# Impact of Land-use Change on Ecohydrological Characteristics of Arial Beel

by

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MASTER OF SCIENCE IN WATER RESOURCES DEVELOPMENT

Institute of Water and Flood Management
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

November 2012

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A Thesis Submitted by

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In partial fulfillment of the requirement for the degree of

MASTER OF SCIENCE IN WATER RESOURCES DEVELOPMENT

**BUET**


Institute of Water and Flood Management

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY


November 2012

The thesis titled **'Impact of Land-use Change on Eco-hydrological Characteristics of Arial Beel '** submitted by Anisa Rahman Siddique, Roll No: M 0409282007F, Session: April 2009, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Science in Water Resources Development on 14 November, 2012.

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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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Anisa Rahman Siddique

# ACKNOWLEDGMENT

The author would like to express her endless regards to the Almighty Allah for His blessings for the successful completion of this research work. The author shows her most sincere gratitude and profound thanks to Dr. Mashfiqus Salehin, Professor, Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology (BUET), for supervising this research work. Successful completion of this study has been possible because of his cordial supervision. The author would like to extend her sincere gratitude and thanks to Dr. Md. Rezaur Rahman, Professor, IWFM, BUET, for his kind supervision during a substantial part of the study.

The author also expresses her sincere gratitude to Dr. Md. Abed Hossain, Associate Professor, IWFM, BUET, for his cooperation and guidance in water quality analysis in the Soil and Water Quality Laboratory of IWFM. The author would like to thank to Dr. Md. Munsur Rahman, Professor and Director, IWFM, BUET and Dr. AKM Saiful Islam, Associate Professor, IWFM, BUET, for reviewing the draft final copy of this thesis and providing their valuable comments and useful suggestions that helped improve the quality of the thesis. The author also expresses her sincere gratitude to Dr. Ahmadul Hassan, Director, Center for Environment and Geographic Information System, CEGIS, Dhaka, for his comments and suggestions that greatly enriched the content and quality of the thesis.

The author would like to thank Mohammad Rashed Jalal, Research Assistant of IWFM, for his help in the analysis of classified images. The author would also like to thank to Md. Monwar-ul Huq, Research Assistant of the Soil and Water Quality Analysis Laboratory of IWFM, for his assistance in analyzing the samples collected in the field for different water quality parameters.

The author gratefully acknowledges the support and cooperation provided by the interviewed farmers of the study areas.

The Crossing Boundaries (CB) Project of IWFM provided all the financial support for this study. The author also happens to be a recipient of the South Asian Water (SAWA) Fellowship under the CB project. The author acknowledges the all kinds of support provided by the project, and by the people involved in the project.

Finally the author wishes to express her gratitude to her family members, relatives and all the individuals for their encouragement, moral supports and blessings during the study.

# ABSTRACT

Land use change can have adverse impacts on aquatic habitats and biodiversity leading to change in socio-economic activities of a country. This study aims to analyze the impact of land use change on eco-hydrology of Arial beel - a depression spanning about 723 $km^2$ between the Ganges and the Dhaleshwari rivers south of Dhaka, the capital of Bangladesh. The changes of land use were detected by studying six classified and two unclassified Landsat TM Satellite images of Arial Beel area. Analysis of the classified images from 1984 to 1999 revealed that the areas under crop production (consists of Boro and other rabi crops) remained relatively unchanged at 32% of the study area during this period. Grass production increased from 5% to 11% over the years when livestock farming become popular in the locality. The analysis of Landsat TM image of the study area for 1989 and 2010 together with data from BBS and ground truthing showed that alteration in cropping pattern (from traditional varieties to high yielding varieties) and reduction of net cultivable area are the most possible pathways of land use change in the study area between 1984 and 2010. As gradual shift of high yielding varieties of crops could lead to more intensive use of chemical fertilizers and pesticides thus degrading the quality of water, water quality was considered as the indicator for ecosystem function of Arial Beel in the current study. Chemical analysis of the water samples taken at two times, one set in pre-monsoon and another set in early monsoon, revealed most of the parameters, including dissolved oxygen, pH, ammonia and nitrogen were within the tolerable limits. Nitrogen concentration varied from 0.15 mg/l to 0.25 mg/l, which is within the acceptable limit (<0.3 mg/l) but phosphorus concentration ranged from 0.2 mg/l to 0.45 mg/l, which is significantly above the acceptable limit (<0.015 mg/l). The high level of phosphorous contribution is mainly attributed to extensive use of fertilizer and popularity of livestock farming in the locality. However, the concentration is likely to decrease with increased mixing of accumulated rainwater in depression areas and floodwater from the surrounding rivers. Nevertheless, the very high level of phosphorous concentration in the month of June is a concern for beel fisheries and other aquatic lives of the beel. Findings from the participatory field research and secondary literature review revealed that the fish availability of the beel has been affected and some native fish species are now endangered- substantially impacting the livelihood activities of the fishermen. Future studies need to be carried out to explore to what extent the high level of phosphorous proliferation will continue, and the likelihood of plankton or algal blooms in Arial Beel.

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**ABBREVIATIONS**

| | |
|---|---|
| AEZ | Agro Ecological Zone |
| BARC | Bangladesh Agricultural Research Council |
| BBS | Bangladesh Bureau of Statistics |
| BOD | Bio-chemical Oxygen Demand |
| CEGIS | Centre for Environment and Geographic Information System |
| COD | Chemical Oxygen Demand |
| DoE | Department of Environment |
| FAO | Food and Agricultural Organization |
| FCDI | Flood Control, Drainage and Irrigation |
| FFWC | Flood forecasting and Warning Centre |
| FGD | Focus Group Discussions |
| HYV | High Yielding Varieties |
| IAEA | International Atomic Energy Agency |
| IUCN | International Union for Conservation of Nature |
| NDVI | Normalized Difference Vegetation Index |
| NWMP | National Water Management Plan |
| SRDI | Soil Resource Development Institute |
| TDS | Total Dissolved Solid |
| TSS | Total Suspended Solid |
| UNESCO | United Nation Educational, Scientific and Cultural Organization |
| USEPA | United States Environmental Protection Agency |
| WARPO | Water Resource Planning Organization |

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background and Present State of the Problem

Land-use change is a common term for the human modification of the earth's terrestrial surface. Examples of land use changes include deforestation, road construction, agricultural development, change of land or soil, drainage, change of crop varieties, dam building, irrigation, coastal zone degradation, wetland modification, mining, the concentration and expansion of urban environments and other activities. Land use change impacts ecosystem of the respective locality as Kashaigili et al. (2009) found that the sustainability of eco-systems requires proper use of land and management of water.

Bangladesh is one of the most densely populated countries in the world. Increased food demand and other growing national economic activities exert pressure on the water resources of the country (EGIS II, 2001). Moreover, runoff from agricultural lands causes toxicity in the surface water, which can have adverse impacts on aquatic habitats (EGIS II, 2001). The reduction of biodiversity, aquatic and amphibian resources, and wildlife habitats lead to the change in wetland-based human occupations and shrinkage of socio-economic activities (Islam and Sadque, 1992). Given these multifaceted impacts of land use change on the water based eco-systems, it has become necessary to study the impact of land use change on the ecohydrology of different regions of the country. The current thesis work is a modest endeavor to that end.

The site chosen for the study is the Arial Beel - a large depression of about 723 $km^2$ lying between the Ganges and the Dhaleshwari rivers south of Dhaka. The Arial Beel, an agro-ecological zone (AEZ-15) (FAO, 1988) and part of Bio-ecological zone 4b (IUCN, 2002), is a wetland of ecological, economic, commercial and socio-economic significance. Approximately 500 species of flowering plants, 150 of vertebrates and 400 species of vertebrates are found in the beel area in addition to approximately 260 species of fin fishes and 25 shell fishes available in the beel (Islam, 2000).

Hossain (2009) carried out a study on Arial Beel in Bangladesh. This study has revealed how the use of pesticides in agricultural lands has affected the ecological resources of freshwater wetlands. As a consequence of resources degradation, the beel dependent fishermen have lost their occupations. He found that the poor fishermen after losing previous occupations could not easily adapt to new occupations and in some cases engaged in illegal works, which ultimately led to social conflicts in the adjacent areas. During a reconnaissance visit to Arial Beel area, most of the fishermen of the beel area blamed the agricultural practices, especially the use of fertilizer and pesticides in agricultural land, for the reduction of aquatic and amphibian resources of the beel. Intensive use of chemical fertilizers and pesticides is identified as one of the major source of degradation of water quality. To obtain farther context on these findings the current study attempts to analyze the land use change of the area and its impacts on water quality parameters of the Arial beel eco-system.

## 1.2 Objectives of the Thesis

The specific objectives of this study were as follows:

- To detect the changes of land-use in the Arial Beel.
- To determine the eco-hydrological characteristics of the study area.
- To assess eco-hydrological effects due to land-use change.

## 1.3 Outline of Methodology

In this study, the changes of land use were carried out by analyzing the classified images of Arial beel from 1984 to 1999. Such maps were collected from Centre for Environment and Geographic Information Services (CEGIS). More information about land use change was collected from field survey and focus group discussions. In addition to the CEGIS images, two additional Landsat TM satellite images dated 13 February, 1989 and 15 February, 2010 (Figure 5.12) obtained from the public domain were used to interpret the changes in more recent times.

Both primary and secondary information sources were used to attain the information about eco-hydrological characteristics of Arial beel. A number of research publications and literatures were reviewed to collect secondary information. The secondary data about hydrological, ecological resources and soil details were collected from relevant organizations like SRDI and BARC. The primary data such as crop types, planning and harvesting times and fertilizer types and used amount etc were collected through focus group discussion.

Water quality was considered as an indicator for ecosystem health of Arial Beel in the current study. Ecohydrological effects of land use change were thus analyzed by identifying catchments of different depression areas of the beel through GIS-based watershed analysis and collecting water samples at different points at different times (before and after inundation) and analyzing the samples for different water quality parameters (the color of water, temperature, pH, dissolved oxygen, conductivity, COD, BOD, TSS, TDS, alkalinity, hardness, ammonia, iron, nitrate and phosphate) which have relevance for ecosystem health. The chemical analysis of water quality parameters were measured in the Soil and Water analysis laboratory, IWFM, BUET.

### 1.4 Limitations of the Study

In this thesis work the changes of land use have been studied primarily by analyzing the classified images of Arial Beel (collected from CEGIS) from 1984 to 2004. Since the classified images for more recent years were not available from CEGIS, two additional unclassified Landsat TM satellite images dated 13 February, 1989 and 15 February, 2010 (Figure 5.12) obtained from the public domain were used to interpret overall pattern of historical land use change in the area until recent times. It was not possible to differentiate between boro crop area, areas under other rabi crops and areas covered with other type of vegetation from the images, since successive time series images for different months were not available.

Furthermore, in-depth study (based on field measurements) of the linkages between hydrology and specific ecological characteristics of Arial Beel was not possible because of limitations of time, cost and logistics. A delineation of the eco-hydrological characteristics of the study area was thus based on secondary data and literature, field observations and analysis of the opinions of local people.

The definition of study area and sampling points also has some limitations. Arial Beel is not a well defined administrative unit. Fifteen (15) selected adjacent unions covering the major area of Arial Beel were picked on judgmental consideration and defined as study area. Since the main focus of this paper is land use change, the unions covering larger share of wetland surrounded by human settlements were selected.

It proved difficult to access the entire beel area during study period. Sample collection points were identified based on watershed analysis and on-the-ground accessibility consideration. A higher number of samples across a longer study period would have produced more reliable results for the study.

The secondary sources of data on eco hydrological characteristics of the study area were also not fully adequate. In Bangladesh SRDI (Soil Resource Development Institute) and DoE (Department of Environment) are two key organizations expected to conduct such studies. During the research no significant secondary data on the eco hydrological characteristics of the area under focus was available from either of these organizations. Some information about the soil characteristics of the area was available from SRDI as discussed in section 6.4.

## 1.5 Organization of the Thesis

The thesis is organized in seven chapters. Chapter one describes the background and present state of the problem, objectives of the study, limitations of the study and outline of methodology. The available literatures related to the study are reviewed in chapter two. This chapter briefly describes land use and land types in Bangladesh, wetland and ecology in Bangladesh. It also includes brief description of a number of earlier studies of land use change and the determinants of eco-hydrology in Bangladesh. Chapter Three outlines the brief description of the study area. Chapter Four discusses the eco-hydrological characteristics of the study area including variation of hydrological features, soil characteristics and ecological resources of the study area. Chapter Five describes generalized land use patterns of the study area from 1984 to 2010 by analyzing the classified and unclassified images. Chapter six focuses on the impacts of water quality parameters on the eco-system health of Arial Beel. Chapter Seven draws some conclusions on the basis of the findings of the study. It also makes some recommendations for further study.

# CHAPTER TWO
# LITERATURE REVIEW

## 2.1 Background

Scientists, environmental managers, social workers, economists and engineers are increasingly concerned about land use change and its effect on hydrological and ecological processes. In recent times, the eco-hydrological effects of landscape pattern change have been discussed intensively. Increased attention has been directed towards comprehensive multi-scale and integrated research of land use change and eco-hydrological processes.

Eco-hydrology is a new science that studies the interdependence of hydrological and ecological processes. More specifically, it can be defined as an interdisciplinary field which aims at a better understanding of hydrological factors determining the natural development of wet ecosystem, especially with regard to their functional value for protection and restoration of natural habitats (Grootjans et al.1996). Zalewski (2000) observed that eco-hydrology provides additional tool to manage the degradation of ecological and water processes in the landscape. The integration of different disciplines has advanced the topic of eco-hydrology.

Research on wetlands has played a central role in the development of eco-hydrology in Europe and the United Kingdom (Baird and Wilby, 1999). Hydrologic and ecological processes are intimately connected in wetlands, and their interaction has consequences not only for these ecosystems, but also for the functions they serve on larger scales. The Water Resources Development Act (WRDA) adopted by the U.S. government in 2000 approves a 40-year public works program to “restore, preserve and protect the South Florida ecosystem”. Water managers in South Florida are now accountable for improving and preserving ecological functions in a natural system (Nuttle, 2002).

## 2.2 Land Use and Land Types in Bangladesh

Bangladesh is a riverine country. Most of the area is a low-lying plain formed from the alluvial soil deposited by rivers. There are some elevated lands and hilly areas. Being basically a floodplain country, Bangladesh consists of extremely low and flat land (see Figure 2.1). Almost half of the area is within ten meters above mean sea level (WARPO, 2002). The land elevation increases towards the north-west and reaches an elevation of about 90 meters above the mean sea level. The highest areas in Bangladesh are the hill tracts in the Sylhet and Chittagong regions.

Agriculture is the dominant land use in the country, covering about 59% of the land. More than 80% of this land area is under paddy cultivation. Forest coverage is about 19% of total area. Mangrove is 3.5% of total forest coverage. Almost all the mangrove forest is in the Khulna Division. The remainder of the forest coverage is in the eastern hill areas of Chittagong and Sylhet Division. River and other water bodies constitute about 9% of the country. Sylhet Division has large open water bodies and Khulna Division has large estuaries (WARPO, 2002)

The agriculture land resource of Bangladesh has been classified into five types (F0, F1, F2, F3 and F4) on the basis of the time of arrival, depth, duration and rate of rise in flood water and cropping pattern. The land types are described in Table 2.1 and their distribution is shown in Figure 2.2. In general, normal seasonal flooding is shallow in the north-west, west, east and south of the country, and is deep in the center and center-east.

**Table 2.1: Land types in Bangladesh (Source: WARPO, 2002)**

| Land type | Flood depth (cm) | % of the total |
|---|---|---|
| F0: Highland | 0-30 | 16 |
| F1: Medium Highland | 30-90 | 45 |
| F2: Medium Lowland | 90-180 | 24 |
| F3: Lowland | 180-300 | 13 |
| F4: Very lowland | >300 | 2 |

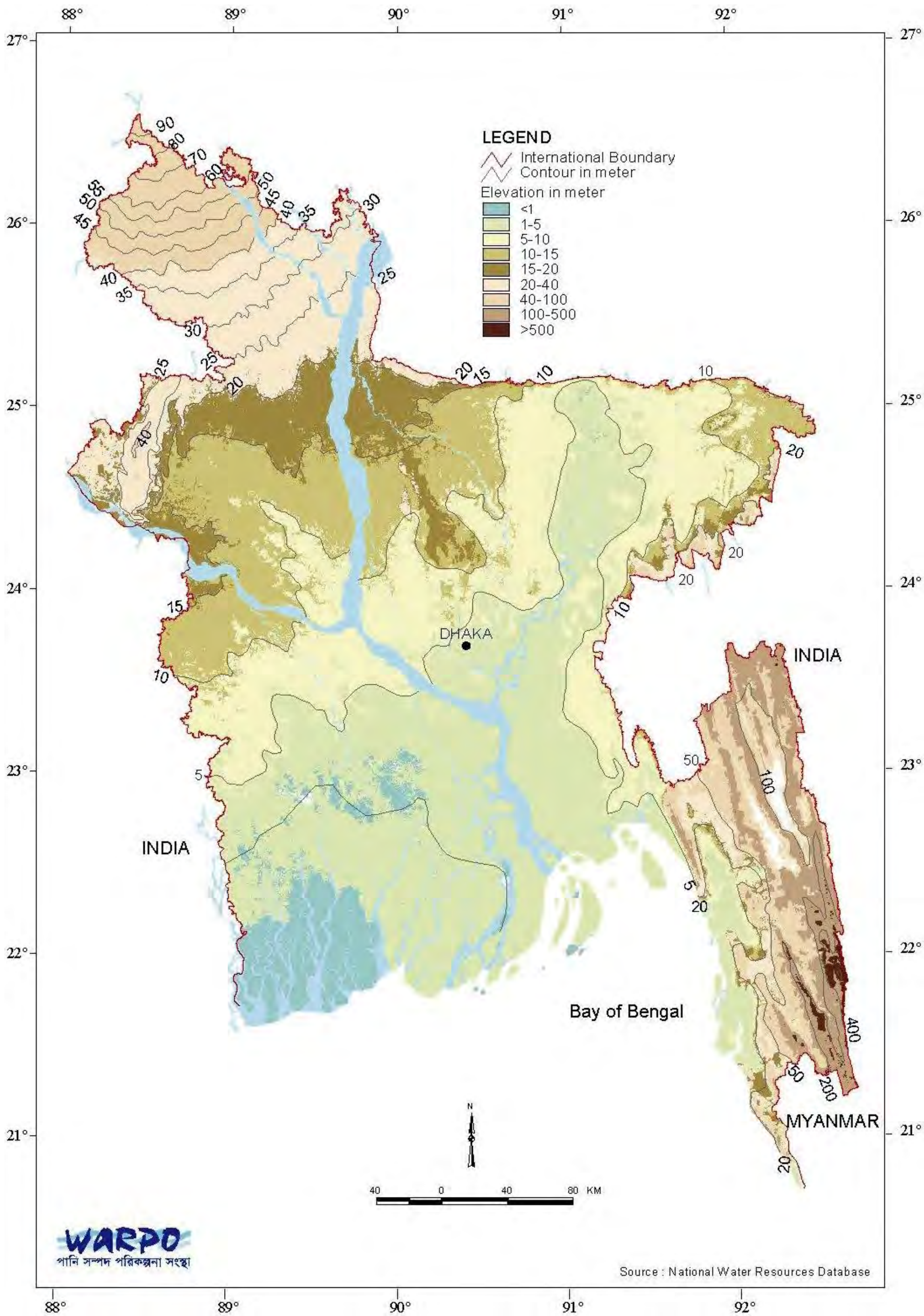



**Figure 2.1: Contour map of Bangladesh**

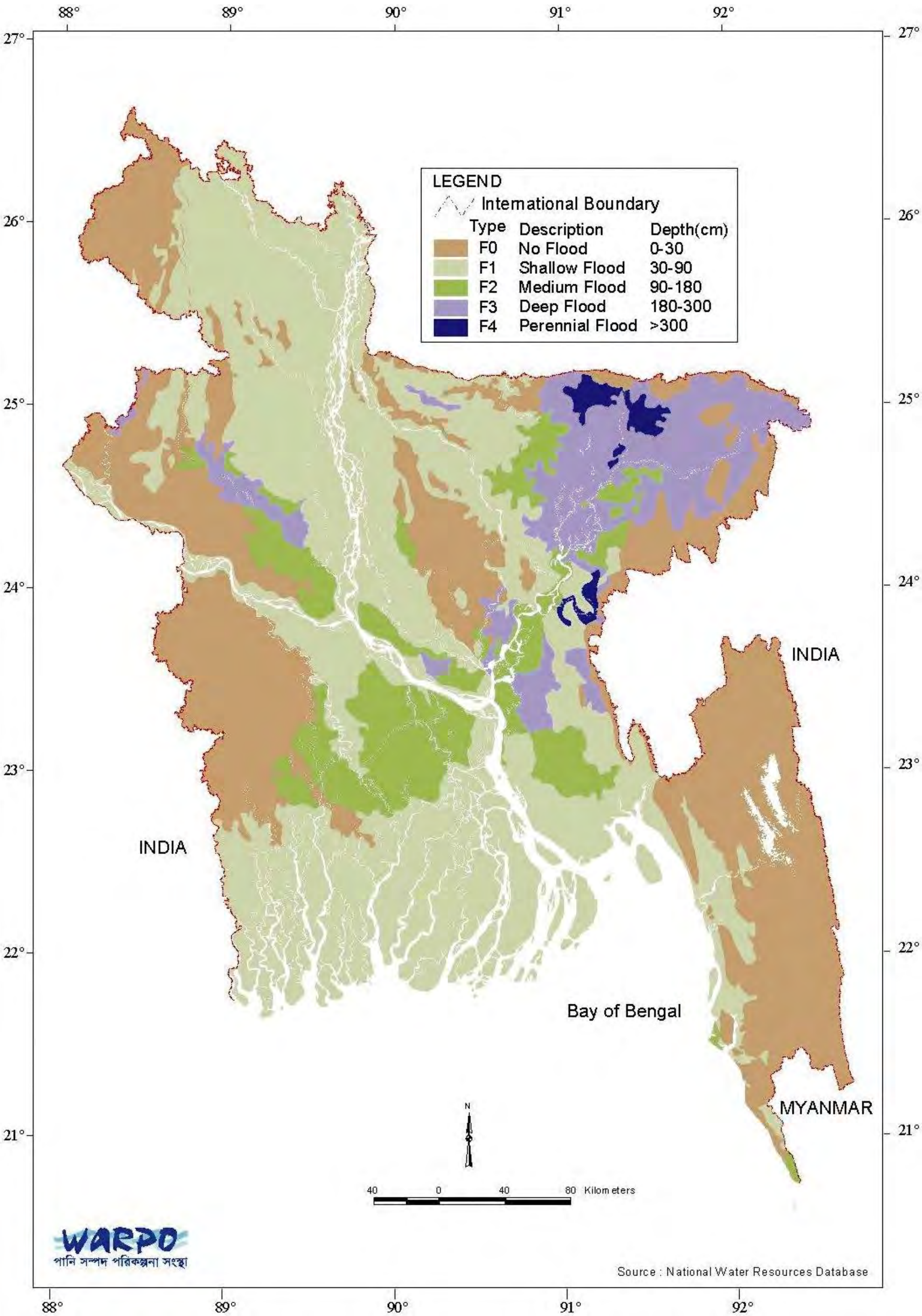



**Figure 2.2: Inundation types of Bangladesh**

## 2.3 Wetland in Bangladesh

Due to deltaic characteristics of the country, Bangladesh has a high areal extent of water bodies, probably one of the highest in the world (Khan, 1994). On the basis of depth and duration of inundation/flooding, the country has been divided into five broad land types: highland, medium highland, medium lowland, lowland and very lowland. Among these land classes, medium lowland (which remains flooded up to a depth of 180 cm during monsoon are considered as areas of wetlands (WARPO, 2002). The total area under wetlands in Bangladesh has been variously estimated at seven to eight million hectares, which is about 50% of the total land surface. Bangladesh possesses enormous area of wetlands including rivers and streams, freshwater lakes and marshes, haors, baors, beels, water storage reservoirs, fish ponds, flooded cultivated fields and estuarine systems with extensive mangrove swamps. The manmade wetlands include lakes, dighis, ponds and borrow pits. Some important wetlands of the country are Chalan Beel, Atrai basin, lower Punarbhaba floodplain, Gopalganj-Khulna Beels, Arial Beel, and Surma-Kushiyara floodplain.

Standing water bodies or marshes belong to topographically depressed areas known as haors, baors and beels with negligible flows. The total standing water bodies in Bangaldesh are about 1,236 $km^2$, 60% of which is located in the Haor basin in the north-eastern part of the country. Haors are the large basins comprising of several small and large depressions, called beels. There are seasonal and perennial beels which during the monsoon may become a single water body. During winter, water begins to recede in the haor basin, concentrating in the beels. Most of the seasonal beels dry up by January- March. The haor basin contains about 47 major haors and some 6,300 beels of which about 3,500 are permanent and 2,800 are seasonal (WARPO, 2002)

Arial Beel occupies a low-lying basin between the Ganges floodplain and the Young Brahmaputra floodplain south of greater Dhaka district. Seasonal flooding is deep in the basin-centre and moderately deep on the higher margins. The centre of the basin remains wet for most of the dry season (GOB- IUCN, 1992)

Nishat (1993) described that wetlands have a wide range of ecological, socio-cultural, economic and commercial importance and values in Bangladesh. These are critically important in

Bangladesh for human settlements, biodiversity, fisheries, agricultural diversity, navigation & communication, and ecotourism.

Khan (1994) stated that over the previous four decades, massive physical infrastructures in the form of rural road and flood embankment have been developed in the wetlands including floodplains and haor areas. Many of these infrastructures disregarded local topographic condition and natural water flow direction, which has often resulted in poor drainage or water logging and impacted on the local surface water regime. As a result, local ecosystems are threatened because of changed water exchange system. Embankment constructed for FCDI projects reduce floodplains and obstruct fish movement and migration from rivers as well as beels to the remaining floodplains for feeding and breeding. As a result, many fishermen have lost their livelihood (Khan, 1994)

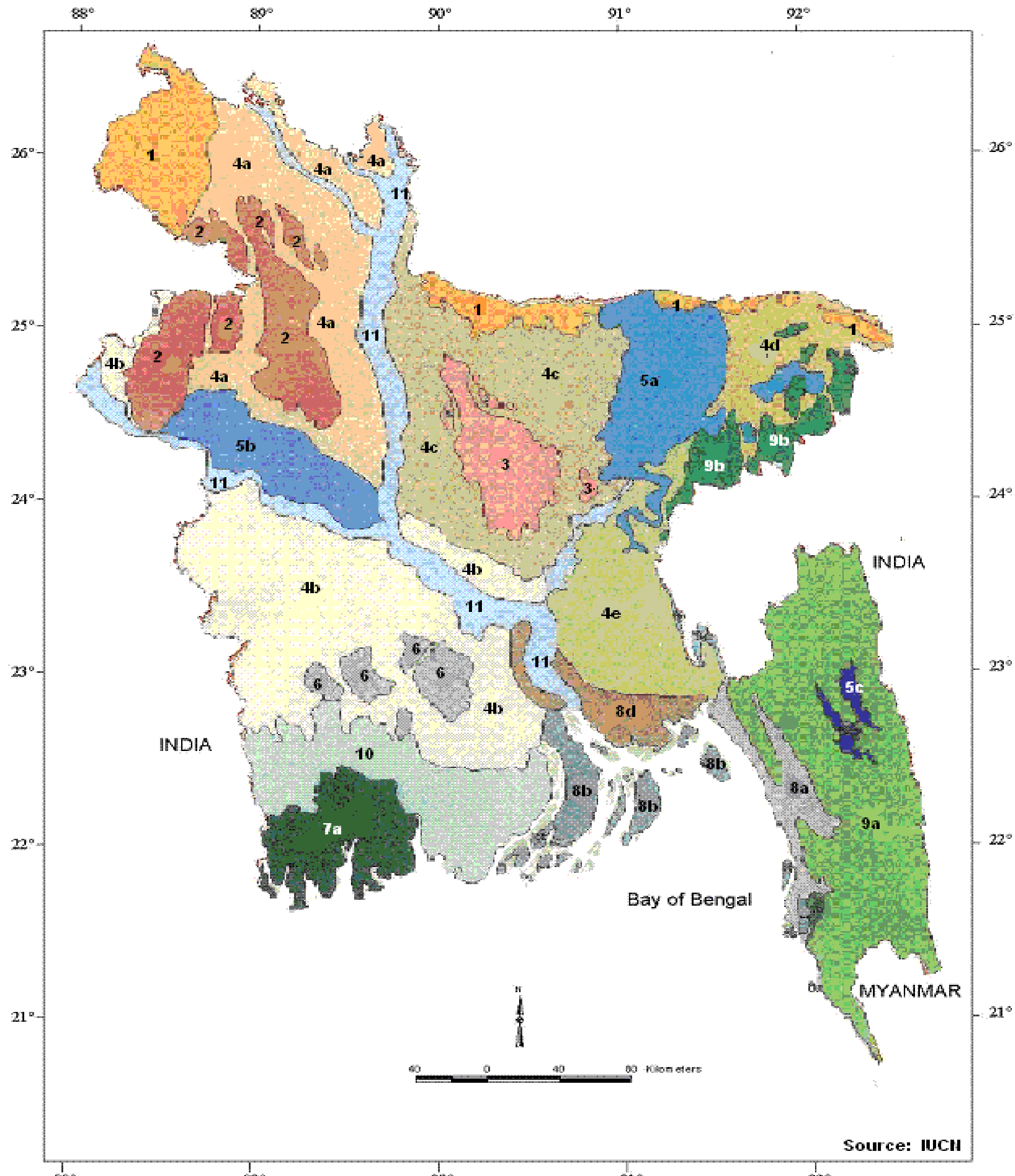
Degradation of wetlands has caused several problems including extinction and reduction of wildlife, extinction of many indigenous wild and domesticated rice varieties, loss of many indigenous aquatic plants, herbs, shrubs and weeds, loss of natural soil nutrients, loss of natural water reservoirs and of their resultant benefits, increase in the occurrence of flooding and degeneration of wetland based ecosystems, occupations, socio-economic institutions and cultures (Khan, 1994).

