CHANGES OF LAND USE AND SOIL PROPERTIES AND THEIR IMPACT ON RICE YIELD IN DACOPE UPAZILA OF KHULNA DISTRICT

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The thesis titled **'Changes of Land Use and Soil Properties and Their Impact on Rice Yield in Dacope Upazila of Khulna District'** submitted by Sultana Maliha, Roll No. 0413282013F, Session April, 2013, has been accepted as satisfactory in partial fulfilment of the requirement for the degree of M.Sc. in Water Resources Development on 28 September, 2016.

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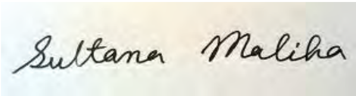
It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.



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Sultana Maliha

Dedicated to

My Beloved Parents and Husband

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Abstract

Polder 31 and polder 32 of Dacope Upazila in Khulna district was selected for the study as it was severely affected by the cyclone Aila 2009 which is observable through the changes of land use and soil properties. The specific objectives of this study are to detect the changes of land-use in the study area of different time periods, determine the change in soil properties due to different land uses and estimate the impact of soil properties changes on rice yield. To identify the land use changes over time in the study area satellite images i.e. Landsat 5 images of 1988, 1996, 2009, 2010 and Landsat 8 image of 2014 were used and supervised classification method was applied to understand the changes. Six classes were delineated i.e., water, forest, bare land, shrimp land (gher), agricultural land and inundated area based on spectral signatures which showed varying degrees of areal extent with time. Each class's areal percentage was also calculated using image processing software to see the actual changes of land uses. Three field visits were conducted from January 2014 to November 2014 in both polders for field verification and soil sample collection. Different physical and physicochemical properties of soil e.g., soil texture, pH, EC, OM, CEC, total N, K, Ca, Mg, P, and S were determined from the SRDI laboratory. Aman and boro production records of ten years from 2004-05 to 2013-2014 were collected from Khulna agricultural office. Other necessary information regarding changes in the study area was collected using different Participatory Rural Appraisal (PRA) tools. Observed dominant land use patterns in the study area were bare land, shrimp cultivation and agricultural land. Major land use practices were shrimp cultivation and bare land in 1988 and 1996; shrimp cultivation, bare land and agricultural land in 2009; agricultural land and bare land in 2014. Bare land in 1988, shrimp cultivating land in 1996 and agricultural land in 2014 were the highest in the study area which means that economically profitable shrimp cultivation has been reduced and agricultural practice is beginning to flourish for last few years. Although local people had already started limited crop production after 2000's as they wanted to go back to agriculture from shrimp cultivation, two deadly cyclones namely SIDR (2007) and Aila (2009) hit the study area and led to many problems, especially cyclone Aila did much damages to the study area which delayed this ongoing shift. Soil and environmental degradation following these two cyclones discouraged local people to continue mass scale shrimp cultivation and forced them to start practicing rice and other agricultural crops. Soil samples of the study area are mostly silty clay forming fine textured soil which is common in any tidal delta. pH of soils in the study area falls under neutral class. Average EC value of the year 1995 and 2014 are 21.35 dS/m and 6.09 dS/m, respectively, which means soil salinity had come down by more than two third. OM content is very low in 2014 compared to that of 1995. Aman is the major rice crop produced in the study area. Yield of aman was low during shrimp cultivation period because of soil salinity, which even after rain-wash remain in the clayey soil. After ceasing of shrimp cultivation practice, aman yield is gradually increasing. Average yield of aman and boro are 2.19 ton/ha and 3.4 ton/ha respectively. The yield of boro is comparatively high though it is being cultivated in very limited and scattered scale mostly because of unavailability of irrigation water. Regular soil health check system should be ensured to keep track of soil's fertility by the GOs and/or NGOs. To increase organic matter content in soil organic matter inputs like livestock manure have to be added in the soil. Reduction of tillage and controlling of soil erosion are required for soil management.

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Abbreviations and Acronyms

AEZ	Agro Ecological Zone
BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BRAC	Bangladesh Rural Advancement Committee (former name)
BRRI	Bangladesh Rice Research Institute
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CEC	Cation Exchange Capacity
CEP	Coastal Embankment Project
DAE	Department of Agricultural Extension
dS	desi-Seimens
EC	Electrical Conductivity
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
GloVis	Global Visualization
GO	Governmental Organization
ha	Hectre
HYV	High Yielding Variety
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
IWFM	Institute of Water and Flood Management
KII	Key Informant Interview
LYV	Low Yielding Variety
meqv	mili-equivalent
MSS	Multispectral Scanner
NGO	Non-governmental Organization
OM	Organic Matter
PRA	Participatory Rural Appraisal
SPARRSO	Bangladesh Space Research and Remote Sensing Organization

SRDI	Soil Resource Development Institute
TM	Thematic Mapper
TNO	Thana Nirbahi Officer
UNDP	United Nations Development Programme
USGS	United States Geological Survey
WAPDA	Water and Power Development Authority

CHAPTER ONE
INTRODUCTION

1.1 Background of the study

The total area of Bangladesh is 147, 570 square km. The coastal area covers about 20% of the country and over thirty percent of the net cultivable area. It extends inside up to 150 km from the coast. Out of 2.85 million ha of the coastal and offshore areas about 0.83 million ha are arable lands, which cover over 30% of the total cultivable lands of Bangladesh. Land use in Bangladesh is generally determined by physiography, climate and land height in relation to water level (Brammer, 2002). Land use in coastal Bangladesh is diverse, competitive and conflicting. Agriculture, shrimp farming, salt production, forestry, ship-breaking yards, ports, industry, settlements and wetlands are some of the uses. One of the most alarming situations in the southwestern part of Bangladesh is, with growing population, and their increasing needs in various sectors, land use patterns are undergoing a qualitative change in which the areas under the net cropped land, and forest land is gradually shrinking. The cultivation of shrimp (bagda) using agricultural land had increased as it is cost effective and more beneficial to the farmers than traditional paddy. As a result, the conversion of quality and valuable agricultural land into shrimp cultivation had increased in the study area.

Most coastal lands are suitable for more than one use. Hence, the many diverse uses of limited land have created conflict. In addition, one land use or another has manifold implications for socio-environmental conditions. The introduction of shrimp farming has gradually changed the land-use patterns of the surrounding farms, transforming agriculture and mangrove areas into shrimp-farming areas (Haque, 2004). The coastal region, especially the southwestern portion (Satkhira, Khulna and Bagerhat), is one of the most promising areas for shrimp cultivation for two major reasons (MOFL, 1997): first, its fresh- and saline-water resources are abundant in almost all seasons; second, the world's largest continuous mangrove forest, the Sundarbans, provides a food source and nursery for the offshore fishery. The mangrove forests provide a critical habitat for shrimp and other fish. Most of the shrimp culture being practiced is by the extensive and improved extensive methods known as gher culture. Gher means an enclosed area characterized by an encirclement of land along the banks of tidal rivers. Dwarf earthen dikes and small wooden sluice boxes control the free entrance of saline water into the enclosed areas (Bala and Hossain, 2009).

Different unplanned shrimp ghers (with low infrastructural facility) had created severe drainage congestion and high soil salinity problem in the area. Land-use conversion can cause important changes in soil physical and chemical characteristics and can affect soil fertility, increase soil erosion or cause soil compaction (Neill et al. 1997). Many researchers also reported that the conversion of the natural forest to other forms of land use can provoke to soil erosion and lead to a reduction in soil organic content, lost soil quality and modification of soil structure (Lichon, 1993; Jiang et al. 2006).

In southwestern part, T. Aman rice is mainly cultivated depending on rainfall and the later part sometimes supplemental irrigation is applied during September to October from the low salinity river water sources and the land remains fallow due to salinity development and scarcity of irrigation water during the rest periods of the year. The present cropping pattern in this part is mostly T. Aman- Fallow- Fallow. Occasionally in few areas, T. Aman - Rabi crops - Fallow is followed. Cropping intensity in the coastal areas is low compared to other part of the country. This is due to unfavourable soil and land characteristics like salinity, flood, water logging, late drainage condition, scarcity of irrigation water, acidity, low fertility status, cyclonic storm surges etc. (Bala and Hossain, 2009).

Salinity causes unfavourable environment and hydrological situation that restrict normal crop production throughout the year. The freshly deposited alluviums from upstream in the coastal areas become saline as it comes in contact with the sea water and continues to be inundated during high tides and ingress of sea water through creeks (Haque, 2006). In some cases the natural calamities influence land use and land management practices. The water surges that accompany the cyclones often sweep the coastal areas with saline water causing the soils to become temporarily more saline and rendering them completely unsuitable for agricultural use. After several washings with rainwater the soils ultimately become normal again by natural ways and can be again suitable for agricultural use. But climate change and associated sea level rise may disrupt this natural sequence. These problems are observed in the study area which is comprised of two polders (polder no. 31 and 32) in Dacope Upazila of Khulna District. But so far, effects of land use and soil properties change studies were not performed in the study area.

1.2 Objectives

The specific objectives of this study are as follows:

i. To detect the changes of land-use in the study area using Remote Sensing data of different time periods
ii. To determine the change in soil properties due to different land uses and
iii. To estimate the impact of soil property changes on rice yield.

Research Questions

In order to address the stated objectives, the following research questions were designed.

i. What is the extent and rate of land use/land cover changes that have occurred in the Dacope upazilla between 1988, 1996, 2009, 2010 and 2014?
ii. What is the nature of land use/land cover changes that have taken place in the past periods under study?
iii. How do land cover changes affect the soil properties of the study area?
iv. How do soil properties changes impact the rice yield?

The output of this research assumed to fill the research gap through a local scale analysis of landscape structure and change detection using satellite imageries in a GIS platform. Results of this research can be utilized as a spatial-temporal land use change map for the region to quantify the extent and nature of development change. It would foster learning about the surrounding environment and planning agencies in developing sound and sustainable land use practices. The study will also help understand the soil quality of the study area and according to that take necessary measures for the betterment of the soil quality.

1.3 Limitations

There are several limitations of this study described as follows:

- First limitation was due to severe accessibility problem in the study area, samples were collected mostly near the riverbanks and where transportation was possible. Because of these, soil data may not be exactly representative of the entire study area.
- Second limitation was unavailability of secondary data and/or inconsistency of data. Soil's previous data were from 1995 and recent data from collected soil samples were from 2014, in between no reliable soil data were found. An in-between soil data would help in well representation of soil data with relation to land use changes.
- Third limitation was deficiency of Landsat imageries of similar time and of good quality. Good quality and similar time Landsat images would have given better output and interpretation.
- Fourth limitation was, rice production data were insufficient for the purpose of research work. Only recent ten years data were collected. If twenty years rice production data were collected a more effective result could be established.

1.4 Organization of the Thesis

The thesis work is organized into six sections which is described as follows:

Chapter One deals with the background of the study, research objectives with which the study was conducted, some research questions, limitations of the study which occurred during study and lastly organization of the thesis chapters.

Chapter Two provides with the relevant literature review for the study. It illustrates mainly polders and associated problems, land use changes and its impact, soil characteristics and soil status, impacts of cyclone Aila, and rice production and food security condition of the southwest Bangladesh.

Chapter Three provides necessary information about study area. It includes area and geographical location, climate, natural disaster, demographic features and livelihood condition. It also includes water resources and major rivers, polders, soil condition and land use pattern.

Chapter Four is structured with the methods adopted during the study which include Landsat images collection, processing and classification, soil sampling, collection of soil samples, determination processes of different soil properties, and other data collection including secondary data, rice production data and local data using PRA tools.

Chapter Five elaborates the results and findings of the study. It summarizes land use changes of different time periods and reason of changing its pattern, and soil condition and brief discussion of reasons of soil properties changes of the study area. It also explains the impact of land use change and soil properties change on rice yield (Aman and Boro rice) of the study area.

Chapter Six concludes the thesis with the findings of the study along with some recommendations for further research on these issues.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The literature review is primarily directed to an overview of southwestern part of Bangladesh, focusing on polders, land use changes and its impact. Also discussions about the soil characteristics, fertility status and rice cultivation scenario of SW Bangladesh are made.

2.2 Polders in Coastal Area

The rivers of the coastal zone of Bangladesh are mainly tidal in nature and its tidal effect extends about 150 km inland. The tidal fluctuation is more extreme (up to several meters) during the rainy season, resulting in tidal flooding of adjacent lands. Polders are major interventions in the southwestern region with protective structures that provide benefits to the protection systems and livelihoods. ‘Polder’ is a Dutch term, meaning a reclaimed landmass with engineering interventions to grow more food by protecting coastal land from saline water intrusion caused by tidal flooding. About 1.2 Mha of the agricultural lands of the coastal zone of Bangladesh were therefore poldered by The Bangladesh Water Development Board (BWDB) under coastal embankment for flood control and drainage activity during the 1960s and 1970s (Mondal et al. 2015). The main function of the polder is to prevent inundation and saline water intrusion, creating scope for improving productivity through improved water management (ibid). This enabled the cultivation of traditional aman rice crop varieties, which needed long duration and were low yielding. After harvesting of aman rice, the majority of lands within the polders were left fallow, or sown with a low input, low yielding legume crop in some locations. Production of high yielding or high value rabi crops was not possible because of the late harvesting of aman rice. Besides most of the lands in the polders are not suitable for growing the improved high-yielding varieties of rice because the water is too deep for their shorter stature. Shrimp and fish are being farmed in many coastal polders but their yields are low and well below potential (Islam et al. 2015).

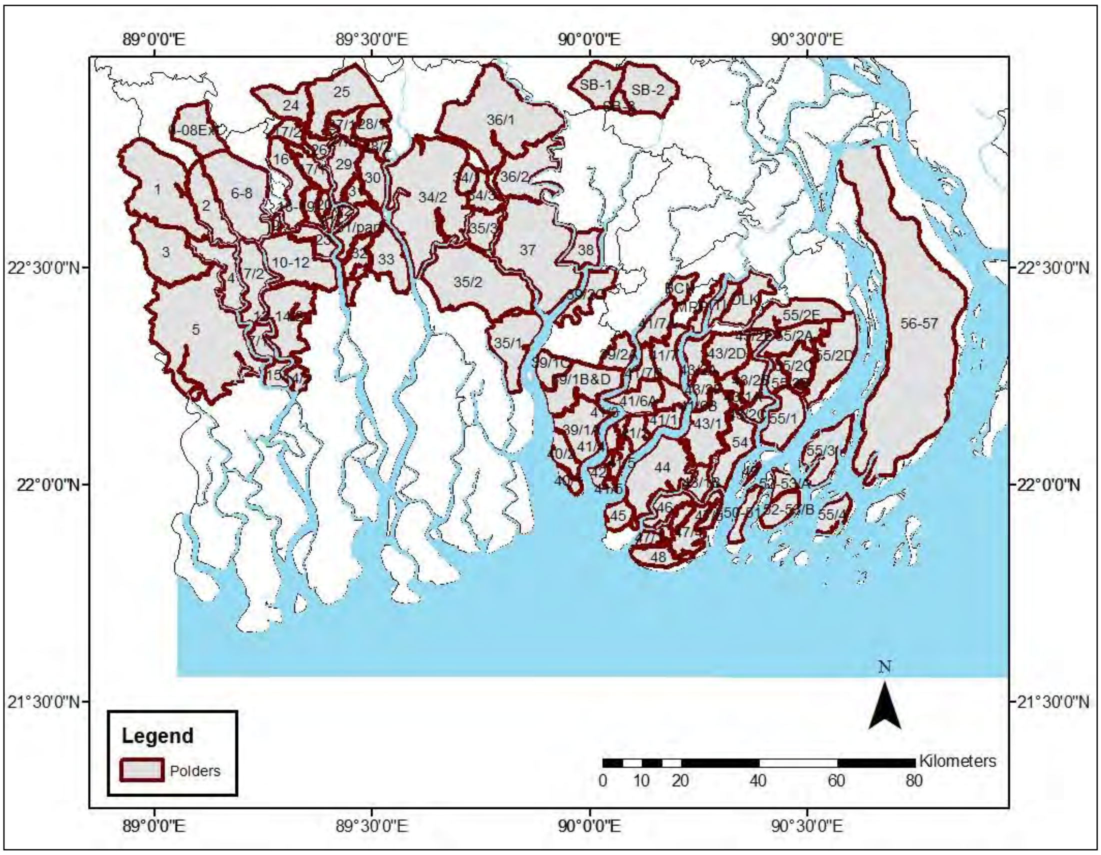


Figure 2.1: Coastal polders of south-west and south-central regions

BWDB has constructed total 139 polders since 1960s (Figure 2.1). While these contributed significantly in enhancing food production in the initial decades, they are now gripped in second generation problems, both social and environmental (MOA, 2012). The current state of the polders has been addressed in a recent study done by International Food Policy Research Institute (IFPRI) on institutional aspects of polder management in the coastal areas (IFPRI, 2012). Problems are mainly manifested through the following phenomena: siltation, drainage, water logging, salinity, and land use conflict.

2.3 Land Use in Coastal Bangladesh

Land use pattern in Bangladesh is determined by physiography, climate and land levels in relation to flooding. The use of land is of paramount importance in a country which is thickly populated and still very reliant on primary production (Banglapedia).

Land use pattern of a country reflects its socio-economic stipulation. Islam and Hassan (2011) stated that while land use changes are concerning topics in perspective of socio-economic changes of a country, in Bangladesh the pattern of its changes is to meet the dynamic demand of the society that creates pressure on natural environment. As a result, various disharmonies occur in natural system. In fact, the land use change is the changes of men's activities on land which mostly occur in two ways: firstly, changes from one type to another and secondly, changes into a type i.e. either decreasing or increasing. Both types of changes take place in our country. Among the changing pattern the changes of agricultural land is remarkable in a land hungry country like Bangladesh. The total arable land of the country is not more than 0.782 crores ha and per capita land is only 0.0526 ha. Moreover, every year 1% of its arable land or 82900 ha of crop land and everyday 221 ha of arable land is being lost in Bangladesh due to various reasons. Table 2.1 shows a general land utilization scenario of Bangladesh in 2010-2011.

Land use in the coastal zone of Bangladesh is diverse, competitive and conflicting and also have gone through major changes over the last half century (Islam, 2006). In coastal Bangladesh, agriculture, shrimp farming, salt production, forestry, shipbreaking yards, ports, industry, human habitation and wetlands are some of the uses of lands in an area of only 47,000 km^2 inhabited by 36.8 million people.

In 1967, The Coastal Embankment Project (CEP) was established, with assistance from the World Bank, primarily for the purpose of empolderment, and to increase agricultural production. The dominant land use during 1950s-1960s period was paddy cultivation, primarily traditional local varieties. Other uses were salt production, mangrove forest and traditional shrimp farming (ibid).

In the 1970s–1980s, the World Bank and other donors helped to continue large-scale polderization of coastal Bangladesh. Polders became part of the natural setting of coastal Bangladesh. Changes in land use occurred because of the intensification of paddy cultivation with the attempted expansion of modern varieties and conversion of agricultural land to non-agricultural use (Sereno, 1981).

In the 1990s, there was a major change in polder utilization pattern. Some polders of southwestern coastal Bangladesh started large scale shrimp cultivation because of increased demand and a high price for shrimp on the international market. Subsequently many coastal polders which were mainly constructed to protect agricultural land from inundation of salt water were turned into large shrimp ghers. The priority was reversed and salt water was willingly being allowed in the ghers to raise shrimp. Land previously used for agriculture and mangroves was transformed, often forcibly, to shrimp farming. Wide-scale land use conflict emerged and created social unrest (Islam, 2006).

Table 2.1: Land Utilization in Bangladesh (2010-2011)

Land use types	Acres (in thousands)
Forest	6368
Not available for cultivation	9238
Cultural waste (a)	542
Current fallows (b)	1153
Net cropped area	19358
Areas sown more than once	17558
Total cropped area (c)	36926

Note: (a) Cultivable waste is the area suitable for cultivation but lying fallow for more than one year

(b) Current fallow is the area already brought under cultivation, but not cultivated during the year

(c) Total cropped area is the sum of the net cropped area and the area sown more than once

Source: BBS, 2012

Land use changes and subsequent conflicts

During past few decades Bangladesh has experienced rapid land use changes more or less for various causes (Ahmed, 2011 and Iftekhar, 2006) while south-west regions are being observed to have frequent changes due to the effects of increased salinity intrusion as well as natural disasters (Ahmed, 2011), intensive agriculture practices and changing land quality (Uddin and Gurung, 2010; Minar et al., 2013). However, Rahman and Begum (2011) showed two causes of land use changes in Khulna and

Satkhira region such as natural (i.e. global warming, climate change, sea level rise (SLR), coastal flood, salinity intrusions, water logging) as well as anthropogenic forces (e.g. population growth, unplanned cultivations, salinity intrusions, water logging, misuse of Sundarbans, political unrest, illiteracy of local people about effect of land cover changes, poverty, higher expectation).

Since there is an acute shortage of land in Bangladesh, continuous competition among the various land uses is very natural. Agriculture, being the dominant land use type, is in constant conflict with other uses. There are competitions for land within each use type. Most often land related disputes end up in litigation and murder. The conflict between agriculture and urbanization is the direct result of population increase, as new living houses are needed for new families. Encroachment of forests for agricultural use and human settlement near the fringe of forests is very common and in this process the actual forest land under tree cover is estimated to have gone down to 6 percent at present (Ullah, 2002).

Shrimp culture is mainly concentrated in the coastal areas of Bangladesh where the previous croplands and forests have been converted to shrimp culture fields. When the shrimp culture fields are abandoned they cannot easily be converted to croplands, as these fields are made saline artificially by adding salts. The estimated area of shrimp cultivation in four coastal districts of Khulna, Shatkhira, Bagerhat and Cox's Bazar is 140,000 ha, around 70 percent of which are located in greater Khulna district (Rahman, 2000). Although economically profitable the unplanned expansion of shrimp culture has created a negative impact on water quality (both surface and ground water), mangrove deforestation and degradation of agricultural land.

2.4 Impacts of Land Use Changes

Kitamura and Kobayashi (1993) and Houghton et al. (1999) have pointed out that wrong land use could lead to serious problems such as degradation and deforestation of tropical forests, climate change with the problems of greenhouse effect. Also loss of biodiversity and negative changes in regional hydrology and biogeochemical cycles could occur due to wrong land use (Chase et al., 1999; Mas et al., 2004).

However, researchers have pointed out some of the frequent impacts of land use and cover changes such as rapid conversion of potentially productive land to unproductive purposes (Lambin et al., 2003), important trade-offs for sustainability, food security, vulnerability of people and ecosystems (Lesschen et al., 2005), deforestation, diminishing soil fertility, permanent degradation of land productivity (Islam and Weil, 2000), inundation of grazing lands, soil erosion, reduction of traditional farming, sedimentation (Tefera and Sterk, 2008), climate change, deforestation, natural hazards (NASA, 2006; Lubowski et al., 2008), climate variability, land degradation, vulnerability of places and people (Veldkamp and Lambin, 2001).

Many studies reveal that land use changes and subsequent conversion lead to a deterioration in the physical and chemical properties of soil, causing degradation of the land (Jiang et al., 2006; Emadodin et al., 2009; Li et al. 2009; Mahmoud et al., 2009; Yao et al., 2010).

Biro and other (2013) described the land use/land cover changes in the northern part of the Gadarif Region during the period 1979–2009 and emphasized on the impacts of land use/land cover changes on the selected soil properties (texture, bulk density, organic matter, soil pH, electrical conductivity, sodium adsorption ratio, phosphorous and potassium). Based on the land use analysis of Landsat and ASTER data of the years 1979, 1989, 1999 and 2009, authors found that the land use change trends varied significantly during the above-mentioned periods. Land degradation, in that study area appeared particularly in the agricultural area, which is a result of rapid land use changes. Soil properties varied within the land classes.

Another study was aimed to assess the variability of soil properties in relation to land use/cover changes in a typical dry land watershed and its adjacent agro-ecosystem, in the northern highlands of Ethiopia. Gebrelibanos and Assen (2013) hypothesized that the environmental conditions such as land-use/cover systems would affect surface soil properties at the sites. The results showed that the land-use/cover changes significantly affected a number of soil physico-chemical properties. The sand, silt, clay, field capacity, permanent wilting point, soil organic matter, total nitrogen, soil pH, exchangeable potassium, calcium, and magnesium contents showed significant variations between the natural forest and the other land-use/cover types ($p<0.05$).

Nishat and Bhuiyan (1995) cited that intensified mono-cropping, shrimp cultivation and numerous brickfields all are degrading the long-term soil quality in Bangladesh. Structures built for flood control and drainage regulation in many areas sometimes drastically altered the land and water use patterns and the environment which have resulted in decline in fresh water fish culture and production in many areas in the recent years.

Rahman and Begum (2011) had researched on the spatial and temporal dynamics of land cover and its impact on the ecosystem in Khulna and Satkhira districts in Bangladesh where majority of the Bangladesh's portion of the mangrove forest is located. The study period was chosen from 1980 to 2009, about 30 years. They found that the land covers in the region are changing and the most noticeable change was conversion of agricultural or non-agricultural land to shrimp farming and homestead between 1989 and 2002 period. The salinity intrusions in the region aided the growth in shrimp farming following a low to high gradient from east to west. Loss of agricultural land and increased water areas have amplified the salinity imbalance in the region through reduced surface runoff and loss of vegetation coverage, leading to decrease in ecosystem productivity following the same low to high gradient from east to west in the study areas.

2.5 Soils of Bangladesh

Soils of Bangladesh reflect the country's physical geography. This is because soils form in response to the interaction of climate and biological activity with geological materials under particular drainage conditions over time. Thus Bangladesh has a wide range of soils, formed from different kinds of rocks and alluvium under different relief and drainage condition over different periods of time. The approximately 500 soil series recognized in Bangladesh up to 1988 were classified within 21 General Soil Types (Brammer 2012). These soils range from freshly deposited alluvium to very deeply weathered Pleistocene and tertiary sediments (Huq and Shoaib, 2013).

Islam and Islam (1956) first attempted without much field investigation to describe the landscape and soils in Bangladesh by dividing the country into seven broad units that were called soil tracts. The basis of this classification was physiographic condition and the geological origin of the parent materials. This classification is used mostly for identifying general soil types even by nonsoil scientists. Table 2.2 shows the seven soil tracts and Figure 2.2 shows the map of those soil tracts.

Table 2.2: Seven soil tracts of Bangladesh

Sl no	Name of Soil tracts	Area sq. km (estimated)	Typical soil series
1	Madhupur Tract	10,000	Tejgaon
2	Barind Tract	13,000	Amnura
3	Tista Silt	16,000	Gangachara
4	Brahmaputra Alluvium	40,000	Ghatail
5	Gangetic Alluvium	27,000	Sara
6	Coastal Saline Tract	20,000	Barisal
7	Chittagong Hill Tract	15,000	Kaptai

2.6 Soil Fertility of Coastal Bangladesh

Soil fertility refers to the ability of soils to supply plants with the nutrients that they need for growth. Fertility depends not only on a soil's total content of essential nutrients. It also requires that those nutrients are in forms which plants can use, and that the soil also contains sufficient moisture and air so that plant roots can reach and absorb the nutrients (Brammer, 2012).

Mineral particles of sand, silt & clay provide nutrients but the soil lacks fertility without organic matter holding the particles together and providing structure. The major and micro or trace elements are made available to plants by breakdown of the mineral and organic matter in the soil. Availability of these nutrients depends on how much is present, the form in which it is present in the soil, the rate at which it is released from organic matter or mineral particles and the soil pH i.e. its acidity or alkalinity.

