correlation with Ca (r = -0.751, p = 0.04) (Table - 3.70). In case of location-2, the mean of upper layers was 12.33 mS/cm and lower was 9.30 mS/cm (Table - 3.58.1a). Mean of the soil conductivity of location-2 was 10.8 mS/cm with minimum value 5.3 mS/cm and maximum 14.95 mS/cm (Table - 3.60). In this area, conductivity maintained significant positive correlation with Mg (r = 0.853, p = 0.010) (Table - 3.71). In the location-3, the mean of upper layers was 15.50 mS/cm and lower was 8.10 mS/cm (Table - 3.58.1a). Mean of the soil conductivity of location-3 was 14.35 mS/cm with minimum value 6.00 mS/cm and with maximum value 17.40 mS/cm (Table - 3.61). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.004) (Table - 3.67). The mean of upper layers was 17.21 mS/cm and lower was 9.81 mS/cm (Table - 3.58.1a) in the location-4. Mean of the soil conductivity of location-4 was 15.05 mS/cm with minimum value 10.35 mS/cm and with maximum value 19.35 mS/cm (Table - 3.63). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.004) (Table - 3.67). In case of location-4, conductivity showed significant positive correlation with salinity (r = 0.940, p = 0.001) (Table - 3.73). In the location-5, the mean of upper layers was 13.51 mS/cm and lower was 8.512 mS/cm (Table - 3.58a). Mean of the soil conductivity of location-5 was 11.95 mS/cm with minimum value 8.00 mS/cm and with maximum value 15.9 mS/cm (Table - 3.64). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.001) (Table - 3.67). In here, conductivity maintained significant very strong positive correlation with salinity (r = 0.911, p = 0.002), Mg (r = 0.835, p = 0.010) (Table - 3.74). In the location-6, the mean of upper layer was 38.00 mS/cm and lower was 26.00 mS/cm (Table - 3.58a). Mean of the soil conductivity of location-6 was 11.15 mS/cm with minimum value 5.95 mS/cm and with maximum value 16.95 mS/cm (Table - 3.65).

The mean value of the soil electrical conductivity of Char Tamaruddin was 322.8 µS/cm, the minimum value was 275.0 µS/cm and maximum value was 410.0 µS/cm (Das 2012) and Mean of the soil conductivity of SMF was 12.17 mS/cm with minimum value 3.22 mS/cm and maximum 37.9 mS/cm (Ataullah *et al.* 2017). High soil conductivity is due to the penetration of seawater during high tides, the evaporation of water and capillary rise of ground water during low tides, thus electrical conductivity in the top soil had a more complex spatial structure than that at a larger depth (Sylla*et al.* 1995) that indicated that the study area showed intermediate values than the other coastal chars of Bangladesh. Ahmed *et al.* (2010*a*) found 3-16 mS/cm soil electrical conductivity in different islands at Buragauranga river estuary, Rangabali, Patuakhali, Bangladesh as affected by different tidal regimes.

3.4.5. Organic carbon

3.4.5.1 (2013)

The amount of OC gradually increased in the soils of the Dwip (Fig.3.7) where significant difference was found between 2013 and 2016.

The mean value of OC of soils collected from upper layers was 0.481 % and lower was 0.480 % (Table - 3.2). Mean of the soil OC of Nijhum Dwip was 0.48 % with minimum value 0.179 % and maximum 1.03 % (Table - 3.9).

In the location-1, the mean value of OC of upper layers was 0.34 % and lower was 0.38 % (Table - 3.1a). Mean of the soil OC of location-1 was 0.36 % with minimum value 0.17 % and maximum 0.71 % (Table - 3.3). In the location-2, the mean value of upper layers was 0.56 % and lower was 0.60 % (Table - 3.1a). Mean of the soil OC was 0.58 % with minimum value 0.26 % and maximum 0.80 % (Table - 3.4). In case of location-3, the mean value of upper layers was 0.42 % and lower was 0.40 % (Table - 3.1a). Mean of the soil OC was 0.41% with minimum value 0.24 % and maximum 0.58 % (Table - 3.5). Here, OC maintained significant positive strong correlation with P ($r = 0.736$, $p = 0.037$) (Table - 3.15). In the location-4, the mean value of upper layers was 0.48 % and lower was 0.47 % (Table - 3.1a). Mean of the soil OC was 0.47% with minimum value 0.22 % and maximum 0.89 % (Table - 3.6). In location-5, the mean value of upper layers was 0.57 % and lower was 0.54 % (Table - 3.1a).The means value of the soil OC was 0.56 % with minimum value 0.24 % and maximum 1.03 % (Table - 3.7).In this area, OC maintained significant very strong positive correlation with Zn ($r = 0.905$, $p = 0.002$)

(Table - 3.17). In the location-6, the mean of upper layers was 0.50 % and lower was 0.47 % (Table - 3.1a). Mean of the soil OC was 0.48 % with minimum value 0.22 % and maximum 0.76 % (Table – 3.8). In the coastal areas, the OC in soil is also derived from the inundation of the soil by fresh and saline water. Therefore the values of OC in location-6 (without vegetation near the river) were almost similar and some time is higher than the soil of the planted area. In case of location-6, OC maintained significant very strong negative correlation with K (r = - 0.823, p = 0.012) (Table - 3.18).

3.4.5.2 (2014)

The mean value of OC of upper layer was 0.59 % and lower was 0.69 % (Table - 3.21). Mean of the soil OC of Nijhum Dwip was 0.64% with minimum value 0.09 % and maximum 1.25 % (Table - 3.28). OC showed negative correlation with Zn (r = -0.383, p = 0.007) (Table - 3.38).

In the location-1, the mean value of OC of upper layers was higher (0.29 %) than that of lower (0.44 %) (Table - 3.20a). Mean of the soil OC of location-1 was 0.37 % with minimum value 0.19 % and maximum 0.89 % (Table - 3.22). Here, OC showed negative correlation with Zn (r = -0.730, p = 0.040) (Table - 3.32). An opposite trend was found in the location-2 where the mean of upper layers was higher (0.78 %) than that of lower layer (0.58 %) (Table - 3.20 a). Mean of the soil OC of location-2 was 0.68 % with minimum value 0.19 % and maximum 1.22 % (Table - 3.23). In location-3, the mean of upper layers was 0.71 % and lower was 0.78 % (Table - 3.20 a). Mean of the soil OC of location-3 was 0.751 % with minimum value 0.19 % and maximum 0.95 % (Table - 3.24). In the location-4, the mean of upper layers was 0.68 % and lower was 0.76 % (Table - 3.20a). Mean of the soil OC of location-4 was 0.72 % with minimum value 0.36 % and maximum 1.812 % (Table - 3.25). In case of location-5, the mean of upper layers was 0.34 % and lower was 0.91 % (Table - 3.20 a). Mean of the soil OC of location-5 was 0.63 % with minimum value 0.09 % and maximum 0.95 % (Table - 3.26). In this area, One way ANOVE showed that there was significant difference between upper and lower layers (P = 0.011) (Table - 3.29). In location-5, there was significant difference between upper and lower layers (P = 0.011) (Table - 3.36). In the location-6, the mean of upper layers was 0.76 % and lower was 0.65 % (Table - 3.20a). Mean of the soil OC of location-6 was 0.70 % with minimum value 0.23 % and maximum 1.25 % (Table - 3.27). In case of location-6, OC maintained significant very strong negative correlation with K (r = - 0.823, p = 0.012) (Table - 3.37).

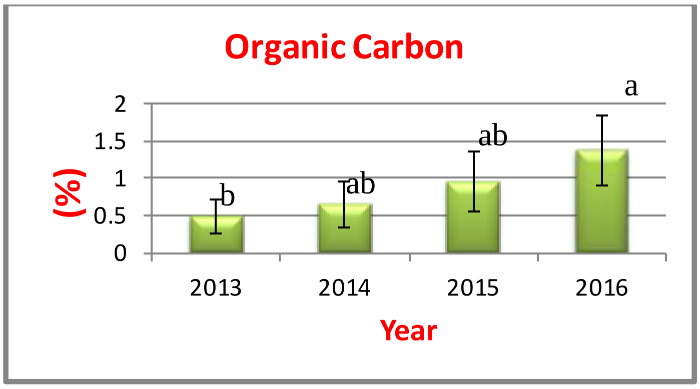

Fig-3.7 Overall mean and standard deviation of organic carbon of the study area from 2013 to 2016.

3.4.5.3 (2015)

The mean values of OC of upper layer was 0.98 % and lower was 0.90 % (Table - 3.40). Mean of the soil OC of Nijhum Dwip was 0.94 % with minimum value 0.24 % and maximum 1.79 % (Table - 3.47).

In location-1, mean of upper layers was 0.82 % and lower was 0.751 % (Table - 3.39.1a). Mean of the soil OC of location-1 was 0.78 % with minimum value 0.52 % and maximum 1.09 % (Table - 3.41). In case of location-2, mean of upper layers was 1.136 % and lower was 1.06 % (Table - 3.39.1a). Mean of the soil OC of location-2 was 1.09 % with minimum value 0.83 % and maximum 1.39 % (Table - 3.42). Here, OC maintained significant very strong positive correlation with Mn (r = 0.816, p = 0.013)

(Table - 3.52). In location-3, mean of upper layers was 0.96 % and lower was 0.93 % (Table - 3.39.1a). Mean of the soil OC of location-3 was 0.95 % with minimum value 0.46 % and maximum 1.51 % (Table - 3.43). In this area, OC maintained significant positive correlation with Zn (r = 0.713, p = 0.047) (Table - 3.53). In the location-4, mean of upper layers was 0.81 % and lower was 0.711 % (Table - 3.39.1 a). Mean of the soil OC of location-4 was 0.76 % with minimum value 0.24 % and maximum 1.51 % (Table - 3.44). Organic carbon maintained significant positive correlation with N (r = 0.718, p = 0.045), P (r = 0.823, p = 0.025,) (Table - 3.54) in location 4. In the location-5, mean of upper layers was 1.30 % and lower was 0.97 % (Table - 3.39.1 a). Mean of the soil OC of location-5 was 0.56 % with minimum value 0.24 % and maximum 1.03 % (Table - 3.45). In case of location-5, OC maintained significant negative correlation with N (r = 0.695, p = 0.056) (Table - 3.55). In the location-6, mean of upper layers was 0.89 % and lower was 0.99 % (Table - 3.39.1 a). Mean of the soil OC of location-6 was 0.94 % with minimum value 0.24 % and maximum 1.45 % (Table - 3.46). There was no significant difference between upper and lower layers in OC (Table - 3.48) through One-Way ANOVA.

3.4.5.4 (2016)

The mean value of OC of upper layers was 0.59 % and lower was 0.69 % (Table - 3.59). Mean of the soil OC of Nijhum Dwip was 1.37 % with minimum value 0.55 % and maximum 2.38 % (Table - 3.66). The mean of upper layers was 0.48 % and lower was 0.48 % (Table - 3.59). OC showed positive correlation with Fe (r = 0.313, p = 0.030) (Table - 3.76). Location and layer showed significance interaction in case of OC (P = 0.024, F = 2.97)

In location-1, the mean of upper layers was 1.40 % and lower was 0.96 % (Table - 3.58.1a). Mean of the soil OC of location-1 was 1.18 % with minimum value 0.65 % and maximum 2.28 % (Table - 3.59). OC showed very strong positive correlation with Mg (r = 0.807, p = 0.015) (Table - 3.70). In the location-2, the mean of upper layers was 1.50 % and lower was 1.48 % (Table - 3.58.1a). Mean of the soil OC of location-2 was 1.49 % with minimum value 0.91 % and maximum 2.07 % (Table - 3.60). Highest amount of OC was found in this sampling occasion. In case of location-3, the mean of upper layers was 1.43 % and lower was 1.57 % (Table - 3.58.1a). Mean of the soil OC of location-3 was 1.420 % with minimum value 0.91 % and maximum 2.079 % (Table - 3.62). The mean of upper layers was 1.30 % and lower was 1.62 % (Table - 3.58.1a) in the location-4. Mean of the soil OC of location-4 was 1.46 % with minimum value 0.55 % and maximum 2.33 % (Table - 3.63). In case of location-4, OC maintained significant negative correlation with Na (r = - 0.718, p = 0.045), K (r = - 0.875, p = 0.004), Pb (r = - 0.859, p = 0.009) (Table - 3.73). In location-5, the mean of upper layers was 1.05 % and lower was 1.29 % (Table - 3.58.1a). Mean of the soil OC of location-5 was 1.17 % with minimum value 0.76 % and maximum 1.57 % (Table - 3.64). Here, OC maintained significant positive correlation with Fe (r = 0.874, p = 0.005) (Table - 3.74). In the location-6, the mean of upper layers was 1.07 % and lower was 1.91% (Table -3.58 a). Mean of the soil OC of location-6 was 1.49 % with minimum value 0.91 % and maximum 2.38 % (Table - 3.65).

In some mangrove forests above 10 % OC is reported (Sukardjo 1994, Rambok *et al.* 2010, Moreno and Calderon 2011) reflecting the peaty nature of the soils. However, less than one percent OC reported by Sah *et al.* (1989) indicated the poor nutritional conditions of the soils of some mangrove forests. Content of organic matter in Char Tamaruddin was very low where mean value was 0.80% with minimum 0.65% and maximum 1.02% (Das 2012). Ataullah *et al.* (2017) found the mean of the soil organic C of SMF was 0.832% with minimum value 0.292 % and maximum 1.54 %. Ahmed *et al.*

(2010a) reported almost similar amount of organic matter (0.88 - 1.56%) from different offshore islands of Patuakhali, Bangladesh.

3.4.6 Total Nitrogen (N)

3.4.6.1 (2013)

Nitrogen showed gradual increase during the study period from 2013 to 2016(Fig.3.8) where significant variation was found between 2013 and 2014, 2015; 2013 and 2016. 2014 and 2015 showed significant variation with 2016.

The mean of total N content of upper layers was 0.65 % and lower was 0.66 % (Table - 3.2). Mean of the soil N of Nijhum Dip was 0.670 % with minimum value 0.301 % and maximum 0.991 % (Table - 3.9). Two way ANOVA showed that there was significant effects on layer (P= 0.045) (Table - 3.12). Nitrogen showed negative correlation with Mn (r = -0.330, p = 0.022) Pb (r = -0.37, p = 0.009) (Table - 3.19).

In location-1, the mean of upper layers was 0.49 % and lower was 0.61 % (Table - 3.1a). Mean of the soil N of this location was 0.55 % with minimum value 0.30 % and maximum 0.79 % (Table - 3.3). In this area, N showed negative correlation with Pb (r = -0.736, p = 0.037) (Table - 3.13). In case of location-2, the mean of upper layer was 0.70 % and lower was 0.70 % (Table - 3.1a). Mean of the soil N was 0.70 % with minimum value 0.52 % and maximum 0.79 % (Table - 3.4). Here, N maintained significant positive correlation with Fe (r = 0.811, p =0.015) (Table - 3.14). In the location-3, the mean of upper layers was 0.64 % and lower was 0.65 % (Table - 3.1a). Mean of the soil N was 0.64 % with minimum value 0.55 % and maximum 0.77 % (Table - 3.5). In the location-4, the mean of upper layers was 0.71 % and lower was 0.77 % (Table - 3.1a). Mean of the soil N was 0.74 % with minimum value 0.60 % and maximum 0.99 % (Table - 3.6). In this area, N maintained significant very strong positive correlation with Zn (r = 0.902, p = 0.002) (Table - 3.16). In case of location-5, the mean of upper layers was 0.66 % and lower was 0.68 % (Table - 3.1a). Mean of the soil N was 0.67 % with minimum value 0.54 % and maximum 0.77 % (Table - 3.7). Here, Nitrogen maintained significant very strong negative correlation with Fe (r = - 0.833, p = 0.010) (Table - 3.17). In the location-6, the mean of upper layers was 0.69 % and lower was 0.694 % (Table - 3.1a). Mean of the soil N was 0.69 % with minimum value 0.63 % and maximum 0.79 % (Table - 3.8). Here, nitrogen maintained significant positive correlation with Fe (r = 0.829, p = 0.011) (Table - 3.18). One-Way ANOVA showed that there was no significant difference between upper and lower layers in nitrogen all in locations.

3.4.6.2 (2014)

The N content of the soil during 2014 was significantly higher than those of 2013 (Fig.3.8). The mean of upper layers was 1.12 % and lower was 1.00 % (Table - 3.21). Mean of the soil N of Nijhum Dwip was 1.06 % with minimum value 0.73 % and maximum 1.79 % (Table - 3.28). In the location-1, the mean of upper layers was 1.17 % and lower was 0.88 % (Table - 3.20a). Mean of the soil N was 1.032 % with minimum value 0.737% and maximum 1.79 % (Table - 3.22).

In location-1, there was significant difference between upper and lower layers (P = 0.035) (Table - 3.32). In thelocation-2, the mean of upper layers was 0.971 % and lower was 1.06 % (Table - 3.20.a). Mean of the soil N was 1.01 % with minimum value 0.85 % and maximum 1.22 % (Table - 3.23). Here, N showed significant positive correlation with, Mn (r = 0.740, p = 0.036), Mg (r = 0.754, p = 0.031) (Table - 3.33). In location-3, the mean of upper layers was 1.23 % and lower was 0.96 % (Table - 3.20a). Mean of the soil N was 1.10 % with minimum value 0.82 % and maximum 1.73 % (Table - 3.24). In thelocation-4, the mean of upper layers was 1.04 % and lower was 1.11 % (Table - 3.20a). Mean of the soil N was 1.07 % with minimum value 0.941 % and maximum 1.19

% (Table - 3.25). Here, N maintained significant positive correlation with Ca (r = 0.709, p= 0.049) (Table - 3.35). In thelocation-5, the mean of upper layers was 1.24 % and lower was 1.00 % (Table - 3.20a). Mean of the soil N of location-5 was 1.12 % with minimum value 0.73 % and maximum 1.79 % (Table - 3.26). In thelocation-6, the mean of upper layers was 1.04 % and lower was 0.98 % (Table - 3.20a). Mean of the soil N of location-6 was 1.01 % with minimum value 0.86 % and maximum 1.14 % (Table - 3.27). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.011) (Table - 3.29). In this case, Nitrogen maintained significant positive correlation with Fe (r = - 0.829, p = 0.011) (Table - 3.37).

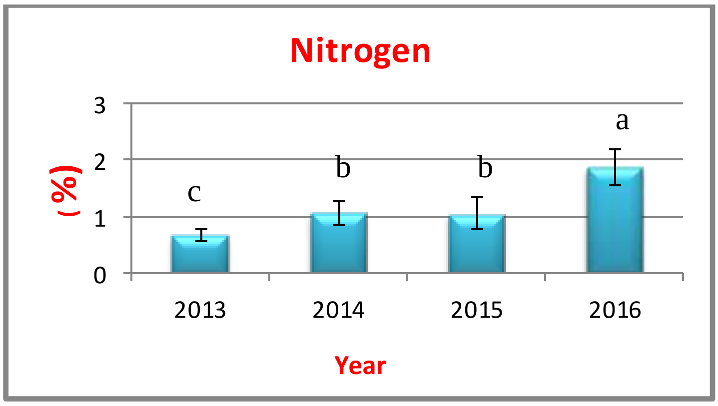

Fig-3.8 Overall mean and standard deviation of soil Nitrogen of the study area from 2013 to 2016.

3.4.6.3 (2015)

The amount of soil N of Nijhum Dwip during 2015 was almost similar in comparison to 2014 but was significantly higher than 2013. The mean of upper layers was 1.00 % and lower was 1.09 % (Table - 3.40). Mean of the soil N of Nijhum Dwip was 1.050 % with minimum value 0.708 % and maximum 2.49 % (Table - 3.47). Nitrogen showed positive correlation with P (r = 0.999, p = 0.000) (Table - 3.57).

In the location-1, mean of upper layers was 1.065 % and lower was 1.054 % (Table - 3.39.1a). Mean of the soil N of location-1 was 1.06 % with minimum value 0.70 % and maximum 1.79 % (Table - 3.41). Here, N showed negative correlation with Mn (r = -

0.650, p = 0.032) (Table - 3.51). In the location-2, mean of upper layers was 0.97 % and lower was 0.91 % (Table - 3.39.1a). Mean of the soil N of location-2 was 0.94 % with minimum value 0.73 % and maximum 1.18 % (Table - 3.42). In the location-3, mean of upper layers was 1.08 % and lower was 1.17 % (Table - 3.39.1a). Mean of the soil N of location-3 was 1.12 % with minimum value 1.05 % and maximum 1.22 % (Table - 3.43). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.007) (Table - 3.48) in the location -4. In the location-4, mean of upper layers was 1.15 % and lower was 1.06 % (Table - 3.39.1a). Mean of the soil N of location-4 was 1.11 % with minimum value 0.99 % and maximum 1.199 % (Table - 3.44). Here, N maintained significant positive correlation with Ca (r = 0.762, p = 0.008) (Table - 3.54). In the location-5, mean of upper layers was 1.00 % and lower was 1.42 % (Table - 3.39.1a). Mean of the soil N of location-5 was 0.67 % with minimum value 0.54 % and maximum 0.77 % (Table - 3.45). In the location-6, mean of upper layers was 0.77 % and lower was 0.77 % (Table - 3.39.1a). Mean of the soil N of location-6 was 0.84 % with minimum value 0.73 % and maximum 1.06 % (Table - 3.46). In case of lacation-6, Nitrogen maintained significant positive correlation with P (r = 0.969, p = 0.000) K (r = 0.754, p = 0.031) (Table - 3.56).

3.4.6.4 (2016)

Nitrogen content of the soils of Nijhum Dwip gradually increased and the values were highest during 2016. Nitrogen content of the soil was significantly higher than those of other sampling occasions. The mean of upper layers was 1.12 % and lower was 1.00 % (Table - 3.59). Overall mean of the soil N of Nijhum Dwip was 1.87 % with minimum value 0.98 % and maximum 2.60 % (Table - 3.66). Two way ANOVA showed that there was significant effects on Interaction (P = 0.024) (Table - 3.69).

In location-1, the mean of upper layers was 1.84 % and lower was 2.05 % (Table - 3.58.1a). Mean of the soil N of location-1 was 1.95 % with minimum value 1.69 % and maximum 2.31 % (Table - 3.59). Nitrogen showed positive correlation with Mn (r = 0.765,p = 0.027) (Table - 3.70). In location-2, the mean of upper layers was 1.50 % and lower was 1.50 % (Table - 3.58.1a). Mean of the soil N of location-2 was 1.69 % with minimum value 0.98 % and maximum 2.40 % (Table - 3.60). In location-3, the mean of upper layers was 1.93 % and lower was 1.80 % (Table - 3.58.1a). Mean of the soil N of location-3 was 1.90 % with minimum value 1.55 % and maximum 2.31 % (Table - 3.62). In location-4, the mean of upper layers was 1.80 % and lower was 2.2 % (Table - 3.58.1a). Mean of the soil N of location-4 was 2.02 % with minimum value 1.61 % and maximum 2.34 % (Table - 3.63). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.038) (Table - 3.67). Here, N maintained significant positive correlation with Fe (r = 0.758, p = 0.029) (Table - 3.73). The mean of upper layers was 1.72 % and lower was 1.76 % (Table - 3.58.1a) in the location-5. Mean of the soil N of location-5 was 1.74 % with minimum value 1.58 % and maximum 2.09 % (Table - 3.64). In location-6, the mean of upper layers was 2.12 % and lower was 1.70 % (Table - 3.58.1a). Mean of the soil N of location-6 was 1.91 % with minimum value 1.61 % and maximum 2.60 % (Table - 6). In case of lacation-6, Nitrogen maintained significant negative correlation with Mn (r = - 0.745, p = 0.034) (Table - 3.75).

Total Nitrogen of Char Tamaruddin varied from 0.056 % to 0.13 % where mean value 0.078 % (Das 2012) and mean of the soil N of SMF was 1.719 % with minimum value 0.667 % and maximum 4.567 % (Ataullah *et al.* 2017). These N concentrations fell within the ranges of other mangroves in the geographical region (Jagtap 1987, Tam *et al.* 1995). The changes of total N in mangrove soils were related to nutrient releases from litter decomposition which was affected by frequency and amplitude of tidal flushing. Mangrove soil nutrient concentrations are assumed to reflect many biogeochemical factors, including litter accumulation and decomposition, plant uptake, tidal flushing, leaching and anthropogenic inputs. Because of these influences, it is difficult to define the trend of temporal variations in soil nitrogen content. Tam and Wong (1998) found negative significant correlation of total N with pH and organic matter.

3.4.7 Phosphorus (P)

3.4.7.1 (2013)

The mean of Phosphorus content (P) of upper layers of soil of Nijhum Dwip was 0.013 % and lower was 0.013 % (Table - 3.2). Mean of the soil P of Nijhum Dwip was 0.013 % with minimum value 0.010 % and maximum 0.018 % (Table - 3.9). Phosphorus showed negative correlation with Mn (r = -0.399, p = 0.005) (Table - 3.19). Two way ANOVA showed that there was significant effects of location and layer (P = 0.016) (Table - 3.12).

In the location-1, the mean of upper layers was 0.023 % and lower was 0.026 % (Table - 3.1a). Mean of the soil P was 0.030% with minimum value 0.010 % and maximum 0.040 % (Table - 3.3). In location-2, the mean of upper layers was 0.024 % and lower was 0.023 % (Table - 3.1a). Mean of the soil P was 0.020 % with minimum value 0.018 % and maximum 0.029 % (Table - 3.4). In case of location-3, the mean of upper layers was 0.027 % and lower was 0.029 % (Table - 3.1a). Mean of the soil P was 0.030 % with minimum value 0.026 % and maximum 0.030 % (Table - 3.5). Here, P maintained significant negative correlation with Pb (r = -0.774, p = 0.042) (Table - 3.15). In location-4, the mean of upper layers was 0.029 % and lower was 0.026- % (Table - 3.1a). Mean of the soil P was 0.030 % with minimum value 0.020 % and maximum

0.030 % (Table - 3.6). The mean of upper layer was 0.025 % and lower was 0.035 % (Table - 3.1a) in the location-5. Mean of the soil P was 0.030 % with minimum value 0.021 % and maximum 0.062 % (Table - 3.7). In case of location-6, the mean of upper layers was 0.018 % and lower was 0.023 % (Table - 3.1a). Mean of the soil P was 0.021 % with minimum value 0.018 % and maximum 0.027 % (Table - 3.8). In this area, P maintained significant negative correlation with Zn (r = -0.874, p = 0.005) (Table - 3.18). There was no significant difference between upper and lower layer in phosphorus all in locations. (Table - 3.10).

3.4.7.2 (2014)

The mean of upper layers was 0.015% and lower was 0.015 % (Table - 3.21). Mean of the soil P of Nijhum Dwip was 0.017 % with minimum value 0.015 % and maximum 0.012 % (Table - 3.28).