## 2.4 Ecology in Bangladesh

IUCN (2001) has recently divided the country into 11 bio-zones as shown in Figure 2.3. The classification has been based on variations in physiography, altitude, inundation depths and dissection by the major rivers.

The Sundarbans – world's largest coastal mangrove forest - is unique in its extent, the height of its forest, and the diversity of its wildlife. It is the largest remaining natural refuge of the Royal Bengal Tiger. The Sundarbans are a UNESCO World Heritage Site.

The Haor Basin in the north-east region, comprising large area of open wetlands, is abundant with fish and migratory waterfowls. Part of the Haor basin in the north-east region has also been declared a Ramsar Site, because of their international importance as wetlands supporting important bio-diversity (Davis, 1994).




| Map Legends | | |
|---|---|---|
| 1. Himalayan Piedmont plain | 5a. Haor Basin | 8d. Meghan Estuarine Floodplain |
| 2. Barind tract | 5b. Chalan Beel | 8e. Sandy Beech/ Sand Dunes |
| 3. Madhupur Sal Tract | 5c. Kaptai Lake | 9a. Chittagong Hills and the CHTs |
| 4a. Teesta Floodplain | 6. Gopalganj-Khulna Peatlands | 9b. Sylhet Hills |
| 4b. Gnages Floodplain | 7a. Sundarbans | 9c. Lalmai-Tipprah Hills |
| 4c. Brahmaputra - Jamuna Floodplain | 7b. Chokoria Sundarbans | 10. Saline Tidal Floodplain |
| 4d. Surma-Kushiyara Floodplain | 8a. Coastal Plains | 11. Major Rivers |
| 4e. Meghna Floodplain | 8b. Off-shore Islands | 12. Coastal and Marine Waters |
| | 8c. Narikel Jingira Coral Island | |

**Figure 2.3: Bio-ecological zones of Bangladesh**

Khan (1994) stated that more than 5,000 species of flowering plants and 1,500 species of vertebrates, of which approximately 750 are birds and over 500 are coastal estuarine and freshwater fish exist in wetland areas. Some 400 vertebrate species and about 300 plant species are dependent on wetlands for all or part of their life spans. Freshwater capture fishery is an important source of employment in the fishery sector and a supply source of animal protein. About 260 species of freshwater fish exist in wetlands of Bangladesh.

Plant resources constitute both wild and cultivated plants. Among the cultivated plants, agricultural crops are the most important ones, which include rice, wheat, jute, cotton, sugarcane, tobacco, tea, fruits, vegetables, pulses, oilseeds and species (GOB-IUCN, 1992).

Wetlands are important habitats for a large variety of flora and fauna of local, national and regional significance. In the freshwater wetlands the floral composition includes trees (eg Hijal (*Barringtonia acutangula*), Madar (*Erythrina variegata*), Gab (*Diospyros peregrina*), Jaldumur (*Ficus sp.*), Barun (*Crataeva nurvala*), Chitki (*Phyllanthus reticulatus*), etc); herbs (eg grass, creepers, thankuni (*Centella asiatica*), kalmi (*Ipomoea aquatica*), helencha (*Enhydra flactuans*), etc); shrubs and aquatic vegetation (eg duckweed, water hyacinth, lotus, water lily) (GOB-IUCN,1992). Moreover, grasses are most abundant in this floodplain.

Bangladesh supports a wealth of faunal diversity, including some 113 species of mammals, 628 birds, 126 reptiles, 22 amphibians, 708 species of freshwater and marine fish, about 400 species of mollusks, 70 bees and many other species (GOB-IUCN, 1992). Both floral and faunal diversities have important effects on eco-hydrology.

Bangladesh is home to an extraordinary array of animal species, the majority of which are wetland dependent. According to IUCN (2000) the country contains 266 inland fishes, 442 marine fishes, 22 amphibians, 109 inland reptiles, 17 marine reptiles, 388 resident birds, 240 migratory birds, 110 inland mammals and 3 marine mammals. The IUCN review of the status of the vertebrate fauna revealed that 54 inland fishes (20%), 8 amphibians (36%), 58 inland reptiles (53%), 41 resident birds (11%) and 40 inland mammals (36%) have come under different categories of threat in Bangladesh. The Royal Bengal Tiger, Gharial and Phallas Eagle are among the critically endangered species.

## 2.5 Studies of land Use change

Studies of land use change have become an important field world-wide (Lovejoy, 1979). Land-use change is a common term representing the human modification of the earth's terrestrial surface. It includes deforestation, road construction, agricultural development, dam building, irrigation, wetland modification, mining, the concentration and expansion of urban environments and other activities. These changes encompass the greatest environmental concerns of human populations today, including climate change, biodiversity loss and the pollution of water, soils and air. Patz et al. (2000) observed that human- induced land use changes are the primary drivers of a range of infectious disease outbreaks and emergence events and also modifiers of the transmission of endemic infections.

Mati et al. (2008) conducted a study on the impacts of land use changes on the hydrology of the Mara River, Kenya. This study utilizes remote sensing and geographical information systems (GIS) tools and ground-truth studies to determine the magnitude of the land use changes in the Mara river basin, and the effects of these changes over the last 30 years. These changes have been attributed to the encroachment of agriculture. Agricultural encroachment represented a net decline of 34% in area. It has increased the vulnerability of thousands of wildlife, posing a risk to the sustainability of their natural habitats. Land degradation particularly deforestation also affected the natural resource base and the river flows. The hydrology of the Mara River also has changed, with sharp increase in flood peak flows by 7% and an earlier occurrence of these peaks between 1973 and 2000.

Ndhlovu et al. (2009) assessed the impacts of land use on biodiversity in Intunjambili Wetland, Matopos, Zimbabwe. The objective of the study was to assess and evaluate the impacts of land use practices on wetland health. The study found 57.9% increase in cultivated areas, 48.5% decline in woodland and 50% decline in wet areas. The study used NDVI values to measure the decline in vegetation health. There was a significant decline in vegetation health with NDVI values as high as 0.64 in 1990 decreasing to values as low as 0.07 in 2008. The impacts were mainly on vegetation, which has deviated from its perceived natural wetland vegetation and reduction of water.

Kashaigili et al. (2009) carried out an integrated assessment of land use and cover changes in the Malagarasi river catchment in Tanzania. Landsat TM and ETM + images and perceptions of local people on historical changes and drivers for the changes were also collected in this assessment. The study found that increased anthropogenic activities have had negative impacts on the wetland. Kashaigili described that the sustainability of ecosystems requires proper use of land and management of water. Between 1984 and 2001, the woodland and vegetation covers declined by 0.09% and 2.5% per year, respectively. The settlement and cultivation increased by 1.05% while the grassland increased by 1.93% annually. The study concludes that there have been significant changes in land use and these require concentrated actions to reserve the changes. The study highlights the importance of integrating remote sensing with local knowledge. It will ultimately inform the policy and decision makers on a need for proper land planning and improvement in agricultural practices for the sustainability of the catchment resources.

Land use in Bangladesh is determined mainly by the monsoon climate and the seasonal flooding which affects the greater part of the country. These physical determinants are reinforced by high population pressure and increasingly, by alterations to the natural environment through flood protection, drainage and irrigation interventions.

Dewan and Yamaguchi (2009) conducted a study on land use and land cover change in Greater Dhaka over a period between 1975 and 2003. The study observed significant decrease in the area of water bodies, cultivated land, vegetation and wetlands. Urban land expansion has been largely driven by population growth and economic development. They found that rapid urban expansion through infilling of low-lying areas and clearing of vegetation resulted in a wide range of environmental impacts, including degradation of habitat quality.

Bangladesh is one of the most densely populated countries in the world. The rapid growth of population impedes the agricultural development of this country. Agriculture in Bangladesh is already under pressure both from huge and increasing demands for food and problems of agricultural land and water resources depletion. The proliferation of high yielding varieties of rice requires increased amount of fertilizer, pesticides and irrigation. Fertilizer sales is increased about four times from 1980-81 to 2003-04 (BBS, 2005). Sales of fertilizer in Bangladesh have increased substantially over the years which are evident in Figure 2.4.

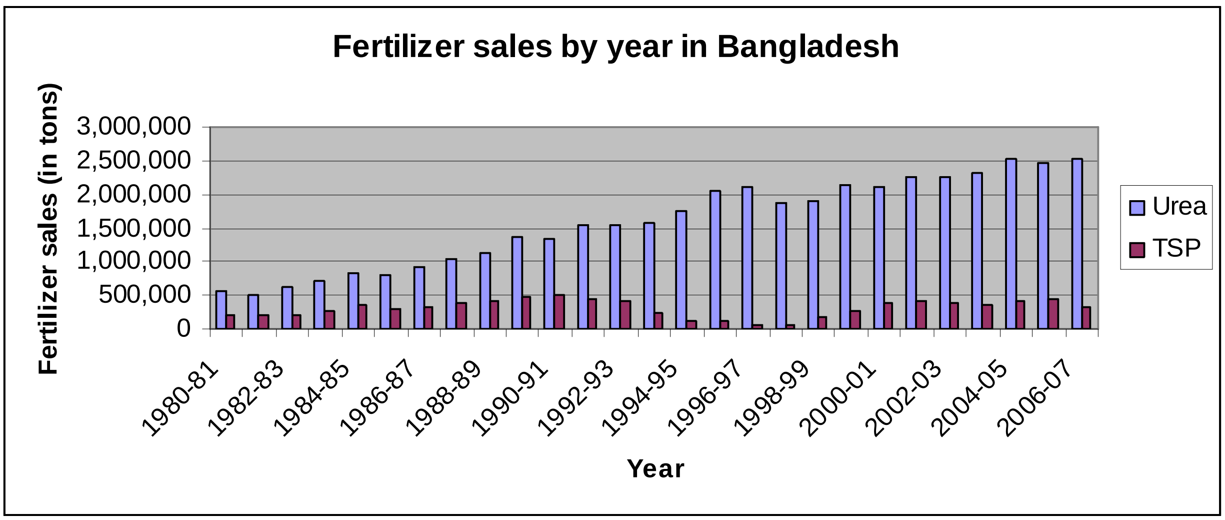



**Figure 2.4: Fertilizer sales in Bangladesh during 1980-81 to 2006-07 (BBS, 2007)**

In Bangladesh, growing use of pesticides and fertilizers by the farmers poses a big challenge to health, environment and the declining of the economy of the country (Parveen and Nakagoshi, 2001). Bazrman and Das (2000) conducted a study to investigate the impact of pesticides on biodiversity in Bangladesh. They found that biodiversity is declining due to the effect of pesticide and fertilizer use.

Jimoh et al. (2003) found an increase in N and P concentrations in surface and ground water, exceeding the safe drinking water standard, after fertilizer application in an irrigation scheme in Nigeria. Similar decline in water quality from excess nutrient in irrigation return flow in many developing countries is reported by Pearce (1998). Excess nutrient load in water bodies are known to have severe impacts on public health and environment in developing countries. These include methaemoglobinaemia, commonly known as “blue baby syndrome”, liver and lung damage, cancer, eutrophication in receiving water bodies and large scale algal blooms (Pearace, 1998; Ongley, 1996)

Rola and Widawsky (1998) found that some extremely hazardous pesticides are used in Bangladesh, although these are prohibited in the producing countries. Meisner (2004) and NOVIB (1993) found that many pesticides used in Bangladesh are banned or restricted under international agreements. Rahman et al. (1995) conducted a survey on the use of the pesticides in Bangladesh as part of the IAEA agrochemical residues project. They found that total pesticide consumption doubled over the previous 6 years.

EGIS (2002) conducted a study of eutrophication in water bodies. Eutrophication is the process of water bodies becoming enriched in nutrients, particularly phosphorus and nitrogen. This process results into degradation of water quality. EGIS (2002) monitored the surface water quality in a beel area in Rangpur and followed an analytical and a modeling approach to assess the eutrophication potential of nitrogen emission from fertilizer application. Nitrate concentration as high as 8.5 mg/L in the beel water was attributed to agricultural runoff. Local people informed that this water body receives runoff water from a large catchment area of a paddy field, where use of fertilizer was a common practice. It was informed from the fishermen that they observed enough fish food (phytoplankton) in the water body during dry season, which might be algal bloom. During field observation, it was observed that the water of the beel was greenish in color and bad odor was produced.

Addition of nitrogen and phosphorus to the water bodies has many significant and negative environmental impacts, especially in relation to ecology, health and economic aspects. The possible major sources of nutrients and their consequent effect on water body are summarized and presented in Figure 2.5.

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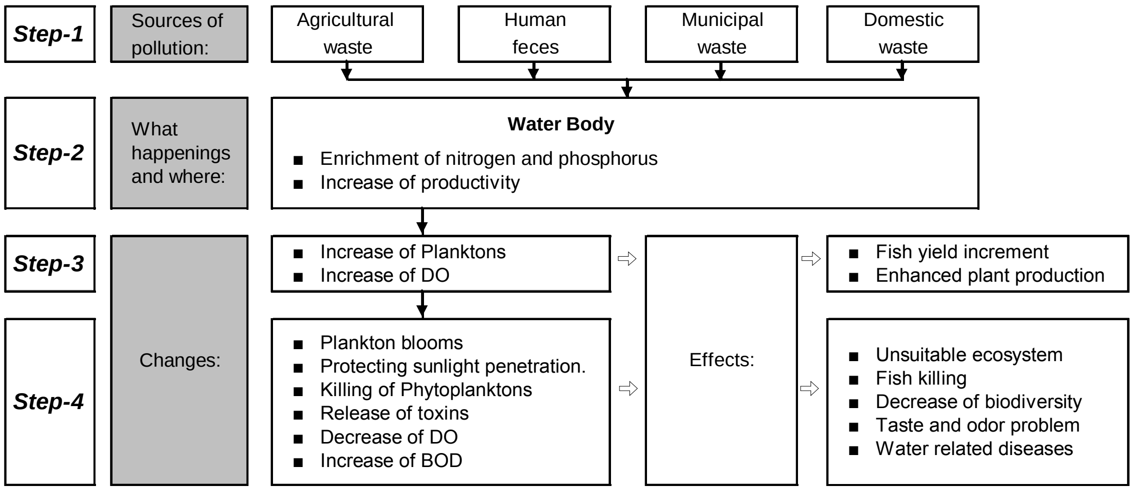



**Figure 2.5: Schematic Diagram of Degradation of Water Quality and Its Effects (Source: EGIS, 2002)**

Khan et al. (2006) conducted a study on pollutant contribution of fertilizers to surface and ground water. Surface and ground water quality was monitored during the Aman and Boro season of 2005-06 in an intensively rice-cultivated area, the 45 ha of Bangladesh Rice Research Institute, Gazipur. Field observations indicated that approximately 4.53kg/ha and 6kg/ha nitrogen were transported to the receiving surface water bodies from the two drainage compartments or blocks of the study site during a rain fed crop season in an average rainfall year. Corresponding phosphorus loads were 2.16 kg/ha and 2.35 kg/ha. They monitored N and P concentrations at the surface water in different locations. The overall concentrations were relatively low.

Alam et al. (2001) monitored the presence of excess fertilizers by measuring levels of ammonium, nitrate, phosphate and potassium to assess the impact of agricultural practices on ground water quality and found relatively high concentrations on ammonium and nitrate.

Because of the risks of pollution associated with the use of agrochemicals including fertilizers, the National Water Management Plan (NWMP) (WARPO, 2001) emphasizes that agrochemicals should be used more carefully to minimize their effects on the environment, and that their residues in receiving water bodies should be monitored. Since N and P fertilizers applied to rice plants, especially the High Yield Varieties (HYV), are most widely used agro chemicals in Bangladesh, pollution risks of their application are likely to be higher.

The reduction of biodiversity, aquatic and amphibian resources, and wildlife habitats lead to the change in wetland-based human occupations and shrinkage of socio-economic activities (Islam and Sadque, 1992). Hossain (2009) carried out a study on Arial Beel in Bangladesh. This study has revealed how the use of pesticides in agricultural lands has affected the ecological resources of freshwater wetlands. He found that ecological resources are decreasing in Arial beel. As a consequence of resource degradation, the beel dependent people lost their occupations which have led to social conflicts in the adjacent areas.

Hossain (2009) described that almost all of the pesticides used by the farmers during the boro season have very high to medium impacts on the indicator species such as catfish, daphnia, algae and rat. However, two widely used pesticides ( Basudin and Furandan) have very high and high impacts , respectively on the ecological resources. In his study, qualitative assessment revealed that Basudin has the highest impact score of 4.5 which means that if the first rainfall occurred within 7 days of application of this pesticide, 75% of the indicator species would be affected. The cumulative impact score for all of the pesticides used by the farmers in the Arial Beel was found to be 3.03 which indicated that approximately 50% of the total ecological resources would be degraded if time interval between the application of the pesticides and the first rainfall was less than 13.5 days. If boro season of the Arial Beel area was started 10 days earlier, substantial protection of ecological resources could be ensured by minimizing rainfall induced migration of pesticides from rice fields to ponds.

### 2.6 Determinants of Ecohydrology

Scientists, environmental managers and researchers are concerned about land use change and they have detected some factors for eco-hydrological processes. The most important determinants of ecohydrology are physiography, soil, climate, hydrology and water quality parameters (Fu et al. 2005). These factors are discussed in context of Bangladesh in the following parts.

### 2.6.1 Physiography

Bangladesh occupies a unique geographic location. Based on the geological and geo-morphological characteristics, Bangladesh has been divided into three major physiographic regions: floodplain areas, terrace areas and hilly areas (Brammer, 1996). The broad divisions are shown in figure 2.6.

*The Hills:* The total area of the hilly areas is 12% of the country, situated in the south-east (Chittagong Division) and the north-east (Sylhet Division). The hills of the south-eastern range in Hill Tracts are 610 meters in average height and are covered with evergreen forest. The hills of north-east are of lower heights with only a few of these are still covered with evergreen forest.

*The Terraces:* The Barind region of Rajshahi division and Modhupur tract of Tangail and Mymensingh districts principally comprise this region. The terraces occupy about 8% of the country. The Barind region is 6-12 meters elevation above the floodplain. The elevation of Modhupur tract from the plain differs from 6 to 30 meters from place to place. The Modhupur tract is covered with *Sal* forest.

*The Floodplain:* Apart from the hilly region and the terraces, the rest of Bangladesh (about 80%) is included in floodplain region, about 10% of which is under tidal regime. Numerous rivers, small and large are spread over the land like a network (Figure 2.4). Except for the Chittagong Coastal Plain, the rest of the rivers and their floodplain belong to Ganges-Brahmaputra-Meghna river system. The floodplain contains numerous water bodies of various shapes and sizes spread all over the country.

The floodplain in Bangladesh is classified into five major categories. They are: active river flood-plains, meander floodplains, piedmont plains, estuarine floodplains and Tidal floodplains (Brammer, 1996).

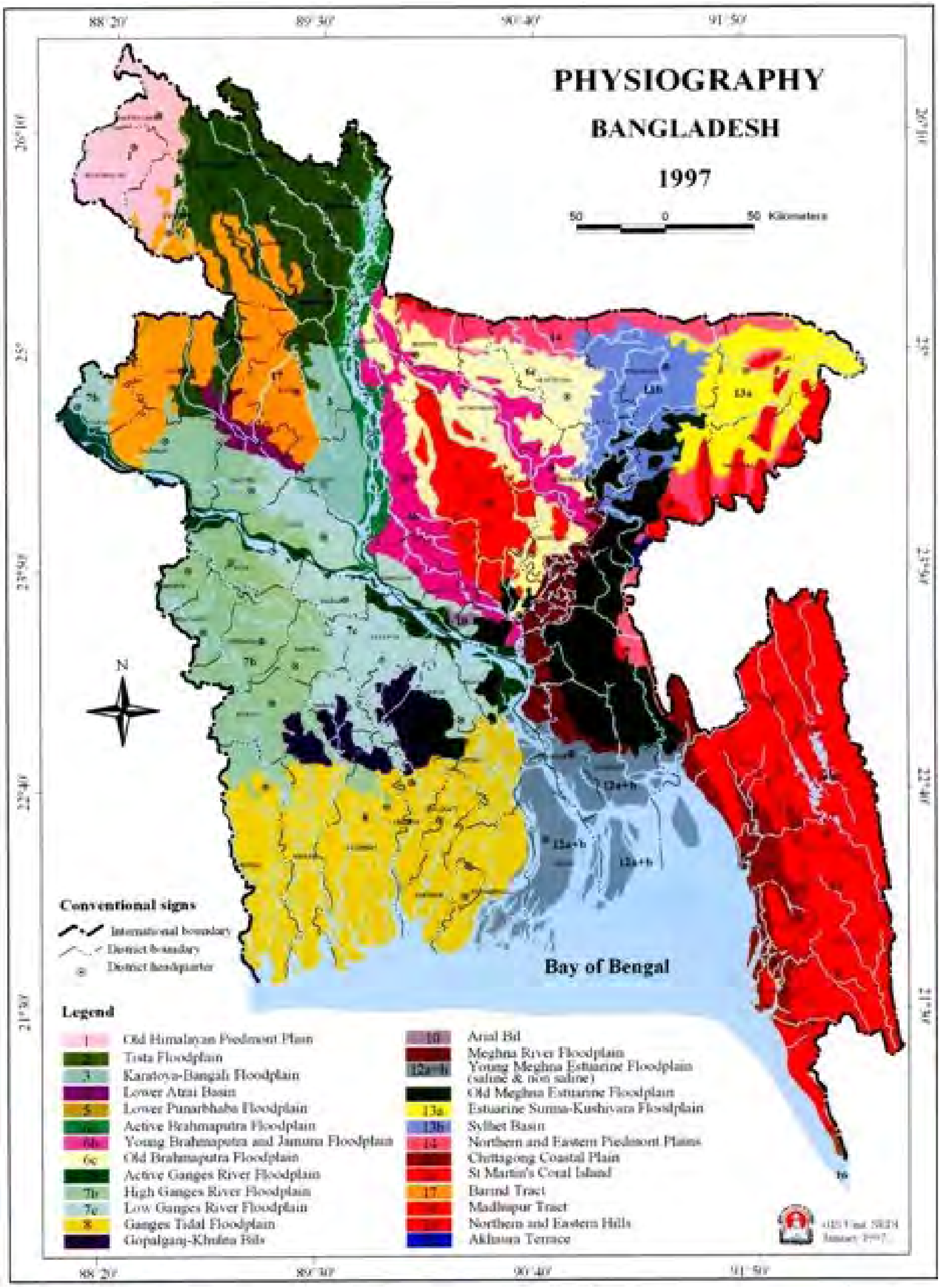



**Figure 2.6: Physiography of Bangladesh**

### 2.6.2 Soil

Bangladesh, in general, has alluvial soils. A total of 21 general soil types have been recognized in Bangladesh. This is a non-technical grouping of soils which have formed in the same way and which have a broadly similar appearance (Brammer, 2000). This diversity of soil provides diverse and complex patterns of land use, crop suitability, soil fertility and agronomic practices in many parts of Bangladesh. It has important implications for agricultural research, extension and the collection of crop statics.

The soil resource can be subdivided into five major groups: flood plain, hill terrace, manmade and miscellaneous land soils. Floodplain soil constitutes about 66.4% of the total soil area of the country. Hilly areas cover 10.8% while terrace areas cover 7.1% of the country's total soil. Man made constitutes only 0.7% of the total soil area. Lastly miscellaneous land soils are not conveniently classified as soil. They include urban, homestead land, roads, embankments, bare rock surfaces, rivers and other areas which remain permanently inundated (Brammer, 1996)

Differences between soils usually are due to texture, infiltration capacity, organic matter and chemical properties of soil. Texture is the dominant property which determines the erodibility of soil. Soil structure, organic matter, water content or compactness as well as chemical or biological characteristics of the soil also influence erodibility (Elliot et al.1993). The infiltration capacity depends on the porosity of a soil which determines the water storage capacity and affects the resistance of water to flow into deeper layers. Porosity differs from one soil type to other. The highest infiltration capacities are observed in loose, sandy soils while heavy clay or loamy soils have considerable smaller infiltration capacities (Critchley et al. 1991).

### 2.6.3 Climate

The Tropic of Cancer passes across almost the middle of Bangladesh. Therefore, it has a tropical monsoon climate. The climate is governed by the wet south-west monsoon that begins in June and continues to October, and the dry period that begins in November and continues through to May. While there are six seasons in a year, three - summer (mid April - mid June), monsoon (mid June to mid August) and winter (mid December to mid February) - are prominent.

*Rainfall:* The monsoon carries warm moist air that produces some of the highest rainfalls in the world over the catchments drawing into Bangladesh from the Indian state of Meghalaya. WARPO (2002) described that mean annual rainfall increases from about 1,500 mm in the west to almost 5,000 mm in the extreme north-east , about 80% of it occurring during the south-west monsoon period.

*Temperature:* The mean annual temperature is about $25^0$C within the country. Mean monthly temperatures range between $18^0$C in January and $30^0$C in the months from April to May. The highest and lowest temperatures throughout the year range between $43^0$C and $4^0$C with the exception in the areas near the coast where the range is narrower.

*Day-Length and Sunshine:* Except for a small variation in the bordering areas in the east and the coastal fringe, day-length and sunshine hours throughout the whole country are in general almost the same. Day-length at Dhaka varies from 10.7 hours in December to 13.6 hours in June. Sunshine at Dhaka ranges from 5.4-5.8 hours/day in the monsoon season to 8.5-9.1 hours/day in the winter (from December to February) and pre-monsoon (from March to May) seasons (WARPO, 2002)

*Wind:* The wind direction is mainly south-west and south-east during the pre-monsoon and monsoon and from between north-west and north-east during the post-monsoon (from October to November) and winter seasons (WARPO, 2002). Tropical cyclones from the Bay of Bengal with high velocity of more than 115 km/hr are liable to hit the coastal areas in the pre-monsoon and post-monsoon seasons.

*Humidity:* The humidity is relatively high throughout the year. It is over 80% during the monsoon. The humidity is around 60% in most of the western areas of Bangladesh in March and April and in the eastern areas in January, February and March.

*Evaporation:* Evaporation rates range from about 50-75 mm per month in the dry season to 100-175 mm per month in the pre-monsoon season. In the monsoon, they are generally about 100-

125 mm. Annual potential evapo-transpiration rates range from about 1,180 mm in the north-east to 1,285 mm in the centre-west (WARPO, 2002)

### 2.6.4 Hydrology

The entire country has been divided into eight hydrological regions (WARPO, 2001) as shown in Figure 2.7. The areas of the regions are given in Table 2.2.