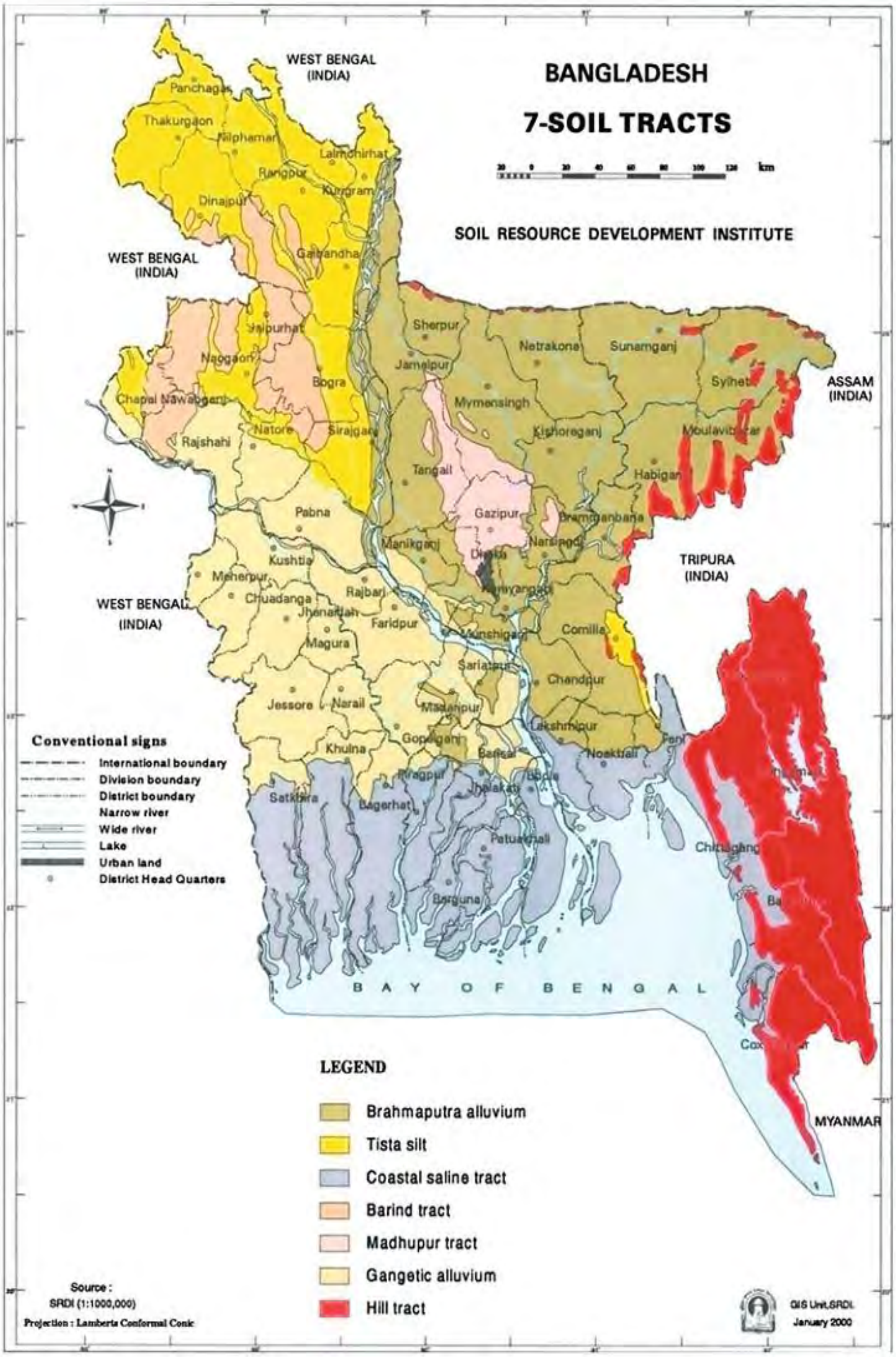


Figure 2.2: The soil tracts of Bangladesh (Source SRDI)

Seasonal flooding is a major way to replenish fertility of soil in river ridden country like Bangladesh. All the major rivers rich in mineral particles flow from north and north eastern part of the country towards Bay of Bengal and become less rich in minerals in coastal areas. The replenishment of fertility by flooding in Bangladesh is provided by three main sources, two of them biological and the other by soil weathering (Brammer, 2004). The biological sources include algae, especially blue-green algae (*cyanobacteria*) growing on the soil surface, in the water and on plant stems. In general the coastal areas of Bangladesh are low in soil fertility (Moselehuddin et al., 2013).

Soil Reaction

Soil reaction i.e. pH is an important indicator for crop yield. Crop's well yield is dependent on a definite soil pH. Most crops grow well when pH is between 5.6 and 7.3. But the average range of pH value of coastal Bangladesh is 6.0 to 8.4. Most of the soils are moderate to strongly alkaline (ibid). Because of pH variations, the nutrient availability, particularly that of phosphorus (P) and some micronutrients, is affected (Banglapedia).

Organic Matter (OM) status

Soil organic matter both stores and supplies plant nutrients. It also holds moisture which makes soil nutrients available to plant roots. The organic matter status of Bangladesh soil is one of the poorest in the world. The average organic matter content of Bangladesh soils is less than 1% ranging between 0.05 and 0.9% in most cases (Huq and Shoaib, 2013). On the other hand, soils in the coast are in general also poor in organic matter content. The organic matter content of the top soil ranges from less than 1 to 1.5% (Moselehuddin et al., 2013).

Cation Exchange Capacity (CEC) status

The CEC of soil is a determining factor in the status and maintenance of soil fertility. The greater the CEC of soil, the better is the fertility level. This property again is dependent on the organic matter status of soils and nature of clay minerals (Huq and Alam, 2005). In Bangladesh soils the organic matter content is low and the majority of soils contain 1:1 clays and illites. As such, the CEC of Bangladesh soils in general is not appreciably high. The CEC of the coastal soils range from 9.4 to 40.6 meqv%.

The higher CEC values of the soils of Khulna and Bagerhat are due to finer texture and higher organic matter content (ibid).

Nitrogen (N) status

Because of low level of OM, the nitrogen status of Bangladesh soils is substantially low and most crops on all soils respond to nitrogen applications. In fact, nitrogen (N) fertilizers are the most commonly used fertilizers in the country (Huq and Alam, 2005). The total N contents of the coastal soils are particularly low, mostly around 0.1%. The low N content may attributed to low OM contents of most of the coastal soils (Moselehuddin et al., 2013).

Potassium (K) Status

Bangladesh soils are deficient in potassium and many soils are found to respond to K-fertilizer application. These are particularly non-alluvial soils and the coastal saline soils. Potassium is severely deficient in 6% of the land, strongly deficient in 45% of soils, and moderately deficient in 33% soils (BARC, 2012). Ganges tidal floodplain is good for K content. Most of the soil samples are very deficient in potassium content, varying from 0.15 to 0.45 μg/mg soil (Huq and Shoiab, 2013).

Calcium (Ca) & Magnesium (Mg) Status

In Ganges tidal floodplain Ca status is optimum to high and Mg status is medium to optimum (BARC, 2012).

Phosphorus (P) status

The available phosphorus in Bangladesh soils could be considered between low and medium. Approximately 6% of the total land is severely deficient, 50% are strongly deficient and 44% are moderately deficient. Phosphorus availability is pH dependent (Huq and Shoiab, 2013). In coastal soils available P ranges between 1 and 25ppm (Moselehuddin et al., 2013).

Sulphur (S) status

Response to S application is common in most soils except in coastal saline soils, acid sulphate soils and some acidic soils (Huq and Shoiab, 2013). S status is medium to optimum in Ganges tidal floodplain area (BARC, 2012).

2.7 Saline Areas of Bangladesh

All soils contain some water soluble salts. Plants absorb essential plant nutrients in the form of soluble salts, but excessive accumulation of soluble salts, called soil salinity suppresses plant growth. Saline or salt affected soils are common in coastal areas in tropical-subtropical region and also common in Bangladesh coast.

It is predicted that withdrawal of fresh river water from upstream, irregular rainfall, introduction of brackish water for shrimp cultivation, faulty management of the sluice gate and polders, regular saline tidal water flooding in unprotected area, capillary rise of soluble salts etc., are the main causes of increased salinity in the top soils of the coastal regions (SRDI, 2010).

Table 2.3: Extent of soil salinity during the last four decades (1973-2009) in coastal areas.

<table>
<tr><th colspan="2">Years</th><th>1973</th><th>2000</th><th>2009</th></tr>
<tr><td colspan="2">Salt affected areas (000’ ha)</td><td>833.45</td><td>1020.75</td><td>1056.26</td></tr>
<tr><td rowspan="4">Salinity class and area (000’ ha)</td><td>S1 (2.0-4.0 dS/m)</td><td>287.37</td><td>289.76</td><td>328.43</td></tr>
<tr><td>S2 (4.1-8.0 dS/m)</td><td>426.43</td><td>307.20</td><td>274.22</td></tr>
<tr><td>S3+S4* (8.1-16.0 dS/m)</td><td>79.75</td><td>336.58</td><td>351.69</td></tr>
<tr><td>S5 (>16 dS/m)</td><td>39.90</td><td>87.14</td><td>101.92</td></tr>
</table>

*S3= 8.1-12.0 dS/m and S4= 12.1-16.0 dS/m

Source: SRDI, 2010

The spatial distribution of saline soils in Bangladesh was assessed in 2009. Out of about 1.689 million ha of coastal land about 1.056 million ha are found affected by soil salinity of various degree. A comparative study of soil salinity during last four decades (1973-2009) in coastal areas is shown in table 2.3. About 50% of the coastal lands face different degrees of inundation, thus limiting their effective uses (SRDI, 2010).

Another comparative study of the salt affected area from 1973 to 2009 showed that about 0.223 million ha (26.7%) new land is affected by various degrees of salinity during about the last four decades (Table 2.4). It was also found that about 35,440 hectares of new land is affected by various degrees of salinity during last 9 years only (2000-2009) (ibid).

Table 2.4: A comparative study of the salt affected area between 1973 and 2009 in coastal areas.

Salt affected areas (000' ha)			Salt affected area increased during last 9 years (000'ha) (2000-2009)	Salt affected area increased during last 36 years (000'ha) (1973-2009)
1973	2000	2009		
833.45	1020.75	1056.26	35.51 (3.5%)	222.81 (26.7%)

Source: SRDI, 2010

2.8 Impact of Cyclone Aila 2009

The devastating cyclone Aila struck the south-western coastal region of Bangladesh and eastern coast of the neighbouring West Bengal province of India at midday on 25 May 2009. In Bangladesh, Khulna and Satkhira were the most affected districts. Moreover, damage information has also been noticed from Bagerhat, Pirojpur, Barisal, Patuakhali, Bhola, Laxmipur, Noakhali, Feni, Chittagong and Cox's Bazar (Roy, et. al, 2009).

Due to its economic cost and long-term sufferings, the impacts of Aila outweigh those of any cyclone in the past. About 2.3 million people were affected by this event and many coastal inhabitants were stranded in the affected area, as they had no safe alternatives to survive (Kumar et.al 2010). At many points the surge had risen 3 to 4 meter high, which caused overtopping of embankments, breaching at some points, and inundation of households and croplands.

Especially overtopping or breaching of embankments at some polder areas during this cyclone made those areas vulnerable to saline water intrusion and subsequently forced the inhabitants to change the land use practice from agriculture to shrimp farming.

2.9 Rice Cultivation and Food Security in Coastal Bangladesh

Agriculture is a major sector of Bangladesh's economy and the coastal area of Bangladesh is also suitable for growing rice like other parts of the country. More than 30% of the cultivable land in Bangladesh is in the coastal area. Out of 2.86 million ha of coastal and off-shore lands about 1.056 million ha of arable lands are affected by varying degrees of salinity (SRDI, 2010).

The agricultural land use and cropping patterns of the coastal area are generally dominated by the rice crop and other crops suitable to the coastal and saline soil. The agricultural practices of the Upazilas are largely determined by the hydro-meteorological characteristics, geographical location and overall coastal features like soil and water salinity, tidal flow, upsurge etc. (FAO and DAE, 2009).

Aman rice is the dominant crop in the coastal region with small and medium scale cultivation of dry season crops. Aman rice occupies more than 30% of the net cultivable area during the monsoon season (Mishu and Zaman, 2013). Farmers mostly grow this low yielding traditional rice varieties (Aman) only during monsoon season and harvest it just after monsoon (July to December). Most of the land remains fallow in the dry (Rabi/Boro) and pre-monsoon (Aus) season (January- May) because of soil salinity, lack of good quality irrigation water and late draining condition (Karim et al., 1990; and SRDI, 2001). Like other part of the country coastal people are not benefitted by high yield Boro rice, which has higher farm productivity. On the contrary, coastal saline areas of Bangladesh have very limited options as they still continue to farm under rain-fed condition and having above constraints. Crop yields, cropping intensity, production levels and people's quality of livelihood are much lower in this region than other part of the country (BBS, 2009). Compared to the national cropping intensity of 175%, the intensity in the coastal area is only about 162.74% (BBS, 2010). All the available agricultural lands are not being efficiently utilized for crop cultivation. From the year of 1996 to 2008, where there is 5.87% increase in net cultivable land of Bangladesh, there has been a loss of 5.89% net cultivable land in the coastal areas, where 16 out of 19 coastal districts have experienced the loss (Mishu and Zaman, 2013).

Rice takes the monopoly position as a staple food of the country and salinity has significant impact on production of this staple. Recognizing this, people of the Pankhali Union of Dacope Upazila (polder 31) in Khulna District banned the intrusion of saline water and brought more land under the cultivation of T. Aman rice, following a rice-plus-golda cropping pattern instead of rice-plus-bagda (Rahman et al. 2013). Since salinity affects certain crops at critical stages of growth, which in turn reduces the crop yield substantially. Salinity also causes unfavourable environment and hydrological situation, restricting the normal crop production throughout the year (Amin et al. 2008).

Bangladesh has made substantial progress in enhancing food security by increasing production of food grains, particularly rice, improving infrastructure, making food delivery to the poor more efficient and liberalizing agricultural input and output markets. Rice has contributed most to self-sufficiency in food grain, currently accounting for 71 percent of the gross cropped area and for 94% of the food grain production. The country has managed to triple its rice production since its independence, from 10 million Metric Ton (MT) in 1971 to over 32 million MT today. Astonishingly, 8.44 million hectare of the land are irrigated, which is over 7 times more than in 1990 (Bangladesh Agriculture Statistics, 2013). Bangladesh became self-sufficient in food grain production from 1999 to 2000 (Talukder, 2005).

However, in the light of coastal Bangladesh, people have been suffering from lack of food security. Lower crop productivity and less cropping intensity are the main reasons for food insecurity in this region (Moselehuddin et al., 2013). The net-farming area of coastal Bangladesh has been gradually decreasing over the years due to various reasons, among them land inundation and salinity intrusion by tidal water is the most common (Sean and Baten, 2012).

CHAPTER THREE
STUDY AREA

3.1 Introduction

This chapter contains an overview of the study area. Dacope Upazila was selected for the study, as it was severely affected by the cyclone Aila 2009; land use changes and soil properties changes are observable. The chapter provides a general description of different important features like geographical location, demographic features, land formation, major river systems, agricultural production, and climatic condition of the study area, which are essential to obtain sufficient understanding of the condition of the area.

3.2 Area and Geographical Location

Dacope, the second largest Upazila of Khulna district in respect of area, came in to existence on the 10th February, 1906 as Thana and upgraded as Upazila in 1983 (Land Zoning Report, Dacope, 2011). In Dacope Upazila, located at 22.5722°N latitude and 89.5111°E longitude in Khulna district, are three polders, named polder 31, 32, and 33. The losses and damages in polders 31 and 32 had been very significant after Alia. So, for this study, these two polders, polder 31 and polder 32 were selected (Figure no. 3.1). The Upazila is bounded by Batiaghata Upazila on the north, Pashur river on the south, Rampal and Mongla Upazilas on the east, Paikgachha and Koyra Upazilas on the west. The southern part of this Upazila is surrounded by Sundarbans. Main rivers are Jhapjhopia, Dhaki, Sibsa, Chunkuri, Bhadra. The landscape of Dacope has a combination of plain land, lower floodplains, rivers, canals and beels.

3.3 Climate

The Upazila falls under tropical monsoon climatic condition like other parts of the country. The Upazila has a hot summer and a mild winter. The summer begins from the middle of April and continues till the middle of June. The winter starts from November and continues till February. Here winter starts almost 15 days later and ends 15 days earlier from the northern part of the country. According to the Meteorological Department report of 2011, the monthly average maximum temperature rises up to

31.1°C during the month of May. The monthly average minimum temperature falls down to 21.8°C in the month of January. The level of humidity rises to 89 percent in the month of July which commences from the middle of June and continues till the end of September. The rainfall is generally heavy in the month from June to September. Annual rainfall recorded in 2011 was 162.3 millimeters (Khulna district statistics, 2013).

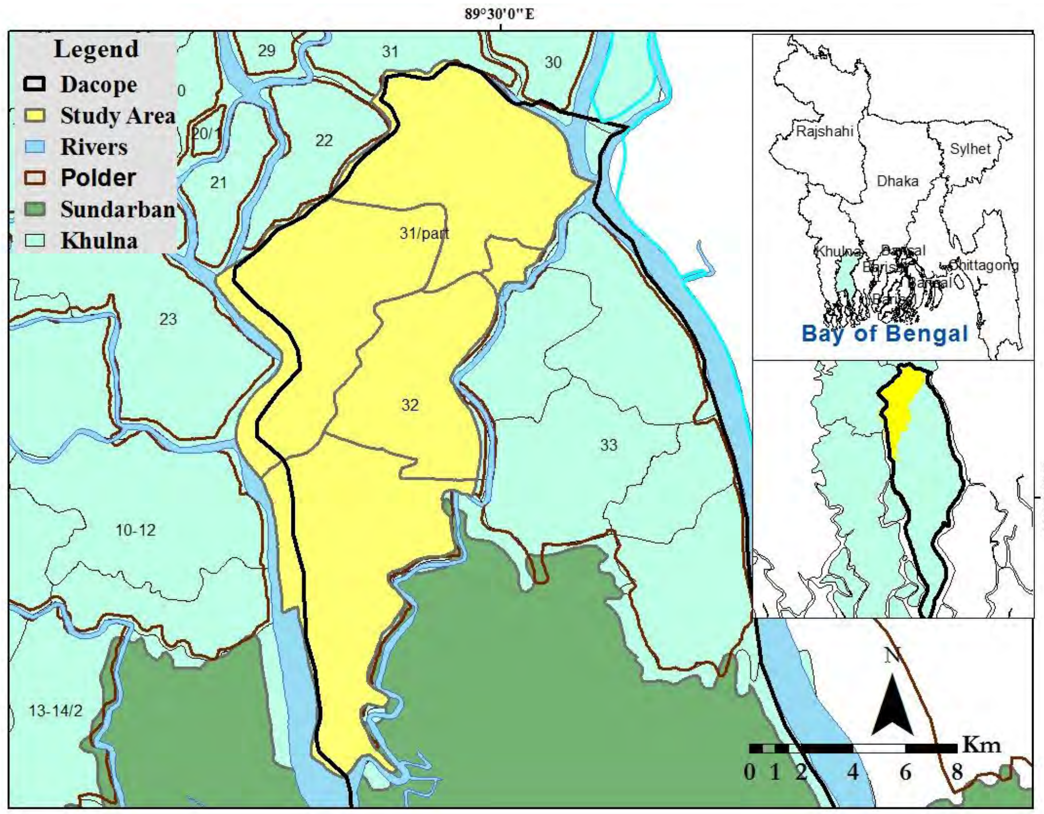


Figure 3.1: Location of the Study area

Table 3.1: Temperature, Rainfall & Humidity in the study area

Year	Temperature (C°)		Rainfall (mm)	Humidity (%)
	Max	Min		
2008	31.0	22.2	132.9	79
2009	31.9	22.4	151.3	77
2010	31.1	22.6	113.2	62.6
2011	31.1	21.8	162.3	76.1

Source: Khulna district statistics, 2013

3.4 Natural Disasters

Cyclone and Tidal Surge

The coastal belt of Khulna is known to be a place severely affected by natural disaster like cyclone and tidal surge forming in the Bay of Bengal. Due to geographical location, Dacope Upazila is more vulnerable to Cyclone and Tidal Surge as it happens to many other Upazilas along the coast of Khulna. Figure 3.2 shows the direction of cyclone occurred in the Bangladesh coast. Wind speed that hits the coast during cyclone reaches up to 240 km per hour accompanied by extreme rain and tidal inundation up to 6-7 meters (MoL 2011). Since 1970, the country has experienced 36 cyclonic storms resulting in over 450,000 deaths and a huge economic loss (UNDP, 2010). The most disastrous cyclones among these, SIDR in 2007 and Aila in 2009, had hit the south-western coast, the most vulnerable region. This had resulted in the loss of scores of lives and severe damage to properties, rendering millions of people homeless.

Aila, the deadliest cyclone, hit the Bangladesh coast on 25 May 2009. It severely affected at least 12 out of 19 districts. These included Satkhira, Khulna, Bagerhat, Pirojpur, Barisal, Patuakhali, Bhola, Laksmipur, Noakhali, Feni, Chittagong, and Cox's Bazar (Roy et al 2009). At the time of landfall at the Bangladesh coast, the sustained wind pressure of Aila was 120.7 km/hr ranking it as a category -1 cyclone (Kumar et al., 2010). Though, by definition, it would still fall into a "weak cyclone" category, due to its economic cost and long-term sufferings, the impacts of Aila outweigh those of any cyclone in the past. At many points the surge had risen almost three to four meters, which caused overtopping of embankments, breaching at some points, and inundation of households and croplands (ibid).

Tidal Flood and tidal effects

Due to huge sediment load from the upstream and river erosion, the river beds and canals of the Upazila are silted up gradually losing their navigation, drainage capacity and water holding capacity of wet lands. So, during monsoon, when the Ganges water exceeds the danger level due to excessive rain in the upstream, flood occurs in the downstream shallow floodplain of the Khulna District that includes study area. It causes loss of life and livelihoods and sufferings; also damages crops, households and infrastructure (MoL, 2011).

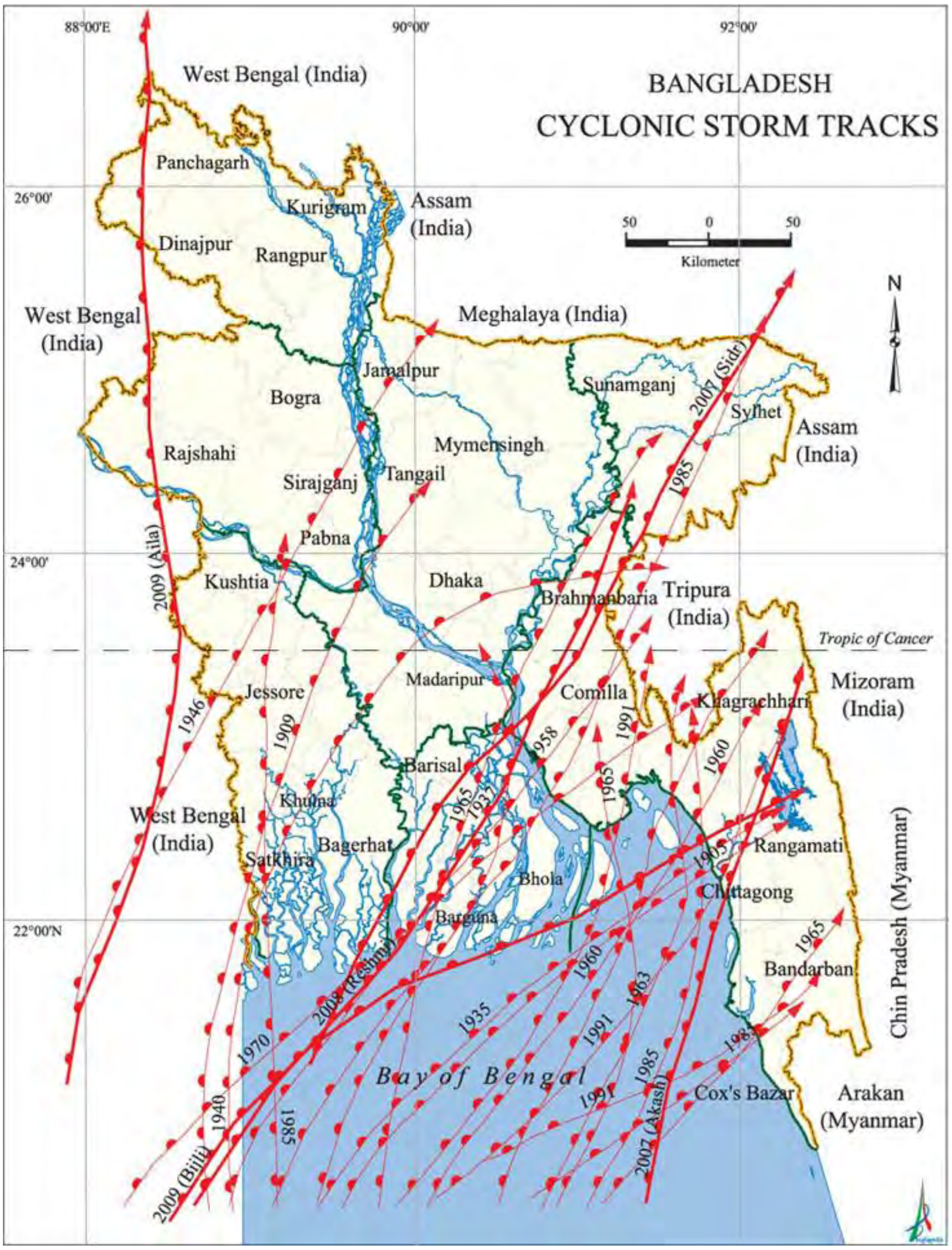


Figure 3.2: Direction of cyclones occurring in the Bangladesh Coast (source: Banglapedia)

Now-a-days, the saline tidal water-flow is moving towards the north having no entrance of passing in the bills (marshy land) due to embankment around the shrimp project. This results in increasing salinity due to tidal effect as well as rivers are being filled up by carrying excessive silt and mud flood (MoL, 2011).

3.5 Demographic Features

According to the population census of 1974, 1981 and 1991 total population of this Upazila were 89381, 110560 and 140466 respectively. From this statistics mean annual population increased rate from 1974 to 1981 and 1981 to 1991 were 3.4 and 2.7 respectively (SRDI, 2000). According to the population census of 2011 the total population of the Upazila is 157489, of which 83193 are males and 74296 are females. Table 4.1 shows population and literacy rate of the study area. The percentage of population growth is 1.5 (Banglapedia). It is observed that number of population had decreased from 2001 to 2011, which is opposite of increasing trend. This had mostly happened due to natural calamities led to loss of lives. People also migrated to other places for the search of livelihood, as they lost their properties during the calamities and also for lack of opportunities for work.

Table 3.2: Population and literacy rate of Dacope.

Year	Population	Literacy rate (%)
1981	111000	30.8
1991	143000	37.7
2001	157000	49.3
2011	152000	56

Source: Khulna district statistics, 2013

3.6 Livelihood Condition

Livelihood conditions of the people largely depend on the resources available at the household level in terms of ownership and access. Land is considered as a major determining factor of the socio-economic conditions of a rural household, though there are some other factors that also contribute to define their social class. Occupations and relations of production characterize social groups e.g. agricultural labour, shrimp gher labours, small farmers, fishermen, urban poor and landless. Livelihood of different social groups are affected if the land and other natural resources are not properly managed. The livelihood conditions of local people especially the landless people are becoming more vulnerable day by day in the study area due to lack of employment opportunities which are mainly due to unplanned uses of natural and social assets. As a result people are shifting their tradition profession to day labour, rickshaw/van pullers etc (MoL, 2011). They are also migrating to other parts of the country in search of new work.

3.7 Water resources and major rivers

There are a number of rivers and riverlets in Dacope Upazila. Figure 3.3 shows the major rivers in the study area. The Sibsa river lies to the west of the area and the Bhadra river lies to the east coming as a tributary from the Rupsa river in the upstream which meets the Sibsa river at the downstream.

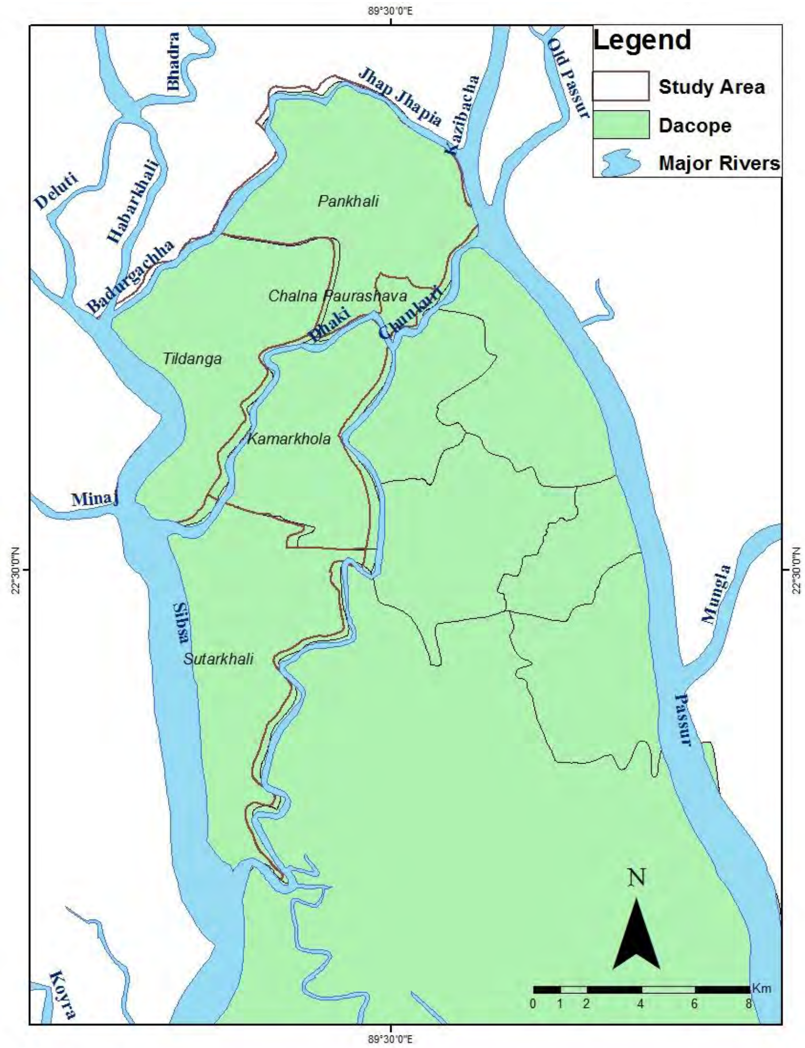


Figure 3.3: Major rivers in the study area

The Bhadra flows through western side with different local names and the Jhapjhapia flows through northern side of the study area. The Dhaki River flows between polder 31 and 32 marking the boundary between these two polders. Pankhali union of Polder 31 is mainly surrounded by the Bhadra river while Tildanga union is at the banks of the Dhaki and Sibsa rivers. The Chunkuri flows through northeastern side of the study area. Besides these rivers, other small river and riverlets flow through the study area. All these rivers are tidal and are mostly navigable during all seasons. During dry season most of the rivers get saline. Table 3.3 shows detailed description of the major rivers in the study area. Apart from these rivers, there are a number of large and medium canals inside the polder area some of which are used for rainwater storage during the monsoon season and also for fish culture. Among these canals, Batbunia khal, Deloti khal, Mora Bhadra khal, Garkhali khal, Moukhali Doani khal, Chalna khal, etc., are the major ones in the entire polder.

