WETLANDS OF TUFANGANJ AND KOCH BIHAR SADAR SUB-DIVISIONS IN THE KOCH BIHAR DISTRICT, WEST BENGAL: A GEO-ENVIRONMENTAL STUDY

A Thesis Submitted to the University of North Bengal

For the Award of
Doctor of Philosophy
In Geography and Applied Geography.

By

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I declare that the thesis entitled "**WETLANDS OF TUFANGANJ AND KOCH BIHAR SADAR SUB-DIVISIONS IN THE KOCH BIHAR DISTRICT, WEST BENGAL: A GEO-ENVIRONMENTAL STUDY**" has been prepared by me under the guidance of Dr. Sudip Kumar Bhattacharya, Assistant Professor of Department of Geography and Applied Geography, University of North Bengal. No part of this thesis has formed the basis of any degree or fellowship awarded previously.

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PREFACE

Wetlands though have tremendous potential for environmental and socio-economic well-being is the most threatened of all ecosystems today. The significance of wetlands lies in their roles in the hydrological cycle, for food and biomass production, bio-geo-chemical functions, and as nutrient and pollution filters for water quality improvement. The researcher from his childhood days, being an inhabitant of the wetland area, has observed that the wetlands, irrespective of their size, are treated as an unproductive landmass. People either dump their wastes here or convert these so called unproductive lands into productive ones by transforming them into agricultural fields or residential and industrial sites and therefore, resulting in fast disappearance and degradation of wetlands. A study by the Wildlife Institute of India revealed that around 70-80% of fresh water marshes and lakes in the Gangetic floodplain region has been lost in the last 50 years. Sometimes the damages to the wetlands are unavoidable as a result of increasing pressure on land but a majority of it occurs because the true values of wetlands are misunderstood.

The study area of Koch Bihar district abounds in wetlands; however, these wetlands are facing a serious threat to its survival due to shrinkage of area, soil and water pollution through anthropogenic activities like urban developmental activities and agricultural practices. Indiscriminate conversion and encroachment of wetlands due to human habitation, agriculture, pisciculture and industrial purposes not only destroy wetland's physical and chemical characteristics but is also detrimental to the ecosystems in general.

The critical condition of wetlands shook the researcher to the core and thereby he decided to do something for the conservation of wetland, not only under academic interest but with a hope to curb the degradation of wetland and pave a path towards rejuvenation of wetlands.

During the research work, I have taken the help of many individuals, groups of people, organizations and institutions. At the very beginning, I have the pleasure to acknowledge my profound appreciation and heartfelt gratitude to my teacher and guide Dr. Sudip Kumar

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I am in short of words towards expressing my heartiest gratitude to my beloved parents, Mamtaj Bibi and Abdul Hamid for their moral support and encouragement throughout my studies and, therefore, I dedicate this work to them. I am also grateful to my sisters, brother in-laws, and in-laws for their cooperation, which has been a powerful source of encouragement and support in all my endeavors.

I am greatly indebted to my brother, teacher and philosopher Dr. Nazrul Islam, Assistant Professor, Department of Geography, Sitalkuchi College and his wife Masuma Parveen, daughter Nausheen Islam (Manali) and Naureen Islam (Mishmi) for their relentless co-operation, motivation and inspiration right from the beginning and without help of whose it would not have been possible to complete my research.

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From the bottom of my heart, I am grateful to my wife Mrs. Pratyusha Parveen who has inspired me and actively cooperated in this regard.

Lastly, I seek apology for unwilling mistakes in the preparation of the research work.

Date: 13.06.2018

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ABSTRACT

TITLE: WETLANDS OF TUFANGANJ AND KOCH BIHAR SADAR SUB DIVISIONS IN THE KOCH BIHAR DISTRICT, WEST BENGAL: A GEO-ENVIRONMENTAL STUDY

Wetlands can be considered as one of the vital components that maintain the ecological harmony of Nature. Wetlands play a significant role in biological productivity, flood control, ground water recharge, regulation of water quality and other activities. However, information from different sources reveals that nearly half of global wetlands have been lost, and the condition of remaining wetlands is deplorable. A study by the Wildlife Institute of India reveals that around 70-80% of fresh water marshes and lakes in the Ganga & Brahmaputra floodplains have been lost in the last 50 years. Sometimes the damages to wetlands are unavoidable due to increasing population pressure. However, in other cases, it is the outcome of ignorance and indifference of individuals and institutions about the true value of wetlands.

The Koch Bihar district abounds in numerous wetlands, which include marshes, *beels*, and pools of stagnant water and tanks or ponds. These are mainly the remnants of the old beds of the river except tanks or ponds. They are named as *'Chhara', 'Dara', 'Doba', 'Jheel', 'Beel', 'Jampoi' and 'Kura'.* The wetlands of the district are presently facing a serious threat to their existence due to land & water pollution, disruption of wetland ecosystem and shrinkage of wetland area. Consequently, for regulation of these problems, there is a dire need for geo-environmental study and research.

The major objectives of the present study are to i) classify and study the distributional pattern of the wetlands ii) investigate the present use of wetlands of the study area iii) examine the present environmental status of the wetlands iv) assess the nature and dimension of degradation of the wetlands within the study area v) provide a conservation framework and management strategies for the wetlands.

Considering the all above objectives the present research has been made with the title "Wetlands of Tufanganj and Koch Bihar Sadar Sub-Divisions in the Koch Bihar District, West Bengal: A Geo-Environmental Study".

To fulfill the objectives, the researcher has adopted a rationalistic and scientific approach. Data on pisciculture, agriculture, use of wetland, flora and fauna endemic to the wetlands and land use in the fringe area of the wetlands were collected through questionnaires especially designed for the purpose. Water and soil samples were collected in pre-monsoon and post-monsoon from selected wetlands of the study area and were tested in the laboratory.

Different species of floras were collected in different seasons of the year with field note and then herbariums were prepared for the identification process. Faunal information was collected with the help of observation and photography method. For intensive field study researcher has selected 10 wetlands of various categories as the representatives of all the wetlands of the study area.

Besides primary data, the researcher used secondary data of different sources such as National Wetland Atlas (West Bengal & India), Hand Book on Government Water Bodies, West Bengal, Hand Book on Fisheries statistics, Koch Bihar, Statistical Hand Book, Koch Bihar etc. Collected data has been presented with different cartographic techniques and different statistical methods like Karl Pearson's Correlation Coefficient, Z-test, ANOVA, Standard Daviation, Standard Error of Estimation, Chi- square (χ^2) Test, Water Quality Index. The map of the wetland has been prepared from the SOI topographical map, Satellite imageries, Google Earth, Bhuban platform and ground survey data using GIS software.

The study investigates the geo-environmental status of wetlands of the study area. The whole research has been divided into seven chapters. The first chapter deals with the statement of the problem, location of the study area, objectives, hypothesis, database and methodology, significance of the study and review of the related literature. The second chapter incorporates the general background of the study area. Chapter three deals with the definition of wetland, classification of wetlands, distribution of wetlands in India, West Bengal, Koch Bihar and the study area. Chapter four discusses about the common use of wetlands in the study area and specific use of selected wetlands with reference to land use and land cover of the surroundings of the wetland. Chapter five deals with the environmental status of wetlands of the study area by analyzing the water & soil quality of wetland and floral & faunal status. Chapter six discusses the main causes of degradation of wetland in the study area and consequences of wetland degradation in relation to the environment and economy of the people in the vicinity of the wetlands. Chapter seven reveals the existing conservation policies and legislation in India, major findings of the study and the corrective measures to be taken for the development of wetland followed by overall conclusion considering the essential points from the preceding chapters.

In the present study, a detailed investigation on the nature of the wetlands and their modifications are made and then Wetlands are categorized into three broad divisions namely Natural wetland, Quasi-natural wetland and man-made wetland. Of all the wetland, rivers are most abundant (63.08%) followed by oxbow lakes (18.55%), riverine wetland (6.12%), quasi-natural oxbow lake (5.47%), pond (3.39%), quasi-natural riverine wetland (2.09%) and lastly brick/clay/sand pits (1.30%). The researcher has identified 486 wetlands that cover a total area of 7898 ha, in the study area. On the other hand, the number of Government wetlands in the study area is only 85 covering an area of 904.51 ha.

Through the survey conducted, it is revealed that with the exception of few, the wetlands have 27 types of services or uses in the study area. Most of the wetlands in the study area provide moderate to low wetland services. In Rasik beel wetland complex, out of 27 services, very common wetland service is 2 in number, fairly common 4, rare (on the verge of extinction) 17 and not found 4 in number. In Dangdhar Chhhara, fairly common services are 5 in number, rare (on the verge of extinction) is 10, not found is 12. In Rasomoti Jheel very common services are 2 in number, fairly common is 3, rare (on the verge of extinction) is 4 and not found is 18. In Baiganbari Chhara, very common wetland services are 3 in number, fairly common is 6, rare (on the verge of extinction) is 12, not found is 6 in number. In Sagardighi, very common wetland services are 3 in number, fairly common is 4, rare (on the verge of extinction) is 5 and not found is15. Based on the above study, it is observed that on an average

46.8% of services are not found, 32.10% are rarely observed, 15.43% services are occasional and only 6.17% services are commonly observed. A sharp decline in the number of services is observed in Chandan Dighi (20) and Rasomati Jheel (18) on accord of being the most degraded wetland in the study area and a protected wetland respectively.

The pH values of all selected wetlands except Sagar Dighi (9.2) are below the standard limit for aquatic life. The TDS, EC and Iron parameters of water were remaining at the permissible limit for aquatic life. The dissolved oxygen (DO) level, required for a healthy aquatic life is very low in Dangdhar Chhara (3.8 mg/L) and Chandan Dighi (1.8 mg/L & 1.9 mg/L) since Dangdhar Chhara is located in the vicinity of brick kiln industry and Chandan Dighi is the most neglected and is a dumping site of waste materials. The BOD level was also so high in Dangdhar Chhara (81mg/L) and Chandan Dighi (86.9 mg/L) and only Satwabhanga Nadi had BOD at the permissible limit in all season. The value TA and TH of water was at the permissible limit in all the selected wetlands except Rasomati Jheel. The free CO_2 of water is much higher than the standard value in all the selected wetlands except Sagardighi.

The pH of the soil in the wetlands bottom was at permissible limit except Sagardighi. The Organic Carbon levels are much higher than the standard levels in Bochamari Beel (4.95 percent), Rasomati Jheel (4.57 percent), Satwabhanga Nadi (3.61 percent), indicating eutrophication. The lowest nitrogen concentration is found in Baiganbari Chhara (37.63 mg/kg) which is unsuitable.

From the survey, a continuous decline in the aquatic life and extinction of many endemic species is observed. In the wetlands of the study are 66.67% flora and 55.56 % fauna may on the verge of Extinction. For example, indigenous reptiles like *Gharials* and turtles, amphibians like Bull Frog (Rana Tigerina) etc cease to exist now.

The major causes of wetland degradation are i) sedimentation in wetland bed ii) blockage of feeder channel iii) construction of engineering structures and fishing obstacles in the wetlands. iv) encroachment of wetland v) over-exploitation of wetland resources like excessive fishing, irrigation, agriculture, Jute retting v) fragmentation of the wetlands vi) garbage dumping & pollutants inflow in wetlands.

Consequences of the degradation of wetlands and their effect on the environment and economy of the individuals in the vicinity of wetlands are identified by water quality index (WQI), soil quality standard, floral and faunal status, areal shrinkage and effect on the local and regional economy. In the study area, all selected wetlands are unsuitable for aquatic life except Sagar Dighi (WQI=30.66) and Rasomati Jheel (WQI=43.92). The water area of the wetlands in the study area is steadily declining as observed between the years 1971 to 2017. Baiganbari Chhara has witnessed the maximum negative change (-84.03) followed by Dhangdhar Chhara (-34.74). The wetland degradation affects the occupation and economy of the surrounding inhabitants as 13% fisherman and 20.83% edible plant collectors were change their occupation.

Joint wetland management committees should be initiated by including the fishermen, farmers in and around the wetlands, selected government and NGOs officials for conservation & management of wetland and the betterment of the beneficiaries. Community fishing, poaching and hunting of residential and migratory birds in the wetlands should be stopped at any cost. Wetlands should be rented to the fishermen co-operative society or government involving local people and NGOs. Unwise construction of engineering structures like- roads, bridges, railway lines, and road cum embankments across the wetland constructed by various departments should be stopped.

Appropriate measures have to be taken to improve the economic and educational condition of the dependent community of wetlands that reduce the pressure on wetlands. The government may initiate many developmental activities like weeds clearance, afforestation programme by implementing National Rural Employment Guarantee Scheme (NREGS) and Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS).

The government should make arrangements for alternative occupation for the fishermen during the breeding period. Paddy cultivation should be replaced by the cultivation of different wetland compatible edible plants like *Kalmi, Hincha* in the dry season and *Saluk* in the monsoon season.

The present investigation deals with the present status of wetland with some recommendations for the betterment of wetlands. It is clear from the study that health of wetlands of the study area is very poor. If the wetlands are properly managed, it may bring a change in the environmental and economic aspect of the study area.

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CHAPTER-I

INTRODUCTION

CHAPTER-I
INTRODUCTION

1.1. Introduction:

Wetlands are the gifts of nature, having much importance at local, national and international perspectives. Undoubtedly, the wetland ecosystems are the most important ecosystems on the earth. These are sometimes described as 'Kidneys of the Landscape' because they function as the downstream recipient of water and wastes from both natural and human sources (William J. Mitsch and James G. Gosselink, 2000). Wetlands perform some useful functions in the maintenance of an overall balance of nature. (IIP Digital, 2012).The interdependence of wetlands and man is obvious. Different individuals, institutions or agencies have defined wetlands differently for different purposes depending on their objectives and needs. As per the definition accepted by the international conservation on wetland held at Ramsar (Iran), 1971 "*wetlands are areas of submerged or water saturated land, whether both natural or artificial or permanent or temporary and whether the waters is static or flowing or fresh brackish or saline including areas of marine waters, the depth of which at low tide does not exceed six meters*." This means that a wetland is neither truly aquatic nor terrestrial; it is possible that wetlands can be both at the same time depending on seasonal variability. Wetlands include rivers, lakes, reservoirs, etc (Panigrahy, 2012) and marshes, swamps, bogs and similar areas (Ramachandra, 2001). Thus, wetlands exhibit enormous diversity according to their genesis, geographical locations, water regime and dominant plants, soil or sediment characteristics. Because of their transitional nature, the boundaries of wetlands are often difficult to define.

During the last thirty years, there has been a great interest in wetland on account of the realisation and demonstration of its significant role in biological productivity, flood control, ground water recharge and discharge, regulation of water quality, treatment of waste water, and other activities. In the study area, there are around 486 wetlands and they all play important roles in their surroundings. However, their very existence has been threatened by natural and anthropogenic activities. In the last century, a large percentage of wetlands have been lost with drainage and land clearance as a consequence of agricultural, urban and industrial development activities (Frenken, 2005, Williams, et. al, 2007, Tijani, et. al, 2011). A comparison with the

19th century estimate reveals that approximately 50% of the world's wetlands have been lost (Ramachandra, 2001). Therefore, the present study of wetlands has its goals in terms of their classification, distribution, present use as well as environmental status, causes of degradation (natural and human-induced) and management strategies.

1.2. Statement of the Problem:

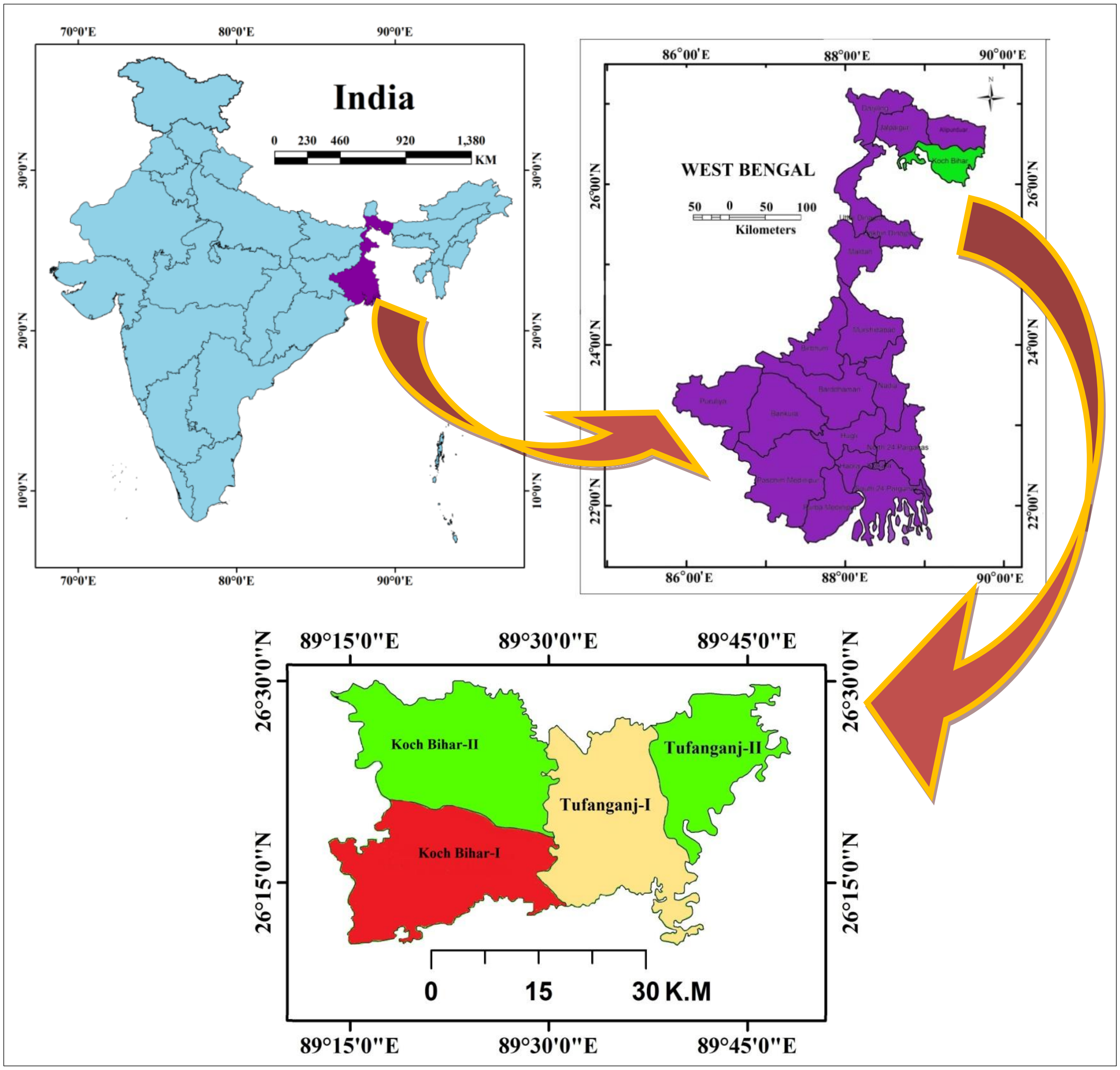
Earlier, Koch Bihar was termed as the "Lake City". The study area of Koch Bihar district abounds in numerous wetlands that exist as marshes, *Beels*, and pools of stagnant water bodies and Tanks or Ponds. Except for Tanks or Ponds, these are mainly the remnants of the old beds of the river. They are named as '*Chhara', 'Dara', 'Doba', 'Jheel', 'Beel', 'jampoi', and 'Kura'.* They are essentially a part of the surrounding ecological areas, bear more or less all the characteristics of wetland, and play an important role in maintaining physical set up and economic base of the area.

But, the wetlands are presently facing a serious threat to its survival due to shrinkage of area, land and water pollution through urban developmental activities and agricultural and piscicultural practices, which alter their physical, chemical and biological characteristics. Indifferent conversion of these wetlands due to human habitation, agricultural and industrial purposes is the main cause of Wetland extinction.

The uses of chemical fertilizers, organic fertilizers and biocides in the agricultural fields of the wetland surroundings and in some wetlands when converted into agricultural land in the dry season result in the disturbance of the wetland ecosystem. Construction of weirs, dams or barrages upset the free movement of water and cause siltation of wetlands.

Besides, some wetlands have been used as sites for dumping of organic and inorganic wastes generated from the nearby markets as well as surrounding areas. This has led to gross shrinkage of the *Beel* area. Thus, understanding of the problems of area shrinkage, land and water pollution, disruption of the wetland ecosystem and drainage congestion of the wetland is vital. Consequently, for regulation of these problems, there is a dire need for geo-environmental study and research in the field of wetland. It is in this context, the present study on

"**WETLANDS OF TUFANGANJ AND KOCH BIHAR SADAR SUB-DIVISIONS IN THE KOCH BIHAR DISTRICT, WEST BENGAL: A GEO-ENVIRONMENTAL STUDY**" has been taken up.



Map1.1: Locational Map of the Study Area, Source: NRSC, Hyderabad, India

1.3. Location of the Study Area:

The northeastern part of the Koch Bihar district, located within the latitude of 26º09´08´´N to 26º29´24´´N and the longitude of 89°17´34´´E to 89º51´50´´E has been chosen as the study area. It comprises of two sub-divisions namely Koch Bihar Sadar and Tufanganj covering an area of 1313.56 sq km. Mathabhanga and Dinhata sub-divisions of the same district bound the western and the southern boundaries of the study area, while the northern and the eastern boundaries are determined by Jalpaiguri district of West Bengal and Bongaigaon district of Assam respectively. In a small stretch in the southeast direction, its boundary is shared with Bangladesh.

1.4. Objectives of the Study:

The major objectives of the present study are:

a) To classify and study the distributional pattern of the wetlands.

b) To investigate the present use of wetlands of the study area.

c) To examine the present environmental status of the wetlands.

d) To assess the nature and dimension of degradation of the wetlands within the study area.

e) To provide a conservation framework and management strategies for the wetlands.

1.5. Hypothesis:

In order to fulfill the above objectives of the present study following hypotheses have been adopted:

1. The distributional pattern of wetlands of the study area mainly conforms to the fluvial characteristics of the surrounding region.
2. The present agricultural and Pisciculture practices play a significant role in changing the wetlands.
3. Unwise developmental activities are responsible for degradation of wetlands.

1.6. Database and Methodology:

Database and Methodology is the main structure of a research. To fulfill this objective and solve the hypothesis discussed above, the researcher has adopted a rationalistic and scientific approach. The database and methodology of the present study are described as follows:

1.6.1. Primary Database:

An initial survey was done during the first quarter of the year 2012 ending in the year 2017. Data on pisciculture, agriculture, uses of wetlands, flora and fauna endemic to the wetlands and land use in the fringe area of the wetlands were collected through questionnaires especially designed for the purpose. Water and soil sample of some selected wetlands in different seasons were collected to analyze the soil and water condition of wetlands. Different species of flora were collected and herbariums were prepared for the identification process. Faunal information was collected with the help of observation and photography method.