**Table 2.2: Areas of Hydrological Regions (Source: WARPO, 2001)**

| **Region** | **Gross Area** | **Gross as % of total** |
|---|---|---|
| South-West (SW) | 26,226 | 17.7 |
| South-Central (SC) | 15,436 | 10.4 |
| North-West (NW) | 31,606 | 21.3 |
| North-Central (NC) | 15,949 | 10.8 |
| North-East (NE) | 20,061 | 13.5 |
| South-East (SE) | 10,284 | 6.9 |
| Eastern Hills (EH) | 19,956 | 13.5 |
| Rivers and Estuaries (RE) | 8,607 | 5.7 |
| Total | 148,130* | 100.0 |

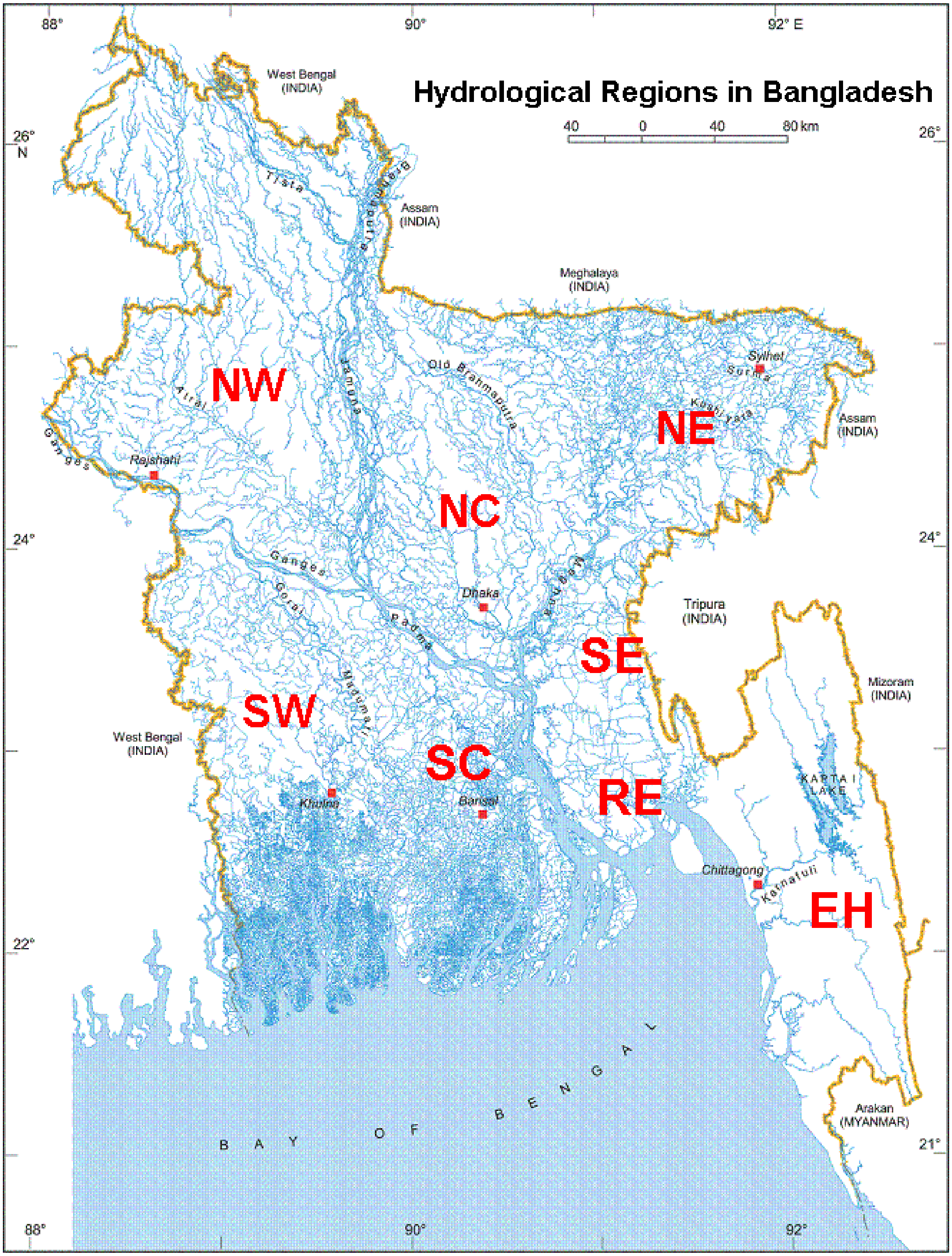



**Figure 2.7: Hydrological Regions in Bangladesh (Source: WARPO, 2002)**

River flow, floods and flooding are important terms in hydrology. Heavy rainfall occurring within the Ganges-Brahmaputra-Meghna catchment area, together with summer snow melt in the Himalayas, causes the main rivers to rise rapidly in May-June, reach peak levels in July-August and then gradually recede to low levels in March-April (Brammer, 2000). Rivers and streams flowing from adjoining hill areas are subject to flash floods. Storm surges associated with tropical cyclones cause the flood in coastal areas.

### 2.6.5 Water Quality Parameters

Water quality parameters are important factor to determine the ecohydrological situation of an area. Some of important water quality parameters are discussed in below.

**pH:** In chemistry, pH is a measure of the acidity or basicity of an aqueous solution. pH measurements are important in medicine, biology, chemistry, agriculture, forestry, food science, environmental science, oceanography, civil engineering and many other applications.

**Conductivity:** The conductivity (or specific conductance) of an electrolyte solution is a measure of its ability to conduct electricity.

**DO:** Dissolved oxygen (DO) is a relative measure of the amount of oxygen that is dissolved or carried in a given medium.

**Color and TSS:** Total Suspended Solids, usually abbreviated TSS, and color are important water quality measurement.

**TDS:** Total Dissolved Solids (often abbreviated TDS) is a measure of the combined content of all inorganic and organic substances contained in liquid.

**Alkalinity:** Alkalinity measures the ability of a solution to neutralize acids to the equivalence point of carbonate or bicarbonate.

**Hardness:** Hard water is water that has high mineral content (in contrast with "soft water"). Hard water is generally not harmful to one's health. In domestic settings, hard water is often indicated by a lack of suds formation when soap is agitated in water.

**Ammonia:** When applied to soil Ammonia, used as fertilizers either as its salts or as solutions, helps provide increased yields of crops such as corn and wheat. Ammonium-N enters wetlands primarily through surface runoff. In the wetland, ammonia is absorbed by plants or converted to nitrogen gas through volatilization.

**Iron:** Iron is not hazardous to health, but it is considered a secondary or aesthetic contaminant.

**BOD:** Biochemical oxygen demand or BOD is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period. The term also refers to a chemical procedure for determining this amount. This is not a precise quantitative test, although it is widely used as an indication of the organic quality of water. The BOD value is most commonly expressed in milligrams of oxygen consumed per liter of sample during 5 days of incubation at 20 °C and is often used as a robust surrogate of the degree of organic pollution of water.

**COD:** The chemical oxygen demand test is commonly used to indirectly measure the amount of organic compounds in water. It is expressed in milligrams per liter (mg/L), which indicates the mass of oxygen consumed per liter of solution.

**Nitrate:** In freshwater or estuarine systems close to land, nitrate can reach high levels that can potentially cause the death of fish. In most cases of excess nitrate concentrations in aquatic systems, the primary source is surface runoff from agricultural or landscaped areas that have received excess nitrate fertilizer.

**Phosphate:** A phosphate, an inorganic chemical, is a salt of phosphoric acid. Addition of high levels of phosphate to environments can have significant ecological consequences.

# CHAPTER THREE
# DESCRIPTION OF THE STUDY AREA

## 3.1 Introduction

The site chosen for the study is Arial Beel. It is a large depression between the Ganges and Dhaleswari rivers south of Dhaka. It has much in common with the lower Atrai Basin and Gopalganj-Khulna Beel. Arial Beel occupies a low lying basin between the Ganges floodplain and the Young Brahmaputra floodplain south of greater Dhaka district. Seasonal flooding is deep in the basin-centre and moderately deep on the higher margins. The centre of the basin remains wet for most of the dry season (GOB- IUCN, 1992).

## 3.2 Location

Arial Beel is one of the major wetlands of Dhaka and Munshigonj districts. As an agro-ecological zone (AEZ-15) (FAO, 1988) and part of Bio-ecological zone 4b (IUCN, 2002), the Arial Beel has a great ecological, commercial and socio-economic importance. It lies approximately between 23˚32´N to 23˚48´N latitudes and 90˚08´E to 90˚27´E longitudes. The total area of the beel is 14436 ha. Figure 3.1 shows the agro-ecological zones of Bangladesh where number 15 represents Arial Beel.

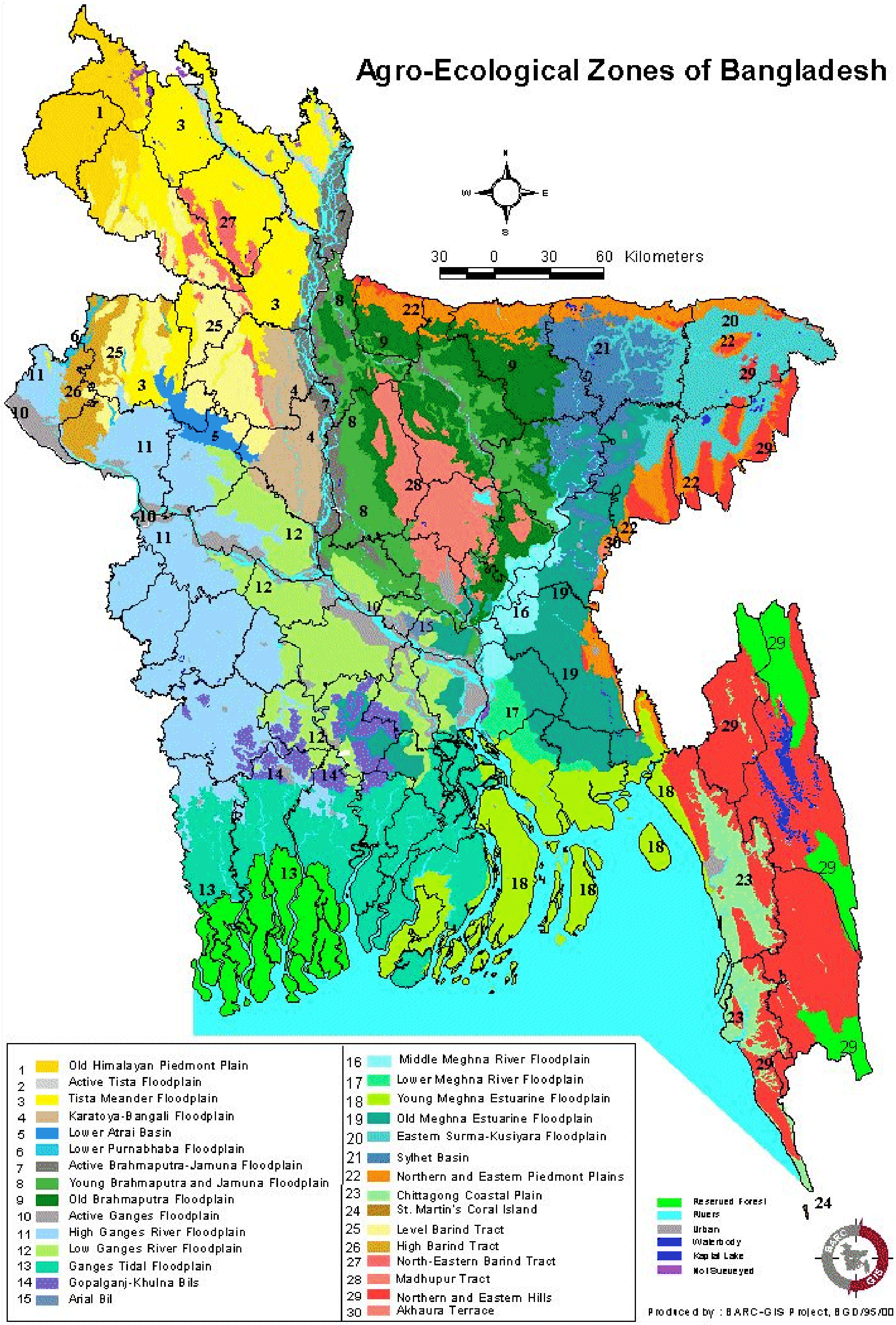



**Figure 3.1: Agro-ecological zones of Bangladesh**

The Arial Beel belongs to Dhaka and Munshigonj districts and covers areas under four upazillas namely Dohar, Nawabgonj. Sreenagar and Sirajdhikhan of which Dohar and Nawabgonj are in Dhaka district and Sreenagar and Sirajdhikhan are in Munshigonj district. The greatest portion (67%) of the beel belongs to Sreenagar upazilla which is followed by Nawabgonj upazilla (24%). The least portion of the beel (4%) belongs to Dohar upazilla. Figure 3.2 shows the areal distribution of the Arial Beel.

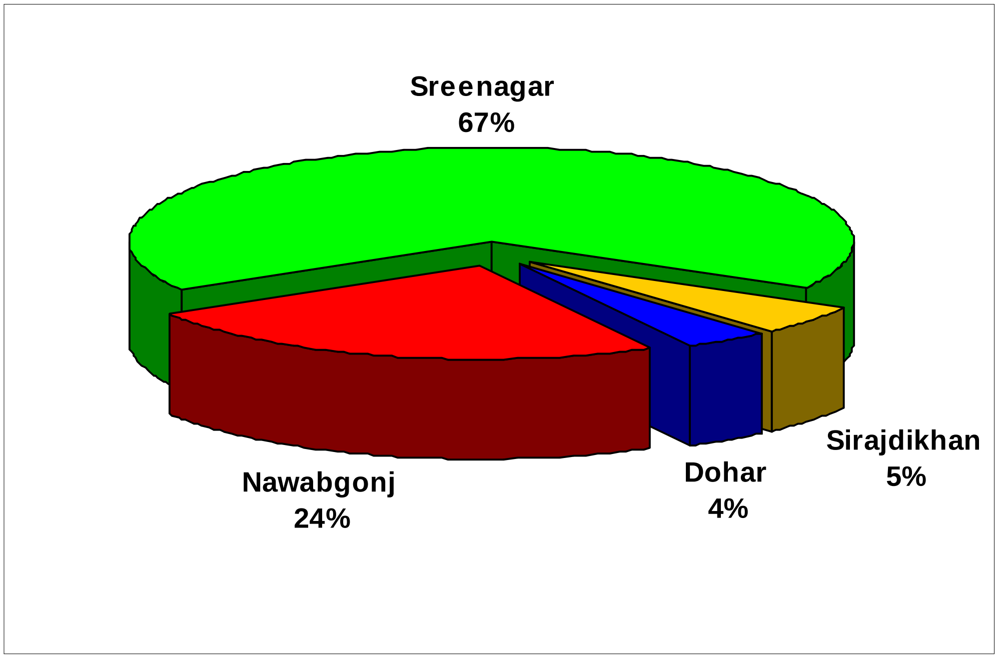



**Figure 3.2: Distribution of the Arial Beel in four upazillas**

### 3.3 Delineation of Study Area for Land Use Characteristics

Arial Beel is not a well defined administrative unit – it is a natural wet-land encompassing several unions across four upazillas. The exact demarcation of the beel area (wet-land) changes depending on the seasonality. Areas which are inundated during monsoon season often become dry land in the winter. Even in two different years during the same season the demarcation of the beel may be different due to difference in rainfall and level of flooding. As such it was necessary to specify the exact dimension of the study area.

It can be generally assumed that manmade land use changes are more prominent near human habitats. Since the main focus of this paper is land use change, the unions covering larger share of wetland surrounded by human settlements were selected as the study area. This objective was achieved through consultation with GIS specialists at CEGIS (Centre for Environment and Geographic Information System). Based on such consultation, the area under the following 15 unions was demarked as the study area: Churain, Galimpur, Baksnagar, Barrah, Kalakopa and Agla unions under Nawabganj Upazila in Dhaka district; Chitrakot, Rajanagar, Kaiyan and Basail unions under Serajdhikhan Upazila in Munshiganj district and Sreenagar, Baraikhali, Hasara, Birtara and Sholagar unions under Sreenagar Upazila in Munshiganj district. Figure 3.3 shows the map of the study area.

### 3.4 Climatic Condition

The nearest BMD station to Arial Beel is in Dhaka. The mean annual rainfall is about 2035 mm, compared to the national average of 2300 mm. Annual rainfall, and however shows considerable variability from year to year. The rainfall also varies considerably within a year (Figure 3.4), with 79% of rainfall occurring in five months from May to September. Arial beel is located in the sub-tropical monsoon climate with hot wet summer from May to September and cool dry winter months. In Arial beel, the maximum temperature varies from 25.2°C to 33.9°C and it is experienced during the pre-monsoon period. Average monthly minimum temperature ranges from 12.4°C to 26.2°C.

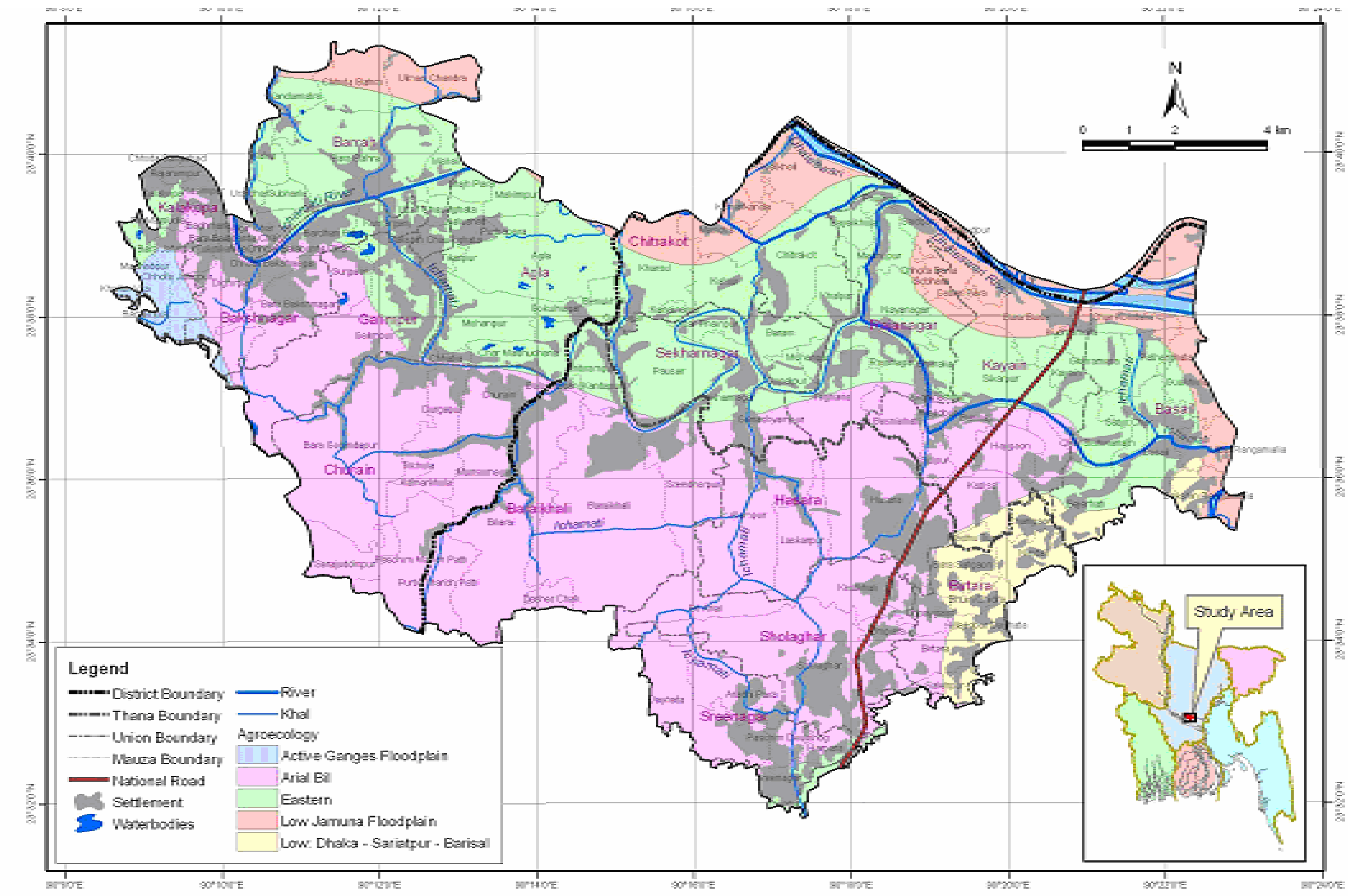



**Figure 3.3: Map of the study area with mouza boundary**

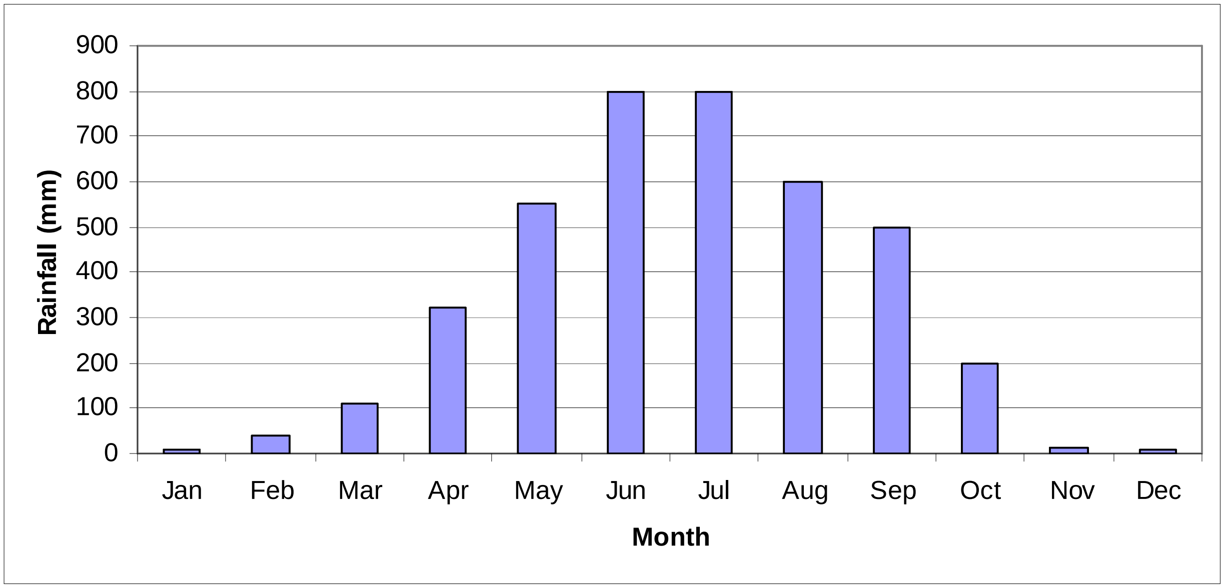



**Figure 3.4: Variation of monthly rainfall in Arial Beel**

### 3.5 River Systems

The Arial Beel lies between the Ganges and the Dhaleshwari rivers. The Ichamati river also flows through the beel area, receiving a large quantity of runoff during the monsoon from its territorial settlements, and acting as a drainage outlet of the inundation water of parts of Arial Beel located in Dohar, Nawabgonj, Sreenagar and Sirajdhikhan upazillas.

### 3.6 Land Types of the Study Area

In Sreenagar thana, 75% of total land-mass is used for agriculture, 5% is covered with rivers and ponds and another 20% includes settlement and fallow land. On the other hand, in Serajdhikhan thana, 67% area is used for cultivation of which 80% is under irrigation and rest 20% under natural wetland (Arial Beel). Settlement and fallow land occupies remaining 30 % of land. In Nawabganj thana, total cultivable land is 74%. Fallow land and settlement covers 22% of the total area. Another 4% is covered by permanent water bodies (Banglapedia, 2006). Figure 3.5 shows the settlement area of the Arial Beel. Figure 3.6 shows the graphical representation of land types of the study area.


**Figure 3.5: Satellite Image of Arial Beel showing the settlement area (2012)**

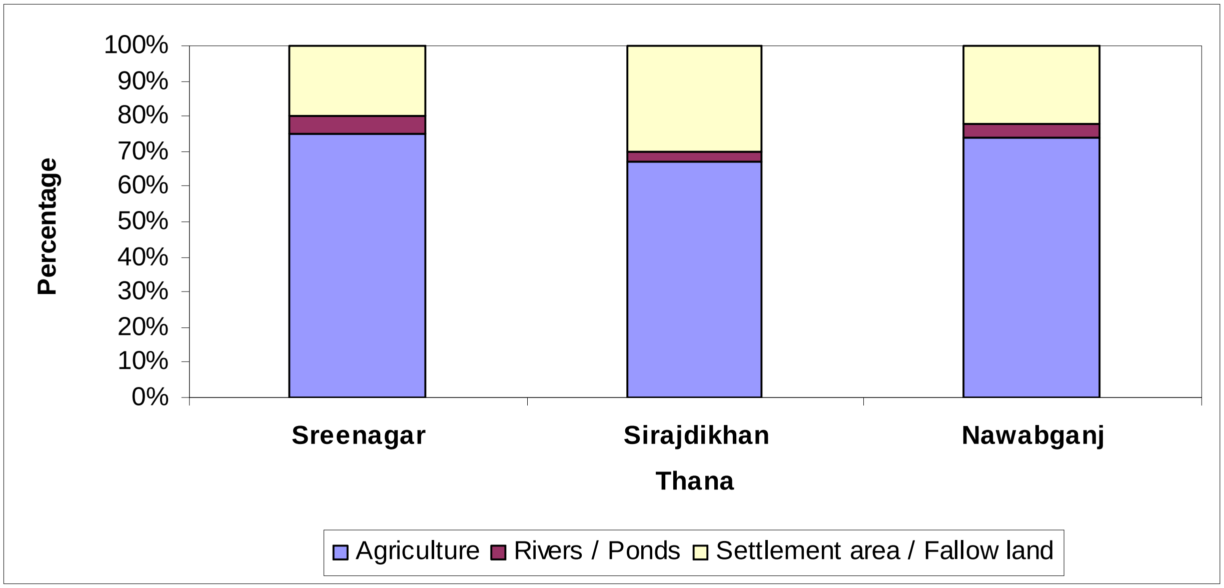



**Figure 3.6: Graphical representation of land types of the study area (Source: Banglapedia,2006)**

## 3.7 Agriculture and Fisheries in the Study Area

Agriculture is the main practice in relatively higher zones of the beel and the deeper portion of the beel is important for floral and faunal diversity. In the past, Aman was mainly practiced there. With the introduction of Low lift Pumps (LLPs) in the 1960s and Shallow Tube Wells (STWs) in the 1970s and 1980s, high yielding variety (HYV) Boro production became prominent. HYV is cultivated in both medium lowland and lowland the yield goal is 6.80±0.50. But in kharif season almost all lands remain fallow. Jute is cultivated as a kharif-1 crop. Besides this in some cases it was found that Grasspea and Mustard is cultivated as rabi crops and Aus and Aman are cultivated as Kharif crops.

Table 3.1 shows the cropping pattern of the Arial Beel with estimated goal for production. It is found that both rain fed and irrigated crops are cultivated in the beel though most of the beel are lowland. HYV Boro is mainly practiced here (BARC, 2005). According to BARC (2005), farm holdings also produce jute, wheat, pulses, cash crops, species and vegetables. It is famous for production of potato and pumpkin.

**Table 3.1: Crop grown in Arial Beel**

| Land Type | Water Source | Season | Crop | Yield Goal(t/ha) |
|---|---|---|---|---|
| Medium Low Land | Rainfed | | Potato | 12.00±0.20 |
| | | Kharif-1 | Jute | 1.80±0.30 |
| | | Rabi | Grasspea | 1.00±0.10 |
| | | Kharif | Aus+ Aman | 2.50±0.30 |
| | | Rabi | Mustard | 1.00±0.10 |
| | | Kharif | Aus+ Aman | 2.50±0.30 |
| | Irrigated | Rabi | Boro | 6.80±0.50 |
| | | Kharif | Fallow | |
| Low Land | Irrigated | Rabi | Boro | 6.80±0.50 |
| | | Kharif | Fallow | |

Source of data: (BARC, 2005)

Arial Beel is a wetland of ecological, economic, commercial and socio-economic significance. Fish is one of the most important resources of the beel. Approximately 260 species of fin fishes and 25 shell fishes are available there (Islam, 2000). The fish species found in the beel include kholisha, bele, mola, dhela, taki, punti, meni, singi, magur, chanda, baim, pholi, darkina etc. Fishes like aire, gazar, major carps like rui, catla, mrigal and kalbaus also visit the Arial Beel to feed and grow. In addition, several species of freshwater mussels and snails are also found in beel area.

There are many large dighis/depression areas in beel area. The smallest size is 21' x 21'. The largest size is 700' x 700'. There are around 500 dighis in beel area. In monsoon, local people catch fish from open water bodies. But in October/November, beel becomes dry and at that time, they catch fish from the dighis only. Arial Beel is a large source of capture fisheries. Recently, capture fisheries is also practiced there.

## 3.8 Socio-economic Condition of the Local People

The rural economy is predominantly agrarian. Almost fifty percent of local people are involved in agriculture. Another fifty percent are related with other occupations like pisciculture, live stock farming, weaving, construction, commerce and industry, service and others. Live stock farming is a good source of income of the people in Sreenagar upazila.