3.8 Polders

The polders were constructed by the Water and Power Development Authority (WAPDA), former Bangladesh Water Development Board under coastal embankment for flood control and drainage activity in 1960s. Brief description of the two Polders of the study area are as follows:

Polder 31

The river Dhaki bounds polder 31 on the southeast and the river Shibsa on the southwest. On the west it is bounded by the rivers Badurgachi, Madurpalta and Bhadra, on the north by the rivers Japjhapia and Manga and on the east by the rivers Pasur and Chunkuri. A number of canals criss-cross the polder area of which Bhadra, Khalisha Khal, Baroikhali khal, Gharkhali Nadi and Nishankhali khal are the major ones. Chalna, once a seaport of the country, is adjacent to polder 31(VLPC Report, 2001). The polder consists of Tildanga, Pankhali and Chalna unions of Dacope Upazila. To the western and northern sides of the polder are located Paikgacha and Batiaghata Upazilas respectively. Geographically the polder is located in northwestern part of Dacope Upazila. The total length of the polder is about 47 km. The polder comprises 43 villages covering 10 mouzas under the two unions (ibid).

Table 3.3: Characteristics of the major rivers in the study area

Description	Name of the rivers				
	Chunkuri	Jhapjhopia	Dhaki	Bhodra	Shibsa
ID no.	SW-31	SW-35	SW-38	SW-66	SW-88
Off take	Kazibaccha river in Dacope, Khulna	Kazibaccha river in Dacope, Khulna	Chunkuri river in Dacope, Khulna	Haporkhali river in Dumuria, Khulna	Kobadak river in Paikgachha, Khulna
Outfall	Dhaki river in Dacope, Khulna	Badurgaccha river in Paikgaccha, Khulna	Shibsa river in Dacope, Khulna	Haporkhali river in Paikgaccha, Khulna	Pasur river in Dacope, Khulna
Length	5 km	9 km	14 km	43 km	85 km
Avg. Width	324 m	180 m	300 m	63 m	1510 m
Discharge type	Perennial	Perennial	Perennial	Seasonal	Perennial
Time of Min discharge and depth	Feb-Apr	Feb-Apr 250 m^3/s	Feb-Apr 300 m^3/s	-	Feb-Apr
Time of Max discharge and depth	Jul-Sep	Jul-Sep 10500 m^3/s	Jul-Sep 1200 m^3/s	Jul-Sep	Jul-Sep
Normal flooding	River bank is over flooded during normal flooding	River bank is over flooded during normal flooding	River bank is over flooded during normal flooding	River bank is over flooded during normal flooding	River bank is over flooded during normal flooding
BWDB project in river basin	Polders 23, 31	Polder 31	Polders 31, 32	Polders 25, 26, 29, 31	Polders 10/12, 16, 18/19, 23, 31, 32
Tidal action	Yes	Yes	Yes	Yes	Yes

Polder 32

The rivers Shutarkhali and Bhadra pass through the eastern side and the rivers Shibsha and Dhaki flows on the western side. The river Dhaki also bounds the northern side of the polder. The South and the Southeast side of the polder is bounded by the Sundarbans, the largest mangrove forest in the world. A number of canals criss-cross the polder area of which Nalian Nadi, Kamargoda Nadi, Hatkhola khal are the major ones (VLPC Report, 2001). The polder comprises Kamarkhola and Sutarkhali unions of Dacope Upazila. The total length of the polder is about 32 km. There are 18 villages distributed in 6 mouzas constituting the two unions under the polder (ibid).

3.9 Soil Condition

The study area lies under Agro-ecological zone: Ganges Tidal Floodplain (AEZ-13) sub region: saline, non-calcareous (13d). The region occupies an extensive area of tidal floodplain in southwest of the country characterized by a close network of interconnected rivers and creeks. Table 3.4 gives a brief description of AEZ 13. The soils in this sub region 13d become slightly to very strongly saline during the dry season (MoL, 2011). The soils formed from clay-loam, loam and clay sediments are seasonally flooded, poorly drained except soils of highland areas. The soil salinity and soil pH level range from 2.5-30.0 dS/m and 5.5-8.0 (slight acidic to slight basic) respectively.

According to SRDI (2000) the soils of the study area are categorized under 6 different soil series. Table 3.5 describes the soil series characteristics.

Table 3.4: A brief description of AEZ 13 of the study area

Agro-ecological zone	Characteristics
AEZ 13-Ganges Tidal flood Plain	**Land type:** Medium high **Soil texture:** Loamy **Organic matter:** Medium **Soil fertility class:** Nitrogen-Very low-low, Phosphorus- very Low-low, Potassium- Optimum-high, Sulphur- Optimum-high, Zinc- Low-medium **Suitable crops:** Wheat, boro rice, mungbean, grass pea, chili, bean tomato, mustard, onion, watermelon, cowpea (Rabi), aus (HYV), indian spinach, amaranth (Kharif-I), T. aman (local improved), T. aman (HYV), gourd, chili etc (Kharif-II).

Source: BARC, 2012

Table 3.5: Soil series and their characteristics

Soil series	Land type	Texture (upper part)	pH	Salinity (EC) dS/m	Organic matter (OM) %
Bajoa	Medium high land	Clay loam/ loam	4.5-8.1 High acidic to basic	19.5 Very high	2.56 Medium
Jhalokathi	Medium high land	Clay loam/ loam	4.4-7.7 Very high acidic to slight basic	22.6 Very high	3.29 Medium
Dumuria	Medium high land	Clay/ clay loam	4.7-7.9 High acidic to slight basic	24.6 Very high	3.30 Medium
Barisal	Medium high land	Clay	4.2-7.6 Very high acidic to slight basic	21.8 Very high	3.30 Medium
Kamalkathi	Medium high land	Clay	5.6 Slight acidic	13.9 High	3.13 Medium
Katal poli	Medium high land	Loam	5.6 Slight acidic	22.6 Very high	2.91 Medium

Source: SRDI 2000

Figure 3.3 shows the soil and landform map of Dacope Upazila. This map shows eight soil resource development units which were divided on the basis of soil quality and development possibility of landforms of Dacope Upazila.

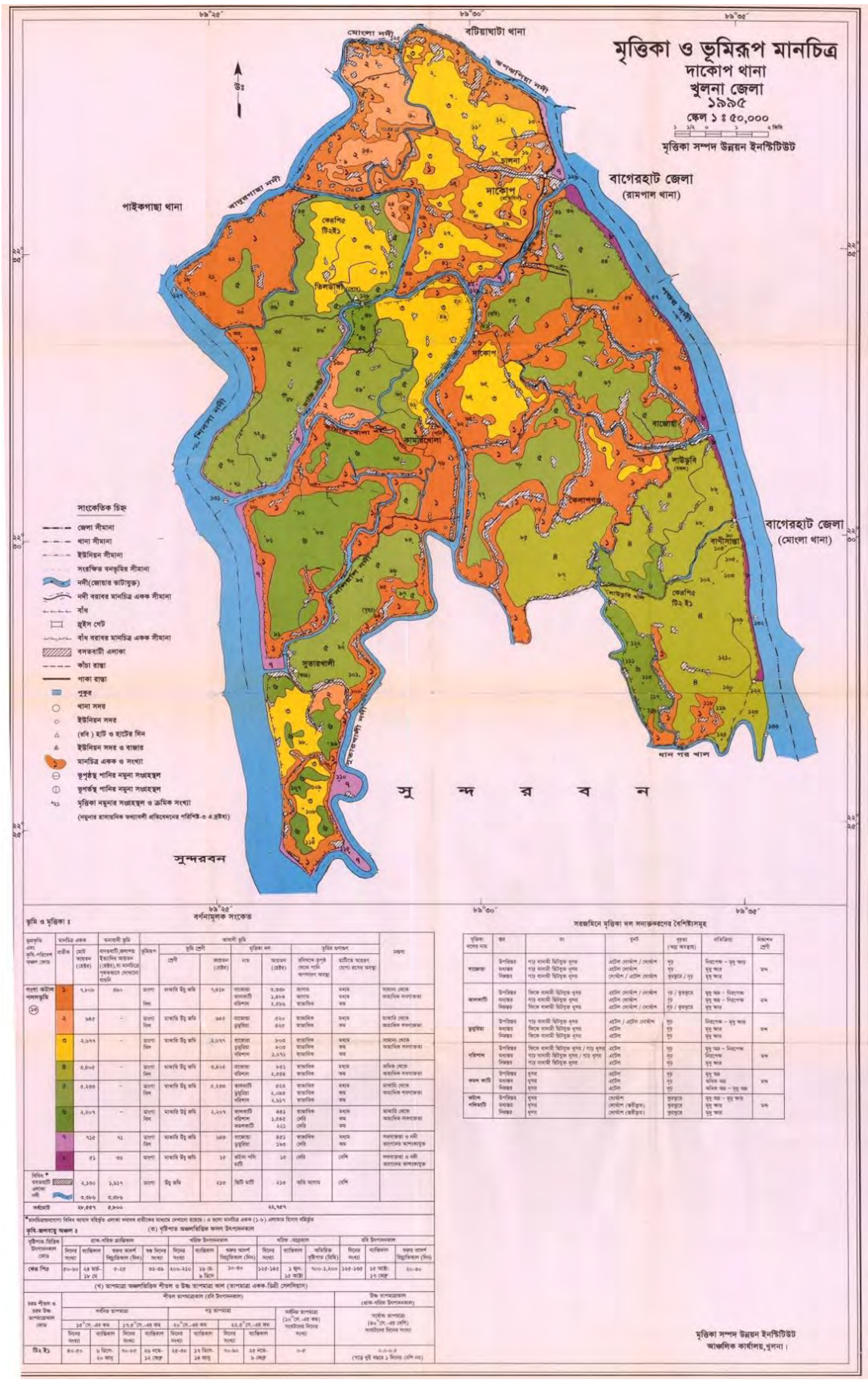


Figure 3.3: Soil and Landform map of Dacope Upazila (source: SRDI, 2000)

3.10 Land use

In the study area agricultural crop and shrimp cultivation dominate the current land use pattern. The land of Dacope Upazila is intensively used for agriculture, housing and settlements with homestead forests, shrimp culture (badga), fisheries (white fish individually) and mixed culture (fisheries with paddy) (MoL, 2011). Also, there are some fish processing industries, small poultry farms, salt research facility, desalinization plant and some infrastructural developments in the area.

Land use pattern has undergone a major shift in the study area over the years, according to the data and information made available under different study methods. Major changes in land use pattern are attributable to the introduction of shrimp cultivation over 1980s and 1990s. The traditional practices of rice cultivation has, to a great extent, been replaced by commercial shrimp farming. Table 3.6 gives union-wise present land use information and identified land zoning of the study area.

Major cropping pattern in the study area are: Fallow-Fallow-T.Aman, Fallow/Rabi-Fallow-Aman and Shrimp (Bagda)-T.aman. The study area is dominated by agricultural crops such as T. Aman (HYV/LYV), Boro (HYV/LYV), potato, pulses, sesame and different kinds of vegetables (major winter vegetables) which are mainly cultivated under both rainfed and irrigated conditions followed by fisheries (major shrimp culture) and other activities.

Table 3.6: Union-wise present land use information and identified land zoning of the study area

Name of the union	Chalna Pouroshava	Pankhali	Tildanga	Sutarkhali	Kamarkhola
Total area of the union (ha)	949	2201	4464	4896	2921
Net Cultivable Area, NCA (ha)	550	1475	3370	2546	1900
Land type (ha)	MHL-55 MLL-495	HL-400 MHL-560 MLL-500 LL-15	MHL- 3370	MHL- 2546	MHL-1900
Soil texture	Silt loam-clay loam	Clay loam-clay	Clay loam, loam and clay	Clay	Clay loam-clay
Soil pH	6-8.0	5.5-7.0	5.5- 7.5	6.5- 8.0	5.5- 7.5
Soil salinity (dS/m)	8.0-22	2.5- 8.0	8.0-22	14-30	14- 30
Present land use (%)	Ag=58, Sett= 11, Wa= 23, Sh= 6, Ub= 2	Ag=67, Sett= 13, Wa= 12, Sh= 6	Ag=75, Sett= 11, Wa= 13, Sh= 10	Ag= 52, Sett= 11, Wa= 25, Sh= 9, Su= 3	Ag= 75, Sett= 13, Wa= 15, Sh= 8
Recommended land zoning	Agro-Urban and Commercial Zone	Agro-Aquaculture (Bagda with white Fish) Zone	Agro-Aquaculture (Bagda with white Fish) Zone	Agro-Aquaculture (Bagda with white Fish) Zone	Agro-Aquaculture (Bagda with white Fish) Zone

[Ag= agriculture, Sett= settlement, Wa = water body, Shr = shrimp area (Bagda with white fish), Ub= urban, Su= Sundarbans]

Source: MoL, 2011

CHAPTER FOUR
METHODOLOGY

4.1 Introduction

This chapter describes the methods followed for this research study. For this study land use changes have been detected using remote sensing softwares; changes of soil properties have been determined by collecting soil data from field visits and other secondary soil data from the related source and organization, and rice yield data have been collected from related organization.

4.2 Landsat image collection

For studying land use changes pattern, remotely sensed data such as aerial photograph and satellite imageries are undoubtedly the most dependable for extracting information (Rahman et al. 2005). Satellite imagery is used for recognition of synoptic data of earth's surface. Landsat Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) data have been broadly employed in studies towards the determination of land cover since 1972, the starting year of Landsat program, mainly in forest and agricultural areas (Campbell 2007).

Identifying the land use changes over the study area, first of all satellite images i.e. Landsat (name indicating Land + Satellite) images were collected. Landsat images are free and downloadable from the internet from USGS Global Visualization server (GloVis). These landsat images were collected from GloVis http://glovis.usgs.gov/ website. Following Landsat images were downloaded from the website. It is important to have the most recent version of Java to access GloVis while collecting satellite images.

Table 4.1: Details of collected Landsat images

Date	**Landsat image**	**Product**	**image code**
25th January 2014	Landsat 8	OLI_TIRS_L1T	LC81370442014025LGN00
22nd February 2010	Landsat 5	TM L1T	LT51380442010053KHC00
23rd March 2009	Landsat 5	TM L1T	LT51380442009082KHC00
16th February 1996	Landsat 5	TM L1T	LT51380441996047BKT01
19th February 1988	Landsat 5	TM L1T	LT51370441988050BKT00

4.3 Landsat image processing and classification

Land use or land cover dataset has been generated from the digital image classification of Landsat 5 and Landsat 8 satellite images. These two Landsat images have different band sets. So for processing of the satellite images, the bands of the satellite images are needed to know beforehand. Without knowing the bands of the image, processing of the image will give error outcome. Table 4.2 shows the bands of Landsat 5 and Landsat 8.

There are two broad classification procedures: supervised classification and unsupervised classification. The supervised classification is the essential tool used for extracting quantitative information from remotely sensed image data (Richards, 1993). Applying different band combinations for the satellite images different features were identified, as those features shows different color combinations and/or reflectance under different band combinations. Also, field knowledge was applied for identifying the features from the images.

Satellite images were processed using remote sensing software ERDAS Imagine 9.2. The image classification process i.e. supervised classification process is divided into two phases: a training phase, where the computer is 'trained', by assigning for a limited number of pixels to what classes they belong in this particular image, followed by the decision making phase, where the "Maximum Likelihood parametric rule" assigns a class label to all (other) image pixels, by looking for each pixel to which of the trained classes this pixel is most similar. To have training areas, ground truthing points collected from field survey have been used for this image classification. For the research purpose five classes were assigned (water, forest, bare land, shrimp land and agricultural land). Similar studies were followed by Islam and Hasan (2011), Paul et al. (2014), and Ries (2008).

Table 4.2: Bands of Landsat 8 and Landsat 5 sensors

Landsat 8 (OLI TIR Sensor)			**Landsat 5 (TM sensor)**		
Bands	**Wavelength (micrometers)**	**Resolution (meters)**	**Bands**	**Wavelength (micrometers)**	**Resolution (meters)**
Band 1	0.433–0.453	30	Band 1	0.45 - 0.52	30
Band 2	0.450–0.515	30	Band 2	0.52 - 0.60	30
Band 3	0.525–0.600	30	Band 3	0.63 - 0.69	30
Band 4	0.630–0.680	30	Band 4	0.76 - 0.90	30
Band 5	0.845–0.885	30	Band 5	1.55 - 1.75	30
Band 6	1.560–1.660	30	Band 6	10.40 - 12.50	120
Band 7	2.100–2.300	30	Band 7	2.08 - 2.35	30
Band 8	0.500–0.680	15			
Band 9	1.360–1.390	30			
Band 10	10.6-11.2	100			
Band 11	11.5-12.5	100			

Each class's areal percentage was calculated using ArcGIS 10 software over the years to see the changes of classes, i.e. the decrease or increase of any class's area.

4.4 Soil Sampling Locations

Three field visits were conducted from January 2014 to November 2014 in Pankhali, Chalna, and Tildanga unions of polder 31, and Kamarkhola and Sutarkhali unions of polder 32. During the field visits soil samples were collected from both polder areas. Samples were collected from all the unions and tried to cover the whole study area. Figure 4.1 shows the locations of collected soil samples from the study area.

4.5 Soil Sample Collection

Soil samples were collected from the field to analyze some important properties of soil to understand the soil present condition and compare them with older soil data. Analysis of soil samples in the laboratory was made on samples collected from field. Samples were collected from the visited places. A spade was used to collect soil samples.

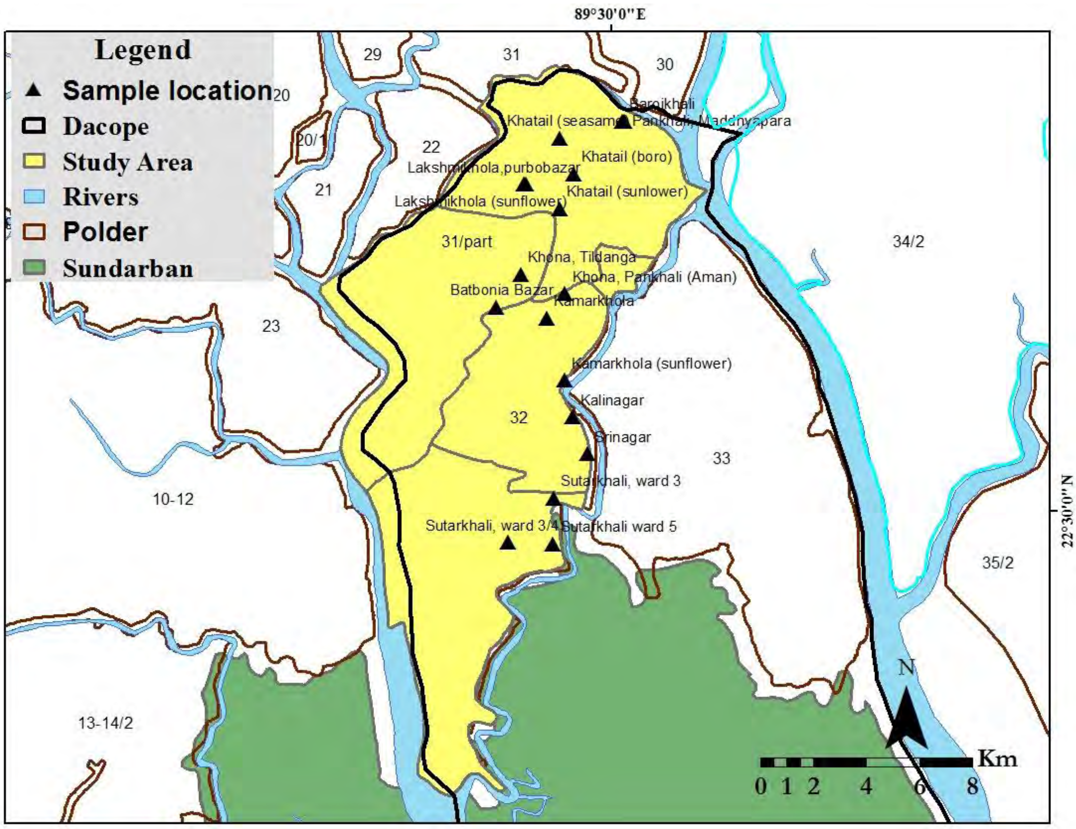


Figure 4.1: Locations of collected soil samples

4.5.1 Procedure of collecting soil samples

For collection of soil sample a suitable site (point sample method) was selected, the surface of the soil was cleared to remove loose plant materials and other debris and a spade was used to dig up soil from a suitable depth, usually 0-15cm. The dug soil was then collected in a polythene bag. Appropriate label with the name of the site of collection, depth and date was put both inside and outside the bag and tied it securely. Figure 4.2 shows collection of soil sample from the field.

4.5.2 Preparation and storage of soil samples

Each of the collected samples are spread on separate sheets of paper or trays and air-dried after it was being transported to the laboratory. Once air-dried, large aggregates were broken preferably in a wooden mortar and pestle and passed the ground soil through a 2mm sieve. The sieved soil was weighed to keep about 500g into a plastic containers and mouths were well capped. Each container was labelled according to their field label and stored then in a cool dry place in the laboratory.

Figure 4.2: Soil sample collection from field.

4.6 Determination of soil properties

Different properties of soil, for example, pH, EC, OM, CEC, soil texture, total N, K, Ca, Mg, P, and S were determined at the SRDI laboratory. Brief description of determination processes and calculations of these soil properties are given in Appendix-1.

4.6.1 Determination of Soil pH

pH is one of the most important characteristics of soil solution. Soil may be acid, neutral or alkaline in reaction. Some soil possess a preponderance of hydrogen over hydroxyl ions and, therefore, are acids. Some show the reverse, and are alkaline, while others, which have an equal concentration of hydrogen and hydroxyl ions, are neutral in reaction. Soil pH influences availability of nutrients to plants, activity of useful and parasitic soil organisms, potency of toxic substances present in soil etc. Soil pH has been determined by using pH meter (Huq and Alam, 2005).

4.6.2 Determination of Soil Electrical Conductivity (EC)

EC is expressed as mmhos/cm, i.e., reciprocal of ohms. The present practice is to use Siemens(S). For most soils mmhos/cm is large unit so that for convenience millimhos/cm or mS or micromhos/cm or µS are used.

The EC of the soil sample has been determined by the EC meter (ibid).

4.6.3 Determination of Soil Organic Matter (OM)

Organic matter is considered the flesh, while the sand; silt and clay are known as the skeleton of a soil. A soil without organic matter is not considered as soil from the edaphological point of view. Organic matter status of soil is linked to its fertility thereby imparting its influences on the productivity.

To determine organic matter of the soil at first soil organic carbon has been calculated. Soil organic carbon has been determined by wet combustion or wet oxidation method (ibid).

4.6.4 Determination of Soil Cation Exchange Capacity (CEC)

The cation exchange capacity is defined as the amount of cation species bound to soil colloids at pH 7.0. Mathematically:

$\Sigma Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Fe^{3+}, Al^{3+} \ldots, H^{+} = CEC$

The cation held on the surface of soil minerals and within the crystals framework of some mineral species plus those which are a part of certain organic compounds can be reversely replaced by those of salt solutions and acids. CEC is usually expressed as milliequivalents (meqv) per 100g of soil or meqv. %. CEC of soil has been determined by the ammonium acetate or sodium acetate extraction method (ibid).

4.6.4 Determination of Soil Texture

Soil texture has been determined by testing the collected soil samples using the Hydrometer method (ibid).

4.6.5 Determination of Total Nitrogen

The Kjeldahl procedure is generally applied for determination of total N and involves two steps: digestion of the sample to convert the N to ammonium sulphate; and, determination of ammonium in the digest (ibid).

4.6.6 Determination of Potassium

The potassium content of a soil depends primarily upon the parent material and degree of weathering. Potassium is determined by the method of cold extraction (ibid).

4.6.7 Determination of Calcium and Magnesium

Calcium occurs widely and absolutely in soils as the carbonate, phosphate, silicate, and sulfate. The carbonate is the most important source of soil calcium. In soil, magnesium occurs principally in the clay minerals, being common in micas, vermiculities and chlorites; it sometimes occurs as carbonate. The classical routine method of determining calcium and magnesium is by complexometric titration using EDTA (ethylenediamine tetra acetic acid) that forms a slightly ionized, colourless, stable complex with alkaline earth metal (Ca, Mg etc.) (ibid).

4.6.8 Determination of Phosphorus

Phosphorous is one of the three macro anions used by plants, the other two being nitrate and sulfate. Phosphorus was determined by Molybdophosphoric blue color method in Sulfuric acid system (ibid).

4.6.9 Determination of Sulfur

In humid climates soil sulfur is mostly in organic combinations. Sulfur occurs in many forms in soil such as sulfide, sulfate etc., in organic forms cysteine, cysteine, methionine etc. Sulfur was determined by turbidimetric method (ibid).

4.7 Other data collection

4.7.1 Secondary soil data

Primary soil data have been collected from the analyses of collected soil samples during field visits. Previous soil data i.e., secondary soil data (year 1995) of the study area have been collected from Land and Soil resources Utilization Guidelines of Dacope Upazila booklet (soil data was analyzed by SRDI).

4.7.2 Rice yield records

Annual rice production records along with total cultivated lands of rice of ten years i.e. from 2004-05 to 2013-2014 have been collected from Khulna agricultural zonal office. For the research purpose two seasonal rice Aman and Boro rice production data have been collected. Annual rice yield (ton/ha) was calculated dividing the rice production (ton) with land area (ha).

4.7.3 Local information using PRA tools

The information on changes in the study area was collected using Participatory Rural Appraisal (PRA) tools such as Focus Group Discussions (FGDs), Key Informant Interviews (KIIs), individual interviews, and resource mapping.

Some qualitative and semi-quantitative information regarding changes of land use, soil properties and rice yield were collected through FGDs with different groups. Relevant data were collected from three field visits to the two polders and to relevant governmental and non-governmental organizations. 12 FGDs were conducted with farmers, fishermen, and wage labourers. These groups comprised both men and women. Following tables show the details of FGDs and KIIs.

Table 4.3: FGD details

Date	Place	Number of people
17/02/2014	Khona, Pankhali	10
18/02/2014	Khatail, Pankhali	8
18/02/2014	Pankhali Madhhyapara, Tidanga	8
19/02/2014	Batbunia, Tidanga	10
20/02/2014	Baroikhali, Pankhali	9
19/05/2014	Batbunia bazar, Tidanga	12
19/05/2014	Lakxmikhola, Pankhali	8
20/05/2014	Kamarkhola, Kamarkhola	15
20/05/2014	Kalinagar, Kamarkhola	11
20/05/2014	Sutarkhali (ward 3)	14
21/05/2014	Sutarkhali (ward 3/4)	10
21/05/2014	Sutarkhali (ward 5)	8

Table 4.4: KII details

Date	Place	KII
29/01/2014	Dacope Upazila Fishery Office	Senior Upazila Fisheries Officer
29/01/2014	Dacope Upazila Fishery Office	Asst. Upazila Fisheries Officer
29/01/2014	Dacope Upazila Agriculture Office	Senior Upazila Agriculture Officer
30/01/2014	Dacope Upazila Headquarter	Thana Nirbahi Officer (TNO)
18/02/2014	BWDB, Khulna Office	Executive Engineer
18/02/2014	SRDI, Khulna Office	Scientific Officer
20/05/2014	BWDB, Khulna Office	Engineer

Figure 4.3: FGD at Baroikhali

Figure 4.4: FGD at Batbunia Bazar

Figure 4.5: After FGD with local people of Sutarkhali

Figure 4.6: KII with Senior Upazila Fisheries Officer

Figure 4.7: KII with BWDB engineer

CHAPTER FIVE
RESULTS AND DISCUSSION

5.1 Introduction

This chapter describes the results of satellite image interpretations i.e. the land use changes and causes, soil data interpretations and relations between land use changes and soil properties changes and lastly rice yields of the study area.

5.2 Land Use Classification

Landsat satellite images were classified using supervised classification method dividing into six classes namely bare land, agricultural land, shrimp land, vegetation/forest, water body and inundated area (Table 5.1). The percentage of each class was calculated to see how much each land use has been changed over the time periods.

Due to availability of suitable environment, shrimp cultivation had started at 1990's in the southwest part of Bangladesh where the study area is situated. With increasing profits this cultivation practice had started to spread over the years in this saline area. The land use classification of satellite images shows how the land uses are being changed. Landsat images from five different times were selected for land use change detection purpose: 1988, 1996, 2009, 2010 and 2014. All of these selected images are dry period images. Over these years, land uses have undergone remarkable changes following various natural and man-made phenomena.