1.6.1.1. Criteria for Selecting the Representative Wetlands:

The following criterions were kept in mind while selecting the 10 wetlands as the representatives of the study area:

a) Urban wetland (Sagar Dighi and Chandan Dighi) and rural wetland (Baignanbari Chhara) had been considered separately.

b) The most well managed urban wetland (Sagar Dighi) and the most neglected wetland (Chandan Dighi) were included with it.

c) The wetland of brick kiln industrial areas (Dhangdhar Chhara) was included.

d) The wetland of protected forest areas (Rasomati Jheel) in which fishing is strictly prohibited had been selected.

e) Wetlands under National Wetland Management and Conservation (Rasik Beel wetland complex& Rasomati Jheel) and non-restricted wetland (Baignanbari Chhara) had been selected separately.

f) In it, natural wetland (Rasik Beel wetland complex) and man-made wetland (Sagar Dighi) were also included.

g) Agriculture predominant wetland (Baignanbari Chhara) and Pisciculture oriented wetland (Atiamochar Beel) were included in it.

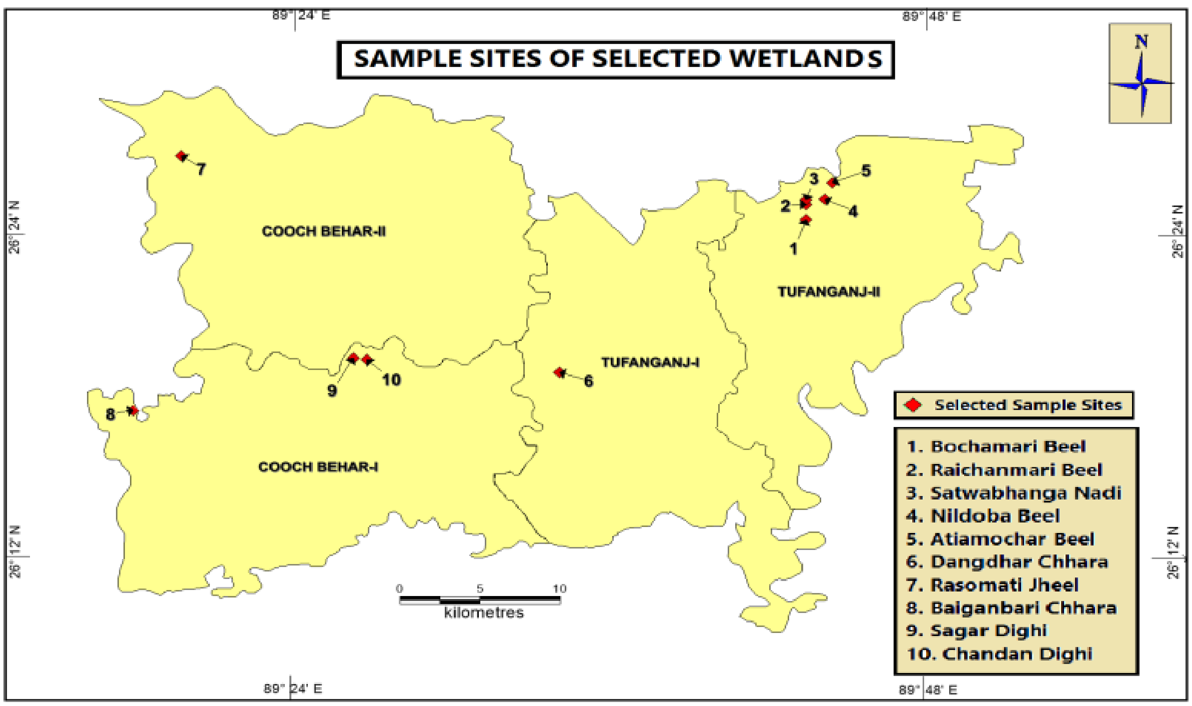
h) Pisciculture predominant wetland (Atiamochor Beel) and subsistence fishing based wetland (Bochamari Beel) were included in it.

i) Moreover, it was kept in mind that the wetlands had to be selected from all blocks of the study area.

j) Besides, the above mentioned 10 wetlands, some other adjacent wetlands had been selected for the study of existing flora and fauna.

Table 1.1: Description of the Sample Sites of Selected Wetlands

Site No.	Site Name	Sample Site	(Block/ Municipality)
1	Bochamari Beel	26°24´30´´N, 89°43´15´´E	Tufanganj-II
2	Raichanmari Beel	26°25´03´´N, 89°43´21´´E	Tufanganj-II
3	Satwabhanga Nadi	26°25´13´´N, 89°43´21´´E	Tufanganj-II
4	Nildoba Beel	26°25´14´´N, 89°44´02´´E,	Tufanganj-II
5	Atiamochar Beel	26°25´51´´N, 89°44´19´´E	Tufanganj-II
6	Dangdhar Chhara	26°18´48´´N, 89°34´07´´E	Tufanganj-I
7	Rasomati Jheel	26°26´51´´N, 89°19´56´´E	Koch Bihar-II
8	Baiganbari Chhara	26°17´24´´N, 89°18´13´´E	Koch Bihar -I
9	Sagar Dighi	26°19´21´´N, 89°26´24´´E	Koch Bihar Municipality
10	Chandan Dighi	26°19´18´´N, 89°26´54´´E	Koch Bihar Municipality



Map 1.2: Sample Sites of Selected Wetlands

1.6.1.2. Questionnaire and Interview:

Data on pisciculture, agriculture, use of wetland, flora and fauna endemic to the wetlands and land use in the fringe areas of the wetlands were collected through questionnaires especially designed for the purpose. Interactions with the agricultural workers, fisherman, the local people, aged people of the area, Panchayat personnel, secretary and other members of concerned fisherman co-operative society and other officials associated directly or indirectly with the subject concerned had been interviewed.

1.6.1.3. Soil Nutrient Data:

1.6.1.3.1. Collection of Soil Sample:

Soil samples were collected during pre-monsoon (May, 2017) period from the above selected sites of the study area. The soil samples were collected by using a spade; a ditch had been dug with a depth of 6-9 inches by setting the soil aside. Then a thin slice of soil was taken from the hole. From the centre of this slice, a 1-inch-wide sub-sample (squared core) was cut from top to bottom. The sub-sample was placed in the clean plastic bucket. 4 to 6 soil samples were collected from each selected wetland and then retaining all sub-samples together in the container. The soil was evenly divided into 4 squares. Then again, two opposite sides were rejected and the other two sides had been mixed up. The process was repeated till about half kg of the soil was remaining. Then soil sample was dried up in shadow for laboratory testing. Finally, soil samples were tested in the laboratory of Department of Soil Science and Agricultural Chemistry, Uttar Banga Krishi Viswavidyalaya, Pundibari, Koch Bihar, West Bengal.

1.6.1.3.2. Soil Analysis Methods:

Soil samples were tested according to the following methods-

1. Organic Carbon (OC) by Walkley and Black Method
2. Available Potassium (K) by Neutral Normal Ammonium acetate method
3. Available Phosphorus (P) by Bray and Kurtz method
4. Available Nitrogen (N) by $KMNO_4$ extraction method
5. PH (1:2.5 soil: water ratio) by Hanna portable pH meter
6. EC (1:2.5 soil: water ratio) by Hanna portable EC meter

1.6.1.4. Water Quality Data:

1.6.1.4.1. Water Sample Collection:

Water samples were collected in pre-monsoon (May, 2016 &May, 2017) and post-monsoon (September 2016 &September 2017) period from above selected sites of the study area. Collection of samples took place at 10:30 am by dipping well labeled sterilized plastic and glass containers at the approximate depth of 1.00 ft. The water samples were collected in three bottles: two glass bottles with the capacity of 100ml and one of them containing a solution of 2ml of $MnSO_4$ and 2ml alkaline iodide solution and a PVC container with a capacity of 1 liter. These bottles were carefully and steadily sunk in the water so that no air bubbles could get inside. With an exception of BOD, all physico-chemical parameters were analyzed in the laboratory of Department of Chemistry, Dinhata College, Koch Bihar, West Bengal on the same day. The value of TDS, EC, pH and Water temperature were calculated on spot by the digital metre.

1.6.1.4.2. Water Analysis Methods:

Method Adopted or Instrument Used for Water Quality Analysis are given in the table1.2.

Table 1.2: Method Adopted or Instruments Used for Water Quality Analysis.

Sl no.	Parameters	Method Adopted/Instrument used
1	Dissolved O2(DO)	Winkler's Method
2	BOD	Titrimetric Method (five days incubation),APHA,2005
3	Free $CO_{2:}$	Titration Method
4	Total Alkalinity	Titration Method
5	Bi-carbonate	Titration Method
6	Carbonate	Titration Method
7	Total Hardness as CaCO3	Conventional titration method.
8	Irone	Spectrophotometric Method
9	Chloride	Argent metric Method
10	pH	HM Digitals pH Hydro tester (Model pH-80)
11	Electrical Conductivity	HM Digitals Aquapro digital water tester (Model AP-2)
12	Total Dissolved Solids(TDS)	HM Digitals Aquapro digital water tester (Model AP-1)
13	Water temperature	Hanna portable Temperature meter (HI 98128)

1.6.1.5. Floristic Survey:

The floristic survey includes all the Macrophytes growing over the different wetlands and its surrounding areas in different seasons of the year. To understand the proper floristic structure of the study area, random sampling has been adopted for collection of plants from selected wetlands of the study area at least three predominant seasons and for a period of 5 years, from 2013 to 2017. During summer, many plants growing in exposed land within the wetland were also collected. Specimens were collected in triplicate cases. The collected specimens were tagged and necessary field data like flower colour, local names, uses, parts used, habitat, distribution pattern, flowering and fruiting etc. were also recorded in the Field Note Book. The collected plant specimens were dried in blotting paper first and then transferred to old newsprint or blotting papers within a short time. The blotting papers or old newsprint were changed every 24 hours or even in shorter intervals for the first three days and then in expected intervals till the plants were properly dried. Then specimens were mounted on herbarium boards using glue and then properly stitched with thread, wherever necessary. But, soft fleshy aquatic (submerged, free-floating plant etc.) plants were treated with aqueous 10 % formaldehyde (HCHO) solution to check the fungal growth. Identification of collected specimens was done primarily with the help of different literature including *Flora of Bhutan* (Grierson and Long, 1983, 1987, 1991, 1994, 1999, 2001; Noltie, 1994, 2000), *Flora of India* (Sharma *et al,* 1993; Sharma and Balakrishnan, 1993; Sharma and Sanjappa, 1993; Hajra *et al,* 1995, 1997), *Flora of West Bengal* (Anonymus, 1997), *Flora of Eastern Himalaya* (Hara, 1966, 1971; Ohashi, 1975).

1.6.1.6. Faunal Survey:

The conventional method through observation and photography of bird species and other major fauna was used during the survey. Faunal Survey through random sampling from selected wetlands of the study area at least three predominant seasons and for a period of 5 years, (2013 to 2017) was undertaken. Avifauna survey was carried out by direct sighting with field binoculars and pictorial guides. Stress was given on recording the calls of the bird, collection of feathers and observing the nests. The avifauna was identified with the aid of Ali and Ripley (1968 – 1974, 1996), Ripley (1982), Ali and Futehally (2004) and Grimmett *et al.* (2007). Waterfowl census was undertaken following Venkataraman (1995). Direct day sighting, night watching, the help of local experienced people and fishermen's knowledge were applied to record and identify the other major faunal species. Aquatic fauna was collected with the help of bag-nets, cast-nets, fishing hooks, and with the help of fisherman. They were identified with the aid of Jhingran (1991), Sen (1992) and Menon (1987 & 1992), as well as some websites likehttp://bn.bdfish.org. The data on the history of occurrence or distribution of the major fauna was cross checked with the local people.

1.6.2. Secondary Database:

Secondary data regarding the wetlands, study area and other related issues were collected from different published books, journals, Maps like National Wetland Atlas (West Bengal,2010), National Wetland Atlas (India,2011), Hand Book on Government Water Bodies, West Bengal, Hand Book on Fisheries statistics (2014-2015 & 2015-2016), Koch Bihar, Statistical Hand Book, Koch Bihar, 2013, District Bureau of Economics & Statistics Govt. of W.B, District Census handbook, Govt. of India, District Gazetteer, maps of Institute of Environmental Studies and Wetland Management, Kolkata Topographical Maps, Satellite imageries, Land Use Map (Department of Science and Technology), District Disaster Management Plan, Cooch Behar, 2016 etc. Other relevant information or data are collected from various secondary sources such as District Fishery Department, B.L R.O and D.L.R.O office.

1.6.3. Data Analysis and Interpretation:

Collected data have been presented with different cartographic technique and a statistical method (like Standard deviation, Karl Pearson co-relation, GIS technique).

1.6.3.1. Wetland Mapping Technique:

The map of the wetland has been prepared from the topographical map, Google Earth, Bhuban platform, Satellite imageries and ground survey data. Satellite imageries of 2017 were analyzed using Global Mapper, QGIS and Arc GIS software and resultant classification was verified by ground verification. Available records and maps of the National Wetland Atlas, 2011 and National Wetland Atlas, West Bengal, 2010 have been consulted for the purpose. Intensive fieldwork had to be conducted for field verification of wetland identification and mapping, to gather information and evidence relating to micro-study of some selected wetlands.

1.6.3.2. Karl Pearson Co-efficient of Co-relation (1896):

The co-efficient of co-relation formulae according to Karl Pearson (1896) has been used.

$$r = \frac{\sum xy}{\sqrt{\sum X^2 \times \sum Y^2}}$$

Where, X= Deviation from x series, Y= Deviation from y series.

1.6.3.3. Z test:

Z score is the number of standard deviation (SD) from the population mean, it measures how many SD below or above the population mean. It is also known as standard score and it can be represented on a normal distribution curve. Z scores value range from -3SD to +3SD. Zero value of Z score indicates the exact value of the population means.

$$Z = \frac{X - \bar{X}}{\sigma}$$

Where Z= Z score, X= Population mean, $\bar{X}$= Sample mean, σ= Standard Deviation.

1.6.3.4. ANOVA:

Ronald Fisher has introduced the analysis of variance. ANOVA is also known as Fisher analysis of Variance, and it is the extension of the t- and z-test. The one-way ANOVA is used to analyze whether there were any statistically significant differences between the means of the three or more independent groups.

1.6.4.5. Standard Deviation:

Karl Pearson introduced the standard deviation concept in 1823. Standard deviation is the square root of the arithmetic average of the squares of all the deviations taken from the mean. The standard deviation measures the absolute dispersion. The greater value of standard deviation indicates the magnitude of the deviations of the values from their mean.

$\sigma = \sqrt{(\frac{\Sigma X^2}{N})}$ where, σ= Standard deviation

$x^2 = X - \bar{X}$ (Deviation of the item from the mean)

N= Number of the observation

1.6.3.6. Standard Error of Estimate:

The Standard Error of Estimate is a measure of dispersion of all the y-value around the regression equation. It is, therefore, a general or overall measure of dispersion indicating the dependability of estimate. It is in equation form-

$SE_{yx} = \sigma_x\sqrt{1 - r^2})$ where, SE_{yx}= Standard Error of Estimate of Y on X,

σ_x= Standard deviation of X,

r= Correlation Co-efficient

1.6.3.7. The chi-square (χ^2) Square Test:

The χ^2 square test is one of the simplest and most widely used non-parametric tests in statistical work. The χ^2 test was first used by Karl Pearson in the year 1900. The quantity χ^2 describes the magnitude of the discrepancy between theory and observation. It is defined as-

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

Where O refers to the observed frequencies and E refers to the expected frequencies.

1.6.3.8. Water Quality Index:

A Water Quality Index (WQI) is a compilation of a number of parameters that can be used to determine the overall quality. Here the calculation of the WQI was done using weighted arithmetic water quality index which was originally proposed by Horton (1965) and developed by Brown et al (1972) in the following form:

WQI = **Σ**QiWi /**Σ**Wi

Where,

Qi = 100 {(Va-Vi)/ (Vs-Vi)}

Va = actual value of the water quality parameter obtained from laboratory analysis.

Vi = ideal value of the water quality parameter obtained from the standard tables.

Vs = recommended standard value of i^{th} parameter.

Wi = K / Vs

K is proportionality constant.

1.7. Significance of the Study:

Wetlands are most productive of aquatic environments; providing a wide range of economic, social, environmental and cultural benefits (Costanza, et. al. 1997) or services to mankind. Even in the recent past wetlands were considered as wasteland and hence today they are the most threatened of all ecosystems. However presently, awareness about the hydrological, physical, chemical, biological, and socio-economic importance of wetlands is being acknowledged both by the academicians and researchers. Sometimes the degradation of wetlands is unavoidable as a result of increasing pressure on land but a majority of it occurs because the true values of wetlands are misunderstood.

The wetlands of the study area have enormous potential for environmental and socio-economic development of the region. Besides, study on the geographical and environmental perspective of wetlands has a great significance from academic as well as societal point of view. In addition, many of the *beels* in the study area are used for cultural and recreational activities. Moreover, wetlands are used as a source of water for irrigation in the dry season, especially for boro paddy cultivation. Generally, the *Beels* are rich in biodiversity, where many species of aquatic plants, fishes, and insects, residential and migratory birds are observed.

Haphazard and rampant growth of settlements and establishment of brick kiln industries causes the large-scale deforestation and massive soil erosion. Soil quarrying for brick kilns and siltation by recurrent flood also leads to wetland degredation. Moreover, the construction of roads, railways and embankments are the serious concern for wetlands. Hunting of migratory birds as well as residential birds, conversion of wetlands into agricultural lands and dissociation or fragmentation of wetland into small ponds for pisciculture poses a serious threat to the wetlands of the region. As a result, the ecosystem and biodiversity of the wetland as well as the surrounding regions is being disrupted. The lowering of the retention-capacity of storm water during flood season is one of the serious issues in the study area. Therefore, it is needless to mention why the wetlands have to be conserved.

The study represents a lucid attempt to examine scientifically some of the basic issues pertaining to the geo-environmental status of wetlands in Tufanganj and Koch Bihar sadar subdivision of Koch Bihar district, West Bengal. In this study, an attempt to analyse the classification and distributional pattern of wetlands, presents use of wetlands of the study area, environmental status of the selected wetlands, the wetland degradation processes, consequences of the wetlands degradation and finally the recommendations and management strategies. As such this study will not only help in understanding the wetland environment in the region but also in other parts of the state or country. In the study, a critical analysis of the water and soil quality, status of flora and fauna, land use, anthropogenic activities etc. are done aiming at conservation and development of wetlands. As such this study may be helpful to mitigate the problems faced by the wetlands and wetland dependent people of the study area. This will undoubtedly have both academic significance and practical relevance. Investigation of the existing status of wetlands in the region would open new vistas for further research in this field. Further, it is expected that the data and information collected for this study will definitely help the future research works and academic activities of students and researchers.

1.8. Review of the Related Literature:

Research on wetlands of Koch Bihar is not scanty. Consequently, there is no dearth of related literature in the field and its allied areas. This literature review abounds in short articles. Major works on the wetland services are not adequate in the field. The types of literature are many and varied. Some works deal with the Physical and chemical parameters of wetlands, while others deal with the problems of the degradation, impact of wetlands on environment etc. The various scholars have performed numerous studies dealing with various aspects of wetlands across the countries. A search in the field of literature for the proposed work unearthed the following works.

Allen (1956) in his article "The Flamingos: Their Life History and Survival their Life History and Survival" stated that the birds living in the water are very much closely related to the hydrological and limnological conditions. The present author showed that the breeding of Flamingos (Phoenicopteridae) are closely associated with habitat condition and food availability. Similar studies have been performed by Zweers et.al (1995), Cazini and Derlindati (2000) on the feeding mechanism of Flamingos and their biological threat due to human interference.

Ara, Khan, and Jargar (2003) studied the "Physico-chemical characteristics of Dal lake water Kashmir valley, India". In this article, they have clearly depicted significant changes in physico-chemical characteristics in the Dal lake water of Kashmir valley during last two decades and also noticed highest dissolved oxygen value during January and concentration of nitrate-nitrogen during June. Excessive use of houseboats and high concentration of weeds led to the significant changes of physic-chemical characteristics of water of Dal Lake in Kashmir Valley.

Baghdadi, Barnier, Gauthier, and Neeson (1999) in their study "Evaluation of C-Band SAR data for wetlands mapping" have attempted to map out the wetlands in Mer Bleue region (Ottawa, Canada) and observed a significant change of that wetland during the vegetation season. They also reported the results of an experiment carried out to examine the potentials of Polarimetric C-band Synthetic Aperture Radar (SAR) for mapping various wetland classes. The Mer Bleue region was surveyed by the C-band (5.3 GHz) Polarimetric (HH, HV, VH, VV) SAR of the Canada Centre for Remote Sensing (CCRS) 3 times within the vegetation season 16 June (spring flush), 6 July (mature growth) and 3 October 1995. Signatures of 6 different cover types (forested and non-forested peat bog, marsh, open water, clearings, and forests) have been derived as a function of incidence angle. A supervised classification was used for wetland mapping by means of multi ploidization data. This study demonstrated some of the capabilities of SAR at C-band for mapping of wetlands.

Bamakanta, Sunakar, Satyabhama, and Prasad (2013) in their article "Seasonal Variation of Nagavali River Water Quality at the Vicinity of Paper Mill near Aykaypur, Odisha, India" made a comparative analysis of the seasonal variation of the physic-chemical characteristics of the Nagavali River of Odisha. The authors found significant fluctuation in the river water quality like pH, conductivity, hardness, DO, COD, TDS, and TSS on seasonal variation.

Bandopadhyay and Mukherjee (2005) in their study "Diversity of Aquatic and Wetland Vascular Plants of Koch Bihar District, West Bengal" revealed 172 aquatic and wetland plant species in various wetlands of Koch Bihar district. They identified 8 eight categories of plants like Epihydates, Helophytes, Hyperhydrate, Plankton, Pleustophytes, Rosulate, Tenagophytes and Vittate, An extensive field study among various wetlands has been performed by the authors during 1995-1998. They opined that aquatic and wetland plants play a vital role in the ecosystem as well as humankind. In the conclusion, they suggested taking proper management for conserving the aquatic plants and habitats.

Begam, Purushothama, Narayana, and Kumar (2006) in their article "Water quality studies of TV station reservoir at Davangere City, Karnataka (India) described that there were variations in physico-chemical concentrations during rainy season and except turbidity all other physicochemical parameters of water resided within the permissible limits in the reservoir at Davangere city, Karnataka (India).

Bhat and Sharma (2015) in their article "Physico-Chemical Analyisis of Ground water Quality of Adjoining Areas of Sambar lake, A Ramsar Wetland of Rajasthan, India" studied the water quality of different sites of lake periphery and in the catchment areas of Sambar lake. The test result of various chemical parameters are : pH= 7.4-8.6 ; EC= 1723 µs/cm-23400 µs/cm; Total hardness = 402.0 mg/L-3657.0 mg/L; Chloride = 103.21 mg/L-943.43 mg/L; Mg= 35.11 mg/L-316.0 mg/L; TDS= 1175 mg/L -14900 mg/L; Sulphate = 117.6 mg/L-943.98 mg/L; Fluoride = .69 mg/L-2.01 mg/L etc. They have also compared the result with the relevant standard value.