In location-1, the mean of upper layers was 0.017 % and lower was 0.017 % (Table - 3.20 a). Mean of the soil P of location-1 was 0.017 % with minimum value 0.016 % and maximum 0.018 % (Table - 3.22). Phosphorus showed positive correlation with Mn (r = 0.938, p = 0.001) (Table - 3.32). In the location-2, the mean of upper layers was 0.016 % and lower was 0.017 % (Table - 3.20a). Mean of the soil P of location-2 was 0.017% with minimum value 0.015 % and maximum 0.017 % (Table - 3.23). In case of location-3, there were no difference in the mean of upper and lower layers and values were 0.017% in both layers (Table-3.20 a). Mean of the soil P of location-3 was 0.017 % with minimum value 0.016 % and maximum 0.018 % (Table - 3.24). In the location-4, the mean of upper layers was 0.016 % and lower was 0.016 % (Table - 3.20a). Mean of the soil P of location-4 was 0.016 % with minimum value 0.016 % and maximum 0.017 % (Table - 3.25). In location-5, the mean of upper layers was 0.017 % and lower was

0.017% (Table - 3.20a). Mean of the soil P of location-5 was 0.017 % with minimum value 0.016 % and maximum 0.019 % (Table - 3.26). In case of location-6, mean of upper layers was 0.016 % and lower was 0.016 % (Table - 3.20 a). Mean of the soil P of this location was 0.016 % with minimum value 0.015 % and maximum 0.016 % (Table - 3.27). Here, P maintained significant negative correlation with Zn (r = -0.874, p = 0.005) (Table -3.37). One-Way ANOVA showed that there was significant difference between upper and lower layers of soil in P content (Table - 3.29).

3.4.7.2 (2015)

The mean values of P content in the soil of Nijhum Dwip was similar during 2015 where the values of upper and lower were 0.015 % (Table - 3.40). Mean of the soil P of Nijhum Dwip was 0.026 % with minimum value 0.018 % and maximum 0.063 % (Table - 3.47).

In location-1, mean of upper layers was 0.014 % and lower was 0.016 % (Table - 3.39.1a). Mean of the soil P of location-1 was 0.012 % with minimum value 0.013 % and maximum 0.018 % (Table - 3.41). In case of location-2, mean of upper layers was 0.015 % and lower was 0.016 % (Table - 3.39.1a). Mean of the soil P of location-2 was 0.015 % with minimum value 0.013 % and maximum 0.019 % (Table - 3.42). In the location-3, mean of upper layers was 0.015 % and lower was 0.015 % (Table - 3.39.1a). Mean of the soil P of location-3 was 0.016 % with minimum value 0.012 % and maximum0.019 % (Table - 3.43). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.027) (Table - 3.48). The mean of upper layers was 0.017 % and lower was 0.020 % (Table - 3.39.1a) in the location-4. Mean of the soil P of location-4 was 0.014 % with minimum value 0.013 % and maximum 0.014 % (Table - 3.44). In this area, P showed positive significant correlation with P (r =0.668, p = 0.017). In the location-5, mean of upper layers was 0.015 % and lower was 0.015 % (Table - 3.39.1a). Mean of the soil P of location-5 was 0.016 % with minimum value

0.013 % and maximum 0.019 % (Table - 3.45). In location-6, mean of upper layers was 0.015 % and lower was 0.015 % (Table - 3.39.1a). Mean of the soil P of location-6 was 0.015 % with minimum value 0.014 % and maximum 0.018 % (Table - 3.46). One-Way ANOVA showed that there was significant difference between upper and lower layers (P= 0.023) (Table - 3.48). Phosphorus showed positive correlation with K (r = 0792, p = 0.019), Mn (r =0756, p = 0.050) (Table - 3.36).

3.4.7.4 (2016)

The overall mean of upper layers was 0.013 % and lower was 0.013 % (Table - 3.59). Overall mean of the soil P of Nijhum Dwip during 2016was 0.017 % with minimum value 0.015 % and maximum 0.019 % (Table - 3.66).

In the location-1, the mean of upper layers was 0.014 % and lower was 0.014 % (Table - 3.58.1a). Mean of the soil P of location-1 was 0.014 % with minimum value 0.011 % and maximum 0.015 % (Table - 3.59). In case of location-2, the mean of upper layers was 0.012 % and lower was 0.012 % (Table - 3.58.1a). Mean of the soil P of location-2 was 0.012 % with minimum value 0.010 % and maximum 0.014 % (Table - 3.60). In location-3, the mean of upper layers was 0.014 % and lower was 0.015 % (Table - 3.58.1a). Mean of the soil P of location-3 was 0.014 % with minimum value 0.012 % and maximum 0.018 % (Table - 3.62). In case of location-3, P maintained significant positive correlation with Ca (r = 0.718, p = 0.045) (Table - 3.72). Inlocation-4, the mean of upper layers was 0.012 % and lower was 0.012 % (Table - 3.58.1a). Mean of the soil P of location-4 was 0.012 % with minimum value 0.010 % and maximum 0.014 % (Table - 3.63). In the location-5, the mean of upper layers was 0.013 % and lower was 0.013 % (Table -3.58.1a). Mean of the soil P of location-5 was 0.013 % with minimum value 0.011 % and maximum 0.014 % (Table - 3.64). In the location-6, the mean of upper layer was 0.014 % and lower was 0.013 % (Table - 3.58.1a). Mean of the soil P of location-6 was 0.011 % with minimum value 0.012 % and maximum 0.016 % (Table - 3.65). One-Way ANOVA showed that there was significant difference between upper and lower layers in P in location all (Table - 3.67).

Other workers have found almost similar results in different mangrove forests (Tam and Wong 1998, Boto and Wellington 1984). But about 10 times more P content (0.276 - 0.638%) was reported by Ahmed *et al.* (2010a) in their studies in different chars of coastal area of Bangladesh. Mean of the soil P of SMF was 0.022 % with minimum value 0.000052% and maximum 0.0956 % (Ataullah *et al* 2017). Mean value of total P in Char Tamaruddin 0.05% with minimum value was 0.025% and maximum value was 0.056% (Das 2012). The levels of total phosphorus of the present study are quite low reflecting the low phosphorus status of the Dwip. Hesse (1961) found total P was 0.15% in the Sierra Leone mangrove soils which is also higher than present studies. The total P content recorded in this study were also lower than other mangrove soils in this geographical region (Lin and Lin 1985; Tam *et al.* 1995), suggesting that this mangrove ecosystem is not P limited. Rambok *et al.* (2010) reported the highest (25.27%) phosphorus in Sibuti mangrove, Sarawak, Malaysia. In mangrove soils, N was considered the primary nutrient that affects species composition and structure of forest, although more recent analysis found that N and P influence structure and composition in approximately equal proportions (Elser and Hamilton, 2007).

3.5 THE EXCHANGEABLE CATIONS

3.5.1 Sodium (Na)

3.5.1.1 (2013)

The concentration of Na in the study area was remained almost similar throughout the study period although non-significant increase were observed from 2013 to 2016 indicating slight accumulation of salt in the soil. The mean of Na in the soil of Nijhum

Dwip in upper layers was 44.15 µg/g and lower was 43.96 µg/g (Table - 3.2). Overall mean of the soil Na of Nijhum Dwip was 44.05 µg/g with minimum value 22.50 µg/g and maximum 75.00 µg/g (Table - 3.9). Location and layer showed significance interaction in case of Soil Na (P = 0.001, F = 5.59) (Table - 3.12). Sodium (Na) showed negative correlation with Pb (r = -0.394, p = 0.015) (Table - 3.19).

In the location-1, the mean of upper layers was 41.00 µg/g and lower was 33.13 µg/g (Table - 3.1b). Mean of the soil Na was 37.21 µg/g with minimum value 22.50 µg/g and maximum 45.50 µg/g (Table - 3.3). The mean of upper layers was 57.25 µg/g and lower was 45.00 µg/g (Table - 3.1b) in the location-2. Mean of the soil Na was 51.21 µg/g with minimum value 34.50 µg/g and maximum 69.00 µg/g (Table - 3.4). In this area, Na showed positive correlation with Pb (r = 0.764, p = 0.027) (Table - 3.19). In the location-3, the mean of upper layers was 48.13 µg/g and lower was 51.13 µg/g (Table - 3.1b). Mean of the soil Na was 49.63 µg/g with minimum value 32.00 µg/g and maximum 68.00 µg/g (Table - 3.5). In the location-4, the mean of upper layers was 36.87 µg/g and lower was 38.50 µg/g (Table - 3.1 b). Mean of the soil Na was 37.69 µg/g with minimum value 30.50 µg/g and maximum 47.50 µg/g (Table - 3.6). In location-5, the mean of upper layers was 46.62 µg/g and lower was 35.37 µg/g (Table - 3.1b). Mean of the soil Na of location-5 was 41.00 µg/g with minimum value 25.00 µg/g and maximum 54.00 µg/g (Table - 3.7). In the area-5, Na maintained significant negative correlation with K (r = -0.773, p = 0.024) (Table - 3.17). The mean of upper layers was 35.00 µg/g and lower was 60.62 µg/g (Table - 3.1b) in the location-6. Mean of the soil Na was 47.81 µg/g with minimum value 32.00 µg/g and maximum 75.00 µg/g (Table - 3.8). One-Way ANOVA showed that there was significant difference between upper and lower layer in Na in location six (F = 16.85, P = 0.006) (Table- 3.10)

3.5.1.2 (2014)

The mean of Na during 2014 of upper layers was 54.54 µg/g and lower was 53.08 µg/g (Table - 3.21). Mean of the soil Na of Nijhum Dwip was 53.81 µg/g with minimum value 30.00 µg/g and maximum 80.00 µg/g (Table - 3.28). Two way ANOVA showed that there was significant effects on interaction between locations and layers (P = 0.018) (Table - 3.31).

In location-1, the mean of upper layers was 56.75 µg/g and lower was 41.50 µg/g (Table - 3.20b). Mean of the soil Na of location-1 was 49.13 µg/g with minimum value 34.00 µg/g and maximum 70.00 µg/g (Table - 3.22). In location one, One way ANOVE showed that there was significant difference between upper and lower layer (P = 0.035) (Table - 3.29). In case of location-2, the mean of upper layers was 67.75 µg/g and lower was 56.2µg/g (Table - 3.20b). Mean of the soil Na of location-2 was 62.00 µg/g with minimum value 40.00 µg/g and maximum 80.00 µg/g (Table - 3.23). In location-3, the mean of upper layers was 59.00 µg/g and lower was 57.25 µg/g (Table - 3.20b). Mean of the soil Na of location-3 was 58.13 µg/g with minimum value 34.00 µg/g and maximum 70.0 µg/g (Table - 3.24). The mean of upper layers was 43.50 µg/g and lower was 47.00 µg/g (Table - 3.20b) in the location-4. Mean of the soil Na of location-4 was 45.25 µg/g with minimum value 34.00µg/g and maximum 70.00 µg/g (Table - 3.25). Here, Na maintained significant very strong positive correlation with K (r = 0.929, p = 0.001) (Table - 3.35). In case oflocation-5, the mean of upper layers was 55.50 µg/g and lower was 46.50 µg/g (Table - 3.20b). Mean of the soil Na of location-5 was 51.00 µg/g with minimum value 30.00 µg/g and maximum 70.00 µg/g (Table - 3.26). In the location-6, the mean of upper layers was 44.75 µg/g and lower was 70.00 µg/g (Table - 3.20b). Mean of the soil Na of location-6 was 57.38 µg/g with minimum value 40.00 µg/g and maximum 80.00 µg/g (Table - 3.27). In this area, one way ANOVE showed that there was significant difference between upper and lower layer (P = 0.001) (Table - 3.29).

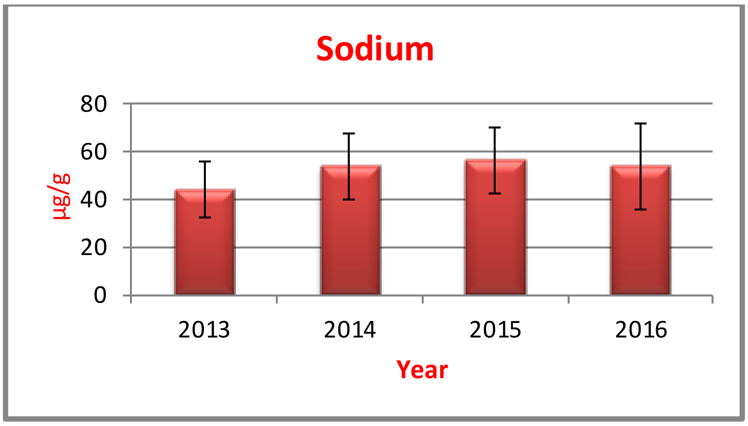

Fig-3.9 Overall mean and standard deviation of Sodium content of the study area from 2013 to 2016.

3.5.1.3 (2015)

The mean of upper layers was 53.38 µg/g and lower was 58.71 µg/g (Table - 3.40). Mean of the soil Na of Nijhum Dwip was 56.04 µg/g with minimum value 36.00 µg/g and maximum 90.00 µg/g (Table - 3.47). Location and layer showed significance interaction in case of Na (P = 0.041, F = 2.61) (Table - 3.50). Na maintained significant positive correlation with K (r = 0.799, p = 0.000) (Table - 3.57).

In location-1, mean of upper layers was 48.25 µg/g and lower was 46.7 µg/g (Table - 3.39.1b). Mean of the soil Na of location-1 was 47.50 µg/g with minimum value 36.00 µg/g and maximum 71.00 µg/g (Table - 3.41). Here, Na maintained significant positive correlation with K (r = 0.836, p = 0.010) (Table - 3.51). In the location-2, mean of upper layer was 55.75 µg/g and lower was 53.75 µg/g (Table - 3.39.1b). Mean of the soil Na of location-2 was 54.75 µg/g with minimum value 39.0 µg/g and maximum 69.00 µg/g (Table - 3.42). In this area, Na maintained significant positive correlation with K (r = 0.718, p = 0.045) (Table - 3.52). In the location-3, mean of upper layers was 64.00 µg/g and lower was 56.00 µg/g (Table - 3.39.1b). Mean of the soil Na of location-3 was 60.00

µg/g with minimum value 44.00 µg/g and maximum 73.00 µg/g (Table - 3.43). Here, Na maintained significant positive correlation with K (r = 0.789, p = 0.020) (Table - 3.53). In the location-4, mean of upper layers was 48.75 µg/g and lower was 53.50 µg/g (Table - 3.39.1b). Mean of the soil Na of location-4 was 51.13 µg/g with minimum value 40.00 µg/g and maximum 65.00 µg/g (Table - 3.44). Na maintained significant positive correlation with K (r = 0.779, p = 0.023) (Table - 3.54) in location-4. The mean of upper layers was 49.25 µg/g and lower was 59.00 µg/g (Table - 3.39.1b) in the location-5. Mean of the soil Na of location-5 was 41.00 µg/g with minimum value 25.00 µg/g and maximum 54.00 µg/g (Table - 3.45). In case of location-5, Na maintained significant positive correlation with K (r = 0.732, p = 0.039) Mn (r = 0.738, p = 0.037) (Table - 3.55). In location-6, mean of upper layers was 54.25 µg/g and lower was 83.25 µg/g (Table - 3.39.1b). Mean of the soil Na of location-6 was 68.75 µg/g with minimum value 44.00 µg/g and maximum 90.00 µg/g (Table - 3.46). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.003) (Table - 3.48). Na maintained significant very strong positive correlation with K (r = 0.908, p = 0.002), Zn (r = 0.901, p = 0.002) (Table - 3.56).

3.5.1.4 (2016)

The mean of Na of upper layers was 54.54 µg/g and lower was 53.08 µg/g (Table - 3.59). Mean of the soil Na of Nijhum Dwip was 54.04 µg/g with minimum value 17.00 µg/g and maximum 94.00 µg/g (Table - 3.66). Two way ANOVA showed that there was significant effects of locations (P = 0.000) (Table - 3.69). Here, sodium (Na) showed positive correlation with Pb (r = 0.331, p = 0.021) (Table - 3.76).

In location-1, the mean of upper layers was 74.25 µg/g and lower was 75.25 µg/g (Table - 3.58.1b). Mean of the soil Na of location-1 was 74.75 µg/g with minimum value 61.00 µg/g and maximum 94.00 µg/g (Table - 3.59). In location-2, the mean of upper layers was 61.50 µg/g and lower was 58.75 µg/g (Table - 3.58.1b). Mean of the soil Na of location-2 was 60.13 µg/g with minimum value 54.00 µg/g and maximum 65.00 µg/g (Table - 3.61). In the location-3, the mean of upper layers was 69.75µg/g and lower was 49.67 µg/g (Table - 3.58.1b). Mean of the soil Na of location-3 was 62.88 µg/g with minimum value 45.00 µg/g and maximum 86.00 µg/g (Table - 3.62). The mean of upper layers was 54.75 µg/g and lower was 37.75 µg/g (Table - 3.58.1b) in the location-4. Mean of the soil Na of location-4 was 46.25 µg/g with minimum value 31.00 µg/g and maximum 87.00 µg/g (Table - 3.63). In case of lacation-4, Na maintained significant positive correlation with K ($r = 0.784$, $p = 0.021$), Pb($r = 0.847$, $p = 0.008$) (Table - 3.73). In the location-5, the mean of upper layers was 36.25 µg/g and lower was 37.00µg/g (Table - 3.58.1b). Mean of the soil Na of location-5 was 36.63 µg/g with minimum value 17.00 µg/g and maximum 55.00 µg/g (Table - 3.64). In case of location-5, Na maintained significant positive correlation with K ($r = 0.885$, $p = 0.003$) (Table - 3.74). In the location-6, the mean of upper layers was 48.50 µg/g and lower was 38.7 µg/g (Table - 3.58.1b). Mean of the soil Na of location-6 was 43.63 µg/g with minimum value 34.00 µg/g and maximum 51.00 µg/g (Table - 3.65). One-Way ANOVA showed that there was significant difference between upper and lower layer ($P = 0.01$) (Table - 3.67). In case of location-6, Na maintained significant very strong positive correlation with K ($r = 0.832$, $p = 0.010$) and negative correlation with Zn ($r = -0.891$, $p = 0.003$) (Table - 3.75).

Although the mean value of soil Na content did not exceed the standard value 278 mg/kg of IAEA (1990), the maximum value showed very high concentration than standard guideline. Sodium concentration ranged from 2.21- 4.13 % in coastal sediment of Abu-Qir Bay (Ghani *et al.* 2013) which was higher than soil Na of Nijhum Dwip. Na content of SMF ranged from 3.50 – 2600 ppm and the mean values of soil Na of upper and lower layers of oligohaline zone were 164 mg/kg and 243.3 mg/kg, mesohaline zone were 259.4 mg/kg and 135 mg/kg, polyhaline zone were 276.2 mg/kg and 237.4 mg/kg respectively (Ataullah *et al.* 2018). Present study showed higher Na content of the soil than Ahmed *et al.* (2010a) who reported 0.431 – 2.23% Na in a coastal island of Bangladesh, Rangabali Patuakhali district.

3.5.2 Potassium (K)

3.5.2.1 (2013)

The overall mean values of K of soils of upper layers of overall Nijhum Dwip was 39.25 µg/g and lower was 44.43 µg/g (Table - 3.2). Overall mean of the soil K of Nijhum Dwip was 41.84 µg/g with minimum value 27.00 µg/g and maximum 74.00 µg/g (Table - 3.9).

In the location-1, the mean of upper layers was 43.50 µg/g and lower was 40.62 µg/g (Table - 3.1b). Mean of the soil K was 42.06 µg/g with minimum value 28.00 µg/g and maximum 55.00 µg/g (Table - 3.3). In location-2, the mean of upper layers was 38.00 µg/g and lower was 35.00 µg/g (Table - 3.1b). Mean of the soil K was 36.50 µg/g with minimum value 27.00 µg/g and maximum 50.00 µg/g (Table - 3.4). The mean of upper layers was 31.00 µg/g and lower was 44.25 µg/g (Table - 3.1b) in the location-3. Mean of the soil K was 37.63 µg/g with minimum value 27.50 µg/g and maximum 57.50 µg/g (Table - 3.5). Potassium maintained significant positive correlation with Mn ($r = 0.870, p = 0.005$) (Table - 3.15). In the location-4, the mean of upper layers was 46.87µg/g and lower was 44.50 µg/g (Table - 3.1b). Mean of the soil K was 45.69 µg/g with minimum value 37.00 µg/g and maximum 52.50 µg/g (Table - 3.6). In case of location-5, the mean of upper layers was 32.25µg/g and lower was 48.75 µg/g (Table - 3.1 b).Mean of the soil K was 40.50 µg/g with minimum value 29.50 µg/g and maximum 56.00 µg/g (Table -

3.7). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.003) (Table - 3.10). In here, K maintained significant positive correlation with Mn (r =719, p = 0.045) (Table - 3.17). In the location-6, the mean of upper layers was 43.88 µg/g and lower was 53.50 µg/g (Table - 3.1b). Mean of the soil K was 48.69 µg/g with minimum value 37.50 µg/g and maximum 74.00 µg/g (Table - 3.8). There was no significant difference between upper and lower layer surface in case of K in all location except location-5.

3.5.2.2 (2014)

The mean of upper layers was 46.58 µg/g and lower was 52.96 µg/g (Table - 3.21). Mean of the soil K of Nijhum Dwip was 49.77µg/g with minimum value 28.00 µg/g and maximum 90.00 µg/g (Table - 3.28). Two way ANOVA showed that there was significant effects of layer (P = 0.002) (Table - 3.31). Potassium showed negative significant weak correlation with Zn (r = -0.299, p = 0.039) (Table - 3.38).

In location-1, the mean of upper layers was 49.25 µg/g and lower was 49.00 µg/g (Table - 3.20b). Mean of the soil K of location-1 was 44.13 µg/g with minimum value 34.00 µg/g and maximum 62.00 µg/g (Table - 3.22). In location-2, the mean of upper layers was 44.75 µg/g and lower was 43.75 µg/g (Table - 3.20b). Mean of the soil K of location-2 was 44.25 µg/g with minimum value 31.00 µg/g and maximum 53.00 µg/g (Table - 3.23). Here, Potassium showed positive correlation with Fe (r = 0.792, p = 0.019) (Table - 3.33). In location -3, the mean of upper layers was 41.50µg/g and lower was 53.00 µg/g (Table - 3.20b). Mean of the soil K of location -3 was 47.25 µg/g with minimum value 37.00 µg/g and maximum 71.0 µg/g (Table - 3.24). In location-4, the mean of upper layers was 40.00 µg/g and lower was 40.00 µg/g (Table - 3.20b). Mean of the soil K of location-4 was 40.25 µg/g with minimum value 33.00 µg/g and maximum 55.00 µg/g (Table - 3.25). In case of location-5, the mean of upper layers was 44.75 µg/g and lower was 59.00 µg/g (Table - 3.20b).Mean of the soil K of location-5 was 51.88 µg/g with minimum value 28.00 µg/g and maximum 71.00 µg/g (Table - 3.26). In the location-6, the mean of upper layers was 59.25 µg/g and lower was 72.50 µg/g (Table - 3.20b). Mean of the soil K of location-6 was 65.88 µg/g with minimum value 48.00 µg/g and maximum 90.00 µg/g (Table - 3.27). One-Way ANOVA showed that there was significant difference between upper and lower layer in K (Table - 3.29).

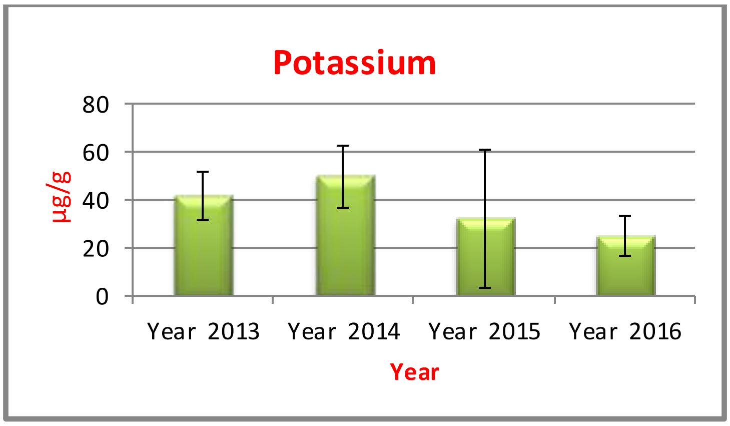

Fig-3.10. Overall mean and standard deviation of soil Potassium of the study area from 2013 to 2016.

3.5.2.3 (2015)

The mean of upper layers was 30.79 µg/g and lower was 33.45 µg/g (Table - 3.40). Overall mean of the soil K of Nijhum Dwip was 32.13 µg/g with minimum value 14.00 µg/g and maximum 50.00 µg/g (Table - 3.47).

In location-1, mean of upper layers was 29.75 µg/g and lower was 25.50 µg/g (Table - 3.39.1b). Mean of the soil K of location-1 was 27.63 µg/g with minimum value 15.00 µg/g and maximum 45.00 µg/g (Table - 3.41). In case of location-2, mean of upper layers was 33.00 µg/g and lower was 37.25 µg/g (Table - 3.39.1b). Mean of the soil K of location-2 was 35.13 µg/g with minimum value 25.00 µg/g and maximum 45.00 µg/g (Table - 3.42). In the location-3, mean of uppers layer was 37.25 µg/g and lower was 34.00 µg/g (Table - 3.39.1b). Mean of the soil K of location-3 was 35.63 µg/g with minimum value 25.00 µg/g and maximum 46.00 µg/g (Table - 3.43). In location-4, mean of upper layers was 26.50 µg/g and lower was 29.50 µg/g (Table - 3.39.1b). Mean of the soil K of location-4 was 28.00 µg/g with minimum value 14.00 µg/g and maximum 41.00 µg/g (Table - 3.44). The mean of upper layers was 26.75 µg/g and lower was 29.75 µg/g (Table - 3.39.1b) in the location-5. Mean of the soil K of location-5 was 40.50 µg/g with minimum value 29.50 µg/g and maximum 56.00 µg/g (Table - 3.45). In case of location-5, K maintained significant positive correlation with Pb (r = 0.751, p = 0.056), Mn (r = 0.725, p = 0.042), Ca (r = 0.705, p = 0.051) (Table - 3.55). In location-6, mean of upper layers was 31.50 µg/g and lower was 44.75 µg/g (Table - 3.39.1b). Mean of the soil K of location-6 was 38.13 µg/g with minimum value 23.00 µg/g and maximum 50.00 µg/g (Table - 3.46). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.014) (Table - 3.48). Here, K maintained significant very strong positive correlation with Zn (r = 0.834, p = 0.010) (Table - 3.56). There was no significant difference between upper and lower layer in K in all locations (Table - 3.48) through One-Way ANOVA .

3.5.2.4 (2016)

The mean of upper layers was 46.58 µg/g and lower was 52.96 µg/g (Table - 3.59). Overall mean of the soil K of Nijhum Dwip was 24.81 µg/g with minimum value 13.00 µg/g and maximum 61.00 µg/g (Table - 3.66). Two way ANOVA showed that there was significant effects of layers (P = 0.045) (Table - 3.69).