Changes in land use pattern

Land use classification maps in different time periods have been examined for detecting the land use pattern changes in the study area. According to the produced land use maps (Figure 5.1, 5.2, 5.3 and 5.4), it was found that bare land and shrimp land were the dominant types of land use classes for the years 1988 and 1996. During this period shrimp cultivation was flourishing and not much dry period agriculture was practiced. The land use map of 2009 (Figure 5.3) illustrates that the predominant types of land use classes were bare land, agricultural land and shrimp land. This change in land use pattern was due to the change in people's perception following the negative impacts of shrimp cultivation and SIDR in 2007. More farmers were returning to agriculture (rice cultivation) and thus increasing the cultivable area even in dry period. This also implies the change in agricultural practices switching from only monsoon aman rice cultivation to both monsoon and dry period rice cultivation. 2010 land use map (Figure 5.5) represents afterward effect of cyclone Aila of the study area. The whole study area was inundated for almost six months to one year and so only bare land and inundated land were the major land use classes from this image. Land use map of 2014 (Figure 5.4) depicts bare land, agricultural land and shrimp land as the dominant land use classes and implies that agriculture was rejuvenated from the impacts of cyclone Aila. Computed percentages of land use classes of different periods are showed in the following Table 5.2.

Table 5.1 Description of land use classes identified in the study area

Classes	**Descriptions**
Bare Land	This class includes all types of cultivable lands without any standing crops, also uncultivable lands or fallow lands which can be cultivated
Agricultural Land	This class includes areas currently under rabi crops or lands are being prepared for raising crops.
Shrimp land	Areas currently under shrimp cultivation
Inundated area	Areas under water due to cyclone Aila
Vegetation/Forest	Mainly mangrove forest, some small fraction is homestead vegetation
Water Body	This class includes all the surface water bodies, e.g., rivers, canals, ponds, etc.

Table 5.2: Percent change of land classes

Class	Image period				
	1988	**1996**	**2009**	**2010**	**2014**
Bare Land	38.76	19.19	27.80	26.12	20.45
Agricultural Land	8.99	7.09	22.66	-	30.74
Shrimp land	24.34	31.63	14.68	-	11.51
Inundated area	-		-	39.76	-
Vegetation/Forest	13.11	20.64	13.61	16.07	14.52
Water Body	14.80	21.45	21.25	18.05	22.78
Total	100	100	100	100	100

For the research purpose four major land use types, bare land, agricultural land, shrimp cultivation land and inundated land types will be discussed in this part. According to Table 5.2 and Figure 5.6 shrimp cultivation land was increased from 24.34% at 1988 to 31.63% at 1996 and showed gradually decreasing trend from 1996 to 2009 to 2014 with land coverage from 31.63% to 14.68% to 11.51%. Shrimp cultivation practice showed a reducing trend, only observable in certain place of the study area. Percentage of bare land was the highest in 1988 with 38.76% and the lowest in 1996 with 19.19%. Overall bare land also showed a decreasing trend with change in agricultural practices and overall improvement of saline tolerant rice which encouraged farmers to cultivate more rice during dry period. This is also supported by gradual increase of agricultural land in the dry season over the time. This land use type were 8.99%, 7.09% 22.66% and 30.74% in 1988, 1996, 2009 and 2014 respectively.

Polder-wise land use practices show some variations. In the year 1988, shrimp cultivation and agricultural practices were mainly observed on polder 31. Polder 32 showed mostly bare lands with very small shrimp cultivation. In the year 1996, shrimp cultivation practice was higher on polder 32 than in polder 31. Agricultural practice was only observed on polder 32 and large barren lands were noticeable on polder 31.

Increase of agricultural practice was observable on both polders in 2009. Shrimp cultivation was only seen on the southern part of polder 31, i.e. the southern part of Tildanga Union. Bare lands were equally spread out on both polders. Agricultural practice was increased potentially in both polders, with higher percentage on polder 31 in 2014. Much barren lands were observed on polder 32 with low agricultural practice. Shrimp cultivation was only seen on the southern part of polder 31 same as in year 2009.

Causes of land use changes

From the Table 5.2, it can be said that bare land of the study area in 1988 was the highest among the studied years. The reason behind this is that, during that time the land was mostly kept fallow or remained uncultivated for the rest of year after harvesting monsoon 'aman' rice. Rabi season's crop were cultivated in limited extend and very low quantity. Later on in 1996 the land use types showing shrimp cultivation was the highest, it is because at that period of time shrimp cultivation sector was spreading quickly as it was highly profitable since its start at the end of 1990's. According to FGDs people of the study area took advantages of uncultivated bare lands for engaging in more shrimp cultivation and grabbed the opportunity to earn extra money as these lands remained fallow most of the time and were not productive at all. During this time period agricultural land was lowest, as people were more interested in doing lucrative shrimp cultivation and this shift in agricultural practices forced poor farmers to switch from rice to shrimp even in the monsoon season.

Continuing agricultural cultivation was difficult due to powerful and affluent shrimp cultivator community. Even if someone wanted to cultivate rice it was not possible due to the prevailing shrimp cultivation which already made the land unhealthy for rice cultivation. In FGDs, local people including small farmers stated the same problem and were also upset regarding this matter. But this profitable sector started to degrade gradually after 2007. The reasons are mostly because of soil degradation due to excessive salinity, salinity intrusion in shallow ground water and also local peoples were failed cultivating crops during dry period. Although local people had already started limited crop production after 2000's as they wanted to go back to agriculture from shrimp cultivation. Two deadly cyclones namely SIDR (2007) and Aila (2009) hit the study area and led to many problems, especially cyclone Aila did much damages to the study area which delayed this ongoing switching. Storm surge occurred from this disasters resulted a long term saline water inundation, the most affected part was the polder 32, the southern part of the study area (Figure 5.5). KIIs of BWDB engineers mentioned that the most affected and damaged part was polder 32 of Dacope Upazila, almost a year this part was inundated with saline water. Surge water height was about 3-4 meters and also stated that their BWDB one-storey rest house at Kamarkhola village went completely under water during Aila. Local people even missed one-two years of aman cultivation.

Soil and environmental degradation following these two cyclones discouraged local people to continue massive scale shrimp cultivation and forced them to start practicing rice and other agricultural cultivations. This process was also speed up both by the agricultural and technological innovation and change in people’s perception.

People of the study area are now by and large interested in crop production which is clearly depicted in the Table 5.2 by increase in agricultural land area and decrease in shrimp cultivation area. People of the study area during FGDs showed the same interest. Though part of the study area in polder 31(eastern part) is still under shrimp cultivation process, as this shrimp farming community is rather strong and powerful.

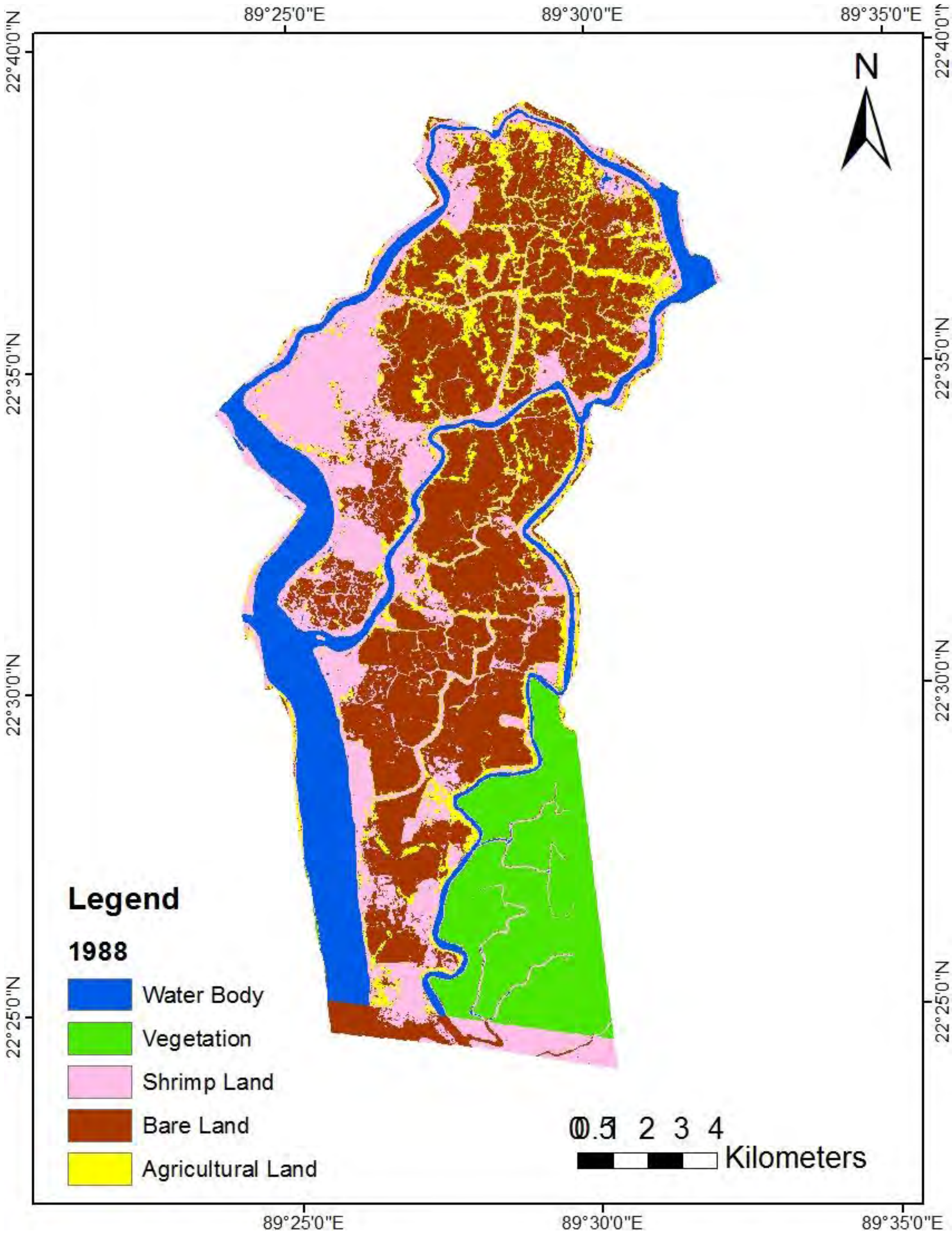


Figure 5.1: Land use map of the year 1988

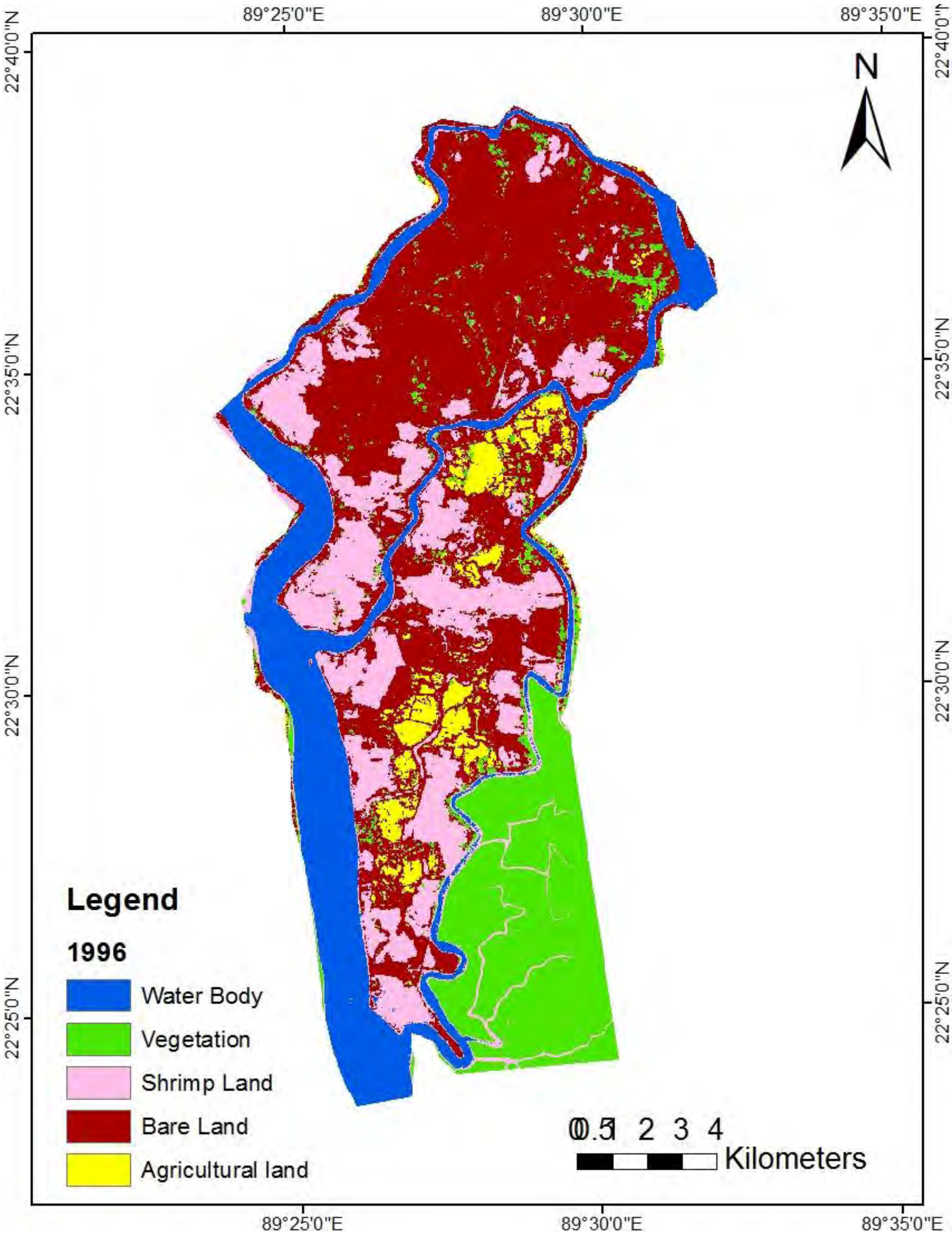


Figure 5.2: Land use map of the year 1996

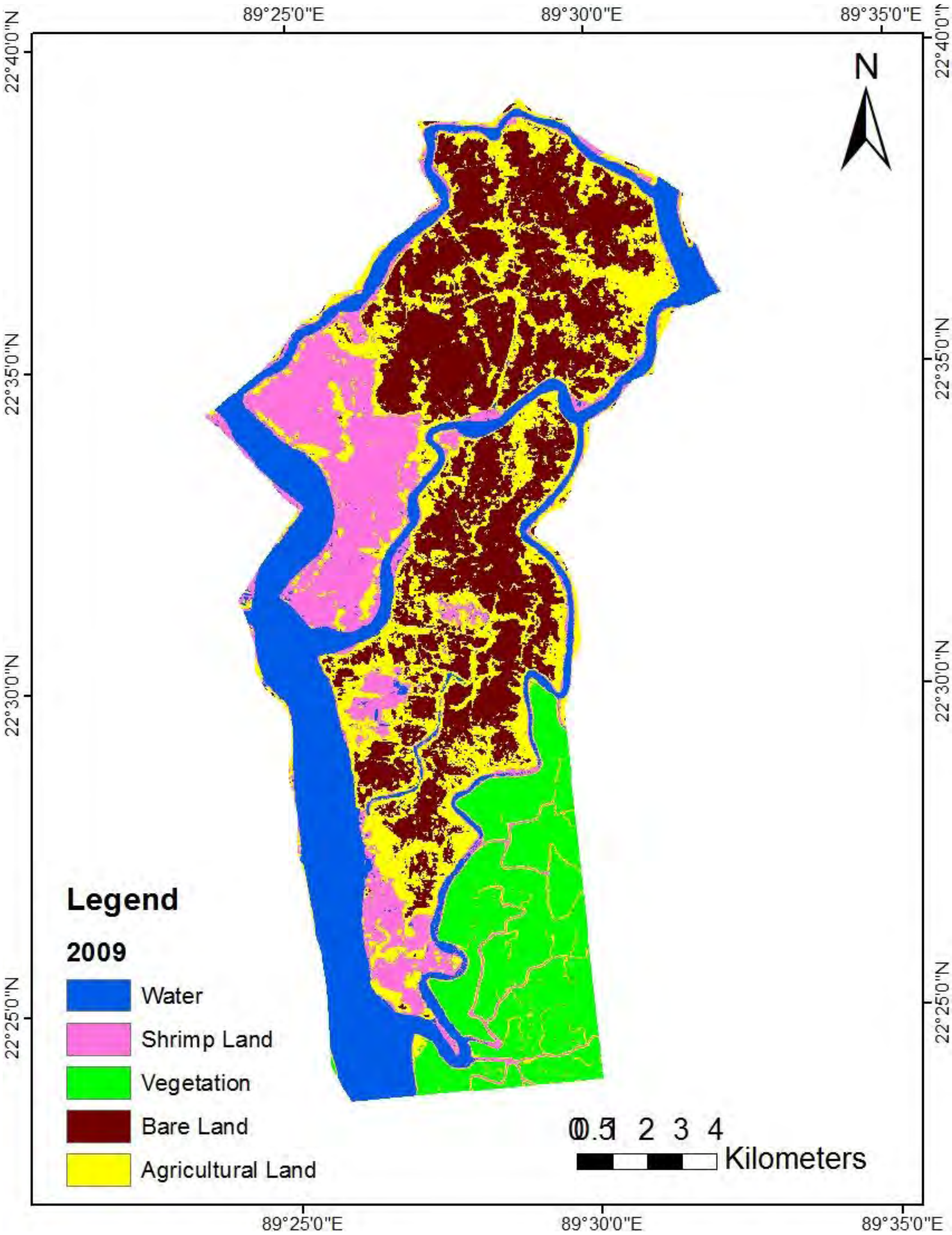


Figure 5.3: Land use map of the year 2009

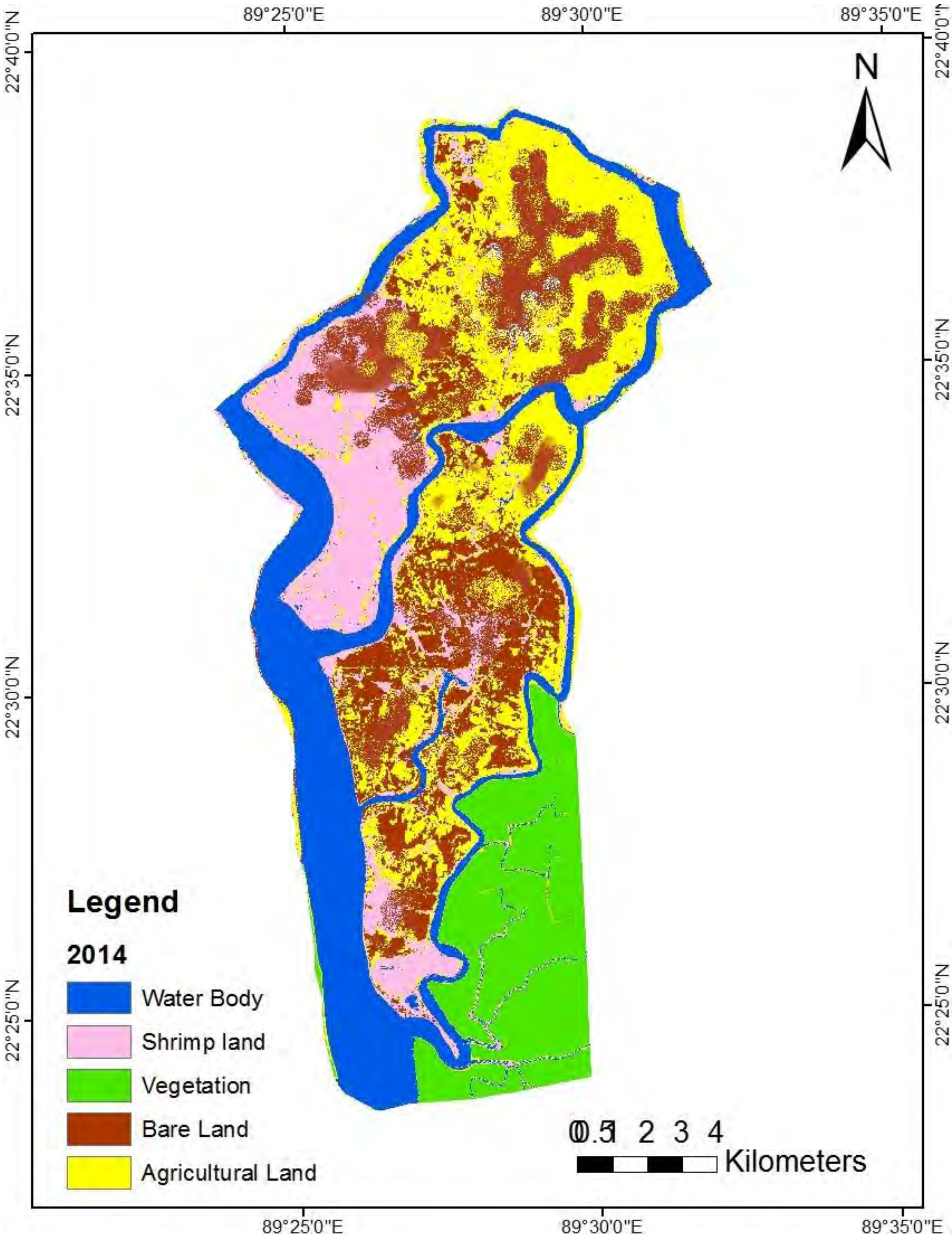


Figure 5.4: Land use map of the year 2014

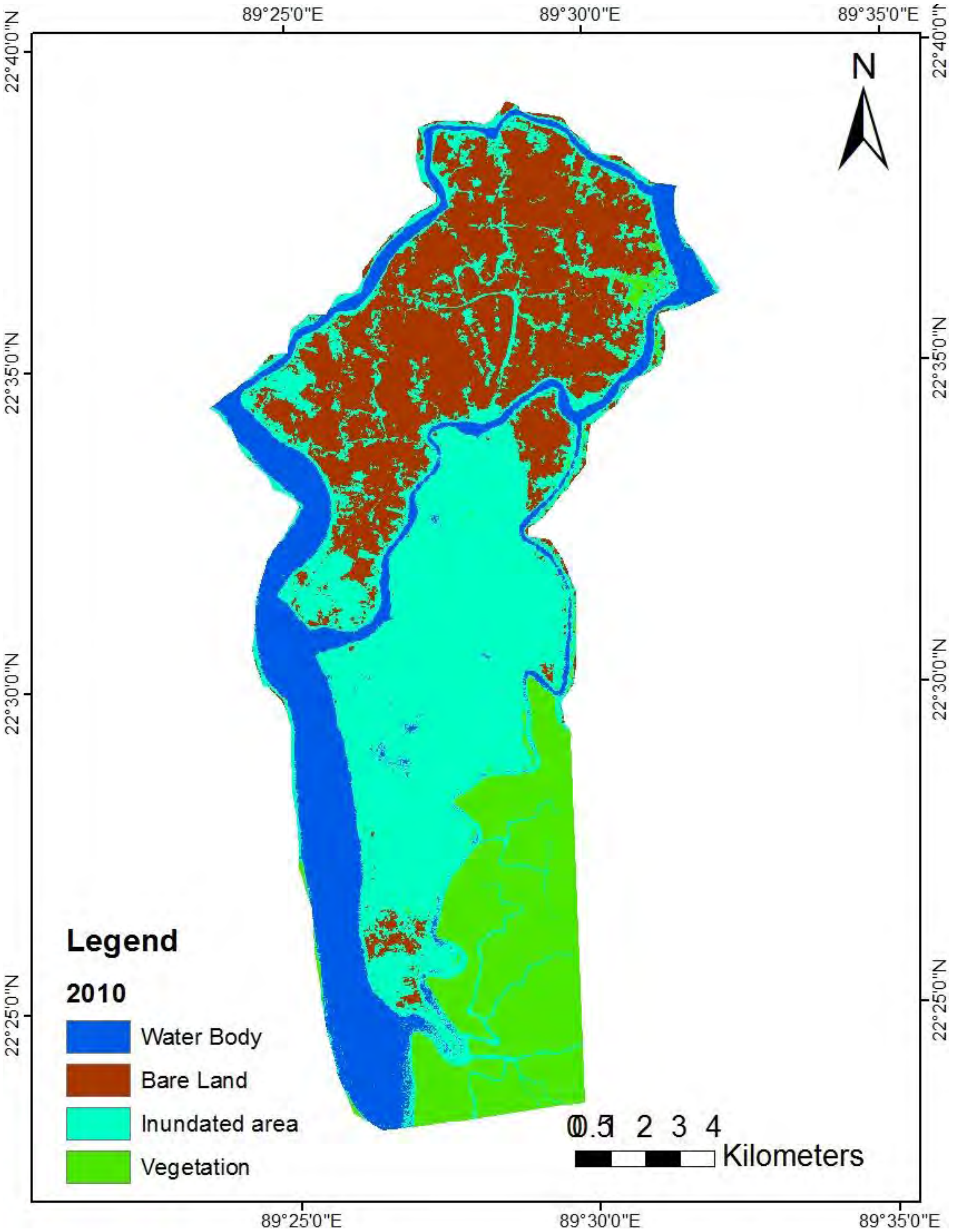
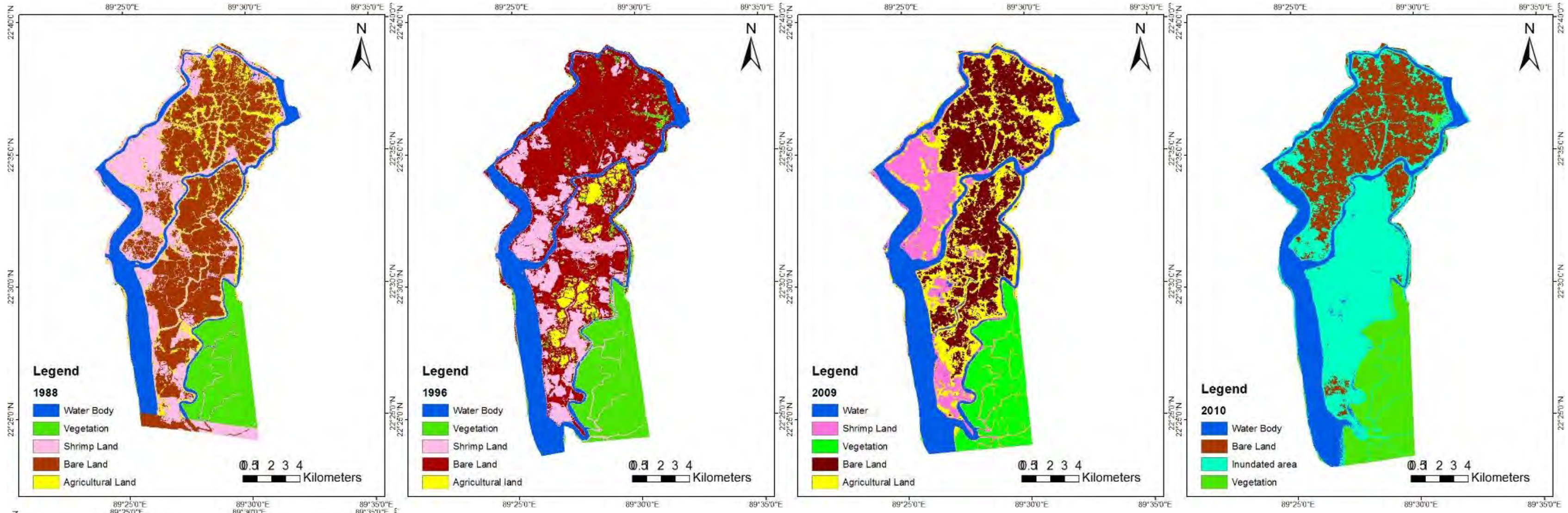


Figure 5.5: Map showing areas inundated with storm surge water after cyclone Aila



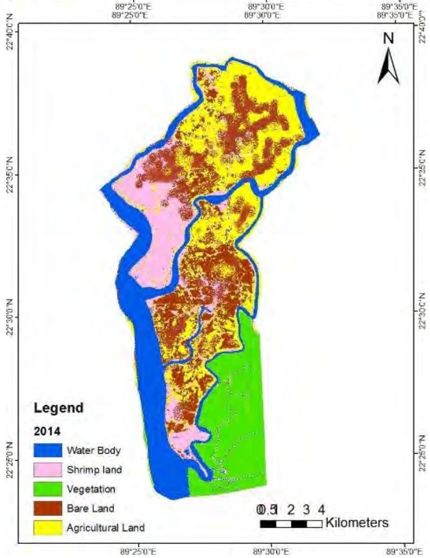


Figure 5.6: Land use maps of (from left to right) 1988, 1996, 2009, 2010 and 2014

5.3 Soil Data interpretation

Collected soil data of the year 1995 and information gathered from the field visit in 2014 were interpreted to understand the soil properties of the study area. Total 17 soil samples were collected during field visits in 2014 and later 17 soil data of 1995 were selected from the acquired data for analyses keeping locations similar or close. These analyses of these soil data are discussed under the following points.

Texture: Soil samples of the study area contains much higher percentage of silt in comparison with sand and clay, forming mainly fine textured soil. Sand (smaller than 2 mm but larger than 0.05 mm in diameter) content is the lowest among the three ranging from 1% to 17%; followed by clay (smaller than 0.002 mm in diameter) content ranging from 29% to 48%; and finally silt (smaller than 0.05 mm but larger than 0.002 mm in diameter) ranging from 49% to 68% forming the majority of the portion. From the external appearance and sieve data it can be said that texture of studied soils fall in mostly silty clay loam category.

Soil texture depends on the types of the parent materials, depositional environment and different physicochemical processes acting upon it over the length of geological period. The content and distribution of different particles in the soils are largely dependent on the lithology of the sediments transported and deposited by the major river systems over different geological periods. As the study area falls under agro-ecological zone 13-Ganges Tidal Floodplain; this zone mostly contains a much higher content of clay and silt and remarkably low content of fine sand (<5 %) due to its long distance river transport from the source area, lack of strong near shore currents and influence of daily tidal inundation.