Biswas. Das and Paul (2013) in their article "Floristic diversity of Rasik Beel and its adjoining areas in Cooch Behar district of West Bengal, India" had identified 614 species of plants, belonging 421 genera of 146 families. Of these, 456 species are belonging to Magnoliopsida, 119 species for Liliopsida, 3 species of gymnosperms and Pteridophytes are represented by 36 species in the Rasik Bill complex. The authors have performed a random survey in different seasons during 2007-2013. They noticed 124 species of angiosperm, 456 Magnoliopsida, 119 Liliopsida and 36 Pteridophyta in the Rasik Beel Complex. A detailed study has been conducted and tabulated in this article. Tourism and picnic in the present study area changed the overall morphology of the Rasik Beel wetland complex. They suggested to declare the place as in situ conservatories and demanded to modify the Rasik Beel Complex as Ramsar Sites.

Chatterjee, Adhikari, Barik and Mukhopadhyay (2013) in their article "The Mid-Winter Assemblage and Diversity of Bird Populations at Patlakhawa Protected Forest, Cooch Behar, West Bengal, India" presented their observation of avian community at Patlakhaoa Protected forest. They identified 154 bird species belonging to the 41 families. Out of all the species, 22 lived in the grasslands and swamp forest. 46 in Riverine forest, 52 in different trees, 43 at the outer periphery of the forest, and 51 species lived in the Rasomati Beel. They also categorized the birds as Insectivorous (53), carnivorous (40), omnivorous (29) and frugivorous (15). Patlakhawa protected forest is located at the riverbank of Torsha in Cooch Behar district. The forest is regarded as "Eastern Wet Alluvial Grassland" according to Champion and Seth's classification (1968). They opined that the bird species of Rasomati Beel is being threatened. The authors tried to map the bird density in the forest and discussed the structure of the avian community. The authors suggested converting the protected forest into Wildlife Sanctuary for conserving the ecosystem and retaining the species diversity.

Carter, (1996) found in the article "Technical Aspects of Wetlands, Wetland hydrology, Water Quality and Associated functions" that Wetlands were often found in places where the water table was close to the surface, resulting in fluctuating discharge or recharge of groundwater supplies. Moreover, Wetlands also reduce waves and shoreline erosion owing to their interlocking root system of vegetation that stabilizes soil at the water edge and enhances soil accumulation through sediment trapping. According to him, this reduces erosion by damping wave action and slowing water currents.

Das and Barat (2014) in their study " Fishing Gears operated in lentic and lotic water bodies of Cooch Behar district, West Bengal, India" tried to explore the various types of fishing gears in Cooch Behar district. They have identified 22 such type of gears that are modified by the anglers resulting in the depletion of fish diversity in different wetlands. They have visited 12 fishermen villages during their field survey. They have categorized the fishing gears as Fishing Net gears and miscellaneous traditional gears. Fishing Net Gears include Chhabi Jal, Phansi Jal, Sitki Jal, Masari Jal, Tana jal, Thela jal, Haath jal etc and traditional miscellaneous gears include Koncha, Shuli, Zakoi, pala, Jhoka, Chak, Tyapai, buring, Khatal etc. They have discussed in detail about these gears with their pros and cons. The authors suggested some measures for enhancing the fish harvesting. They also opined that mesh size of fishing net gears should be greater than 1 centimetre and fishing should be restricted during the breeding season of the fishes.

Das, Sen, and Mitra (2012) in their proceeding article "Biodiversity of Rasik Beel Wetland Complex (WB, India)" tried to explore the biodiversity of Rasikbeel Complex. They have recorded 171 bird species, 53 ichthyofaunas, 4 annelids, 49 arthropods including 24 butterflies, 6 molluscans, 5 amphibians, 6 reptilians, 9 mammalians in this wetland complex. They had also analyzed the Physical and chemical properties of Rasik Beel wetland complex. They identified various hydrophytes, thallophytes, 23 types of planktons in these wetlands. The authors suggested proper management plan for sustainable development of wetlands.

Dawaki, Noma, and Aliyu (2014) studied on "Heavy Metals and Physico-chemical Properties of Soils in Kano Urban Agricultural Lands." For this purpose they have chosen three metropolitan and suburban rivers namely Challawa, Jakarta and Watari in Kano, Kano State, Nigeria to determine the total, exchangeable and soluble concentrations of the heavy metals Cu, Cr, Ni, Zn, Pb, and Cd. The results showed that the soils of the study areas were at risk of contamination from those metals, which are gradually being released into the rivers from adjacent urban centers. They observed the low to medium values of CEC, organic matter, clay and the slightly alkaline nature of the pH; as well as the higher levels of the metals detected at some sites of the study. They also found the trace of such toxic elements in the plants that grow or are planted in the vicinity of the rivers.

Devaraju, Venkatesha, and Singh (2005) in their article "Studies on the physicochemical parameters of Maddur Lake with reference to suitability for aquaculture" investigated the gradual decline of endemic fish varieties. They have chosen Maddur Lake situated in southern Karnataka for studying the physico-chemical analysis of water and vulnerability of aquaculture for some selected aquatic species. Their studies also showed the fluctuation of water physico-chemical parameters such as highest DO in October. The higher concentration of DO during October largely depends upon photosynthetic activity and microbial decomposition. The phosphate concentration was usually higher during summer and lowest during winter.

Dey, Nur, Sarkar, and Barat (2015) in their article "Ichthyofauna Diversity of River Kaljani in Cooch Behar District of West Bengal, India" studied the diversity of Ichthyofauna in the Kaljani River. The study was conducted in four sites namely Amlaguri, Chhatoa, Jaigir Chilakhana and Chhat Bhelakopa during August 2012 to August 2014. They have collected samples with the help of local fishermen by using different fishing nets. They have identified 138 indigenous fish species of 31 families. They opined that out of all species, 58 have ornamental value and 55 species have food value. They also tried to enlist 1as critically endangered, 13 as endangered, 41 as vulnerable, 35 having lower risk or nearly threatened, 41 as least affected and 7 species have not been evaluated due to deficiency of data or related issues. They concluded that due to the rampant catching of fish with the fine geared fishing net and agricultural pesticide and chemicals the fish species more vulnerable in the Kaljani river.

Dipson,(2012) in his doctoral dissertation "Spatio-Temporal Changes in the Wetland Ecosystem of Cochin City using Remote Sensing and GIS (Unpublished thesis)" highlighted the land use, land cover and change detection in the study area. For this purpose, he used various temporal satellite data and integrated secondary data from various sources. He also prepared a vulnerability map of the wetlands. He outlined the reasons for reclamation of wetland in Kerala. He made some suggestions or strategies for sustainable use of wetlands and directed some future scope of the study on wetlands.

Feyssa, Njoka, Asfaw and Nyangito (2011) in their study "Physico-chemical Soil Properties of Semiarid Ethiopia in Two Land Use Systems: Implications to Crop Production" tried to explore the major soil fertility status of semi-arid part of East Shewa in Ethiopia. They have chosen six study sites (3 from each district) and thirty composite soil samples of five plots from each site for determination of the major soil physical and chemical parameters and the variation of soil properties across locations. The results indicated that shifting land use system was more eco-friendly than the land use of settled farmers which was confirmed by the little soil bulk density and high soil organic carbon.

Ghavzan, Gunale and Trivedy (2006) in their study "Limnological evaluation of an urban freshwater river with special reference to phytoplankton" investigated the high value of BOD, COD, Chloride, Phosphate, Nitrate, Sulphate and fCO_2 in the Mutha River. They concluded that temperature played an important role in controlling the occurrences and abundance of algal diversity and phosphate has been considered as one of the important nutrients limiting the growth of phytoplankton.

Gopal and Sharma's (1994) investigation deals with the Sambar lake of Rajasthan. They identified the various macrophytes around the lake area which underwent severe anthropogenic pressure due to fodder and fuel demand. They have also thrown light on the natural vegetation in the catchment area of the Sambhar Lake which mainly consists of thorny scrub, typical to the arid and semi-arid zones. The surrounding Aravalli's are covered in Anogeissus pendula, Boswellia sp, and Euphorbia caducifolia, plain areas have trees like Prosopis spicigera, Acacia nilotica, A. senegal, Capparis deciduas and C. aphylla and shrubs like Salvadora persica and S. oleoides. Coarse grasses such as Saccharum sp ontaneum and S. bengalense are common and the species Cenchrus sp. is widely grazed on by the cattles.

Goswami, Pal and Palit (2010) in their article "Studies on the Physico-Chemical characteristics, Macrophyte Diversity and their Economic Prospect in Rajmata Dighi: A wetland in Cooch Behar District, West Bengal, India" studied the seasonal changing nature of macrophytes diversity and physic-chemical properties of Rajmata Dighi (man-made and Government owned) wetland of Cooch Bahar district. They studied 10physico-chemical properties and have identified 48 species in that wetland during pre, on, and post-monsoon periods. They used Margalef's index, Simpson's index, Shannon's index and Pielou's index for their study. They also tested water pH, DO, BOD, free CO_2, Soil pH, EC, nitrate-Nitrogen (SN2), PO_4 and Carbon – Nitrogen Ratio(C/N). They found the specific relation of macrophyte diversity with physico-chemical parameters of water and soil in the wetland.

In the similar study "Diversity and Distribution of Bird Species in Cooch Behar District of West Bengal" Das, et.al. has identified 226 species of the avifauna of 141 genera with 43 families and 16 orders in Cooch Behar district. They identified one critically endangered, 3 endangered 3 nearly threatened species in the study area. They have pointed out the vulnerability of such avifauna and suggested appropriate measures for conserving the indigenous as well as migratory bird species in the district.

Jain, Das, and Goyal (2005) in their thesis "Conservation Planning of Sambhar Lake, Rajasthan using Satellite Remote Sensing and GIS" discussed the conservation eco-sensitive zone within 3 km buffer from the Sambhar lake boundary in Rajasthan. They identified the land cover and land use patterns in the catchment area of the lake by using remote sensing and GIS methods. The study area covered a total area of about 550 sq. km including the lake itself. The land use within this limited area was estimated as: Open forest (3.47%), Dry lake bed (16.23 %), Salt-affected land (5.77%), Saltpans (other than SSL 3.98%), Saltpans (SSL) (3.04%), Fallow land (22.19%), Agricultural land (10.63%), Settlements (1.52%), Scrub (19.88 %) and Water (13.29%)..

Joshi and Shringi, (2014) in their study "Floristic Diversity with Special Reference to Rare and Threatened Plants of Jawahar Sagar Sanctuary Area near Kota Rajasthan" analyzed the floristic diversity of Jawahar Sagar, which is one of the richest floristic regions of Rajasthan. In the floristic analysis, 422 species of angiosperms were documented, 37 plant species were recorded as rare or endangered. They also highlighted some rare or endangered plants abundantly found in Jawahar Sagar area.

Khatri (1992) in his article "Seasonal distribution of zooplankton in Lakhotia lake, Rajasthan" conducted a study on zooplankton at Lakhotia Lake of Pali city located in the Western part of Rajasthan. The study was conducted in three seasons: summer, monsoon, and winter. The zooplankton comprised of Cladocera, Ostracoda, Copepoda, and Rotifera. The first peak was mainly occupied by Copepoda while the second and third peak was shared by Copepoda and Rotifera respectively. Among zooplanktons, Moina sp, Cypris sp, Cyclops sp, Diaptomus sp, Nauplius larvae and Brachionus sp were permanent in occurrence whereas Daphnia sp and Ceriodaphnia sp appeared occasionally.

Krause, Bock, Weiers, & Braun(2004) in their article "Mapping Land-Cover and Mangrove Structures with Remote Sensing Techniques: A Contribution to a Synoptic GIS in Support of Coastal Management in North Brazil" assessed the changes in the mangrove coverage observed during 1991 to 1999 in North Brazil using Landsat TM - 5, ETM, ASTER DEM data. His mapping data helped in the evaluation of the heterogeneous data sets of the inter-disciplinary scientific research program MADAM (Mangrove Dynamics and Management). The main objective of the study is to formulate an integrated coastal management scheme for the mangrove ecosystem at Braganca (North Brazil). An assessment of temporal and spatial changes of the mangroves, the type of mangrove structure, land-use cover analysis, as well as the adjacent rural socio-economic impacts were tested using various innovative processing techniques and different scale-resolution levels. They identified the differentiation of the strong and weak patterns of coastal morphodynamics and mangrove ecosystem in North Brazil.

Kumar and Kumar, (2013) focused on the physicochemical contamination of groundwater in Jhansi (Goramachia), of Uttar Pradesh due to the granite mines situated in the vicinity. The result was derived based on sample testing on six different sites situated at various distances from the mines. The physico-chemical parameters such as pH, D.O., E.C., T.D.S., alkalinity, turbidity, Ca (calcium) and Mg (magnesium) hardness, total hardness, NO3 (nitrate), F (fluoride), Fe+3 (iron) and Cl- (chloride) were tested and it was found that those parameters were not within the limit as compared with the WHO standards.

Kumawat and Jawale (2003) in their article "Phytoplankters of a fish pond at Anjale, Maharastra" discussed the abundance, periodicity, and composition of phytoplankton in relation to physico-chemical factors in the fish ponds at Anjale, Maharastra. They had opined that the abundance of algae in a pond increased progressively during late winter and early summer and water temperature is not a significant factor in determining the total algal abundance. The presence of high pH and DO during winter was correlated with the abundance of phytoplankton and the high value of dissolved oxygen indicated growth that is more algal. The maximum number of blue-green algae was recorded in January when pH, dissolved oxygen, chemical oxygen demand and electrical conductivity were more, while water temperature, chloride, silicate, and nitrate were less and the phytoplankton communities depended directly or indirectly on different physicochemical factors.

Mathur, Patan, Sharma Nair, & Shobhawat, (2010) in their study "Assessment of Physico-Chemical properties of Anasagar Lake of Ajmer (India)" discussed the variation of physico-chemical characteristics of Anasagar Lake in Ajmer city of Rajasthan. They have tested Water Temperature (Avg- 27.9 oC), Transperancy (Avg- 5.8 cm), ph (9.8), EC (3.18 (mmhos/cm), TDS (1762 mg /L), DO (9.2 mg/L), Alkalinity (627.3 mg/L), TH (476.4 mg/L), Ca Hardness (107.7 mg/L), Mg Hardness (418.05 mg/L), phosphate (1.8 mg/L), Sodium (42.96 mg/L), Potassium (24.7 mg/L), COD (169 mg/L). In this study, the authors have identified the fluctuation of the said parameters in different seasons.

Mitsch and Gosselink (1993) in their book Wetlands, (Third Edition) stated that Wetlands are the most biologically productive ecosystem in the temperate grassland and tropical rainforest regions. The wetlands play a vital role in the biological productivity derived from their ability to recycle nutrients and energy. Their research also revealed that Wetlands provide habitat for fish and wildlife. Most freshwater fish depend on wetlands as wetlands serve as nursery grounds for many species such as Alewife, Blue-black herring. They concluded that wetland habitats are critical for the survival of species threatened or endangered with extinction, primarily because of habitat loss.

Moayeri, Mokarram, Hamzeh, and Zaheri (2012) in the article "Change Detection of Wetland Development with Satellite Data and GIS" conducted change detection during 1990 to 2005 at HurolAzim wetland located in the southwestern Khuzestan province, bordering Iran and Iraq using principal components analysis of TM and ETM+ sensor of Landsat imagery. Wetland water supply sources include Karkheh River and its tributaries, Mime, Doiraj subsets of Iran and the Tigris in Iraq. Landsat satellite images revealed that Hurol Azim wetland area has shrunk in recent decades. The study showed that this wetland area has shrunk from 515.4

km2 in 1990 to 230.59 km2 in 2000. The main reasons for the reduced water levels are the dam of Karkheh and frequent droughts.

Mushtaq and Pandey, (2014)in their article "Assessment of land use/land cover dynamics vis-à-vis hydrometeorological variability in Wular Lake environs Kashmir Valley, India using multi-temporal satellite data" discussed the degradation of Wular lake of J& K. They also examined the anthropogenic impact and changes in the land use and land cover and hydrometeorology of the lake region. They used satellite images, which were acquired during the year 1992, 2001, 2005, and 2008, for determining changes in the LULC in a buffer area of 5 km^2 around the Wular Lake. The lake area has been reduced to 24 km2 in 1992 to 9 km2 in 2008 (−62.5 %).

Pal, Das and Chakraborty (2015) in their article "Colour optimization of the Secchi disk and assessment of the water quality in consideration of light extinction coefficient of some selected water bodies at Cooch Behar, West Bengal" made the assessment of water quality of some selected water bodies in Cooch Bihar using Secchi disk method. For this study, they have chosen 5 wetlands namely Mali dighi, Bairagi dighi, Sagar dighi, Narasingha dighi, Panishala Beel. Besides the determination of water transparency, they also determined TDS in all the wetlands. They observed that Panishala beel was least turbid and Mali dighi had the highest turbidity and they opined that White-Yellow disk type shows more efficiency than the other colored disks.

Patel and Parikh, (2013) in their article "Physico-chemical parameters of the Mahiriver" investigated on the physico-chemical parameters of the Mahi river water during summer, monsoon, and winter. The results showed deterioration in water quality during winter due to increase in organic load as result of anthropogenic activities.

Saha, T.K. (2004) in his article "Net plankton diversity in coal mining areas of Jharkhand" analyzed the community structure and diversity of phytoplankton and zooplankton in North Kanpura ponds. The maximum richness index value was observed during May in the ponds of North Kanpura and the minimum value in the Jharia ponds. The phytoplankton richness index was maximum in August and the minimum value was observed in November and February. The high and low evenness value for phytoplankton and zooplankton was in August, June, and October respectively in the North Kanpura ponds.

Sajeeva and Subramanian (2003) in their article"Land use/land cover changes in Ashtamudi wetland region of Kerala - A study using remote sensing and GIS" have used IRS-1A LISS-II, and IRS-1C LISS III images and SOI topographic maps to quantify LULC changes in the Ashtamudi wetland region from 1967 to 1997. Based on their research it was seen that the area shrinkage was due to increasing population density, changes in the family system, extensive coconut husk retting and deposition of husk waste along the margin of the estuary, solid waste deposition from factories, and reclamation of the estuary by the local population and low profit obtained from paddy cultivation. Thus, the author tried to correlate unwise and land use/ land cover and encroachment in the wetland region with its environmental degradation in the study area.

Singh, and Panday, (1991) in their article "Water quality of stagnant water bodies of North Bihar" analyzed the water quality of 13 stagnant water bodies of North Bihar and reported high-temperature range (24-30°C) affecting the dissolved oxygen concentration and alkalinity of water with the fair amount of carbonate and bicarbonate concentrations.

Sinha (2012) in her article "Scenario of Rasik bill Wetland, Cooch Behar District: A Geographical Perspective" studied the general description of Rasik beel wetland complex. In her study, Miss Sinha tried to explore the present status, diverse habitat& ecosystem, and degradation of Rasik beel wetland complex. She measured water salinity, pH, Ox-red potential, DO, COD, and BOD of Rasik beel. She also identified 3 Pteridophytes, 31 Dicotyledons, 41 Monocotyledons species of flora and 125 various species of Fauna in this wetland complex. Finally, she suggested various management plans to conserve the biodiversity of Rasik beel wetland complex.

Sirajudeen, Manikandan and Manivel (2013) in their study "Water quality index of groundwater around Ampikapuram area near Uyyakondan channel Tiruchirappalli District, Tamil Nadu, India" evaluated the Water Quality Index (WQI) of groundwater samples collected in Ampikapuram area near Uyyakondan channel of Tiruchirappalli district. They have selected the parameters like pH, E.C, T.D.S, Total hardness, D.O, C.O.D, B.O.D, Cl-, NO3, and Mg. The WQI for these samples ranged between is 244 to 383.8 and hence they concluded that the groundwater of the area needed some degree of treatment before consumption and that it needed to be protected from the hazard of wastewater contamination.

Teferi, Uhlenbrook, Bewket, Wenninger, and Simane, (2010) in their article "The use of remote sensing to quantify wetland loss in the Choke Mountain range, Upper Blue Nile basin, Ethiopia" had quantified the wetland dynamics during the period 1986-2005. They showed that about 17.443 km2 area of the Choke Mountain range in the Upper Blue Nile basin has been lost due to human interference. They have used a hybrid unsupervised classification approach for classifying the LULC. The results showed that 607 km2 of seasonal wetland with low moisture and 22.4 km2 of open water were lost in the study area during the period 1986 to 2005.

Verma and Khan, (2014) in their article "Biodiversity assessment of aquatic plants in Jhunjhunu district of Rajasthan, India" studied the aquatic angiosperm diversity of Jhunjhunu district of Rajasthan. They have identified 15 aquatic angiosperm plant species belonging to 11 families. Among five morpho-ecological groups, free-floating with 40% dominated in the study areas followed by anchored submerged (20%), anchored floating (20%), emergent amphibious (13%) and free submerged with only 6.66%.

The various scholars have performed numerous studies dealing with various aspects of wetlands across the countries. However, only a few works have been done so far on the wetlands of Koch Bihar. De (1999) studied the ecological aspects of the Sundarbans while Singh (1988) discussed the development of wetlands in the Manipur valley. Energy flow in the aquatic systems was studied by Ganapati (1970), Natarajan and Pathak (1983). Jhingram (1987), Pathak and others (1985), highlighted the pattern of energy utilization in beel system. Westlake (1963, 1957) stated that the wetlands were naturally fertile areas for their year-round primary productivity. They have been ranked third highest in the net primary production of the entire world ecosystem. Pieczynska (1975) commented in the similar study that wetlands play an important role in hydrology. A large number of national and international organizations have prepared various epitomes on wetland

1.9. Research Gaps:

Now problems of wetland are a burning issue. A number of researchers highlighted several issues concerning the wetland. It is observed from the review of the above-mentioned literature that different scholars approach the domain of wetlands in different countries or different parts of India differently but there is still a necessity of more exploration and need for in depth study. Certain research gaps identified by the present researcher are laid down as follows.

1. Most of the researchers highlighted the physico-chemical properties of Wetlands.
2. A considerable number of the researchers have considered one or two component/s like water or soil, floral diversity or faunal distribution; temporal or chronological change of the wetlands.
3. Some of the studies dealt with the causes and consequences of wetland degradation and only a few studies were conducted on Water Quality Index.
4. Some of the studies were descriptive and exploratory in nature. In neither of the studies, the effort had been taken to explore the variation in the wetland in the different geographical locations.
5. None of the studies have been documented on the wetland services and its spatial variations.
6. Many of the scholars classified wetlands but a few have combined the types of wetlands with their distributional pattern.
7. Fragmentation of wetlands into smaller ponds is a serious concern towards degradation of wetlands. No one of the researchers has addressed this issue.
8. Lastly, none of the available studies has been conducted in the present area of study i.e. in Koch Bihar District.

Therefore, there is a need to take a holistic view of this issue and view it from a policy perspective. The present researcher has taken into consideration on almost all the components such as water quality, soil quality, the status of flora and fauna, the temporal change of wetlands. The study also focuses on the causes and consequences of wetland degradation in the present study area.

1.10. Conclusion:

The present chapter deals with statement of the problem, the location of the study area, hypothesis, objectives, methodology and significance of the study. Also, brief reviews of literatures that are directly or indirectly related to the study have been outlined.