In location-1, the mean of upper layers was 43.50 µg/g and lower was 40.62 µg/g (Table - 3.58.1b). Mean of the soil K of location-1 was 23.00 µg/g with minimum value 15.00 µg/g and maximum 32.00 µg/g (Table - 3.59). In the location-2, the mean of upper layers was 38.00 µg/g and lower was 35.00 µg/g (Table - 3.58.1b). Mean of the soil K of location-2 was 22.88 µg/g with minimum value 13.00 µg/g and maximum 32.00 µg/g

(Table - 3.60). In the location-3, the mean of upper layers was 31.00 µg/g and lower was 44.25 µg/g (Table - 3.58.1b). Mean of the soil K of location-3 was 21.50 µg/g with minimum value 16.00 µg/g and maximum 30.00 µg/g (Table - 3.61). Here, K maintained significant very strong positive correlation with Zn (r = 0.851, p = 0.007) (Table - 3.72). In the location-4, the mean of upper layers was 46.87µg/g and lower was 44.50 µg/g (Table - 3.58.1b). Mean of the soil K of location-4 was 31.13 µg/g with minimum value 18.00 µg/g and maximum 61.00 µg/g (Table - 3.63). The mean of upper layers was 32.25 µg/g and lower was 48.75 µg/g (Table - 3.58.1b) in the location-5. Mean of the soil K of location-5 was 22.50 µg/g with minimum value 13.00 µg/g and maximum 34.00 µg/g (Table - 3.64). In location-6, the mean of upper layers was 43.88 µg/g and lower was 53.50 µg/g (Table - 3.58.1b). Mean of the soil K of location-6 was 27.88 µg/g with minimum value 22.00 µg/g and maximum 35.00 µg/g (Table - 3.65). There was no significant difference between upper and lower layers in all location in K (Table - 3.67) through One-Way ANOVA.

Different authors reported higher amount of total K contents, e.g. 1.6 % in Shenzhen (Tam *et al.* 1995), 2.07 % in Fujian (Lin *et al.* 1987), 0.42–1.19 % in Hainan (Liao 1990) and 0.39-4.79 % in Hong Kong mangroves (Tam and Wong 1998). The amount of K in a coastal island of Bangladesh Char Tamaruddin at Hatiya, Noakhali, ranged from 42.5 - 52.50 µg/g (Das 2012). The amount of K content of SMF ranged from 37.08 – 42.78 ppm and the mean values of soil K of upper and lower layers of oligohaline zone were 15.558 mg/kg and 15.837 mg/kg, mesohaline zone were 25.07 mg/kg and 32.507 mg/kg, polyhaline zone were 30.245 mg/kg and 31.127 mg/kg respectively (Ataullah *et al.* 2018). Present study showed lower K content of the soil than Ahmed *et al.* (2010a) who reported 0.016 - 0.084 % K in the soil of Rangabali.

3.5.3 Lead (Pb)

3.5.3.1 (2013)

The Pb concentration of soil was almost similar throughout the study period except there were significant difference between 2014 and 2016. The amount of Pb decreased from 2014 to 2016. The mean values of Pb concentration of upper layers of soils of Nijhum Dwip was 0.336 µg/g and lower was 0.31 µg/g (Table - 3.2). Mean of the soil Pb of Nijhum Dwip was 0.49 µg/g with minimum value 0.23 µg/g and maximum 0.88 µg/g (Table - 3.9). Two way ANOVA showed that there was significant effects on layer (P = 0.000) (Table - 3.12). Lead showed positive correlation with Mn (r = 0.310, p = 0.032), Mg (p = 0.001, r = 0.467), Ca (p = 0.003, r = 0.421) (Table - 3.19).

In the location-1, the mean values of upper layers were 0.67 µg/g and lower were 0.53 µg/g (Table - 3.1b). Mean of the soil Pb was 0.60 µg/g with minimum value 0.37 µg/g and maximum 0.87 µg/g (Table - 3.3). In this area, Pb showed positive correlation with Ca (r = 0.856, p = 0.007) (Table - 3.13). In location-2, the mean of upper layers was 0.57 µg/g and lower was 0.55 µg/g (Table - 3.1b). Mean of the soil Pb was 0.56 µg/g with minimum value 0.37 µg/g and maximum 0.75 µg/g (Table - 3.4). Here, Pb showed positive correlation with Mn (r = 0.762, p = 0.028) (Table - 3.14). The mean of upper layers was 0.68 µg/g and lower was 0.52 µg/g (Table - 3.1b) in the location-3. Mean of the soil Pb was 0.58 µg/g with minimum value 0.26 µg/g and maximum 0.83 µg/g (Table - 3.5). In case of location-4, the mean of upper layers was 0.49 µg/g and lower was 0.47 µg/g (Table - 3.1b). Mean of the soil Pb was 0.47µg/g with minimum value 0.37 µg/g and maximum 0.63 µg/g (Table - 3.6). In the location-5, the mean of upper layers was 0.46 µg/g and lower was 0.44 µg/g(Table - 3.1b). Mean of the soil Pb was 0.83 µg/g with minimum value 0.67 µg/g and maximum 1.17 µg/g (Table - 3.7). In location-6, the mean of upper layers was 0.37 µg/g and lower was 0.35 µg/g (Table -

3.1b). Mean of the soil Pb of location-6 was 0.36 µg/g with minimum value 0.33 µg/g and maximum 0.40 µg/g (Table - 3.8). Comparative lower amounts of Pb was found in location-6 than those of other 5 locations. Pb showed positive correlation with Fe ($r = 0.814$, $p = 0.014$), (Table - 3.18). In location-6, One-Way ANOVA showed that there was no significant difference between upper and lower layers in Pb in location all.

3.5.3.2 (2014)

The overall mean of upper layers was 0.52 µg/g and lower was 0.54 µg/g (Table - 3.21). Overall mean of the soil Pb of Nijhum Dwip was 0.54 µg/g with minimum value 0.23 µg/g and maximum 0.820 µg/g (Table - 3.28). Pb showed highly positive correlation with Mn ($r = 0.642$, $p = 0.000$) and Mg ($r = 0.766$, $p = 0.000$) (Table - 3.38).

In location-1, the mean of upper layers was 0.57 µg/g and lower was 0.587 µg/g (Table - 3.20b). Mean of the soil Pb of location-1 was 0.58 µg/g with minimum value 0.38 µg/g and maximum 0.73 µg/g (Table - 3.22). Lead showed significant positive correlation with Mn ($r = 0.642$, $p = 0.044$) (Table - 3.32). In case of location-2, the mean of upper layers was 0.56 µg/g and lower was 0.62 µg/g (Table - 3.20b). Mean of the soil Pb of location-2 was 0.59 µg/g with minimum value 0.30 µg/g and maximum 0.82 µg/g (Table - 3.23). In this area, Pb showed positive correlation with Mn ($r = 0.924$, $p = 0.001$) and Mg ($r = 0.880$, $p = 0.004$) (Table - 3.33). In the location-3, the mean of upper layers was 0.43 µg/g and lower was 0.51 µg/g (Table - 3.20b). Mean of the soil Pb of location-3 was 0.47 µg/g with minimum value 0.36 µg/g and maximum 0.62 µg/g (Table - 3.24). Here, Pb showed very strong positive correlation with Mn ($r = 0.801$, $p = 0.017$) and Mg ($r = 0.980$, $p = 0.000$) (Table - 3.34). In the location-4, the mean of upper layers was 0.53 µg/g and lower was 0.52 µg/g (Table - 3.20b). Mean of the soil Pb of location-4 was 0.52 µg/g with minimum value 0.44 µg/g and maximum 0.64 µg/g (Table - 3.25). Pb showed positive correlation with Mg ($r = 0.733$, $p = 0.039$) (Table - 3.35). In the location-5, the mean of upper layers was 0.60 µg/g and lower was 0.55 µg/g (Table - 3.20b). Mean of the soil Pb of location-5 was 0.57µg/g with minimum value 0.49 µg/g and maximum 0.67 µg/g (Table - 3.26). Pb showed very strong positive correlation with Mg (r = 0.839, p = 0.009) (Table - 3.36) in location -5. In the location-6, the mean of upper layers was 0.46 µg/g and lower was 0.47 µg/g (Table - 3.20b). Mean of the soil Pb of location-6 was 0.47 µg/g with minimum value 0.41µg/g and maximum 0.51µg/g (Table - 3.27). In this area, Pb showed very strong positive correlation with Fe (, r = 0.814, p = 0.014), (Table - 3.37). One-Way ANOVA showed that there was significant difference between upper and lower layers in Pb (Table - 3.29).

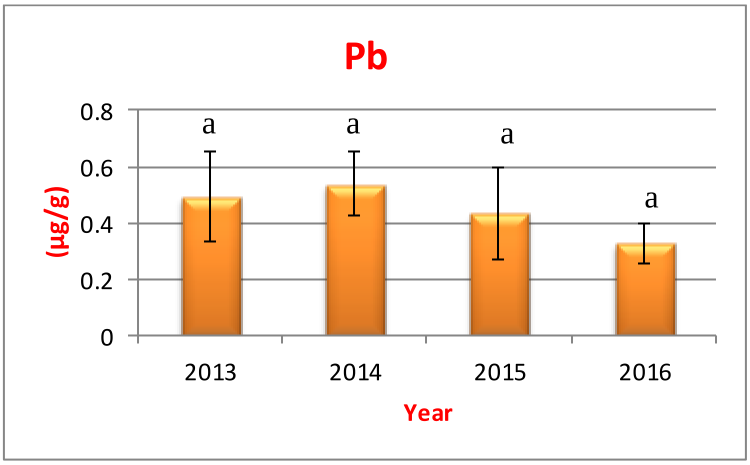

Fig-3.11. Overall mean and standard deviation of soil lead content of the study area from 2013 to 2016.

3.5.3.3 (2015)

The overall mean of upper layers was 0.46 µg/g and lower was 0.40 µg/g (Table - 3.40). Overall mean of the soil Pb of Nijhum Dwip was 0.43 µg/g with minimum value 0.17 µg/g and maximum 0.82 µg/g (Table - 3.47). Two way ANOVA showed that there was significant effects of locations and layers (P = 0.023) (Table - 3.50).

In location-1, mean of upper layers was 0.61 µg/g and lower was 0.47 µg/g (Table - 3.39.1b). Mean of the soil Pb of location-1 was 0.54 µg/g with minimum value 0.30 µg/g and maximum 0.81 µg/g (Table - 3.41). In case of location-2, mean of upper layers was

0.40 µg/g and lower was 0.42 µg/g (Table - 3.39.1b). High range of variation was found in location-2 where the mean value was 0.41 µg/g with minimum value 0.17 µg/g and maximum 0.71 µg/g (Table - 3.42). In location-3, mean of upper layers was 0.62 µg/g and lower was 0.42 µg/g (Table - 3.39.1b). Mean of the soil Pb of location-3 was 0.53 µg/g with minimum value 0.20 µg/g and maximum 0.77 µg/g (Table - 3.43). The mean of upper layers was 0.43 µg/g and lower was 0.40 µg/g (Table - 3.39.1b) in the location-4. Mean of the soil Pb of location-4 was 0.41 µg/g with minimum value 0.30 µg/g and maximum 0.57 µg/g (Table - 3.44). In the location-5, mean of upper layers was 0.40 µg/g and lower was 0.38 µg/g (Table - 3.39.1b). Mean of the soil Pb of location-5 was 0.38 µg/g with minimum value 0.28 µg/g and maximum 0.51 µg/g (Table - 3.45). In the location-6, mean of upper layers was 0.31 µg/g and lower was 0.29 µg/g (Table - 3.39.1 b). Mean of the soil Pb of location-6 was 0.30 µg/g with minimum value 0.27 µg/g and maximum 0.34 µg/g (Table - 3.46). One-Way ANOVA showed that there was significant difference between upper and lower layers in Lead (Pb) in all location (Table - 3.48).

3.5.3.4 (2016)

The overall mean of upper layers was 0.52 µg/g and lower was 0.54 µg/g (Table - 3.59). Mean of the soil Pb of Nijhum Dwip was 0.49 µg/g with minimum value 0.23 µg/g and maximum 0.87µg/g (Table - 3.66). Two way ANOVA showed that there was significant effects on locations (P=0.023) (Table - 3.69).

In the location-1, the mean of upper layers was 0.37 µg/g and lower was 0.38 µg/g (Table - 3.58.1b). Mean of the soil Pb of location-1 was 0.30 µg/g with minimum value 0.262 µg/g and maximum 0.40 µg/g (Table - 3.59). In case of location-2, the mean of upper layers was 0.46 µg/g and lower was 0.48 µg/g (Table - 3.58.1b). Mean of the soil Pb of location-2 was 0.47µg/g with minimum value 0.23 µg/g and maximum 0.77 µg/g

(Table - 3.60). The mean of upper layers was 0.28 µg/g and lower was 0.24 µg/g (Table - 3.58b) in the location-3. Mean of the soil Pb of location-3 was 0.26 µg/g with minimum value 0.12 µg/g and maximum 0.39 µg/g (Table - 3.61). In the location-4, the mean of upper layers was 0.178 µg/g and lower was 0.177 µg/g (Table - 3.58.1b). Mean of the soil Pb of location-4 was 0.177 µg/g with minimum value 0.146 µg/g and maximum 0.20 µg/g (Table - 3.63). In the location-5, the mean of upper layers was 0. 37 µg/g and lower was 0.36 µg/g (Table - 3.58.1b). Mean of the soil Pb of location-5 was 0.38 µg/g with minimum value 0.32 µg/g and maximum 0.42 µg/g (Table - 3.64). Here, Pb maintained significant positive correlation with Mn ($r = 0.751$, $p = 0.032$) (Table - 3.74). In the location-6, the mean of upper layers was 0.25 µg/g and lower was 0.26µg/g (Table - 3.58.1b). Mean of the soil Pb of location-6 was 0.258 µg/g with minimum value 0.221 µg/g and maximum 0.285 µg/g (Table - 3.65). One-Way ANOVA showed that there was no significant difference between upper and lower layers in Pb in all locations (Table - 3.67).

Hasan *et al.* (2013) found 18.09 mg/g Pb in Chittagong coast of Bay of Bengal. The amount of Pb found by other workers in SMF ranged from 10.96-61.66 mg/g (Ahmed *et al.* 2002) from 1.88-45.53 mg/g (Haque *et al.*2004) and from 9.97–25.61 mg/g (Kumar *et al.* 2016). The amount of Pb in SMF ranged from 0.41-0.78 mg/kg (Ataullah *et al.* 2018). The mean value (even minimum value) of soil Pb content exceeded the standard guideline of GESAMP (1982) which indicated the contamination form of Pb content in SMF soils.

3.5.4 Manganese (Mn)

Manganese concentration of soils of Nijhum Dwip showed gradual accumulation in the soil. The values increased from 180.74 in (2013) to 394.3 in 2016 (Fig 3.12)

3.5.4.1 (2013)

There were significant differences between 2013 and 2015, and 2013 and 2016. The mean concentration of Mn of upper layers of soils of Nijhum Dwip was 170.36 µg/g and lower was 191.11 µg/g (Table - 3.2). Mean of the soil Mn of Nijhum Dwip was 180.74 µg/g with minimum value 100.75 µg/g and maximum 314.60 µg/g (Table - 3.9). Location and layer showed significance interaction in case of Mn ($p = 0.004$, $F = 4.25$) (Table - 3.12). Mn showed strong positive correlation with Ca ($r = 0.495$, $p = 0.000$), (Table - 3.19).

In location-1, the mean of upper layers was 265.36 µg/g and lower was 204.53 µg/g (Table - 3.1b). Mean of the soil Mn was 234.9 µg/g with minimum value 183.8 µg/g and maximum 314.6 µg/g (Table - 3.3). Here, One-Way ANOVA showed that there was significant difference between upper and lower layers in Mn concentration ($F = 8.22$, $p = 0.029$) (Table - 3.10). In location-2, the mean of upper layers was 178.18 µg/g and lower was 159.18 µg/g (Table - 3.1b). Mean of the soil Mn was 168.7 µg/g with minimum value 111.9 µg/g and maximum 236.4 µg/g (Table - 3.4). The mean of upper layers was 175.54 µg/g and lower was 190.93 µg/g (Table - 3.1b) in the location-3. Mean of the soil Mn was 183.2 µg/g with minimum value 109.5 µg/g and maximum 260.1 µg/g (Table - 3.5). In location-4, the mean of upper layers was 154.64 µg/g and lower was 200.80 µg/g (Table - 3.1b). Mean of the soil Mn, was 248.5 µg/g with minimum value 144.4 µg/g and maximum 560.0 µg/g (Table - 3.6). One-Way ANOVA showed that there was significant difference between upper and lower layers ($F = 8.22$, $p = 0.000$) (Table - 3.10). The mean of upper layers was 154.64 µg/g and lower was 200.80 µg/g (Table - 3.1 b) in the location-5. Mean of the soil Mn was 164.8µg/g with minimum value 101.3 µg/g and maximum 225.1 µg/g (Table - 3.7). In this area, One-Way ANOVA showed that there was significant difference between upper and lower layers ($F = 8.22$, $p = 0.000$) (Table - 3.10). In case of location-6, the mean of upper layers was 118.95 µg/g and lower was 191.14 µg/g (Table - 3.1b). Mean of the soil Mn was 155.0µg/g with minimum value 100.8 µg/g and maximum 261.2 µg/g (Table - 3.8). Here, One-Way ANOVA showed that there was significant difference between upper and lower layer ((F = 6.42, p = 0.000)) (Table - 3.10).

3.5.4.2 (2014)

The mean of upper layers was 244.61 µg/g and lower was 311.16 µg/g (Table - 3.21). Mean of the soil Mn of Nijhum Dwip was 278.1 µg/g with minimum value 164.5 µg/g and maximum 462.1 µg/g (Table - 3.28). Mn showed strong positive correlation with Mg (r = 0.702, p = 0.000), Ca (r = 0.404, p = 0.004) (Table - 3.38).

In location-1, the mean of upper layers was 257.80 µg/g and lower was 331.31 µg/g (Table - 3.20b). Mean of the soil Mn of location-1 was 294.6 µg/g with minimum value 240.9 µg/g and maximum 313.68 µg/g (Table - 3.22). In case of location-2, the mean of upper layers was 244.43 µg/g and lower was 313.68 µg/g (Table - 3.20b). Mean of the soil Mn of location- 2 was 318.6 µg/g with minimum value 235.9 µg/g and maximum 401.0 µg/g (Table - 3.23). Here, Mn showed positive correlation with Mg (r = 0.769, p = 0.026) (Table - 3.33). In the location-3, the mean of upper layers was 216.04 µg/g and lower was 371.66 µg/g (Table - 3.20b). Mean of the soil Mn of location- 3 was 293.9 µg/g with minimum was 172.7 µg/g and maximum was 454.5 µg/g (Table - 3.24). In this year, Mn showed positive correlation with Mg (r = 0.885, p = 0.003) (Table - 3.34). In the location-4, the mean of upper layers was 263.69 µg/g and lower was 274.66 µg/g (Table - 3.20b). Mean of the soil Mn of location- 4 was 269.2 µg/g with minimum value 173.6µg/g and maximum 439.8µg/g (Table - 3.25). Here, Mn showed very strong positive correlation with Mg (r = 0.911, p = 0.001) (Table - 3.35). The mean of upper layers was 256.75 µg/g and lower was 289.02 µg/g (Table - 3.20b) in the location-5. Mean of the soil Mn of location- 5 was 272.9 µg/g with minimum value 209.1 µg/g and maximum 313.1 µg/g (Table - 3.26). In the location-6, the mean of upper layers was 267.34 µg/g and lower was 264.99 µg/g (Table - 3.20 b). Mean of the soil Mn of location-6 was 266.2 µg/g with minimum value 214.5 µg/g and maximum 356.8 µg/g (Table - 3.27). One-Way ANOVA showed that there was significant difference between upper and lower layer in Mn (Table - 3.29).

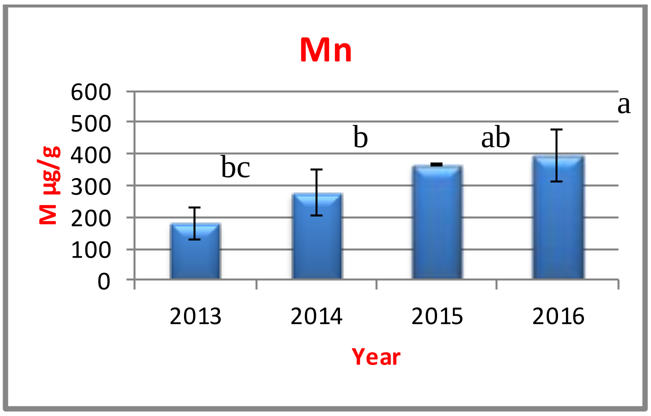

Fig.3.12. Overall mean and standard deviation of Manganese of soil of the study area from 2013 to 2016.

3.5.4.3 (2015)

In the location-1, mean of upper layers was 365.36 µg/g and lower was 420.11 µg/g (Table - 3.39.1b). Mean of the soil Mn of location-1 was 392.7 µg/g with minimum value 254.8 µg/g and maximum 483.8 µg/g (Table - 3.41). In case location-2, mean of upper layers was 320.93 µg/g and lower was 286.41 µg/g (Table - 3.39.1b). Mean of the soil Mn of location- 2 was 303.7 µg/g with minimum value 169.5 µg/g and maximum 404.4 µg/g (Table - 3.42). In location-3, mean of upper layer was 313.5 µg/g and lower was 212.0 µg/g (Table - 3.39.1b). Mean of the soil Mn of location-3 was 262.7µg/g with minimum value 102.5 µg/g and maximum 387.0 µg/g (Table - 3.43). The mean of upper layers was 215.34 µg/g and lower was 203.75 µg/g (Table - 3.39.1b) in the location-4. Mean of the soil Mn of location- 4 was 209.5 µg/g with minimum value 153.7µg/g and maximum 285.6 µg/g (Table - 3.44). In the location-5, mean of upper layers was 387.43

µg/g and lower was 391.51µg/g (Table - 3.39.1b). Mean of the soil Mn of location- 5 was 389.5 µg/g with minimum value 311.4 µg/g and maximum 557.3 µg/g (Table - 3.45). In location-6, mean of upper layers was 156.53 µg/g and lower was 147.01 µg/g (Table - 3.39.1b). Mean of the soil Mn of location- 6 was 151.77 µg/g with minimum value 135.05 µg/g and maximum 171.60 µg/g (Table - 3.46). There was significant difference between upper and lower layer in Mn in all location (Table - 3.48) through One-Way ANOVA .

3.5.4.4 (2016)

The mean of upper layers was 402.28 µg/g and lower was 386.23 µg/g (Table - 3.59). Mean of the soil Mn of Nijhum Dwip was 394.3 µg/g with minimum value 197.5µg/g and maximum 585.3 µg/g (Table - 3.66). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.001) (Table - 3.68). In the location-1, the mean of upper layers was 448.11 µg/g and lower was 393.36 µg/g (Table - 3.58.1b). Mean of the soil Mn of location- 1 was 420.7 µg/g with minimum value 282.8 µg/g and maximum 511.8 µg/g (Table - 3.59). The mean of upper layers was 348.93 µg/g and lower was 314.41 µg/g (Table - 3.58.1b) in the location-2. Mean of the soil Mn of location- 2 was 331.7µg/g with minimum value 197.50 µg/g and maximum 432.40 µg/g (Table - 3.60). In case location-3, the mean of upper layers was 392.54 µg/g and lower was 389.33 µg/g (Table - 3.58 a). Mean of the soil Mn of location- 3 was 390.90 µg/g with minimum value 317.30 µg/g and maximum 535.30 µg/g (Table - 3.61). In case of location-4, the mean of upper layers was 387.4 µg/g and lower was 351.7 µg/g (Table - 3.58.1b). Mean of the soil Mn of location- 4, was 369.5 µg/g with minimum value 251.3 µg/g and maximum 517.0 µg/g (Table - 3.63). In the location-5, the mean of upper layers was 419.51 µg/g and lower was 415.43 µg/g (Table - 3.58.1b). Mean of the soil Mn of location-5 was 417.5 µg/g with minimum value 339.4 µg/g and maximum 585.3µg/g (Table - 3.64). In the location-6, the mean of upper layers was 454.95 µg/g and lower was 415.45 µg/g (Table - 3.58.1b). Mean of the soil Mn of location- 6 was 435.2 µg/g with minimum value 384.1µg/g and maximum 499.6 µg/g (Table - 3.65).

Total Mn concentration 41.3±9.4 µg/g found in the SaiKeng, Hong Kong, 509.2 ± 37.1 µg/g in the Shenzhen, People's Republic of China (Tam and Wong 1996). The amount of Mn in Char Tamaruddin ranged from 6.30-15.5 mg/kg where mean value was 12.62 mg/kg (Das 2012). Hasan *et al.* (2013) found 938.27 mg/g Mn in Chittagong coast of Bay of Bengal. The amount of Mn in SMF ranged from 95.8 – 1000.6 mg/g (Ahmed *et al.*2002) and 389.43–696.33 mg/g (Kumar *et al.* 2016). The amount of Mn in SMF ranged from 0.45-0.99 mg/kg and mean value was 0.77 mg/kg (Ataullah *et al.* 2018).

3.5.5 Magnesium (Mg)

The mean concentration of Mg was gradually increased during the study period of the soils of Nijhum Dwip. There were no significant difference between the values of 2013 and 2014, but they both showed significant differences with the values of Mg concentration of 2015 and 2016 respectively (Fig.3.13)

3.5.5.1 (2013)

The mean value of Magnesium of upper layers of soils was 244.89 µg/g and lower was 213.81 µg/g (Table - 3.2). Mean of the soil Mg of Nijhum Dwip was 229.4 µg/g with minimum value 113.7 µg/g and maximum 560.0 µg/g (Table - 3.9). Magnesium showed positive significant correlation with Ca ($r = 0.495$, $p = 0.002$) (Table - 3.19).

In location-1, the mean of upper layers was 285.54 µg/g and lower was 286.02 µg/g (Table - 3.1b). Overall mean of the soil Mg was 285.8 µg/g with minimum value 213.7 µg/g and maximum 398.5 µg/g (Table - 3.3). The mean of upper layers was 290.43 µg/g and lower was 208.68 µg/g (Table - 3.1b) in the location-2. Mean of the soil Mg was

249.6 µg/g with minimum value 148.5 µg/g and maximum 359.4 µg/g (Table - 3.4). In the location-3, the mean of upper layers was 217.28 µg/g and lower was157.43 µg/g (Table - 3.1b). Mean of the soil Mg was 187.4 µg/g with minimum value 113.7µg/g and maximum 262.3µg/g (Table - 3.5). Mg maintained strong significant positive correlation with Ca ($r = 0.965$, $p = 0.000$) (Table - 3.15) in here. In the location-4, the mean of upper layers was 312.0 µg/g and lower was 185.0 µg/g (Table - 3.1b). Mean of the soil Mg was 282.10 µg/g with minimum value 221.50 µg/g and maximum 383.70 µg/g (Table - 3.6). In this area Mg maintained significant very strong positive correlation with Fe ($r = 0.803$, $p = 0.016$), Ca ($r = 0.832$, $p = 0.010$) (Table - 3.16). The mean of upper layers was 277.71 µg/g and lower was 198.36 µg/g (Table - 3.1b) in the location-5. Mean of the soil Mg was 238.0 µg/g with minimum value 152.4 µg/g and maximum 477.3 µg/g (Table - 3.7). In the location-6, the mean of upper layers was 166.12 µg/g and lower was 167.62 µg/g (Table - 3.1b). Mean of the soil Mg was 166.9 µg/g with minimum value 125.4 µg/g and maximum 233.4 µg/g (Table - 3.8). One-Way ANOVA showed that there was significant difference between upper and lower layer in all location in Mg (Table - 3.10).