Soil reaction (pH): Figure 5.7 shows the pH values of the soil samples. The overall mean value of soil pH in 1995 and 2014 were 6.79 and 7.25, respectively, and fall under the neutral pH class (6.6 to 7.3). pH value of 1995 ranges from 4.4 to 7.9 which belongs to strongly acidic to slightly alkaline. On the other hand, pH value of 2014 ranges from 6 to 8.1 and belongs to slightly acidic to slightly alkaline. Higher pH value mostly observed in the polder 32 and some southern part of polder 31. Classification of soil according to pH is given in Appendix-2.

From Figure 5.8 it is observed that in 1995 neutral pH class was spatially distributed over the study area. Only some small parts of Pankhali, Kamarkhola and Sutarkhali had slightly acidic pH distribution. In 2014 pH slightly increased. The upper parts of polder 31 which is Tidanga, Chalna pouroshova and Paankhali, and the lower parts of polder 32 which is Sutarkhali belonged to pH neutral class. The middle part of the study area belonged to slightly basic class of pH.

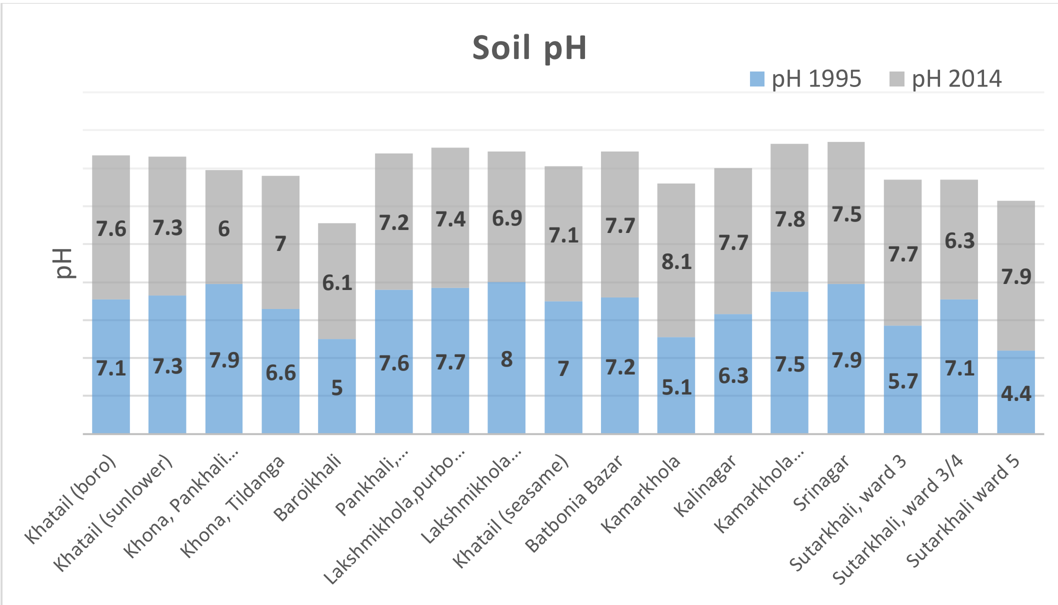


Figure 5.7: Soil pH values of 1995 and 2014

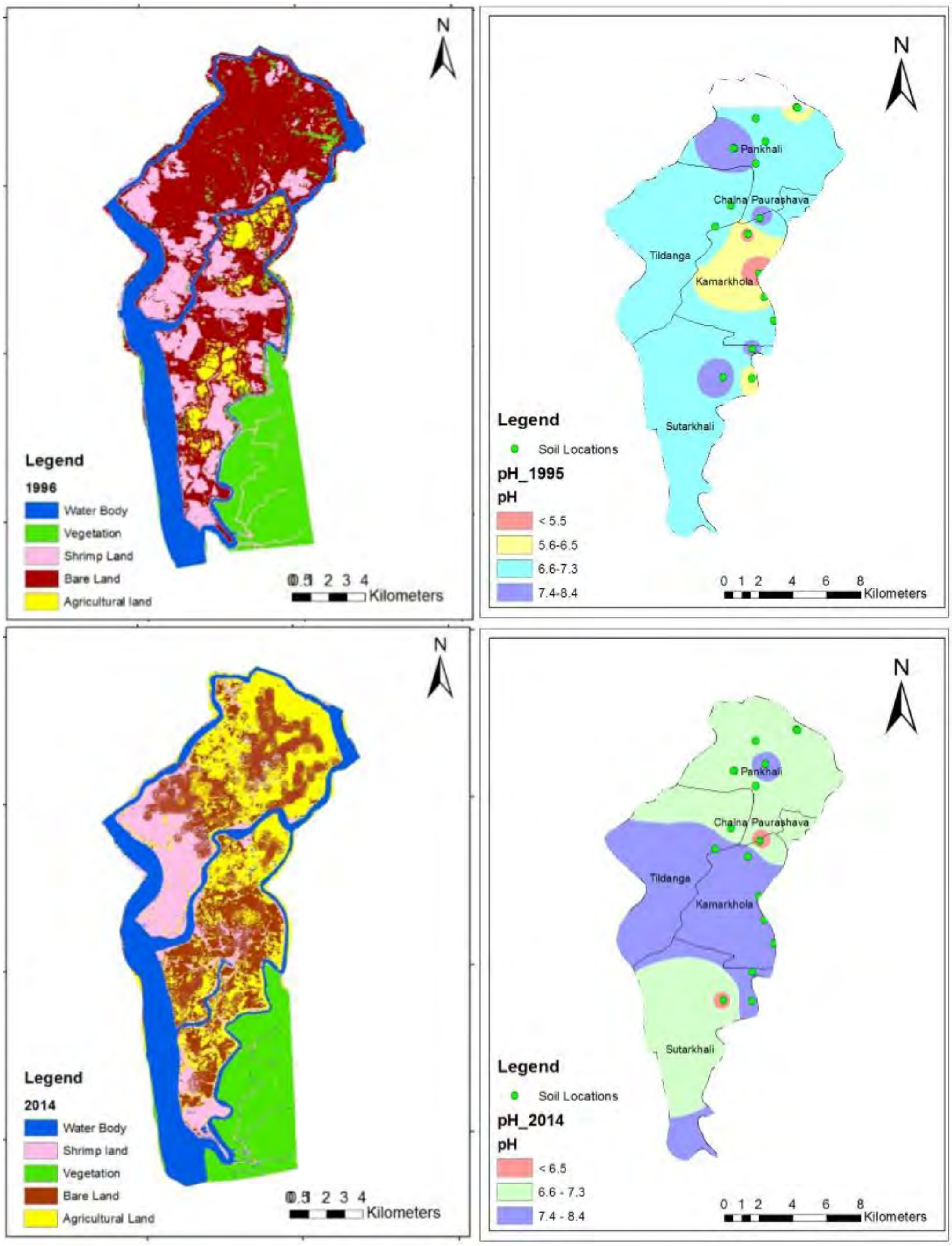


Figure 5.8: Land use and spatial distribution of pH (upper panel 1995 and lower panel 2014)

Soil Salinity: Electrical Conductivity (EC) value of the soils ranges from 11.2 dS/m to 32 dS/m (strongly saline to very strongly saline) in 1995 and 1.58 dS/m to 13.3 dS/m (non-saline to strongly saline) in 2014 (Figure 5.9). Soil classification according to soil salinity is given in Appendix-2. Average EC value of the year 1995 was 21.35 dS/m and was reduced to 6.09 dS/m in 2014. EC value came down to almost one third from 1995 to 2014 showing the overall declining trend in soil salinity. Yearly declining trend could not be interpreted due to the lack of continuous soil salinity data. Very strongly saline area was observed almost all over the study area except some small parts in Kamarkhola which showed moderate salinity class in 1995 (Figure 5.10). Whereas most of the study area in 2014 showed overall improvement and showed slightly saline spatial distribution. Higher salinity had disturbed plant development by limiting its nutrient uptake and reducing the quality of the water available to the plant. It had affected the metabolism of soil organisms, leading to severely reduced soil fertility.

In 1990's shrimp cultivation was vastly practiced in the study area, and because of the induced saline water which was needed for a certain type of shrimp cultivation EC value was found higher in 1995. After cyclone Aila in 2009, shrimp cultivation has dropped off for various reasons which have been mentioned earlier. Only small part of the study area is now economically cultivating shrimp. This resulted in gradual lowering of EC value of the soil.

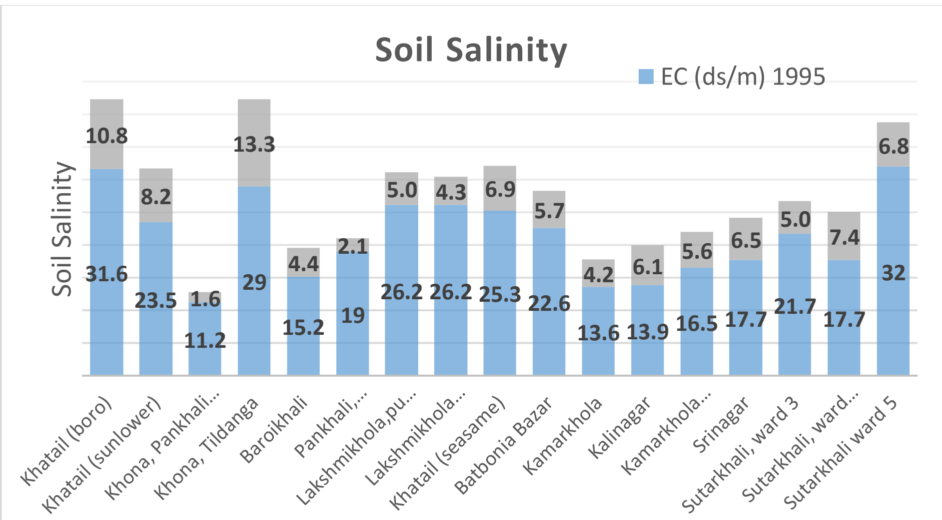


Figure 5.9: Soil salinity values of 1995 and 2014

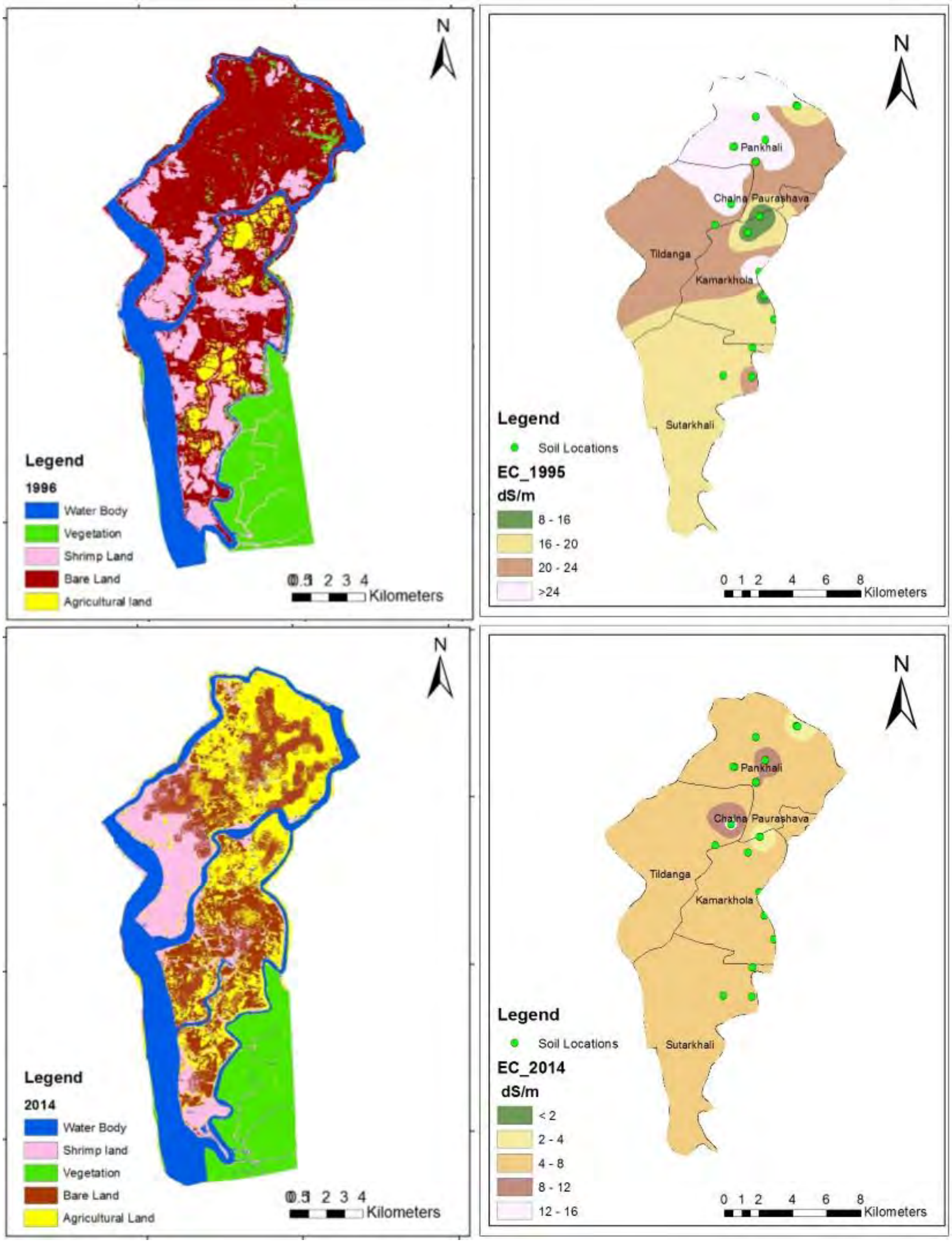


Figure 5.10: Land use and spatial distribution of EC (upper panel 1995 and lower panel 2014)

Organic Matter content (OM): Average OM Content of the study area in 1995 and 2014 were 3.08% and 0.76% respectively. The OM in the soil samples represent moderate to very low in 1995 and 2014, respectively. The range of OM in 1995 and 2014 are 1.75% to 4.38% (moderate to high) and 0.73% to 2.69% (very low to moderate), respectively (Figure 5.11). Soil classification on the basis of soil organic matter content is given in Appendix-2. From Figure 5.12 it is seen that moderate class of OM content was spatially distributed over all parts of the study area in 1995. Some small parts in Tildanga and Kamarkhola showed high class of OM content in the study area. On the other hand, in 2014 OM content was showing very low class of OM content distribution all over the study area.

Generally this part of the area (under Ganges Tidal Floodplain) has good organic matter status. Present low OM indicates poor physical condition in the study area possibly due to the lack of vegetation in the last few years and no running water bodies. A decline in organic matter in the study area was caused by the reduced presence of decaying organisms, or an increased rate of decay as a result of changes in anthropogenic factors, which was shrimp cultivation. Loss of organic matter also occurs because erosion washes away topsoil and humus. Also decrease of soil organic matter may cause a decrease in nutrient holding capacity.

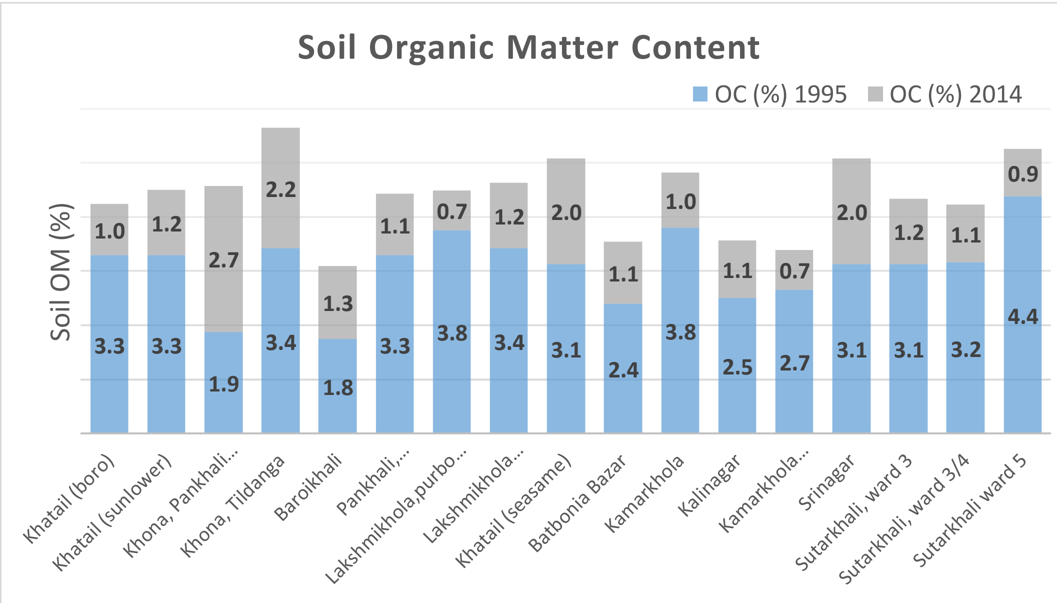


Figure 5.11: Soil OM values of 1995 and 2014

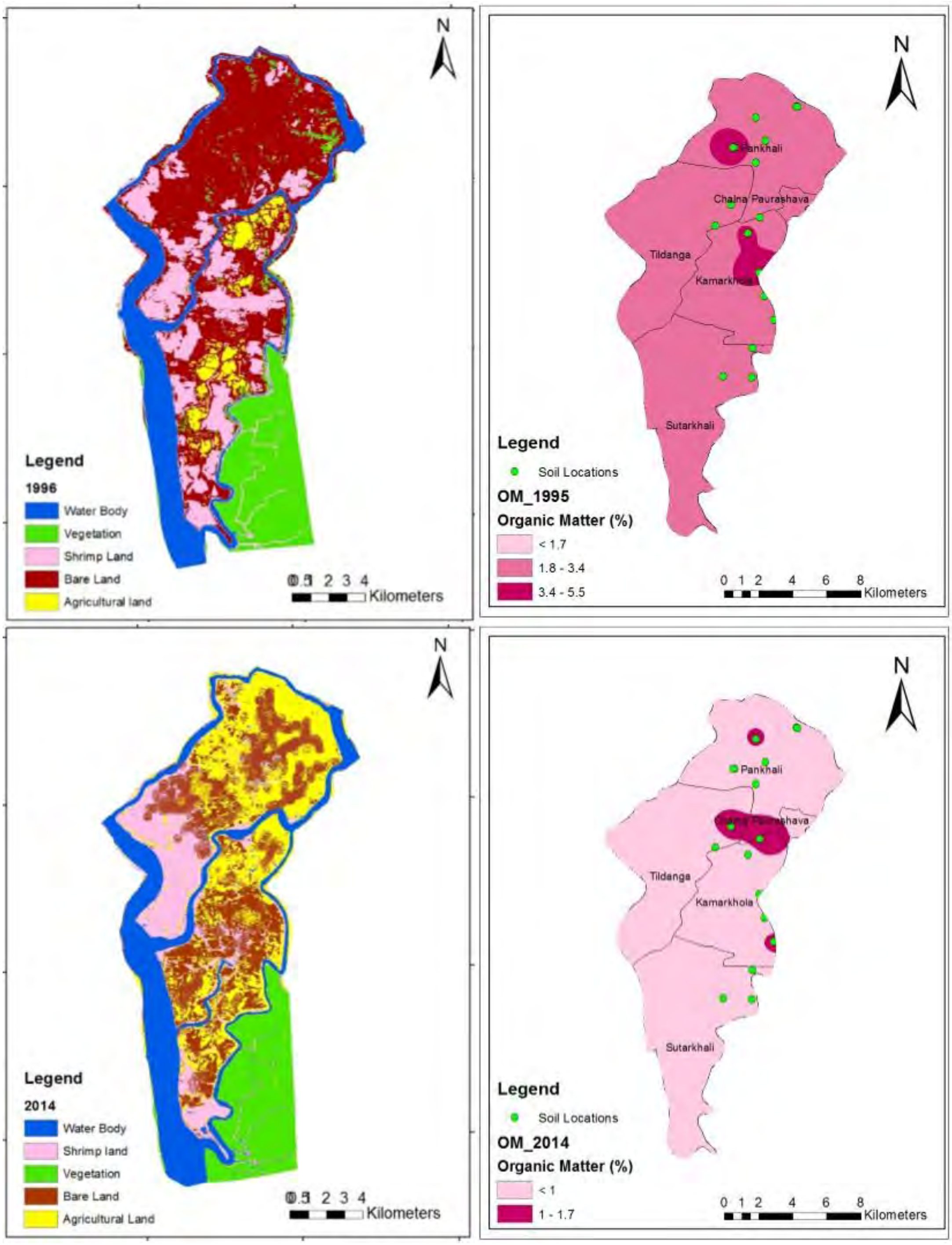


Figure 5.12: Land use and spatial distribution of OM content (upper 1995 and lower 2014)

Cation Exchange Capacity (CEC): Figure 5.13 compares CEC values in 1995 and 2014. Only six CEC values of 1995 could be collected for data interpretation. The average CEC of soil in 1995 and 2014 are 0.31 meqv% (very low) and 19.48 meqv% (high), respectively. Soil classification according to percentage of CEC is given Appendix-2. The CEC of soils varies according the clay %, the type of clay, soil pH and amount of organic matter. CEC is generally higher in fine texture soil which supports the textural data of the collected soil samples. Higher CEC is also responsible for higher content of cations.

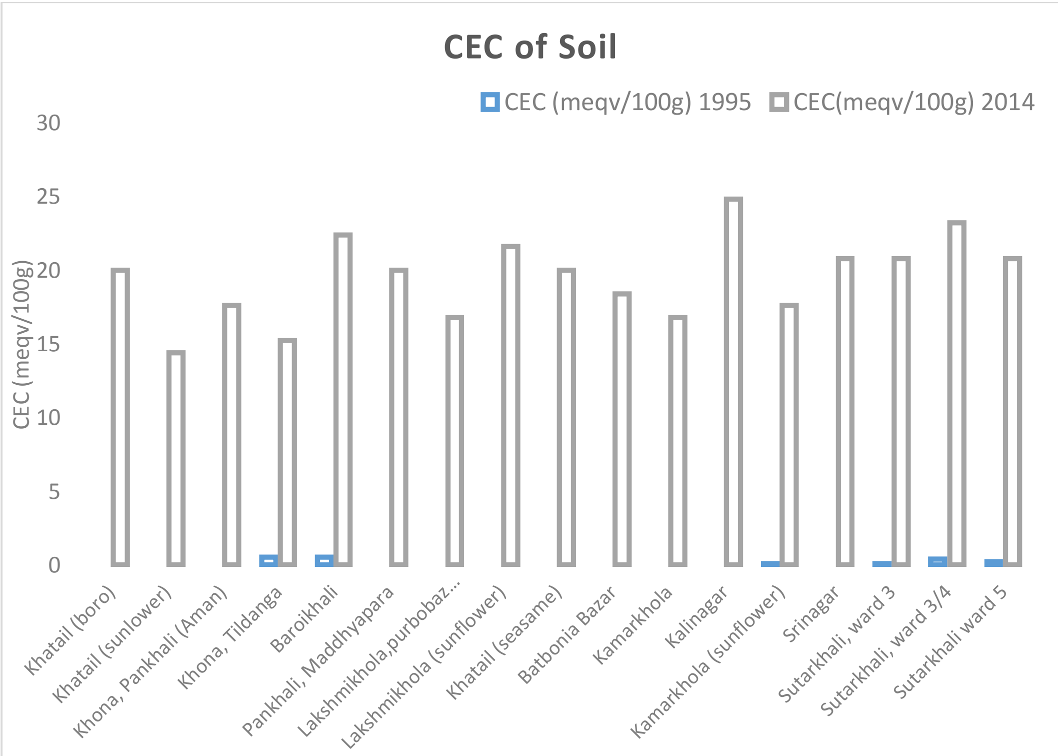


Figure 5.13: CEC value of soil in 1995 and 2014

Total Nitrogen (N): Because of the low level of OM, the nitrogen status of Bangladesh soils is substantially low and most crops on all soils respond to N-applications. In fact, N-fertilizers occupy the major fertilizer being consumed in the country (Huq and Shoaib, 2013). In the study area nitrogen content of the soil also shows lower status. 16 samples were selected for data interpretation as one data shows an abnormal value. Average nitrogen content in 1995 and 2014 were 0.06% and 0.14%, respectively. Range of percentage of total nitrogen are 0.084 to 0.218 in 1995 and 0.037 to 0.111 in 2014 (Figure 5.14). In 1995 and 2014, spatial distribution of total N percentage of soil samples was showing low class of total N%. Only in Chalna pouroshova union total N was showing medium class of total N% in 2014 which represents mostly agricultural land (Figure 5.15).

Higher value of total N reported in the samples is due to the use of nitrogen fertilizers. Classification of determined nutrient elements based on soil's chemical characteristics for wetland rice in loam to clay soil is given in Appendix-2.

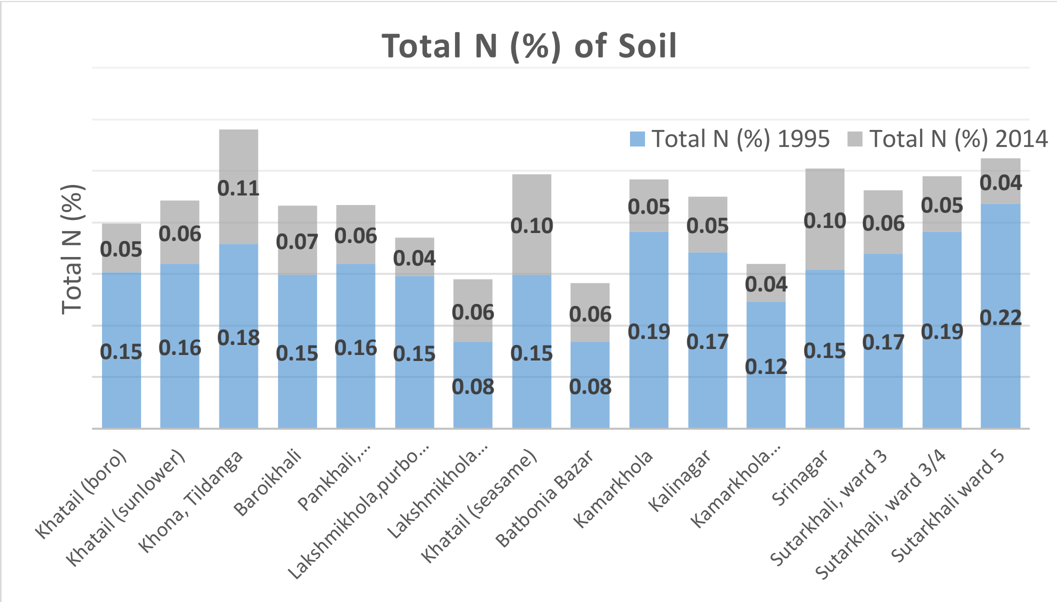


Figure 5.14: Total N (%) of soil of 1995 and 2014

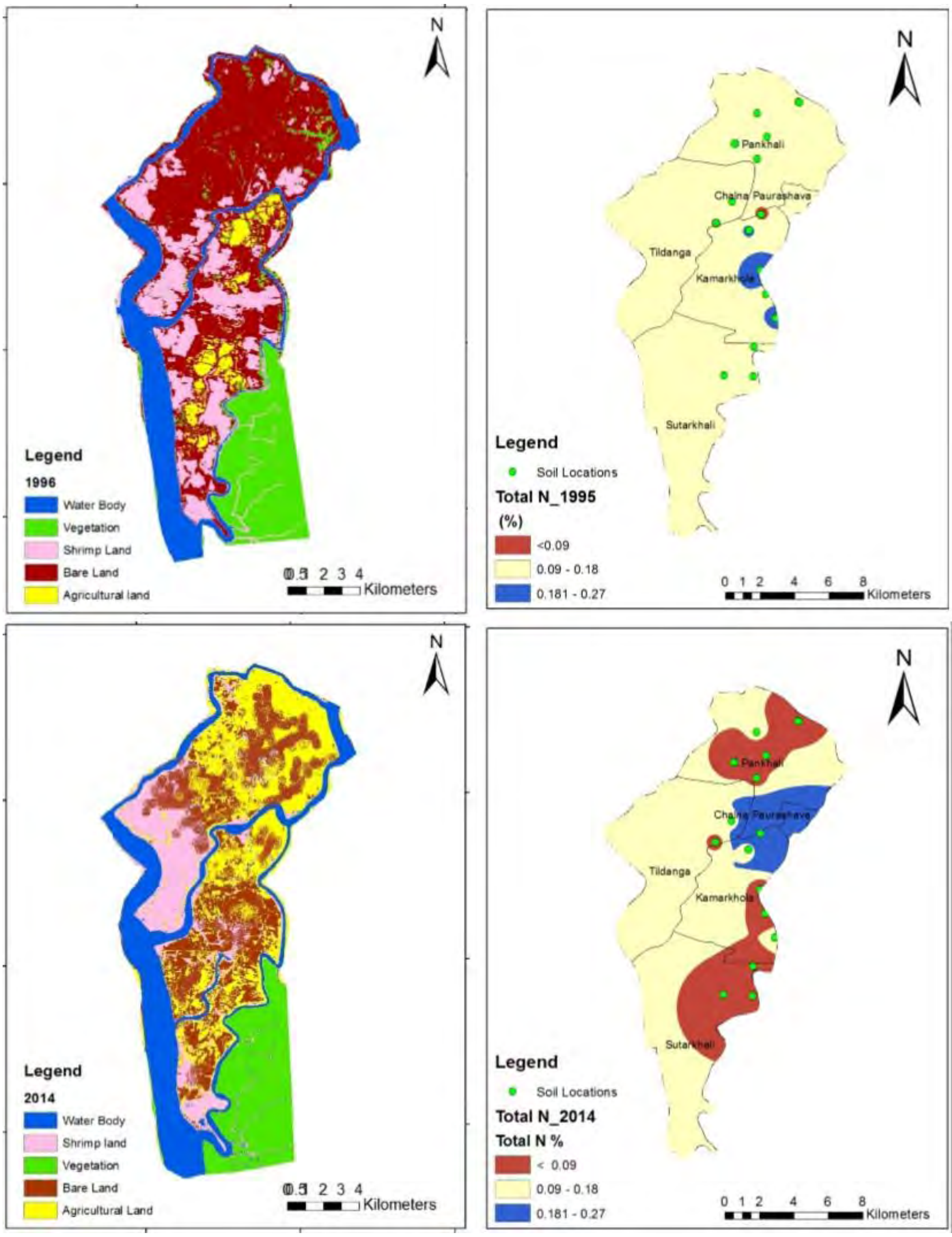


Figure 5.15: Land use and spatial distribution of Total N (upper panel 1995 and lower panel 2014)

Available Potassium (K): The coastal saline soil has higher content of K. Average available K content were 0.78 meqv/100g and 0.51 meqv/100g in 1995 and 2014, respectively, both are very high. Ranges of available K content are 0.07 to 1.39 meqv/100g (very low to very high) in 1995 and 0.35 to 0.7 meqv/100g (high to very high) in 2014 (Figure 5.16). Very high class of available K was spatially distributed in both years 1995 and 2014 in the study area (Figure 5.17). Compared to K values in 2014, K values in 1995 were much higher. This variation in K content is mainly because of the different locations of the soil samples. Overall K content is very high in the study area.