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CHAPTER-II

GEOGRAPHICAL BACKGROUND OF THE STUDY AREA

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2.1. Introduction:

Study Area is the prime concern of any research especially in a spatial science like Geography. It is the place, based on which, the researcher carries out in-depth study and data collection. A discussion on the study area is fundamental as it helps in understanding the contextual background of the area under investigation. Mead defined study area as "the geographical studies pursued in a well-defined area" (Mead, 1969). Generally, a research is conducted within or beyond an area delimited by political or physical boundaries. However, it is sometimes difficult to delineate a study area as it may stretch beyond either of the boundaries. The study area is the geographic framework within which the field work is conducted, and thus its exact areal extent must be determined to focus and further define the purposes of the research. As the present research is based on the Geo-environmental study of the wetlands of Tufanganj and Koch Bihar Sadar subdivisions within Koch Bihar District, the study area and subsequent data collection have been confined to four community development blocks, namely Tufanganj-I, Tufanganj-II, Koch Bihar-I and Koch Bihar-II. Thus the main focus of the present chapter is on the historical background, physical and socio-economic background as well as the administrative jurisdiction and geographic location of Koch Bihar District.

2.2. Historical Background:

Etymologically, 'Koch Bihar' or 'Cooch Behar' has been derived from two words- 'Cooch' and 'Behar'. While the word 'Cooch' is a corrupted form of the word 'Koch' that signifies an indigenous mongoloid tribe, the word 'Behar' is derived from Sanskrit word 'Vihara', which means 'abode', or 'sport'. Thus HN Chowdhury (1930) rightly described Koch Bihar as the 'land of sporting with the Koches'. On 13th April 1896, Maharaja Nripendra Narayan in a notice published in the Cooch Behar Gazette approved the name 'Cooch Behar', however later the term 'Koch Bihar' was used in 1981 of the census of India.

The territory of Koch Bihar has its mention in the Epics and Puranas as the part of Pragjyotichpur or Pragjyotisha which extended from Bay of Bengal in the South and Koshi

River in the west. The region was inhabited by indigenous people who were attributed the names Danaba, Asura, Kirat etc. In the 2nd half of the century, the area was known as 'Kamrupa' (Debnath, 2008). The Kamrupa was mentioned in the Allahabad Inscription of Samudra Gupta. Between 7th and 12th century the land was ruled by different dynasties like Guptas and Palas. In the later stage the Kamrupa Kingdom was ruled by Khen dynasty and named as 'Kamta' and Khen king Nildhwaja established his capital at Kamtapur near Koch Bihar and it was extended to parts of Dinajpur, Jalpaiguri, and Rangpur of Bangladesh. In 'Baharisthan -i- Ghaibi' the area was named as 'Kamta'. J. Blaeu (C.1664) in his world Atlas 'Nova et Accuratissima Terrarum Orbis Tabula' mentioned the land as *'Comotay'*. Koch Bihar was first used in 'Shah Jahan Nama' in the middle 17th century. After the fall of Pala dynasty (C.900-C.1100), the Khen dynasty was established in 1185AD by Prithu. However, in 1498 AD the khen lineage to the throne came to an end when Alaudding Husain Shah, the independent sultan of Gour defeated the last khen ruler Nilambar. Again in 1505 the kingdom passed into the hands of the Ahom king Sahungmung. However, taking advantage of the political upheaval the indigenous Koch tribe assumed full control and the Koch dynasty was established in 1515AD by Koch Raja Viswa Singha. In 1581, the Kamtapur kingdom was again divided into two parts – Koch Bihar and Koch Hajo- demarcated by Sankosh River. The Koches were the collection of Mongoloid race who was the admixture of Mech and Koch Hajo tribes. In course of time Koch Bihar transformed from a Kingdom to a princely state under the protection of the British Government from 1773 and notably in 1863, Colonel J.C.Haughton was appointed to cater the minor Maharaja Nripendra Narayan (one year old). After Independence of India in 1947, Jagaddipendra Narayan the last ruler of Koch Bihar transferred full power and jurisdiction to the Government of India on 12th September, 1949. On the basis of the Government of India Act, 1935 and under the order of U/S 290A, the Koch Bihar merged with the state of West Bengal on 1st January, 1950 under Jalpaiguri division.

2.3. Administrative Background:

2.3.1. Administrative Boundary of Koch Bihar:

The district of Koch Bihar is a part of the Himalayan Terai of West Bengal. Koch Bihar district is bounded by rivers and International, State and district boundaries. Raidak in Tufanganj subdivision and Jaldhaka in Mekhliganj subdivision form the boundaries. While the western part of the district is bounded by Jalpaiguri Sadar, Maynaguri and Dhupguri blocks of Jalpaiguri district; northern part is bounded by Alipurduar and Kumargramduarof Alipurduar district. In the East, Koch Behar is bounded by Goalpara district of Assam and in the Southern part, it is bounded by Boda, Debiganj, Domar, Dimla, Patgram, Hatibandha, Kaliganj, Lalamonirhat, Phulbari, Nageswari and Bhrungamari of Bangladesh. The total geographical area of the district is 3387 sq.km after the inclusion of Panishalamouza of Maynaguri PS of Jalpaiguri district in 1981. Approximately Koch Bihar extends from 25º57'57" N to 26º32'58" N latitude and 88º45'28"E. to 89º 51'50" E longitude.

Table 2.1: Administrative Setup of the Study Area

<table>
<tr><th rowspan="2">Sub-Divisions</th><th rowspan="2">P.S.</th><th rowspan="2">C.D Block</th><th colspan="2">Towns</th><th rowspan="2">No of Inhabited Villages</th><th rowspan="2">Total No of inhabited villages</th></tr>
<tr><th>Municipal</th><th>Census Town</th></tr>
<tr><td rowspan="3">Dinhata</td><td>1.Sitai</td><td>1.Sitai</td><td>-</td><td>-</td><td>53</td><td rowspan="3">299</td></tr>
<tr><td rowspan="2">2.Dinhata</td><td>2.Dinahata-I</td><td>1.Dinahata</td><td>1.Bhangri PrathamKhanda</td><td>130</td></tr>
<tr><td>3.Dinahata-II</td><td>-</td><td>-</td><td>119</td></tr>
<tr><td rowspan="2">Tufanganj</td><td>1.Tufanganj</td><td>1.Tufanganj-I</td><td>1.Tufanganj</td><td>1.Kamat Phubari</td><td>72</td><td></td></tr>
<tr><td>2 .Baxirhat</td><td>2.Tufanganj-II</td><td>-</td><td>2.Chhota Laukuthi</td><td>54</td><td rowspan="2">126</td></tr>
<tr><td rowspan="3">Mathabhanga</td><td>1.Mathabhanga</td><td>1.Mathabhanga-I</td><td>1.Mathabhanga</td><td>-</td><td>102</td></tr>
<tr><td>2. Ghokshadanga</td><td>2.Mathabhanga-II</td><td>-</td><td>-</td><td>92</td><td rowspan="2">260</td></tr>
<tr><td>3. Sitalkuchi</td><td>3.Sitalkuchi</td><td>-</td><td>-</td><td>67</td></tr>
<tr><td rowspan="3">Mekhliganj</td><td>1.Mekhliganj</td><td>1.Mekhliganj</td><td>1.Mekhliganj</td><td>1.Nagar Changrabhanda</td><td>140</td><td></td></tr>
<tr><td>2.Kchlibari</td><td rowspan="2">2.Haldibari</td><td rowspan="2">2.Haldibari</td><td rowspan="2"></td><td rowspan="2">58</td><td rowspan="2">198</td></tr>
<tr><td>3.Haldibari</td></tr>
<tr><td rowspan="8">Koch Bihar(Sadar)</td><td rowspan="8">1.Koch Bihar Kotwali</td><td rowspan="3">1.Koch Bihar-I</td><td rowspan="3">1.Koch Bihar</td><td>1.Kharimala Khagrabari</td><td rowspan="3">142</td><td rowspan="3">143</td></tr>
<tr><td>2.Guriahati</td></tr>
<tr><td>3.Dhaliabari</td></tr>
<tr><td rowspan="5">2.Koch Bihar-II</td><td rowspan="5"></td><td>1.Baisguri</td><td rowspan="5">111</td><td rowspan="5">116</td></tr>
<tr><td>2.Chakchaka</td></tr>
<tr><td>3.Takagach</td></tr>
<tr><td>4. Baneswar</td></tr>
<tr><td>5. Khagrabari</td></tr>
<tr><td>5</td><td>11</td><td>12</td><td>6</td><td>12</td><td>1140</td><td>1140</td></tr>
</table>

Source: DCHB, 2011 and Census, 2011

2.3.2. Administrative Set up of Koch Bihar:

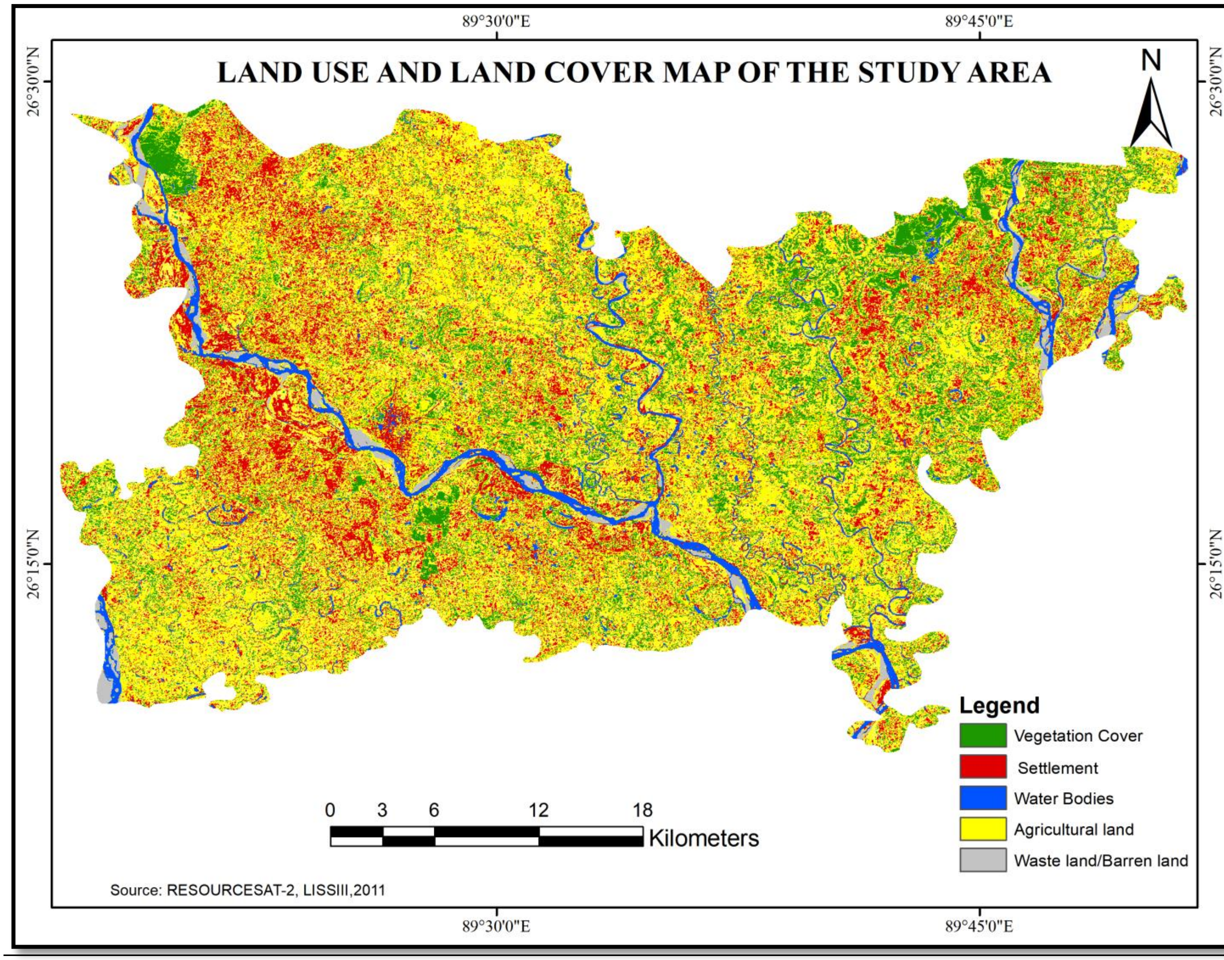
At the time of merging into the Dominion of Government of India, Koch Bihar District had 5 subdivisions (Vide Notification No- 3549,GA on 1st January,1950) namely Koch Bihar Sadar, Dinhata, Tufanganj, Mathabhanga and Mekhliganj and 8 police stations namely Kotwali, Dinhata, Sitai, Tufanganj, Mathabhanga, Sitalkuchi, Mekhliganj and Haldibari. Later 3 more police stations were added to the district namely Ghosadanga, Kuchlibari and Baxirhat. The district has been divided into 12 community development blocks and 1202 mouzas out of which 1140 mouzas are inhabited. The district has 6 municipalities namely Koch Bihar, Dinhata, Tufanganj, Mathabhanga, Mekhliganj, Haldibari which comprises of 80 municipal wards and 12 census towns.

2.3.3. Location of the Study Area:

The study area lies between Sankosh- Mansai interfluves. The area is bounded by Mathabhanga-II in the west, Dinhata Subdivision in the south, Assam in the east and Alipurduar district in the north. The whole area comprises two subdivisions namely Tufanganj and Koch Bihar Sadar. Besides, the study area has 4 community development blocks viz. Tufanganj-I& II and Koch Behar-I& II (Map-2.1). The geographical coordinates of the area are 26º9'8''N to 26º29'24''N and meridians of 89º 17' 34'' E to 89º 51'50''E. The study area has 380 mouzas with 285750 households as per 2011 records. There are 2 municipalities and 10 census towns in the two subdivisions along with 32 wards. The total geographical area of the study area is 1341.28 sq km (39.60% of the district). Total population according to 2011 census in Tufanganj subdivision and Koch Bihar subdivision is 4, 56,319 and 1, 75,419 (42.73 % of the district) respectively.

2.4. Physical Background:

Physical background of any study area is concerned with natural features and phenomenon of the earth’s surface such as geology, Physiography and relief, climate, drainage system, soil and natural vegetation.



Map 2.1: Land use and Land cover Map of the Study Area

2.4.1. Geology:

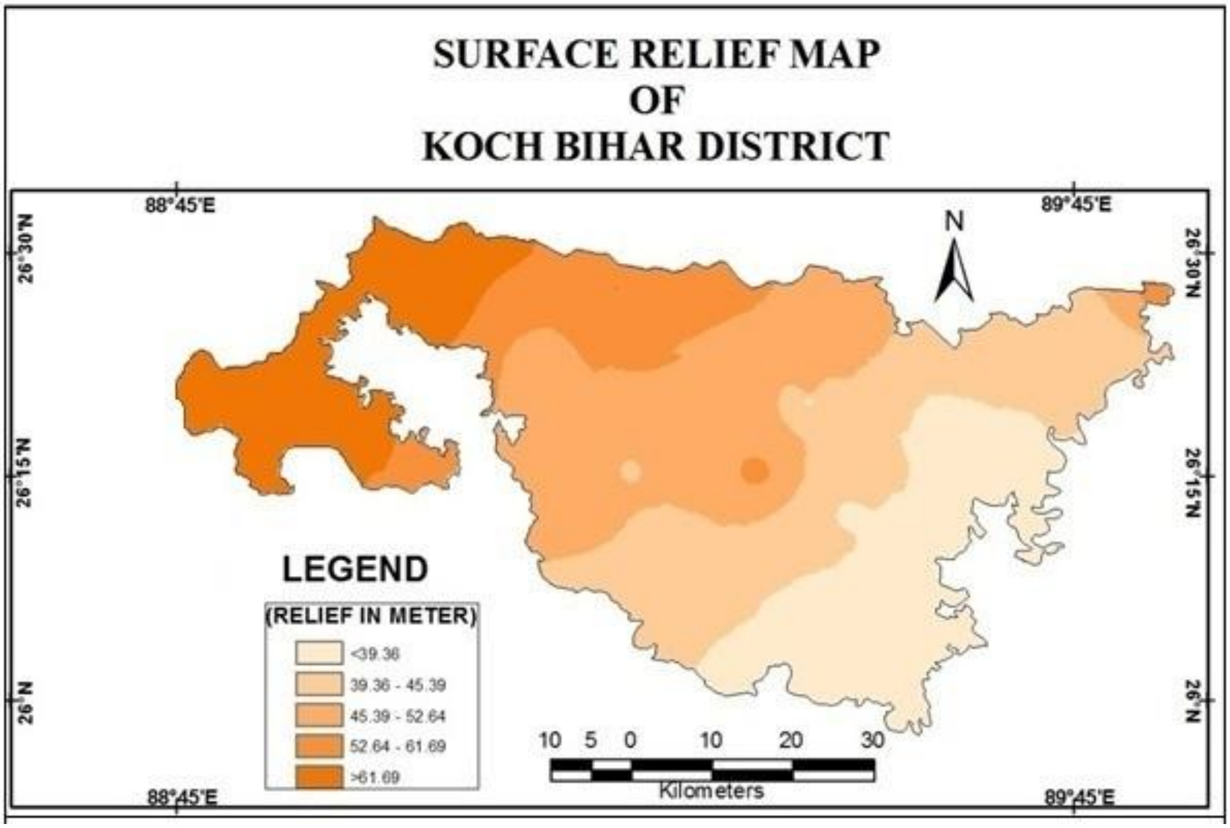
The region is studied based on morpho and litho-stratigraphy. The northern part of the district along the Siwaliks or foothills of Bhutan Himalayas constitutes of alluvial fan sediments, which lie unconformably. The fan sediments are divided into 3 formations viz.1) Deema formation 2) Jayanti formation and 3) Santrabari formation. Highly assorted sub-angular large boulders and pebbles of high-grade gneiss, granite and quartzite characterize the Deema formation. This formation also has Carbonized plant remains in the lower altitudinal area. On the other hand, Jayanti formation is characterized by mélange with an admixture of the matrix and clastic rocks which are smaller in size than those in Deema Formation. Constituents also range from Khaki and reddish brown silt to fine-grained sand which is susceptible to gully erosion. This formation also shows weak stratification at some places. Santrabari formation is generally found at the highest topographic level, its constituents range from small boulders to pebbles, with compact stratification. This formation is also characterized by small quantities of carbonized plant remnants.

The southern part constitutes of alluvial flood plain elements. The flood plain is divided into 3 formations, namely 1) Present day Flood Plain formation 2) Shaogaon formation and 3) Baikanthapur formation. Present day flood plain deposits comprise of fine greyish silver micaceous sand which is deposited as point bar, mid-channel bars along the river bed. The Shaogaon formation lies above the present day flood plain deposits. This formation is slightly undulated and has sparsely distributed human settlements. The formation is inundated by flood during the monsoon period. The Baikanthapur formation lies in the upper part of the flood plain and is hardly inundated by the flood. This formation is characterized by grey to dark grey alluvium.

Neo-tectonic activities are common in this area along the faults and it affects the fan and flood plain deposits. The area has witnessed several tectonic activities during Quaternary times which have resulted in the frequent alterations of the size of sand and silt and sudden changes in the steam gradient. It is assumed that the Deema, Jayanti and Santrabari formations are Glacio-Fluvial in origin. It is further observed that the Santrabari is the primary Fan and Jayanti is the secondary fan. The provenance of the Deema formation indicates that the materials are carried from a distant location. The older alluvium formation is absent at 304 m bgl. Thus it may be assumed that Siwaliks and other Tertiary deposits, if present, occur below this depth.

2.4.2. Relief:

Physiographically Koch Bihar district lies below the sub-Himalayan region of West Bengal. This zone comprises the plains of Jalpaiguri, Koch Bihar and Siliguri sub-division of Darjeeling district. The region is demarcated as Terai which is formed by the deposition of sand, gravel and pebbles brought in by the rivers. Koch Bihar basically is a flat province with a slight south-eastern slope along which the main rivers of the district flow. A number of rivers and their tributaries have traversed the district. Due to the lower course, the rivers flow in the meandering course and most of them form natural levee and ox bow lakes. The region is, thus, a flood-prone area which is inundated during the monsoon season. Numerous remnant channels which are present in the region create bills, locally known as *Chhara*. In the district, elevation of Sitalkuchi block is the highest and Sitai is the lowest. The average height of the district is 60 m msl(Map 2.2).



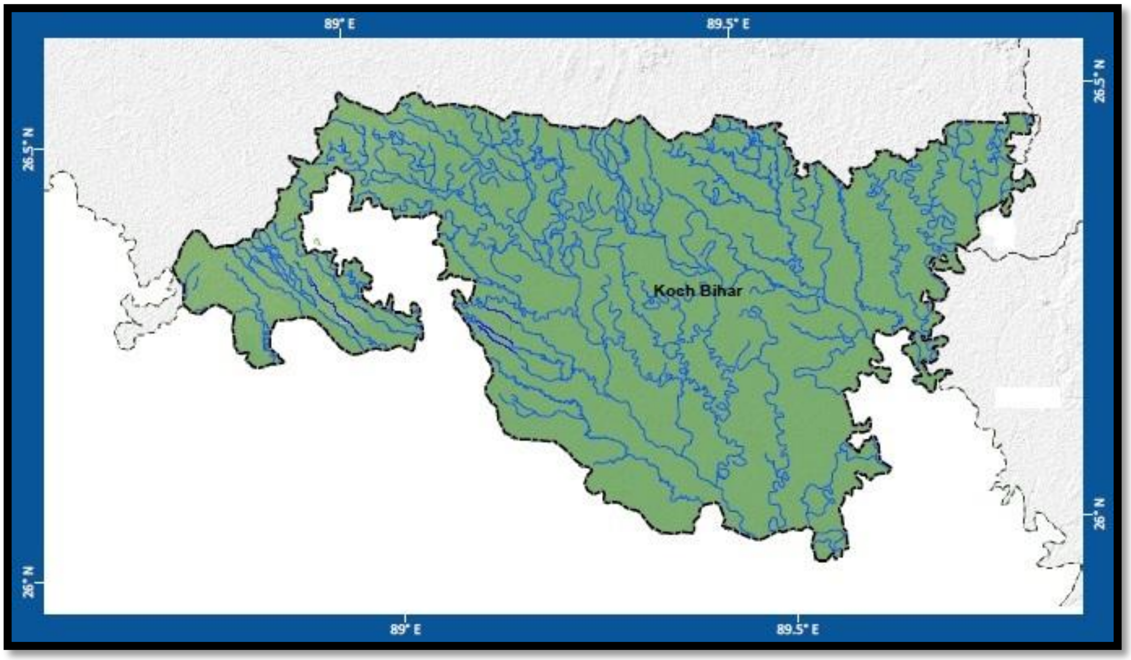
Map 2.2: Surface Relief Map of Koch Bihar, Source: SRTM 3 Arc Second DEM

2.4.3. Drainage:

Koch Bihar district is a well-drained region owing to a number of river systems. The rivers are mostly perennial and ephemeral in nature, and a majority of them originates from the northern Himalayan Mountains and is snow fed. Irrespective of their origins, either from the glaciers of Greater Himalayas or the lesser Himalayas, the rivers of the district finally enter into the Brahmaputra in Bangladesh. During their course in the hills and the Dooars region, the rivers carry heavy loads of sediments, which are deposited, along the foot hills and eventually these sand and silt are carried across the river to be deposited along the riverbeds.