3.5.5.2 (2014)

The mean of upper layers was 292.87 µg/g and lower was 311.61 µg/g (Table - 3.21). Mean of the soil Mg of Nijhum Dwip was 320.5 µg/g with minimum value 164.5 µg/g and maximum 555.8 µg/g (Table - 3.28).

In the location-1, the mean of upper layers was 400.9 µg/g and lower was 331.3 µg/g (Table - 3.20b). Overall mean of the soil Mg of location-1 was 366.1 µg/g with minimum value 234.5 µg/g and maximum 520.1 µg/g (Table - 3.22). In case of location-2, the mean of upper layers was 427.8 µg/g and lower was 413.7 µg/g (Table - 3.20 b). Mean of the soil Mg of location-2 was 425.1µg/g with minimum value 231.5 µg/g and maximum 620.3 µg/g (Table - 3.23). In the location-3, the mean of upper layers was 241.5 µg/g and lower was 371.7 µg/g (Table - 3.20b). Mean of the soil Mg of location-3 was 306.6 µg/g with minimum value 172.7 µg/g and maximum 454.5 µg/g (Table - 3.24). In location-4, the mean of upper layers was 294.73 µg/g and lower was 283.48 µg/g (Table - 3.20b). Mean of the soil Mg of location-4 was 289.1 µg/g with minimum value 221.5 µg/g and maximum 439.8 µg/g (Table - 3.25). In case of location-5, the mean of upper layers was 300.74 µg/g and lower was 289.02 µg/g (Table - 3.20b). Mean of the soil Mg of location-5 was 294.9 µg/g with minimum value 248.6 µg/g and maximum 339.6 µg/g (Table - 3.26). In the location-6, the mean of upper layers was 231.21 µg/g and lower was 264.99 µg/g (Table - 3.20b). Mean of the soil Mg of location-6 was lowest among the locations where the value was 248.1 µg/g with minimum value 205.7 µg/g and maximum 356.8 µg/g (Table - 3.27). One-Way ANOVA showed that there was no significant difference between upper and lower layer in Mn (Table - 3.29) in all locations.

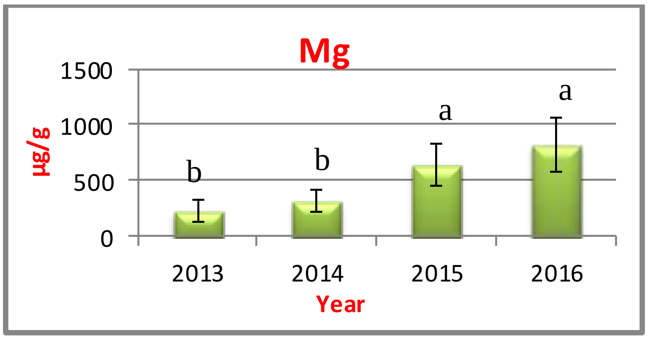

Fig.3.13. Overall mean and standard deviation of soil Magnesium of the study area from 2013 to 2016.

3.5.5.3 (2015)

The overall mean of upper layers was 713.7 µg/g and lower was 574.8 µg/g (Table - 3.40). Overall mean of the soil Mg of Nijhum Dwip was 644.2 µg/g with minimum value 252.1 µg/g and maximum 1210.9 µg/g (Table - 3.47). One-Way ANOVA showed that there was significant difference between upper and lower layer (p = 0.009) (Table - 3.48).

In the location-1, mean of upper layers was 713.7 µg/g and lower was 490.7 µg/g (Table - 3.39.1 b). Magnesium concentration of location-1 was 602.2 µg/g with the minimum value 344.5 µg/g and maximum 861.8 µg/g (Table - 3.41). One-Way ANOVA showed that there was significant difference between upper and lower layers (p = 0.042) (Table - 3.48). In location-2, mean of upper layer was 663.1 µg/g and lower was 558.2 µg/g (Table - 3.39.1b). Mean of the soil Mg of location-2 was 610.6 µg/g with minimum value 252.1 µg/g and maximum 921.7 µg/g (Table - 3.41). In case of location-3, mean of upper layer was 364.54 µg/g and lower was 361.33 µg/g (Table - 3.39.1 b). Mean of the soil Mg of location-3 was 362.9 µg/g with minimum value 289.3 µg/g and maximum 507.3 µg/g (Table - 3.43). The mean of upper layer was 323.7 µg/g and lower was 359.4 µg/g (Table - 3.39.1b) in the location-4. Mean of the soil Mg of location-4 was 341.5 µg/g with minimum value 223.3 µg/g and maximum 489.0 µg/g (Table - 3.44). In the location-5, mean of upper layers was 896.0 µg/g and lower was 616.4 µg/g (Table - 3.39.1b). Mean of the soil Mg of location-5 was 756.2 µg/g with minimum value 506.1 µg/g and maximum 1210.9 µg/g (Table - 3.45). In the location-6, mean of upper layers was 387.45 µg/g and lower was 426.95 µg/g (Table - 3.39.1b). Mean of the soil Mg of location-6 was 407.2 µg/g with minimum value 356.1 µg/g and maximum 471.6 µg/g (Table - 3.46).

3.5.5.4 (2016)

The mean values of Mg of upper layers was 888.60 µg/g and lower was 749.70 µg/g (Table - 3.59). Overall mean of the soil Mg of Nijhum Dwip was 819.1 µg/g with the minimum value 427.00 µg/g and maximum 1385.80 µg/g (Table - 3.66). Two way ANOVA showed that there was significant effects of layer (p =0.006) (Table - 3.69).

In location-1, the mean of upper layers was 888.70 µg/g and lower was 665.70 µg/g (Table - 3.58.1b). Mean of the soil Mg of location-1 was 777.20 µg/g with minimum value 519.40 µg/g and maximum 1036.70 µg/g (Table - 3.59). Here, Mg showed positive correlation with Fe (r = 0.726, p = 0.042) (Table - 3.70). In case of location-2, the mean of upper layers was 838.00 µg/g and lower was 733.10 µg/g (Table - 3.58.1b). Mean of the soil Mg of location-2 was 785.6 µg/g with minimum value 427.00 µg/g and maximum 1096.60 µg/g (Table - 3.60). One-Way ANOVA showed that there was strongly significant difference between upper and lower layer (p = 0.042) (Table - 3.67). In location-3, the mean of upper layers was 828.30 µg/g and lower was 687.80 µg/g (Table - 3.58.1b). Mean of the soil Mg of location-3 was 758.10 µg/g with minimum value 621.00 µg/g and maximum 1031.10 µg/g (Table - 3.61). In the location-4, the mean of upper layers was 779.80 µg/g and lower was 950.00 µg/g (Table - 3.58.1b). Mean of the soil Mg of location-4 was 864.90 µg/g with minimum value 700.20 µg/g and maximum 1158.80 µg/g(Table - 3.63). In location-5, the mean of upper layers was 1070.90 µg/g and lower was 791.30 µg/g (Table - 3.58.1b). Mean of the soil Mg of location-5 was 931.10 µg/g with minimum value 681.00 µg/g and maximum1385.80 µg/g (Table - 3.64). In the location-6, the mean of upper layers was 926.00 µg/g and lower was 670.20 µg/g (Table - 3.58 a). Mean of the soil Mg of location-6 was 798.10 µg/g with minimum value 499.90 µg/g and maximum 1299.90 µg/g (Table - 3.65). In this area, Mg maintained significant negative correlation with Fe (, r = -0.698, p = 0.054) (Table - 3.74).

Present study showed almost similar concentration of Mg of the soil of different chars at Rangabali, Patuakhali (Ahmed *et al.* 2010a) who reported 0.111 – 1.016% Mg but the value were very high than those of char Tamaruddin, Rangabali and SMF of Bangladesh. The mean value of Mg content was 177.3 mg/kg with minimum value 46.5

mg/kg and maximum value 271.1 mg/kg in Char Tamaruddin (Das, 2012). Ukpong (2000) reported 5.2 ± 0.1 - 24.6 ±2 .0 mg per 100g (mean ± sd) Magnesium in some Nigerian mangroves. The amount of Mg in SMF ranged from 1.9 - 4.23 mg/kg and mean value was 2.74 mg/kg. The Fe content of the SMF soils showed variation among locations. The mean values of soil Mg of upper and lower layers of oligohaline zone were 2.793 mg/kg and 2.695 mg/kg, mesohaline zone were 2.568 mg/kg and 2.520 mg/kg, polyhaline zone were 2.920 mg/kg and 2.994 mg/kg respectively (Ataullah *et al.* 2018).

3.5.6 Iron (Fe)

The Fe content of soil of Nijhum Dwip showed variation among the locations. The value of soil Iron was lower in 2013 and it gradually increased during the study period (Fig. 3.14).

3.5.6.1 (2013)

The mean of upper layers was 7215.60 µg/g and lower was 7380.00 µg/g (Table - 3.2). Mean of the soil Fe of Nijhum Dwip was 7297.80 µg/g with minimum value 6034.10 µg/g and maximum 9011.90 µg/g (Table - 3.9).

In the location-1, the mean of upper layers was 6655.00 µg/g and lower was 7609.10 µg/g (Table - 3.1b). Mean of the soil Fe of location- 1 was 7132 µg/g with minimum value 6116 µg/g and maximum 7906 µg/g (Table - 3.3). The mean of upper layers was 7491.8 µg/g and lower was 7235.5 µg/g (Table - 3.1b) in the location-2. Mean of the soil Fe was 7364 µg/g with minimum value 6034 µg/g and maximum 7952 µg/g (Table - 3.4). Here, Fe maintained significant positive correlation with Zn ($r = 0.736$, $p = 0.037$) (Table - 3.14). In the location-3, mean of upper layers was 7405.5 µg/g and lower was 7477.9 µg/g (Table - 3.1b). Mean of the soil Fe was 7222 µg/g with minimum value 6309 µg/g and maximum 7949 µg/g (Table - 3.5). In location-4, the mean of upper layers was 7477.90 µg/g and lower was 7437.90 µg/g (Table - 3.1b). Mean of the soil Fe was 7458 µg/g with minimum value 6806 µg/g and maximum 8850 µg/g (Table - 3.6). In this area, Iron maintained significant positive correlation with Zn (r = 0.762, p = 0.028) (Table - 3.16). In location-5, the mean of upper layers was 7491.80 µg/g and lower was 7235.50 µg/g (Table - 3.1b). Mean of the soil Fe was 7196 µg/g with minimum value 6579 µg/g and maximum 7845 µg/g (Table - 3.7). The mean of upper layers was 7378 µg/g and lower was 7454 µg/g (Table - 3.1b) in the location-6. Mean of the soil Fe of location- 6 was 7416 µg/g with minimum value 6387 µg/g and maximum 9012 µg/g (Table - 3.8). One-Way ANOVA showed that there was no significant difference between upper and lower layers in all location in Fe (Table - 3.10).

3.5.6.2 (2014)

In location-1, the mean of upper layers was 7822.60 µg/g and lower was 7767.40 µg/g (Table - 3.20b). Mean of the soil Fe of location- 1 was 7795 µg/g with minimum value 7178µg/g and maximum 8339 µg/g (Table - 3.22). In thelocation-2, the mean of upper layers was 7859.6 µg/g and lower was 8004.3 µg/g (Table - 3.20b). Mean of the soil Fe of location- 2 was 7795 µg/g with minimum value 7178 µg/g and maximum 8339 µg/g (Table - 3.23). The mean of upper layers was 7945.9 µg/g and lower was 8112.0 µg/g(Table - 3.20b) in thelocation-3. Mean of the soil Fe of location- 3 was 8029 µg/g with minimum value 7602 µg/g and maximum 8470 µg/g (Table - 3.24). In thelocation-4, the mean of upper layers was 7826.70 µg/g and lower was 7937.00 µg/g (Table - 3.20b). Mean of the soil Fe of location- 4 was 7881.80 µg/g with minimum value 7490.20 µg/g and maximum 8161.10 µg/g (Table - 3.25). In case oflocation-5, the mean of upper layers was 7843.90 µg/g and lower was 8011.20 µg/g (Table - 3.20b). Mean of the soil Fe of location- 5 was 7928 µg/g with minimum value 7481 µg/g and maximum 8426 µg/g (Table - 3.26). In location-6, the mean of upper layers was 7795.80 µg/g and lower was 7916.60 µg/g (Table - 3.20b). Mean of the soil Fe of location- 6 was 7856 µg/g with minimum value 7131 µg/g and maximum 8431 µg/g (Table - 3.27). One-Way ANOVA showed that there was significant difference between upper and lower layer in Fe (Table - 3.29).

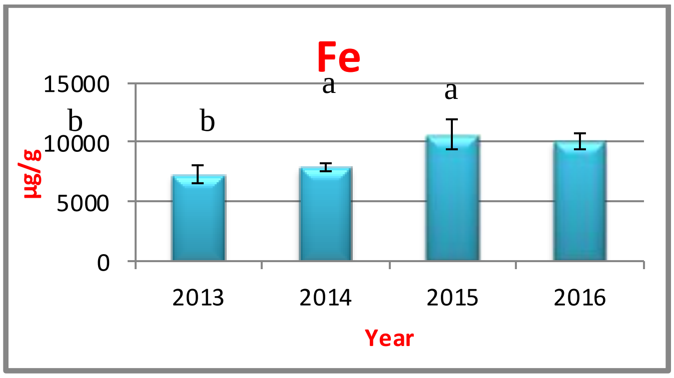

Fig.3.14. Overall mean and standard deviation of soil Iron of the study area from 2013 to 2016

3.5.6.3 (2015)

The mean of upper layers was 10539 µg/g and lower was 10836 µg/g (Table - 3.40). Overall mean of the soil Fe of Nijhum Dwip was 10688 µg/g with minimum value 7856 µg/g and maximum 14239 µg/g (Table - 3.47).

In location-1, mean of upper layers was 9348 µg/g and lower was 8767 (µg/g) (Table - 3.39.1b). Mean of the soil Fe of location- 1 was 9058 µg/g with minimum value 8056 µg/g and maximum 9732 µg/g (Table - 3.41). One-Way ANOVA showed that there was significant difference between upper and lower layer ($p = 0.008$) (Table - 3.48). In location-1, Fe maintained significant positive correlation with k ($r = 0.712$, $p = 0.048$) (Table - 3.51). The mean of upper layers was 9860 µg/g and lower was 11004 µg/g (Table - 3.39.1b) in the location-2. Mean of the soil Fe of location- 2 was 10432 µg/g with minimum value 9497 µg/g and maximum 14293 µg/g (Table - 3.42). In case of location-3, mean of upper layers was 10946 µg/g and lower was 11112µg/g (Table - 3.39.1b). Mean of the soil Fe of location- 3 was 11029 µg/g with minimum value 9602 μg/g and maximum 12470 μg/g (Table - 3.43). In the location-4, mean of upper layers was 10465 μg/g and lower was 10894 μg/g (Table - 3.39.1b). Mean of the soil Fe of location- 4 was 10679 μg/g with minimum value 7983μg/g and maximum 12054 μg/g (Table - 3.44). The mean of upper layers was 10344 μg/g and lower was 11511 μg/g (Table - 3.39.1b) in the location-5. Mean of the soil Fe of location- 5 was 10928 μg/g with minimum value 9561 μg/g and maximum 12426 μg/g (Table - 3.45). In the location-6, mean of upper layers was 10296 μg/g and lower was 10731 μg/g (Table - 3.39.1b). Mean of the soil Fe of location- 6 was 10513 μg/g with minimum value 7856 μg/g and maximum 12411 μg/g (Table - 3.46).

3.5.6.4 (2016)

The mean of Fe content of upper layers was 9882 μg/g and lower was 10266 μg/g (Table - 3.59). Overall mean of the soil Fe of Nijhum Dwip was 10074 μg/g with the minimum value 8850 μg/g and maximum 12034 μg/g (Table - 3.66).

In the location-1, the mean of upper layers was 10155 μg/g and lower was 9609 μg/g (Table - 3.58.1b). Mean of the soil Fe of location- 1 was 9882 μg/g with minimum value 9103 μg/g and maximum 10409 μg/g (Table - 3.59). Here, Fe maintained significant positive correlation with Zn ($r = 0.748$, $p = 0.033$) and negative correlation with Ca ($r = -0.767$, $p = 0.026$) (Table - 3.70). The mean of upper layer was 9492 μg/g and lower was 10236 μg/g (Table - 3.58.1b) in the location-2. Mean of the soil Fe of location- 2 was 9864 μg/g with minimum value 9332 μg/g and maximum 12034 μg/g (Table - 3.60). In the location-3, the mean of upper layers was 10036 μg/g and lower was 10408 μg/g (Table - 3.58.1b). Mean of the soil Fe of location-3 was 10222 μg/g with minimum value 9472 μg/g and maximum 11087 μg/g (Table - 3.62). In the location-4, the mean of upper layers was 9978 μg/g and lower was 10438 μg/g (Table - 3.58.1b). Mean of the soil Fe of location- 4 was 10208 μg/g with minimum value 8850 μg/g and maximum

11242 µg/g (Table - 3.63). In location-5, the mean of upper layers was 9756 µg/g and lower was 10635 µg/g (Table - 3.58.1b). Mean of the soil Fe of location- 5 was 10196 µg/g with minimum value 9404 µg/g and maximum 11081 µg/g (Table - 3.64). In the location-6, the mean of upper layers was 9878 µg/g and lower was 10269 µg/g (Table - 3.58a). Mean of the soil Fe of location- 6 was 10073 µg/g with minimum value 9006 µg/g and maximum 11309 µg/g (Table - 3.65).

Very high amount of Fe was found in the present study than that of Das (2012) who reported the amount of Fe of the soils of Char Tamaruddin ranged from 52.0 - 685 mg/kg where mean value was 299.4 mg/kg where as in the soils of the Zhaigan Mangrove Nature Reserve, China where *Sonneratia apetala* plantations were taken place, the values were almost similar to the present study and it was 17.61 g/kg (Ren *et al.* 2009) found. Hasan *et al.* (2013) found almost 5 times more Fe content (58959.09 mg/g) in the Chittagong coast of Bay of Bengal. Other authors have found the amount of Fe in SMF ranged from 501.5-3985.2 mg/g (Ahmed *et al.*2002), from 1198.66-12984.35 mg/g (Haque *et al.* 2004) and from 2.29–4.22 % (Kumar *et al.* 2016). Ataullah *et al. (*2018) found mean of the soil Fe of SMF was 4.76 mg/kg with minimum value 0.54 mg/kg and maximum 6.9 mg/kg. The Fe content of the SMF soils showed variation among locations. The mean values of soil Fe of upper and lower layers of oligohaline zone were 4.452 mg/kg and 4.327 mg/kg, mesohaline zone were 4.561 mg/kg and 4.622 mg/kg, polyhaline zone were 5.765 mg/kg and 5.815 mg/kg (Ataullah *et al.* 2018).

3.5.7 Calcium (Ca)

Calcium concentration of soil of Nijhum Dwip gradually increased where the values of 2013 were significantly lower than those of the values of 2015 and 2016 (Fig**.** 3.15)

3.5.7.1 (2013)

The mean of Ca concentration of soil of upper layers was 292.87 µg/g and lower was 305.98 µg/g (Table - 3.2). Mean of the soil Ca of SMF was 299.40 µg/g with minimum value 164.50 µg/g and maximum520.1 µg/g (Table - 3.9).

In the location-1, the mean of upper layers was 400.90 µg/g and lower was 331.30 µg/g (Table - 3.1b). Mean of the soil Ca was 366.10 µg/g with minimum value 234.50 µg/g and maximum 520.10 µg/g (Table - 3.3). In location-2, the mean of upper layers was 317.80 µg/g and lower was 313.70 µg/g (Table - 3.1b). Mean of the soil Ca was 315.70 µg/g with minimum value 164.50 µg/g and maximum 476.70 µg/g (Table - 3.4). In case of location-3, the mean of upper layers was 241.50 µg/g and lower was 371.70 µg/g (Table - 3.1b). Mean of the soil Ca was 306.60 µg/g with minimum value 172.70 µg/g and maximum 454.50 µg/g (Table - 3.5). In location-4, the mean of upper layers was 265.19 µg/g and lower was 298.98 µg/g (Table - 3.1b). Mean of the soil Ca was 163.00 µg/g with minimum value 100.50 µg/g and maximum 251.00 µg/g (Table - 3.6). The mean of upper layers was 300.74 µg/g and lower was 289.02 µg/g (Table - 3.1b) in the location-5. Mean of the soil Ca was 294.90 µg/g with minimum value 248.60 µg/g and maximum 339.60 µg/g (Table - 3.7). Here, Ca maintained significant negative correlation with Zn ($r = 0.834$, $p = 0.010$) (Table - 3.17). In the location-6, the mean of upper layers was 231.21 µg/g and lower was 231.21 µg/g (Table - 3.1b). Mean of the soil Ca of location- 6 was 231.21 µg/g with minimum value 205.68 µg/g and maximum 240.13 µg/g (Table - 3.8). There was no significant difference between upper and lower layer in all location in Calcium (Ca) (Table - 3.10) through One-Way ANOVA.

3.5.7.2 (2014)

The mean of upper layers was 507.90 µg/g and lower was 716.20 µg/g (Table - 3.21). Mean of the soil Ca of Nijhum Dwip was 612.10µg/g with minimum value 262.30 µg/g and maximum 922.60 µg/g (Table - 3.28). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.000) (Table - 3.29). Two way ANOVA showed that there was significant effects of layers (P = 0.000) (Table - 3.31). Calcium showed negative correlation with Zn (r = -0.374, p =0.009) (Table - 3.38)

In location-1, the mean of upper layers was 406.23 µg/g and lower was 753.60 µg/g (Table - 3.20b). Mean of the soil Ca was 579.90 µg/g with minimum value 358.10 µg/g and maximum 857.60 µg/g (Table - 3.22). In location-1, there was highly significant difference between upper and lower layer (P= 0.000) (Table - 3.32). In location-2, the mean of upper layer was 462.96 µg/g and lower was 656.09 µg/g (Table - 3.20 b). Mean of the soil Ca of location- 2 was 592.50 µg/g with minimum value 421.60 µg/g and maximum 722.60 µg/g (Table - 3.23). In case of location-3, the mean of upper layers 541.90 µg/g and lower was 656.10 µg/g (Table - 3.20 b). Mean of the soil Ca of location- 3 was 599.00 µg/g with minimum value 427.60 µg/g and maximum 782.60 µg/g (Table - 3.24). In location-4, the mean of upper layers was 583.65 µg/g and lower was 729.75 µg/g (Table - 3.20b). Mean of the soil Ca of location- 4 was 656.70 µg/g with minimum value 510.70 µg/g and maximum 680.40 µg/g (Table - 3.25). The mean of upper layers was 567.60 µg/g and lower was 680.40 µg/g (Table - 3.20b) in the location-5. Mean of the soil Ca of location- 5 was 624.00 µg/g with minimum value 485.60 µg/g and maximum 810.80 µg/g (Table - 3.26). In the location-6, the mean of upper layers was 601.00 µg/g and lower was 946.40 µg/g (Table - 3.20b). Mean of the soil Ca of location- 6 was 636.20 µg/g with minimum value 527.60 µg/g and maximum 771.00 µg/g (Table - 3.27).

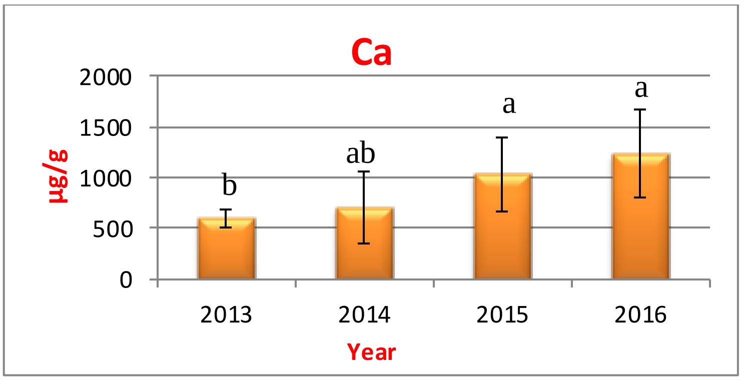

Fig.3.15. Overall mean and standard deviation of soil Calcium of the study area from 2013 to 2016.

3.5.7.3 (2015)

The mean of upper layers was 902.70 µg/g and lower was 1177.10 µg/g (Table - 3.40). Overall mean of the soil Ca of Nijhum Dwip was 1039.8 µg/g with minimum value 314.30 µg/g and maximum 1921.70 µg/g (Table - 3.47). One-Way ANOVA showed that was significant difference between upper and lower layer (p = 0.029) (Table - 3.49). Location and layer showed significance interaction in case of Ca (P = 0.040, F = 2.63) (Table - 3.50).

In the location-1, mean of upper layers was 1093.50 µg/g and lower was 1527.70 µg/g (Table - 3.39.1 b). Mean of the soil Ca of location-1 was 1311.00 µg/g with minimum value 656.0 µg/g and maximum1856.0 µg/g (Table - 3.41). In location-2, mean of upper layers was 738.0 µg/g and lower was 1649.2 µg/g (Table - 3.39.1b). Mean of the soil Ca of location- 2 was 1194 µg/g with minimum value 522.00 µg/g and maximum 1922.00 µg/g (Table - 3.42). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.004) (Table - 3.48). The mean of upper layers was 869.80 µg/g and lower was 803.00 µg/g (Table - 3.39.1b) in the location-3. Mean of the soil Ca of location- 3 was 836 µg/g with minimum value 446 µg/g and maximum 1437 µg/g (Table - 3.43). In the location-4, mean of upper layers was 893.25 µg/g and lower was 670. 1µg/g (Table - 3.39.1 b).Mean of the soil Ca of location- 4 was 782 µg/g with minimum value 314 µg/g and maximum 12054 µg/g (Table - 3.44). In case of location-5, mean of upper layer was 821.0 µg/g and lower was 1316.4 µg/g (Table - 3.39.1 b). Mean of the soil Ca of location- 5 was 1069.00 µg/g with minimum value 686.00 µg/g and maximum 1693.00 µg/g (Table - 3.45). One-Way ANOVA showed that there was significant difference between upper and lower layer (p = 0.034) (Table - 3.48). In the location-6, mean of upper layers was 1001.00 µg/g and lower was 1095.30 µg/g (Table - 3.39.1b).Mean of the soil Ca of location- 6 was 1048 µg/g with minimum value 486 µg/g and maximum 1627 µg/g (Table - 3.46).

3.5.7.4 (2016)

The mean of upper layers was 1102.70 µg/g and lower was 1377.00 µg/g (Table - 3.59). Mean of the soil Ca of Nijhum Dwip was 1239.80 µg/g with minimum value 514.30 µg/g and maximum 2121.70 µg/g (Table - 3.66). Two way ANOVA showed that there was significant effects of layers (P = 0.013), Interactions (P = 0.040) (Table - 3.69).