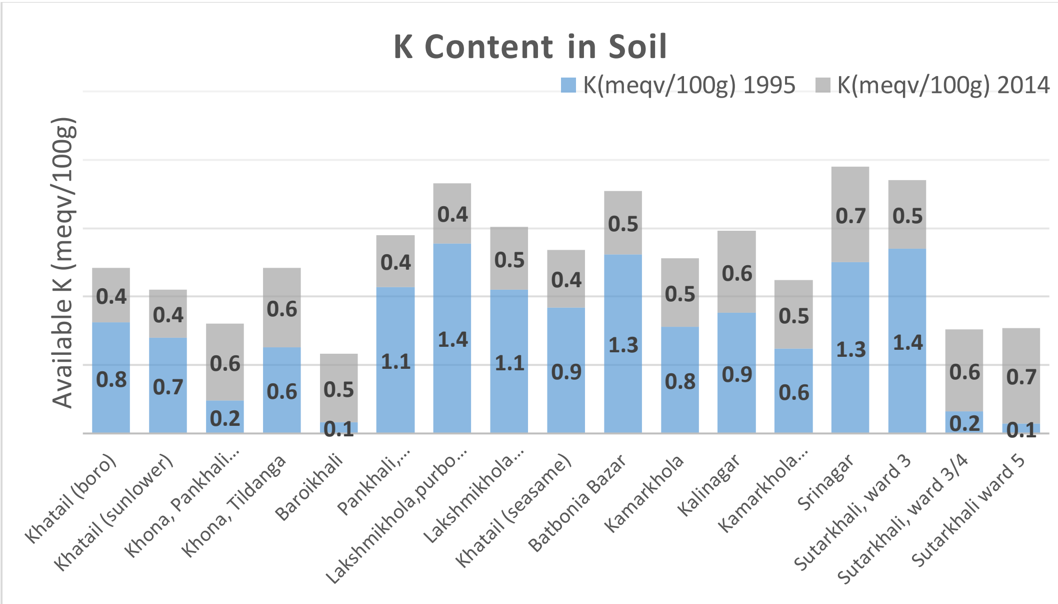


Figure 5.16: Soil available K content of 1995 and 2014

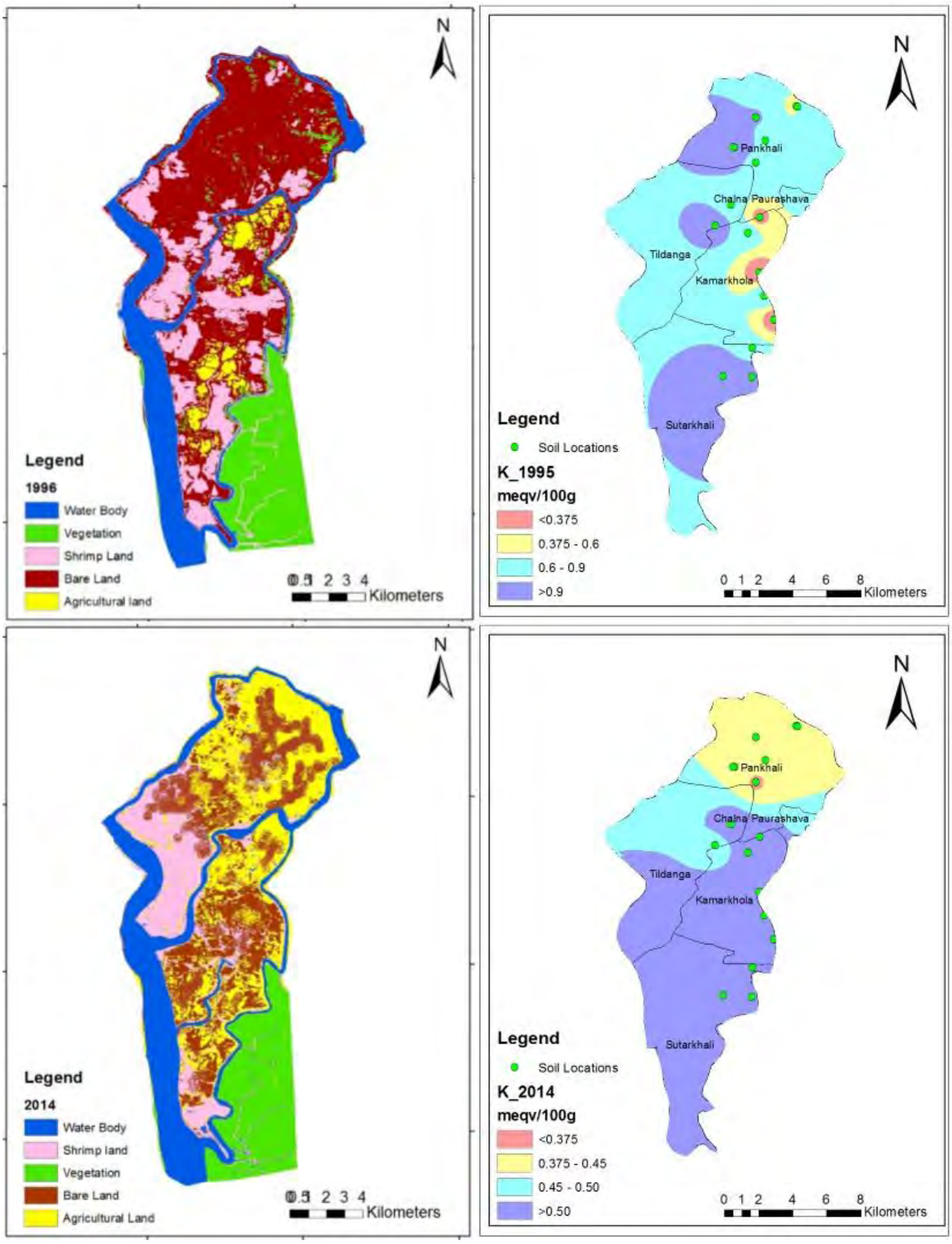


Figure 5.17: Land use and spatial distribution of K (upper 1995 and lower 2014)

Available Calcium (Ca): Ranges of available Ca content in the study area were 5.8 to 28 meqv/100g (moderate to very high) in 1995 and 7.25 to 22.25 meqv/100g (high to very high) in 2014 (Figure 5.18). Average available Ca content in the study area were 15.74 meqv/100g in 1995 and 15.23 meqv/100g in 2014. Observed data shows that most part of the study area has very high class of Ca content dispersion (Figure 5.19).

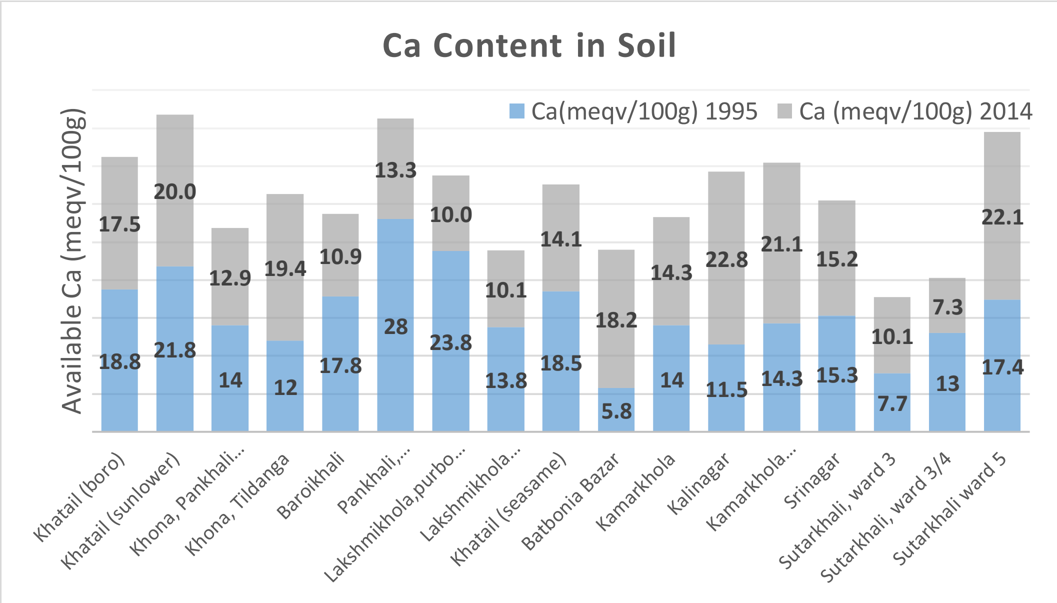


Figure 5.18: Soil available Ca content of 1995 and 2014

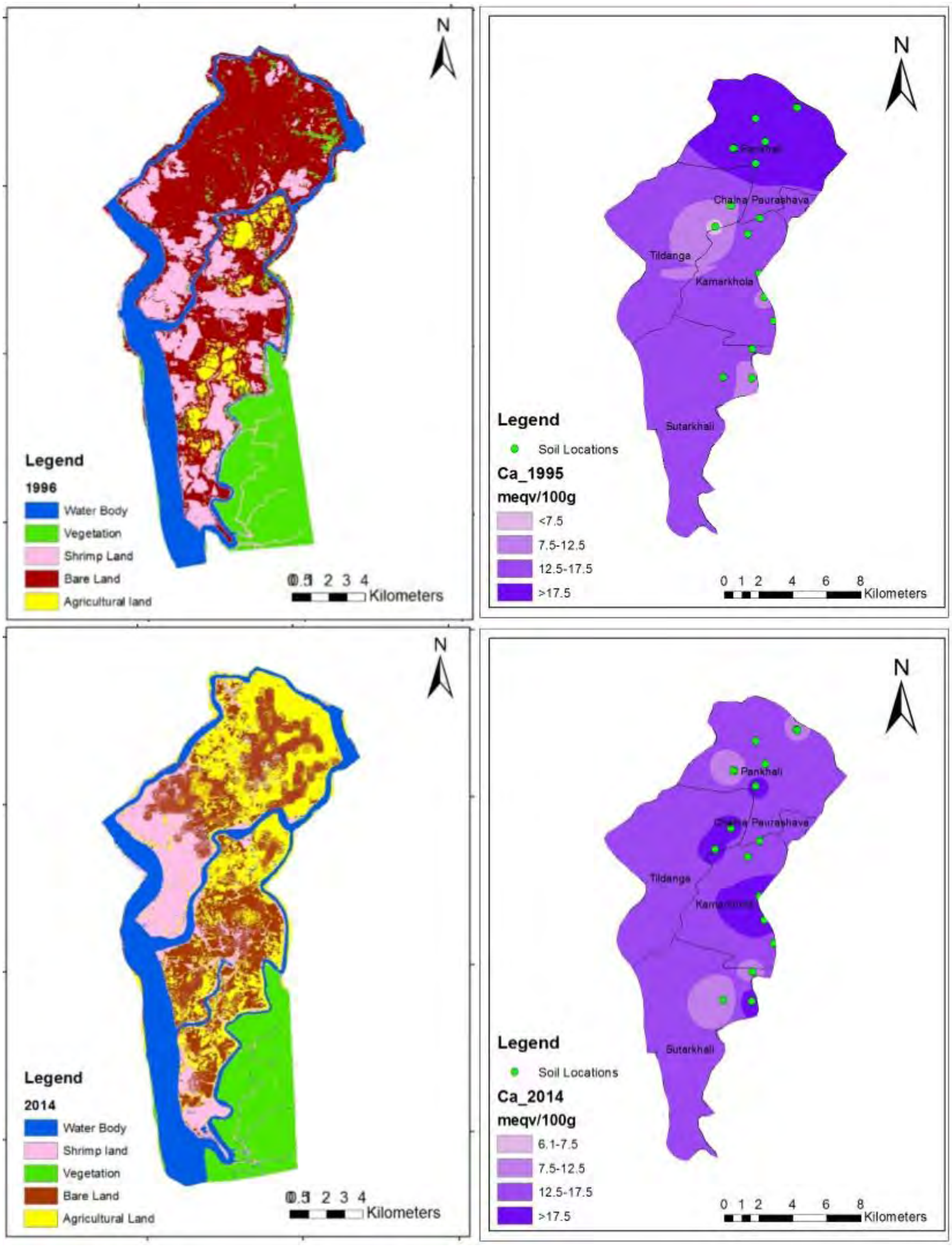


Figure 5.19: Land use and spatial distribution of Ca (upper panel 1995 and lower panel 2014)

Available Magnesium (Mg): Ranges of available Mg content were 1 to 9.5 meqv/100g and 5.49 to 17.92 meqv/100g in 1995 and 2014, respectively (Figure 5.20). Available Mg content is very high in the study area. Average Mg content were 7.64 meqv/100g and 11.37 meqv/100g in 1995 and 2014, respectively. In both years (Figure 5.21) very high class of Mg content was spatially dispersed. Available Mg content in 2014 was much higher than that of 1995. Most part of the study area in 2014 belonged to 10-12 meqv/100g class range. Higher Mg saturation of the exchange complex is harmful for soil physical properties and offsets plant nutrition.

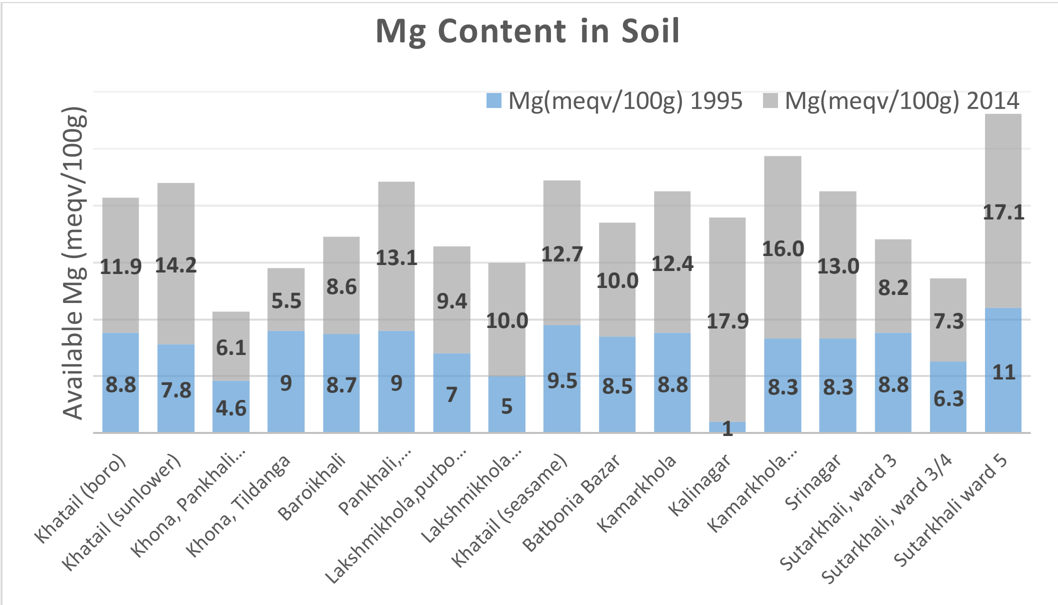


Figure 5.20: Soil available Mg content of 1995 and 2014

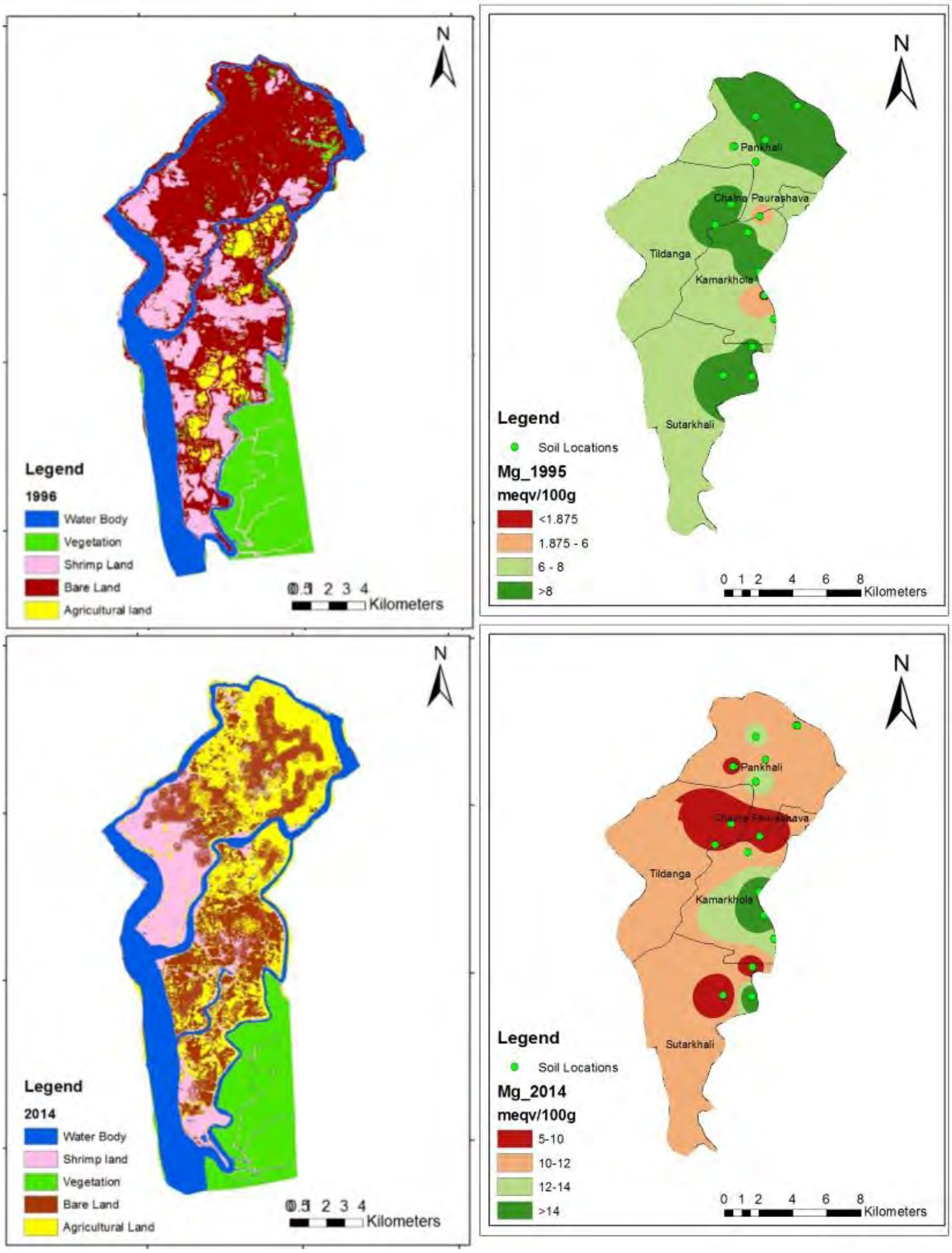


Figure 5.21: Land use and spatial distribution of Mg (upper panel 1995 and lower panel 2014)

Available Phosphorus (P): The available P in Bangladesh soils could be considered between low to medium. Most soils respond to P-fertilization. P availability is pH dependent (Huq and Shoaib, 2013). Total 15 samples were selected for data interpretation as two data show very high value. Average available P content were 9.4 µg/g (low) and 11.3 µg/g (low) in1995 and 2014, respectively (Figure 5.22). Available P ranges from 1 to 20 µg/g (very low to medium) in 1995 and 0.03 to 27.52 µg/g (very low to optimum) in 2014. Low class of P content was spatially distributed in 1995 almost all over the study area. In 2014 P content became higher than 1995. In 2014 two distinct classes low and optimum are observable. Mainly polder 32, except some northern part of Kamarkhola union and the southern part of Tildanga union of polder 31 show optimum class of P content distribution. Upper part of polder 31 and some rest part of polder 32 show low class of P content distribution. A thin layer of medium class of available P distribution can be seen in between optimum and low class of available P.

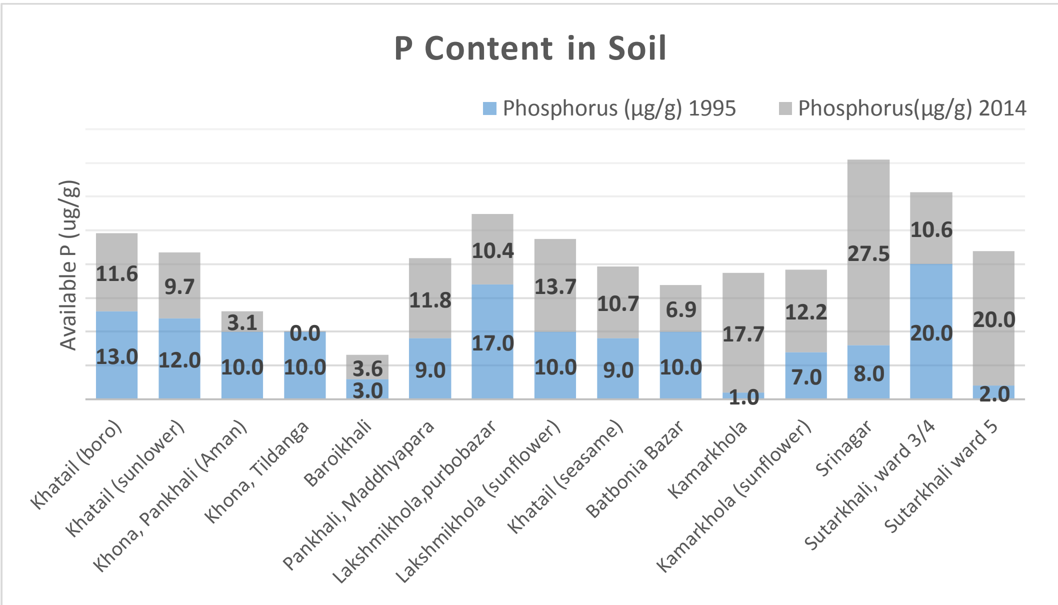


Figure 5.22: Soil available P content of 1995 and 2014

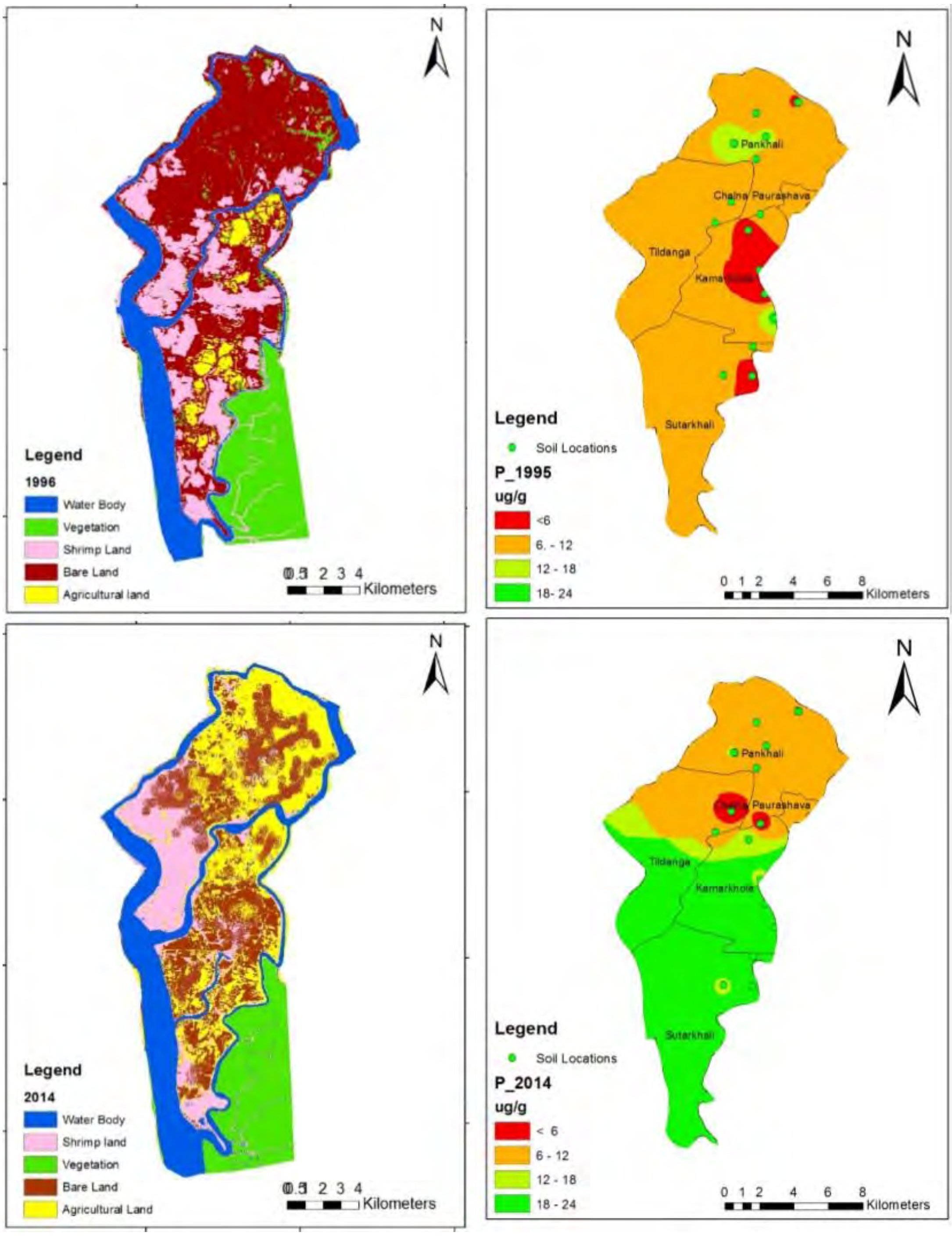


Figure 5.23: Land use and spatial distribution of P (upper panel 1995 and lower panel 2014)

Available Sulphur (S): Average content of available S in 1995 and 2014 were 463.41 µg/g and 169.3 µg/g, respectively, which represent very high content of S. Available S content ranges from 288 to 603 µg/g and 72.22 to 574.57 µg/g in 1995 and 2014, respectively (Figure 5.24). Very high class of S content distribution all over the study area is shown in both years (Figure 5.25).

According to field investigation, the land which was once very productive, now has become unproductive due to salinization as the result of prolonged retention of saline water for shrimp growing. The soil characteristics in the study area have been substantially deteriorated due to gradual accumulation of salt over the years, reduced the fertility of the land i.e. soil and resulted the cropland to remain fallow. Soil flocculation is also lost and became white powder-like in many places of the study area. Trees and grass cannot grow in this soil condition.