The region has 6 major river systems (Map-2.3) viz. 1) The Tista system 2) The Jaldhaka system 3) The Torsa system 4) The Kaljani system, 5) The Raidak system and 6)

Sankosh or Gangadhar system. A brief account of the important rivers of the district is discussed in the table-2.2.



Map 2.3: Drainage System of Koch Bihar

2.4.4. Climate:

2.4.4.1. Temperature:

The climate of Koch Bihar District is hot-humid and sub-tropical in nature. The cold season is observed from mid-November to the end of February. This is followed by hot season from March to May. During June to August south-west monsoon causes heavy rain fall in the district. During summer, April is the hottest month with a mean daily maximum temperature of 32°C and mean daily minimum temperature of 20°C. Koch Bihar experiences cold winters, characterized by foggy mornings and nights. Starting from the end of November and lasting until February mercury rises to a maximum of about 24°C with minimum temperature about 10°C. The temperature begins to drop steadily from December and reaches to its lowest between the last week of December and second week of January. The transition from cold to hot weather and from hot to cold weather occurs in the months of March and October respectively denoting spring and autumn in Koch Bihar. The weather is very pleasant during this time.

Table 2.2: Major River Systems of the District

Sl No	Name of the River	Source	Local Name	Length	Basin area	Mouth	Tributaries	Basic Features
1	Tista	Pahunri Glacier, at 7068 m in Sikkim	Lachen Chu and Lachung Chu	310.15km 24 km in Koch Bihar	12450 km2	Brahmaputra at Kurigram, Bangladesh	**Right:**Dik Chu, Rangpo,Lang Lang Chu, Rani Khola **Left:**Ranghap Chu, Rangit, Ringyong Chu, Rajini, Lish, Ghish, Karola,	* It enters in Koch Bihar at Boxiganj, in Mekhliganj. * It runs through Mekhliganj and Haldibari * It is divided into 6 branches * Tista has 3 distributaries- Two BuriTista and another Mora Tista
2	Jaldhaka	Bidang lake at Sikkim	Di Chu and Li Chu	192km 87 km in Koch Bihar	3960 km2	Dharla river near Kuri gram and finally Brahmaputra	**Right:** Bindu, Murko, Murti, NaksalKhola, Sutunga, Jarda, Khutamara or Giridhari **Left:** Diana, Rehti-Duduya, Mujnai, Kumlai, Gelandi, Dolong, JariDharla, BuraDharla,Malda, Baniadaha, Nilkumar	* It has several names- the upper part is known as Jaldhaka, Middle part Mansai and then Singimari and after merging with Dharala in Bangladesh it is named as Dharla. * It enters in the district in the North-West corner near Kheti and then flows South Easterly direction
3	Torsa	Chumbi Valley in Tibet, at 7060 m height .	Ma Chu in Tibet and in Bhutan Amo Chu	358 km , 60km in Koch Bihar	4883 km^2	Brahmaputra near Kurigram	Holong, Kala Torsa, Malangi, Raidak -1, Ghargharia, Kaljani, Gadadhar, buraRaidak, Sanfola, Mora Torsa, Sanjai, Khutamura, Rasmoti, NayaTorsa, Bherbheri or Sengsengi	* Torsa river has two parts in the duars- ShilTorsa and Char or BuraTorsa * Char Torsa merges to ShilTorsa at Khopatuli * BuraTorsa and Mujnai merged together and was flowing in the south * After merging Torsa and Bura Mansai at Kalpani, The Torsa has been divided into two parts- one is Dharla and another is the Torsa. *Bura Mansai merged to Khutamara River. * Ghargharia, Kaljani, , Raidak-1 all are fall in the Torsa river and named as Dudhkumar in Bangladesh

4	Kaljani	Southern part of Bhutan Himalaya	Combination of Alaikura and Dima	32 km in Koch Bihar		ChoukushiBalrampur atTorsa River.	**Right:**Pana, Gabur Basra, Buribasra, Raymatang, Garam, Doria, Gidari, Ghargharia, **Left:** NimtiJhora, Paro, ChhotoGadadhar, Nonai, Cheko, Ghungundara, Khatajani, Betra- Combined course of KhoraandNyaro.	* It enters into the district at South Kholta of AlipurDuar. * The combination of Raidak, Ghargharia, Gadadhar and Torsa is known as Dudhkumar in Bangladesh. It finally falls into the River Brahmaputra near Kurigram.
5	Raidak	Chomolahari of Indo-Tibet border at the height of 7314 m.Border		R-2-47km R-1= 15		Meets with Kaljani at Balbhut.	BuraRaidak, Ghoramara, Jorai, DipaRaidak,	* It is also known as Nang chu, Oyang Chu, Chin Chu, Thimpu Chu etc. * It enters into the district NW part of Tufanganj near Chengtimari. * It is divided into parts. One in the east with the name RongBarsuti, and another in the west as Raidak. * RongBarsuti is then falling in the river Sankosh with the name Raidak-2. At Fersabari and Falimari. * Tufanganj Town is situated anong the Raidak-1.
6	Sankosh (Gangadhar)	Northern Bhutan at the height of 6794m	Mo Chu, Puna Tsang Chu,	6km in Koch Bihar		It falls into the Brahmaputra at Assam.	Mo Chu, Pho chu, Jorai, Raidak-2, Takullya,	* It enters in the district in the North-North East. * It demarcates the East and West Kamrup during the Reign of Maharaja Narnarayan. The eastern part is given to BirChilaray.

Source: Choudhury, 1903 and Dam, M.K, 2015

Table 2.3: Average Maximum, Minimum Temperature and Rainfall of Koch Bihar

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Avg Maximum Temp °C	33.1	32.7	32.8	32.6	32.7	33.6	33.8	34.1	34.1	34.2	33.9	33.4	34.2
Avg Minimum Temp °C	15.3	15.6	15.7	14.8	17.3	17.1	16.1	18.6	16.6	16.8	16.1	14.8	15.8
Average Rainfall (cm)	21.1	23.2	26.8	25.6	27.3	18.1	21.1	30.6	30.5	40.8	26.7	33.5	27

Source: IMD, Kolkata

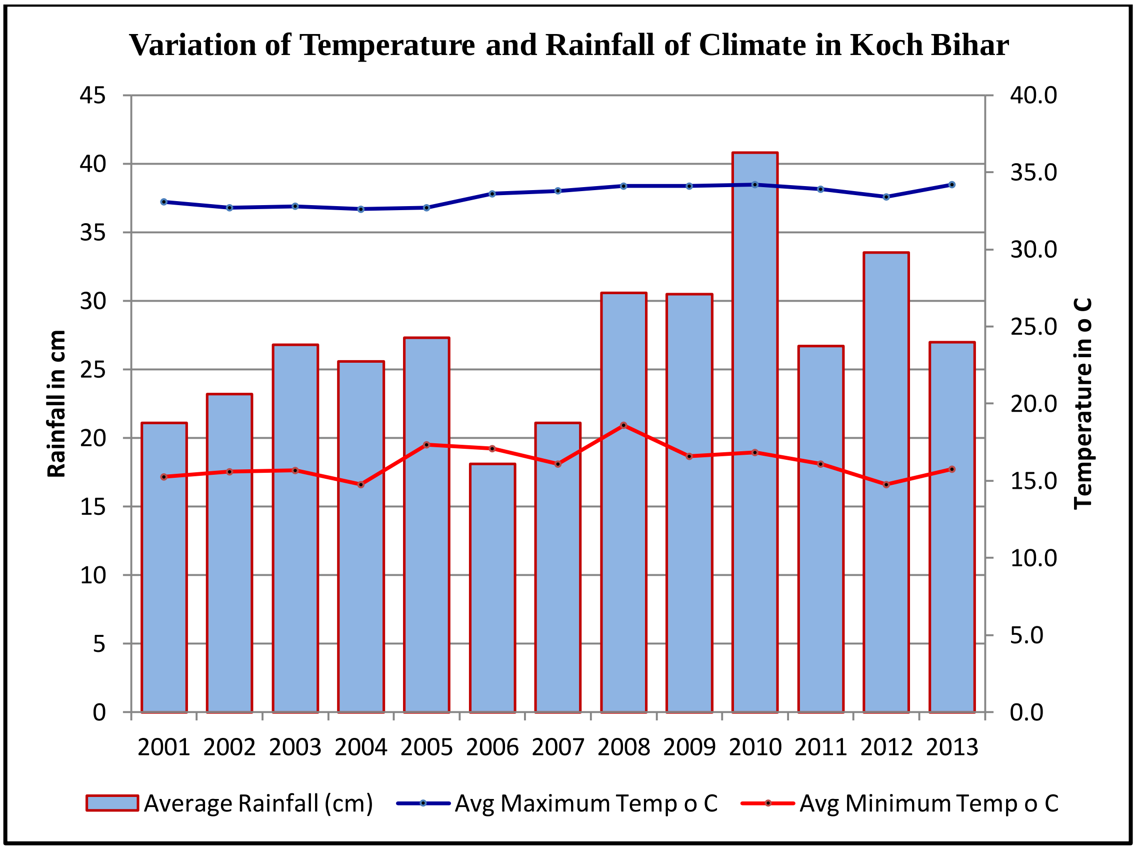


Fig 2.1: Variation of Temperature and Rainfall of Climate in Koch Bihar

Table-2.3 shows the mean daily maximum and minimum temperature in ºC from 2001 to 2013. The highest temperature recorded is 38oC in the month of April of the year 2010. The maximum temperature may sometimes rise above 35ºC. The fig-1.1 depicts that the mean maximum temperature was highest in the year of 2010 and lowest in the year of 2004. The highest mean minimum temperature was recorded in the year of 2008 and lowest was recorded in the year of 2004. The figure also shows that the variation in the mean maximum temperature of the study area.

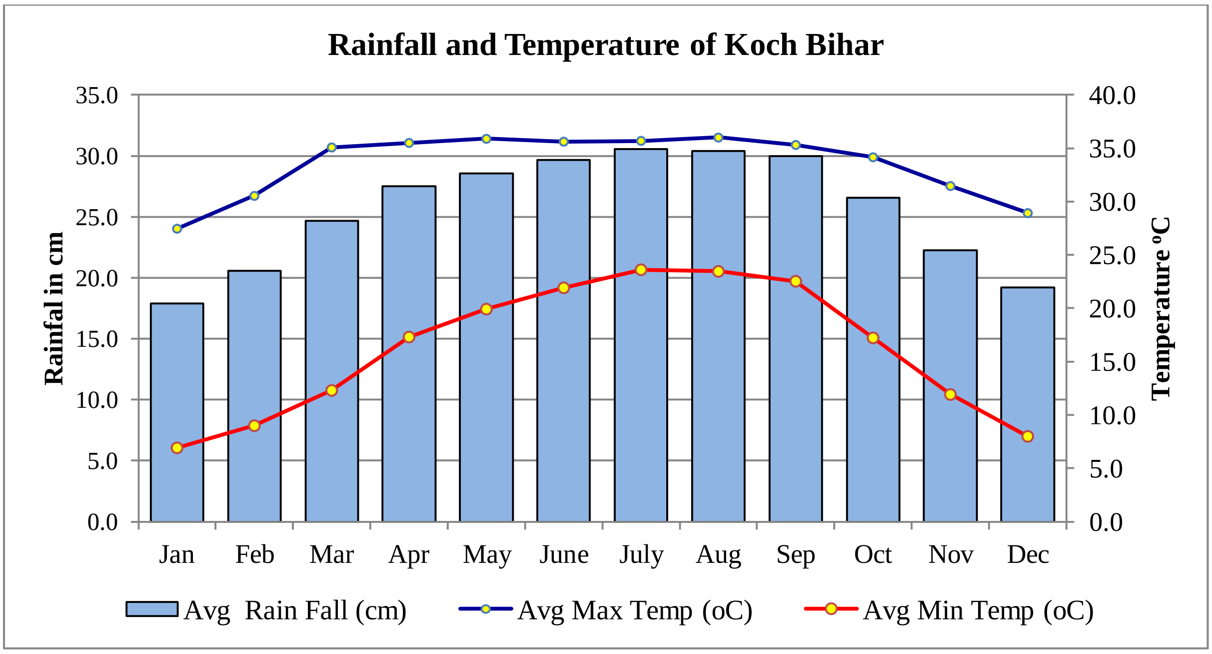


Fig 2.2: Rainfall and Temperature of Koch Bihar

The Fig-2.2 Shows that January is the coldest month in the short winter season with the lowest temperature of (6.9ºC). The mean minimum temperature was also recorded in January (6.9ºC) followed by December (8.0˚C). The highest mean minimum temperature was observed in the month of July whereas mean maximum temperature was highest in the month of August (36˚ C). It was also observed that the mean maximum temperature was consistently high during the summer season.

2.4.4.2. Rainfall:

Koch Bihar has a sub-tropical monsoon with heavy downpour during the summer season. The rainfall in the winter is scanty due to depression, western disturbances and retreating monsoon. During March and April, the district witnesses *Kalbaishakhi* which is thunder storm accompanied by hail. It often damages the Zaid crops and the tobacco cultivation. Tables 2.3 and 2.4 show the maximum amount of rainfall during the summer monsoon. From the month of May to September the district receives about 88.62 % of rainfall. This huge amount of rainfall causes a recurrent flooding almost in every year. As per the Fig 1.1, the maximum rainfall occurred in the year 2010(40.8 cm) and lowest rainfall occurred in the year of 2006 (18.1 cm).

Table 2.4: Rainfall (mm) of Koch Bihar District

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
January	0	28	8	7	26	0	0	39	-	-	3	3	-
February	2	1	37	2	8	11	52	10	-	-	11	11	14
March	31	86	163	5	59	3	14	76	36	30	56	3	10
April	77	295	240	164	163	62	161	188	108	385	138	173	115
May	402	109	268	355	253	355	216	282	287	600	294	242	244
June	504	560	817	500	747	551	475	569	510	711	431	947	404
July	338	975	795	990	638	529	597	606	402	863	775	779	661
August	390	274	319	227	622	113	439	841	629	525	476	337	348
September	419	414	296	646	288	382	496	299	196	496	465	614	398
October	358	42	248	165	470	135	87	147	270	61	20	245	237
November	5	2	0	6	0	18	0	-	-	2	-	-	-
December	0	0	27	0	0	10	0	-	-	-	-	-	-

Source: IMD, Kolkata

2.4.5. Ground Water:

The district heavily depends on groundwater for domestic, industrial and irrigation purposes and so this resource is under immense pressure resulting in a decline in its water level. Due to an agrarian economy, expansion of irrigation facility is must and it can only be achieved when proper management of groundwater is made a priority.

Table 2.5: Depth of Ground Water Table

Name of the Block	Depth of Ground Water Table (m bgl)					
	Jan	April	Avg. Pre-Monsoon	Aug	Nov	Avg Post-Monsoon
Mekhliganj	2.81	3.36	3.08	1.09	1.83	1.46
Haldibari	2.48	2.96	2.72	1.30	1.65	1.47
Mathabhanga-I	3.03	3.91	3.47	1.61	2.34	1.98
Mathabhanga-II	3.68	3.72	3.70	1.73	2.42	2.07
Sitalkuchi	2.02	3.02	2.52	1.62	1.46	1.54
Koch Bihar-I	2.46	2.80	2.63	1.02	1.54	1.28
Koch Bihar-II	3.45	3.23	3.34	0.97	1.96	1.46
Tufanganj-I	4.18	4.59	4.38	2.45	3.24	2.84
Tufanganj-II	2.93	1.88	2.40	0.73	1.43	1.08
Dinhata-I	3.15	4.05	3.60	2.23	2.42	2.32
Dinhata-II	2.66	4.05	3.35	2.82	3.19	3.01
Sitai	2.50	4.36	3.43	2.05	2.88	2.46
		Mean	3.22		Mean	1.91
		SD	0.58		SD	0.63

Source: www.cgwb.gov.in (2014-15)

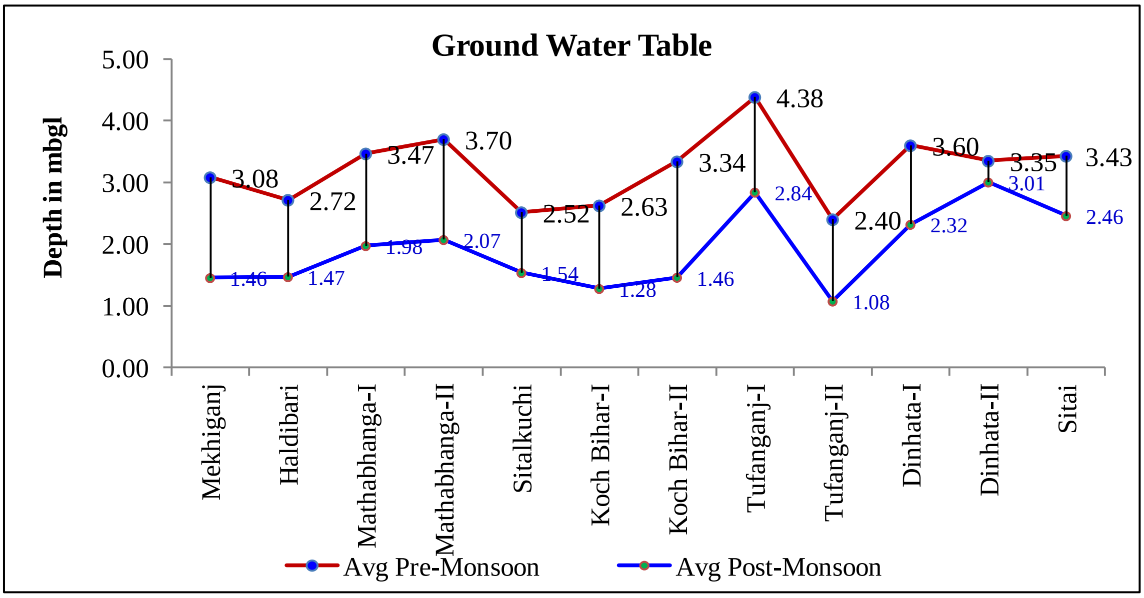


Fig 2.3: Depth of Ground Water Table

As per the records of 2014, in January the average water level varied from 0.11 to 26.93 meters below ground level (m bgl) in West Bengal. According to the report of Central Ground Water Board (CGWB), in 2011, the total ground water recharge in the district Koch Bihar was 2,31,666 Million Hectare Metre (HAM). Irrigation system is catered mainly through dug wells (1.612 sq km area irrigated), shallow tube wells (12.399 sq km area irrigated), deep tube wells (182.96 sq km area irrigated), surface lift (175.80 sq km), river lift(3.554 sq km area), tank(14.44 sq km area), and canals(121 sq km), as on 2004-05. The recharge of ground water depends on the amount and duration of rainfall and it ranges from 2.5-3.04 m bgl in Koch Bihar. Ground water is generally being developed through open wells i.e. dug wells, in the weathered zone. However, groundwater in the zone of semi-confined to confined aquifers can yield 80-170 Litres per minute (lpm) which at places goes as high as 350 lpm. From the Fig-2.2 it is observed that the depth of ground water during pre-Monsoon varies from 2.52 (Sitalkuchi) to 4.38 m bgl (Tufanganj-I) and during post-Monsoon it varies from 1.08 (Tufanganj-II) to 3.01 m bgl (Dinhata-II). Mean depth of ground water table in both seasons were 3.22 m bgl (CV= 18 %) and 1.91 m bgl (CV =33%) Table-2.5.

The chemical quality of ground water in the area is slightly acidic to slightly alkaline. The pH value ranges from 6.5 to 7.8. Iron content varies from 0.04-10.2 ppm. Fluoride concentration varies from 0.12-.037 ppm. The average EC in the ground water in the district is 319.4. Thus, the chemical quality of ground water in shallow and deep aquifers is safe and suitable for both domestic and agricultural purposes.

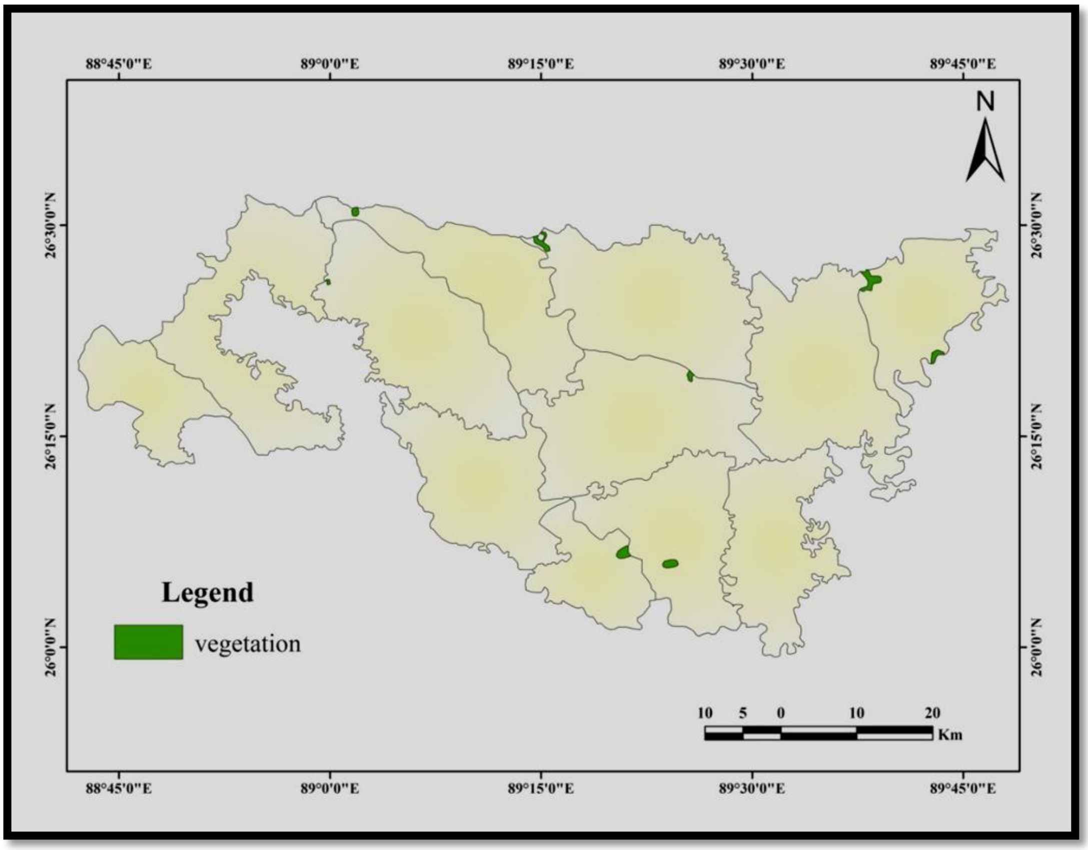
2.4.6. Natural Vegetation:

Koch Bihar district abounds in natural vegetation. Old river beds, ponds, marshes, and streams with a sluggish current have a copious vegetation of Vallisneria and other plants. Land here is subjected to inundation and usually has a covering of Tamarix and reedy grasses; and in the parts, where the ground is more or less marshy, Rosa involucrate is plentiful. Few trees occur on these inundated lands; the most plentiful and largest is Barringtonia acutangula. Among the trees, the most conspicuous is the red cotton tree (Bombax malabaricum); the Sissu (Dalbergia sissoo); Mango (Mangifera indica); Jack Fruit; Sal (Shorea robusta); Mahua; Teak; Bamboo; Khayer (Acacia catechu); Palms etc. Near the villages, there are usually thickets or shrubberies and more or less useful trees of a rapid growth and weedy nature. Koch Bihar district at present has no large forest patch (Table. 2.6). There are two small forests, namely Bochamari-Chengtimari forest & Patlakhawa forest. These are cleared for cultivation.