In the location-1, the mean of upper layers was 1293.50 µg/g and lower was 1727.70 µg/g (Table - 3.58a). Mean of the soil Ca of location-1 was 1511.00 µg/g with minimum value 856.00 µg/g and maximum 2056.00 µg/g (Table - 3.59). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.000) (Table - 3.68). In location-2, the mean of upper layers was 938.00 µg/g and lower was 1849.20 µg/g (Table - 3.58.1b). Mean of the soil Ca of location- 2 was 1394.00 µg/g with minimum value 722.00 µg/g and maximum 2122.00 µg/g (Table - 3.60). One-Way ANOVA showed that there was significant difference between upper and lower layers (P = 0.004) (Table - 3.67) in this area. The mean of upper layers was 1069.80 µg/g and lower was 1003.00 µg/g (Table - 3.58.1b) in the location-3. Mean of the soil Ca of location- 3 was 1036 µg/g with minimum value 646.00 µg/g and maximum 1637.00

µg/g (Table - 3.62). In case of location-4, the mean of upper layers was 1093.20 µg/g and lower was 870.10 µg/g (Table - 3.58.1b). Mean of the soil Ca of location- 4 was 982.0 µg/g with minimum value 514.0 µg/g and maximum 1391.0 µg/g (Table - 3.63). In the location-5, the mean of upper layers was 1021.00 µg/g and lower was 1516.40 µg/g (Table - 3.58.1b). Mean of the soil Ca of location- 5 was 1269.00 µg/g with minimum value 886.00 µg/g and maximum 1893.00 µg/g (Table - 3.64). The mean of upper layers was 1201.00 µg/g and lower was 1295.30 µg/g (Table - 3.58.1b) in the location-6. Mean of the soil Ca of location- 6 was 1248.0 µg/g with the minimum value 686.0 µg/g and maximum 1827.0 µg/g (Table - 3.65).

The amount of Ca in SMF ranged from 0.21 – 2.09 mg/kg and mean value was 1.02 mg/kg and the mean values of soil Ca of upper and lower layers of oligohaline zone were 1.195 mg/kg and 1.160 mg/kg, mesohaline zone were 0.810 mg/kg and 0.795 mg/kg, polyhaline zone were 0.908 mg/kg and 0.878 mg/kg respectively (Ataullah *et al.* 2018).

3.5.8 Zinc (Zn)

Zn is one of the earliest known trace metal**.** Zinc concentration of soils of Nijhum Dwip was found to increase gradually although significant difference existed only between values of 2013 and 2016 (Fig.3.16)

3.5.8.1 (2013)

The mean values of Zn concentration of soils of upper layers was 179.63 µg/g and lower was 198.00 µg/g (Table - 3.2). Mean of the soil Zn of Nijhum Dwip was 188.81 µg/g with minimum value 71.90 µg/g and maximum 295.00 µg/g (Table - 3.9).

In location-1, the mean of upper layers was 204.75 µg/g and lower was 194.23 µg/g (Table - 3.1b). Mean of the soil Zn was 183.95 µg/g with minimum value 87.9 µg/g and maximum 280.0 µg/g (Table - 3.3). The mean of upper layer was 194.13 µg/g and lower was 213.00 µg/g (Table - 3.1b) in the location-2. Mean of the soil Zn was 203.60 µg/g with minimum value 109.50 µg/g and maximum 292.50 µg/g (Table - 3.4). In the location-3, the mean of upper layers was 187.13 µg/g and lower was 173.00 µg/g (Table - 3.1 b). Mean of the soil Zn was 180.1µg/g with minimum value 105.50 µg/g and maximum 239.50 µg/g (Table - 3.5). In case of location-4, the mean of upper layers was 139.51 µg/g and lower was 186.50 µg/g (Table - 3.1 b). Mean of the soil Zn was 177.72 µg/g with minimum value 146.05 µg/g and maximum 201.55 µg/g (Table - 3.6). In the location-5, the mean of upper layers was 182.75 µg/g and lower was 172.00 µg/g (Table - 3.1b). Mean of the soil Zn was 177.40 µg/g with minimum value 105.00 µg/g and maximum 270.50 µg/g (Table - 3.7). In location-6, the mean of upper layers was 169.50 µg/g and lower was 249.25 µg/g (Table - 3.1b). Mean of the soil Zn was 209.40 µg/g with minimum value 101.00 µg/g and maximum 284.00 µg/g (Table - 3.8). One-Way ANOVA showed that there was no significant difference between upper and lower layers in Zn in locations.

3.5.8.2 (2014)

The mean of upper layers was 242.73 µg/g and lower was 209.87 µg/g (Table - 3.21). Mean of the soil Zn of Nijhum Dwip was 226.30 µg/g with minimum value 105.50 µg/g and maximum 341.00 µg/g (Table - 3.28).

In the location-1, the mean of upper layers was 257.00 µg/g and lower was 206.73 µg/g (Table - 3.20b). Mean of the soil Zn of location-1 was 231.90 µg/g with minimum value 121.9 µg/g and maximum 333.5 µg/g (Table - 3.22). In case of location-2, the mean of upper layers was 241.38 µg/g and lower was 231.25 µg/g (Table - 3.20 b). Mean of the soil Zn of location-2 was 236.3 µg/g with minimum value 136.00 µg/g and maximum 336.00 µg/g (Table - 3.23). In location-3, the mean of upper layers was 245.75 µg/g and lower was 209.25 µg/g (Table - 3.20b). Mean of the soil Zn of location-3 was 227.5 µg/g with minimum value 170.00 µg/g and maximum 271.00 µg/g (Table - 3.24). In the location-4, the mean of upper layers was 256.38 µg/g and lower was 228.38 µg/g (Table - 3.20b). Mean of the soil Zn of location-4 was 242.40 µg/g with minimum value 140.50 µg/g and maximum 341.00 µg/g (Table - 3.25). In case of location-5, the mean of upper layers was 241.13 µg/g and lower was 207.75 µg/g (Table - 3.20b). Mean of the soil Zn of location-5 was 224.40 µg/g with minimum value 155.5 µg/g and maximum 267.00 µg/g (Table - 3.26). In the location-6, the mean of upper layers was 216.01 µg/g and lower was 158.38 µg/g (Table - 3.20b). Mean of the soil Zn of location-6 was 187.2 µg/g with minimum value 105.50 µg/g and maximum 311.50 µg/g (Table - 3.27). One-Way ANOVA showed that there was significant difference between upper and lower layers in Fe concentration (Table - 3.29).

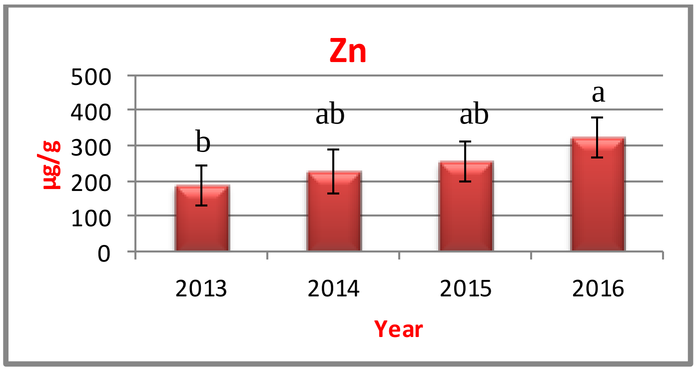

Fig. 3.16. Overall mean and standard deviation of soil Zinc of the study area from 2013 to 2016

3.5.8.3 (2015)

The mean of upper layers was 238.38 µg/g and lower was 271.98 µg/g (Table - 3.40). Overall mean of the soil Zn of Nijhum Dwip was 255.18 µg/g with minimum value 134.50 µg/g and maximum 370.50 µg/g (Table - 3.47). One-Way ANOVA showed that there was significant difference between upper and lower layer (p = 0.039) (Table - 3.49).

In the location-1, mean of upper layers was 310.38 µg/g and lower was 269.23 µg/g (Table - 3.39.1b). Mean of the soil Zn of location-1 was 289.80 µg/g with minimum value 193.50 µg/g and maximum 320.00 µg/g (Table - 3.41). In case of location-2, mean of upper layer was 190.63 µg/g and lower was 263.00 µg/g (Table - 3.39.1b). Mean of the soil Zn of location-2 was 226.80 µg/g with minimum value 161.00 µg/g and maximum 292.50 µg/g (Table - 3.42). There was significant difference between upper and lower layer (P = 0.016) (Table - 3.48). The mean of upper layers was 208.63 µg/g and lower was 268.75 µg/g (Table - 3.39.1b) in the location-3. Mean of the soil Zn of location-3 was 238.70 µg/g with minimum value 134.50 µg/g and maximum 343.50 µg/g (Table - 3.43). In location-4, mean of upper layers was 256.88 µg/g and lower was 257.75 µg/g (Table - 3.39.1b). Mean of the soil Zn of location-4 was 257.30 µg/g with minimum value 217.00 µg/g and maximum 319.00 µg/g (Table - 3.44). In the location-5, mean of upper layer was 230.50 µg/g and lower was 268.38 µg/g (Table - 3.39.1b).Mean of the soil Zn of location-5 was 249.40 µg/g with minimum value 160.50 µg/g and maximum 370.50 µg/g (Table - 3.45). In case location-6, mean of upper layer was 233.25 µg/g and lower was 304.75 µg/g (Table - 3.39.1b). Mean of the soil Zn of location-6 was 269.00 µg/g with minimum value 194.00 µg/g and maximum 322.00 µg/g (Table - 3.46).

3.5.8.4 (2016)

The mean of upper layers was 308.38 µg/g and lower was 341.98 µg/g (Table - 3.59). Mean of the soil Zn of Nijhum Dwip was 325.18 µg/g with minimum value 204.50 µg/g and maximum 440.50 µg/g(Table - 3.66). Location and layer showed significance interaction in case of Ca (P = 0.040, F = 2.63)) (Table - 3.69).

In the location-1, the mean of upper layers was 380.38 µg/g and lower was 339.23 µg/g (Table - 3.58.1b). Mean of the soil Zn of location-1 was 359.8 µg/g with minimum value 263.50 µg/g and maximum 390.00 µg/g (Table - 3.59). In location-2, the mean of upper layers was 260.63 µg/g and lower was 333.00 µg/g (Table - 3.58.1b). Mean of the soil Zn of location-2 was 296.80 µg/g with minimum value 231.00 µg/g and maximum 362.50 µg/g (Table - 3.60). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.016) (Table - 3.67). The mean of upper layers was 278.63 µg/g and lower was 338.75 µg/g (Table - 3.58.1b) in the location-3. Mean of the soil Zn of location-3 was 308.70 µg/g with minimum value 204.50 µg/g and maximum 413.50 µg/g (Table - 3.62). In case of location-4, the mean of upper layers was 326.88 µg/g and lower was 327.75 µg/g (Table - 3.58.1b). Mean of the soil Zn of location-4 was 327.30 µg/g with minimum value 287.00 µg/g and maximum 389.00 µg/g (Table - 3.63). The mean of upper layers was 300.50 µg/g and lower was 338.38 µg/g (Table - 3.58.1b) in the location-5. Mean of the soil Zn of location-5 was 319.40 µg/g with minimum value230.5 µg/g and maximum 440.50 µg/g (Table - 3.64). In the location-6, the mean of upper layers was 303.25 µg/g and lower was 374.75 µg/g (Table - 3.58.1b). Mean of the soil Zn of location-6 was 339.00 µg/g with minimum value 264.00 µg/g and maximum392.00 µg/g (Table - 3.65). One-Way ANOVA showed that there was significant difference between upper and lower layer (P = 0.019) (Table - 3.67).

Total Zn 40.2 ± 3.3µg/g found in the SaiKeng, Hong Kong, 143.3 ± 22.4 µg/g in the Shenzhen, People's Republic of China (Tam and Wong 1996) were less than present studies. The amount of Zn in SMF ranged from 0.13 – 0.74 mg/kg and mean value was 0.40 mg/kg and the mean values of soil Zn of upper and lower layers of oligohaline zone were 0.457 mg/kg and 0.445 mg/kg mesohaline zone were 0.411 mg/kg and 0.424 mg/kg, polyhaline zone were 0.277 mg/kg and 0.275 mg/kg respectively (Ataullah *et al.* 2018) which were very low than those of the present studies.

3.6: Principle Component Analysis (PCA)

Principle component analysis (PCA) was carried out of the values of different variables of soils of 2013, 2014, 2015 and 2016 and the results have been shown in different figures. The PCA of different locations of 2013 are shown in the Figure 3.6.1, 3.6.2, 3.6.3, 3.6.4, 3.6.5 and 3.6.6. PC-1 showed the positive loading of conductivity, P , N and Zn with negative loading of moisture, pH, salinity, K, Pb, Mg, Fe, Mn, and Ca. PC-2 showed positive loading of salinity, OC, N, K and Mg with negative loading of moisture, pH, Conductivity, P, Na, Pb, Fe and Ca. PC-3 showed positive loading of pH, conductivity, OC, P, Na, Pb, Mn, Mg, Ca and Zn with negative loading of Moisture, salinity, N, K, and Fe. PCA also showed the Cluster form among the Fe, Ca and Mg in Figure 3.6.1 in 2013

Principle component analysis (PCA) of the values of different variables of soils of different locations of 2014 has been shown in the Figure 3.6.7, 3.6.8, 3.6.9, 3.6.10, 3.6.11 and 3.6.12. PC-1 showed the positive loading of pH, P, Na, Pb, Mn, Mg, Ca and Zn with negative loading of moisture, Conductivity, salinity, K, N, and Fe. PC-2 showed positive loading of Moisture, pH, Conductivity, Pb Mg, Fe and Zn with negative loading of salinity, OC, K Mn, and Ca. PC-3 showed positive loading of pH, conductivity, salinity, K, Pb and Mg with negative loading of Moisture, N, P, Mn, Ca and Zn. PCA also showed the cluster formation among the moist, conductivity and N and Mg in Figure 3.6.7 in 2014.

Principle component analysis (PCA) was carried out of the values of different variables of soils different locations of 2015 and the results have been shown in the Figure 3.6.13, 3.6.14, 3.6.15, 3.6.1, 3.6.17 and 3.6.18. PC-1 showed the positive loading of pH, Conductivity, salinity, OC, Na, K, Pb, Mn, Mg , Fe and Zn with negative loading of moisture, N, P and Ca. PC-2 showed positive loading of moisture, salinity, OC, Na, Pb, Mn and Ca pH, Conductivity, OC, Na, K, Fe, and Ca with negative loading of pH , conductivity, N, P, K, Mg, Fe and Zn . PC-3 showed positive loading of OC, N, P, Na, and

K with negative loading of moisture, Mn, Fe, pH, conductivity, and salinity, Pb, Mg, Ca and Zn. PCA also showed the cluster formation among the Na, OC, Pb and K in Figure 3.6.13 in 2015

Principle component analysis (PCA) was carried out of the values of different variables of soils of different locations of 2016 and the result weres shown in the Figures 3.6.19, 3.6.20, 3.6.21, 3.6.22, 3.6.23 and 3.6.24. PC-1 showed the positive loading of moisture, conductivity, salinity, OC, K ,Pb, Mg, Fe and Zn with negative loading of pH, N, P, Na, Mn and Ca. PC-2 showed positive loading of moisture, salinity, P and Ca with negative loading of pH, conductivity, OC, N, Na,K, Pb, Mn, Mg, Fe and Zn. PC-3 showed positive loading of OC, Pb, K, Mg, Ca and Zn with negative loading of moisture, pH , conductivity, salinity, P, Na, Mn and Fe. PCA also showed the cluster formation among the OC, conductivity, Fe and Mg (Fig. 3.6.19)

4.1 Introduction

To the scientists mangroves have long been a foundation of importance and for the untrained people. It is a substance of surprise (Prakash 2011). The collective noun mangrove describes an intertidal marshland ecosystem molded by a very superior association of flora and fauna which increase splendidly in the coastal spaces and river bays during the low lying tropical and sub-tropical spaces (Bandaranayake 2002). These wetland environments are among the most dynamic and various in the ecosphere and more than 80% of aquatic vicious circle are directly or indirectly reliant on mangrove and other coastal ecosystems universal (Bandaranayake 2002). They inhabit great zones along protected coasts, estuaries and in channels where they are inclined by waves and broadly changed situations of salinity and rainfall commands. They are also found everywhere coastal lagoons, interactive with the ocean and where the consequence of streams may be weak and the salinity very little. The term mangrove is also used to entitle halophytic (salt loving) and salt resistant marine tidal forests covering of trees, shrubs, palms, epiphytes, ground ferns and grasses, which are connected in attitudes or stands (Premanathan *et al.* 1999). Mangroves are generally established only in tropical environments, as they need regularly warm situations for growth and survival (Bandaranayake 2002). Among current approaches used to measure the number of mangrove resources in a country, remote sensing is now also been considered as the greatest applied system for mangrove record.

The uses of mangroves are regularly repeated in scientific and common courses (Bandaranayake 1998) and described in two major classes: Firstly the indirect application of the mangrove ecosystem in the system of vital ecological roles such as regulate of coastal destruction and defense of coastal land, maintenance of sediment, natural decontamination of coastal water from toxic waste. Secondly, the economic assistances which are numerous and different.

The mangrove leaves are suitable contributors to the nutrient structure of the mangrove ecology (Bandaranayake 2002). It is known that mangrove leaves enclose adequate quantities of minerals, vitamins and amino acids, which are important for the development and nourishment of marine creatures and livestock. Mangrove vegetation plays a vital part in the development of detritus which is consumed by several estuarine and marine detritus creatures and mangrove plants make greater forage due to their great salt and iodine content (Bandaranayake 1998). The present study was conducted to know foliar nutrient content in the leaf of some mangrove species such as *Sonneratia apetala* Buch.-Ham, *Ceriops decandra* (Griff.) Ding Hou, *Avicennia officinalis* (Forssk.) Vierh, *Acanthus ilicifolius* L.which were successfully growing plant in the newly accreted chars in the coastal region of Bangladesh and to know the effect of some soil variables on it.

4.2 Materials and Methods

4.2.1 Samples collection

Different mangrove species were planted in the coastal areas where *S. apetala* were proved to be the most successful which alone constitutes about 94.5% of the total existing mangrove plantations (Siddiqi 2001). A few other species are namely *C. decandra and A. officinalis* which grow sparsely in the coastal chars, while *A. ilicifolius* is invading the chars seriously. The leaves of *S. apetala, A. officinalis, C. decandra, A. ilicifolius* were collected from Nijhum Dwip, Hatiya, Noakhali, Bangladesh. Among these, leaf samples were collected from the location-1, Location-2, Location-3, location-4 and Location-5. Leaf samples were collected from the different locations during sampling years in 2013, 2014, 2015 and 2016. As location-6 is situated in the river bank and there were no tree species growing, leaf samples were not possible to collect from four locations.

4.2.2 Analytical method

Leaves were dried at 70º C in the heating cabinets directly after incoming to the laboratory. The dried samples were finely ground (particles size less than 1mm) and kept at room temperature until investigates (Ogner *et al.* 2000)

4.2.2.1. Nitrogen and Phosphorus:

Nitrogen content of the leaves was determined by the modified Kjeldahl method (1883) as described by Jackson (1973). 0.2g air dried leaves sample was digested with nitric acid-perchloric acid mixture (2:1) (Piper 1950). P content of the digest was determined by vanadomolybdo phosphoric yellow color method in nitric acid system (Jackson 1973). These parameters were determined at the Soil Chemistry Laboratory of Soil, Water and Environment Department, University of Dhaka and Centre for Advanced Research in Sciences (CARS), DU.

4.2.2.2 K, Ca, Mg, Fe, Mn, Zn and Pb:

Total K was determined by flame photometry at the MS laboratory, Department of Botany. Total Ca, Mg, Fe, Mn, Zn were determinate at the Centre for Advanced Research in Sciences, University of Dhaka and Bangladesh Council of Scientific and Industrial Research (BCSIR) with the help of atomic absorption spectrophotometer.

4.2.3 Statistical method

In the present study eight (8) variables of the leaves of *S. apetala, Avicennia officinalis, C. decandra, A. ilicifolius,* were analyzed. To compare plant variables between locations, one-way ANOVA was performed using Minitab 14 software. Pearson's correlations were calculated for plant variables. Principles component analysis was done using Minitab 14 software. Pearson's correlation also calculated among the soil and plants variables. Linear Regression analysis was calculated to know the relationship between soil and plants variables.

4.3: Results and Discussion

4.3.1. Nitrogen (N)

Avicennia officinalis maintained a higher amount of N content in the leaves than the other mangrove species throughout the study period.

4.3.1.1 (2013)

Mean of the N content of leaves of *S. apetala* growing in Nijhum Dwip was 0.703 % with minimum value 0.521 % and maximum 1.302 % (Table - 4.1). In *S. apetala* Plant, N maintained positive significant correlation with Fe (r = 0.956, p= 0.011) (Table - 4.5). Mean of the N of the *C. decandra* leaves was 0.688 % with minimum value 0.542 % and maximum 1.063 % (Table - 4.2). In *C. decandra* Plant, N maintained negative significant correlation with Pb (r = - 0.918, p = 0.028), Ca (p = 0.044, r = - 0.889) (Table - 4.6). Mean of the N of the *A. officinalis* leaves was 0.865 % with minimum value 0.544 % and maximum 1.229 % (Table - 4.3). Mean of the N of the *A. ilicifolius* leaves was 0.562 % minimum value 0.506 % and maximum 0.636 % (Table - 4.4). In *A. ilicifolius* Plant, N maintained positive significant correlation with P (r = 0.874, p = 0.053), Pb (r = 0.931, p= 0.021) (Table - 4.8). In 2013, N content of leaves is as follows.

A. officinalis> S. apetala> C. decandra> A. ilicifolius

4.3.1.2 (2014)

Mean of the N of *S. apetala* leaves of Nijhum Dwip was 0.629 % with minimum value 0.592 % and maximum 0.661 % (Table - 4.14). In *S. apetala* plant, N maintained positive significant correlation with Fe (r = 0.956, p = 0.011) (Table - 4.5). Mean of the N of the *C. decandra* leaves was 0.874 % with minimum value 0.702 % and maximum 1.037 % (Table - 4.15). Mean of the N of the *A. officinalis* leaves was 1.177 % with minimum value 0.956 % and maximum 1.533 % (Table - 4.16). In *A. officinalis* plant, N maintained t positive significant correlation with Mg (r = 0.952, p = 0.013) and negative significant correlation with Zn (r =- 0.873, p = 0.053) (Table - 4.21). Mean of the N of the *A. ilicifolius* leaves was 0.915 % minimum value 0.841 % and maximum 0.965 % (Table - 4.17). In *A. ilicifolius* plant, N maintained very strong negative significant correlation with Mn (r = -0.923, p = 0.025) (Table - 4.22). N content of leaves in 2014 was as follows.

A. officinalis>A. ilicifolius> C. decandra >S. apetala

4.3.1.3 (2015)

Mean of the N *S. apetala* leaves of Nijhum Dwip was 0.717 % with minimum value 0.654 % and maximum 0.781 % (Table - 4.27). Mean of the N of the *C. decandra* leaves was 1.064 % with minimum Value 0.872 % and maximum 1.537% (Table - 4.28). Mean of the N of the *A. officinalis* leaves was 1.582 % with minimum value 0.923 % and maximum 1.896 % (Table - 4.29). Mean of the N of the *A. ilicifolius* leaves was 0.915 % minimum value 0.841 % and maximum 0.965 % (Table - 4.30). In all location, in *A. ilicifolius* plant, One way ANOVA showed that there was significant difference in N (p = 0.031) (Table - 4.31). In *A. ilicifolius,* N maintained very strong negative significant correlation with Mn (r = -0.935, p = 0.020) (Table - 4.35).

A. officinalis> C. decandra > A. ilicifolius >S. apetala

4.3.1.4 (2016)

Mean of the N *S. apetala,* leaves of Nijhum Dwip 0.944 % with minimum value 0.886 % and maximum 0.992 % (Table - 4.40). Mean of the N of the *C. decandra* leaves was 0.954 % with minimum value 0.810 % and maximum 1.934 % (Table - 4.41). Mean of the N of the *A. officinalis* leaves was 1.345 % with minimum value 0.912 % and maximum 1.946 % (Table - 4.42). Mean of the N of the *A. ilicifolius* leaves was 1.08 % minimum value 0.881 % and maximum 1.280 % (Table - 4.43). In *A. ilicifolius* plant, N maintained very strong negative significant correlation with Mn (r = -0.906, p = 0.034) (Table - 4.48).

A. officinalis> *A. ilicifolius* > *C. decandra* > *S. apetala*

Ahmed et al. (2010b) found more nitrogen of the specie *S. apetala* which was collected from Rangabali Upazila, Patuakhali, Bangladesh than the present studies. N content of the leaves of some other mangrove species were almost similar such as 0.80 ± 0.06% in the leaves of *Rhizophora* sp., 1.01 ± 0.13 % in the leaves of *Laguncularia* sp. and 1.10 ± 0.20 % in the leaves of *Avicennia* sp. (Sherman *et al*. 1998).

4.3.2. Phosphorus (P)

Highest total P content was found in leaves of S.apetala throughout the study
Period and other studied species showed fluctuation in p content**.**

4.3.2.1 (2013)

Mean of the P of *S. apetala* leaves of Nijhum Dwip was 0.064 % with minimum value 0.031 % and maximum 0.087 % (Table - 4.1). Mean of the P of the *C. decandra* was 0.051 % with minimum value 0.013 % and maximum 0.091 % (Table - 4.2). Mean of the P of the *A. officinalis* leaves was 0.057% with minimum value 0.051% and maximum 0.100 % (Table - 4.3). Mean of the P of the *A. ilicifolius* leaves was 0.015 % with minimum value 0.012% and maximum 0.019% (Table - 4.4). In 2013, the P content of leaves was in the following chronological order:

S. apetala> *A. officinalis*> *C. decandra* > *A. ilicifolius*

4.3.2.2 (2014)

Mean of the P of *S. apetala* leaves of Nijhum Dwip was 0.043 % with minimum value 0.043% and maximum 0.043% (Table - 4.14). In case of *S. apetala* plant, one way ANOVA showed that there was significant difference in P (p = 0.006) (Table - 4.18). Mean of the P of the *C. decandra* was 0.027 % with minimum value 0.012 % and maximum 0.065 % (Table - 4.15). In *A. officinalis* plant, P maintained very strong positive significant correlation with Pb (r = 0.934, p = 0.020) and very strong negative significant correlation with Mn (r = - 0.973, p = 0.025), Ca (r = - 0.922, p = 0.026) (Table - 4.21). Mean of the P of the *A. officinalis* leaves was 0.039 % with minimum value 0.068 % and maximum 0.011 % (Table - 4.16). Mean of the P of the *A. ilicifolius* leaves was 0.027% minimum value 0.009 % and maximum 0.045 % (Table - 4.17).

S. apetala> *A. ilicifolius*> *A. officinalis*> *C. decandra*

4.3.2.3 (2015)

Mean of the P of *S. apetala* leaves of Nijhum Dwip was 0.085 % with minimum value 0.050 % and maximum 0.112 % (Table - 4.27). Mean of the P of the *C. decandra* was 0.040 % with minimum value 0.025 % and maximum 0.075 % (Table - 4.28). Mean of the P of the *A. officinalis* leaves was 0.010 % with minimum value 0.008 % and maximum 0.014 % (Table - 4.29). Mean of the P of the *A. ilicifolius* leaves was 0.030 % minimum value 0.013 % and maximum 0.050 % (Table - 4.30).