**Figure 3.7: A photograph showing local people engaged in husking rice**

Hossain (2009) conducted a survey to find out the socio-economic conditions of the community residing in the deep zone of the beel who are directly or indirectly dependent on the beel for their lives and livelihood. From the surveys, it was found that most of the people belonged to the low-income group who had annual income of less than Taka 20,000 and most of the members of this group were professional fishermen. On the other hand, only 7% of total population had the annual income of more than Taka. 100,000.

**Figure 3.8: A photograph showing young local boys catching fish in the beel**

The lives and livelihood of the fishermen mostly depend on the availability of fish in the beel. The living standard of the fishermen communities was found to be very simple and mainly regulated by the availabilities of fish in the wet land. Usually the children of poor fishermen communities do not go to school and help their parents in fishing and its associated activities (Figure 3.8). The poor fishermen and their families spent their whole day in fishing and their associated activities like weaving and repairing of nets, processing of fish for selling in the market, etc. Due to decrease of fish in the beel areas, the socio-economic conditions of those communities became worse day by day.

# CHAPTER FOUR

# ECOHYDROLOGICAL CHARACTERISTICS OF ARIAL BEEL

## 4.1 Introduction

The term ‘eco-hydrology’ refers to an integrated approach that aims to analyze and quantify the interactions between biological and hydrological processes at a catchment scale (Trepel and Kluge, 2002; Zalewski, 2002). In the context of wetland research, a variety of components are linked with hydrology, as depicted in Figure 4.1. Ecology, with components such as vegetation, nutrients and soils, is the principal component that is affected by hydrology. Hydrology is the primary control on the complex interactions between biological and ecosystem function (Trepel and Kluge, 2002; Blyth, 2011). Vegetation composition in wetlands is controlled directly by water movement and its abundance. Aquatic biology will also change relative to hydrological processes, where macro-invertebrates and fish species will be less or more abundant depending on food sources (nutrients and vegetation detritus) and hydrological stability (Blyth, 2011).

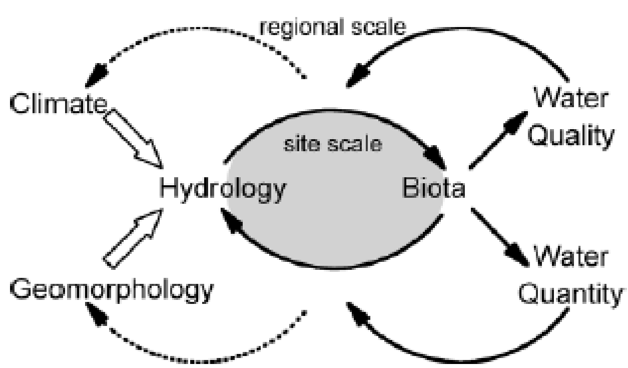



**Figure 4.1: The concept of eco-hydrology (Source: Trepel and Kluge, 2002)**

Conventional wetland eco-hydrological studies typically include ‘functional assessments’ principally for evaluating the potential impacts of developments which threaten wetland ecosystems by evaluating the change in wetland functioning over time, and ‘biological assessment’ or bio-assessment to evaluate a wetland’s ability to support and maintain a balanced, adaptive community of organisms having a species composition, diversity and functional organization comparable with that of minimally disturbed wetlands within a region (DWAF, 2004). Within an ecosystem evaluation framework, 'habitat assessment is often used alongside bio-assessment, to provide information on the quality, quantity and suitability of the physical environment supporting the biota being measured'. The studies typically include doing the field assessments along a transect through the chosen study area and measuring or monitoring eco-hydrological parameters periodically to derive the linkages between ecology, hydrology (flood regime) and land use (e.g. Blyth, 2011; DWAF, 2004; Kotzee, 2010). In the present study, there was no scope for such an in-depth study of the linkages between hydrology and specific ecological characteristics of Ariel beel because of limitations of time, cost and logistics. A delineation of the eco-hydrological characteristics presented in this chapter is based on secondary data and literature and field observations. Analysis of water quality, a key indicator of ecosystem health (ref: Figure 4.1), of Ariel beel is presented in a later chapter.

## 4.2 Hydrological Features

Arial Beel occupies a low lying basin between the Ganges floodplain and the Young Brahmaputra floodplain south of greater Dhaka district. The beel area is between the Ganges and Dhaleswari rivers south of Dhaka. As can be seen in Figure 4.2, the Ichamati river also flows through the beel area, draining water to the Dhaleswari river. It receives a large quantity of runoff during the monsoon from its territorial settlements. It is the drainage outlet of the Dohar, Nawabgonj, Sreenagar and Sirajdhikhan upazillas. A satellite image of the Arial Beel with its major rivers is given in Figure 4.2. There are a number of large and small depressions in the beel which are locally known as ponds. These depressions of the beel are able to store a large amount of water even in winter and are the main reservoirs of freshwater fisheries. The centre of the basin remains wet for most of the dry season (GOB- IUCN, 1992). Figure 4.3 presents the satellite image of the Arial Beel showing the depression areas. Seasonal flooding is deep in these areas in the basin-centre and moderately deep on the higher margins.

Despite the proximity to the two major river channels, the deep seasonal flooding is caused at earlier times predominantly by accumulated rainwater which is unable to drain into rivers when they run at high levels. With increasing water levels of the rivers, greatest portion of the beel (approximately 10105 ha) is inundated round the year. In moderate to high flood years, the depression areas are flooded to depths from 3 to more than 4 meters, with peripheral areas flooded to depths about 1 meter (Figure 4.4). A number of canals like Modonkhali canal, Jahanabad canal, Morichputi canal, Rarikhal, Sreenagar canal, etc help drain out the water when the water level of major rivers of this region begins to decrease (Hossain, 2009).

BARC (2005) found that the greatest portion (approximately 10538 ha) of the Arial Beel is lowland where the flooding depth is about 1.53-3.05 m. On the other hand, 1877 ha of land can be classified as medium lowland and there the flooding depth varies from 0.93 m to 1.52 m and approximately 2021 ha of land contain variable depth. Complete surface drainage of the deeper flooded areas (depression areas) does not occur and some of this portion remains wet even through the dry season (BARC, 2005). Table 4.1 shows the distribution of land according to drainage.

**Table 4.1: Distribution of land of the Arial Beel according to drainage**

| Surface Drainage Condition | Amount of Land (ha) |
|---|---|
| Poorly Drained but Surface Drains Early | 2310 |
| Poorly Drained but Surface Drains Late | 10105 |
| Total | 12415 |

Source of data: (BARC, 2005)


**Figure 4.2: Satellite Image of Arial Beel showing the Hydrological settings (2012)**

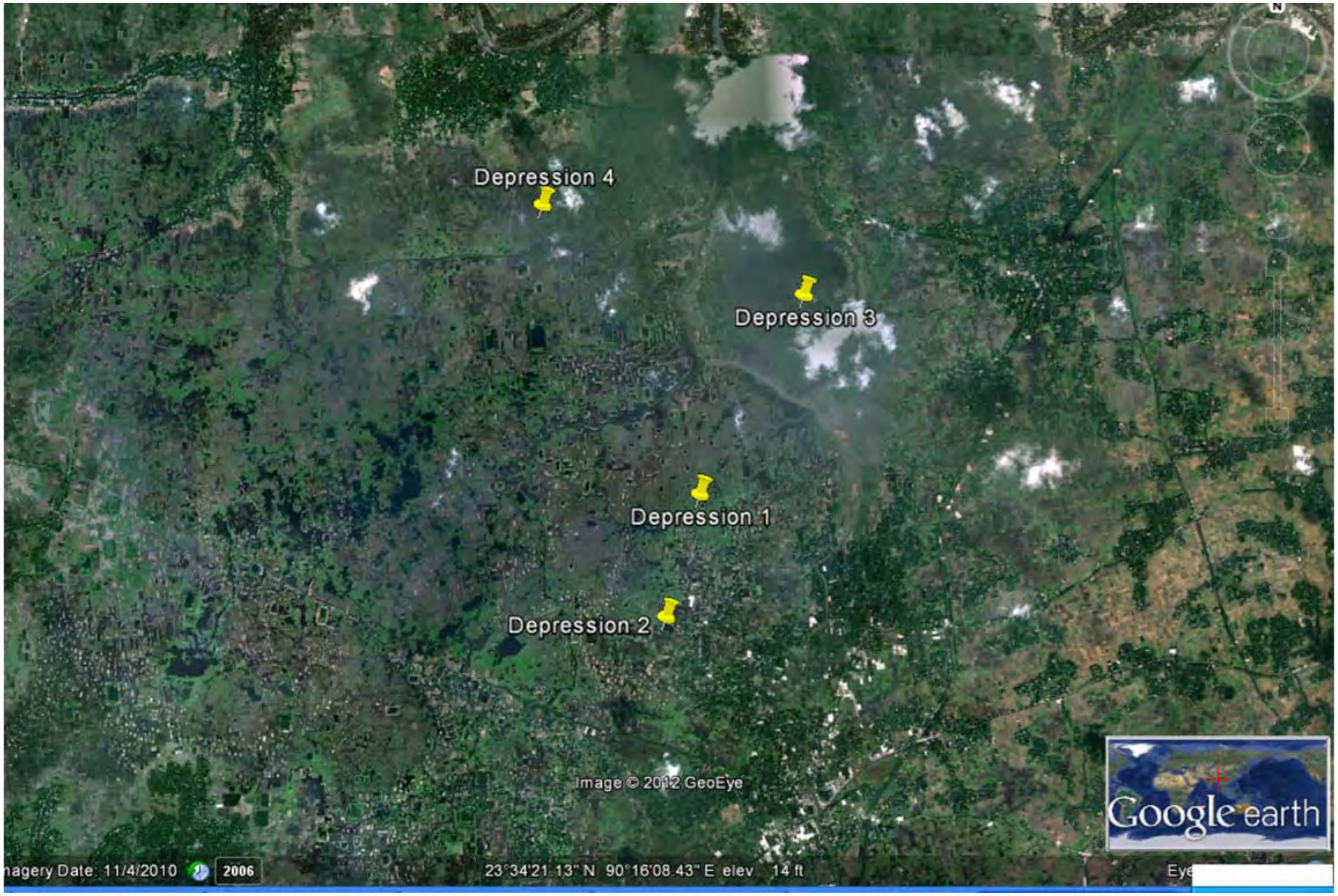



**Figure 4.3: Satellite Image of Arial Beel showing the depression area (2012)**

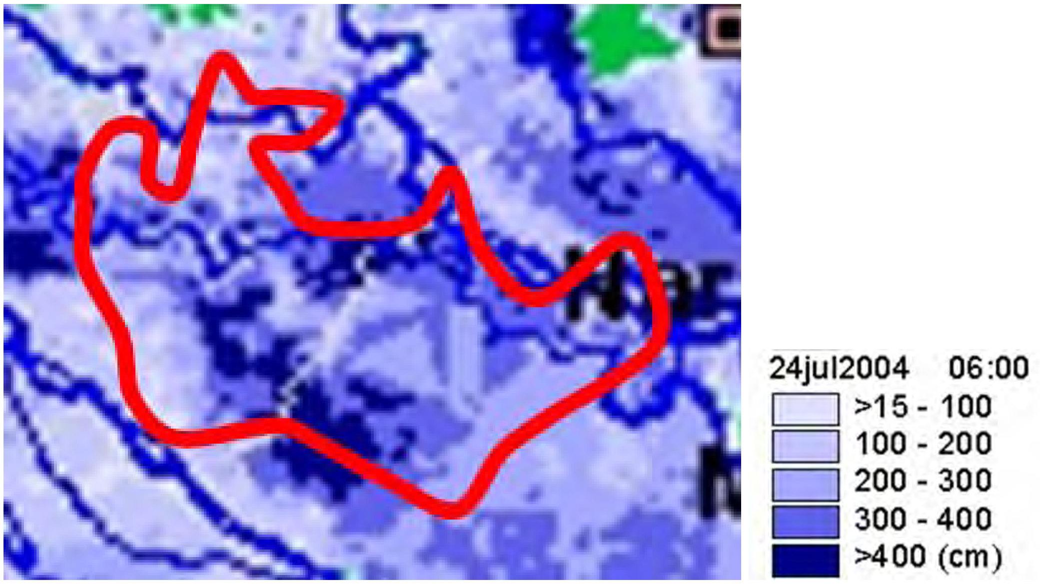



**Figure 4.4: Flood inundation depth in the Ariel Beel area in 2004 (Source: FFWC)**

**Figure 4.5: A photograph showing a portion of Arial Beel during April, 2012.**

**Figure 4.6: A photograph showing the same portion of Arial Beel during June, 2012**

### 4.3 Soils Characteristics

Soil is one of the most important of the physical variables, and it is widely used as an indicator of the wetting regime in wetlands (DWAF, 2004). Bangladesh Agricultural Research Council (BARC) conducted a study to find the soil characteristics of Arial Beel. The land slopes of the area not so steep and in most cases it does not exceed 3%. The relief of the lands of the beel is almost regular. The beel does not contain a large depth of effective soil and the effective soil depth of the largest portion of the beel (10105 ha) is only 0.60-0.90 m. Table 4.2 shows the classification of land according to their effective soil depth.

**Table 4.2: Classification of land according to effective soil depth**

| Effective Soil Depth | Amount of Land (ha) |
|---|---|
| D3 (0.60-0.90 m) | 10105 |
| D4 (0.90-1.22 m) | 1588 |
| D5(>1.22 m) | 722 |
| Total | 12415 |

Source of data: (BARC, 2005)

The soils of the beel are dark grey and acidic heavy clays. These are typical features of soils of wetland which are seasonal, with shallow effective soil depth (Kotze et al., 1994). Most of the soils of the Arial Beel are clay soils and other dominating soil classes are: silty clay, silty loam and silty clay loam. Table 4.3 shows the classification of land according to soil textures.

**Table 4.3: Classification of land according to soil textures**

| Texture Class | Amount of Land (ha) |
|---|---|
| Silt Loam | 289 |
| Silty Clay loam | 289 |
| Silty Clay | 1299 |
| Clay | 10538 |
| Miscellaneous | 2021 |
| Total | 14436 |

Source of data: (BARC, 2005)

Almost all soils of the Arial Beel contain more than 2% organic matter and organic matter contents are high in topsoil only. The moisture holding capacity of the soils of the beel is inherently low. BARC (2005) found that most of the soils of the Arial Beel have moderate permeability and it varies from 12 to 305 cm/day. Table 4.4 shows the classification of land according to their moisture holding capacity. Table 4.5 presents the classification of land according to soil permeability.

**Table 4.4: Classification of land according to their moisture holding capacity**

| Moisture Holding Capacity | Amount of Land (ha) |
|---|---|
| 100-200 mm | 10538 |
| 200-300 mm | 1877 |
| Total | 14436 |

Source of data: (BARC, 2005)

**Table 4.5: Classification of land according to soil permeability**

| Soil Permeability | Amount of Land (ha) |
|---|---|
| Slow (< 12 cm/day) | 2,310 |
| Moderate ( 12- 305 cm/day) | 10105 |
| Total | 12415 |

Source of data: (BARC, 2005)

According to BARC (2005), 73% of the total lands of the Arial Beel are lowland which has flooding depth of 1.83 m- 3.05 m. BARC also mentioned that the soils of the lowland are acidic in nature ($p^H$ 4.7-5.4). On the other hand $p^H$ of the medium lowland is 5.3-6.8. Table 4.6 shows the nutrient status and $p^H$ of the land of the Arial Beel according to their heights. From the table it can be found that the soils of the Arial Beel contain low amount of Nitrogen but optimum amount of Ca aad Mg, B and Mo. The P content is low to medium there and Zn content is medium. The contents of K and S are medium to optimum in the beel soil. However there are no difference in the nutrient contents between the medium lowlands and lowlands.

**Table 4.6: $p^H$ and Nutrient Status of soils of the Arial Beel**

| Major land type | Soil pH | Soil OM | Nutrient status | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | N | P | K | S | Ca | Mg | Zn | B | Mo |
| Medium lowland (13%) | 5.3-6.8 | M-H | L | L-M | M-Opt | M-Opt | Opt | Opt | M | Opt | Opt |
| Lowland (73%) | 4.7-5.4 | M-H | L | L-M | M-Opt | M-Opt | Opt | Opt | M | Opt | Opt |

Source of data: (BARC, 2005)

## 4.4 Ecological Resources of Arial Beel

### 4.4.1 Flora

The Arial Beel has a great ecological, economic, commercial and socio-economic importance. It contains very rich components of biodiversity of local, national and regional significance. Approximately 500 species of flowering plants, 150 vertebrates and 400 species of vertebrates were found in the beel area (Islam, 2000). It also provides habitat for a variety of resident and migratory waterfowls, a significant number of endangered species of international interest, and a large number of commercially important plants and animals.

Some important plant species of the Arial Beel are Hizal ( Barringtonia acutangula), Tamal ( Diospyros cordifolia), Barun ( Crataeva nurvala), Madar (Erythrina variegate), Gab ( Diospyros peregrina), Dumur (Ficus hispida), Chalta ( Dillenia indica) and Dehua (Artocarpus lacucha). Paniphal (Trapa bispinosa and T. maximowickzii) is plentiful available in the beel and provides nutritious starchy kernels to the poor community. Large varieties of aquatic vegetation and fruits like Makna (Euryale ferox), Singara ( Trapa bispinosa) , Lotus, Lily and Hogla ( Typha elephantina) have created a source of livelihoods of the local people.

The beel is important for medicinal plants. A number of species of Polygonum, locally known as bishkatali of kukra are available in the beel which are used as antibacterial agents. The flowers and seeds of paddo (Indian lotus) are used for the treatment of piles and as cardiac tonic. The flowers of water lilies are reputed as a remedy for heart ailments. Local quacks harvest these medicinal resources for their livelihood income earning and many local people use these for the remedies from various diseases (Islam, 2000).

### 4.4.2 Fauna

Approximately 260 species of fin fishes and 25 shell fishes are available in the beel (Islam, 2000). The fish species found in the beel are kholisha, bele, mola, dhela, taki, punti, meni, singi, magur, chanda, baim, pholi, darkina etc. Fishes like aire, gazar and major carps like rui, catla, mrigal and kalbaus also visit the Arial Beel to feed and grow. Besides fish, several species of freshwater prawn such as kucha chingree, guraicha, golda chingree, thengua chingree etc and their larvae and juveniles are also found. In addition, several species of freshwater mussels and snails also found in beel area.

# CHAPTER FIVE

# CHANGES OF LAND USE IN ARIAL BEEL

## 5.1 Introduction

Land use changes have become central component of strategies for managing natural resources and monitoring environmental change. In recent studies, the dynamics of land use - particularly settlement expansion in the area - are being analyzed using GIS and Remote Sensing data as they provide a more extensive coverage of large areas compared to area photography. Change detection is a technique that is used to highlight conversion of land from one use to another within a given time frame (Karanja, 2002). GIS technology is very useful in monitoring environmental change, forest management, monitoring crop health and damage (Mather, 1999). Kashaigili et.al. (2009) conducted a study on integrated assessment of land use and cover changes in the Malagarasi river catchment in Tanzania. He used Landsat TM and ETM+ images to locate and quantify the changes. A study on the dynamics of land use and cover in the Malagarasi river catchment therefore investigated long term and seasonal changes that have occurred as a result of human and development activities in the area from the periods between 1984 and 2001. In the current study, the change of land use was carried for Arial Beel by studying the classified images of Arial beel between 1984 and 2004. These maps were collected from Centre for Environment and Geographic System (CEGIS). There were some limitations in analyzing land use change using satellite images. The latest classified image available from CEGIS was that for year 2004. Two additional unclassified Landsat TM satellite images including one from a recent year (2010) have been visually inspected to interpret overall pattern of historical land use change until recent times.

## 5.2 Methodology for Land-use Change Detection

### 5.2.1 Data sources

In this study, the change of land use was analyzed by first studying classified images of Arial Beel from 1984 to 2004. The types and sources of satellite images are given in Table 5.1. These maps were collected from Centre for Environment and Geographic Information Services (CEGIS). Both primary and secondary information sources were used to attain the information of the Beel area. More information about land use change was collected from field survey and focus group discussion. The primary data, such as crop types and varieties, planning and harvesting times, fertilizers amount and types of fertilizers etc were collected through focus group discussion. Other secondary information with spatial and non spatial dimensions was collected from Bangladesh Agricultural Research Council (BARC), Bangladesh office of International Union for Conservation of Nature (IUCN), Soil Research Development Institute (SRDI) and various other journals and publications.

**Table 5.1: Types and sources of classified images used in the study**

| Date and Year | Types of and Sources Data | Resolution |
|---|---|---|
| 19-Mar-84 | Landsat Multispectral Scanner (CEGIS) | 68m x 82m |
| 30-Jan-90 | Landsat TM Satellite Image (CEGIS) | 30m x 30m |
| 28-Feb-96 | Landsat TM Satellite Image (CEGIS) | 30m x 30m |
| 18-Dec-98 | Landsat TM Satellite Image (CEGIS) | 30m x 30m |
| 25-Feb-99 | Landsat TM Satellite Image (CEGIS) | 30m x 30m |
| 29-Dec-04 | Landsat TM Satellite Image (CEGIS) | 30m x 30m |

### 5.2.2 Image classification

The satellite images collected from CEGIS were already enriched with image classification. The numerous different color shades seen in the images were lumped together and digitally classified into seven broad classes. The classification was done based on unsupervised method and hence the expected accuracy of data is not very high. The definitions of seven classes are as follows:

**Crop:** Given the season of the image capture times the major part of the crops grown in the area consists of mainly Boro and some other rabi crops such as wheat, pulse, oil seeds, etc.

**Grass:** This class includes fallow land with stubble and grass. This type of area is used as gazing area for domestic cattle heads.

**Land:** This class denotes fallow bare land or land areas used for seasonal vegetable production – not under regular cultivation.

**Moist land:** This class represents fallow land with relatively greater moisture content – usually seen in increased proportion after flooding.

**Settlement:** This class represents rural settlements recognized by large trees that usually surround villages and are digitized as feature objects which may include ponds, gardens etc. that are within the settlements.

**Urban:** Urban areas are recognized by higher density of settlements of more permanent nature including buildings and commercial structures.

**Water:** This class covers all water areas in the study area. It includes rivers, ponds and those areas within the beel which are perennially water covered.

### 5.2.3 Image analysis

For the purpose of quantitative analysis of the spatial classification included in the CEGIS images, it was first necessary to clip the images in the exact shape of the study area. The study area was defined as the collective geographic region denoted by 15 administrative unions. The clipping of CEGIS enriched Landsat TM satellite images was performed using ArcView GIS 3.2a – a commercial GIS analysis tool by Environmental Systems Research Institute, Inc. ArcView GIS software allowed to convert the satellite image file and a geo-coded administrative map of 15 unions selected as the study area into two shape files and clip the former based on the later.

The ArcView GIS software also offers a “dissolve” function which aggregates features of a shape file that has the same value for a specified attribute. Using this feature the satellite images clipped against the study area were dissolved based on the class name attribute. Finally using the script interface of the software the aggregate land area of each class was determined. This same procedure was applied on each of the six geo coded satellite images to quantify land use in the broad seven classes for the study area in the image capture periods.

### 5.2.4 Ground truthing

This study uses both primary and secondary data. Information was collected from primary sources through Focus Group Discussion (FGD) (Figure 5.1) and Interviews (Figure 5.2). The ground truthing of the image analysis was performed through Focus Group Discussion (FGD) (Figure 5.1) involving selected representatives of the communities in two selected unions within the study area – Alompur mouza in Hasara union under Sreenagar thana in Munshiganj district and Ardhipara mouza in Sreenagar union under Sreenagar thana in Munshiganj district. In the discussions, the participants explained their cropping patterns (Figure 5.3) and the land use change in their locality.

**Figure 5.1: A photograph of Focus group discussion at Sreenagar Union**

**Figure 5.2: A photograph showing local people were interviewed about their land use change**

**Figure 5.3: A photograph of local people explaining the cropping pattern**

## 5.3 Generalized Land Use Pattern of the Study Area

### 5.3.1 Land use pattern in March 1984

Figure 5.4 shows generalized land use pattern of the Arial Beel area in 19th March 1984. The major part of agricultural land covered south-west section of the study area. On the other hand, fallow lands are found in the northern and the eastern sides. Scattered rural settlement areas stretch from north-west section to the south east section almost demarking between the areas predominantly covered with agricultural land from the area mostly remaining fallow. Urban settlements are concentrated in the north-west corner featuring Kalakopa union and in the south marking the center of Sreenagar union. Water bodies mostly demarking relatively lower areas in the region which perennially lie under water are scattered across the study area. The only discernible water body is Dhaleswari river flowing in the north-east corner and Ichamati river flowing in the north-west corner of the study area.

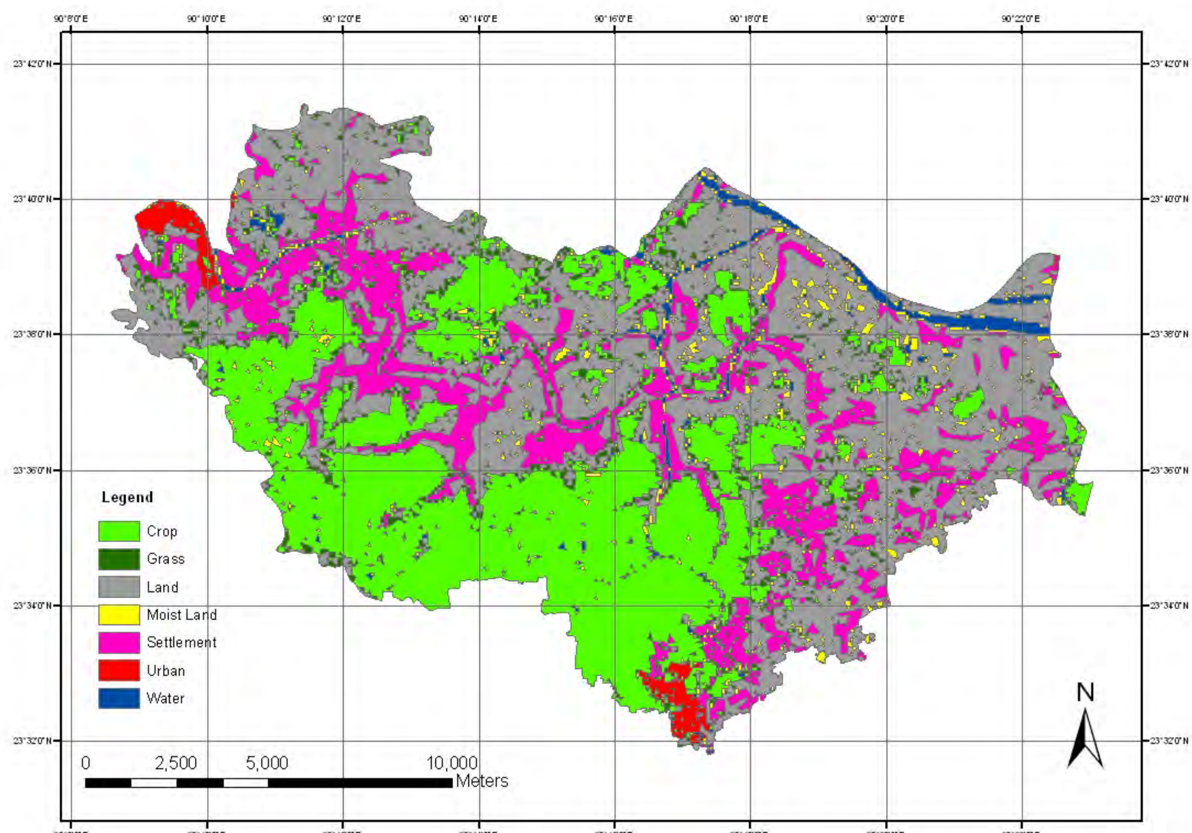



**Figure 5.4: Land use map of Arial Beel, 19th March 1984**

### 5.3.2 Land use pattern in January 1990

Figure 5.5 illustrates generalized land use pattern of the Arial Beel area in 30th January 1990. The discernable change in land use from the 1984 image is that the vast fallow land area seen in the northern and eastern region earlier is now found to be under agricultural use. Location and intensity of settlement areas remain mostly unchanged.