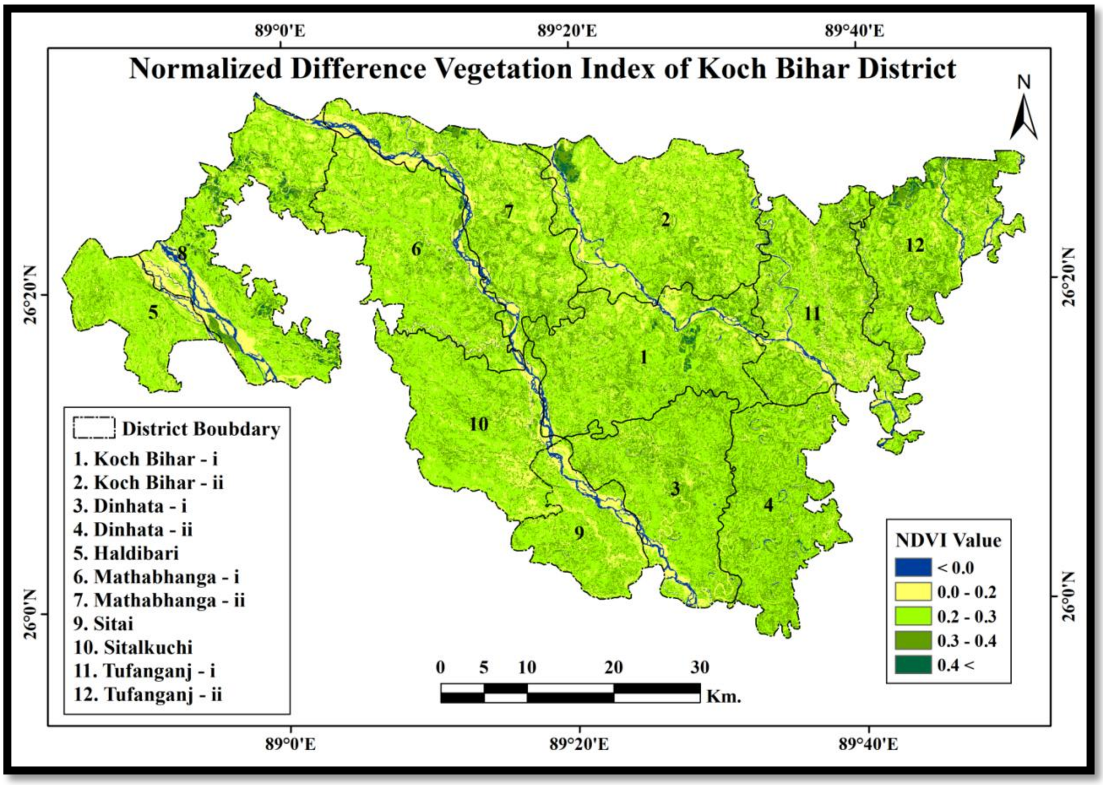
Table 2.6: District Wise Area under Forests by Legal Status in West Bengal ***Area in sqkm***

Sl. No.	District	Reserved Forests	Protected Forests	Non-classified State Forests & Others	Total Area in Sq Km	Total Area in (Sq km)	Recorded Forest Area (Sq.Km.)	% age of Recorded Forest Area	Non- Forest Tree Cover	Total Tree Cover	% forest Cover	% Tree cover
1	Koch Bihar	-	42	15	57	3,387	57	1.68 %	764	808	1. 3	23 .9
2	West Bengal	7,054 (59.38 %)	3,772 (31.75%)	1,053 (8.87%)	11,879 (100%)	88,75 2	11,8 79	13.3 8%	9816	272 81	15 .7	30 .7
3	All India	4,23,31 1	2,17,245	1,27,881	7,68,437							

Source: State Forest Report, West Bengal 2008- 2009



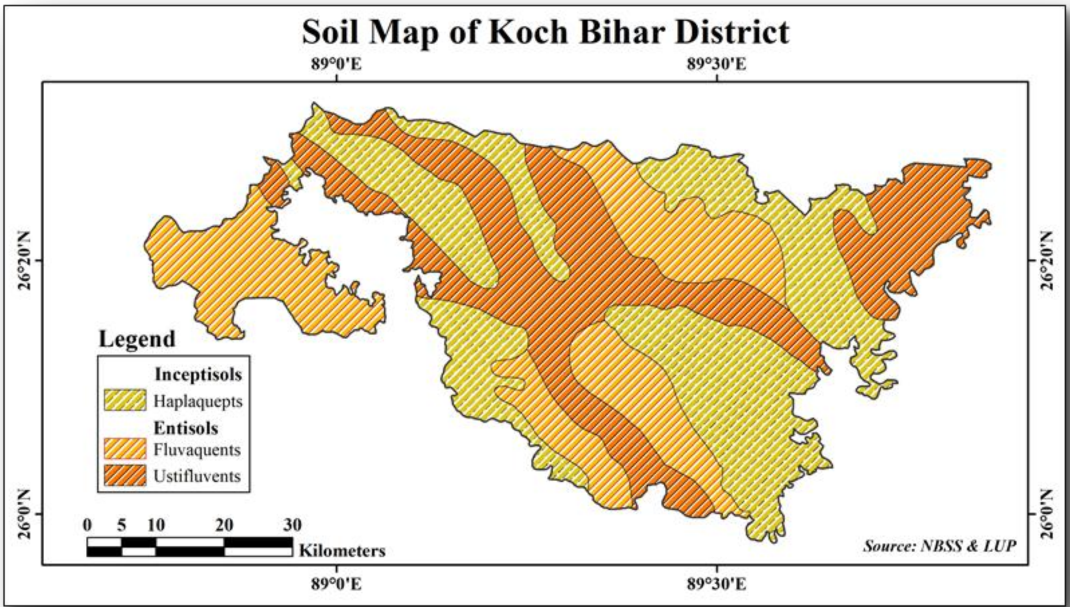
Map 2.4: Natural Vegetation Cover of Koch Bihar District



Map 2.5: Vegetation Cover Map of Koch Bihar District

2.4.7. Soil:

Soil of the study area is alluvial in nature, varying in depth from 15cm to 300cm. It is formed in the quaternary period through the sand and silt deposition, which has been carried by the rivers from Himalaya. While older alluvium soil is found far away from river courses, newer alluvium soil is found near the river and every year this newer alluvium is deposited over the low-lying areas. This soil is ideal for the cultivation of paddy, jute, tobacco, mustered oil seed etc. The turbulent water of different rivers carry huge amount of detritus material, which have an adverse effect on crop production as well as the hydrology of the study area. (Banerjee, 1984). Recurrent floods also affect the quality of the soil. The colour of the soil varies from ash to black (Census, 1977). Black soil is found in Kaljani to Sankosh River and between Jaldhaka and Dharla River. pH value of the soil varies from 5.31 -7.10 (Map-2.6). The parent rock constitutes of Igneous and metamorphic rock lies at the depth of 1000-1500 metre from the surface. The soil of the district has high water holding capacity and so the depth of the ground water table is high (1.91m bgl). The soil has a low level of nitrogen with moderate levels of potassium and phosphorus and is deficient in zinc, calcium and magnesium. The soil has high level of sulphur. The moisture retentive capacity of land in the high concentration of sulphur causes low fertility. Organic matter in recent years indicates the augmentation of consciousness among the farmers regarding utility and necessity of organic farming. The district also suffers from deficiency of micronutrient.



Map 2.6: Soil Map of Koch Bihar District

Table 2.7: Soil Texture of Different Blocks of Koch Bihar District

Sl.No.	Name of The Block	Soil Texture				USDA Classification	Soil pH
		Sand	Silt	Clay	Total		
1	MEKHLIGANJ	55.54	31.29	13.17	100.00	Sandy Loam	6.50
2	HALDIBARI	69.68	21.72	8.60	100.00	Sandy Loam	6.18
3	MATHABHANGA-I	43.96	40.08	15.96	100.00	Loam	5.83
4	MATHABHANGA-II	53.71	31.26	15.03	100.00	Sandy Loam	6.50
5	SITALKUCHI	61.10	27.72	11.18	100.00	Mixed	5.31
6	KOCH BIHAR-I	42.12	45.78	12.10	100.00	Loam	7.10
7	KOCH BIHAR-II	44.53	47.24	8.23	100.00	Loam	6.47
8	TUFANGANJ-I	32.15	36.70	31.15	100.00	Clay Loam	6.25
9	TUFANGANJ-II	51.92	29.19	18.89	100.00	Mixed	5.88
10	DINHATA-I	42.38	43.24	14.38	100.00	Loam	7.25
11	DINHATA-II	48.86	36.27	14.87	100.00	Loam	6.40
12	SITAI	51.57	32.57	15.86	100.00	Sandy Loam	6.51

Source: Soil Testing Lab, Koch Bihar

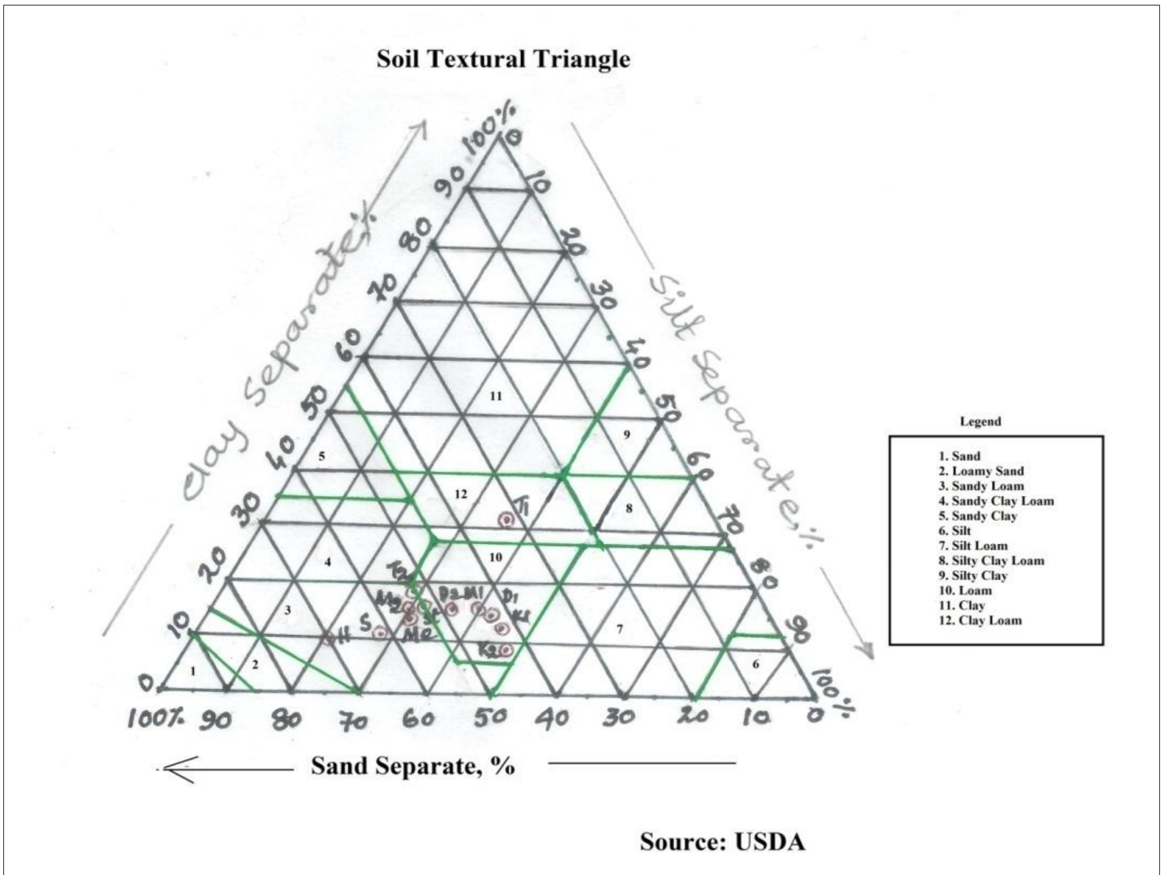


Fig 2.4: Ternary Diagram Showing the Soil Texture in Koch Bihar District

The soil is generally acidic in nature, because of heavy rainfall and greater gradient. The soil is highly leached. Sheet erosion is a problem in the areas of tea plantation in the district. Sandy-loam soil is found in Mekhliganj, Haldibari, Mathabhanga-I and Sitai Block. Loamy Soil is found in Mathabhanga-I, Koch Bihar-I, Koch Bihar-II, Dinhata-II, and Dinhata-I. The textural classification of Tufanganj-I is Clay loam (Table-2.8) which is suitable for brick making as well as agriculture. The soil of Sitalkuchi and Tufanganj-II blocks is mixed in nature.

There are four soil series in the study area namely- Lotafela, Matiarkuthi, Rajpur, and Balrampur series as classified by NBSS & LUP, 2001 Publication No-89. Out of which three series are observed in Koch Behar Sadar and Tufanganj subdivision. A brief description of the 3 soil series is incorporated in the following table-2.8.

Table 2.8: Soil Classification of the Study Area

Name of the Series	Location	USDA Classification	Physiographic position	Elevation	Horizon	Nature
Matiarkuthi	Sadar (East and Central)	Coarse-Loamy, mixed, hyperthermic, Aquic, Ustifluvets	Indo-GangeticTista Plain, Recent alluvial plain	40-50m above MSL	AP, AB, 2C1, 2C2, 2C2,	Gently sloping (1-3%), Imperfect Drained and rapid permeable; Land Capability Sub-class: VIs; Irritability: 4d; Productivity potential: Low
Rajpur	Extensive part in Koch Bihar Sadar	Fine-Loamy, mixed, hyperthermic, Aeric, Endoaquaepts	Indo-GangeticTista Plain, Recent alluvial plain	40-50m above MSL	AP, Bw1, Bw2, Bw3, Bw4	Level to nearly level sloping (0-1%), Imperfectly drained, and moderate to slow permeable ; Land Capability Sub-class: IIIs; Irritability: 2S; Productivity potential: Low to Medium
Balarampur	Tufanganj	Fine-Silty, mixed, hyperthermic, Typic, Fluvaquents	Indo-GangeticTista Plain, Recent alluvial plain	60-70 m above MSL	AP, AC, C1, C2, C3, 2C4,2C5	Level to nearly level sloping (0-1%), Imperfectly drained, and moderate permeable ; Land Capability Sub-class: IIw; Irritability: 2d; Productivity potential: High

Source: NBSS & LUP, 2001 Publication No-89

2.5: Socio-Economic Background:

The Socio-cultural setting of the area under study has been discussed under demographic characteristics, ethnic and economic composition.

2.5.1: Demographic Characteristics:

The 2011 census points out that in terms of the population size, Koch Bihar district stands 17th in the state. With a total area of 3387 sq km, this district accommodates 3.08% of the state's total population and ranks 11th among other districts of West Bengal in respect to population density, indicating that the pressure of the population on the land is moderately high. As per census 2011, Koch Bihar's total population was 2.819,086, which shows a 13.8% in decennial growth rate (Table-2.9). In pre-independence period, the population of this area registered a negative growth due to several occurrences of epidemics. Since 1951, an unprecedented rate of growth was recorded mainly due to a huge influx of immigrants from Bangladesh. Although from 1991 onwards growth rate has started declining. The table Table 2.9 presents the nature of population growth in Koch Bihar district.

Table 2.9: Population Growth of Koch Bihar District

Year	Population Koch Bihar	Decadal Growth (%)	Population WB	% to state's total Population	Rural Population	% to district's total	Urban Population	% to district's total
1901	565116	---	1,69,40,088	3.34	5,51,056	97.51	14,060	2.49
1911	591012	4.58	1,79,98,769	3.28	5,75,218	97.33	15,794	2.67
1921	590599	-0.07	1,74,74,348	3.38	5,73,338	97.08	17,261	2.92
1931	589053	-0.26	1,88,97,036	3.12	5,71,023	96.94	18,030	3.06
1941	638703	8.43	2,32,29,552	2.75	6,11,882	95.80	26,821	4.20
1951	668949	4.74	2,62,99,980	2.54	6,18,769	92.50	50,180	7.50
1961	1019806	52.45	3,49,26,279	2.92	9,48,360	92.99	71,446	7.01
1971	1414183	38.67	4,43,12,011	3.19	13,17,531	93.17	96,652	6.83
1981	1771643	25.28	5,45,80,647	3.25	16,49,383	93.10	1,22,260	6.90
1991	2171145	22.55	6,80,77,965	3.19	20,01,648	92.19	1,69,497	7.81
2001	2479155	14.19	8,01,76,197	3.09	22,53,537	90.90	2,25,618	9.10
2011	2819086	13.71	91276115	3.09	25,29,652	89.73	2,89,434	10.27
					Average	94.10	Average	5.90

Source: District Census Hand Book

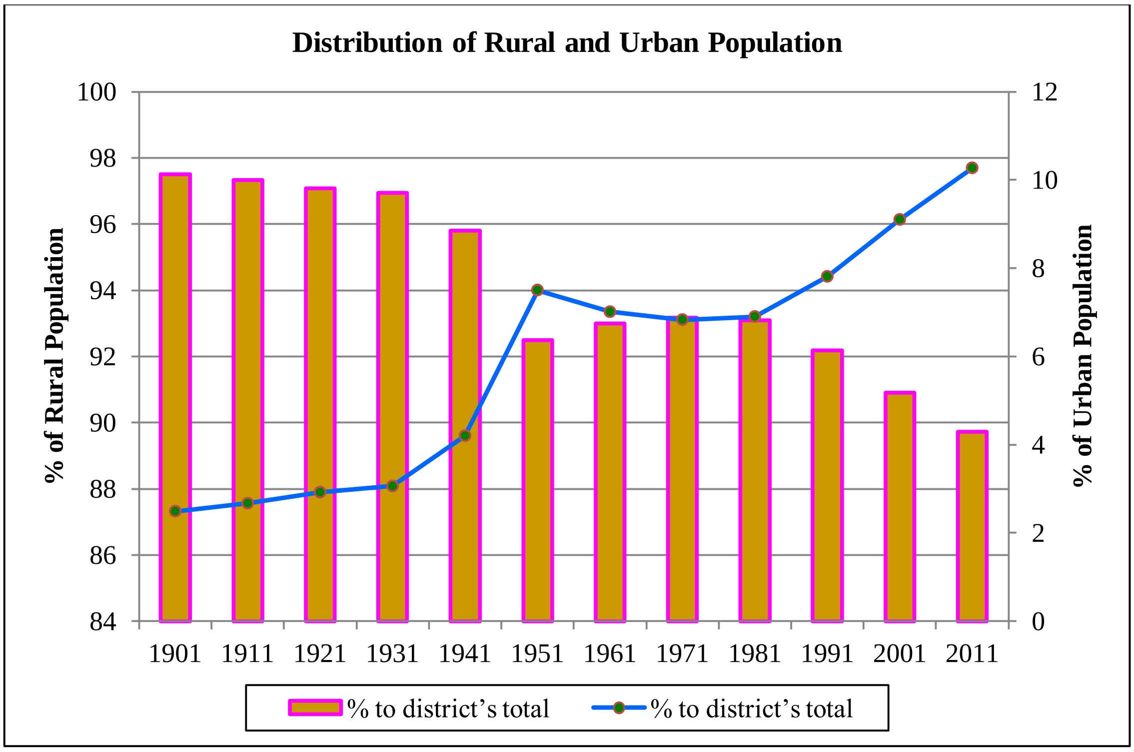


Fig 2.5: Distribution of Rural and Urban Population

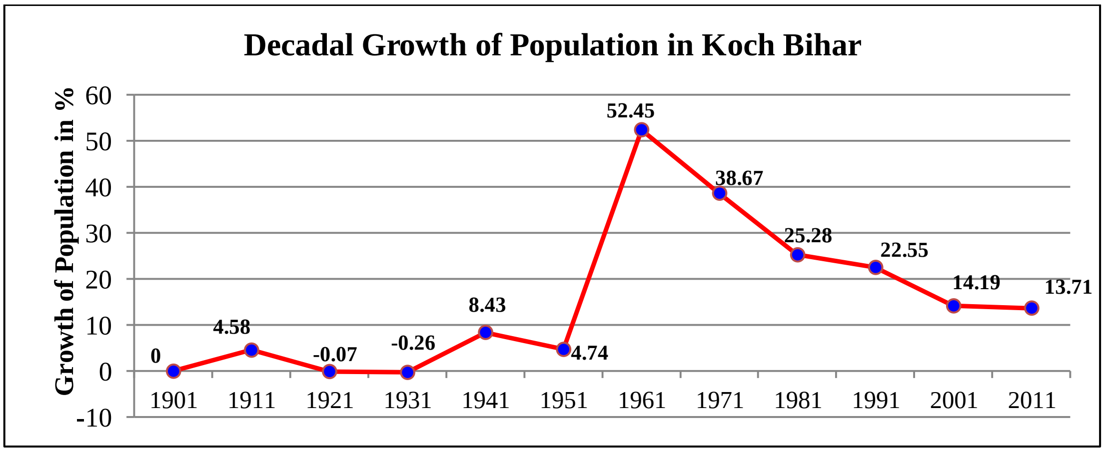


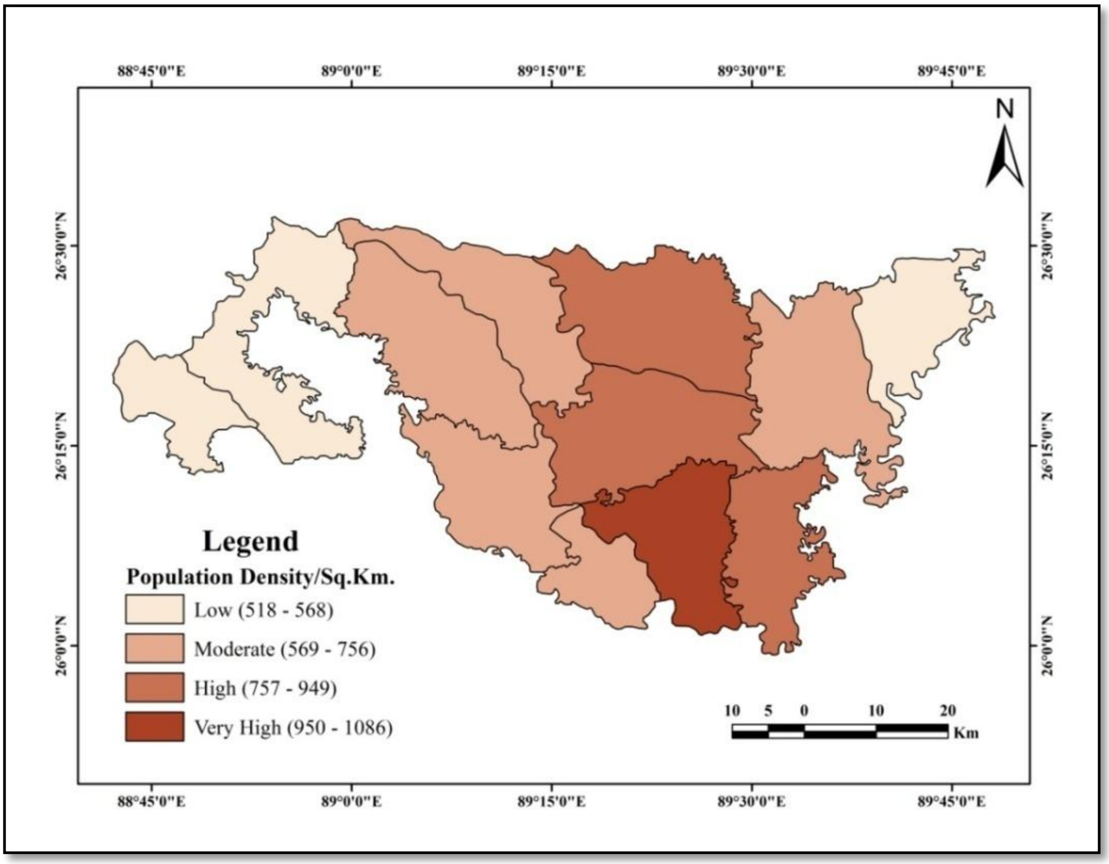
Fig 2.6: Decadal Growth of Population in Koch Bihar

This district is predominantly rural in nature. The avearage share of the rural population is 94.10% and the average urban population is 5.90%. As per 2011 census, 89.73 % population of Koch Bihar districts lives in rural areas. Out of 2,529,652 rural populations, the number of males and females are 1,304,916 and 1,224,736 respectively. In rural areas of Koch Bihar district, sex ratio is 939 females per 1000 males. The child sex ratio of Koch Bihar district is 949 girls per 1000 boys. Child population in the age 0-6 is 319,225 in rural areas of which males are 163,815 and 155,410 are females. The child population comprises 12.55 % of the total rural population of Koch Bihar district. From the year 1901, there is an increasing urbanization trend with the highest growth rate observed during 2001-2011. Gradually increasing urban population and the number of census towns from 2001 to 2011 (Fig- 2.6) give a clear indication of rapid urbanization trend though the growth rate is slower than the other districts of West Bengal.