S. apetala> *C. decandra*> *A. ilicifolius*> *A. officinalis*

4.3.2.4 (2016)

Mean of the P of *S. apetala* leaves of Nijhum Dwip was 0.083 % with minimum value 0.007 % and maximum 0.159 % (Table - 4.40). In all location, in *S. apetala* plant, one way ANOVA showed that there was significant difference in P (p = 0.007) (Table - 4.44). Mean of the P of the *C. decandra* was 0.040 % with minimum value 0.003 % and maximum 0.075 % (Table - 4.41). Mean of the P of the *A. officinalis* leaves was 0.011 % with minimum value 0.009 % and maximum 0.014 % (Table - 4.42). Mean of the P of the *A. ilicifolius* leaves was 0.036 % minimum value 0.004 % and maximum 0.068 % (Table - 4.43).

S. apetala> C. decandra> A. ilicifolius> A. officinalis

Ahmed et al. (2010b) found similar amount of phosphorus in the S. apetala . In the other mangrove species such as *Rhizophora*, *Laguncularia*, and *Avicennia*, mean concentrations of P were found to be 0.06 ± 0.003 %, 0.12 ± 0.011 % and 0.12 ± 0.01 % respectively (Sherman *et al.* 1998). These values were same as the present studies.

S. apetala> C. decandra> A. ilicifolius> A. officinalis

4.3.3 Lead (Pb)

There were variations found in lead content in different mangrove species studied**.** *A. officinalis showed highest concentration of lead during most of the tie except 2016. When highest value was found in A. ilicifolius.*

4.3.3.1 (2013)

Mean of the Pb of the *S. apetala* leaves of Nijhum Dwip was 0.93 µg/g with minimum value 0.59 µg/g and maximum 1.16 µg/g (Table - 4.1). In *S. apetala* plant, Pb maintained very strong negative significant correlation with Mg (r = -0.925, p = 0.024) (Table- 4.5). Mean of the Pb of the *C. decandra* was 1.43 % with minimum value 1.19

% and maximum 1.58 % (Table - 4.2). Mean of the Pb of the *A. officinalis* leaves was 0.63 % with minimum value 0.58 % and maximum 0.70 % (Table - 4.3). Mean of the Pb of the *A. ilicifolius* leaves was 0.28 % minimum value 0.22 % and maximum 0.38 % (Table - 4.4).

A. officinalis> C. decandra> S. apetala> A. ilicifolius

4.3.3.2 (2014)

Mean of the Pb of the *S. apetala* leaves of Nijhum Dwip was 0.45 µg/g with minimum value 0.76 µg/g and maximum 0.144 µg/g (Table - 4.14). In *S. apetala* plant, Pb maintained negative significant correlation with Mg (r = -0.925, p = 0.024,) (Table- 4.5). Mean of the Pb of the *C. decandra* was 0.15 µg/g with minimum value 0.13 µg/g and maximum 0.18 µg/g (Table - 4.15). In *C. decandra*, Pb maintained very strong positive significant correlation with Ca (r = 0.906, p = 0.043) (Table - 4.20). Mean of the Pb of the *A. officinalis,* was 0.86 µg/g with minimum value 0.69 µg/g and maximum 0.98 µg/g (Table - 4.16). In *A. officinalis,* P maintained very strong negative significant correlation with Mn (r = -0.874, p = 0.053), Ca (r =- 0.939, p = 0.018) (Table - 4.21). Mean of the Pb of the *A. ilicifolius* was 0.36 µg/g minimum values 0.25 µg/g and maximum 0.42 µg/g (Table - 4.17). In *A. ilicifolius* plant in all location, One way ANOVA showed that there was significant difference in Pb (P = 0.024) (Table - 4.18).

A. officinalis> A. ilicifolius> C. decandra> S. apetala

4.3.3.3 (2015)

Mean of the Pb of the *S. apetala,* of Nijhum Dwip was 0.13 µg/g with minimum value 0.11 µg/g and maximum 0.16 µg/g (Table - 4.27). Mean of the Pb of the *C. decandra* was 0.21 µg/g with minimum value 0.18 µg/g and maximum 0.26 µg/g (Table - 4.28). Mean of the Pb of the *A. officinalis* leaves was 0.62 µg/g with minimum value 0.44 µg/g and maximum 0.80 µg/g (Table - 4.29). Mean of the Pb of the *A. ilicifolius* leaves was 0.52 µg/g minimum values 0.42 µg/g and maximum 0.61 µg/g (Table - 4.30).

A. officinalis> A. ilicifolius> C. decandra> S. apetala

4.3.3.4 (2016)

Mean of the Pb of the *S. apetala leaves* of Nijhum Dwip was 0.14 µg/g with minimum value 0.10 µg/g and maximum 0.20 µg/g (Table - 4.40). Mean of the Pb of the *C. decandra* was 0.22 µg/g with minimum value 0.18 µg/g and maximum 0.29 µg/g (Table - 4.41). In *A. officinalis,* Pb maintained negative significant correlation with Zn (r = -0.863, p = 0.059) (Table - 4.46). Mean of the Pb of the *A. officinalis was* 0.13 µg/g with minimum value 0.08 µg/g and maximum 0.19 µg/g (Table - 4.42). Mean of the Pb of the *A. ilicifolius* leaves was 0.62 µg/g minimum values 0.49 µg/g and maximum 0.71 µg/g (Table - 4.43)

A. ilicifolius> C. decandra> S. apetala>A. officinalis

4.3.4 Magnesium (Mg)

Magnesium content in the leaves of A. officinalis was found to be lowest in most of the cases. When the value was higher in S. apetala in all cases except 2013.

4.3.4.1 (2013)

Mean of the Mg of the *S. apetala* leaves of Nijhum Dwip was 1484 µg/g with minimum value 988 µg/g and maximum 1980 µg/g (Table - 4.1). Mean of Mg of the *C. decandra* leaves of Nijhum Dwip was 3937.50 µg/g with minimum value 1186 µg/g and maximum 6689 µg/g (Table - 4.2). Mean of the Mg of the *A. officinalis* was 1549 µg/g with minimum value 969 µg/g and maximum 1987 µg/g (Table - 4.3). Mean of the Mg of the *A. ilicifolius* leaves was 1487 µg/g minimum value 988 µg/g and maximum 1986 µg/g (Table - 4.4).

C. decandra> S. apetala> A. ilicifolius> A. officinalis

4.3.4.2(2014)

Mean of the Mg of the *S. apetala* leaves of Nijhum Dwip was 3117 µg/g with minimum value 2000 µg/g and maximum 6988 µg/g (Table - 4.14). Mean of the Mg of the *C. decandra* leaves of Nijhum Dwip was 2271 µg/g with minimum value 1796 µg/g and maximum 2799 µg/g (Table - 4.15). In *C. decandra* plant, Mg maintained positive significant correlation with Mn (r = 0.431, p = 0.006) (Table - 4.20). Mean of the Mg of the *A. officinalis* was 422.7 µg/g with minimum values 392.2 µg/g and maximum 498.3 µg/g (Table - 4.16). Mean of the Mg of the *A. ilicifolius* leaves was 2175.2 µg/g minimum values 2057.30 µg/g and maximum 2279.80 µg/g (Table - 4.17). In *A. ilicifolius* plant, N maintained negative significant correlation with Mn (r = -0.987, p = 0.002) (Table - 4.22).

S. apetala> C. decandra> A. ilicifolius> A. officinalis

4.3.4.3(2015)

Mean of the Mg of the *S. apetala* leaves of Nijhum Dwip was 3436 µg/g with minimum value 2123 µg/g and maximum 7579 µg/g (Table - 4.27). Mean of Mg of the *C. decandra* leaves of Nijhum Dwip was 2448 µg/g with minimum value 2154 µg/g and maximum 2943 µg/g (Table - 4.28). In *C. decandra*, Mg maintained negative significant correlation with Mn (r =- 0.976, p = 0.005) (Table - 4.33). Mean of Mg of the *A. officinalis* leaves was 2241.9 µg/g with minimum value 2134.9 µg/g and maximum 2312.4 µg/g (Table - 4.29). Mean of the Mg of the *A. ilicifolius* leaves was 2175.2 µg/g minimum values 2057.3 µg/g and maximum 2279.8 µg/g (Table - 4.30). In *A. ilicifolius*, N maintained very strong negative significant correlation with Mn (r = -0.935, p = 0.020) (Table - 4.35).

S. apetala> C. decandra>A. officinalis> A. ilicifolius

4.3.4.4 (2016)

Mean of Mg of the *S. apetala* leaves of Nijhum Dwip was 3436 µg/g with minimum value 2123 µg/g and maximum 7579 µg/g (Table - 4.40). Mean of Mg of the *C. decandra* was 3084 µg/g with minimum value 1076 µg/g and maximum 6546 µg/g (Table - 4.41). Mean of Mg of *A. officinalis* leaves was 2242.8 µg/g with minimum value 2134.9 µg/g and maximum 2365.4 µg/g (Table - 4.42). In *A. officinalis*, Mg maintained very strong positive significant correlation with Fe (r = 920, p = 0.027) (Table - 4.47). Mean of the Mg of the *A. ilicifolius* leaves was 2389 µg/g minimum value 2248 µg/g and maximum 2850 µg/g (Table-4.43).

Ahmed et al. (2010b) found mean values 0.39 % Mg. Kotmire and Bhosale (1979) found 0.31 - 1.66 % Mg in the mangrove plant S. *apetala* of the coast of India (Maharashtra). The adequate amount of Mg in the mangrove is reported as 0.2 % (Epstein 1972).

S. apetala> C. decandra> A. ilicifolius> A. officinalis

4.3.5 Manganese (Mn)

4.3.5.1 (2013)

Mean of the Mn of the *S. apetala* leaves of Nijhum Dwip was 274.50 µg/g with minimum value 99.60 µg/g and maximum 597.80 µg/g (Table - 4.1). Mean of the Mn of the *C. decandra* was 544 µg/g with minimum value 176 µg/g and maximum 811 µg/g (Table - 4.2). Mean of the Mn of the *A. officinalis* leaves was 362.0 µg/g with minimum value 165 µg/g and maximum 690.5 µg/g (Table - 4.3). Mean of the Mn of the *A. ilicifolius* leaves was 233.8 µg/g minimum values 75.6 µg/g and maximum 597.8µg/g (Table - 4.4). In *A. ilicifolius* plant, Mn maintained very strong negative significant correlation with Zn (r = -0.943, p= 0.016) (Table- 4.8).

C. decandra> A. officinalis> S. apetala> A. ilicifolius

4.3.5.2 (2014)

Mean of the Mn of the *S. apetala* leaves of Nijhum Dwip was 199.7 µg/g with minimum value 102.3 µg/g and maximum 392.8 µg/g (Table - 4.14). In *S. apetala* plant, Mn maintained very strong negative significant correlation with Ca (r = -0.944, p = 0.016)(Table - 4.19) Mean of the Mn of the *C. decandra* was 348 µg/g with minimum value 120 µg/g and maximum 598 µg/g (Table - 4.15). Mean of the Mn of the *A. officinalis* leaves was 648 µg/g with minimum value 375 µg/g and maximum 1094 µg/g (Table - 4.16). Mean of the Mn of the *A. ilicifolius* leaves was 115.72 µg/g minimum values 101.2 µg/g and maximum 152.3 µg/g (Table - 4.17). In *A. ilicifolius* plant, Mn maintained very strong negative significant correlation with Zn (r = -0.943, p = 0.016) (Table - 4.8).

A. officinalis >C. decandra> > S. apetala> A. ilicifolius

4.3.5.3 (2015)

Mean of the Mn of the *S. apetala* leaves of Nijhum Dwip was 296.3 µg/g with minimum value 225.6 µg/g and maximum 437.2 µg/g (Table-4.27). In all location, in *S. apetala* plant, One way ANOVA showed that there was significant difference in Mn (p = 0.030) (Table - 4.31). In *S. apetala* plant, Mn maintained very strong negative significant correlation with Ca (r = -0.934, p = 0.020) (Table - 4.32). Mean of the Mn of the *C. decandra* was 596.3 µg/g with minimum value 346.5 µg/g and maximum 769.9 µg/g (Table-4.28). Mean of the Mn of the *A. officinalis* leaves was 532.2 µg/g with minimum value 299.5 µg/g and maximum 702.3 µg/g (Table- 4.29). Mean of the Mn of the *A. ilicifolius* leaves was 158.7µg/g minimum value 131.1µg/g and maximum 196.3 µg/g (Table - 4.30).

C. decandra> A. officinalis > S. apetala> A. ilicifolius

4.3.5.4 (2016)

Mean of the Mn of the *S. apetala* leaves of Nijhum Dwip was 296.3 µg/g with minimum value 225.6 µg/g and maximum 437.2 µg/g (Table - 4.40). In *S. apetala* plant, Mn maintained negative significant correlation with Ca ($p = 0.027$, $r = -0.919$) (Table- 4.45). Mean of the Mn of the *C. decandra* was 596.3 µg/g with minimum value 346.5 µg/g and maximum 769.9 µg/g (Table - 4.41). Mean of the Mn of the *A. officinalis* leaves was 482.0 µg/g with minimum value 299.5 µg/g and maximum 648.3 µg/g (Table - 4.42). In *A. officinalis* plant, Mn maintained s very strong positive significant correlation with Fe ($r = 0.952$, $p = 0.013$) (Table - 4.47). Mean of the Mn of the *A. ilicifolius* leaves was 145.1 µg/g minimum values 123.8 µg/g and maximum 198.3 µg/g (Table - 4.43).

Ahmed *et al.* (*2010b*) found mean value of 1074.60 ppm Mn in their study. Kotmire and Bhosale (1979) found 4 mg to 80 mg per 100 gm Mn in the mangrove plant of the coast of India (Maharashtra). Mn found on the some mangrove species in the Bhitarkanika, Orissa, east coast of India were 6.9-7.2 µg/g in the leaves of *R. mucronata*, 6.2-6.8 µg/g in the leaves of *A. officinalis*, 6.4-6.6 µg/g in the leaves of *X. granatum*, 6.1-6.8 µg/g in the leaves of *C. decandra*, 5.7-6.1 µg/g in the leaves of *B. cylindrica* ((Sarangi *et al.* 2002). These values were lower than the present studies. Manganese content of different mangrove species of Nijhum Dwip were comparatively very higher than those the different mangrove species growing in location Orissa coast.

C. decandra> A. officinalis > S. apetala> A. ilicifolius

4.3.6 Iron (Fe)

4.3.6.1 (2013)

Mean of the Fe of the *S. apetala* leaves of Nijhum Dwip was 1941µg/g with minimum value 803 µg/g and maximum 3918 µg/g (Table - 4.1). Mean of the Fe of the the *C. decandra* leaves of Nijhum Dwip was 1926 µg/g with minimum value 890 µg/g and maximum 3979 µg/g (Table - 4.2). In *C. decandra* plant, Fe maintained negative significant correlation with Zn (r = -0.546, p = 0.012) (Table - 4.6). Mean of the Fe of the *A. officinalis* leaves was 2445 µg/g with minimum value 651µg/g and maximum 9183 µg/g (Table - 4.3). Mean of the Fe of the *A. ilicifolius* leaves was 1606.0 µg/g minimum values 649 µg/g and maximum 2607 µg/g (Table - 4.4).

A. officinalis > S. apetala> C. decandra> A. ilicifolius

4.3.6.2 (2014)

Mean of the Fe of *S. apetala* leaves of Nijhum Dwip was 1959 µg/g with minimum value 1124 µg/g and maximum 3751 µg/g (Table - 4.14). In *S. apetala* plant, Fe maintained positive significant correlation with Zn (r = 0.882, p = 0.048) (Table - 4.19). Mean of the Fe of the *C. decandra* leaves of Nijhum Dwip was 2489 µg/g with minimum value 1957 µg/g and maximum 2825 µg/g (Table - 4.15). In *C. decandra* plant, Fe maintained significant negative correlation with Zn (r = -0.546, p = 0.012) (Table - 4.6). Mean of the Fe of the *A. officinalis* leaves was 1477 µg/g with minimum value 898 µg/g and maximum 1886 µg/g (Table - 4.16). Mean of the Fe of the *A. ilicifolius* leaves was 1857 µg/g minimum value 825µg/g and maximum 2879 µg/g (Table - 4.17).

C. decandra> S. apetala> A. ilicifolius> A. officinalis

4.3.6.3 (2015)

Mean of the Fe of *S. apetala* leaves of Nijhum Dwip was 1466 µg/g with minimum value 781µg/g and maximum 2594 µg/g (Table - 4.27). In *S.apetala* plant, Fe maintained very strong positive significant correlation with Ca (r = 0.929, p = 0.023) (Table - 4.32). Mean of the Fe of the *C. decandra* leaves of Nijhum Dwip was 2782 µg/g with minimum value 2189 µg/g and maximum 3226 µg/g (Table-4.28). In *C. decandra* plant, Fe maintained very strong negative significant correlation with Zn (r = -0.946, p= 0.015) (Table - 4.33). Mean of the Fe of the *A. officinalis* leaves was 1233.2 µg/g with minimum value 944.8 µg/g and maximum 1440.4 µg/g (Table - 4.29). Mean of the Fe of the *A. ilicifolius* leaves was 2238 µg/g minimum value 1342 µg/g and maximum 3185 µg/g (Table - 4.30)

C. decandra > A. ilicifolius> > S. apetala >A. officinalis

4.3.6.4 (2016)

Mean of the Fe *S. apetala* leaves of Nijhum Dwip was 1504 µg/g with minimum value 800 µg/g and maximum 2612 µg/g (Table - 4.40). In *S. apetala* plant, Fe maintained very strong positive significant correlation with Ca (r = 0.950, p = 0.013) (Table - 4.45). Mean of the Fe of the *C. decandra* leaves of Nijhum Dwip was 2945 µg/g with minimum value 2512 µg/g and maximum 3339 µg/g (Table - 4.41). In *C. decandra* Plant, Fe maintained negative significant correlation with Zn (r = -0.896, p = 0.040) (Table - 4.46). Mean of the Fe of the *A. officinalis* leaves was 1164.4 µg/g with minimum value 944.80 µg/g and maximum 1386.40 µg/g (Table - 4.42). Mean of the Fe of the *A. ilicifolius* leaves was 2540.90 µg/g minimum values 1490.60 µg/g and maximum 3180.50 µg/g (Table-4.43).

C. decandra > A. ilicifolius> > S. apetala >A. officinalis

Ahmed *et al.* (2010b) found more mean value of 363.50 ppm Fe in their study. Kotmire and Bhosale (1979) found 0.012 % - 2.80 % Fe in the mangrove plants of the coast of India (Maharashtra). The requirement of Fe in the normal plants is 11 mg per 100 g of dry tissue (Epstein 1972). Fe found in the leaves of other mangrove species in the Bhitarkanika, Orissa, east coast of India were 19-32 ppm in *R. mucronata,* 33-61 ppm in *A. officinalis,* 07-36 ppm in *X. granatum,* 19-22 ppm in *C. decandra*, 17-41 ppm in *B. cylindrica* (Sarangi *et al* 2002).

C. decandra > A. ilicifolius> S. apetala >A. officinalis

4.3.7 Calcium (Ca)

4.3.7.1 (2013)

Mean of the of Ca of *S. apetala* leaves of Nijhum Dwip was was 5111 µg/g with minimum value 1959 µg/g and maximum 13548 µg/g (Table - 4.1). Mean of the Ca of the *C. decandra* leaves of Nijhum Dwip was 5810 µg/g with minimum value 2136 µg/g and maximum 9237 µg/g (Table - 4.2). Very chaining variation was found in Ca content in the leaves of *A. officinalis* during 2013. Mean of the Ca of the *A. officinalis* leaves was 4969 µg/g with minimum value 191 µg/g and maximum 9856 µg/g (Table - 4.3). In *A. officinalis* Plant, Ca maintained positive significant correlation with Fe (r = 0.960, p = 0.010) (Table - 4.7). Mean of the Ca of the *A. ilicifolius* leaves was 1642 µg/g minimum value 191µg/g and maximum 2282 µg/g (Table - 4.4)

C. decandra > S. apetala >A. officinalis> A. ilicifolius

4.3.7.2 (2014)

Mean of the Ca of S. *apetala* leaves of Nijhum Dwip was 6665 µg/g with minimum value 5389 µg/g and maximum 7489 µg/g (Table - 4.14). In case of *S. apetala* plant, one way ANOVA showed that there was significant difference in Ca (p = 0.043) (Table - 4.18). Mean of the Ca of the *C. decandra* leaves of Nijhum Dwip was 1893 µg/g with minimum value 638 µg/g and maximum 2790 µg/g (Table - 4.15). Mean of the Ca of the *A. officinalis* leaves was 6980 µg/g with minimum value 6180 µg/g and maximum 8376 µg/g (Table - 4.16). In *A. officinalis* plant, Ca maintained positive significant correlation with Fe (r = 0.960, p= 0.010) (Table - 4.7). Mean of the Ca of the *A. ilicifolius* leaves was 2454 µg/g minimum value 1187 µg/g and maximum 3158 µg/g (Table - 4.17).

A. officinalis> S. apetala > A. ilicifolius> C. decandra

4.3.7.3 (2015)

Mean of the Ca of *S. apetala* leaves of Nijhum Dwip was 6775 µg/g with minimum value 5724 µg/g and maximum 7579 µg/g (Table - 4.27). Mean of the Ca of the *C. decandra* leaves of Nijhum Dwip was 9743 µg/g with minimum value 3431 µg/g and maximum 14350 µg/g (Table - 4.28). Mean of the Ca of the *A. officinalis* leaves was 3999 µg/g with minimum value 3360 µg/g and maximum 4440 µg/g (Table - 4.29). Mean of the Ca of the *A. ilicifolius* leaves was 2400 µg/g minimum value 1250 µg/g and maximum 3250 µg/g (Table - 4.30).

C. decandra> S. apetala > A. ilicifolius> A. officinalis

4.3.7.4 (2016)

Calcium (Ca) (2016)

Mean of the Ca of *S. apetala* leaves of Nijhum Dwip was 7418 µg/g with minimum value 6325 µg/g and maximum 8511 µg/g (Table - 4.40). In all location, *S. apetala* plant, One way ANOVA showed that there was significant difference in Ca ($p = 0.033$) (Table - 4.44). Mean of the Ca of the *C. decandra* leaves of Nijhum Dwip was 9743 µg/g with minimum value 3431 µg/g and maximum 14350 µg/g (Table -4.41). Mean of the Ca of the *A. officinalis* leaves was 3814 µg/g with minimum value 3360 µg/g and maximum 4386 µg/g (Table - 4.42). Mean of the Ca of the *A. ilicifolius* leaves was 2570 µg/g minimum value 1250 µg/g and maximum 3250 µg/g (Table - 4.43).

Ahmed *et al. (2010b)* found mean content of Ca in the leaves of same plant to be 1.71 %. In their study, Kotmire and Bhosale (1979) found Ca ranging from 0.14-2.80 % in the different mangrove species in the west coast of India (Maharashtra) and. Calcium content of the some mangrove species in the Bhitarkanika, Orissa, east coast of India were 02 - 08 µg/g in *R. mucronata* , 13 - 26 µg/g in *A. officinalis* , 10-24 µg/g in X. *granatum*, 11 - 32 µg/g in *C. decandra*, 31 - 72 µg/g in *B. cylindrica* (Sarangi *et al.* 2002).

C. decandra> S. apetala > A. officinalis >A. ilicifolius

4.3.8 Zinc (Zn)

The Zn content of studied four mangrove species of Nijhum Dwip followed a similar pattern of distribution among them, being higher in *A. officinalis followed by C. decandra, S. apetala and A. ilicifolius* all throughout the study period. The amount of Zn was lowest among the 6 metals.

4.3.8.1 (2013)

Mean of the Zn of the *S. apetala* leaves of Nijhum Dwip was 317.0 µg/g with minimum value 147.0 µg/g and maximum 592.0 µg/g (Table - 4.1). In all location, in *S. apetala*, One way ANOVA showed that there was significant difference in Zn ($p = 0.002$) (Table - 4.9). Mean of the Zn of the *C. decandra* leaves of Nijhum Dwip was 328.0 µg/g with minimum value 189.0 µg/g and maximum 499.0µg/g (Table - 4.2). Mean of the Zn of the *A. officinalis* leaves was 354.6 µg/g with minimum value 175.0 µg/g and maximum 675.0 µg/g (Table - 4.3). Mean of the Zn of the *A. ilicifolius* leaves was 237.0 µg/g minimum values 175.0 µg/g and maximum 289.0 µg/g (Table - 4.4).

A. officinalis > C. decandra> S. apetala > A. ilicifolius

4.3.8.2 (2014)

Zinc (Zn) (2014)

Mean of the Zn of the *S. apetala* leaves of Nijhum Dwip was 296.60 µg/g with minimum value 237.0 0µg/g and maximum 447.00 µg/g (Table - 4.14). In all location, One way ANOVA showed that there was significant difference in Zn ($p = 0.002$) (Table-4.9). Mean of the Zn of the *C. decandra* leaves of Nijhum Dwip was 325.00 µg/g with minimum value 108.00 µg/g and maximum 541.00 µg/g (Table - 4.15). Mean of the Zn of the *A. officinalis* leaves was 394.60 µg/g with minimum value 284.00 µg/g and maximum 613.00 µg/g (Table - 4.16). Mean of the Zn of the *A. ilicifolius* leaves was 226.40 µg/g minimum values 154.00 µg/g and maximum 298.00 µg/g (Table - 4.17).

A. officinalis > C. decandra> S. apetala > A. ilicifolius

4.3.8.3 (2015)

Mean of the Zn of the *S. apetala* leaves of Nijhum Dwip was 315.80 µg/g with minimum value 212.00 µg/g and maximum 523.00 µg/g (Table- 4.27). Mean of the Zn of the *C. decandra* leaves of Nijhum Dwip was 553.00 µg/g with minimum value 333.00 µg/g and maximum 724.00 µg/g (Table - 4.28). Mean of the Zn of the *A. officinalis* leaves leaf was 578.60 µg/g with minimum value 458.00 µg/g and maximum 674.00 µg/g (Table - 4.29). Mean of the Zn of the *A. ilicifolius* leaves was 224.90 µg/g minimum values 0.60 µg/g and maximum 314.00 µg/g (Table - 4.30).

A. officinalis > C. decandra> S. apetala > A. ilicifolius

4.3.8.4 (2016)

Mean of the Zn of the *S. apetala* leaves of Nijhum Dwip was 315.80 µg/g with minimum value 212.00 µg/g and maximum 523.00 µg/g (Table - 4.40). Mean of the Zn of the *C. decandra* leaves of Nijhum Dwip was 553.00 µg/g with minimum value 333.00 µg/g and maximum 724.00 µg/g (Table - 4.41). Mean of the Zn of the *A. officinalis* leaves was 565.80 µg/g with minimum value 458.00 µg/g and maximum 661.00 µg/g (Table - 4.42). Mean of the Zn of the *A. ilicifolius* leaves was 272.40 µg/g minimum values 199.00 µg/g and maximum 314.00 µg/g (Table - 4.43).

Ahmed *et al.* (*2010b)* found 23.62 ppm (mean) Zn in the Patuakhali, Bangladesh is the same plant. Zn found on other mangrove species in the Bhitarkanika, Orissa, east coast of India were 0.7 - 1.1 µg/g in the leaves of *R. mucronata*, 0.7 - 1.5 µg/g in the leaves of *A. officinalis,* 0.4 - 0.6 µg/g in the leaves of X*ylocarpus granatum*, 0.3 - 1.0 µg/g in *C. decandra*, 0.8-2.0 µg/g *B. cylindrica* (Sarangi *et al.* 2002).