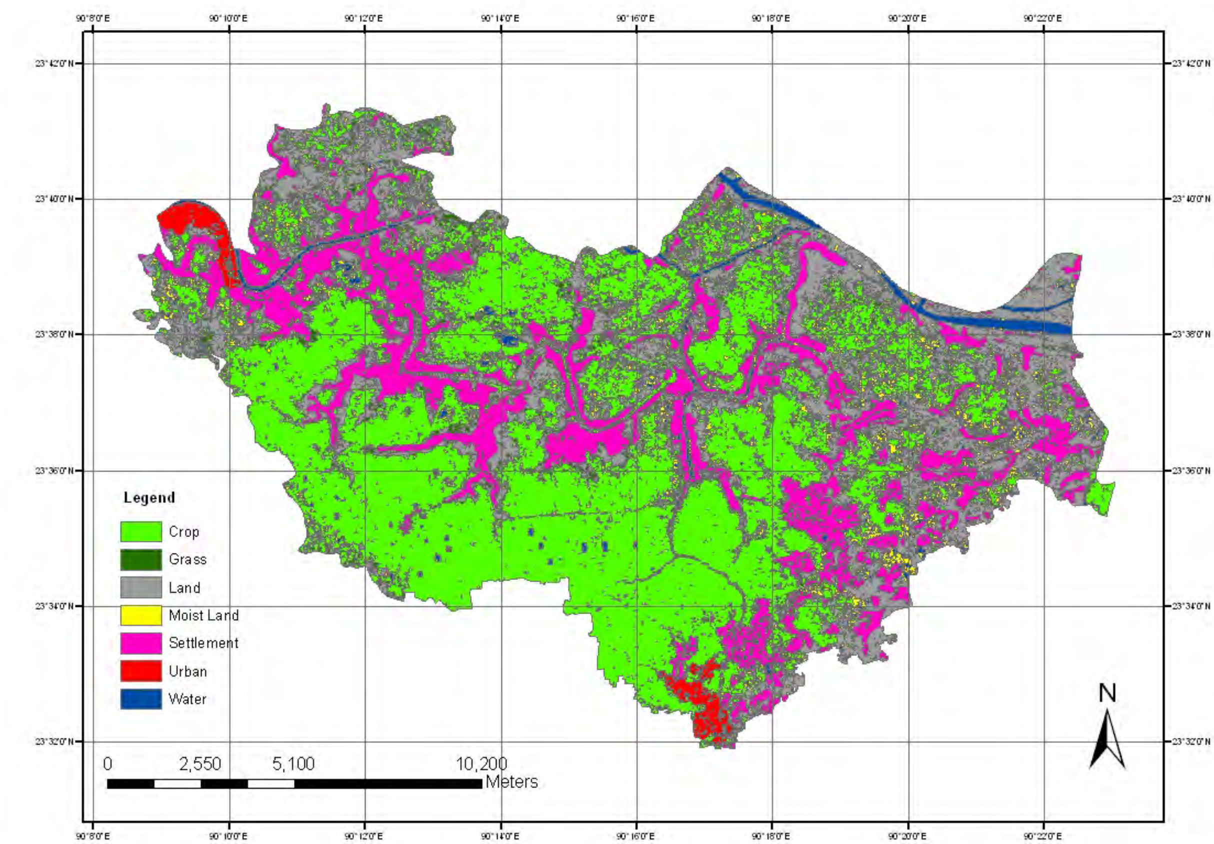



**Figure 5.5: Land use map of Arial Beel, 30th January 1990**

### 5.3.3 Land use pattern in February 1996

Figure 5.6 indicates the generalized land use pattern of the study area in 28th February 1996. This image illustrates a higher propensity of moist land. Land under cultivation has slightly decreased in the northern section from the available earlier image.

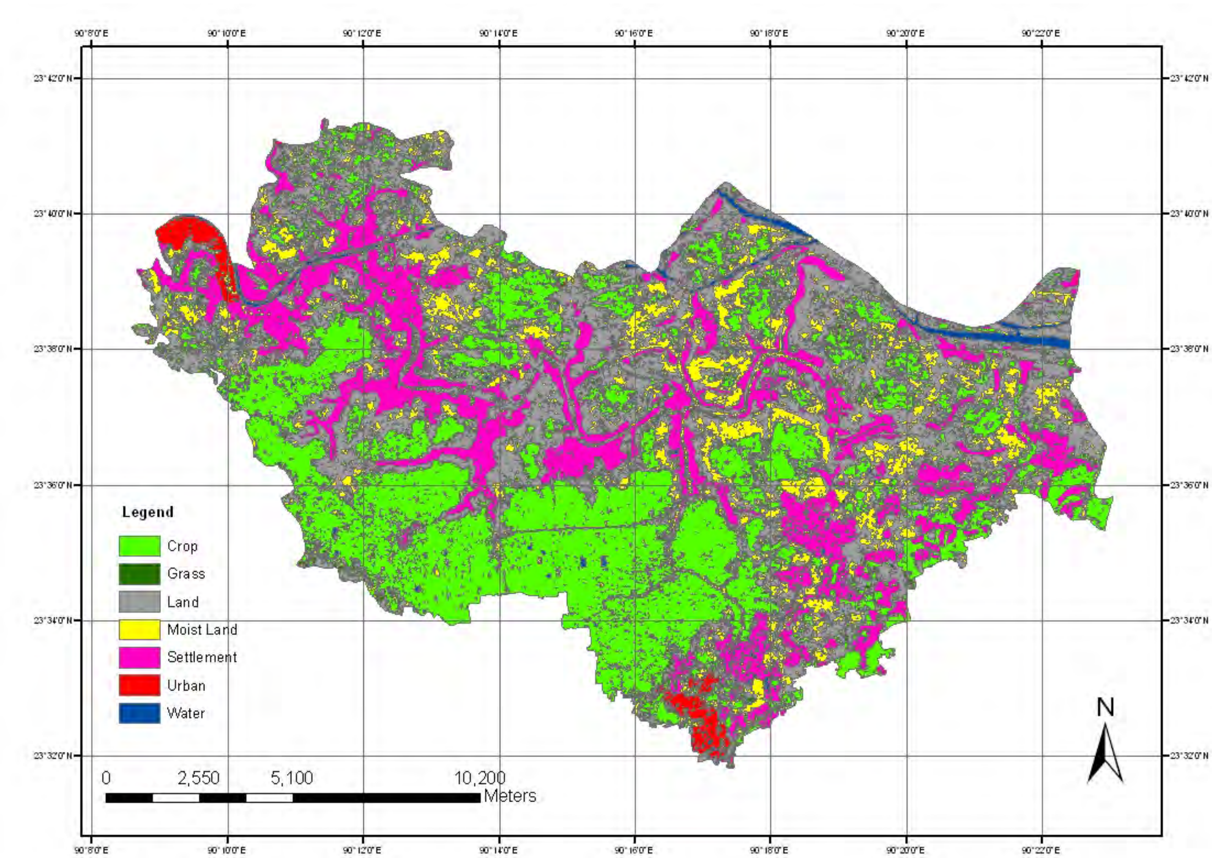



**Figure 5.6: Land use map of Arial Beel, 28th February 1996**

### 5.3.4 Land use pattern in December 1998

Subsequent development in land use pattern in 18th December 1998 is illustrated in Figure 5.7. The distinctive feature of this map is the relative absence of agricultural land and significantly higher propensity of moist land. Ground truthing confirmed that in December the crops are still at nascent stage and hence not detected in the satellite image. Furthermore the increased appearance of moist land can be linked to the devastating flood of 1998.

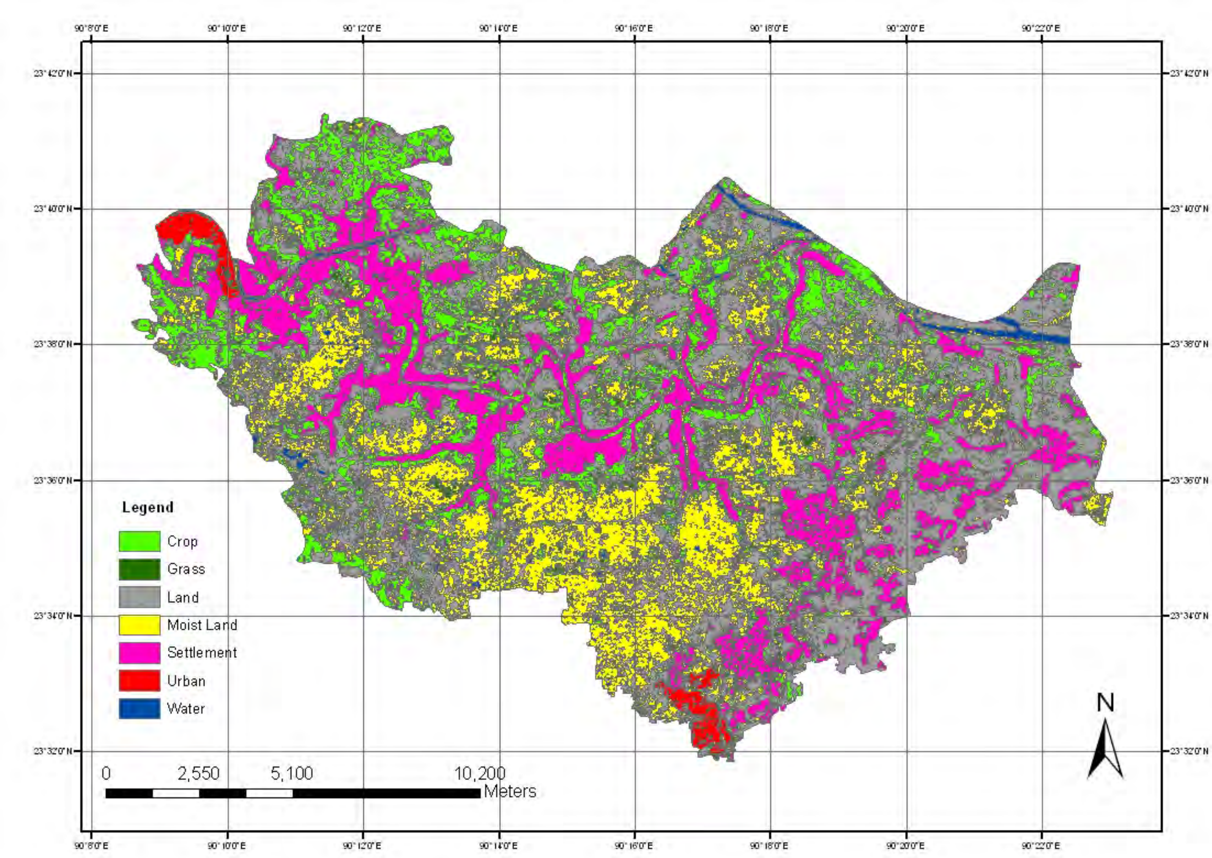



**Figure 5.7: Land use map of Arial Beel, 18th December 1998**

### 5.3.5 Land use pattern in February 1999

Figure 5.8 displays generalized land use pattern of the Arial Beel area in 25th February 1999 – less than a year later than the earlier image. This image again shows the agricultural production restored in the south-west region although the propensity of moist land continues to be high.

Location and intensity of settlement areas still remain mostly unchanged.

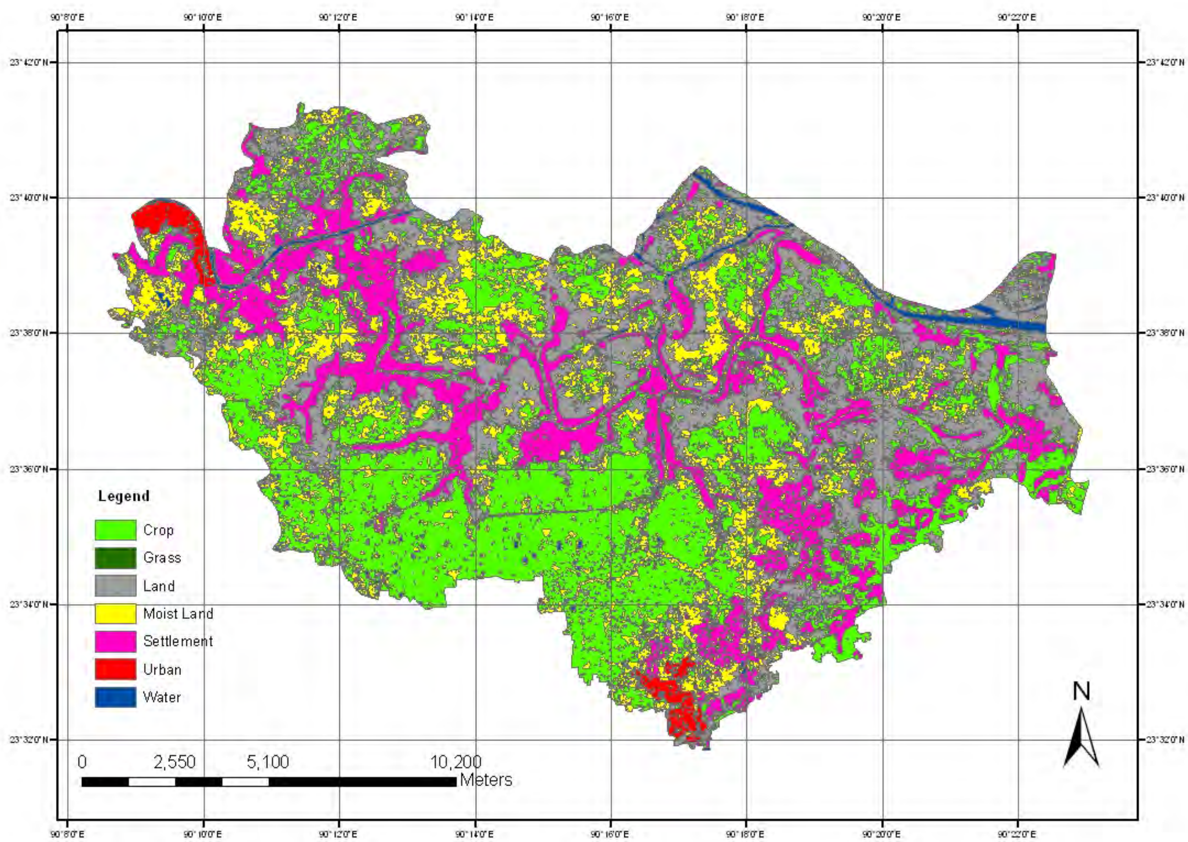



**Figure 5.8: Land use pattern map of Arial Beel, 25th February 1999**

### 5.3.6 Land use pattern in December 2004

Lastly, the most recent of the available generalized land use pattern maps of the study area as of 29th December 2004 is presented in Figure 5.9. This image features remarkable low propensity of agricultural land due to the seasonal variation discussed earlier. A highly remarkable observation from these chronological images is that there is almost no change in rural or urban settlement areas throughout the study period spanning 20 years.

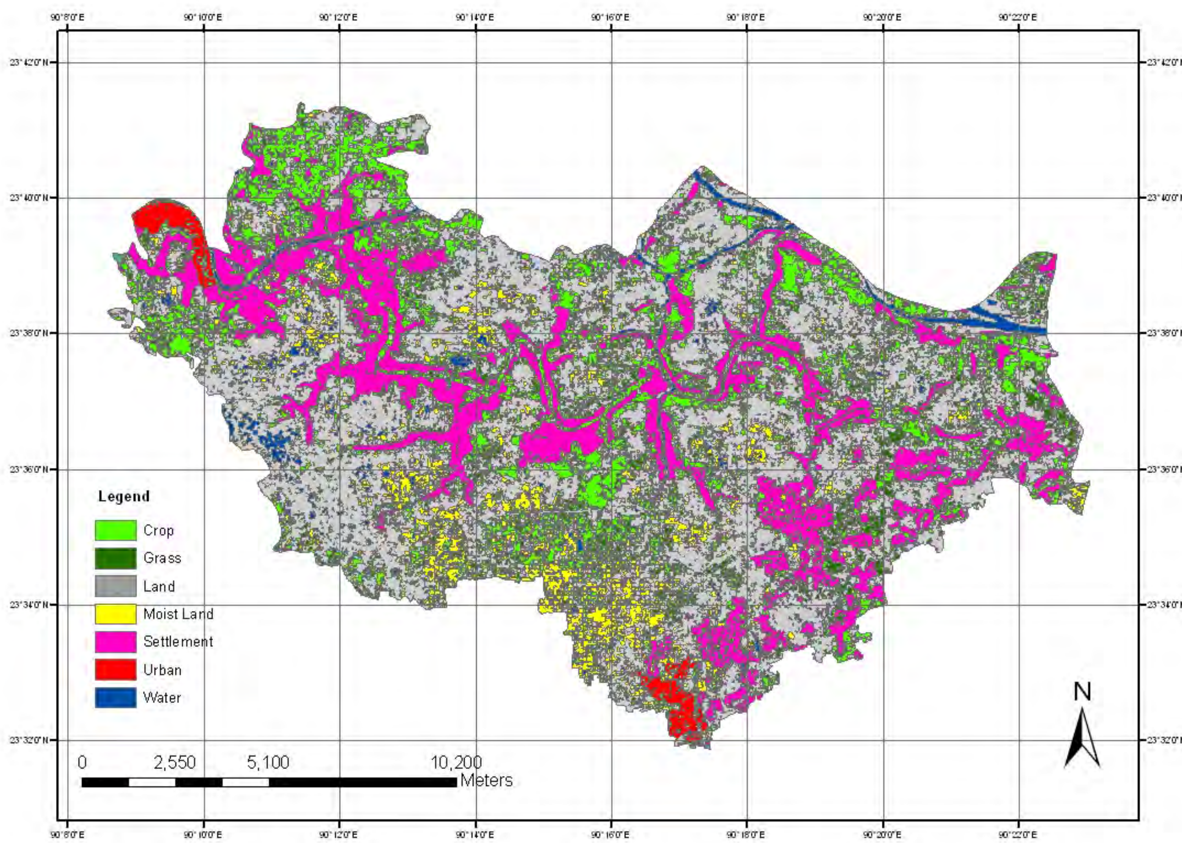



**Figure 5.9: Land use map of Arial Beel, 29th December 2004**

### 5.4 Analysis of Land Use Change

#### 5.4.1 Analysis of classified images

The quantitative analysis of the seven different classes across the six images is presented in Table 5.2 and 5.3, which has been further discussed class by class later.

**Table 5.2: Distribution of the land cover classes within the area as derived from image classification (area in hectares)**

| CLASS_NAME | Mar-84 | Jan-90 | Feb-96 | Dec-98 | Feb-99 | Dec-04 |
|---|---|---|---|---|---|---|
| Crop | 7183.18 | 10353.32 | 7372.74 | 4215.56 | 7654.81 | 3731.38 |
| Grass | 1149.04 | 1295.95 | 1017.00 | 1227.51 | 469.10 | 2406.82 |
| Land | 9082.57 | 4938.20 | 7109.78 | 8127.14 | 5672.90 | 10227.91 |
| Moist Land | 683.96 | 1231.80 | 2767.32 | 4768.19 | 4477.02 | 1606.31 |
| Settlement | 3828.96 | 3799.45 | 3849.75 | 3841.80 | 3840.30 | 3840.83 |
| Urban | 301.67 | 293.19 | 296.91 | 301.18 | 300.72 | 297.80 |
| Water | 462.25 | 552.50 | 334.75 | 266.32 | 332.14 | 628.35 |

**Table 5.3: Distribution of the land cover classes within the area as derived from image classification (area in percentage)**

| CLASS_NAME | Mar 84 | Jan 90 | Feb 96 | Dec 98 | Feb 99 | Dec 04 |
|---|---|---|---|---|---|---|
| Crop | 32 | 46 | 32 | 19 | 34 | 16 |
| Land | 40 | 22 | 31 | 36 | 25 | 45 |
| Moist Land | 3 | 6 | 12 | 21 | 20 | 7 |
| Grass | 5 | 6 | 5 | 5 | 2 | 11 |
| Settlement | 17 | 17 | 17 | 17 | 17 | 17 |
| Urban | 1 | 1 | 1 | 1 | 1 | 1 |
| Water | 2 | 2 | 2 | 1 | 1 | 3 |

Distribution of land cover classes from image analysis between1984 to 2004 is presented in figure 5.10. Here the land cover classes are presented in six graphs.

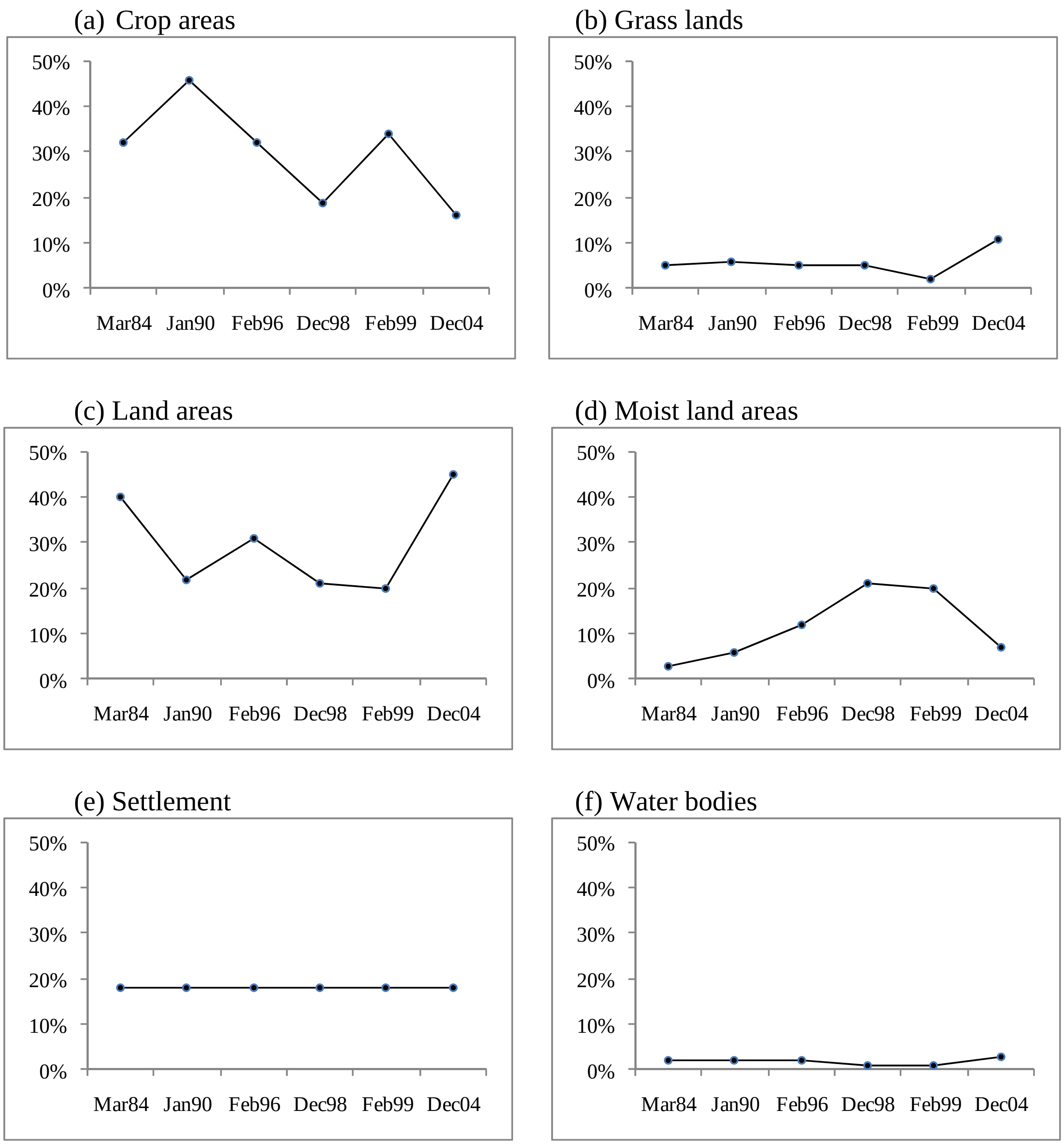



**Figure 5.10: Distribution of land cover classes in different years**

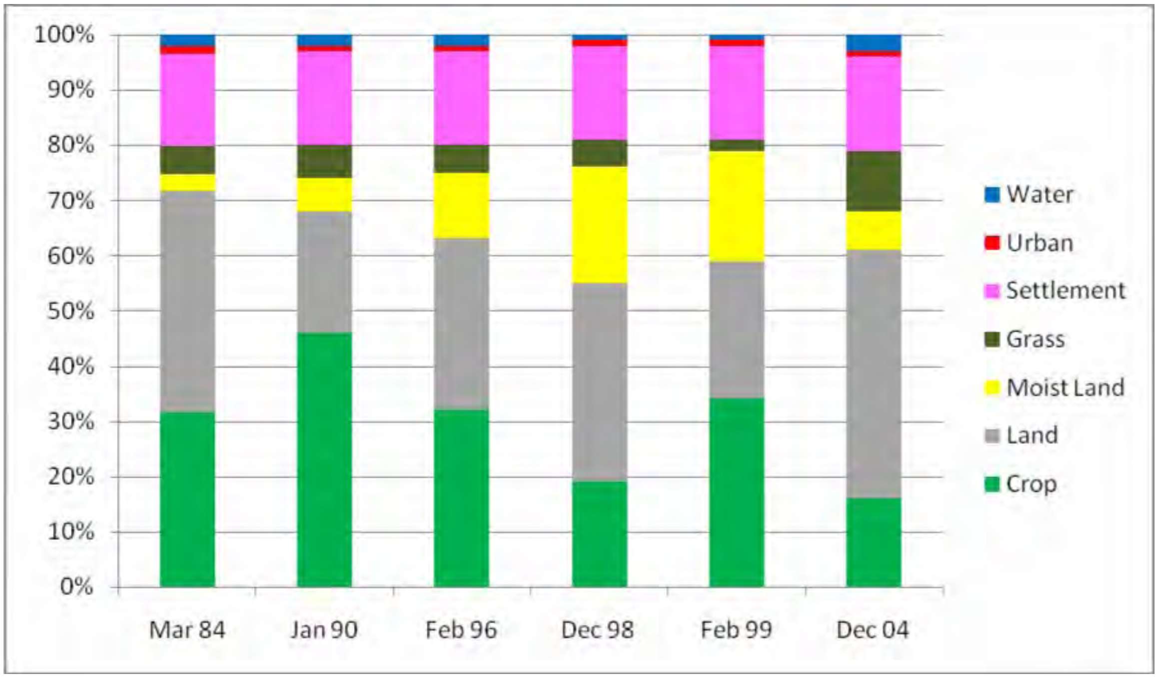



**Figure 5.11: Relative shares of different classes of land in different images**

The analysis presented above dealt with land use changes of Arial Beel from 1984 to 2004. From 1980s, the major part of the crops grown in the area consisted of Boro. Due to seasonal variation agricultural crops are relatively less visible in December images when the crops are at an early stage of growth. Ignoring the two December images of 1998 and 2004 (for which the true picture of crop area can not be accurately interpreted because of early times of images), it can be seen in Figure 5.11 that the aggregate area under agricultural production has remained relatively unchanged over the years till 1999

### 5.4.2 Analysis of unclassified Landsat TM satellite image

Since the image classifications for satellite images included 2004 as the latest year (moreover the year 2004 is less significant because of its earlier date, which is December), two more Landsat TM satellite images dated 13 February, 1989 and 15 February, 2010 (Figure 5.12) were used to interpret overall pattern of historical land use change until recent time. These two images are represented by a simple graphical indicator Normalized Difference Vegetation Index (NDVI). NDVI is used to measure and monitor vegetation cover from multispectral satellite data. Increase in positive NDVI values, shown in increasing shades of green on the images, indicate increasing amounts of green vegetation. NDVI values near zero and decreasing negative values indicate non-vegetated features such as barren surfaces (rock and soil) and water, snow, ice, and clouds.

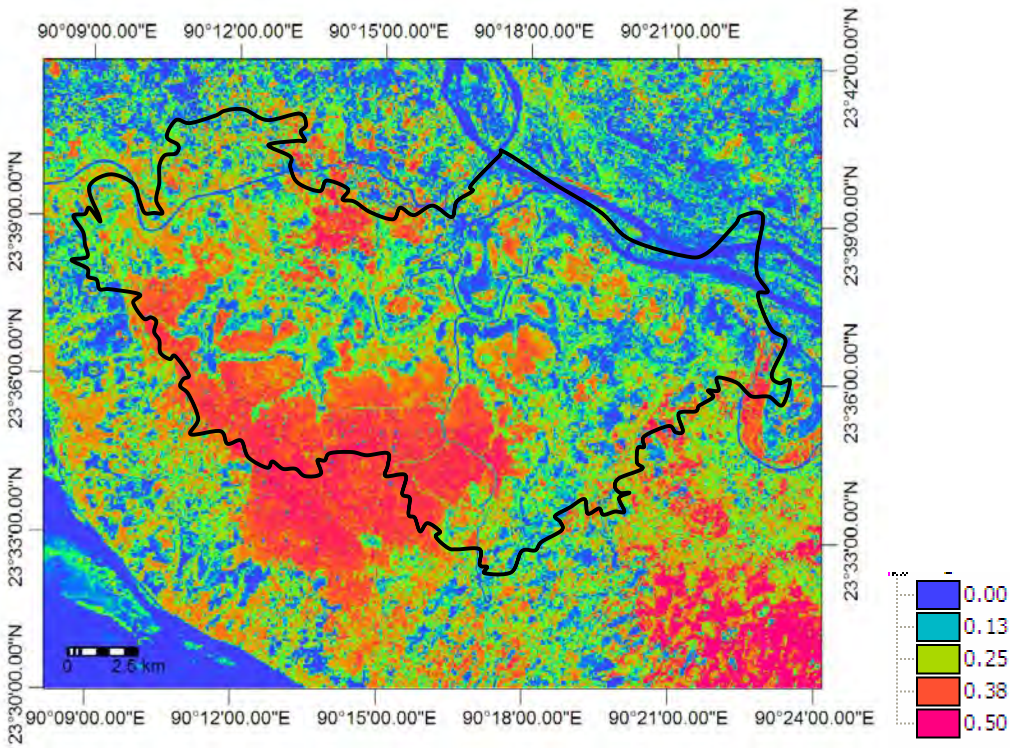
The NDVI is calculated from these individual measurements as follows:

$$NDVI = (NIR-VIS) / (NIR+VIS)$$

Here VIS and NIR stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively. For visual interpretation of the images, it is helpful to note that band width 0.25-0.5, reflecting the greenish to the reddish areas normally represent vegetation cover, which predominantly include agricultural crops. A higher value of NDVI indicates larger plantations such as trees. The lower NDVI values (<0.25), with bluish to blue color, indicates a vegetation range from marshy land to water bodies.