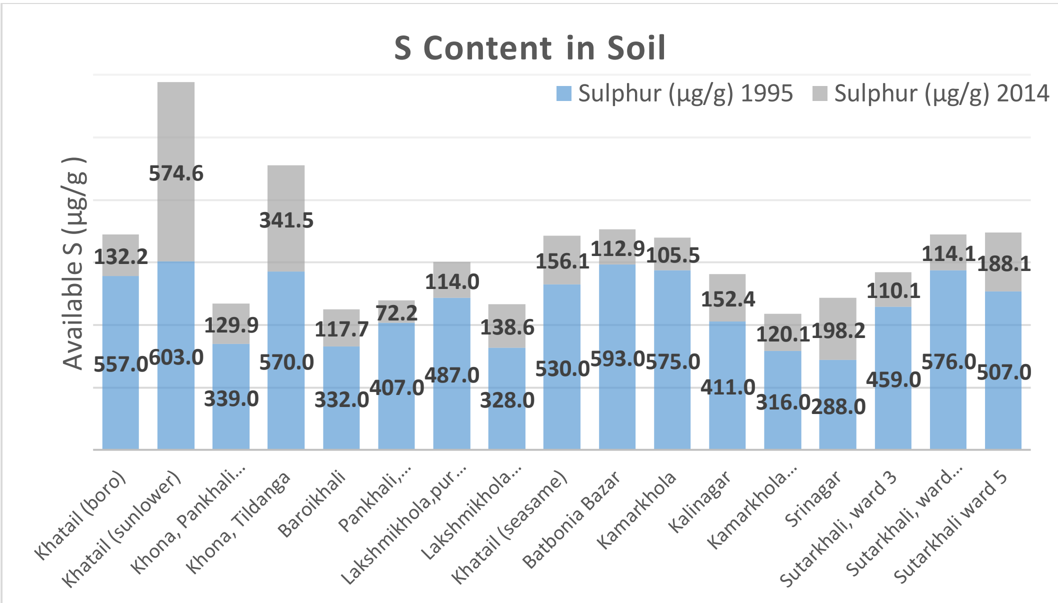


Figure 5.24: Soil available S content of 1995 and 2014

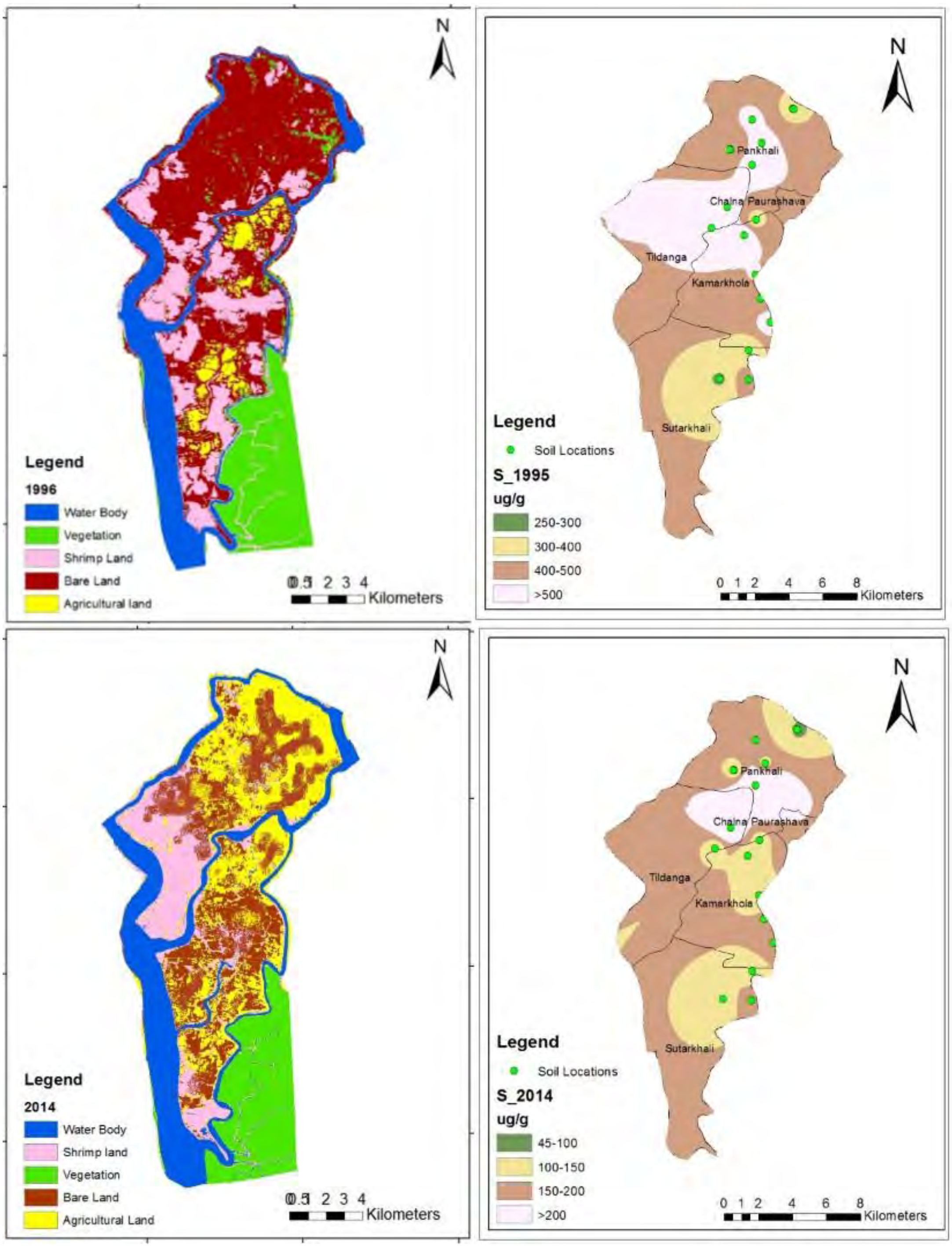


Figure 5.25: Land use and spatial distribution of S (upper panel 1995 and lower panel 2014)

5.4 Rice yield analysis

Rice production data of ten years (2004-05 to 2013-14) were collected from Khulna agricultural office. In the study area mainly two seasonal rice are being produced, one is Rabi season i.e. dry season rice Boro and the other is Kharif II season i.e. monsoon season rice Aman.

Aman rice is regularly cultivated by the local farmers during monsoon season. Figure 5.26 and 5.28 are showing 10 years i.e. from 2004-05 to 2013-14 aman and boro rice production status along with total cultivated land area. Compared to aman, boro is being cultivated in very small scale in the study area than the other part of the country. Aman is major rice crop in the study area. From Figure 5.26 the highest aman rice production of 52311 ton cultivated under 18750 ha land was in the year 2013-14 and the lowest aman rice production of 14080 ton cultivated under 10064 ha land was in the year 2007-08. In 2007-08, aman rice production was the lowest as well as the cultivable land area was also the lowest. Figure 5.27 shows the aman yield. The yield of aman rice was low during the shrimp cultivation period (2004-05 to 2006-07) average yield being 1.92 ton/ha, because of shrimp cultivation and high soil salinity. Shrimp cultivation led to high soil salinity, which even after rain wash, did not remove and thus local people were getting low yield of aman rice. Since high salinity problem, farmers of the study area are experiencing problem in rice production. The average yield of rice per hectare of land has declined substantially. As soil texture of the study area is slity clay loam and is relatively impermeable, the filtration process of saline water is slow. Soil salinity also affects plant growth mainly through reduced water uptake and essential nutrients and simultaneously results in low yield of rice. Another reason which can affect the yield of rice was low OM content in the soil. The loss of topsoil leads to reduced fertility, resulting in lower yields. The transported soil sometimes contributes to the contamination and silting up of waterways. After two deadly cyclones in 2007 and 2009 local people decided to cease the shrimp cultivation as this was adversely affecting the rice yield. Average yield of aman in 2007-08 to 2013-14 is 2.27 ton/ha. Consecutive two years 2006-07 and 2007-08 (Figure 5.27) rice yield was very low 1.61 ton/ha and 1.40 ton/ha respectively, as the farmers missed two kharif seasons rice due to cyclone effect on polder 32. Aman yield started to rise again from 2010-11. In 2013-14 the highest yield 2.79 ton/ha of aman was observed. On average, the yield of aman is 2.19 ton/ha.

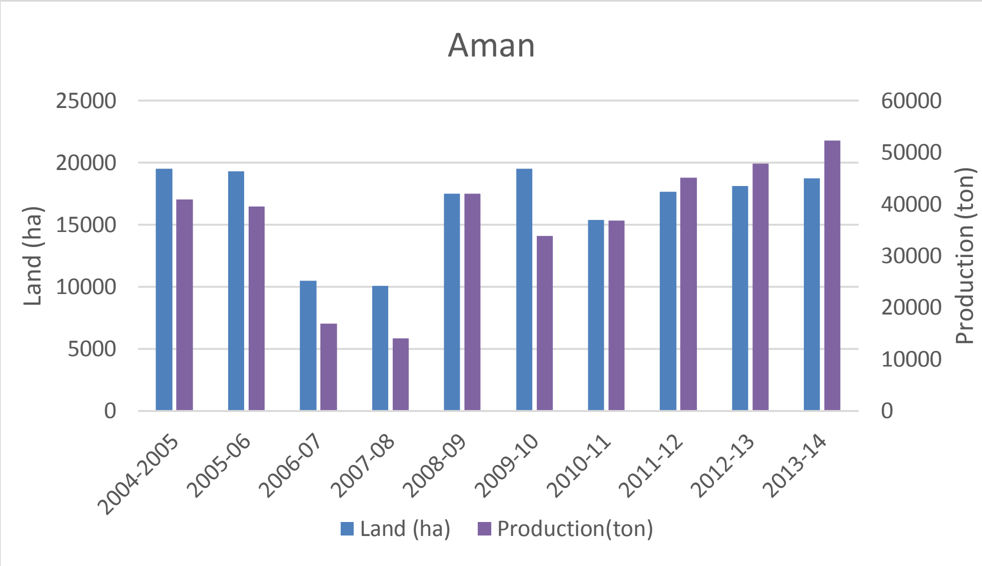


Figure 5.26: Aman rice production with land area.

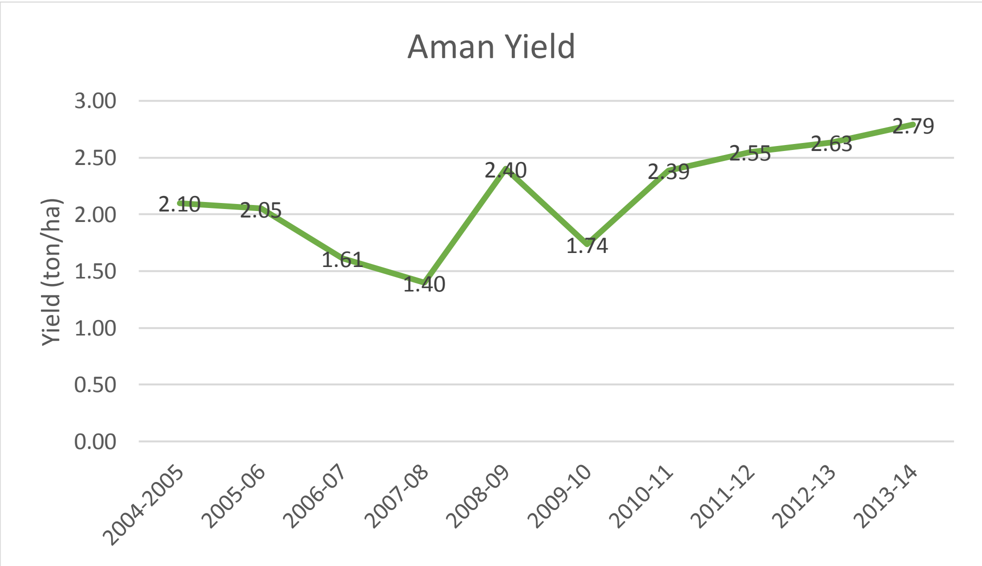


Figure 5.27: Yield of aman rice.

From the Figure 5.28 it is shown that boro was cultivated only on 5 ha land in 2004-05 and production of boro was only 14 ton. The highest boro production was 1844ton with highest yield 4.30 ton/ha in the year 2008-09 because of low production of aman rice people tried to cover their loss by cultivating more boro. After that year boro cultivation became lower because of cyclone Aila many places were under water and became more saline and deficiency of fresh irrigation water. The yield of boro was very low at the beginning (Figure 5.29) due to high soil salinity and poor soil fertility, and unavailability of irrigation water. The lowest yield was 1.80 ton/ha in 2005-06. After cyclone Aila, yield of boro started to increase, though boro cultivation is still in small scale. Average yield of boro in the study area is 3.4 ton/ha.

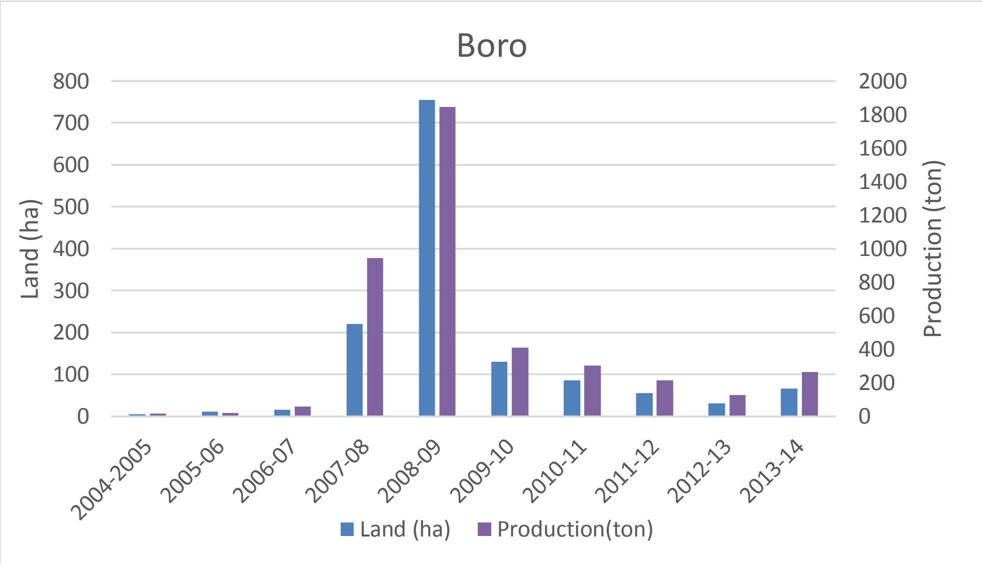


Figure 5.28: Boro rice production with land area.

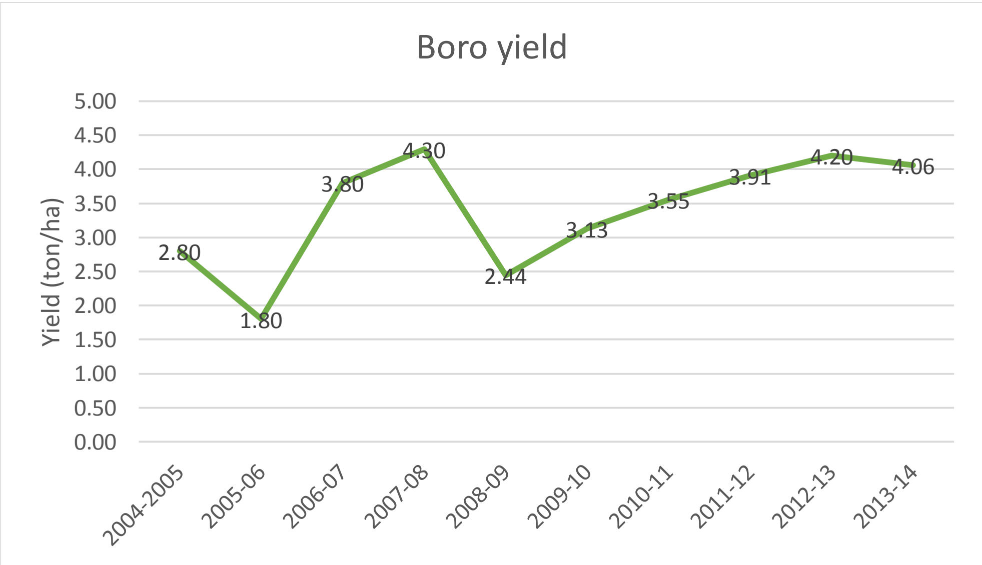


Figure 5.29: Yield of boro rice.

Figure 5.30 and 5.31 are showing comparison between cultivated land and production of two rice respectively. As said earlier, aman is the main rice which is being cultivated in the study area in the monsoon season. So, it is being cultivated almost over the study area. Whereas boro is being cultivated in a limited and scattered scale, mainly because of above mentioned problems.

As rice is the staple food, local people wanted to go back to cultivating more rice, rather than doing shrimp cultivation. Shrimp cultivation not only deteriorated soil quality, but also created many social and environmental consequences in the study area.

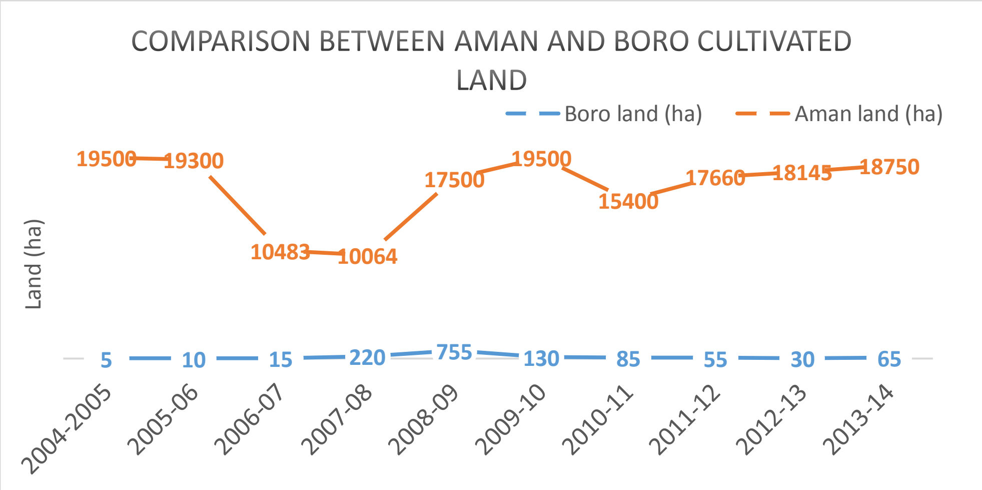


Figure 5.30: Comparison between aman and boro rice cultivated land

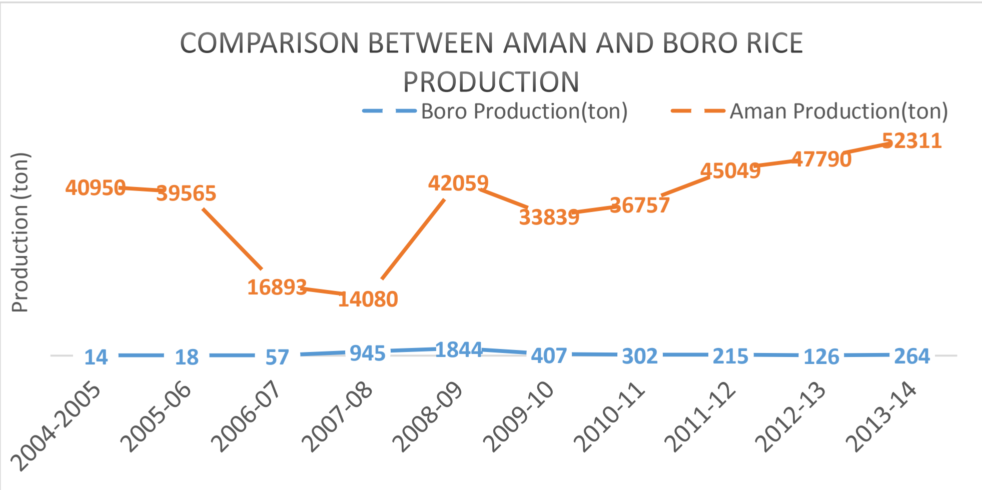


Figure 5.31: Comparison between aman and boro rice production

5.5 Social impact

It is also observed that the livelihoods in the study area are severely affected because of land use changes and soil quality degradation. The increased salinity of both soil and water has seriously affected all livelihood resources, in particular, agriculture, fishery, livestock and forestry. The increase in frequency and intensity of natural disasters, i.e. floods and cyclones, have made it difficult for the local people to secure their livelihood. Due to a large portion of land lying fallow, the wage labourers face unemployment and are forced to migrate in search of employment. Some gender specific vulnerability in the study area is also identified and found that the women are more vulnerable to disaster and climate risk due to gender inequalities in various social, economic and political institutions.

Though most of the coastal people have abandoned the shrimp farming practice few years before Aila to avoid further deterioration of the water and soil condition, but the situation was already worse, making significant threat to the sustainability of coastal agriculture and also causing scarcity of suitable drinking water. Moreover, faulty management and lack of proper operation and maintenance of the sluice gates in the polders also caused exacerbation of the salinity condition in the study area. These sluice gates were provided to allow freshwater during the monsoon season inside the poldered area and prevent entrance of saline water during the dry season, but lack of coordination among the community members and unwillingness of a certain class of people to continue prevention of saline water intrusion hampered the purpose of sluice gates. All of these factors were responsible for the worsening of salinity situation, which is also affecting soil quality and rice yield in the study area.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the study the following can be concluded:

- Two major land use patterns shrimp cultivation and bare land were observed before Aila in the study area during dry period. After Aila two different land use patterns agricultural cultivation and bare land were observed.
- Shrimp cultivation land use practice created many adverse effects including deteriorating soil quality and low yield of rice.
- Shrimp cultivation land increased from 24.34% at 1988 to 31.63% at 1996 and showed gradually decreasing trend from 1996 to 2009 to 2014 with land coverage from 31.63% to 14.68% to 11.51%.
- Percentage of bare land was the highest in 1988 with 38.76% and the lowest in 1996 with 19.19%. Overall bare land also showed a decreasing trend with change in agricultural practices and overall improvement of saline tolerant rice which encouraged farmers to cultivate more rice during dry period. This is also supported by gradual increase of agricultural land in the dry season over time.
- Average EC value of the year 1995 and 2014 are 21.35 dS/m and 6.09 dS/m respectively, soil salinity had come down by more than two third.
- OM content is very low in 2014 compared to that of 1995. Present low OM indicates poor soil health in the study area possibly due to the lack of vegetation in the last few years and no running water bodies. A decline in organic matter in the study area was caused by the reduced presence of decaying organisms, and/or an increased rate of decay as a result of changes in anthropogenic factors, which was shrimp cultivation.
- Percentage of total N is very low in the soils of the study area like other part of the country. K content were high both in the year 1995 and 2014, average value were 0.78 meqv/100g and 0.51 meqv/100g in 1995 and 2014 respectively. Ca and Mg content were also high in the study area.

- Average available P content were 9.4 µg/g (low) and 11.3 µg/g (low) in1995 and 2014, respectively. Average content of S in 1995 and 2014 were 463.41 µg/g and 169.3 µg/g respectively which represent very high content of S.
- Aman is major rice crop production in the study area. Average yield of aman rice is 2.19 ton/ha. Yield of aman was low 1.97 ton/ha during shrimp cultivation period because of soil salinity, which even after rain-wash remain in the clayey soil. After ceasing of shrimp cultivation practice, aman yield is gradually increasing. The average yield is 2.19 ton/ha.
- Average yield of boro is 3.4 ton/ha. The yield of boro is comparatively high than yield of aman rice though boro is being cultivated in very limited and scattered scale in the study area mostly because of unavailability of irrigation water.

6.2 Recommendations

The following recommendations have been suggested based on the above study:

- Research of similar nature is highly recommended that covers more areas, at different districts in the coastal areas of Bangladesh with different hydrological regimes, to have more comprehensive idea about the changing land use pattern, soil fertility status and rice yield.
- Build good soil quality by managing the soil in a proper scientific and environment friendly way. Rather keeping land fallow, people should plant plenty of trees which are suitable for that area. Governmental organizations and NGOs are needed to come forward and distribute these trees and plants.
- Ensure regular soil health check system to keep track of soil's fertility by the GOs and/or NGOs.
- The primary sources of organic residues in crop production are manure and compost. So, to increase organic matter content in soil organic matter inputs like livestock manure have to be added in the soil. Reduction of tillage and controlling of soil erosion are also necessary for soil management.
- To increase boro rice production availability of irrigation water arrangements are necessary.

- The silted up canals should be dredged to required depths and width to increase the storage capacity of the canal system in each polder. This will significantly increase the cultivable area of irrigated Boro rice in the polder areas.
- Protection of agricultural land through proper awareness and education should be provided to local people.
- Proper management of polders and sluice gates should be done so that saline water does not enter and hamper the land.
- Conserve the mangrove forest, which acts as a barrier during cyclones and later helps the lands and soils from saline storm surge inundation which negatively affects them.
- All soil quality data should be recorded properly and regularly. Respective organizations should maintain a database with yearly updates and these data can be uploaded to their websites for easy access to individuals.

References

Ahmed, A. 2011. Some of the Major Environmental Problems Relating to Land Use Changes in the Coastal Areas of Bangladesh: A Review. Journal of Geography and Regional Planning. 4(1), pp. 1-8.

Amin, M., Rahman, M. A., Zaman, S. M., Howlader, M. I. A., Hossain, M. Z., and Islam, M. I. 2008. Cropping system in coastal and barind area. Paper presented at national workshop on multiple cropping, held at BARC, Farmgate, Dhaka, 0n 23-24 April.

Bala, B. K. and Hossain, M. A. 2009. Integrated Management of Coastal Zone for Food Security. Department of Farm Power and Machinery, Bangladesh Agricultural University. Final report CF# 5/07

Banglapedia http://en.banglapedia.org/index.php?title=Landuse [Accessed on 3 July, 2015]

BARC. 2012. Fertilizer Recommendation Guide-2012. Bangladesh Agricultural Research Council.

BBS (Bangladesh Bureau of Statistics). 2009. Statistical yearbook of Bangladesh. Statistical Division, Ministry of Planning, Dhaka.

BBS, 2010. Census of Agriculture 2008. National series, volume-1. Bangladesh Bureau of Statistics. Dhaka, Bangladesh.

BBS, 2012. Statistical Year Book of Bangladesh. 32nd edition. Statistics and Informatics Division, Ministry of Planning, Dhaka.

Brammer, H. 2002. Land Use and Land Use Planning in Bangladesh. The University Press Limited, Dhaka, Bangladesh, pp 554.

Brammer, H. 2004. Can Bangladesh be protected from floods? The University Press Limited, Dhaka, Bangladesh.

Brammer, H. 2012. The Physical Geography of Bangladesh. The University Press Ltd., Dhaka, Bangladesh. pp 89.

Campbell, J.B. 2007 Introduction to Remote Sensing, Fourth edition, The Guilford Press, New York, USA.

Chase, T.N., Pielke, R.A., Kittel, T.G.F., Nemani, R.R. and Running, S.W. 1999. Simulated Impacts of Historical Land Cover Changes on Global Climate in Northern Winter, Climate Dynamics, 16, pp. 93–105.

District Statistics 2011- Khulna. 2013. Bangladesh Bureau of Statistics. Statistics and Informatics Division Ministry of Planning, Government of the People's Republic of Bangladesh. June, 2013. pp. 4.

Emadodin, I., Reiss, S., Mitusov, A.V., Bork, H.R. 2009. Interdisciplinary and multidisciplinary approaches to the study of long-term soil degradation: A case study from Schleswig-Holstein, Germany. Land Degradation & Development, vol 20. pp 551–561.

FAO and DAE. 2009. Situation Assessment Report in S-W coastal region in Bangladesh. Food and Agriculture Organization of the United Nations (FAO) and Department of Agricultural Extension (DAE).

FAO, Land resources appraisal of Bangladesh for agricultural development, Vol 2, Rome, 1988.

Gebrelibanos, T. and Assen, M. 2013. Effects of Land-Use/Cover Changes on Soil Properties in a Dryland Watershed of Hirmi and its Adjacent Agro Ecosystem: Northern Ethiopia. International Journal of Geosciences Research. Vol. 1 no. 1, pp. 45-57.

Haque, A.K.E. 2004. Sanitary and Phyto-Sanitary Barriers to Trade and Its Impact on the Environment: the Case of Shrimp Farming in Bangladesh. IUCN Bangladesh Country Office, Dhaka, Bangladesh, 63 pp.

Haque, S. A. 2006. Salinity problems and crop production in coastal regions of Bangladesh. pp 1359-1365.

Houghton, R. A., Hacker, J. L., Lawrence, K. T. 1999. The U.S. carbon budget: contribution from land use changes. Science 285, pp 574-578

Huq, S. M. I. and Alam, M. D. 2005. A Handbook on Analyses of soil, Plant and Water. Bangladesh-Australia Centre for Environmental Research (BACER-DU).

Huq, S. M. I. and Shoiab, J. U. M. 2013. The Soils of Bangladesh, World Soils Book Series 1, DOI: 10.1007/978-94-007-1128-0_11, Springer Science+Business Media Dordrecht 2013. pp 3-4.

IFPRI, 2012. Institutional Arrangements for Sustainable Polder Management (draft report)

Iftekhar, M.S. 2006. Conservation and Management of the Bangladesh Coastal Ecosystem: Overview of an Integrated Approach. Natural Resources Forum, 30(2006), pp. 230–237.

Islam M. R and Hassan M. Z. 2011. Land Use Changing Pattern and Challenges for Agricultural Land: A Study on Rajshahi District. J. Life Earth Sci., Vol. 6, pp 69-74.

Islam, K.R. and Weil, R.R. 2000. Land Use Effects on Soil Quality in a Tropical Forest Ecosystem of Bangladesh, Agriculture, Ecosystems and Environment, 79, pp. 9-16.

Islam, M. A. and Islam, W. 1956. Nutrient status of East Pakistan soils. Directorate of Agriculture, Government of East Pakistan, Dacca, Bulletin No. 1, pp 52

Islam, M. R. 2006. Chapter 18: Managing Diverse Land Uses in Coastal Bangladesh: Institutional Approaches. CAB International 2006. Environment and Livelihoods in Tropical Coastal Zones.

Islam, M. S., Biswas, S.K., Gain, D., Kabir, M.A. and Quarashi, T.A. 2015. Increasing agricultural and aquacultural productivity in the coastal zone of Bangladesh. Conference proceeding on Revitalizing the Ganges Coastal Zone: Turning Science into Policy and Practices. CIGAR Challenge Program on Water and Food's Ganges Basin Development Challenge. pp 566-575.