A. officinalis > C. decandra> S. apetala > A. ilicifolius

5.1 Introduction

The coastal resources of Bangladesh have been exploited extensively since long without understanding the basic functional ecological systems. The supervision of these assets is also very inadequate. The security and preservation of the coastal zones and their environments are principal of all decent ecological and environmental condition. It needs detailed information of ecosystem functioning (Ducrotoy and Elliott 2006) and descriptive studies are also essential in order to measuring ecosystem dilapidation as a result of anthropogenic (Olenin and Ducrotoy 2006) and as well as other animals' actions and natural calamities.

Coastal plains and lowland river basins have been spaces for human advancement all over the history of human existences (Wolanski *et al.* 2006) although there is an troubled but extended relationship occurred among the coasts with man. The coast delivers rich environmental conditions (Van der Zwiep 1991) and diverse attractive and culturally significant landscapes are placed in these extremely complex zones. Because of great biological production (Blaber *et al.* 2000) and valuable environment service and functions (Costanza *et al.* 1997) the coastal regions of the world are under stress from human actions. Presently almost 60% of the world's inhabitants is living close to the coastline (Lindeboom 2002).

Bangladesh has a coastline of about 710 km long and mangrove forests (natural and planted) are the major vegetation type present there. Mangrove plantations are dynamic environments and support a great abundance and different diversity of flora and fauna. Litter fall has been valued to account for 30–60% of whole main production (Bunt *et al.* 1979). The significance of mangrove leaf litter in the conservation of waste-based nourishment webs in the coastal surroundings and their consequence for coastal fisheries has been directed for some time (Golley *et al.* 1962; Odum and Heald 1975; Ong *et al.* 1984; Lee 1995).

Bangladesh is considered as an economically 'developing' population and covers most exceptional and various coastal assets. Mangrove forests (natural and planted) of the coastal regions play an important part in the economy of the societies of these spaces. The supervision of this forest ecology - rich in plant and animal variety is important for the socio-economy and ecosystem of the country. But no formal or direct coastal resource management legislation occurred. Bangladesh has coastline zone of around 20,000 km^2 with about 24 million or 22% of the inhabitants existing there (Hossain 2001) and they are directly or indirectly reliant on the assets of this forest. Further, it shelters the lives and arrangement during the tornadoes and coastal currents. But for regular mangroves, the extended seashore was without plant protect till the commencement of the sound mangrove afforestation platform in 1966 (Siddiqi 2001). The natural assets of changed coastal islands of Bangladesh such as Nijhum Dwip, Char Tamaruddin, Char Kukri Mukri, Char Motherbunia, Char Taposhi etc. are managed by Forest department by establishing of trees in these zones with species such as *Sonneratia apetala* (Keora), *Avicennia officinalis* (Bain) and *Ceriops decandra* (Goran) since 1960s and 70s. *Porteresia coarctata*, locally known as Uri-Gash characterizes the only naturally budding pioneer species on the new deposits of the eastern and central seashores. Forest department hosted deer in these coastal islands which is fed on the Uri-gash and leaves of Keora plants. This help in the rapid build in of new ecosystems in the coastal areas. But the rapid growth in number of deer and ban on killing has created an ecosystem service problem in these areas. For appropriate management of resources of these islands, assessments of resources available are required.

From the viewpoint of vegetation, livestock, wildlife and economic return, correct stocking rate selection is the most significant of all grazing management decisions. Since the commencement of technical supervision early in the twentieth century this has been the greatest basic difficult challenging the ecosystem and range supervisors and specific methods to this problem were generally until the late 1980s (Holechek 1988, Toxel and White 1989). Knowledge in stocking rate results on particular parts or ranges have been established to be most significant and it is commonly approved that there is no additional for it. However, techniques now accessible will give reasonable assessment of providing rates for regions (Holechek *et al*. 1995)

So, the management and security of these irreplaceable but endangered natural assets of the coastal regions are vital. However, the actual management of coastal assets needs significant economic investment, strong capacity building including engagement of proper and knowledge staff and acceptance and assistance by the local populations which could be established within a administration framework built on complete scientific evidence on the structure and function of the ecosystems specially the biology and ecology (i.e. distribution and adaptation) of the target species. Over all, procedures framed based on ground level figures on the natural properties, stakeholders' view and current procedures such as Satellite images, Geographic Information Systems (GIS) (Ahmed *et al.* 2010, 2011, Ali *et al.* 2013, Giri *et al.* 2007) are precondition for the actual and workable management of any means. However, there is an absence of strategy procedures for the controlling of the natural resources of the coastal environments of Bangladesh. So, it is very essential to focus on the coastal territory to understand the ecology of the coastal sector. The objective of the study is to suggest suitable supervision policy by defining the applicable stoking rate and hence carrying capacity.

5.2 Materials and Methods

5.2.1 Determination of primary productivity

1m × 1m quadrats were established at different places throughout the char and fresh weight were measured to measure production of Uri-grass since April 2013 to December 2015 (three times a year).

Net primary production (NPP) can be measured by the following formula

NPP = ΔB + L + G

Where ΔB = B2 – B1

ΔB = Biomass change in the community between time t1 and time t2

B1 = Biomass at t1

B2 = Biomass at t2

L = Possible biomass losses by death of plants or plant parts

G = biomass losses by consumer organisms

5.3: Results and discussions

The island is 6.904 sq. km with length 5.235 km and width varied from 0.502 to 1.819 km. The annual primary production of the key forage species (Uri-grass) of the char was found during the study period to be 12000 tons. It is however usual for ecologists to use the “rule of thumb” to determine allowable levels of utilization. The rule is “take 50 leave 50”. The 50% that is left behind as the residual biomass necessary for the continued plant growth. Thus the allowable biomass to be removed is 1500 tons per year. Forage demand of the particular species of livestock (here spotted deer is

Table 5.1: Fresh and dry weight of Uri grass (*Porteresia coarctata*) of Dwip Tamaruddin during the study period

a. First visit (April 2013)

Serial No	Sample Name	Fresh weight *(gm^{-2})*	Dry weight *(gm^{-2})*	Total Production Ton/ha (fresh wt. basis)	Total production Ton/ha (dry wt. basis)
1	S1	60	25.25	0.55 ± 0.01	0.25 ± 0.04
2	S2	50	22.23		
3	S3	60	16.56		
4	S4	40	19.38		
5	S5	55	21.26		
6	S6	66	30.86		
7	S7	50	20.56		
8	S8	68	24.12		
9	S9	42	15.36		
	Mean value	54.555 ± 9.89	21.73111± 4.96		

b. *S*econd visit (July 2013)

Serial No	Sample Name	Fresh weight (gm^{-2})	Dry weight (gm^{-2})	Total production Ton/ha (fresh wt. basis	Total production Ton/ha (dry wt. basis)
1	S1	72	35.25	0.69 ± 0.09	0.28 ± 0.05
2	S2	59	28.23		
3	S3	73	25.56		
4	S4	52	20.31		
5	S5	67	21.22		
6	S6	80	34.81		
7	S7	79	33.51		
8	S8	75	29.12		
9	S9	66	25.36		
Mean value =		69.222 ± 9.24	28.15 ± 5.5		

Table: 5.1 Continued

c. Third visit (December 2013)

Serial No	Sample Name	Fresh weight (gm^{-2})	Dry weight (gm^{-2})	Total production Ton/ha (fresh wt. basis	Total production Ton/ha (dry wt. basis)
1	S1	102	50.25	0.77 ± 0.29	0.35 ± 0.12
2	S2	98	34.23		
3	S3	101	45.53		
4	S4	78	35		
5	S5	29.31	15.21		
6	S6	92	41		
7	S7	42.26	23.21		
8	S8	103	45.52		
9	S9	50.81	24.02		
Mean value =		77.37± 28.96	34.88 ± 11.94		

d. First visit (April 2014)

Serial No	Sample Name	Fresh weight (gm^{-2})	Dry weight (gm^{-2})	Total production Ton/ha (fresh wt. basis	Total production Ton/ha (dry wt. basis)
1	S1	130	62.25	0.97 ± 0.55	0.63 ± 0.29
2	S2	56	24.23		
3	S3	210	95.45		
4	S4	115	68		
5	S5	21.28	29.31		
6	S6	120	92		
7	S7	60	42.26		
8	S8	90	103		
9	S9	70	50.81		
Mean value =		96.92 ± 55.08	64.03 ± 29.08		

Table: 5.1 Continued

e. Second visit (July 2014)

Serial No	Sample Name	Fresh weight (gm^{-2})	Dry weight (gm^{-2})	Total production Ton/ha (fresh wt. basis	Total production Ton/ha (dry wt. basis)
1	S1	160	80	1.10 ± 0.59	0.66 ± 0.30
2	S2	240	135		
3	S3	130	60.28		
4	S4	70	50.05		
5	S5	100	67.05		
6	S6	75	55.87		
7	S7	55	35.88		
8	S8	90	75.09		
9	S9	68	35.24		
Mean value =		109.78 ± 59.06	66.05 ± 31.16		

f. Third visit (December 2014)

Serial No	Sample Name	Fresh weight (gm^{-2})	Dry weight (gm^{-2})	Total production Ton/ha (fresh wt. basis	Total production Ton/ha (dry wt. basis)
1	S1	180	70	1.28 ± 0.58	0.67 ± 0.31
2	S2	255	145		
3	S3	140	50.25		
4	S4	85	35.15		
5	S5	115	75.05		
6	S6	90	57.27		
7	S7	69	61.88		
8	S8	121	59.19		
9	S9	95	55.21		
Mean value =		127.77 ± 58.15	67.66 ± 31.16		

Table: 5.1 Continued

g. First visit (April 2015)

Serial No	Sample Name	Fresh weight (gm^{-2})	Dry weight (gm^{-2})	Total production Ton/ha (fresh wt. basis)	Total production Ton/ha (dry wt. basis)
1	S1	201	75	1.38 ± 0.76	0.72 ± 0.30
2	S2	275	145		
3	S3	170	61.18		
4	S4	102	55.15		
5	S5	145	85.05		
6	S6	121	59.27		
7	S7	90	41.82		
8	S8	140	67.20		
9	S9	115	55.11		
Mean value =		155.5 ± 60.06	71.64 ± 30.18		

h. Second visit (July 2015)

Serial No	Sample Name	Fresh weight (gm^{-2})	Dry weight (gm^{-2})	Total production Ton/ha (fresh wt. basis)	Total production Ton/ha (dry wt. basis)
1	S1	220	90	1.66 ± 0.57	0.86 ± 0.28
2	S2	286	155		
3	S3	185	81.88		
4	S4	119	65.25		
5	S5	159	96.05		
6	S6	135	70.27		
7	S7	112	55.82		
8	S8	152	87.20		
9	S9	126	75.11		
Mean value =		166 ± 56.57	86.28 ± 28.72		

Table: 5.1 Continued

i. Third visit (December 2015)

Serial No	Sample Name	Fresh weight (gm^{-2})	Dry weight (gm^{-2})	Total production Ton/ha (fresh wt. basis	Total production Ton/ha (dry wt. basis)
1	S1	236	138	1.84 ± 0.66	0.77 ± 0.39
2	S2	320	75		
3	S3	222	73		
4	S4	130	80.20		
5	S5	180	146		
6	S6	160	55.35		
7	S7	125	44.34		
8	S8	159	48.09		
9	S9	120	35.99		
Mean value =		183.55 ± *65.52*	*77.33* ± 39.62		

considered with body weight of female is considered to be 45 kg and that of male 65 kg) is about 328.5 kg/y and 474.5 kg/y for female and male spotted deer respectively. These values showed that if we plan to have only female in the herd then the number will be 2341 and 3600 in 2014 and 2015 respectively (Table 5.6) and if only male is used then the number will be 1700 and 2500 in 2015 respectively. If we use 50:50 of female and male then the number will half in either case. But in case of commercial carrying capacity, i.e. meat is the goal, and then male spotted dear with higher body weight might be preferable to the authority. But in this case reproduction of next generation will be a problem. In western ranches, usually 2 bulls are maintained per 20 oxen. If we take this into consideration then of 2341 female deer we will need 234 and 3600 female deer in will need 360 male deer 2014 and in 2015 respectively. Depending on the management goal the type of carrying capacity have to select. Besides Keora plant could be considered as another key species and deer like it very much. According to Bunt *et al.* (1979) mangrove litter fall analyses for about 30 – 60 %, which calculates the number of deer could be improved also depending on the litter biomass production of the particular char.

A more modest and conventional technique had been suggested by Toxel and White (1989) that assigned 25 % of present year forage manufacture to livestock, another 25 % to natural departure (insects, wildlife, weathering) and 50 % is left for the protection of the area. It has been established that stocking rate encourages flora productivity more than any other elements do (Holechek 1988). An increase of annual herbage production by 13 % was recorded when specialized grazing systems were implemented at a moderate stocking rate (Hazell 1967). When continuous livestock use was reduced from heavy to moderate caused in an average growth of 35 % (Van Poollen and Lacey 1979). Forage demand is a purpose of the figure of animals and the number of days they will

Table: 5.2 Average forage productions in 2013

Visit	Forage Production (gm^{-2})	Production of the island (Ton)
Ist	52.555	362.84
2nd	69.222	477.91
3th	95.777	661.24
	Average value = 72.518	500.66

Table: 5.3 Average forage productions in 2014

Visit	Forage Production (gm^{2})	Production of the island (Ton)
Ist	96.666	667.38
2nd	109.777	757.90
3th	127.777	882.17
	Mean value = 111.4067	769.15

Table: 5.4 Average forage productions in 2015

Visit	Forage Production (gm^2)	Production of the island (Ton)
Ist	151	1042.504
2nd	166	1146.064
3th	183.555	1267.26
	Mean value = 166.8517	1151.94

Table: 5.5 Average forage productions from 2013 to 2015

Year	Forage Production (gm^{-2})	Production of the island (Kg)	Difference 13-15
2013	72.518	500664.27	------
2014	111.4067	769151.63	268487.36
2015	166.8517	1151943.91	382792.28

Table: 5.6 proposed total number of deer 2013 to 2015 in Nijhum Island

Name of year	Production of the Island (KG)	KG/Year for 45KG deer (Female)	KG/Year for 65KG deer (male)	Total Number Female deer (increment basis)	Total Number male deer (increment basis)
2013	500664.2720	328.5	474.5		……………
2014	769151.6267	328.5	474.5	2341	1700
2015	1151943.9070	328.5	474.5	3600	2500

inhabit the range (Holechek 1988). Whitson *et al.* (1982) have considered the effect of grazing methods on the magnitude and steadiness in the profits of ranch of Texas. It will help to maximize the utilization of the natural resources of the study area without any harm to the chars. As the coastal zone of Bangladesh is one of the most vulnerable areas of the current world climate change scenario, the coastal chars along with the mangrove plantation are helping us to mitigate the natural calamities and saving lives and millions of dollar. The knowledge gained from this study can also be scaled up to help manage other similar coastal chars. Meat produced can be sold in local market in higher price as meat of deer has a higher demand. Besides deer can be used as sacrificing animals during the Eid-Ul-Azha festival. Community based natural resource management is gaining popularity throughout the world in conserving resources and for the betterment of local people. Local community should be given the ownership of the land of the chars to manage the resources which will help them to earn their livelihood, helps in gaining the food security and the resources will be better managed.

6.1 General discussion

Nijhum Dwip is a small island under Hatiya upazila. It is situated in Noakhali District in Bangladesh. Once it was called Char Osmani, Baluar Char and Golden Island. A cluster of islands (mainly, Ballar Char, Kamlar Char, Char Osman and Char Muri) emerged in the early 1950s as an alluvium in the shallow estuary of the Bay of Bengal on the south of Noakhali. These new sand banks first drew the notice of a group of fishermen who named it Baular Char (literally, the alluvium of sand) later transformed into Ballar Char. Occupying an area of 14,050 acres (5,686 hectares) the island is situated between 21 0 1 / to 22 0 6 /North latitude and 90 0 3 / to 91 0 4 / East longitude. An investigation was done of the Dwip to know the ecological conditions in relation to edaphic properties, foliar nutrient status of the different planted mangrove species and to know the carrying capacity of the Dwip for the better management.

Land and forest cover have been changed very significantly of this Island in the last forty years i.e. from 1973 to 2015. The natural causes are also affecting the study area. Lack of proper management of the mangrove forest resources results in serious consequences not only locally but also concerns Bangladesh as a whole. Among the causes of change natural ones cannot be controlled fully, while man-made causes may be controlled more effectively. Remote sensing and GIS provides a great potential to monitor this island. It also offers the possibility to monitor large regions and to study changes in the entire ecosystem over space and time.

Moisture showed gradually decreased from 2013 to 2016 indicating the Dwip is raising resulting less inundation by tidal waves. The mean value of soil moisture in the island was 42.41 % where the minimum value was 32.90 % and maximum value was 60.60 % in 2013 and in 2016 it was the mean value of soil moisture in the island was 22.09 % where the minimum value was 10.20 % and maximum value was 28.00 %. The values of pH slightly decreased in four years i.e. in 2013, the mean value of pH was 7.6 with minimum value 6.5 and maximum 9.3 and in 2016 it was 6.69 with minimum value 5.10 and maximum 9.05. Some other researchers reported soil pH above 7.0 ranging from 7.4 - 8.22 (Sah *et al.* 1989, Hossain *et al.* 2012, Das *et al.* 2012). Salinity also decreased in the study period i.e. in 2013 mean value is 9.5 ‰ and in 2016 mean value of salinity 3.29 ‰ which is the good sign for the island because mangrove flora is more rich in lower salinities (Kathiresan *et al.* 1996) Organic carbon and Nitrogen showed increasing tendency between the study time i.e. mean of organic carbon was 0.48 % in 2013 and in 2016 the mean value was 1.4 %. Some researchers established that content of organic carbon in Char Tamaruddin was very low where mean value was 0.80% with minimum 0.65% and maximum 1.02 % (Das 2012). Ahmed *et al.* (2010) stated nearly related volume of organic carbon was from 0.88 % to 1.56 % from different offshore islands of Patuakhali, Bangladesh and mean value of Nitrogen was 0.67 % with minimum value 0.301 % and maximum 0.991 % in 2013 and the mean of the soil N of Nijhum Dwip was 1.87 % with minimum value 0.989 % and maximum 2.60 % in 2016. Others variables i.e. P, Na K, Mg, Mn, Ca, Zn and Pb showed fluctuation within this period and the values of these variables of soil did not surpass the standard value of IAEA (1990). Principal component analysis (PCA) was used to assist to recognize the underlying data structure and/or to form a smaller number of uncorrelated variables (for example, to avoid multi collinearity in regression). Estimation of productivity and carrying capacity has been done to find out proper for management approach, food security and livelihood earning of the local communities in the Coastal Islands. Meat produced can be sold in local market in higher price as meat of deer has a higher demand. Besides deer can be used as sacrificing animals during the Eid-Ul-Azha festival. Community based natural resource management is gaining popularity throughout the world in conserving resources and for the betterment of local people.

Local community should be given the ownership of the land of the chars to manage the resources which will help them to earn their livelihood and the resources will be better managed. These chars also play a vital role in minimizing the effect of sea level rise. The chars in the coastal area must be protected properly because they save the lives of the coastal communities from natural disasters.

7.1 Conclusion

This study dealt with the findings of land area and vegetation area changed of Nijhum Dwip in Bangladesh over the last forty years i.e. since 1973 to 2015 with the help of Satellite Image by using Remote Sensing (RS) and GIS technology and dynamics of physico-chemical properties of soil, mineral nutrient diversity of different mangrove species and relationship among different variables of soil in this Island. The land area and vegetation cover of Nijhum Dwip has increased from that time i.e. 1973 to 2015 except in 2010. The land and forest area have been found to decline in 2010. On the basis of production of *Porteresia coarctata* (Uri grass) and leaves of *Sonneratia apetala* plants from 2013 to 2015, the proposed carrying capacity of deer of this island was very high. If the knowledge of carrying capacity be applied in other similar coastal islands, the protein demand of local people and hence the food security and economic condition will increase. Among the physico- chemical properties of soil of this island, moisture showed gradually decreased from 2013 to 2016, salinity decreased in the study period which was the most positive change of this Island because salinization leads to a partial or total loss of the productive capacity of a soil because of degradation of its chemical and physical properties. Organic carbon and Nitrogen of soil showed increasing tendency between that times. Increase in OC and N will facilitate the luxurious growth of mangrove species which will help to regulate more C from the atmosphere and thus will have a positive feedback in climate change. Others variables i.e. P, Na K, Mg, Mn, Ca, Zn and Pb showed fluctuation in that time and the mean value of these heavy metals did not exceed the standard value of IAEA (1990).

Principal component analysis (PCA) was carried out and showed positive, negative loading and cluster formation among the variables in different locations of this island in 2013, 2014, 2015 and 2015. *Soneratia apetala* is most dominant tree in Nijhum Dwip.

Other commonly found mangrove species are *Avicennia officinalis, Ceriops decandra and A. ilicifolius.* Mineral nutrients of leaves showed increasing tendency of Nitrogen in leave from 2013 to 2016 and the rest variables showed fluctuating within this time. Pearson's correlation and regression were used to detect correlations and linear regressions between soil and plant variables.

7.2 Recommendations

Change detection is helpful for understanding the change in forest coverage and land area of any remote area by using RS and GIS technology. So for the better management of this island, this technology should be used at a regular interval. Coastal zone of Bangladesh is very vulnerable in the context of current world climate change scenario, the coastal zone char along with mangrove plantation are helping us to mitigate natural calamities and saving lives and it will help to maximize utilization of natural resources without any harm to the island. Meat produced can be sold in local market in higher price as meat of deer has a higher demand and would helpful for food security as well as protein demand. Besides deer can be used as sacrificing animals during the Eid-Ul-Azha festival. Community Based Natural Resource Management (CBNRM) is gaining popularity through the world in conserving resource and for the betterment of local people. Local people should be given the ownership of the land of this island to manage the resource which helps them to earn their livelihood and the resource will be better managed. This knowledge should be scaled up to manage other similar coastal islands which the reduce pressure on Sundarbans.

Referrences

Abrahim GMS and Parker RJ 2008. Assessment of heavy metal enrichment factors and the degree of contamination in marine sediments from Tamaki Estuary, Auckland, New Zealand. Environ. Monit. Assess. **136**: 227 - 238.

Agarwal A (1987). "Development Policies Ecology and Gandhi's Last Person", Social Action, Vol. **37**: No. 1, pp. 45-60.

Ahmed A, Ohlson M, Hoque S and Moula MG 2010a. Edaphic conditions of different chars under different hydrological regimes in the coastal zones of Bangladesh. Dhaka Univ. J. Biol. Sci. **19** (1): 27-40.

Ahmed A, Ohlson M, Hoque S and Moula MG 2010b. Chamical composition of leaves of a mangrove tree (*Sonneratia apetala*, Buch.-Ham) and their correlation with some soil variables. Bangladesh J. Bot. **39** (1): 27-40.

Ahmed A, Aziz A, Islam MN, Iqubal KF, Nazma and Islam MS 2011. Tree diversity as affected by salinity in the Sundarban Mangrove Forests, Bangladesh. Bangladesh J.Bot. **40** (2):197-202.

Ahmed A, Ataullah M, Rashid P, Paul AR, Dutta S and Ali MS 2018. Species diversity, change in forest cover and area of the Sundarbans, Bangladesh. Bangladesh J. Bot. **47** (3):351-360.

Ahmed K, Mehedi MY, Haq R and Ahmed F 2002. Heavy metals concentration in water and sediment of the Sundarbans reserved forest, Bangladesh. Asian J. Microb Biotec & Environ Sci. **4** (2):171-179.

Alemayehu M 2006. Range Management for East Africa: Concepts and Practices, Sponsored by RPSUD and Printed by A.A.U Printed Press. Addis Ababa, Ethiopia.

Ali A 1999. Climate change impacts and adaptation assessment in Bangladesh. Clim. Res. **12**:109-116.

Ali HK. 2013. Towards sustainable tourism: The need to integrate conservation and development using the Buccoo Reef Marine Park, Tobago, West Indies. Natural Resources Fourm **37**. pp. 90-102.

Ali MS, Haque MF, Rahman SMM, Iqubal KF, Nazma, Ahmed A 2013**.** An estimation of loss and gain of land of Manpura Island in Bhola district: an integrated approach using remote sensing and GIS technologies. Dhaka Univ. J. Biol. Sci. **22** (1): 29-37.

Ali MS, Rahman SMM, Mohammad A, Saha SB, Haque SAMA, Nazma, Ahmed A 2018. Land use and land cover changes and their geo-environmental impacts in nachole upazila under chapai-nawabgang district of Bangladesh: A RS and GIS approach Vol.**6**: ISSN- 2350-0530(O), ISSN- 2394-3629(P)

Ali MS, Dutta S, Pramanik AT, Haque SAMA Rahman SMM, Nazma, Ahmed A 2017**.** Assessment of Landuse and Land Cover Changes in St Martin’s Island under Cox’s Bazar District of Bangladesh using RS and GIS Technology. ISSN- 2320-9283Peer Reviewed International Journal, IJSD, Ranchi,India,Vol,5(4),India 201

Alexander SE, Schneider SH and Lagerquist K (1997). The interaction of climate and life. In G. C.Daily, ed.Nature’s Services pp.71–92. Island Press,Washington DC.

Aprile FM and Bouvy M 2008. Distribution and Enrichment of Heavy Metals in Sediments at the Tapacurá River Basin, North Eastern Brazil. Brazilian J. Aquat. Sci. Tech. **12:** 1-8.

Ataullah M, Chowdhury MMR, Hoque S and Ahmed A 2017. Physico-chemical properties of soils and ecological zonations of soil habitats of Sundarbans of Bangladesh. Inter. J. Pure and Applied Researches, **1** (1):80-93.

Ataullah M, Hoque S, Rashid P and Ahmed A 2018. Spatial variation and contamination levels of different metals in soils of Bangladesh Sundarbans. Indian Forester. **144** (5): 412-423.

Bandaranayake WM 1998. 'Traditional and medicinal uses of mangroves" Mangrove and Salt Marsh **2**: 133–148.

Bandaranayake WM 2002. Bioactivities, bioactive compounds and chemical constituents of mangrove plants. Wetlands Ecol. Manage **10**: 421–452.

Bhasin V 1989. Ecology, culture, and change: tribals of Sikkim Himalaya. New Delhi: Inter-India Publications.

Bhosale.LJ 1979. Distribution of trace elements in leaves of mangroves, Indian J. Mar. Sci. **8**: 58-59

Biging GS, Colby DR, Congalton RG 1999. Sampling systems for change detection accuracy assessment. In: Lunetta RS, Elvidge C eds. Remote sensing change detection: environmental monitoring methods and applications. Taylor & Francis, London. Pp. 281–308

Blaber SJM, Cyrus DP, Albaret JJ, Ching CV, Day JW, Elliott M, Fonseca MS, Hoss DE, Orensanz J, Potter IC and Silvert W 2000. Effects of fishing on the structure and functioning of estuarine and near shore ecosystems. ICES J. Marine Sci **57**: 590–602.