The Average Sex ratio of the district was 942 females/ 1000males whereas in West Bengal it was 950. The sex ratio has increased steadily after 1951 which may be considered as the most significant demographic change. Table 2.10 shows that Sitai block has the highest sex ratio (970) followed by Sitalkuchi (966). The Lowest Sex Ratio is observed in Dinhata-I Block (840). The average density of population in the district was 748 persons/sq.km (Table-2.10) whereas during 2011 census the average density of population in the West Bengal state was 1028 persons/sq km. The highest density was observed in Dinhata-I (1086) (Map- 2.7).

Table 2.10: Block Wise Population of Koch Bihar District (2011)

Name of the Block	Area Sq Km	Male	Female	Sex Ratio	Total	Density km/sq km
Koch Bihar – I	375.32	1,68,185	1,58,373	942	3,26,558	870
Koch Bihar – II	362.36	1,79,591	1,64,310	915	3,43,901	949
Dinhata – I	250.00	1,47,602	123935	840	2,71,537	1086
Dinhata – II	293.11	1,26,663	1,17,403	927	2,44,066	833
Haldibari	200.70	52,851	51,118	967	1,03,969	518
Mathabhanga - I	312.96	1,12,497	1,05,694	940	2,18,191	697
Mathabhanga - II	313.84	1,17,100	1,10,297	942	2,27,397	725
Mekhliganj	292.42	80,052	75,198	939	1,55,250	531
Sitai	151.25	56,016	54,317	970	1,10,333	729
Sitalkuchi	261.60	94,277	91,076	966	1,85,353	709
Tufanganj – I	328.62	1,28,415	1,20,180	936	2,48,595	756
Tufanganj – II	328.62	96,222	90,504	941	1,86,726	568
Source: District Census Hand Book, Koch Bihar, 2011			Average	942	Average	748
			WB	950	WB	1028



Map-2.7: Population Density Map of Koch Bihar, 2011

2.5.2. Literacy Status and Sex Composition:

This district is placed at the 10th position in terms of state's literacy level. It is presently 74.48% in 2011, which is 1.59% less than the state average. The low level of literacy indicates the backwardness of the district. The male-female literacy level also shows great variation; the male being much lower than the female.

Table 2.11: Sex Ratio and Literacy Rate of Koch Bihar District

Year	Sex Ratio		Percentage of Literacy	
	Koch Bihar	West Bengal	Koch Bihar	West Bengal
1901	881	945	5.9	9.8
1911	873	925	7.4	10.8
1921	877	905	7.8	12.3
1931	886	890	6.6	12.4
1941	879	852	NA	19.7
1951	855	865	15.0	24.61
1961	890	878	21.00	34.46
1971	916	891	21.92	38.86
1981	935	911	30.10	48.65
1991	935	917	45.80	57.70
2001	949	933	66.30	68.64
2011	942	950	74.78	76.26

Source: District Census of India

But there has been a sharp 11.45% increase in the female literacy rate of 2001(Table-2.11), which again confirms the improvement in the status of the females. The following table shows the trend of sex ratio and a literacy rate of the district in the last six decades.

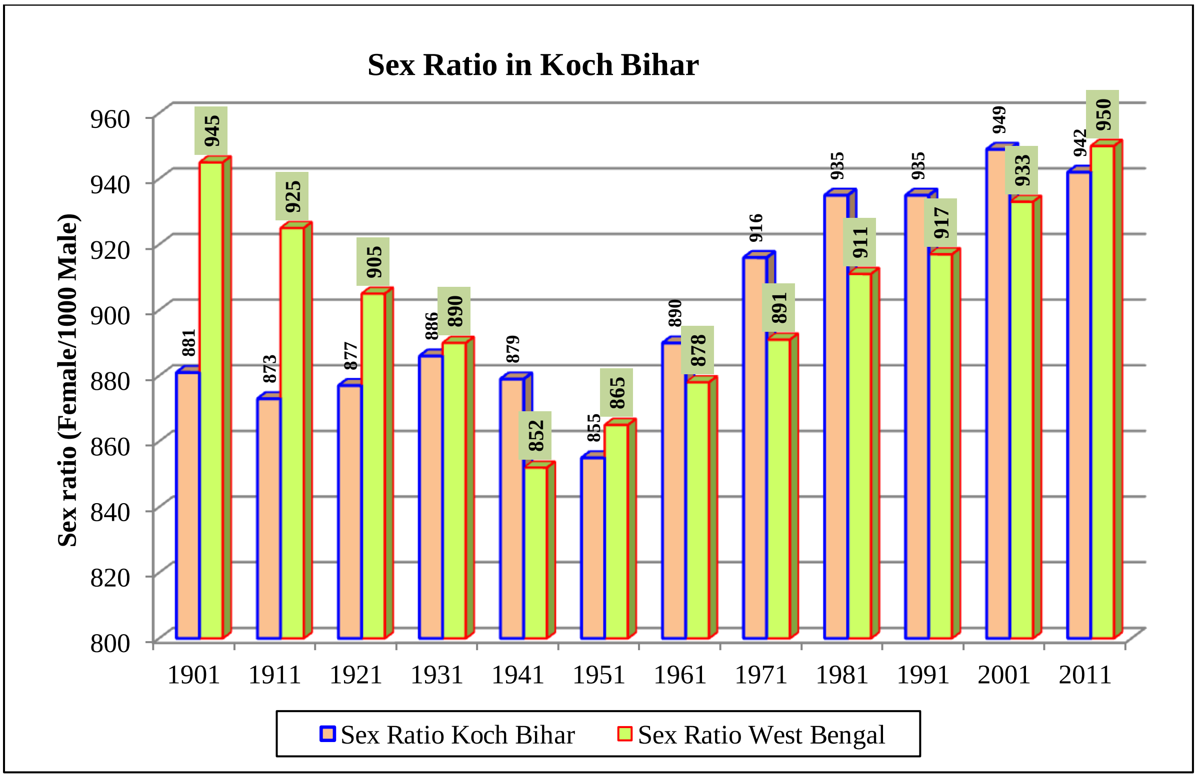


Fig 2.8: Sex Ratio in Koch Bihar

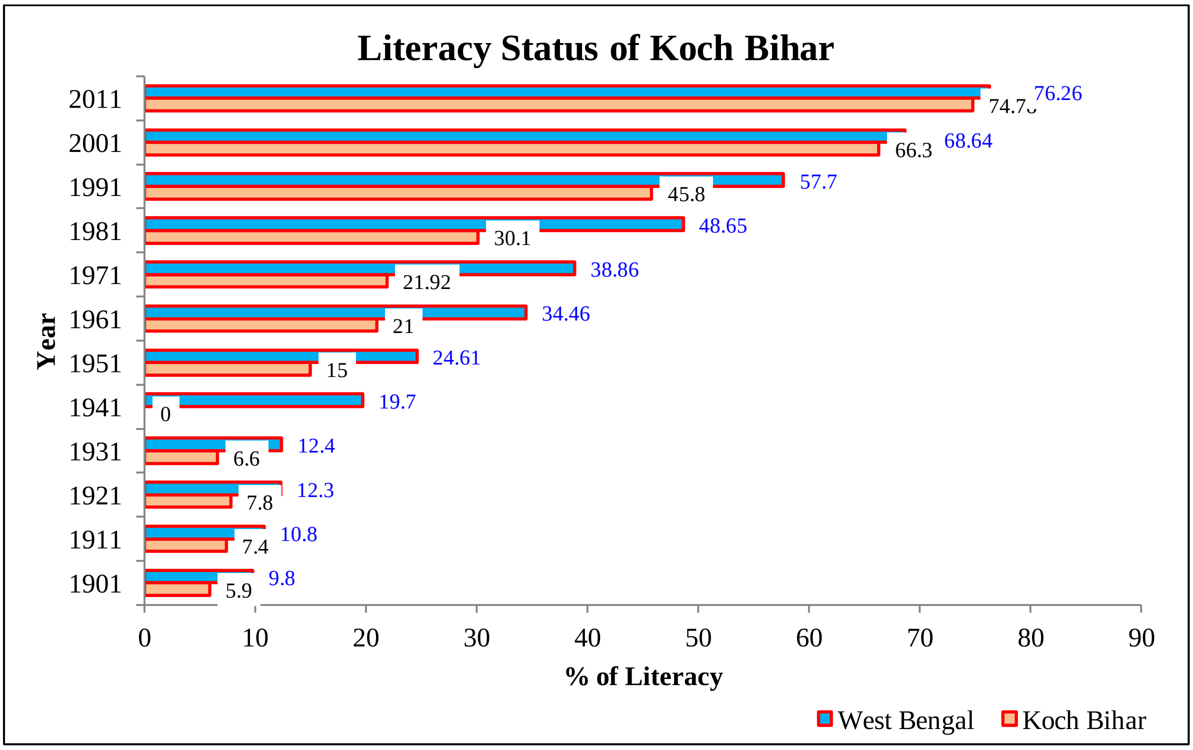


Fig 2.9: Literacy Status of Koch Bihar

2.5.3. Religion and Caste Composition:

About half of the total population (50.2%) belongs to the scheduled castes and a negligible portion belongs to the scheduled tribes (0.60%). This is caused due to the nature of the ethnic composition of the district. Koch Bihar district contains the largest number of SC population in West Bengal. The table shows that over the years there is a hike in SC population, while the ST population is decreasing. Rajbanshis – the single largest hinduised social group, followed by the Namasudras are the majority among scheduled caste population. The majority of the tribal population is constituted of Oraon, Rabha, Munda, Santal, Bedia and Garo. Muslims constitute the second largest (25.54% in 2011) religious group of population in the district (Table 2.12).

Table 2.12: Religion and Caste Composition

Year	SC	% to total	ST	% to total	Hindu	% to total	Muslim	% to total	Others	% to total
1981	883084	49.84	10105	.57	13,99,844	79.01	368176	20.78		
1991	1123719	51.76	13273	.60	1,659,733	76.44	506728	23.34	4684	.22
2001	1242374	50.11	14246	.54	187,1857	75.50	600911	24.24	5648	.23
2011	1,414,336	50.2	18,125	.60	2,087,766	74.06	720,033	25.54	7033	.27

Source: Census of India

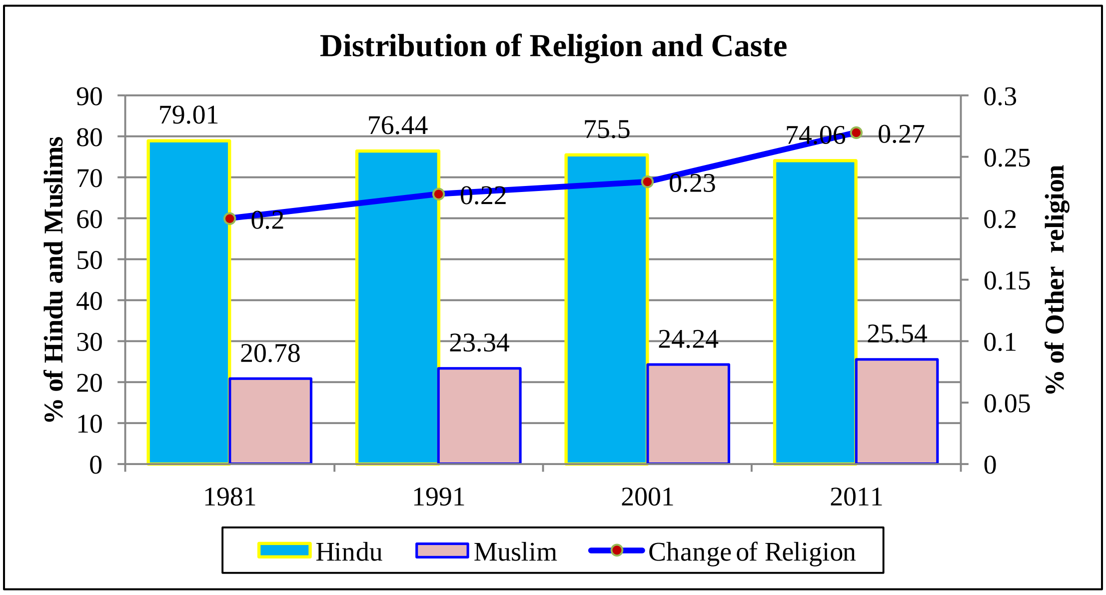


Fig 2.10: Distribution of Religion and Caste

2.5.4. Occupational Structure:

Occupational structure is defined as the distribution of working force among various sectors of economic activity. Working force is referred to the population engaged in various productive activities in an economy.

The percentages of male and female workers were 54.91% and 22.22 % with respect to the total male and female population in 2001 (Table-2.13). However, in 2011, the percentage of male workers increased to 58.24 % and the percentage of female workers declined to 20.67 % (Fig-2.11).

Table-2.13: Working Population

Place	Persons		Male		Female	
	2001	2011	2001	2011	2001	2011
Koch Bihar	2479155	2819086	1272094	1451542	1207061	1367544
Total Worker	966705	1127977	698550	845308	268155	282669
Percentage (%)	38.99	40.01	54.91	58.24	22.22	20.67
Tufanganj-I	223088	248595	113796	128415	109292	120180
Total Worker	76418	100657	60927	76376	15491	24281
Percentage (%)	34.25	40.49	53.54	59.48	14.17	20.2

Source: Census, 2001 and 2011

Table-2.14: Percentage of Population Distribution over Different Categories of Workers & Non-Workers in the District of Koch Bihar (As Per Census, 2011)

Name of the Block / Municipality	Total Population	[all figures in percentage (%) to respective Total Population]							
		Cultivators	Agricultural Labourers	Household Industrial Workers	Other Workers	Total Workers	Main Workers	Marginal Workers	Non-Workers
Koch Bihar-I	326558	27.9	32.37	5.44	34.34	41.21	30.96	10.25	58.79
Koch Bihar-II	343901	21.4	33.77	3.04	41.85	37.31	30.85	6.46	62.69
Koch Bihar (M)	77935	0.9	0.83	1.94	96.33	35.16	31.39	3.77	64.84
Koch Bihar Sadar	748394	22.4	30.01	4.04	43.51	38.79	30.96	7.83	61.21
Tufanganj-I	248595	24.7	34.95	9.94	30.42	40.49	31.19	9.31	59.51
Tufanganj-II	186726	28.7	33.82	5.77	31.72	39.77	29.5	10.26	60.23
Tufanganj (M)	20998	1.06	0.61	7.96	90.36	35.78	33.28	2.51	64.22
Tufanganj	456319	25.4	33.07	8.16	33.42	39.98	30.59	9.39	60.02
District Total	2819086	32.3	34.74	3.6	29.32	40.01	31.44	8.57	59.99

Source: Census of India, 2011, Note: Total Workers = Main Workers + Marginal Workers

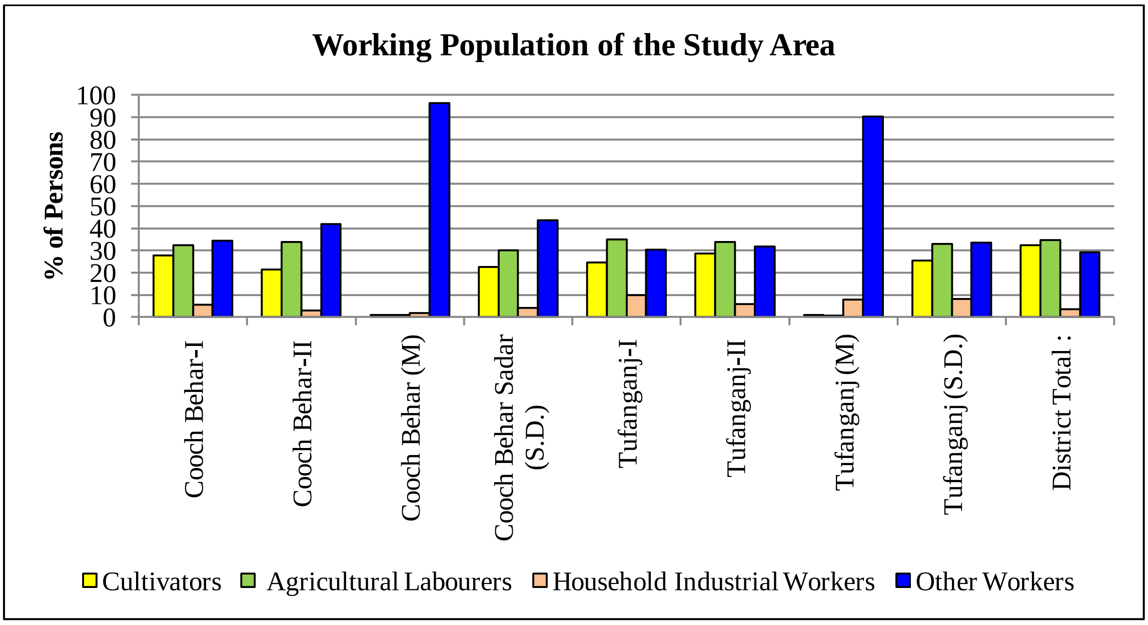


Fig 2.11: Working Population of the Study Area

The different categories of working population of the study area have been diagrammatically represented in Fig 2.11. The statistics on population composition of Koch Bihar district reveals that the percentage of workers (main and marginal) is only 31.44% and 8.57% (Census 2011), against a significant proportion of about 60% non- workers. Hence, the burden of the dependent population is high and which is also indicative of a limited scope for employment opportunities in the district. The occupational composition shows a large proportion of primary sector workers. About 77.18% of workers are cultivators and agricultural labourers, whereas only 3.8% of workers are engaged in household industries and 29.32% are engaged in other industrial and service sectors (Table-2.15) and Fig- 2.12.

Table 2.15: Percentages of Different Categories of Working Population in Koch Bihar

Category	1981	1991	2001	2011
A. Main Worker	28.99	30.56	30.4	31.44
1.Cultivators	15.03	14.72	37.4	32.34
2.Agri. Labourer	7.90	7.96	29.5	34.74
3.Household Industry	0.58	0.71	4.1	3.60
4. Other Workers	5.43	7.17	29.0	29.32
B. Marginal Worker	0.81	1.59	8.6	8.57
C. Non-Worker	70.20	67.85	61.0	59.99

Source: DCHB, Koch Bihar

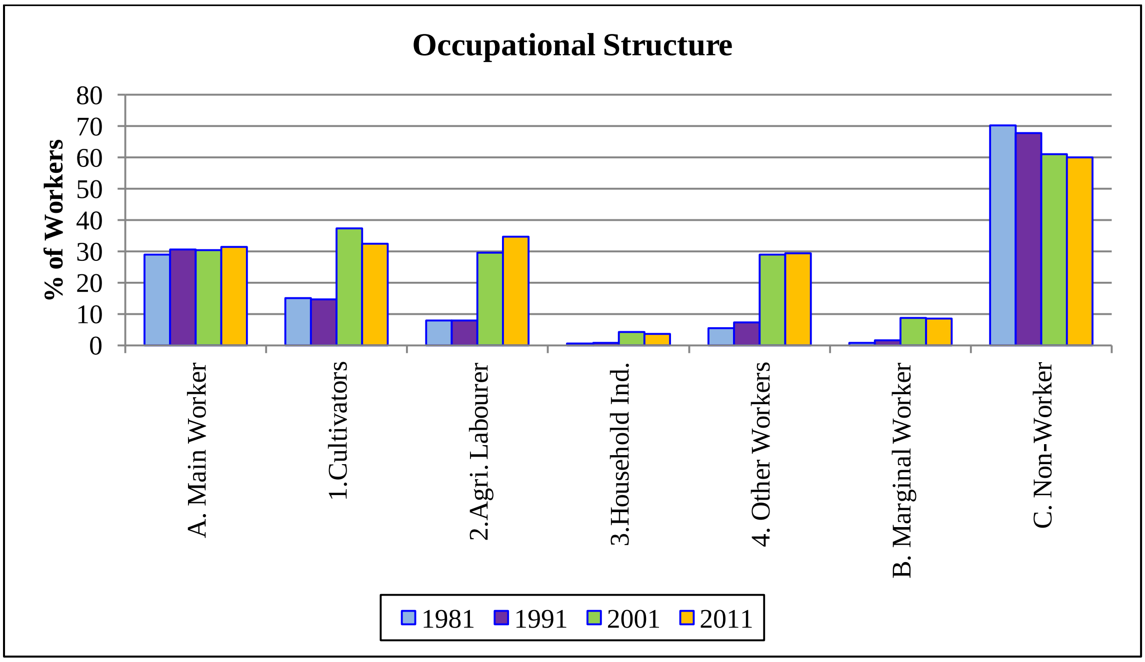


Fig 2.12: Occupational Structure

The fall in the number of cultivators, during the decade 2001-11 from 58.2% to 55% has been identified (Census, 2011). But the district witnessed a significant rise of cultivators during last 3 decades as against the national trend of declining number of cultivators. Simultaneously, the slight increase in the number of industrial workers indicates an expansion in industrial activities. Overall, the gradual rise in the proportion of industrial activities indicates a gradual sectoral shift in the economy of the district, though it still relies on farm-based activities leaving the identity of the district as rural in particular.