Jiang, Y. J., Yuan, D. X., Kuang, M, S., Wang, J. L., Xie, S. Y., Li, L. L., Zhang, G. H., Rao-Sheng, H. 2006. Impact of land-use change on soil properties in a typical karst agricultural region of Southwest China: A case study of Xiaojiang watershed, Yunnan. Environmental Geology, vol. 50, pp 911-918.

K. Biro, B. Pradhan, M. Buchroithner and F. Makeschin. 2013. Land Use/Land Cover Change Analysis and its Impact on Soil Properties in the Northern Part of Gadarif Region, Sudan. Land Degradation &Development, vol. 24,pp 90–102.

Karim, Z., Hussain, S. G., and Ahmed, M. 1990. Salinity problems and crop intensification in the coastal region of Bangladesh. Soils publication, vol. 33. BARC, Dhaka, pp17.

Khresat, S.; Al-Bakri, J. and Al-Tahhan, R. 2008. Impacts of Land Use/Cover Change on Soil Properties in the Mediterranean Region of Northwestern Jordan. Land Degradation & Development, vol. 19. pp 397–407.

Kitamura, T. and Kobayashi, S. 1993. Rural Land Use in the Asia Region II: Towards Sustainable Land use, Rural Land Use in Asia and the Pacific, Asian Productivity Organization (APO), Tokyo, Japan, 29th September – 6th October 1992, pp. 91-109.

Kumar, U., Baten, M.A., Masud, A., Osman, K.S. and Rahman, M.M. 2010. Cyclone Aila: One Year on Natural Disaster to Human Sufferings. Khulna, Bangladesh: Unnayan Onneshan - Humanity Watch – Nijera Kori.

Lambin, E.F., Geist, H.J. and Lepers, E. 2003. Dynamics of Land-use and Landcover Change in Tropical Regions, Annual Review of Environment and Resources, 28, pp. 205-241.

Lesschen, J.P., Verburg, P.H. and Staal, S.J. 2005. Statistical Methods for Analyzing the Spatial Dimension of Changes in Land Use and Farming Systems, Land-Use and Land-Cover Change (LUCC) Report, IV, International Human Dimensions Program on Global Environmental Change (IHDP), Stockholm, Bonn.

Li XY, Ma YJ, Xu HY, Wang JH, Zhang DS. 2009. Impact of land use and land cover change on environmental degradation in Lake Qinghai watershed, northeast Qinghai-Tibet Plateau. Land Degradation & Development, vol. 20, pp 69–83.

Lichon, M. 1993. Human impacts on process in karst terrenes, with special reference to Tasmania. Cave Science, vol. 20, no. 2, pp 55-60.

Lubowski, R.N., Plantinga, A.J. and Stavins, R.N. 2008. What Drives Land-use Change in the United States? A National Analysis of Landowner Decisions, Land Economics, vol. 84, no. 4, pp. 529–550.

Mahmoud A, Shendi M M, Pradhan B, Attia F. 2009. Utilization of remote sensing data and GIS tools for land use sustainability analysis: Case study in El-Hammam area, Egypt. Central European Journal of Geosciences, vol. 1, pp 347–367.

Mas, J.F., Vela´zquez, A., Dı´az-Gallegos, J.R., Mayorga-Saucedo, R., Alca´ntara, C., Bocco, G., Castro, R., Ferna´ndez, T. and Pe´rez-Vega, A. (2004). Assessing Land Use/Cover Changes: a Nationwide Multidate Spatial Database for Mexico, International Journal of Applied Earth Observation and Geoinformation, vol. 5, pp. 249–26.

Minar, M.H., Hossain, M.B. and Shamsuddin, M.D. 2013. Climate Change and Coastal Zone of Bangladesh: Vulnerability, Resilience and Adaptability, MiddleEast Journal of Scientific Research, vol. 13, no. 1, pp. 114-120.

Mishu, M. M. R and Zaman, M. K. B. 2013. Agricultural Vulnerability in the Context of Coastal Region of Bangladesh, Bangladesh Research Publications Journal, vol. 9, no. 1, pp. 64-68.

MOA. 2012. Master Plan for Agricultural Development in the Southern Region of Bangladesh. Ministry of Agriculture, Government of the People's Republic of Bangladesh and Food & Agricultural Organization of the United Nations.

MOFL (Ministry of Fisheries and Livestock). 1997. Fisheries resources development and management. Paper presented at the National Workshop, 29 October to 1 November 1997, MOFL, Dhaka, Bangladesh.

MoL, 2011. Land Zoning Report of Dacope Upazila of Khulna District, Study of Detailed Coastal Land Zoning with Two Pilot Districts of Plain Land Project. Ministry of Land, Government of People's Republic of Bangladesh. pp- 93

Mondal, M.K., Humphreys, E., Tuong, T.P., Rahman, M.N. and Islam, M.K. 2015. Community water management and cropping system synchronization: The keys to unlocking the production potential of the polder ecosystems in Bangladesh. Conference proceeding on Revitalizing the Ganges Coastal Zone: Turning Science into Policy and Practices. CIGAR Challenge Program on Water and Food's Ganges Basin Development Challenge. pp 119-130.

Moslehuddin, A. Z. M., Abedin, M. A., Hossain, M. A. R., and Habiba, U. (2015). Soil Health and Food Security: Perspective from Southwestern Coastal Region of Bangladesh. Chapter 11. Food Security and Risk Reduction in Bangladesh, Disaster Risk Reduction. Springer, Japan.

NASA. 2006. 'Quantifying Changes in the Land over Time with Landsat', A Landsat Classroom Activity, National Aeronautics and Space Administration (NASA), USA.

Neill, C., Piccolo, M.P., Cerri, C.C., Steudler, P.A., Melillo, J.M., Brito, M. 1997. Net nitrogen mineralization and net nitrification rates in soils following deforestation for pasture across the southwestern Brazilian Amazon Basin landscape. Oecologia 110, pp 243–252.

Nishat, A., and M.A. Bhuiyan, 1995. Strategy for Integrated Management for Land and Water in FCDI Projects with Focus on Fisheries Development. Paper presented at National Fisheries Conference. Dhaka.

Paul A, Nath B, Abbas M R, Islam H and, Mallick B. 2014. Land Use Change Monitoring of Hariteka River Basin, Jessore, Bangladesh Using Remote Sensing and GIS. IJARSGG. Vol.2, no.1, pp 1-8.

Rahman M.R., Islam A.H.M. and Hassan M.S. 2005. Change detection of winter crop coverage and the use of Landsat data with GIS. J. Geo- Environ. vol. 4, pp 1-13.

Rahman, A. 2000. Environmental losses eclipse profits from shrimp sector. In Chowdhury, Q.I. (Edi.). State of Environment Report. Forum of Environmental Journalists of Bangladesh, Dhaka.

Rahman, M M and Begum, S. 2011. Land Cover Change Analysis around the Sundarbans Mangrove Forest of Bangladesh Using Remote Sensing and GIS Application. J. Sci. Foundation, 9(1&2): pp 95-107.

Rahman, M.C., M.A.B. Siddique, M.A. Salam, M.A. Islam, and M.S. Al-Faisal. 2013 (a). Assessment of technical efficiency of rice farmers in a selected empoldered area of Bangladesh. European Journal of Agricultural Sciences 102, no. 10. http://bellpress.org/Journals/index.php/EJAS/article/viewFile/959/199.

Rahman, M.C., M.A.B. Siddique, M.A. Salam, M.A. Islam, M.F. Kabir, and M.S. Mahamud. 2013 (b). Farm level evaluation of T. aman rice cultivation in selected saline and non-saline areas of Bangladesh. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) 91, no. 4. http://www.iosrjournals.org/iosr-javs/papers/vol4-issue4/O0449198.pdf?id=6498 .

Reis, S. 2008. Analyzing Land Use/Land Cover Changes Using Remote Sensing and GIS in Rize, North-East Turkey. Sensors 2008, 8, 6188-6202.

Richards, J. A. 1993 Remote sensing digital image analysis: an introduction (second edition).

Roy, K., Kumar, U., Mehedi, H., Sultana, T. and Ershad, D. M. 2009. Initial damage assessment report of cyclone Aila with focus on Khulna district. Khulna, Bangladesh: Unnayan Onneshan - Humanity Watch – Nijera Kori.

Sean, L. and Baten, M. A. 2012. Salinity intrusion ininterior coast: a new challenge to agriculture in South Central part of Bangladesh. A working draft, Climate Change, Biodiversity and Disaster Risk Reduction Unit, Unnayan Onneshan- The Innovators, Center for Research and Action on Development. pp 47.

Sereno, G. 1981. A Reconnaissance Study of Changes in Settlement and Related Non-Agricultural Land Use in Bangladesh. FAO/UNDP Land Use Policy Project. Ministry of Agriculture, Dhaka, Bangladesh.

SRDI, 2001. Soil Resources in Bangladesh: Assessment and Utilization. pp 105.

SRDI. 2000. Land and Soil Resources Utilization Guidelines: Dacope Thana, Khulna. Thana Guideline Series-345

SRDI. 2010. Saline Soils of Bangladesh. Soil Resource Development Institute, SRMAF Project, Ministry of Agriculture.

Talukder, R. K. 2005. Food Security, Self-sufficiency and Nutrition Gap in Bangladesh. The Bangladesh Development Studies, Vol. XXXI, No. 3 & 4. pp 35-62.

Tefera, B. and Sterk, G. 2008. Hydropower-induced Land Use Change in Fincha'a Watershed, Western Ethiopia: Analysis and Impacts, Mountain Research and Development, vol. 28 no.1, pp. 72–80.

Uddin, K. and Gurung, D.R. 2010. Land Cover Change in Bangladesh- A Knowledge Based Classification Approach. Grazer Schriften der Geographie und Raumforschung, Band 45/2010, pp. 41 – 46.

Ullah, M. 2002. Biodiversity irreplaceable asset. Weekly Holiday. Center for sustainable development (CFSD). Dhaka.

UNDP. 2010. Cyclone Aila: Joint Multi-Sector Assessment and Response Framework. The United Nations.

Veldkamp, A. and Lambin, E.F. 2001. Predicting Land-Use Change (Editorial), Agriculture, Ecosystems and Environment, 85, pp. 1-6.

VLPC. 2001. Feasibility Studies for Shrimp Component of the Fourth Fisheries Project. Final Report. Department of Fisheries (DoF), Government of Bangladesh and Department for International Development (DFID), UK.

Wikipedia https://en.wikipedia.org/wiki/Polder [Accessed on 3 July, 2015]

Yao, M.K., Angui, P.K. T., Konaté, S., Tondoh, J. E., Tano, Y., Abbadie, L., Benest, D. 2010. Effects of land use types on soil organic carbon and nitrogen dynamics in mid-west Côte d'Ivoire. European Journal of Scientific Research. Vol. 40, pp 211–222.

APPENDIX 1

Description of Different Soil Properties Determination Process

Appendix- 1

Description of Different Soil Properties Determination Process

1. **Soil pH:** Soil pH has been determined by using pH meter. 20g of soil has been placed into a 100ml beaker and then 50ml water was added. The suspension has been stirred for several times for 30 minutes. The pH meter has been switched on and adjusted it with the buffers. The electrodes' of pH meter has been placed into the soil suspension and the pH value has been noted (Huq and Alam, 2005).

2. **EC:** To determine the soil EC, an amount of 200g soil sample has been taken into a container. Distilled water has been added to the sample and simultaneously stirred it with a spatula. The process has been continued until a saturated soil paste is obtained (at saturation, the soil paste glistens as it reflects light, flows slightly when the container is tipped). The sample has been allowed to stand for an hour and rechecked the criteria for saturation. The sample has been filtered through a Buchner funnel by applying vacuum to obtain a clear filtrate. Vacuum extraction has been stopped when the air began to pass through the soil. The EC of the soil sample has been read after putting the EC meter into the filtrate (ibid).

3. **OC:** To determine organic matter of the soil at first soil organic carbon has been calculated. Soil organic carbon has been determined by wet combustion or wet oxidation method. 2g of soil sample (which passed through a 2mm sieve) has been weighted and transferred it to a 500ml clean dry conical flask. 10ml of normal potassium dichromate and 10ml of concentrated sulfuric acid have been added, and mixed thoroughly. After half an hour, when the flask is cold; 150ml distilled water, 10ml phosphoric acid and 0.2g of sodium fluride have been added. After that 3ml of diphenylamine indicator has been added and color of the solution has been changed to deep violet. The excess of chromic acid which is left in the flask titrated with the help of normal ferrous sulphate solution from a burette. At the end point the color of the sodium changed to deep bottle green. The amount of ferrous sulphate solution (T) has been recorded which required in the titration and repeated the experiment three times. A blank experiment in the same way has been run with all the reagents except soil. The amount of required ferrous sulphate solution (B)

has been recorded and the strength of $FeSO_4$ solution from this determination, and repeated the experiment three times (ibid).

4.

Calculation

Following formulas have been used for calculating organic matter of soil (ibid):

1000ml of N $K_2Cr_2O_7$ solution = 1000ml of N Carbon= 3g of C (eq. wt. of C=12/4= 3)

Or, 1ml of N $K_2Cr_2O_7$ solution = 0.003g of C.

Thus the amount of carbon in soil expressed as percent, oxidized by 1N $K_2Cr_2O_7$ solution is calculated as follows:

$$\text{Percentage of organic carbon} = \frac{(B-T)\times f \times 0.003 \times 100}{W}$$

Where, B = Amount in ml of N $FeSO_4$ solution required in blank experiment

T = Amount in ml of N $FeSO_4$ solution required in experiment with soil

f = Strength of N $FeSO_4$ solution (from blank experiment)

W = Wight of soil taken

It has been estimated that only about 77% carbon in soil is oxidized by normal $K_2Cr_2O_7$ solution.

So, 0.003 should be multiplied by 1.3 to get the percentage of total carbon present in the soil. Then the expression becomes:

$$\%\ \text{Organic carbon in soil} = \frac{(B-T)\times f \times 0.003 \times 1.3 \times 100}{W}$$

$$\%\ \text{Organic matter in soil}$$
$$= \%\ \text{of organic carbon} \times 1.724 * (\text{Van Bemmelen factor})$$

* The organic matter of soil is determined by multiplying the content of organic carbon with a factor 1.724 on the assumption that organic matter of average soil contains 58% of organic matter.

5. **CEC:** To determine CEC of soil 10g of collected soil has been taken to a 250ml conical flask and added 100ml of neutral, 1N NH_4OAc solution. The flask has been shaken thoroughly and allowed it to stand overnight. The suspension has been filtered through a filter paper no. 42 and collected the filtrate in a 250 ml

volumetric flask and removed the flask and made the volume upto the mark with 1N NH_4OAc. The filtrate has been preserved in the refrigerator. The residue on the filter paper has been washed five times with ethyl alcohol, till the residue is ammonium free. Later the filter has been discarded. The soil material has been leached on the filter paper four times with neutral 1N NaCl solution in a 250ml flask and the made the volume up to the mark with 1N NaCl (pH 7.0) solution. Alkali distillation has been followed. A blank experiment has been run simultaneously using all chemicals except soil (ibid).

Calculation

Following formulas have been used for calculating CEC (ibid):

1000ml of 1N H_2SO_4 or 1N HCl = 1000ml of 1N ammonium solution.

= Equivalent amount of nitrogen

= 14g of nitrogen

Therefore, % of N in soil $= \frac{(T-B)\times f \times 14 \times 100\text{ml volume} \times 100}{1000 \times W \times \text{volume of exract used}}$

Where, T= Amount in ml of N/20 H_2SO_4 required in titration of the experiment with soil.

B = Amount in ml of N/20 H_2SO_4 required in titration of the blank experiment

W = Weight of the soil sample taken.

F = Normality factor of N/20 H_2SO_4

Therefore, CEC in $\frac{\text{m.e}}{100\text{g}}$ of soil $= \frac{X\times 1000}{14}$

Where, X = % of N_2 found in the above calculation.

6. **Soil Texture:** Soil texture has been determined by testing the collected soil samples using the ‘Hydrometer method’. For the analysis, 40 gm of soil sample has been placed in a 600 ml beaker with 100 ml of distilled water. The beaker has been heated on a hot plate for 15 minutes and shaken when necessary to control frothing. The contents have been boiled for 5 minutes, cooled down, stirred by a glass rod until well mixed after addition of 100 ml 5% calgon solution and allowed to stand overnight. Then the solution has been transferred to the dispersion cup,

using a stream of distilled water and the volume has been made 400 ml. After mixing for 3 minutes on the electric stirrer, the suspension has been transferred to the sedimentation cylinder and the cylinder has been filled up to 1000 ml mark with distilled water. The suspension has been stirred with a stirring paddle for 1 minute and the time has been recorded immediately after removal of the paddle from the suspension and also the hydrometer has been carefully placed in the suspension. Exactly after 40 seconds of paddle removal, hydrometer reading has been taken and it has been removed carefully. Without remixing the suspension, another hydrometer reading has been taken by placing it in the suspension exactly at the end of 2 hours. The temperature of the suspension has been noted down after each hydrometer reading. For blank reading, 100 ml calgon solution has been put in a 1000 ml sedimentation cylinder and the cylinder has been filled with distilled water up to the mark. The suspension has been mixed thoroughly, temperature has been recorded and blank reading has been taken by placing the hydrometer into the suspension (ibid).

Calculation

After some error correction, final hydrometer reading is obtained by following formula (ibid):

$$\mathrm{Rc} = (\mathrm{R} - \mathrm{RL}) + (\mathrm{t} - 20.0) \times 0.3$$

Where, R = hydrometer reading at a different time (40 sec & 2 hour)

Rc = corrected hydrometer reading

RL = blank

t = temperature

it is assumed that all sand particles settle beyond the range of hydrometer reading after 40 seconds and all silt clay particles settle after 2 (preferably 8 hours) hours. Therefore, from the corrected hydrometer readings, percentage of sand, silt and clay can be calculated as follows:

$$\%\ \mathrm{silt} + \mathrm{clay} = \frac{\mathrm{Rc\ at\ 40\ sec}}{\mathrm{oven\ dry\ wet}} \times 100$$

$$\%\ \mathrm{clay} = \frac{\mathrm{Rc\ at\ 2\ hours}}{\mathrm{oven\ dry\ wet}} \times 100$$

$$\% \text{ silt} = (\% \text{ silt} + \text{clay}) - \% \text{ clay}$$

$$\% \text{ sand} = 100 - (\% \text{ silt} + \text{clay})$$

Percentage sand, silt and clay are plotted on textural triangle to determine the textural class of the sand.

7. **Total Nitrogen:** The Kjeldahl procedure is generally applied for determination of total N and involves two steps: digestion of the sample to convert the N to ammonium sulphate; and, determination of ammoinium in the digest.

For determination of total N, 10g of finely soil sample has been taken in a 500ml Kjeldahl flask. 20ml of distilled has been added to it and left for 20 minutes. After that 25ml of concentrated H_2SO_4 has been added to it and mixed it thoroughly. The flask has been heated over a low flame in a digestion chamber for 15 minutes. When white fumes of H_2SO_4 appears, the flask has been removed from the heater and added 2-3g of catalyst to raise the boiling temperature of H_2SO_4 digestion and to accelerate the reaction. The flask then has been placed over the heater to raise the temperature slowly and continued the digestion for two hours or more till the liquid is clear. The digest has been cooled down and diluted it with 100ml of distilled water. 10ml of the extract has been distilled at a time with 10ml of 40% NaOH using micro Kjeldahl's distillation apparatus. About 50-75ml volume of distillate (NH_3 gas) has been collected in a 125ml conical flask containing 10ml of 4% boric acid with mixed indicator. The conical flask has been removed and washed the delivery outlet of the distillation apparatus with distilled water. The distillate has been titrated against the standard H_2SO_4 or HCl. A blank experiment has been run simultaneously using all the chemicals except soil (ibid).

Calculation

Following formula has been used for calculating percentage of N (ibid):

1000ml of 1N H_2SO_4 = 1000ml N = 14g N

Or, 1ml of 1N H_2SO_4 = 0,014g N

$$\% \text{ of N in soil} = \frac{(\text{T} - \text{B}) \times \text{f} \times 0{,}014 \times 250 \times 100}{\text{W} \times \text{vol. of extract used}}$$

Where,

B = Amount in ml of N/20 or N/56 or N/100 H_2SO_4 required in titration of the blank experiment

T = Amount in ml of N/20 or N/56 or N/100 H_2SO_4 required in titration of the experiment with soil

f = Normality actor of N/20 or N/56 or N/100 H_2SO_4

W = Weight of the soil sample

8. **Potassium**: Potassium is determined by the method of cold extraction. For this, 10g of sample of soil was placed in a 100ml beaker. 25ml of water and 1ml of concentrated sulfuric acid was added. The mixture was stirred and allowed the mixture to stand for 30min. the suspension was filtered and received the filtrate in a 100ml volumetric flask. Soil was washed and filtered with 15ml portions of 0.1 N sulfuric acid until the filtrate was brought to volume. The solution was mixed and determined K on a flame photometer. The emission was compared with that from standards made up in the same concentration of sulfuric acid as used in the sample. Standards of 0 to 60ppm K was used (ibid).

Calculation

Following formula has been used for calculating potassium in soil (ibid):

ppm K in soil = Reading × factor from standard × dilution factor

Or, m.e. K $100g^{-1}$ soil = ppm/390

9. **Calcium and Magnesium:** The classical routine method of determining calcium and magnesium is by complexometric titration using EDTA (ethylenediamine tetra acetic acid) that forms a slightly ionized, colorless, stable complex with alkaline earth metal (Ca, Mg etc.).

Procedure for Calcium

10g of soil sample was taken in a 250ml conical flask and added 100ml of neutral 1N NH_4OAc solution. The flask was shaken thoroughly and allowed to stand overnight. Later the suspension was filtered through a filter paper no. 40 or 42 and the filtrate was collected. 2ml or 5ml aliquot (depending on the Ca concentration in the extract) was taken in a small porcelain cup. After that 5ml 10% NaOH was added to the solution and finally a .02g murexide indicator. This was titrated against 0.01N EDTA solution. At the end point color changed from pink to light blue. A blank experiment was run in exactly same manner, taking 2ml of water instead of Ca extract. 0.01 N EDTA solution was standardized with the help of standard Ca solution using all the reagents as above (ibid).

Calculation

Following formula has been used for calculating calcium in soil (ibid):

1000ml of 1N EDTA = 20g of Ca

1ml of 1N EDTA = 20/100 = 0.02 g of Ca

% Ca in soil

$$= \frac{0.02 \times \text{ml of EDTA used} \times \text{normality of EDTA} \times 100\text{ml volumes}}{\text{ml of extract used} \times \text{weight of soil}} \times 100$$

Procedure for Calcium plus Magnesium

2ml of extract prepared early in Ca procedure was taken in porcelain cup. 25ml of distilled water, 10-15ml buffer solution ferrocyanide, 10 drops hydroxylamine hydrochloride, and 5 drops Triethanolamine (TEA) was added. After adding all the reagents the solution was warmed gently for 2-3 minutes, cooled and added 3 drops of Eriochrome Black-T solution. It was then titrated with 0.005 M EDTA. A blank solution was prepared in exactly in same manner, taking 2 ml of water instead of Ca+Mg extract. The EDTA solution was standardized by standard magnesium solution using all the reagents used in the titration for soil extract (ibid).

Calculation

The amount of available Mg was determined by subtracting the amount of Ca from the value obtained for Ca+Mg (ibid)

1000ml of 1N EDTA = 12g of Mg

1ml of 1N EDTA = 12/100 = 0.012 g of Mg

$$\% \text{ Mg in soil} = \frac{0.012 \times \text{ml of EDTA used} \times \text{normality of EDTA} \times 100\text{ml volumes}}{\text{ml of extract used} \times \text{weight of soil}} \times 100$$

10. Phosphorus: Phosphorus was determined by Molybdophosphoric blue color method in Sulfuric acid system. To determine phosphorus at first 5g of soil was taken in a 250ml beaker and 50ml of 0.002 N H_2SO_4 (Troug's extraction solution) was added and shaken for 30 minutes. The suspension was filtered through a Whatmann No. 42 filter paper discarding the filter until it came through clear and collected the filtrate in a 250 ml beaker. Suitable amount of the filtrate (5 or 10 or 25 ml depending on phosphorus concentration) was taken in a 50ml volumetric flask and added about 25ml of distilled water. Exactly 2ml of ammonium sulphomolybdate solution was added and mixed thoroughly. 2 drops of 2,4-dinitrophenol indicator was added to the solution and if it gave yellow color, N/20 HCl was added drop wise until it became colorless. Again when the indicator gave a colorless solution, indicating a solution of pH below 3.0, then N/20 NaOH was added drop wise until a yellow color was appeared and N/20 HCl yellow became faint. Freshly prepared stannous chloride solution was added and shaken. 10ml of the clear solution was transferred to spectrophotometer tube and the intensity of the color in a spectrophotometer at 660nm was read (ibid).

Calculation

Following formula has been used for calculating phosphorus (ibid):

$$\text{Available Phosphorus (or Troug's extractable P in ppm)} = \frac{\text{ppm from the standard curve} \times 50\text{ml volume of extraction} \times 50\text{ml (dilution)}}{\text{amount of soil in g} \times \text{volume of exract used}}$$

11. Sulphur: Sulphur was determined by turbidimetric method. To determine sulphur at first 10g of soil sample was transferred in a 250ml conical flask and 50ml of Morgan's extraction solution was added. The flask was shaken thoroughly for half an hour. Later the suspension was filtered through a filter paper (Whatmann No. 42) and collected the filtrate. 10ml of clear aliquot was taken in a 100ml volumetric flask and added 1ml of each of gum acacia and 6N HCl. Then 0.4g of $BaCl_2$ was added to the solution and let the mixture was kept stand for 5 minutes, and then was swirled the solution in the flask frequently until the crystals of BaCl2 were dissolved. Within the time interval of 3 to 5 minutes after the crystals had dissolved, the volume was made upto the mark with distilled water. The density of the sample solution was read by taking absorbance using spectrophotometer at a wave length of 420nm and the sulphate concentration from the standard curve was found. By using different proportions of standard 100ppm solution was made which standards containing 0, 2.5, 10, 15 and 30ppm of added sulphate and developed the turbidity as described above (ibid).

Calculation

Following formula has been used for calculating sulphur in soil (ibid):

$$\text{Ppm of sulphur in the sample} = \frac{\text{ppm from the curve} \times 50\text{ml volume} \times 100\text{ml (dilution)}}{\text{ml of extract used} \times \text{weight of sample}}$$

APPENDIX 2

CLASSIFICATION OF SOIL ACCORDING TO VALUES OF SOIL'S PHYSICAL AND CHEMICAL PROPERTIES

Appendix 2

CLASSIFICATION OF SOIL ACCORDING TO VALUES OF SOIL'S PHYSICAL AND CHEMICAL PROPERTIES

Table 2A: Classification of soil according to soil's pH value

Class	**pH**
Very strongly acidic	< 4.5
Strongly acidic	4.6-5.5
Slightly acidic	5.6-6.5
Neutral	6.6-7.3
Slightly alkaline	7.4-8.4
Strongly alkaline	8.5-9.0
Very strongly alkaline	> 9.0

Table 2B: Soil Salinity Class

Salinity Class	**EC dS/m**
Non-saline	< 2
Very slightly saline	2 – 4
Slightly saline	4 – 8
Moderate	8 – 12
Strongly saline	12 - 16
Very strongly saline	> 16

Table 2C: Soil Salinity Classes and Crop Growth

Soil Salinity Class	**Conductivity of the Saturation Extract (dS/m)**	**Effect on Crop Plants**
Non saline	0 - 2	Salinity effects negligible
Slightly saline	2 - 4	Yields of sensitive crops may be restricted
Moderately saline	4 - 8	Yields of many crops are restricted
Strongly saline	8 - 16	Only tolerant crops yield satisfactorily
Very strongly saline	> 16	Only a few very tolerant crops yield satisfactorily

Table 2D: Classification of soil according to the quantity of organic matter in soil

Class	**Quantity of organic matter (%) in soil**
Very low	<1.0
Low	1.0-1.7
Moderate	1.7-3.4
High	3.4-5.5
Very high	>5.5

Table 2E: Classification of soil according to percentage of CEC

Class	**CEC (meqv %)**
Very high	>30
High	15-30
Medium	7.5-15.0
Low	3.0-7.5
Very low	<3.0

Table 2F: Classification of determined nutrient elements based on soil's chemical characteristics for wetland rice in loam to clay soil.

Element	**Very low**	**Low**	**Medium**	**Optimum**	**High**	**Very high**
Nitrogen (N) %	≤ 0.09	0.091-0.18	0.181-0.27	0.271-0.36	0.361-0.45	> 0.45
Phosphorus (P) µg/g	≤ 6.0	6.0-12.0	12.1-18.0	18.1-24.0	24.1-30.0	> 30.0
Sulphur (S) µg/g	≤ 9.0	9.1-18.0	18.1-27.0	27.1-36.0	36.1-45.0	> 45.0
Potasssium (K) meqv/100g	≤ 0.075	0.076-0.15	0.151-0.225	0.226-0.30	0.31-0.375	> 0.375
Calcium (Ca) meqv/100g	≤ 1.5	1.51-3.0	3.1-4.5	4.51-6.0	6.1-7.5	> 7.5
Magnesium (Mg) meqv/100g	≤ 0.375	0.376-0.75	0.751-1.125	1.126-1.5	1.51-1.875	> 1.875

Source: Upazila Nirdeshika, SRDI 1995, BARC 2012