Blanco AVR 2006: Local initiatives and adaptation to climate change. Disas-ters, **30**:140-147.

Boojh Ram 1992. "Environmental Management of Natural Living Resources". In C.V. Rajashekhara(ed.). Global Environment Series: Environmental factors in Economic and Industrial Management. Vol.**4**. New Delhi: Discovery Publishing House.

Boto KG and Wellington JT 1983. Phosphorus and nitrogen nutritional status of a northern Australian mangrove forest. Mar. Ecol. **11**: 63-69.

Boto KG and Wellington JT 1984. Soil N Characteristics and Nutrient Status in a Northern Australian Mangrove Forest. Estuaries **7**(1): 61-69.

Braman KA, Daily GC, Duarte TK, and Mooney HA (2007). The nature and value of ecosys-tem services: an overview highlighting hydrologic services. Ann. Rev. Env. Res. **32**: 67–98.

Bunt JS, Boto KG and Boto G 1979. A survey method for estimating potential levels of mangrove forest primary production. Mar. Biol. **52**:123-128.

Bunt JS, Williams WT and Duke NC 1982. Mangrove distributions in North East Australia J. of Bioge **9**: 111-120.

Chowdhury AM 1998. Monitoring of Tropical Cyclone of May 1997 that Hit Bangladesh Using Data from GMS-5 Satellite, J. Rem. Sens. Environ **2,** 51-53.

Congalton R 1991. A review of assessing the accuracy of classifications of remotely sensed data. Rem.Sens. Environ. **37**:35–46.

Congalton R and Green K 1999. Assessing the accuracy of remotely sensed data: Principles and Practices, CRC/Lewis Press, Boca Raton, Florida, 137 p.

Costanza R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, Paruelo J, Raskin RG, Sutton P and Belt M 1997. The value of the world's ecosystem services and natural capital. **387**: 253–260.

Costanza R and Folke C 1997.Valuing ecosystem Service with efficiency, fairness and sustainability and goals. In: Daily G(ed) Nature's Services: Societal Dependence on Natural Ecosystem. Island Press, Washington, DC, pp 49-97

Curtin R and Prellezo R 2010. Understanding marine ecosystem based management: A literature review. Marine Policy. **34 (5)**:821-830.

Das D 2012. Ecological studies on the planted mangrove forest of Meghna estuary at Hatiya, Noakhali. M.S. Thesis, University of Dhaka, Bangladesh. Pp-76

Das S, Ganguly D, Maiti TK, Mukherjee A, Jana TK and De TK 2012. Depth integrated microbial community and physico-chemical properties in mangrove soil of Sundarban, India. Adv. Microbiol**. 2**: 234-240.

Davaulter V and Rognerud S 2001. Heavy metal pollution in sediments of the Pasvik River drainage. Chemosphere **42** (1): 9-18.

Davis FW and DS Simmonett 1991. GIS and remote sensing. Pages 191-213 in Geographical Information Systems: Principles and Applications, edited by D. J. Maguire M F Goodchild and DW Rhind. Longman Scientific and Technical, United Kingdom.

Dengsheng 2004. Photogrammetric engineering and remote sensing. **70** pp. 1053-1062

Dobriyal RM, Singh GS, Rao KS and Saxena KG 1997. "Medicinal Plant Resources in Chhakinal Watershed". Journal of Herbs, Spices and Medicinal Plants **5**: 15-27.

Dodson SI, Allen TFH, Carpenter SR, Ives AR, Jeanne RL, Kitchell JF, Langston NE and Turner MG 1998. Ecology,Oxford University Press, New York, New York, USA. knowledge of earth asa system.Sci. **290**: 291–296.

Durham WH 1976. Resource competition and human aggression, Part 1: A review of primitive war. Q. Rev. Biol. **51**:385-415.

Ducrotoy JP and Elliott M 2006. Recent developments in estuarine ecology and management. Mar. Poll. Bull. **53**:1-4.

Epstein E 1972. Mineral nutrition in plants: principles and perspective. John Wiley and Sons, New York. 51-82.Gesamp (imo/fao/ijnesco/wmo/iaea/un/ijnep) (1982). The health of the oceans: Rep. Stad. GESAMP 15:108.

Falkowski P, Scholes RJ, Boyle E et al. (2000). The global carbon cycle: a test of our knowledge of earth asa system.Sci. **290**: 291–296.

Folke C and Berkes F. 1995. Traditional ecological knowledge, biodiversity, resilience and sustainability. In CA Perrings, K-G Marler, C Folke and CS Holing (eds), Biodiversity Conservation. Dordrecht: Kluwer Academic Publishers, pp 281-299.

Filho S and Costa FR 2006. Using mangroves as a geological indicator of coastal changes in the Branganca macrotidal flat Brazilian Amazon: a remote sensing data approach. Ocean Coast. Manage. **49**: 462-475.

Gadgil M and Berkes F 199l. "Traditional Resource Management Systems". Resource Management and Optimization **8**: 127-141.

Gadgil M, Berkes F and Folke C 1993. "Indigenous Knowledge for Biodiversity Conservation". Ambia, **22**: 151-156.

Gammon MD 1984. Principles of grazing management. Agritex Notes, Zimbabwe, Mimeo.

Ghani SA, Zokm G, Shobier A, Othman T, Shreadah M 2013. Metal pollution in surface sediments of Abu-Qir Bay and Eastern Harbour of Alexandria, Egypt. Egyptian J. Aquat. Res. **39:** 1–12.

Giri C, Pengra B, Zhu Z, Singh A , Tieszen LL 2007. Monitoring mangrove forest dynamics of the Sundarbans in Bangladesh and India using multi-temporal satellite data from 1973 to 2000. Estua, Coastal Shelf Sci. **73**: 91-100.

Golley F, Odum HT, and Wilson RF 1962. The structure and metabolism of a Puerto Rican red mangrove forest in May. Ecol. **43**: 9-19.

Gould W 2000. Remote sensing of vegetation, plant species richness, and regional biodiversity hotspots. Ecol. Appl. **10**(6): 1861-1870.

Granatstein D and Bezdicek DF 1992. "The Need for a Soil Quality Index: Local and Regional Perspectives." Am. J. of Alternative Agriculture **7** (Nos. 1 and 2):12-16.

Greenway H and Munns R 1980. Mechanisms of salt tolerance in nonhalophytes. Ann.l Rev. Plant Physiol. **31**(1): 149-190.

Gupta AK 1997. "Getting Creative Individuals and Communities their Due". Paper presented at the South and Central Asian Regional Workshop on Community-based Conservation, 9~ 11 February, Indian Institute of Public Administration, New Delhi.

Gupta AK 1999. Securing Traditional Knowledge and Contemporary Innovations: Global Trade Can Links help Grassroots Innovations.Honey Bee Perspective. Invited paper for World Trade Forum, Bern, August 27-29.

Hakanson L 1980. An ecological risk index for aquatic pollution control: A sedimentological approach. Water Res. **14** (8): 975-1001.

Harold F, Heady 1971. Specialized grazing and production. J. Range Manage, **20**: 249-252.

Hasan AB, Kabir S, Reza AHMS, Zaman MN, Ahsan A and Rashid M 2013. Enrichment factor and geo-accumulation index of trace metals in sediments of the ship breaking area of Sitakund Upazilla (Bhatiary–Kumira), Chittagong. Bangladesh. J. Geochem. Explor. **125**: 130–137.

Haque MDR, Ahmed JU, Chowdhury MDDA, Ahmed MDK and Rahman MDS 2004. Seasonal variation of heavy metals concentration in sediments of the rivers and estuaries of Sundarbans mangrove forests. Asian J. Microbiol. Biotech. Environ. Sci. **6** (2):175-185.

Hasan AB, Kabir S, Reza AHMS, Zaman MN, Ahsan A and Rashid M 2013. Enrichment factor and geo-accumulation index of trace metals in sediments of the ship breaking area of Sitakund Upazilla (Bhatiary–Kumira), Chittagong. Bangladesh J. Geochem. Explor. **125**: 130–137.

Hazell 1967. Effect of grazing intensity on plant composition, vigor, Shiflet.

Henderiks J and Brabec B 2002. Calibration of Gephyrocapsa coccolith abundance in Holocene sediments for paleotemperature assessment. Paleocean. **17**: 7-9.

Hersom M 2010. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Available online at http://edis.ifas.ufl.edu (Accessed on March 23, 2012)

Hesse PR 1961. Phosphorus relationships in a mangrove swamp mud with particular reference to aluminium toxicity. Plant Soil. **19:** 205-218.

Holechek JL 1988. An approach for setting the stocking rate. Rangelands **10**:10-14.

Holechek JL and Pieper RD 1992. Estimation of stocking rate on New Mexico rangeland. J Soil Cater Conser. **47**:116–119.

Holechek JL, Pieper RD and Herbel CH 1995. Range management: principles and practices. Printice -Hall Inc, NJ. pp

Hossain MZ, Aziz CB and Saha ML 2012. Relationships between soil physico-chemical properties and total viable bacterial counts in Sunderban mangrove forests, Bangladesh. Dhaka Univ. J. Biol. Sci. **21**:169-175.

Hossain MS 2001**.** Biological aspects of the coastal and marine environment of Bangladesh. Ocean Coast. Manage **44**: 211-282.

Hossain MS 2003. Land use zoning for solar salt production in Cox's Bazar coast of Bangladesh: A Remote Sensing and GIS analysis. Asian J Geoinform. **3** (4):69-77.

Holmer M, Kristensen E, Banta G, Hansen K, Jensen MH and Bussawarit N 1994. Biogeochemical cycling of sulfur and iron in sediments of a south-east Asian mangrove, Phuket Island, Thailand. Biogeochem. **26** (3): 145-161.

Howe CW 1979. Natural Resource Economics. John Wiley and Sons, New York.

IAEA (1990). Guidebook on applications of radio tracers in industry. Tech. Rep. Seri. No. 316.

Iyengar S. and Shukla N 2000. "Regeneration and Management of Common Property Land Resources in India". In B.C. Barik (ed.) Resource Management and Contours of Development: Reflections through Macro-Micro Narratives. New Delhi: Rawat Publications.

Chapter – 8: Referrence

Jackson ML 1973. Soil chemical analysis. Constable and Co. Ltd, London.

Jagtap TG 1987. Distribution of algae, sea grasses and coral communities from Lakshadweep, Eastern Arabian Sea. Indian J. Mar. Sci., **16** (4): 256-260.

Jaafari S, Alizadeh SA, Danehkar A, Nazari SA 2014. Quarterly journal of natural environment (Iranian journal of natural resources) **66**: 34 - 350

Karim A 1994. The physical environment. *In: Mangrove of the Sunderbans* (Hussain Z and G Achanya Eds), Vol 2. Bangladesh. pp. 11-42. IUCN, Bangkok.

Karlen DL, Eash NS and Unger PW 1992. Soil and crop management effects on soil quality indicators. American J. Altern. Agricul. **7**: 48-55

Kathiresan K, Rajendran N and Thangadurai G 1996. Growth of mangrove seedlings in the intertidal area of Vellar estuary, southeast coast of India. Indian J. Mar. Sci.**25**: 240-243.

Kerr JM. and Swarup R 1997. Natural resource policy and problems in India. In: Natural resource economics - theory and application in India(eds. Kerr, J.M., D.K. Marothia K. Singh C. Ramasamy and W.R. Bentley). Pp. 3–33. New Delhi: Oxford & IBH.

Ketchum BH 1972. The water’s edge: critical problems of the coastal zone. In Coastal Zone Workshop, Woods Hole Oceanographic Institution, Cambridge: MIT Press Massachusetts.

Khan H and Brush GS 1994. Nutrient and Metal Accumulation in Freshwater Tidal Marsh. Estua. **17** (2): 345.

Khan ZH, Hussain MS and Muzumder AR 1998. Properties of soils from the offshore islands of Bangladesh. Bangladesh J. F. Sci. **27**: 114-120.

Khorram S 1999. Accuracy Assessment of Remote Sensing-Derived Change Detection, American Society for Photogrammetry and Remote Sensing, Bethesda MD.

Khulbe RD 1989. "Water and Aquatic Resources of Kamaun Himalaya: Problems and Management". In V.P. Agarwal, B.N. Desai and S.A.H. Abidi (eds). Management of Aquatic Ecosystems. Delhi: Narendra Publishing House.

Klemas V 2011. Remote sensing techniques for studying coastal ecosystems: An overview. J. Coast. Res. **27**(1): 2–17.

Kotmire SY and Bhosale LJ 1979. Some aspects of chemical composition of mangroves leaves and sediments. Mahasagar **12** (3):149-154.

Kumar A, Ramanathan AL, Prasad MBK, Datta D, Kumar M and Sappal SM 2016. Distribution, enrichment, and potential toxicity of trace metals in the surface sediments of Sundarban mangrove ecosystem, Envir. Sci. Poll. Res. **23**: 8985-8999.

Lacerda LD, Ittekkotb V and Patchineelama SR 1995. Biogeochemistry of Mangrove Soil Organic Matter: a Comparison between Rhizophora and Avicennia Soils in South-eastern Brazil. Estua. Coast. Shelf Sci. **40**:713–720

Lambin EF and Ehrlich D 1997. Land-cover changes in sub-Saharan Africa (1982–1991): application of a change index based on remotely sensed surface temperature and vegetation indices at a continental scale. Rem. Sens. Environ. **61:** 181–200.

Lal R 1991. Tillage and agricultural sustainability. Soil Till. Res. **20** :133-146.

Lee SY 1995. Mangrove out welling: a review. Hydrobiol. **295**: 203–212.

Lee SY 1998. Ecological role of grapsid crabs in mangrove ecosystems: a review. Mar. Fresh. Res. **49**:3 35–343.

Liao JF 1990. The chemical properties of mangrove Solonchak in the northeast part of Hainan Island. The Acta Scien. Nat. Universities Sunyatseni **9** (4): 67 - 72.

Lin P, Su L and Lin QY 1987. Studies on the mangrove ecosystems of the Jiulong River Estuary in China. II. Accumulation and biological cycle of potassium and sodium elements in the *Kandelia candel* community Acta Ecol. Sin 7 (2): 102–110.

Lin G and Sternberg LSL 1993. Effects of salinity fluctuation on photosynthetic gas exchange and plant growth of the red mangrove (*Rhizophora mangle* L.). J. Exp. Bot. **44**: 9-16.

Lin P and GH Lin 1985. Studies on the mangrove ecosystems of Jiulong Jiang River estuary in China. IV. The accumulation and biological cycle of nitrogen and phosphorus elements in the Kandelia candel community. Acta Phytoecol. et Geobot. Sin. **9** (1): 21-31.

Lindeboom H 2002 . The coastal zone: an ecosystem under pressure. In Oceans Science, Trends and the Challenge of Sustainability. Field JG, G Hempel and CP Summerhayes (Eds), pp. 49–84.

Lucas R, Rowlands A, Brown A, Keyworth S and Bunting P 2002. Rule-based classification of multi-temporal satellite imagery for habitat and agricultural land cover mapping. ISPRS J. Photogram. Rem. Sens. **62** (3), 165–185.

Mas JF 1999. Monitoring land-cover changes: a comparison of change detection techniques. Inter. J. Rem. Sens. **20**, 139–152.

Mahajan KK 1989. "Management of Surface Water for National Prosperity: An Ecosystem Approach". In V.P. Agarwal B.N. Desai and Abidi S.A.H (eds). Management of Aquatic Ecosystems. Delhi: Narendra Publishing House, **16:** 1355-1492

Maikhuri RK, Rao KS, Nautiyal S and Saxena KG 1998. "Role of Medicinal Plants in Traditional Health Care System: A Case Study of Nanda Devi Biosphere Reserve". Curr. Sci. 75: 152-156.

Maskri A, Al-Kharusi L, Al-Miqbali H and Khan MM 2010. Effects of salinity stress on growth of lettuce (*Lactuca sativa*) under closed-recycle nutrient film technique. Int. J. Agr. Biol. **12:** 377-380.

McNeely JA 1988. Economics and Biological Diversity: Developing and Using Economic Incentives to Conserve Biological Resources. Gland: IUCN

Mishra 1987. "Sukhomajri Nada: A New Model of Eco-Development" Business India, Issue No. **253** pp. R-90.

Mitra AK 1999. "Need for Proper Water Resources Management in North-East India". In: Datta Ray B and Athparia R.P (eds). Water and Water Resource Management. New Delhi: Omsons Publications.

Misra R 1992. "Resources and Environment". In C.V. Rajashekhara (ed.). Global Environment Series: Environmental Factors in Economic and Industrial Management. Vol.4. New Delhi: Discovery Publishing House.

Moore PD 1986. Methods in Plant Ecology, Blackwell Scientific Publications, Oxford,

p 589.

Moreno ANM and Calderon JHM 2011. Quantification of organic matter and physical-chemical characterization of mangrove soil at Hooker Bay, San Andres

Island-Colombia. Proceedings of the Global Conference on Global Warming, Lisbon, Portugal pp: 1-7.

Naidoo G 1980. Mangrove soils of the beach wood area, Durban. South African J. Bot. **46**:293–304.

Naidoo G and Raiman F 1982. Some physical and chemical properties of mangrove soils at Sipingo and Mgeni, Natal. J. South African Bot **48**: 85-90.

Odum WE and Heald EJ 1972. Trophic analyses .of estuarine mangrove community. Bull. Mar. Sci. **22**: 671-738.

Ogner G, Wickstrøm T, Remedios G, Gjelsvik S, Hensel GR, Jacobsen JE, Olsen M, Skretting E and Sørlie B 2000. The chemical analyses program of the Norwegian Forest Research Institute. NISK 2000. ISBN 82-7169-917-2.

Olenin S and Ducrotoy JP 2006. The concept of biotope in marine ecology and coastal management. Mar Pollut Bull **53**: 20–29.

Ogner G, Wickstrøm T, Remedios G, Gjelsvik S, Hensel GR, Jacobsen JE, Olsen M, Skretting E and Sørlie B. 2000. The chemical analyses program of the Norwegian Forest Research Institute. NISK 2000. ISBN 82-7169-917-2. 23 pp. Preda M. and M.E. Cox. 2002.

Ong JE, Gong WK, Wong CH and Dhanarajan G 1984. Contribution of aquatic productivity in managed mangrove ecosystem in Malaysia. In: Soepadmo E, AN Rao and DJ Macintosh DJ (eds.) Proc. Asian Symp. Mang. Env : Res. & Manage. University of Malaya, Kuala Lumpur, pp. 209-215.

Otsyina RM, Issae I and Asenga D 1997. Traditional grassland and fodder management systems in Tanzania and potential for improvement. In: Proceedings of the International Grassland Congress, March, 1997, Saskatoon, Ottawa, Canada.

Parida A, Das AB, Sanada Y and Mohanty P 2008. Effects of salinity on biochemical components of the mangrove, *Aegiceras corniculatum.* Aquatic Botany 80(2): 77-87

Parker D 1999. Criteria for evaluating the condition of a tropical cyclone warning system. Disasters **23:**193–216.

Phat N K, Knorr W and Kim S (2004). Appropriate measures for conservation of terrestrial carbon stocks - analysis of trends of forest management in Southeast Asia. For. Ecol. Manage. **191**, 283–299.

Piper CS 1950. Soil and Plant Analysis. University of Adelaide.

Postel SL, Daily GC and Ehrlich PR (1996). Human appropriation of renewable fresh water. Sci. **271**:785–788.

Posey DA 1990. "Intellectual Property Rights and Just Compensation for Indigenous Knowledge". Anthrop. Today 6 **(4):** 13-16.

Prakash S 2011. Der Pharmacia Sinica,. Ann. Biol. Res. **2** (1): 51-59.

Premanathan M, Arakaki R, Izumi H, Kathiresan K, Nakano M, Yamamoto N, Nakashima H 1999. Antiviral properties of a mangrove plant, *Rhizophora apiculata*. Blume **44** (2):113-22.

Rafay M, Abdullah MR, Khan TH and Ruby T 2016. Grass productivity and carrying capacity of the Cholistan desert rangelands. Pakistan Journal of Botany 48(6):2385-2390.

Rambok E, Gandaseca S, Ahmed OH and Majid NMA 2010. Comparison of selected soil chemical properties of two different mangrove forests in Sarawak. Am. J. Environ. Sci. **6**: 438-441.

Ramsey E 1998. "Radar Remote Sensing of Wetlands," in Remote Sensing Change Detection: Environmental Monitoring Methods and Applications, Lunetta R and Elvidge C (Eds.), Arbor Ann, MI: Ann Arbor Press, Inc, 211– 243.

Ren H, Lu H, Shen W, Huang C, Guo Q, Li Z, Jian S 2009. *Sonneratia apetala* Buch.Ham in the mangrove ecosystems of China, an invasive species or restoration species. Ecol. Eng. **35** :1243–1248.

Roy, Spencer 2000: Diurnal variation of precipitation over the tropical oceans observed by TRMM/TMI combined with SSM/I. J. Climate. **13:** 4149-4158.

Sah KD, AK Sahoo, Gupta SK and Banerjee SK 1989. Mangrove vegetations of sunderbans and their effect on the physicochemical and nutrient status of the soils. Proc. Indian Nat. Sci. Acad. Part B: Biol. Sci. **55**: 125-132.

Sanders DW 1992. International activities in assessing and monitoring soil degradation. Am. J. Altern. Agric.: 17-24.

Sarangi RK, Kathiresan K and Subramanian AN 2002. Metal concentration in five mangrove species of the Bhitarkanika, Orissa, east coast of India. Indian J. Mar. Sci. **31** (3) : 251-253.

Satapathy KK 2000. Natural resources conservation and management for mountain development innorth-eastern region. In: Natural Resources Conservation and Management for MountainDevelopment, (Eds.), Tiwari, S.C. and Dabral, P.P., International Book Distributors,Ddehradun, Uttaranchal. pp. 305-322.

Scholes RJ and Baker MJ 1993. Nutrient cycling in semi-arid grasslands and savannas: Its influence on pattern, productivity and stability. Grassl. World, 21: 484-487.

Sharma E 1992. Integrated Watershed Management: A Case Study in Sikkim Himalaya. Gyanodaya Prakashan, Nainital, India.

Sherman RE, Fahey TJ and Howarth RW 1998. Soil-plant interactions in a neotropical mangrove forest: Iron, phosphorus and sulfur dynamics. Oecol. **115**: 553–563.

Shiklomanov IA (1993). World's fresh water resources. InP. E. Gleick, ed.Water in crisis: a guide to the world's fresh water resources, pp. 13–24. Oxford University Press,New York, NY.

Sodhi NS, Brook BW and Bradshaw CJA. (2007).Tropical conservation biology. Wiley-Blackwell, Boston, MA.

Siddiqi NA 2001. Mangrove Forestry in Bangladesh. Institute of Forestry & Environmental Sciences, University of Chittagong, Chittagong. 201pp.

Singh A 1989. Digital change detection techniques using remotely sensed data. Inter. J. Rem. Sens. **10:** 989–1003.

Skole DL 1994. Data on global land cover change: acquisition, assessment, and analysis. In Changes in land use and land cover: a global perspective (W. B. Meyer and B. L. Turner II, eds.) pp. 437–471. Cambridge University Press, New York.

Steinke TD and Ward CJ 1988. Litter production by mangroves. II. St. Lucia and Richards Bay. S. Afr. J. Bot. **54**:445–454.

Sterner RW, Elser JJ (2002) Ecological Stoichiometry: The Biology of Elements from Molecules to the Biosphere (Princeton Univ Press, Princeton.

Sukardjo S 1994. Soils in the mangrove forests of the Nature Reserve, Tanah Grogot, East Kalimantan, Indonesia. Southeast Asian Stud. **32**: 385- 398.

Sutton MO and Anderson EN (2004). Introduction to Cultural Ecology. New York: Altamira Press.

Suwa R, Deshar R and Hagihara A 2009. Forest structure of a subtropical mangrove along a river inferred from potential tree height and biomass. Aquat. Bot. **91**: 99-104.

Sylla M, Stein A, Breemen N and Fresco LO 1995. Spatial variability of soil salinity at different scales in the mangrove rice agro-ecosystem. West Afr. Agri. Eco. Envir. **54**:1-15.

Tang Z, W Xu, Zhou G, Bai Y, Lib J, X Tang, D Chen, Q Liue, We Maf, G Xiong, H Heg, N Heg, Y Guo, Q Guo, J Zhu, W Hanh, H Hub, J Fang, and Z Xie 2018. Patterns of plant carbon, nitrogen, and phosphorus concentration in relation to productivity in China's terrestrial ecosystems. PNAS . **115**: 4033–4038.

Tam NFY, Lie SH, Lane CY, Chen GZ, Li MS and Wong YS 1995. Nutrients and heavy metal contamination of plants and sediments in Futian mangrove forest. Hydrobiol. **295**: 149-158.

Tam NFY and Wong YS (1996). Retention and distribution of heavy metals in mangrove soils receiving waste water. Environ. Poll. **94**: 283–291.

Tam NFY and Wong YS 1998. Variations of soil nutrient and organic matter content in a subtropical mangrove ecosystem. Water, Air Soil Poll. **103**:245-261.

Tiwari BK and Surendra Singh (eds) 1995. Eco restoration of Degraded Hills. Shillong: Kaushal Publications.

The Intergovernmental Panel on Climate Change (IPCC) 2007.

Toxel TR and White LD 1989. Balancing forage demand with forage supply. Texas A & M Univ. Ext. Ser. Pub. B – 1606.

Ukpong IE 2000. Ecological classification of Nigerian mangroves using soil nutrient gradient analysis, Wetlands Ecol. Manage. **8**: 263-272.

Van der Zwiep K 1991. The Ramsar Convention and coastal planning. ECOS **12**: 27–31.

Van Poollen HW and Lacey JR 1979. Herbage response to grazing systems and stocking intensities. J. Range Manage. **32**:250-253.

Wakushima S, Kuraishi S and Sakurai N 1994. Soil salinity and pH in Japanese mangrove forests and growth of cultivated mangrove plants in different soil conditions J. Plant Res. **107** (1): 39 - 64.

Webb M 2009: A quantitative performance assessment of cloud regimes in climate models, Clim. Dyn. **33**: 141–157.

Wells MK, Brandon and Hannah L 1992. People and Parks: Linking Protected Area Management with Local Communities. Washington, DC: World Bank.

Whitson RE, Heitshmidt RK, Kothmann MM and Lundgren GK 1982. The Impact of Grazing Systems on the Magnitude and Stability of Ranch Income in the Rolling Plains of Texas. J. Range Manage. **35**: 526-532.

Wilkie DS and Finn JT 1996. Remote Sensing Imagery for Natural Resources Monitoring. Columbia University Press, New York. p. 295.

Wolanski E, Chicharo L, Chicharo MA and Morais P 2006. An ecohydrology model of the Guadiana Estuary (South Portugal). Estua, Coast Shelf Sci **70**:132-143.

Workman JP and MacPherson DW 1973. Calculating yearlong carrying capacity: An algebraic approach. J. Range Manage., **26**: 274-277.

Zitova B 2003. Image registration methods: a survey. Image and Vision Computing, **21**:977–1000.

Zimmermann EW (1951). World resources and industries: A functional appraisal of the available agricultural and industrial materials (Revised edition). New York: Harper and Brothers Publishers.