The visual interpretation of 13 February, 1989 shows more reddish color which indicate that larger area were under agricultural practice. This same phenomenon was observed from the classified image analysis of January 1990 as presented in section 5.3.2. This higher propensity of agricultural land can be linked to the devastating flood of 1988. After the flood of 1998, fertility of land increased and consequently larger area were under agricultural practice in 1989 and 1990. However, visual interpretation of 15 February, 2010 shows a decline in reddish color, implying a reduction in area under cultivation (including all types of vegetations). If the same images of March were collected, then more area would be under cultivation, especially since boro crops start to become visible in late February images. It was not possible to differentiate between boro crop area, areas under other rabi crops and areas covered with other type of vegetation from the image, since successive time series images for different months were not available. Table 5.4 shows the areas under different types of crop cultivation for three different years, 1983, 1996 and 2008, for Srinagar thana as per the records of Bangladesh Bureau of Statistics (BBS). It is seen that boro coverage area gradually increased from 1983 to 2008, but this was more than offset by rapid reduction of areas under cultivation for other rabi crops (wheat/pulses/oil seeds etc.). Table 5.4 also suggests that the Net Cultivable Area (NCA) decreased by about 20% between 1983 and 2008.

**(a)**




**(b)**

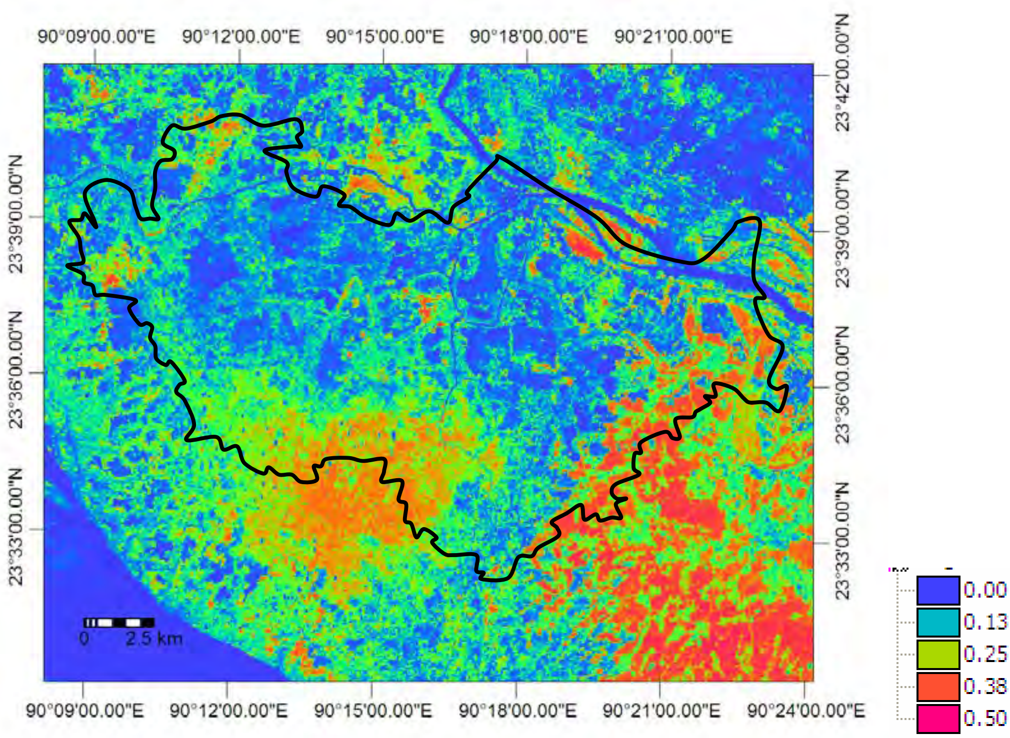



**Figure 5.12: Comparison of NDVI indices on (a) 13 February 1989 and (b) 15 February 2010**

**Table 5.4: Comparison of areas under different types of crop production from 1983-2008(area in acres)**

| Year | NCA | Local Aman | HYV Aman | Local Boro | HYV Boro | Wheat/pulses/ oild seeds etc | Vegatables |
|---|---|---|---|---|---|---|---|
| 1983 | 29852 | 4180 | 915 | 500 | 10954 | 10082 | 3221 |
| 1996 | 26546 | 1236 | 553 | 545 | 15272 | 4843 | 4097 |
| 2008 | 23854 | 1585 | 480 | 426 | 16494 | 2065 | 3144 |

Source of data: Census of Agricultute, Zila Series Munshiganj, BBS, 2008

### 5.5 Analysis of Field Observations

During the field discussion with the local people, the participants were enquired about the land use change in their locality. Analyzing the responses of the two FGDs it can be concluded that about 30 years prior to the survey date, almost half of the area of Arial Beel remained outside cultivation. At that time the main cultivated crop was aman and the production was 2~2.5t/ha. Subsequently in the last 25 years, the beel community have gradually changed their cropping pattern. Now the position of the primary crop is taken by IRRI/29 and the production is 7~7.5t/ha. Some of the fallow land has also been brought under cultivation. The FGDs also revealed that the local people have been growing many seasonal vegetables in fallow land like gourd, sweet-gourd, pumpkins, radish, brinjal, tomato, potato, cauliflower, green-cauliflower, pepper, different types of herbs etc. since last 25 years. In monsoon hizal, hogla, Kachuripana, water lily, dancha, snail, paniphal, chalta are available in the beel area.

The agricultural production doesn’t span round the year because the beel area remains under deep water during the monsson season. During October-November, the local farmers prepare the seed-bed and in November- December they transplant the seeds for boro. Later on in April, they cut the crops. Once they raise the seeds from seed beds, then they plant different kharif corps including onion, garlic, wheat, oilseeds and mustard in the land used as seed beds.

### 5.6 Discussion

This chapter has mainly analyzed the land use changes of Arial Beel from 1984 to 2010. Analyzing the classified images and from ground truthing it was observed that, from 1980s, the major part of the crops grown in the area consisted of Boro. Due to seasonal variation agricultural crops are relatively less significant in December images when the crops are at an early stage of growth. Ignoring the two December images it can be concluded that the area under cultivation (consisting of Boro and other rabi crops) have remained relatively unchanged across the year 1984 to 1999.

However, the analysis of Landset TM image of the study area for 1989 and 2010 coupled with BBS data for 1983-2008 suggest that net cultivable area dropped significantly between 1990 and 2010. This could be the result of the growth of human settlements in 2000-2010 as a consequence of growing economic importance of the area due to proximity of Dhaka. Field observations have also revealed that real estate companies have acquired and earmarked significant portion of the study area (Figure 5.13).


**Figure 5.13: Real estate developers marking acquired land in Arial Beel**

The mushrooming real estate projects (a trend starting in early 2000s) put significant pressure on land available for cultivation.

FGDs conducted as part of this study have also clearly established that the crop production has gradually increased in the region. Such increase of production keeping net agriculture area decreasing was possible through higher production of high yielding varieties of rice, especially IRRI/29. Thus, alteration in cropping pattern (from traditional varieties to high yielding varieties) coupled with reduction of net cultivable area due to reduction of rabi crops and the growth of the real estate projects have been detected as the major themes of land use change in the study area between 1984 and 2010.

# CHAPTER SIX

# IMPACTS ON WATER QUALITY AND ECOSYSTEM HEALTH OF ARIAL BEEL

## 6.1 Introduction

There are different ecohydrological factors and effects with landscape pattern change and most attention was paid to water and soil quality (Fu et al. 2005). Water quality parameters are important factor to determine the ecohydrological situation of an area. In addition the land use change has potential impacts on water quality. In recent years, the eco hydrological effects of land use change have been discussed intensively, in particular with respect to water quality (Amatya et al. 2004; Basnyat et al. 1999). Land use activities like intensified agriculture accompanies with wide application of chemicals including fertilizer and pesticides, affecting water quality by altering chemical loads (Basnyat et al. 1999). Dlamini et al. (2009) collected and analyzed water samples to assess the impacts of agricultural land use on ecosystem health. Alam et al. (2001) monitored the presence of excess fertilizers by measuring levels of ammonium, nitrate, phosphate and potassium to assess the impact of agricultural practices on ground water quality and found relatively high concentrations on ammonium and nitrate.

In the current study, analysis of the images has revealed that one noticeable change in land use pattern during the period of analysis is the alternation of cropping pattern: the gradual shift from traditional varieties to high yielding varieties of crops. Alternation of cropping pattern (i.e shifting to high yielding varieties) is likely to lead to more intensive use of chemical fertilizers and pesticides which is identified as one of the major source of wetland water pollution. So, in this study, most attention is paid on water quality which is one of the major ecohydrological effects due to land use change.

## 6.2 Water Quality as Indicator of Ecosystem Health

There are three common indicators of wetland ecosystem health: biological (vegetation, algae, zooplanktons, macro-invertebrates, microbes, amphibians, birds), chemical (pH, turbidity, DO, phosphorous, nitrogen concentrations, metals, particles, dissolved organic carbon) and physical (water depth, temperature, hydrology, sediment composition and decomposition etc) (Wray and Bayley, 2006).

While biological indicators are often considered to be the most useful indicators (because it is generally assumed that the plant and animal communities of wetlands most accurately reflect wetland health) (USEPA, 2002), measurement of the biological indicators was beyond the scope of the present study. Instead, water quality was used as an indicator or surrogate for ecosystem health of Arial Beel.

Water quality assessment is often viewed as an integrated environmental indicator of ecosystem function (Berka et al, 1995). There have been many studies that assessed the impacts on water quality and water based eco-systems caused by agricultural land use practices (Brakebill,2001; Bradbury and Van Metre, 1997). Poor water quality affects vegetation (changes species composition), aquatic and terrestrial communities and diminishes the overall health of the wetland (Sorrel and Gerbeaux, 2004). Total phosphorus is strongly correlated to the tropic status of wetlands (Bayley and Prather, 2003) which is also related to the plant and invertebrate communities present.

Several FGDs conducted in the study area revealed that farmers use more fertilizer than before for cultivation of IRRI/29. Local farmers apply an amount of 300-350kg fertilizer per hectare of land. Extensive use of fertilizers is one of the most common sources of nutrients, entering into the beel, which turn into pollutants for the beel when exist in excessive amounts. Most of the fishermen of Arial Beel area blamed the agricultural practices, especially the use of fertilizer and pesticides in agricultural land, for the reduction of aquatic and amphibian resources of the beel. So, water quality is considered as the major parameter of ecosystem health for Arial Beel.

### 6.3 Methodology for Impact Detection

Impacts on water quality and hence eco-system health of Arial Beel were analyzed by identifying catchments and hence sampling points of different depression areas of the beel through GIS-based watershed analysis and collecting water samples at different points at different times (before and after inundation). Water samples were analyzed for different water quality parameters which have relevance for ecosystem health mentioned in previous section.,

### 6.3.1 Delineation of catchments for depression areas

Catchments of different depression areas were delineated using Arc GIS 9.3 version. The SRTM digital elevation data, produced by NASA was used in this study. It provides a major advance in the accessibility of high quality elevation data for large portions of the tropics and other areas of the developing world. The SRTM 90m DEM has a resolution of 90m at the equator (CGIAR-CSI 2004). Some hydrology tools are used in Arc GIS 9.3 to delineate watershed areas like: sink and fill, flow direction, flow accumulation, stream network, stream links, stream orders and watershed.

Before attempting hydrology analysis, sinks which are caused by possible error in the elevation data were identified. Then sinks were filled. Using filled sink DEM, flow direction raster was applied. Flow accumulation was done based on flow direction. Flow accumulation was selected as input conditional raster for stream network. Each section of the stream raster line was assigned a unique value and was associated with the flow direction. In stream order a numeric order was assigned to stream link following Shreve ordering (Figure 6.1). A threshold volume value was used in drainage network analysis such that drainage networks for individual depressions could be delineated separately. Finally watershed analysis was done selecting stream link as input raster. Watershed delineates a drainage area that contributes water to a common outlet. Figure 6.2 shows the watershed in the study area.

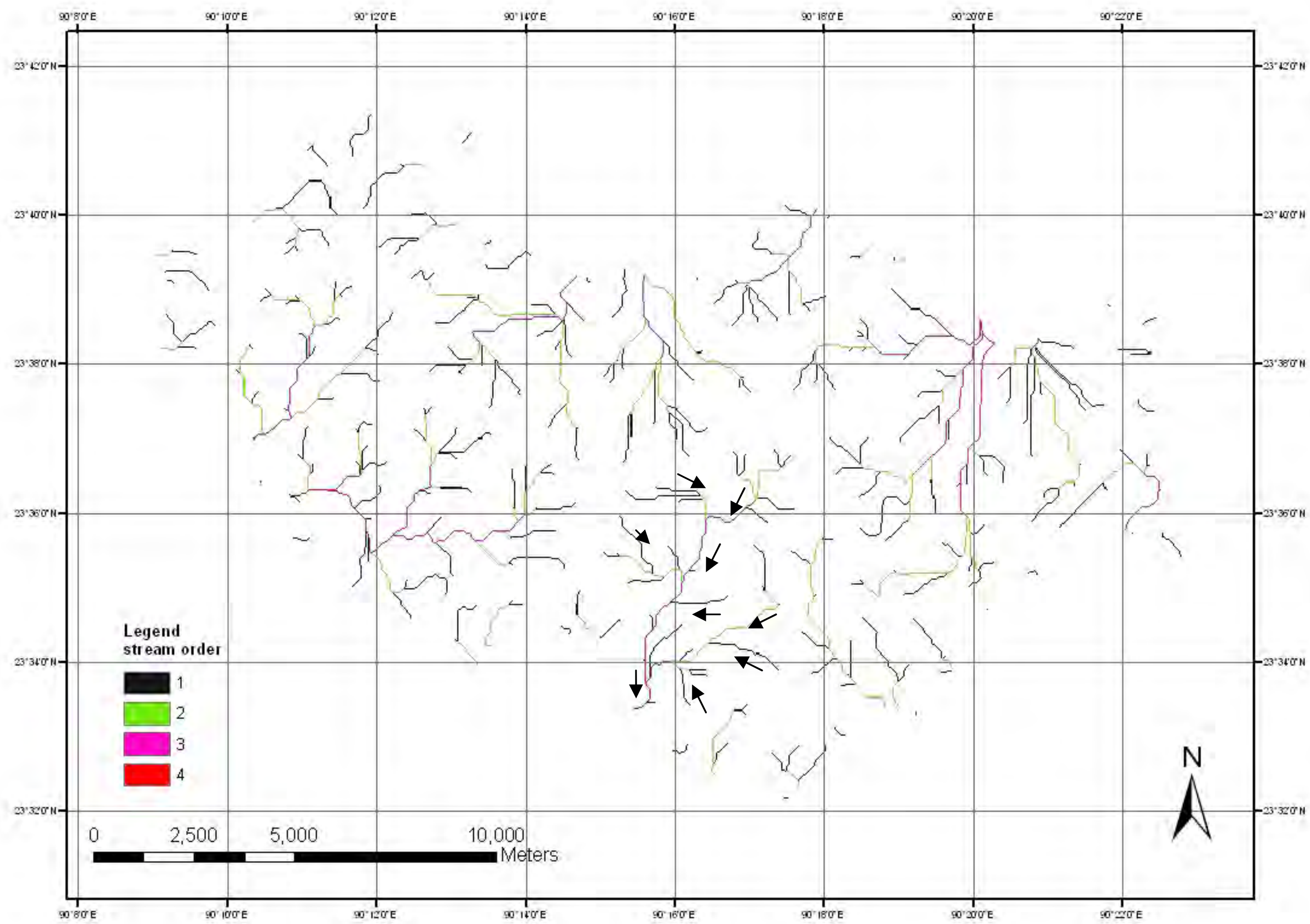



**Figure 6.1: Drainage network derived for different depression areas in Arial Beel**

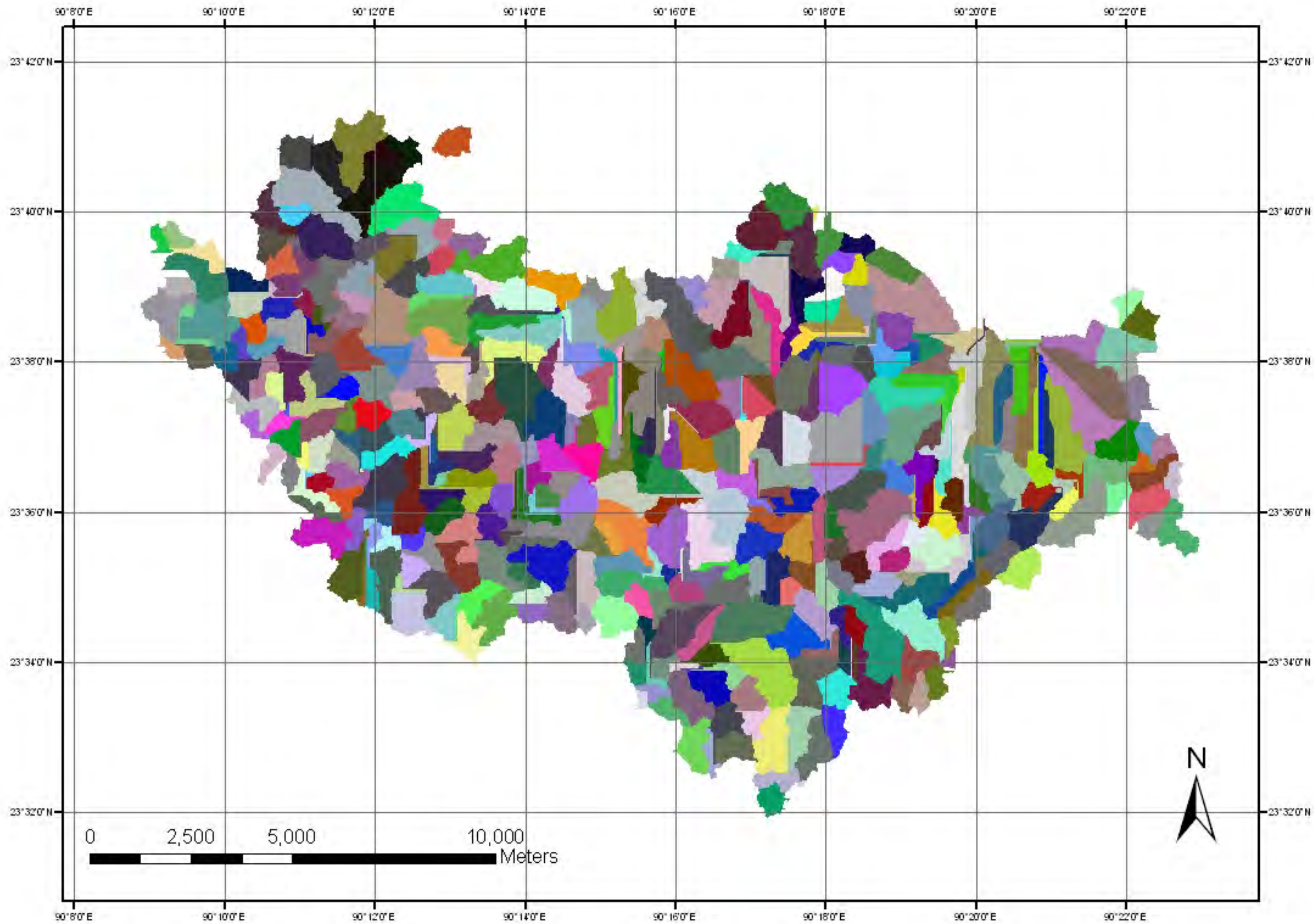



**Figure 6.2: Delineation of sub-catchments in the study area**

### 6.3.2 Selection of water quality sampling points

At first two criteria were considered for locating the sampling points for water quality: lowest depression area with defined sub-catchment or contributing area and landuse pattern close to the sampling points. Reviewing the sub-catchment map and the drainage network of the study area it was observed that there were a few (4 to 5) well connected drainage networks in the study area which represent different depression areas. Since 67% of Arial beel is located within Sreenagar thana, the most prominent drainage network, i.e depression in Sreenagar thana located at the central south section of the study area was selected as the potential location for sample collection (Figure 6.3).

It is to be noted that the central south section of the study area thus selected constitute of a number of depressions. To identify these areas, contour maps at different intervals were drawn for the study area (Figures 6.4 and 6.5). The contour maps were compared with a soil and land use map of Sreenagar thana collected from SRDI (Figure 6.6). Based on these maps the deepest regions within Sreenagar thana were identified. The deep regions were corroborated well with the connected drainage network identified for sample collection.

Two sampling points were initially selected (sampling points 1 and 3 as shown in figure 6.7). Sampling point 1 is representing an area in which the land use pattern is a mixture of agriculture and settlement, while sampling point 3 is representing an area in which the land use pattern is dominated by agriculture only (Figure 6.8). However, during the first field visit for water quality sampling, sampling point 3 was wrongly located at another location hereby called sampling point 2. The location was corrected (sampling point 3 is shown in figure 6.8) during the second set of sampling. This means that the samples were collected from two locations (sampling point 1 and 2) during first sampling and three locations (sampling point 1, 2 and 3) during second sampling. Here it is to be noted that the sampling locations did not exactly match with the deepest parts of the beel as shown in figure 6.7. This was because of difficulty in accessing the deepest parts of the beel faced by the researcher. However, the locations were close enough to the deepest parts of the depressions such that water quality parameters would be representative.

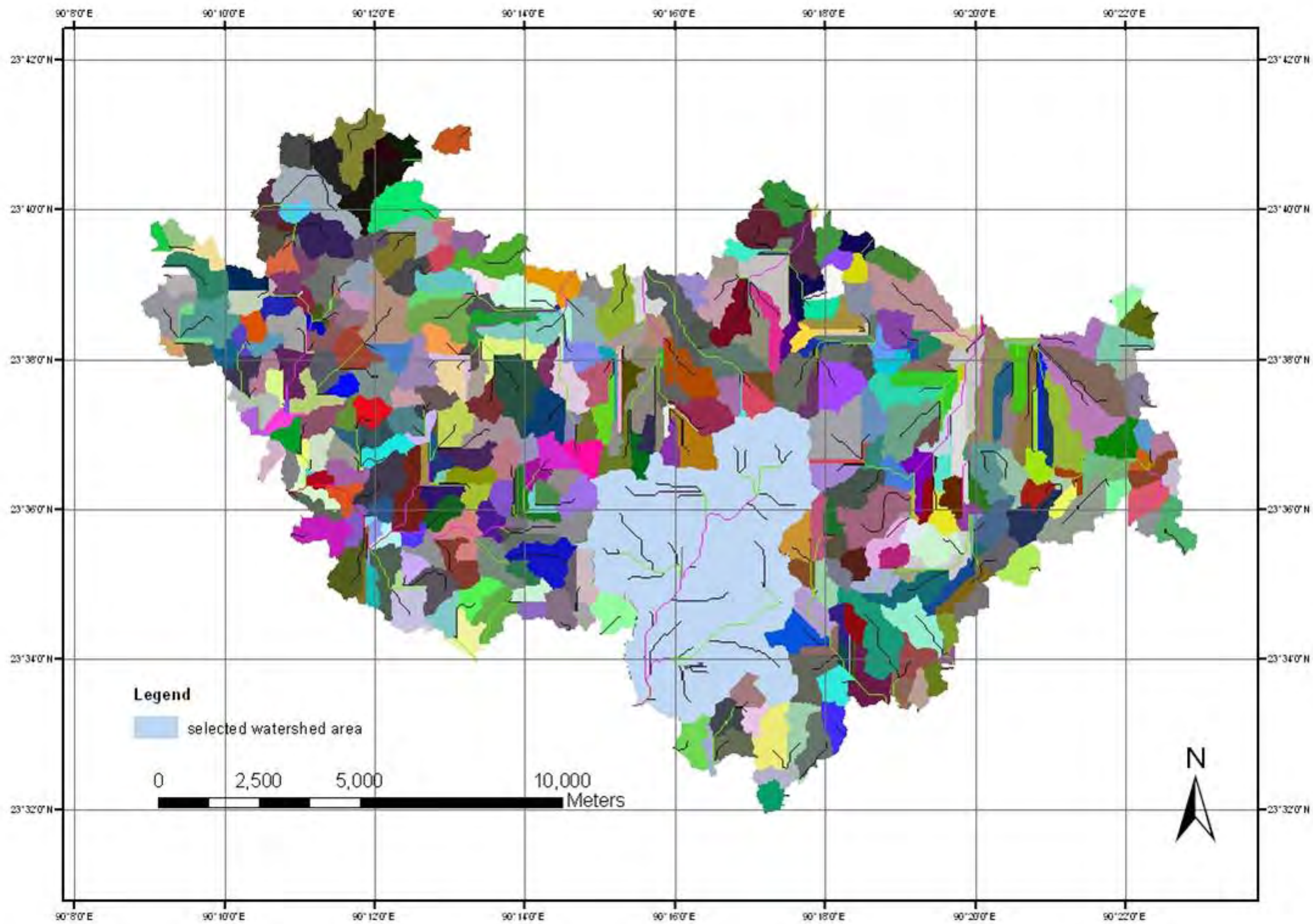



**Figure 6.3: Selected watershed in the study area**

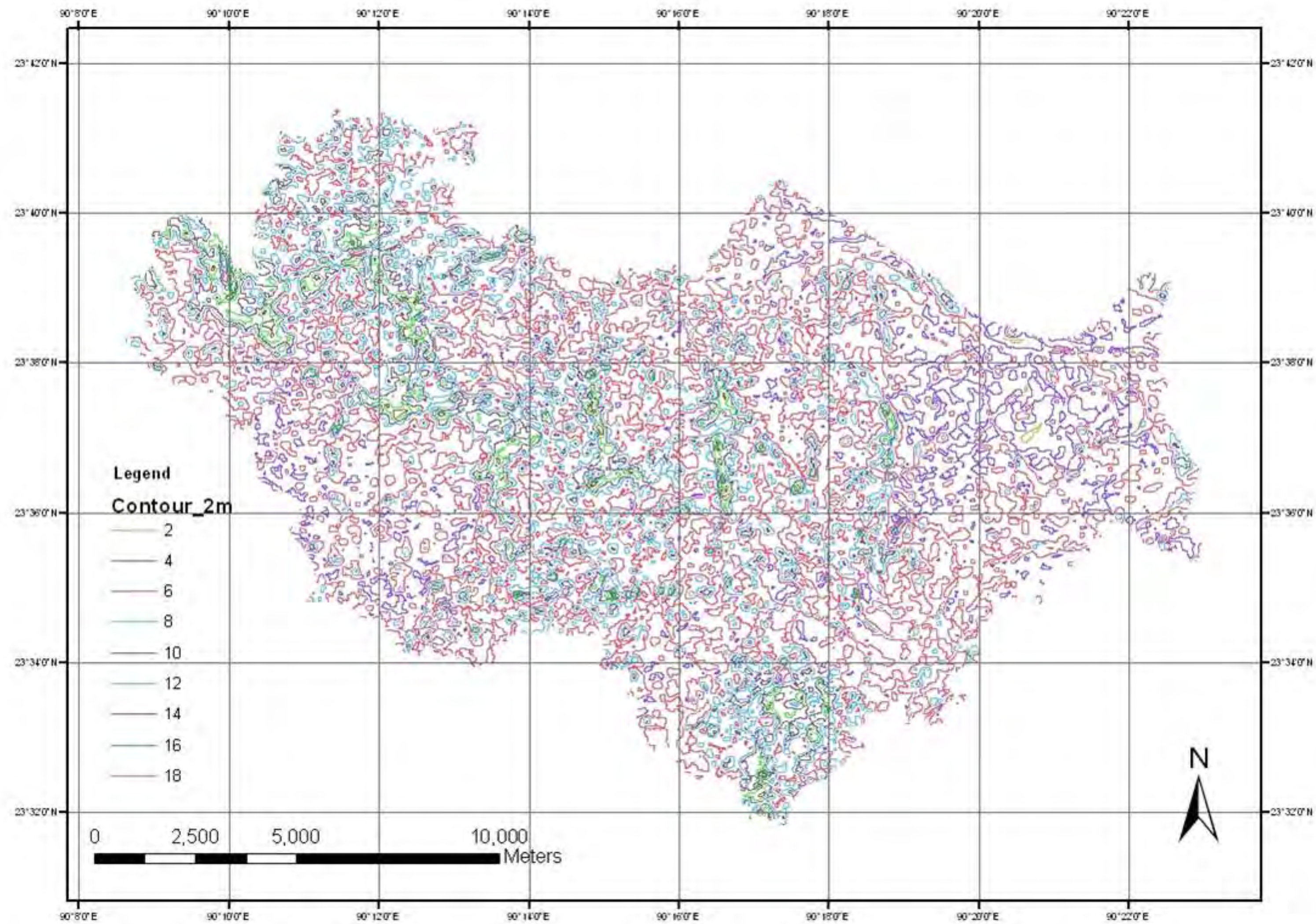



**Figure 6.4: Contour_2m intervals in the study area**

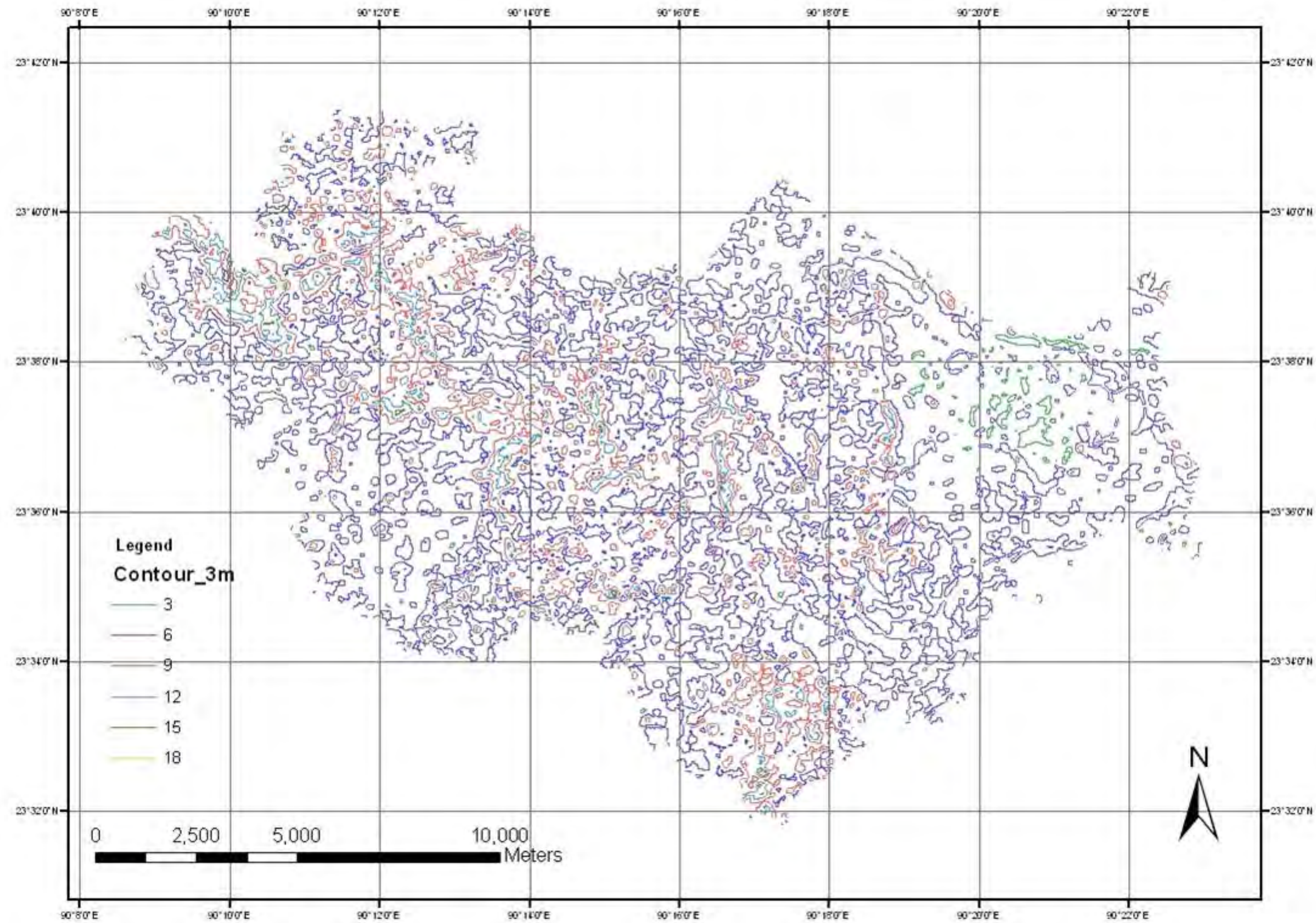



**Figure 6.5: Contour_3m intervals in the study area**

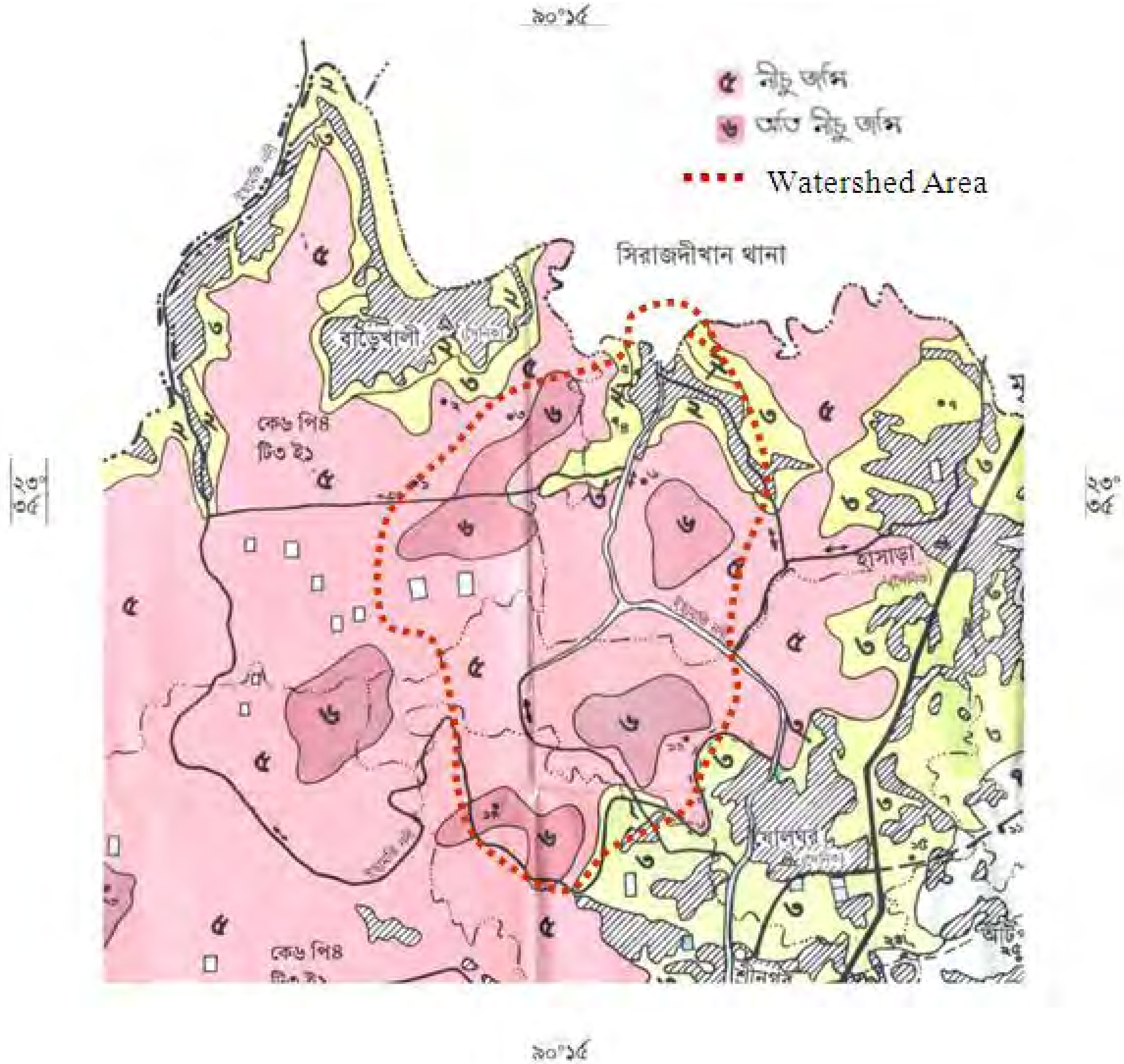



**Figure 6.6: Soil and Land use map of Sreenagar thana (Source: SRDI, 1991)**

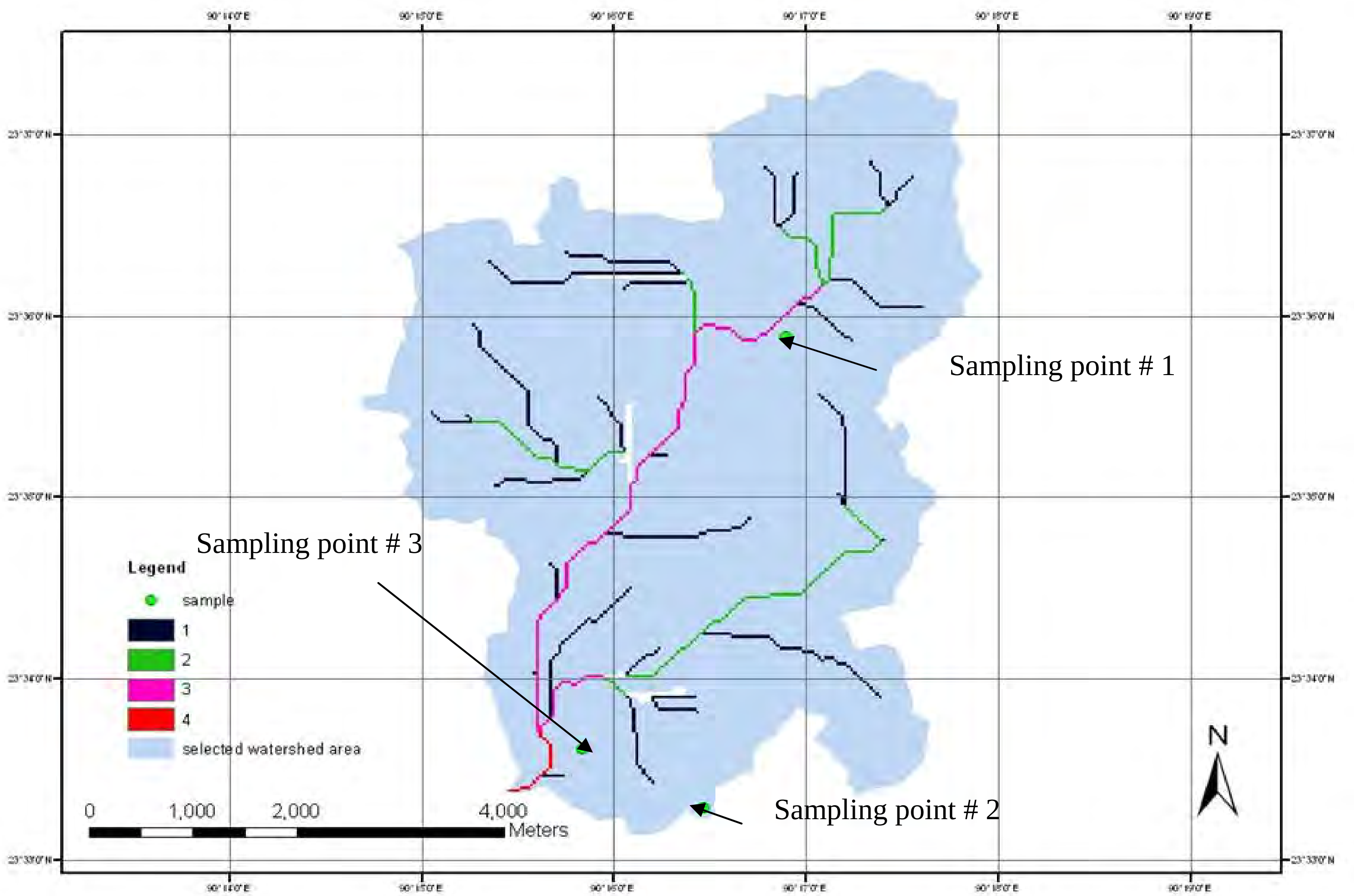



**Figure 6.7: Selected watersheds with sample collection pts and drainage network**

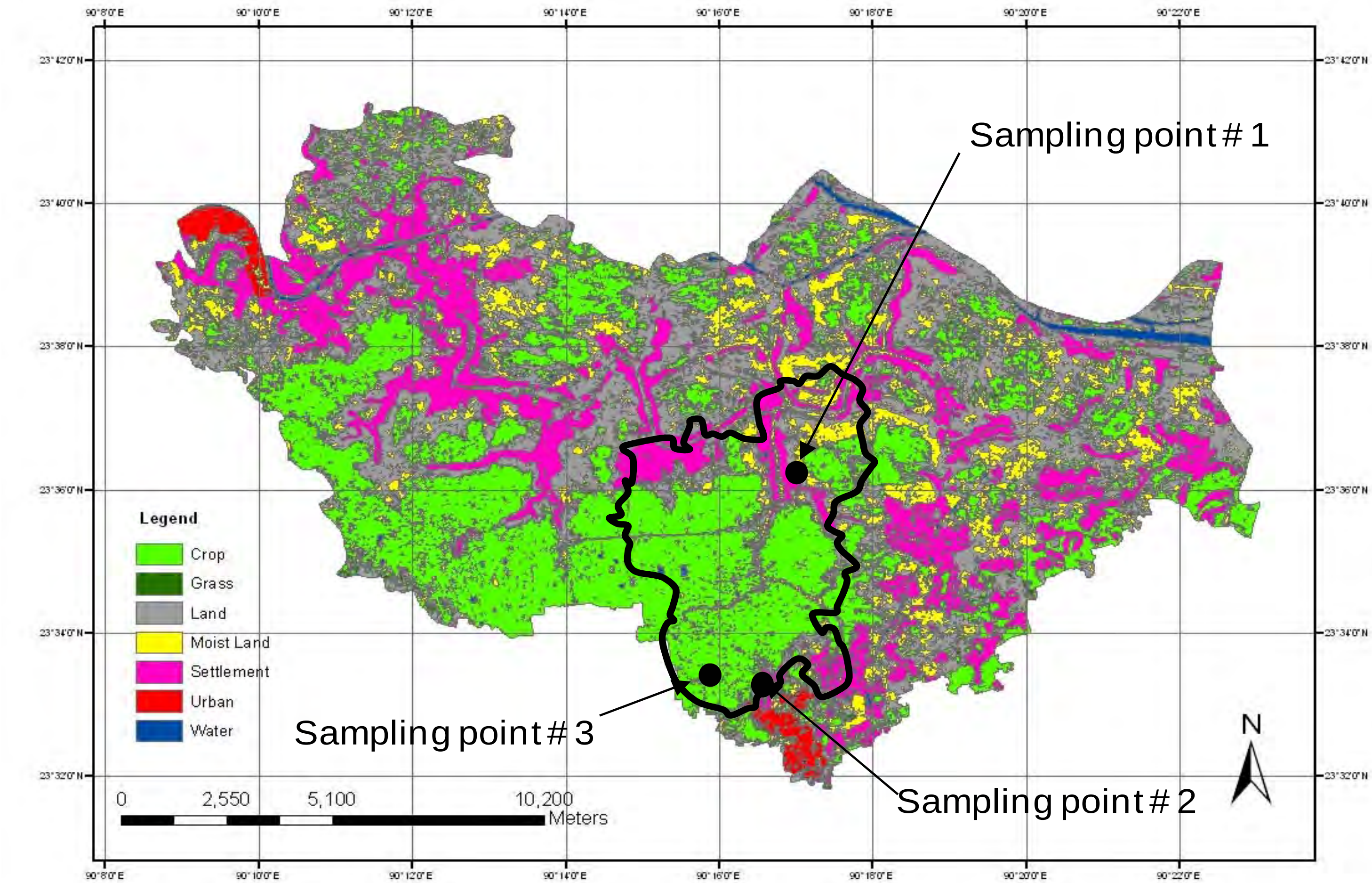



**Figure 6.8: Land use pattern near the sample collection points**

### 6.3.3 Water sampling

Water samples were collected in plastic bottles following the standard technique from the sampling points. Samples were collected from one foot below from the surface. Each sample size was approximately 600 ml.

The first group of samples was collected from Alompur mouza in Hasara union under Sreenagar thana in Munshiganj district (Figure 6.9) and Ardhipara mouza in Sreenagar union under Sreenagar thana in Munshiganj district (Figure 6.10). The first group of samples was collected on 7$^{th}$ April, 2012. The second group of samples was collected from two places mentioned earlier (Figures 6.11 and 6.12) and a new place called Dayahata mouza in Sreenagar union under Sreenagar thana in Munshiganj district (Figure 6.13). The second group of samples was collected on 30$^{th}$ June, 2012. Thus the first group of samples was collected in pre-monsoon and second group of samples was collected in early monsoon season. The reason for this choice of timing for sample collection was to compare the pre-monsoon and monsoon season data so that the researcher can analyze whether there was any significant change in water quality from agricultural runoff in the depression areas and whether the changes, if any, were of any concerns in terms of ecosystem health of the beel area. In early monsoon, the depression areas start to get inundated by rainfalls and runoff from individual sub-catchments of each depression areas. During the later part of the monsoon, the inundated areas increase with more rainfall and floodwater from surrounding rivers, eventually becoming one big inundated area. The second group of sampling was done in June 2012 after the depressions had already received substantial quality of water. Figure 6.14 shows the satellite images of sample collection points.

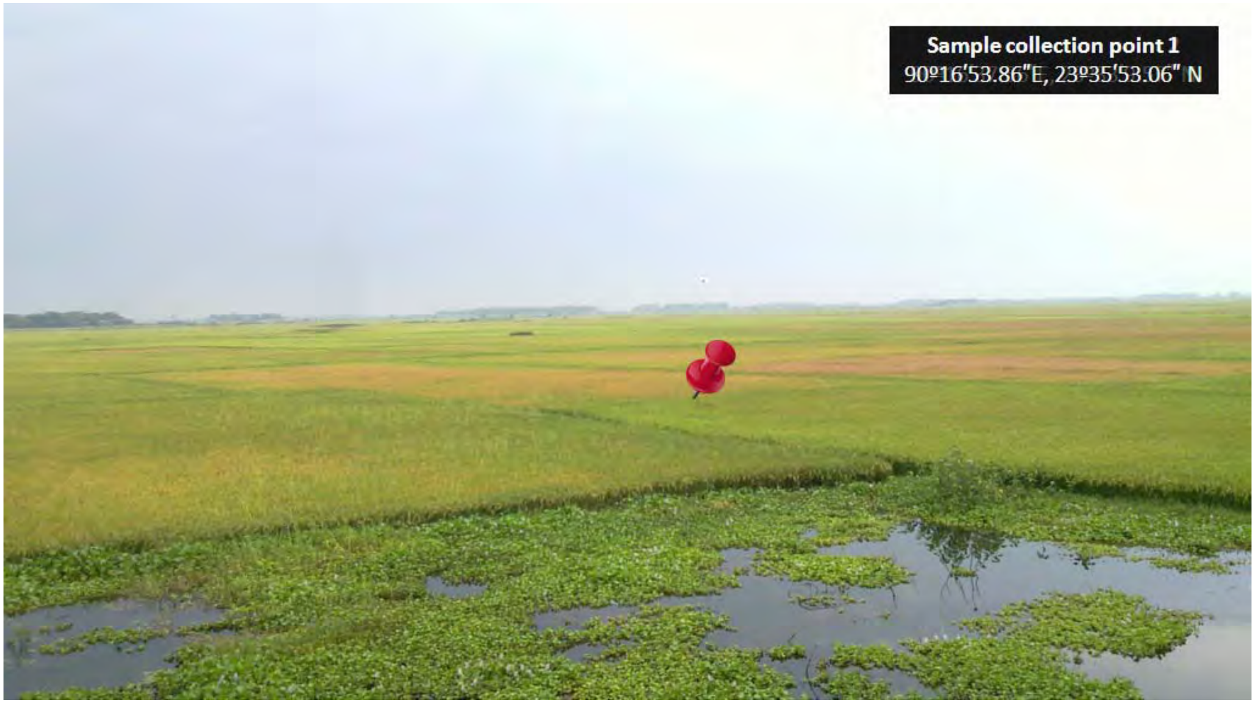



**Figure 6.9: Sample collection point 1 on 7th April 2012**


**Figure 6.10: Sample collection point 2 on 7th April 2012**


**Figure 6.11: Sample collection point 1 on 30th June 2012**

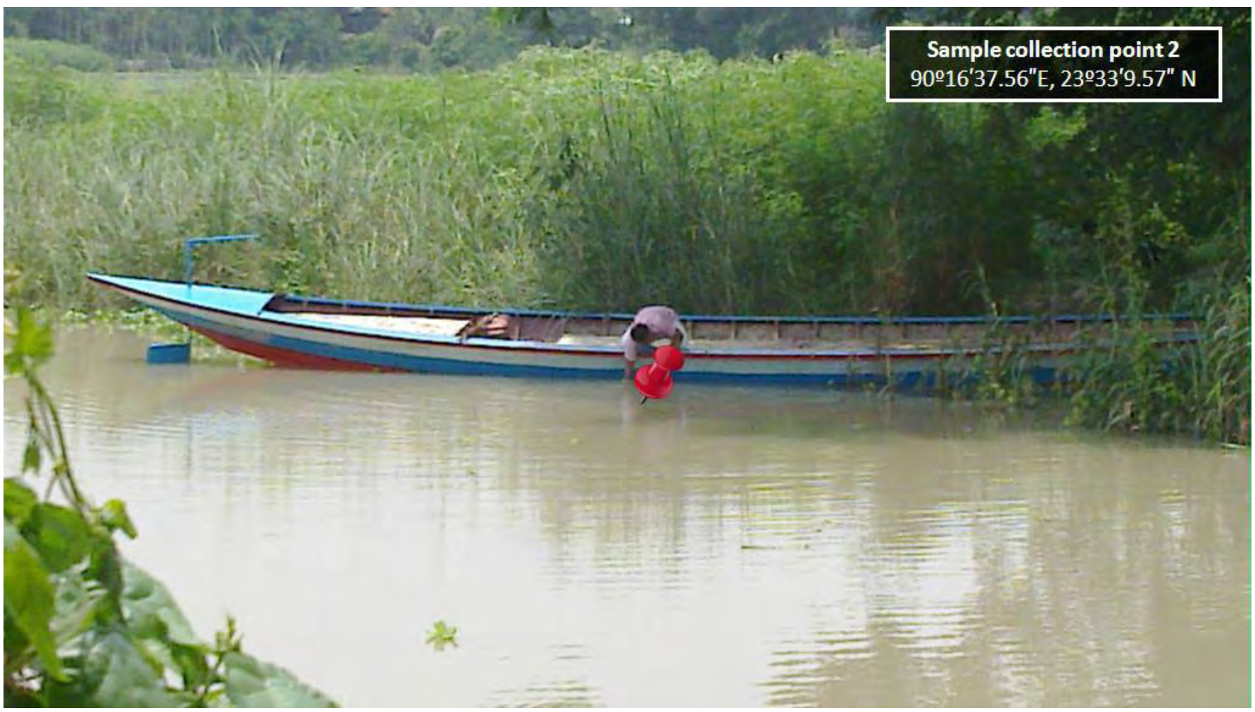



**Figure 6.12: Sample collection point 2 on 30th June 2012**

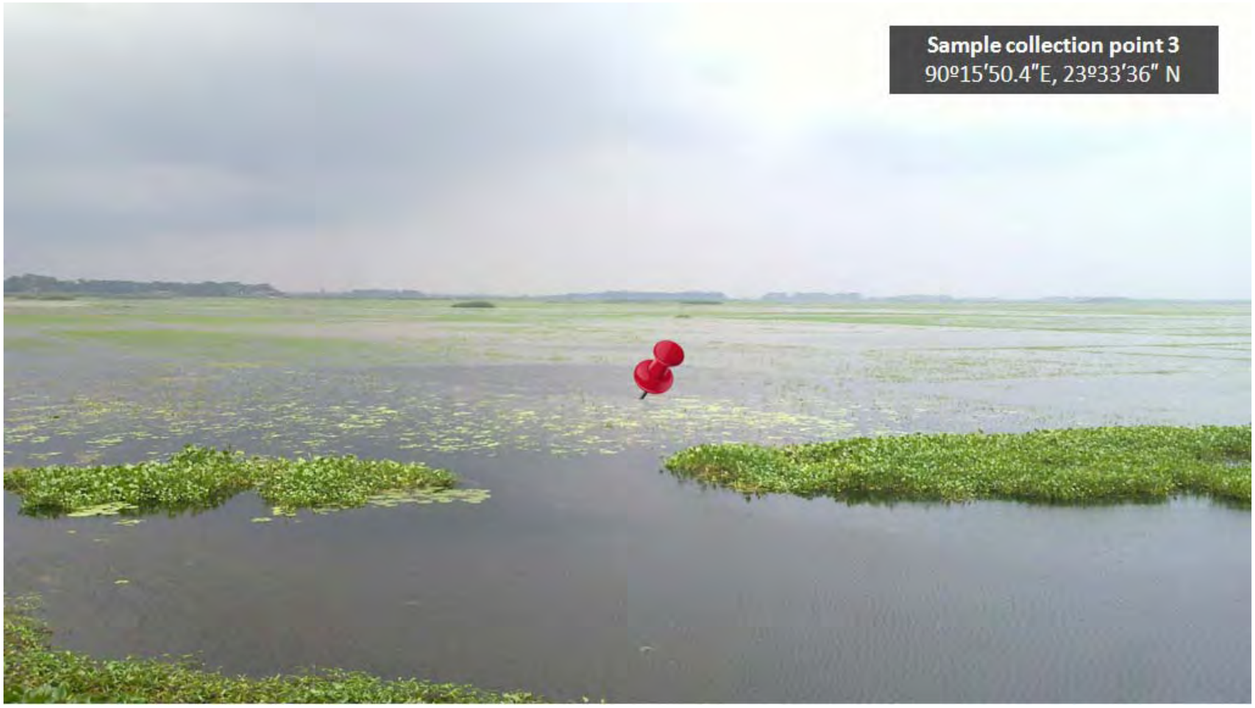



**Figure 6.13: Sample collection point 3 on 30th june 2012**


**Figure 6.14: Satellite image of 3 sample collection points**

### 6.3.4 Laboratory analysis of water quality parameters

The collected water samples were analyzed for the color of water, temperature, pH, dissolved oxygen, conductivity, COD, BOD, TSS, TDS, alkalinity, hardness, ammonia, iron, nitrate and phosphate. The chemical analysis of water quality parameters was conducted in the Soil and Water analysis laboratory, IWFM, BUET (Figure 6.16). For chemical analysis of these parameters a number of methods, Hach (2007) were used. They are listed in Table 6.1.

**Table 6.1: Methods used for chemical analysis of different water quality parameters**

| SI | Parameters | Unit | Methods/Instruments |
|---|---|---|---|
| 1 | pH | | HI 8424 pH meter |
| 2 | Temperature | ° c | HI 8424 pH meter |
| 3 | DO | mg/l | HI 8043 DO meter |
| 4 | Conductivity | µs | HI 8033 Conductivity meter |
| 5 | Color | ptco | 8025 Platinum-Cobalt Std method (15~500 units) |
| 6 | TSS | mg/l | 8006 Photometric method(5~750mg/L) |
| 7 | TDS | mg/l | TDS meter |
| 8 | BOD | mg/l | BOD Track II Respirometric method |
| 9 | COD | mg/l | 8000 Reactor Digestion method( 0.7~40mg/L) |
| 10 | Alkalinity | mg/l as $CaCO_3$ | Phenolphthalein and Total method (10~4000 mg/L as $CaCO_3$ |
| 11 | Hardness | mg/l as $CaCO_3$ | Hardness, Total using EDTA (10~4000 mg/L as $CaCO_3$ |
| 12 | Iron | mg/l as Fe | 8008 Ferover Method Powder Pillows or Accuvac Ampuls(0.02~3.00 mg/L) |
| 13 | Ammonia | mg/l as $NH_3$-N | 8038 Nessler method (0.02~2.50 mg/L as $NH_3$-N) |
| 14 | Nitrate | mg/l as $NO_3$-N | 8039 Cadmium Reduction Method Powder Pillows or Accuvac Ampuls (0.3~30mg/L as $NO_3$-N) |
| 15 | Phosphate | mg/l as $PO_4^{-3}$ | 8114 Molybdovanadate method Reagent Solution or AccuVac Ampuls (0.3~45 mg/L as $PO_4^{-3}$) |

**Figure 6.15: Laboratory analysis of water samples**

## 6.4 Water Quality in Arial Beel

Different water quality parameters analyzed for Arial Beel for two different times of the year (April and June) are summarized in Tables 6.2 and 6.3.

**Table 6.2: Results of water quality parameters of Arial Beel during April 2012**

| SI No | Parameter | Unit | Standard Value | Observed value | |
|---|---|---|---|---|---|
| | | | | Sample 1 | Sample 2 |
| 1 | pH | | 6.5-8.5*** | 7.8±0.04 | 7.9±0.08 |
| 2 | Temperature | ° c | | 27.5±0.1 | 27.4±0.1 |
| 3 | DO | mg/l | ≥5* | 4.67±0.6 | 4.03±0.5 |
| 4 | Conductivity | μs | <2.5-4** | 0.54±0.02 | 0.52±0.08 |
| 5 | Color | ptco | | 270±29 | 163±7 |
| 6 | TSS | mg/l | | 41±5 | 25±2 |
| 7 | TDS | mg/l | <100*** | 271±2 | 266±3 |
| 8 | BOD | mg/l | ≤6* | 2.5±0.7 | 3.3±0.5 |
| 9 | COD | mg/l | <60*** | 35±5 | 140±7 |
| 10 | Alkalinity | mg/l as CaCO3 | 100-200*** | 128 | 136 |
| 11 | Hardness | mg/l as CaCO3 | 121-180*** | 206±2 | 185±5 |
| 12 | Iron | mg/l as Fe | <0.3*** | 0.13±0.01 | 0.13±0.01 |
| 13 | Ammonia | mg/l | <0.5*** | 0.38±0.02 | 0.47±0.02 |
| 14 | Nitrogen | mg/l | <0.3**** | 0.25±0.02 | 0.15±0.02 |
| 15 | Phosphorus | mg/l | <0.015**** | 0.4±0.01 | 0.45±0.01 |

Notes: * standard for wetland fisheries, **standard for agriculture, *** standard for freshwater, **** to cause algal blooms.
Standard are compiled from Ontario Drinking Water Standard, 2003; USEPA, 1988; MoE Ontarion, 1997; Sawyer (1947) ; Nordin, 1986.

**Table 6.3: Results of water quality parameters of Arial Beel during June 2012**

| SI No | Parameter | Unit | Standard Value | Observed value | | |
|---|---|---|---|---|---|---|
| | | | | Sample 1 | Sample 2 | Sample 3 |
| 1 | pH | | 6.5-8.5*** | 7.5±0.06 | 7.8±0.02 | 7.9±0.02 |
| 2 | Temperature | ° c | | 28.4±0.1 | 28.5±0.2 | 28.8±0.4 |
| 3 | DO | mg/l | ≥5* | 14.3±0.2 | 13±0.1 | 13±0.2 |
| 4 | Conductivity | µs | <2.5-4** | 0.88±0.02 | 0.80±0.02 | 0.76±0.02 |
| 5 | Color | ptco | | 48±3 | 120±7 | 47±3 |
| 6 | TSS | mg/l | | 11±1 | 193±6 | 10±1 |
| 7 | TDS | mg/l | <100*** | 86±2 | 60±1 | 66±1 |
| 8 | BOD | mg/l | ≤6* | -- | -- | -- |
| 9 | COD | mg/l | <60*** | -- | -- | -- |
| 10 | Alkalinity | mg/l as $CaCO_3$ | 100-200*** | 71±2 | 70±4 | 72±6 |
| 11 | Hardness | mg/l as $CaCO_3$ | 121-180*** | 47±2 | 47±2 | 47±4 |
| 12 | Iron | mg/l as Fe | <0.3*** | 0.25±0.01 | 0.4±0.01 | 0.2±0.02 |
| 13 | Ammonia | mg/l | <0.5*** | 0.3±0.02 | 1.6±0.02 | 0.48±0.03 |
| 14 | Nitrogen | mg/l | <0.3**** | 0.15±0.02 | 0.16±0.02 | 0.15±0.01 |
| 15 | Phosphorous | mg/l | <0.015**** | 0.26±0.05 | 0.9±0.01 | 0.26±0.05 |

Notes: * standard for wetland fisheries, ** standard for agriculture, *** standard for freshwater, **** to cause algal blooms.
Standard are compiled from Ontario Drinking Water Standard, 2003; USEPA, 1988; MoE Ontarion, 1997; Sawyer (1947) ; Nordin, 1986.

**pH and temperature**: Aquatic organisms differ as to the range of pH in which they flourish (Dallas and Day, 2004). There are guidelines (Ontario Drinking Water Standard, 2003) specifying a pH range of 6.5-8.5 for flowing water. No direct guideline is available for wetlands. According to DWAF (1996), pH level below 6.5 may cause accumulation of heavy metals over the long term. However, in wetlands this is not a big concern as wetland plants are known for their heavy metal tolerance (Brooks, 1998).

pH value ranges from 7.5 to 7.9 in two groups of samples; there is almost no change in pH from April to June. The pH (7.5-7.9) range indicates neutral value and in the recommended range (6.5-8.5). Temperature varies from 27.5°c to 28.8°c with laboratory room temperature, with similar values in April and June.

**DO:** The standard for DO concentration for wetlands according to the guideline (USEPA, 1988) is ≥ 5 mg/l. DO is a function of temperature and some guidelines (e.g. MoE, Ontario, 1979) recommend standard DO range as 4-8 mg/l with temperature ranging from 10-25°c. The concentration of DO in the first group of samples is below the EQS≥ 5 mg/l. This indicates slightly anaerobic condition. However, due to the monsoon rains the value of DO became >13 mg/l in the second group of samples and it is above the EQS≥ 5 mg/l. It indicates an aerobic condition which is good for fisheries health. This clearly suggests that there is seasonality in the DO concentration, with lower values with inputs from agricultural runoff after early rains, gradually increasing with increasing surface area and volume of wetland water.

**Conductivity:** In USA water with conductivity above 0.83 µs is not recommended for drinking water and water with conductivity above 2.5-4 µs is problematic for irrigation (USEPA, 1988). At high value of conductivity, water becomes saline, which is unsuitable for drinking and stressful for plants. The value of conductivity (0.52-0.88 µs) is within the tolerable limit (2.5-4 µs).

**TDS:** The standard value of TDS for freshwater water is 100 mg/l (USEPA, 1988). TDS value is varied from 60-271 mg/l against the EQS standard of 100 mg/l.

**BOD**: The BOD value is varied from 2.5-3.3 mg/l while the standard value of BOD is ≤ 6 mg/l for fisheries (USEPA, 1988).

**COD:** The value of COD is varied from 35-140 mg/l while EQS is 4 mg/l for COD for drinking water.

**Alkalinity and Hardness:** Alkalinity values of 100 – 200 mg/l are ideal (USEPA, 1988). The values of Alkalinity in both seasons (pre-monsoon and early monsoon) are within the range. The value of hardness is varied from 47-206 mg/l while EQS is 121-180 mg/l.

**Iron:** The provincial water quality guidelines for Ontario, Canada (MoE Ontarion, 1997) recommended iron concentration was 0.3 mg/l. Iron is an essential element to all organisms and is used in a variety of biological processes. Iron is moderately toxic to plants and only minimally toxic to mammals (MoE Ontarion, 1997). Iron can lead to a decrease in water pH and an increase in turbidity, which can reduce the primary productivity. The concentration of iron (0.13-0.25 mg/l) is within the range 0.3 mg/l except in sample 2 (0.4 mg/l) in early monsoon samples. This is due to the fact that sampling point 2 is near a cattle farm (Figure 6.17) and also in close proximity of settlement area, and hence is likely to receive animal and human wastes with the runoff.

**Ammonia**: For ammonia, fresh-water quality standard is <0.5 mg/l (USEPA, 1988). The concentration of ammonia (0.3-0.48 mg/l) is within the range <0.5 mg/l except in sample 2 (1.6 mg/l) in early monsoon samples. Concentration of ammonia in sample 2 is above the standard value (<0.5 mg/l) because of presence of livestock and settlement area near sample collection point 2 (Figure 6.17).

**Nitrogen**: Sawyer (1947) suggests that a nitrogen concentration above 0.3 mg/l is sufficient to cause blooms of algae. The same limit is also specified by British Columbia (BC) criteria 1980 for lake aquatic life (Nordin, 1986). Nitrogen concentration (calculated from nitrate concentration) is 0.25 mg/l on the first group of samples (collected on 7$^{th}$ April) and 0.15 mg/l on 2$^{nd}$ group of sample (collected on 30$^{th}$ June). Both values are below the expected level (0.3 mg/l).

**Phosphorous**: Sawyer (1947) suggests that phosphorus concentration in excess of 0.015 mg/l is sufficient to cause blooms of algae. USEPA criteria for water quality (USEPA, 1988) also specify the acceptable phosphorous concentration to be less than 0.015 mg/l. Phosphorus in the form of phosphates can make its way into a wetland via runoff and stream flow from sources such as livestock, birds including chickens, ducks which use wetland as a roost or feeding area, surface runoff from anthropogenic sources such as farming and mining, runoff from the landscape, rainfall, and wind inlets (Palmer et al 2002).

**Figure 6.16: Livestock farms near sample collection point 2**

Phosphorus concentration is 0.4 mg/l and 0.26 mg/l (calculated from phosphate concentration) on first group of samples (collected on 7th April) and second group of samples (collected on 30th June) respectively near paddy field. In the samples collected from collection point 2 located near the livestock firms and settlement area (Figure: 6.16), the phosphorous concentration is 0.9 mg/l. It receives a large amount of animal and human wastes with the runoff. All the values of phosphorous concentration are significantly higher compared to recommended value (<0.015 mg/l)

**Figure 6.17: Poultry farm near Arial Beel**

Sreenagar thana is known for livestock farming and poultry farming. From, analysis of classified images, it was seen that, grass production is gradually increasing in the study area over the years. This trend has aggravated the quantity of cow dung and garbage from other domestic sources discharged contributing to nutrient discharge in beel water. Higher concentration of phosphorous is attributed to agricultural runoff in addition to runoff with animal and human wastes.

## 6.5 Water Quality and Impacts on Arial Beel Ecosystem

From the water quality analysis, results presented in the previous section, it is clear that the major inorganic nutrients entering into the beel are nitrogen and phosphorus. The concentration of nitrogen and phosphorus are the important parameters in context of Arial Beel water quality and ecosystem of that beel area.

In pre-monsoon, due to higher rate of oxidation, early rainfall and lower runoff volume to nutrient loading ratio, the concentration of nitrogen and phosphorous will be high but in early monsoon; while lower rate of oxidation and higher runoff volume to nutrient loading ratio can lead to lower concentration of nitrogen and phosphorous. A recent study conducted by Weilhoefer et al. (2008) showed that mixing of flood water and wetland waters decreased the levels of conductivity, concentration of nitrogen and phosphorous. Changes in algal biomass followed changes in water chemistry with the high magnitude floods producing condition unfavorable for algal growth. The study found that the changes in water chemistry and algal biomass depend on the duration and magnitude of flooding.

From the water quality analysis it is seen that, the nitrogen concentrations were within acceptable limit, the phosphorous concentrations were found to be substantially high even in June. But it can be expected that with more rainfall occurring later and with water also coming from surrounding river over flows, the concentration would go down even further. However, no measurements were made in later times that could have verified this.

The very high level of phosphorous concentrations in beel water is definitely a concern. However, how much its impact would be on accelerated algal growth and eutrophication in turn cannot be inferred at this point. The results can be considered as indicative; there is clearly a need to carry out a detailed, in-depth study to investigate the impact of agricultural activities on Arial Beel ecosystem. This will require extensive monitoring of water quality parameters as well as soil conditions at different locations of the beel area at different times with a regular interval and if possible over a number of years. Modeling of agricultural runoff could then be employed to clarify the processes and impacts. Such modeling requires simulation combined with wash off and nutrient loading like- applied amount of fertilizer, plant uptake ratio, absorbed amount by soil and infiltration amount etc. It also needs the collection of data for minimum two hydrological years, where one year data will be used for model calibration and the successive year's data will be used for validation. This is one of the reasons no modeling was employed in the current study.

Based on secondary literature review, field observation and FGDs, impact on Arial beel eco-system was conducted. The soil quality measured by the Soil Resources Development Institute (SRDI) in 1991 showed an average phosphorous concentration of about 10μg/gm (SRDI, 1995) while more recent measurements by SRDI in around 2007-08 showed an average concentration of about 2μg/gm in the very low land area. This data is a little contradictory, as it indicates less binding of phosphorous to the sediments over time. Since soil samples in the depression areas, could not be analyzed, it is not possible to discuss adequately about how much phosphorous is available in the soil samples in long term for binding to the bottom sediments.

The researcher explored various secondary sources for research on water quality parameters of Arial Beel region. As of the research date, the Department of Environment (DoE) has not yet conducted any study on Arial beel or surrounding areas. They conducted a study on river water quality of ten selected rivers in Bangladesh in 2010. Of the ten rivers studied by DoE, Dhaleswari is the closest to Arial beel region. DoE conducted test on some selected parameters like: TDS, BOD, COD, DO and ammonia in dry and wet season in 2010. The value of these parameters is presented in Table 6.4.

**Table 6.4: Results of water quality parameters in Dhaleswari river, in dry and wet season in 2010**

| Parameters | Standard value (mg/l) | Observed value in dry season (mg/l) | Observed value in wet season (mg/l) |
|---|---|---|---|
| TDS | <100 | 127 | 63 |
| DO | >5 | 5.1 | 9.2 |
| BOD | ≤6 | 3.5 | 2.3 |
| COD | <60 | 58 | 70 |
| Ammonia | <0.5 | 0.6 | 0.7 |

Source of data: (DoE, 2010)

DoE did not conduct test on the other parameters like nitrogen and phosphorous which are the major nutrients entering into beel area through agricultural runoff. The study also did not cover the changes over time. So, it was not possible to relate how water quality changed due to land use change.

A series of interviews were conducted with a group of local people, including fishermen (Figure 6.18) and gypsy people (Figure 6.19) in this study. The local fishermen reported that some native fish species like-boal (wallago attu), shoal (channa striata), koi (anabas testudineus) are now endangered. The number of professional fishermen is decreasing day by day because it is not possible for them to lead life only by fishing. The gipsy men and women, who come to Arial beel in monsoon to collect different types of snake, snail, oyster etc, complained that day by day number of snakes, snails and oysters are decreasing. Though it can not be said that decrease of fish availabilities was occurred only for excessive use of fertilizer and pesticides, it can be said that excessive use of fertilizer and pesticides and increased livestock and poultry farming are the most important factors in this reduction.

**Figure 6.18: Interview with a local fisherman**

**Figure 6.19: Gipsy boats visiting Arial beel**

The high level of phosphorous concentration found in this study, can be considered as indicative of gradual deterioration of water quality in the study area. Future studies need to be carried out to explore to what extent the high level of phosphorous proliferation will continue, and the likelihood of plankton or algal blooms in Arial Beel.

# CHAPTER SEVEN

# CONCLUSIONS AND RECOMMENDATIONS

## 7.1 Conclusions

Land use changes of the selected study area –Arial Beel – were studied by analyzing the Landsat TM satellite images of the area. Six classified images from 1984 to 2004 and two more unclassified images dated 13 February 1989 and 15 February 2010 were used to interpret overall pattern of historical land use change of the study area until the recent times. More information about land use change was collected from field survey and focus group discussions. To determine the eco-hydrological characteristics of Arial beel, the ecological resources, hydrological features, climate, soil and land types are discussed in details. To assess the eco-hydrological effects due to land use change, water quality was used as an indicator for ecosystem function of Arial Beel.

Based on the findings, the following conclusions are drawn:

- Analyzing the classified images from 1984 to 1999, it can be concluded that the area under crop production (consists of Boro and other rabi crops) have remained relatively unchanged at 32% of the total land mass throughout these 15 years.
- Fallow bare land not under regular cultivation was found to be used for seasonal vegetable production and the average percentage of land under such usage was also 32% of the total area studied over the same period.
- Grass production has increased from 5% to 11% over the years. This can be interpreted as an impact of increasing popularity of livestock farming in the locality.
- There was almost no change in rural or urban settlement areas from 1984 to 1999. Rural and urban settlements remained constant over the period at 17% and 1% of total land area during that period respectively. This signifies low level of urbanization in the study area during this period.
- The analysis of Landsat TM image of the study area for 1989 and 2010 together with BBS data for 1983-2008 suggests that net cultivable area dropped significantly between 1990 and 2010 due to reduction of rabi crops and the growth of the real estate projects.

- The mushrooming real estate projects (a trend starting in early 2000s) put significant pressure on land available for cultivation.
- Analyzing the images and from ground truthing it was observed that, from 1980s, the major part of the crops grown in the area consisted of Boro. Now the position of the primary crop is taken by IRRI/29 and the production is 7~7.5 t/ha.
- Thus, alteration in cropping pattern (from traditional varieties to high yielding varieties) together with reduction of net cultivable area due to reduction of rabi crops and the growth of the real estate projects have been detected as the major themes of land use change in the study area between 1984 and 2010.
- Extensive use of fertilizers is a common source of nutrients entering into the beel area through agricultural runoff.
- Nitrogen concentration is 0.25 mg/l on 1$^{st}$ group of sample (collected on 7$^{th}$ April) and 0.15 mg/l on 2$^{nd}$ group of sample (collected on 30$^{th}$ June). Both values are below (0.3 mg/l) to cause algal blooms.
- Phosphorus concentration is 0.4 mg/l and 0.2 mg/l on 1$^{st}$ group of sample (collected on 7$^{th}$ April) and 2$^{nd}$ group of sample (collected on 30$^{th}$ June) respectively near paddy field. Near cattle firm and the settlement area, the phosphorous concentration is 0.9 mg/l. These levels of phosphorous concentration are significantly higher than the acceptable limit of 0.015 mg/l.
- The high level of phosphorous contribution is mainly attributed to extensive use of fertilizer and popularity of livestock farming in the locality.
- The concentration is likely to decrease with increased mixing of accumulated rainwater in depression areas and floodwater from the surrounding rivers.
- The very high level of phosphorous concentration in the month of June is a concern for beel fisheries and other aquatic lives of the beel.
- Through interview of local fishermen it has been verified that some native fish species like-boal *(wallago attu),* shoal *(channa striata),* koi *(anabas testudineus)* are now scarce. Number of snakes, snails and oysters are also decreasing day by day. Substantially the livelihood of the fishermen has been impacted.

## 7.2 Recommendations

- It was not easy to access the entire beel area during study period. The greatest portion (67%) of the beel belongs to Sreenagar upazilla which is followed by Nawabgonj upazilla (24%). The unions covering larger share of wetland surrounded by human settlements were selected as the study area. Sreenagar upazilla was selected for FGD and potential location for sample collection. Such studies may be replicated for other adjuscent upazilas.
- Landsat TM satellite image can be classified using supervised classification technique with sufficient ground truthing.
- Samples were collected from three points in pre-monsoon and monsoon season. A higher number of samples across a longer study period would have produced more reliable results for the study.
- Unplanned urbanization initiatives could cause further disturbance to the eco-hydrological balance of Arial beel. The concerned authorities should take into consideration the possible impacts of land use change on the bio-diversity and the socio-economic environment of the area
- Land use change may cause further impact on soil quality, climatic factors and runoff. In this study most attention was paid to water quality. So further study on soil quality or runoff may be conducted.
- Future studies need to be carried out to explore to what extent the high level of phosphorous proliferation will continue, and the likelihood of plankton or algal blooms in Arial Beel
- Government should take necessary measures to ban the ecologically hazardous pesticides and fertilizers and also should take legal actions to control the import, supply and use of unauthorized pesticides and fertilizer in the country.

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**OFFICE OF THE MEMBER SECRETARY OF THE COMMITTEE FOR ADVANCED STUDIES & RESEARCH, BUET, DHAKA**

## Application for the approval of M. Sc. (Water Resources Development) thesis proposal

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**6. Date of First Enrolment in the Programme: April 2009**

**7. Tentative title:**

**IMPACT OF LAND-USE CHANGE ON ECO-HYDROLOGICAL CHARACTERISTICS OF ARIAL BEEL**

**8. Background and present state of the problem:**

Land-use change is a common term for the human modification of the earth's terrestrial surface. These land use changes include deforestation, road construction, agricultural development, change of land or soil, drainage, change of crop varieties, dam building, irrigation, coastal zone degradation, wetland modification, mining, the concentration and expansion of urban environments and other activities. Kashaigili et.al. ( 2009) found that the sustainability of eco-systems requires proper use of land and management of water. This study highlights the importance of integrating remote sensing and local knowledge in understanding the catchment resources dynamics and ultimately informing the policy and decision makers on a need for proper land planning and improvement in agricultural practices for the sustainability of the catchment resources.

Bangladesh is one of the most densely populated countries in the world. Increased food demand and other growing national economic activities exert pressure on water resources. (EGIS II, 2001). Moreover, runoff from agricultural lands causes toxicity in the surface water, which can have adverse impacts on aquatic habitats (EGIS II, 2001). The reduction of biodiversity, aquatic and amphibian resources, and wildlife habitats lead to the change in wetland-based human occupations and shrinkage of socio-economic activities (Islam and Sadque, 1992). As a consequence of resources degradation, the beel dependent fishermen had lost their occupations. From field surveys, Hossain (2009) found that the poor fishermen after losing previous occupations could not easily adapt to new occupations and in some cases they have already engaged in illegal works, which ultimately leads to social conflicts in the adjacent areas. So it is necessary to identify the impacts of land-use change on eco-hydrological processes and to predict the eco-hydrology based tools for sustainable land use change.

The site chosen for the study is the Arial Beel a large depression of about 723 $km^2$ lying between the Ganges and the Dhaleshwari rivers south of Dhaka. It is one of the major wetlands of Dhaka and Munshigonj districts. The Arial Beel itself is an agro-ecological zone (AEZ-15) (FAO, 1988) and part of Bio-ecological zone 4b (IUCN, 2002). It has a great ecological, economic, commercial and socio-economic importance. Approximately 500 species of flowering plants, 150 of vertebrates and 400 species of vertebrates are found in the beel area in addition to approximately 260 species of fin fishes and 25 shell fishes available in the beel (Islam, 2000).

**9. Objectives with specific aims and possible outcome:**

The specific objectives of this study are as follows:

- To detect the changes of land-use in the Arial Beel.
- To determine the eco-hydrological characteristics of the study area.
- To assess eco-hydrological effects due to land-use change.
-

Possible outcome:
The ultimate result of the study will be helpful for the sustainable land use change by adapting eco-hydrology based tools.

**10. Outline of Methodology/ Experimental Design:**

In recent times, the dynamics of land use and particularly settlement expansion in the area are analyzed using sophisticated systems such as GIS and Remote Sensing data as they provide a more extensive coverage of large areas compared to area photography. Kashaigili et.al. (2009) conducted a study on the dynamics of land use for the periods between 1984 and 2001 using Landsat TM and ETM+ images to locate and quantify the changes. In my study, the change of land use can be carried out by studying the satellite image based land-use maps of Arial beel over the last 35 years. Such maps will be collected from Centre for Environment and Geographic Information Services (CEGIS). More information about land use change can be collected from field survey and focus group discussions.

Both primary and secondary information sources will be used to attain the information of the Beel area. Dlamini et.al (2009) collected and analyzed water samples to assess the impacts of agricultural land use on ecosystem health. The water depth, color of water, temperature, turbidity, light penetration, pH, dissolved oxygen, conductivity and nitrogen can be estimated on the spot. Some of the chemical parameters like nitrate, phosphate and chlorophyll can be measured in the Soil and Water analysis laboratory, IWFM, BUET. The primary data needed, such as crop types and varieties, planning and harvesting times, fertilizers amount and types of fertilizers etc can be collected through focus group discussion. A number of research publications and literatures may be also consulted to collect secondary information. The secondary data such as soil texture, organic matter content of soils, rainfall may be collected from relevant organizations like BMD, SRDI and BARC.

In recent years, the eco-hydrological effects of landscape pattern change have been discussed intensively, in particular with respect to runoff (Bellot et al. 2001; Felix et al. 2002), water quality (Basnyat et al. 1999), soil quality (Sheng et al. 2003), and climate (Taylor et al. 2002). To examine the effects of land use change on annual runoff SWAT model (Arnold et.al., 1998) can be used. Using a core component of more complex models, a simple spreadsheet analysis can estimate the change in runoff (Harbor, 1994).

Improper land-use activities including crop farming lead to diffuse pollution. The main constituents of this pollution are nitrogen and phosphorus. Yuan et al. (2007) developed some functions for estimating diffusion pollution input loads using the gray prediction model developed by Wang et al.(2004). The discharge load of agricultural pollution was mainly correlated to the amount of rainfall, soil type, and type of crops being planted. Land-use changes may cause a further impact on climatic factors, soil quality and vegetation covers. Participatory rapid appraisals can be used to collect socioeconomic data on local knowledge and perceptions regarding changes in temperature and rainfall, soil quality and vegetation covers (Mati et al. 2008).

## 11. References:

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Yuan, D, Lin, B, Falconer, RA & TAO, J (2007), Development of an integrated model for assessing the impacts of diffuse and point source pollution on coastal waters, Environmental Modelling & Software, 22 (6): 871-879.

**12. List of Courses Taken:**

| Course No | Course Name | Credit | Grade | Grade Point | GPA |
|---|---|---|---|---|---|
| WFM 6201 | Hazards and Risk Analysis | 3 | B+ | 3 | 3.17 |
| WFM 6309 | Water Quality Management | 3 | B+ | 3 | |
| WFM 5202 | Socio-economic Analysis | | S | | |
| WFM 6209 | Interdisciplinary Field Research Methodology | 3 | B+ | 3 | |
| WFM 6104 | Gender and Water | 3 | B+ | 3 | |
| WFM 6303 | Integrated Water Resources Management | 3 | A | 3.5 | |
| WFM 6202 | Remote Sensing and GIS in Water Management | 3 | A | 3.5 | |
| WFM 6000 | Thesis | 18 | Ongoing | | |

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**Signature of the Tabulator**

**13. Cost Estimate:**

**a) Cost of materials**

Maps from CEGIS***** :

| Image Date/ Year | Geo-reference Cost (BDT) | Classification Cost (BDT) | Total (BDT) |
|---|---|---|---|
| 29-Dec-04 | n.a | 6,000 | 6,000 |
| 18-Dec-99 | n.a | 6,000 | 6,000 |
| 01-Feb-99/ 08-Feb-99 | n.a | 6,000 | 6,000 |
| 9-Feb-96 | n.a | 6,000 | 6,000 |
| 7-Jan-90 | 5,000 | 6,000 | 11,000 |
| 19-Mar-84 | n.a | 6,000 | 6,000 |
| **Sub Total (Maps)** | | | **41,000** |

**b) Field survey and data collection** **3,000**
**c) Water Quality Parameter test** **30,000**
**d) Thesis Preparation (Printing, binding and paper)** **3,000**

**Total cost of the research (BD. Taka): **** **80,000**
( Taka eighty thousand only)

Note: ***** Copy of Invoice from CEGIS for the Maps enclosed
****** Total cost (Tk. 50,000/-) will be borne by CB project of IWFM

**14. Approximate time (in hour) for BUET workshop facilities (if required)**: None

**15. Justification of having Co-Supervisor: N/A**

**16. Doctoral Committee/BPGS/RAC reference:**

**Meeting no. -------------------------Resolution No. -------------------------Date: --------------**

**17. Appointment of Supervisor & Co-Supervisor Approved by the CASR Meeting No. (For Ph. D): N/A**

**18. Appointment of Doctoral Committee Approved by the CASR Meeting No. (For Ph. D)**: **N/A**

**19. Result of the comprehensive examination for Ph. D (Photocopy of the result should be enclosed)**

**Date: N/A**

**20. Number of Post-Graduate Student(s) working with the Supervisor at Present: 4**

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**Signature of the Student**

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**Signature of the Supervisor**

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**Signature of the Director of the Institute**