2.5.5. Infrastructural Facilities:

The role of infrastructure in the economic development of any area is immense. Hence an understanding of the study area in the light of the availability of infrastructural facilities is very crucial. Moreover, it also helps in determining the quality of life of the inhabitants, which could have an influence on health and sanitation of the people under study. The following table gives information on the distribution of educational institutions in Koch Bihar district.

Table 2.16: Distribution of Educational Facilities in Koch Bihar District (2011-12)

Schools	College	University	Technical school	Technical College	Technical University	Non- formal institutions
2180	15	1	28	14	1	4847

Source: District Census hand Book, 2011

The district provides primary level education in almost all the rural and urban areas, the number (210) in Koch Bihar II block. The number of secondary (101) and higher secondary schools (159) is less in terms of the total population of the district.

An analysis of the health care facilities available for the inhabitants of the district reveals that 400 bedded district hospital plays a focal role in the health care scenario. There are 4 sub-divisional hospitals in sub-divisional headquarters of Koch Bihar Sadar, Dinhata, Mekhliganj and Mathabhanga. The district is also endowed with a few special hospitals like Mental Hospital (1), TB hospital (1), Cancer hospital (1) and Leprosy hospital (1). The private nursing homes also operate within the district and are mainly located in the sub-divisional towns with maximum concentration in Koch Bihar Sadar area. In Koch Bihar district Ayurvedic and Homeopathic treatments are also very popular. The relative cheaper cost of medicine, age old practice and lack of side effects are the few reasons for wide scale preference for such treatment methods. The following table shows the distribution of medical institutions in (2011) Koch Bihar district.

Table 2.17: Categories of Medical Institution Available in Koch Bihar District (2011)

DH	H	RH	BPHC	PHC	FWC	SC	Blood Bank	N.H (reg.)	Urban FWC	Ayurvedic Shops	Homeo. Clinic and shops
1	4+4	1	12	38	33	406	3	15	3	15	21

Source: District Census hand Book, 2011

According to census report (2011), 89.93% of villages under Koch Bihar district avail medical facilities. The secondary level facilities are concentrated only in urban areas of Koch Bihar Sadar and other 3 sub-divisional blocks. The absence of tertiary level care implies lack of specialised medical facilities in the district. The total number of beds (2052) and that of doctors (278) in terms of the total population of the district indicate a gloomy health care scenario.

Table 2.18: Availability of Amenities in Villages (%) of Koch Bihar District (2011)

Total Villages	Drinking water	P.O.	Telephone	Power	Pucca Road	Transport
1132	99.03	24.20	86.84	100	49.47	32.42

Source: District Census Hand Book, 2011

Apart from educational and medical facilities, other amenities available within the district include safe drinking water, sanitation, power supply, transport and communication. From the table below, it can be concluded that in terms of power supply and access to safe drinking water facility, the villages under Koch Bihar district are well placed (with 100% power supply and near to 100% drinking water facility). The proportion of villages having telephone facility (86.84%) is also very high, however the villages lag far behind in enjoying the facilities of Post offices (24.20%), transport and communication (32.42%) and access to Pucca road (49.47%) (Table 2.18). Interestingly, the district is well connected with internet and mobile network services, which leaves a better prospect for introducing mobile health technology in health care services of the district.

2.5.6. Conclusion:

From the preceding discussion, it seems that the area under study has many advantages in terms of availability of fertile agricultural lands, rich natural and agricultural resources, developed agro-based industries and satellite connectivity. The district is also not at a disadvantage position in terms of literacy rate. Yet, according to West Bengal Human Development Report (2004), the district is placed at the lower rung (HDI 0.52; HDI rank 11th) in terms of human development index which indicates that the district is not favourably positioned on certain spheres of economy. The health care facility too in the district is inadequate to meet all needs of the people in the district. Moreover, lack of industries and poor transport connectivity indicates backwardness of the district, which demands governmental interventions for a better prospect.

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CHAPTER –III

CLASSIFICATION AND DISTRIBUTION OF WETLANDS

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CLASSIFICATION AND DISTRIBUTION OF WETLANDS

3.1. Definition of Wetland:

“Wetlands encompasses a wide array of “wetlands” also called marshes, bogs, swamps, fens, pocosins, and other names” (Tiner, 1999).Wetlands are neither truly aquatic nor terrestrial, generally depending on seasonal variability. Thus, wetlands reveal vast diversity according to their genesis, geographical location, water regime, dominant plants, animals and soil. Because of their transitional nature, the boundaries of wetlands are also difficult to delineate. Based on multifaceted observations and diverse objective and orientation, different individuals, institutions, agencies and countries have given different definitions for wetlands**.** Wetlands are defined differently by countries in their domestic legislations (MOEF, 2009). Most of the countries have given a narrow definition in order to limit the field and scope of wetland protection. There is a lot of controversy regarding the definition of a wetland not only in our country but also all over the world.

3.1.1. Definition of Wetland before Ramsar Convention:

One of the most well accepted early definitions of wetland was given by S.P. Shaw & C.G. Fredine (1956) who suggested the term Wetlands as ‘lowlands covered with shallow and sometimes temporary or intermittent waters.’ These are referred to by such names as marshes, swamps, bogs, wet meadows, potholes, sloughs, and river-overflow lands. Shallow lakes and ponds, usually with emergent vegetation as a conspicuous feature, are included in the definition, but the permanent waters of the streams, reservoirs and deep lakes are not included. Neither are water areas that are so temporary as to have little or no effect on the development of moist soil vegetation”

3.1.2. Definition of Wetland after Ramsar Convention:

The first World Convention on Wetlands was held on 2 February 1971 in Ramsar city, Iran. The Ramsar Convention took a broad approach in determining the wetlands which come under its mandate in Articles 1.1 and 2.1 as shown below:

3.1.2.1. Article-1.1:

Under the text of the Convention (Article1.1), wetlands are defined as an “ area of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water, the depth of which at low tide does not exceed six metres.”

3.1.2.2. Article-2.1:

In addition, to serve the purpose of protecting coherent sites, the Article 2.1 provides the wetlands as: “May incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands”.

3.1.2.3. Other Notable Definitions:

Space application centre (ISRO) defineswetlands as: “All submerged or water-saturated lands, natural or man-made, inland or coastal, permanent or temporary, static or dynamic, vegetated or non-vegetated, which necessarily have a land-water interface”.

The US Department of Interior Fish and Wildlife Service Authority adopted the following definition of Cowrdin in 1979 to prepare a status of wetlands in the USA: “Wetlands are lands, transitional between terrestrial and aquatic systems, where the water table is usually at or near the surface, or the land is covered by the shallow water”.

The notification of the Government of India in the Ministry of environment and Forest, S.O number 114 (E) dated 19th February, 1991 described that, wetland is an area or of marsh, fen, peat land or water; natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters and includes all inland waters such as lakes, reservoir, tanks, backwaters, lagoon, creeks, estuaries and manmade wetland and zone of direct influence on wetlands that is to say the drainage area or catchment region of the wetlands as determined by the authority but does not include main river channels, paddy fields and the coastal wetland.”

The Kerala Conservation of Paddy Land and Wetland Act, 2008 (Section 2(XVII) defines wetland as: “… land lying between terrestrial and aquatic systems, where the water table is usually at or near the surface or which is covered by shallow water or characterized by the presence of sluggishly moving or standing water, saturating the soil with water and includes backwaters, estuary, fens, lagoons, mangroves, marshes, salt marshes and swamp forests but does not include paddy lands and rivers".

Shaler (1890), who defined it in a report, gave one of the earliest definitions of wetland in his article "General Account of the Freshwater Morasses of the United States" as "all areas… in which the natural declivity is insufficient, when the forest cover is removed, to reduce the soil to the measure of dryness necessary for agriculture. Wherever any unprofitable until the land is necessary to secure this desiccation, the area is classified as swamp".

"…… areas of seasonally, intermittently, or permanently waterlogged soils or inundated land, whether natural or artificial, fresh or saline, e.g., waterlogged soils, ponds, billabongs, lakes, swamps, tidal flats, estuaries, rivers and their tributaries." (Semeniuk, 1995).

Wetlands form the transitional zone between land and water, where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in and on it (Cowardin et al, 1979).

Wetlands are "land permanently or temporarily underwater or waterlogged. Temporary wetlands must have surface water or waterlogging of sufficient frequency and/or duration to affect the biota. Thus the occurrence, at least sometimes, of hydrophytic vegetation or use by water birds is necessary attributes. This wide definition includes some areas, whose wetland nature is arguably, notably land subject to inundation but having little or no hydrophytic vegetation and bare 'dry lakes' in the arid interior" (Paijmans et al, 1985).

"A wetland is an ecosystem that depends on constant or recurrent, shallow inundation, or saturation at or near the surface of the substrate. The minimum essential characteristics of a wetland are recurrent, sustained inundation, or saturation at or near the surface and the presence of physical, chemical, and biological features reflective or recurrent, sustained inundation or saturation. Common diagnostic features of wetlands are hydric soils and hydrophytic vegetation. These features will be present except where specific physiochemical, biotic or anthropogenic factors have removed them or prevented their development" (NRC, 1995).

3.2. Classification of Wetland:

3.2.1. Ramsar Classification of Wetland:

The wetland types scheduled under, are from the "The Ramsar Classification System for Wetland Type" as accepted by Recommendation 4.7 and amended by Resolutions VI.5 and VII.11 of the 1990 Conference of the Contracting Parties. The categories scheduled herein are proposed to provide only a very broad framework to aid rapid identification of the main wetland habitats represented at each site. The Ramsar Convention developed a new and more widespread wetland classification system (adopted in 1990 and modified in 1996) (Table-3.1).

Table3.1:Ramsar Classification System for Wetland Type

Code	Marine/Coastal Wetlands
A	Permanent shallow marine waters; in most cases, less than six metres deep at low tide; including sea bays and straits
B	Marines btidal aquatic beds; including kelp beds, sea-grass beds, and tropical marine meadows.
C	Coral reefs.
D	Rocky marine shores; including rocky offshore islands, sea cliffs.
E	Sand, shingle or pebble shores; including sand bars, spits and sandy islets; dune systems and humid dune slacks.
F	Estuarine waters; permanent water of estuaries and estuarine systems of deltas.
G	Intertidal mud, sand or salt flats.
H	Intertidal marshes; including salt marshes, salt meadows, saltings, raised salt marshes; tidal brackish and freshwater marshes.
I	Intertidal forested wetlands; including mangrove swamps, nipah swamps and tidal freshwater swamp forests.
J	Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea.
K	Coastal freshwater lagoons; including freshwater delta lagoons.
Zk(a)	Karst and other subterranean hydrological systems, marine/coastal
	Inland Wetlands
L	Permanent inland deltas.
M	Permanent rivers/streams/creeks; including waterfalls.
N	Seasonal/intermittent/irregular rivers/streams/creeks.
O	Permanent freshwater lakes (over 8 ha); including large oxbow lakes.
P	Seasonal/intermittent freshwater lakes (over 8 ha); including floodplain lakes.
Q	Permanent saline/brackish/alkaline lakes.

R	Seasonal/intermittent saline/brackish/alkaline lakes and flats.
Sp	Permanent saline/brackish/alkaline marshes/pools.
Ss	Seasonal/intermittent saline/brackish/alkaline marshes/pools.
Tp	Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.
Ts	Seasonal/intermittent freshwater marshes/pools on inorganic soils; including sloughs, potholes, seasonally flooded meadows and sedge marshes.
U	Non-forested peatlands; including shrub or open bogs, swamps and fens.
Va	Alpine wetlands; including alpine meadows, temporary waters from snowmelt.
Vt	Tundra wetlands; including tundra pools, temporary waters from snowmelt.
W	Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.
Xf	Freshwater, tree-dominated wetlands; including freshwater swamp forests, seasonally flooded forests and wooded swamps on inorganic soils.
Xp	Forested peat lands; peatswamp forests.
Y	Freshwater springs; oases.
Zg	Geothermal wetlands
Zk(b)	Karst and other subterranean hydrological systems, inland
Note: “Floodplain" is a broad term used to refer to one or more wetland types, which may include examples from the R, Ss, Ts, W, Xf, XP, or other wetland types. Some examples of floodplain wetlands are seasonally inundated grassland (including natural wet meadows), shrublands, woodlands and forests. Floodplain wetlands are not listed as a specific wetland type herein.	
	Human-made wetlands
1	Aquaculture (e.g., fish/shrimp) ponds
2	Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).
3	Irrigated land; includes irrigation channels and rice fields.
4	Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture).
5	Salt exploitation sites; salt pans, saline’s, etc.
6	Water storage areas; reservoirs/barrages/dams/impoundments (generally over 8 ha).
7	Excavations; gravel/brick/clay pits; borrow pits, mining pools.
8	Wastewater treatment areas; sewage farms, settling ponds, oxidation basins, etc.
9	Canals and drainage channels, ditches.
Zk(c)	Karst and other subterranean hydrological systems, human-made

3.2.2. Indian Classification of Wetland:

Wetlands in India are distributed in different geographical regions ranging from the Himalayas to Deccan plateau. The variability in climatic conditions and changing topography is responsible for significant diversity.

3.2.2.1. Well-Known Classification:

National Wetland Atlas (1997) classified Indian wetlands into different types based on their origin, vegetation, nutrient status, thermal characteristics, like:

a. **Glaciatic Wetlands** [e.g., Tsomoriri in Jammu and Kashmir, Chander tal in Himachal Pradesh].
b. **Tectonic Wetlands** [e.g., Nilnag in Jammu and Kashmir, Khajjiar in Himachal Pradesh, and Nainital and Bhimtal in Uttaranchal].
c. **Oxbow Wetlands** [e.g., Dal Lake, Wular Lake in Jammu and Kashmir and Loktak Lake in Manipur and some of the wetlands in the river plains of Brahmaputra and Indo-Gangetic region. Deepor Beel in Assam, Kabar in Bihar, Surahtal in Uttar Pradesh]
d. **Lagoons** [e.g., Chilika in Odisha /Orissa]
e. **Crater Wetlands** [Lonar lake in Maharashtra]
f. **Salt Water Wetlands** [e.g., *Pangong Tso*in Jammu & Kashmir; *Sambhar*in Rajasthan]
g. **Urban Wetlands** [e.g.,*Dal Lake* in J &K; *Nainital* in Uttaranchal; *Bhoj* in Madhya Pradesh]
h. **Ponds/Tanks, Man-Made Wetlands** [e.g.,*Harike*in Punjab; *Pong Dam* in Himachal Pradesh]
i. **Reservoirs** [e.g., *Idukki*, *Hirakud dam, Bhakra-Nangal dam*)
j. **Mangroves** [e.g., *Bhitarkanika* in Odisha]
k. **Coral Reefs** [e.g., *Lakshadweep*]
l. **Creeks** [*Thane Creek* in Maharashtra)**,** sea grasses, estuaries, thermal springsare some other kinds of wetlands in the country.

3.2.2.2. Modified National Wetland Classification System:

The Indian Space Research Organisation (2011) has classified Indian wetlands according to the latest information based on satellite imagery, which named as Modified National Wetland Classification System. ThisModified National Wetland Classification System for wetland delineation and mapping comprising 19 wetland classes, which are organized under a Level III hierarchical system (Table-3.2). Level one has two classes: inland and coastal, these are further bifurcated into two categories as natural and man-made under which the 19 wetland classes are suitably placed.

Table3.2:Modified National Wetland Classification System

Wettcode*	Level I	Level II	Level III
1000	Inland Wetlands		
1100		Natural	
1101			Lakes
1102			Ox-Bow Lakes/ Cut-Off Meanders
1103			High altitude Wetlands
1104			Riverine Wetlands
1105			Waterlogged
1106			River/stream
1200		Man-made	
1201			Reservoirs/ Barrages
1202			Tanks/Ponds
1203			Waterlogged
1204			Salt pans
2000	Coastal Wetlands		
2100		Natural	
2101			Lagoons
2102			Creeks
2103			Sand/Beach
2104			Intertidal mud flats
2105			Salt Marsh
2106			Mangroves
2107			Coral Reefs
2200		Man-made	
2201			Salt pans
2202			Aquaculture Ponds

Source: National Wetland Atlas, West Bengal, 2010 * Wetland type code

Table 3.3: Definitions of Wetland Categories Used by Indian Space Research Organization (ISRO)

Wetland Type Code	Definition and Description
1000	**Inland Wetlands**
1100	**Natural**
1101	**Lakes:** Large bodies of standing water occupying distinct basins (Reid et al, 1976). These wetlands occur in natural depressions and are normally fed by streams/rivers.
1102	**Ox-bow lakes/ Cut off meanders:** When a meandering stream erodes the outer shores of its broad bends to the extent that the loops widen and is cut-off from the main stream of the river creating shallow crescent-shaped lakes are called oxbow lakes (Reid et al, 1976).
1103	**High Altitude lakes:** These lakes occur in the Himalayan region. Landscapes around high lakes are characterized by hilly topography (3000 m above MSL).All lakes above this contour line will be classified as high altitude lakes.
1104	**Riverine Wetlands:** Especially in the plains, water accumulates in the adjacent areas along the major rivers, leading to the formation of marshes or swamps. In some areas, reed grass-dominated wetlands are also called swamps. (Mitsch and Gosselink, 1986).
1105	**Waterlogged:** An area in which water stands near, at, or above the land surface, so that the roots of all plants except the hydrophytes are drowned, leading to the death of those plants is said to be waterlogged (Margarate et al, 1974). However, during the dryseason, the majority of such areas dries up and gives the appearance of mud/salt flats (grey-bluish).
1106	**River/stream:** Rivers are linear water features of the landscape. Rivers that are wider than the mapping unit will be mapped as polygons. Its importance arises from the fact that many stretches of the rivers in Indo-Gangetic Plains and peninsular India are declared important national and international wetlands.
1200	**Man-made**
1201	**Reservoir:** A pond or lake built to mitigate the storage of water, usually by the construction of a dam across a river (Margarate et al, 1974).
1202	**Tanks/Ponds:** Ponds Generally, suggest a small, quiet body of standing water, usually shallow enough to permit the growth of rooted plants from one shore to another (Reid et al, 1976). These ponds can be of any shape and size.
1203	**Waterlogged:** Man-made activities like construction of unlined canals cause waterlogging in adjacent areas due to seepage.
1204	Salt pans: Inland salt pans in India occur in Rajasthan (Sambhar lake). These are shallow rectangular man-made depressions in which saline water is accumulated for drying in the sun for making salt.
2000	**Coastal Wetlands**
2100	Natural

2101	**Lagoons/Backwaters:** coastal bodies of water, partly separated from the sea by barrier beaches or bass of marine origin, are termed as lagoons. As a rule, lagoons are elongated and lie parallel to the shoreline.
2102	**Creek:** A notable physiographic feature of salt marshes, especially low marshes. These creeks develop as do rivers "with minor irregularities sooner or later causing the water to be deflected into definite channels" (Mitsch and Gosselink, 1986). Creeks will be delineated; however, their area will not be estimated.
2103	**Sand/Beach:** Beach is a non-vegetated part of the shoreline formed of a loose material, usually sand that extends from the upper berm.
2104	**Intertidal mudflats:** Most of the non-vegetated areas that are alternately exposed and inundated by the falling and rising of the tide.(Clark, 1977).
2105	**Salt Marsh:** Natural or semi-natural halophytic grassland and dwarf brushwood on the alluvial sediments bordering saline water bodies whose water level fluctuates either tidally or non-tidally (Mitsch and Gosselink, 1986).
2106	**Mangroves:** The mangrove swamp is an association of halophytic trees, shrubs, and other plants growing in brackish to saline tidal waters of tropical and sub-tropical coastlines (Mitsch and Gosselink, 1986).
2107	**Coral reefs:** Consolidated living colonies of microscopic organisms found in warm tropical waters. The term coral reef or organic reef is applied to the rock- like reefs built-up of living things, principally corals.
2200	Man-made
2201	**Salt pans:** An undrained usually small and shallow rectangular, man-made depression or hollow in which saline water accumulates and evaporates leaving a salt deposit (Margarate et al, 1974).
2202	**Aquaculture ponds:** Aquaculture is defined as "The breeding and rearing of fresh-water or marine fish in captivity.

Source: National Wetland Atlas, West Bengal, 2010

3.2.3. Classification of Wetland in the Study Area:

The classification of wetlands is very difficult due to its unique character. The study area has numerous wetlands of diverse variety. The researcher has tried to classify the wetlands of the study area based on Modified National Wetland Classification system and is also modified by the researcher based on field survey.

3.2.3.1. Natural Wetland:

The wetlands which are originated by the natural processes categorized as natural wetland. This natural wetland are also sub-divided into following three types-

3.2.3.1.1. River/ Stream:

All type of natural perennial and non-perennial rivers are included in these type. Among all the wetland types, river/stream occupies 4982ha area (63.08 %).

3.2.3.1.2. Oxbow lake:

Oxbow is a horseshoe-shaped or crescent-shaped small lakeformed by an abandoned meander loop of a meandering river. Among all the wetland types oxbow lake covers 146 ha area (18.55 %). In the study area, 74 oxbow lakes are identified.

3.2.3.1.3. Riverine Wetland:

A hydro geomorphic class of wetlands found in floodplains and riparian zones associated with a stream or river channel. Among all the wetland types Riverine wetlands occupy483haarea (6.12 %). There are 89 riverine wetlands in the study area.

3.2.3.2. Quasi-Natural Wetland:

The wetlands which are originated by the natural processes and whose physical appearances have changed by 50% or more by anthropogenic activities such as separation of wetlands into small parts or ponds are categorized as Quasi-natural wetland. This Quasi-natural wetland are also sub-divided into following two types-

3.2.3.2.1. Quasi-Natural Oxbow Lake:

The oxbows whose physical appearances have changed by 50% or more by anthropogenic activities such as division of an oxbow lake into small parts or ponds are categorized in this type. Among all the wetland types Quasi-natural Oxbow Lake occupies 432ha area (5.47 %). In the study area, 37 Quasi-natural oxbow lakes are identified.

3.2.3.2.2. Quasi-Natural Riverine Wetland:

The Riverine wetlands, which are physically modified by 50% or more by anthropogenic activities such as division of Riverine lakes into smaller parts or ponds, are categorized in this type. Among all the wetland types river/stream occupy 165 ha area (2.09 %). There are 25 riverine wetlands in the study area.

3.2.3.3. Man Made Wetland:

The wetlands, which are originated by the anthropogenic activities, categorized as Man Made wetland. This Man Made wetland are also sub-divided into following two types-

3.2.3.3.1. Brick/Clay/Sand Pit:

A wetland formed because of soil excavation by the brick kiln industry, which is further dug for sand mining are categorized in this type. Among all the wetland types Brick/Clay/sand pit occupy 103 ha area (1.3%). In the study area, 24 Brick/Clay/sand pit oxbow lake is identified.

3.2.3.3.2.. Pond/ Tanks:

It is a purely mane made wetland. The ponds were dug for fishing, bathing, drinking water, beautification etc. Among all the wetland types pond occupy 268 ha area (3.39 %). There are 237 important ponds in the study area.

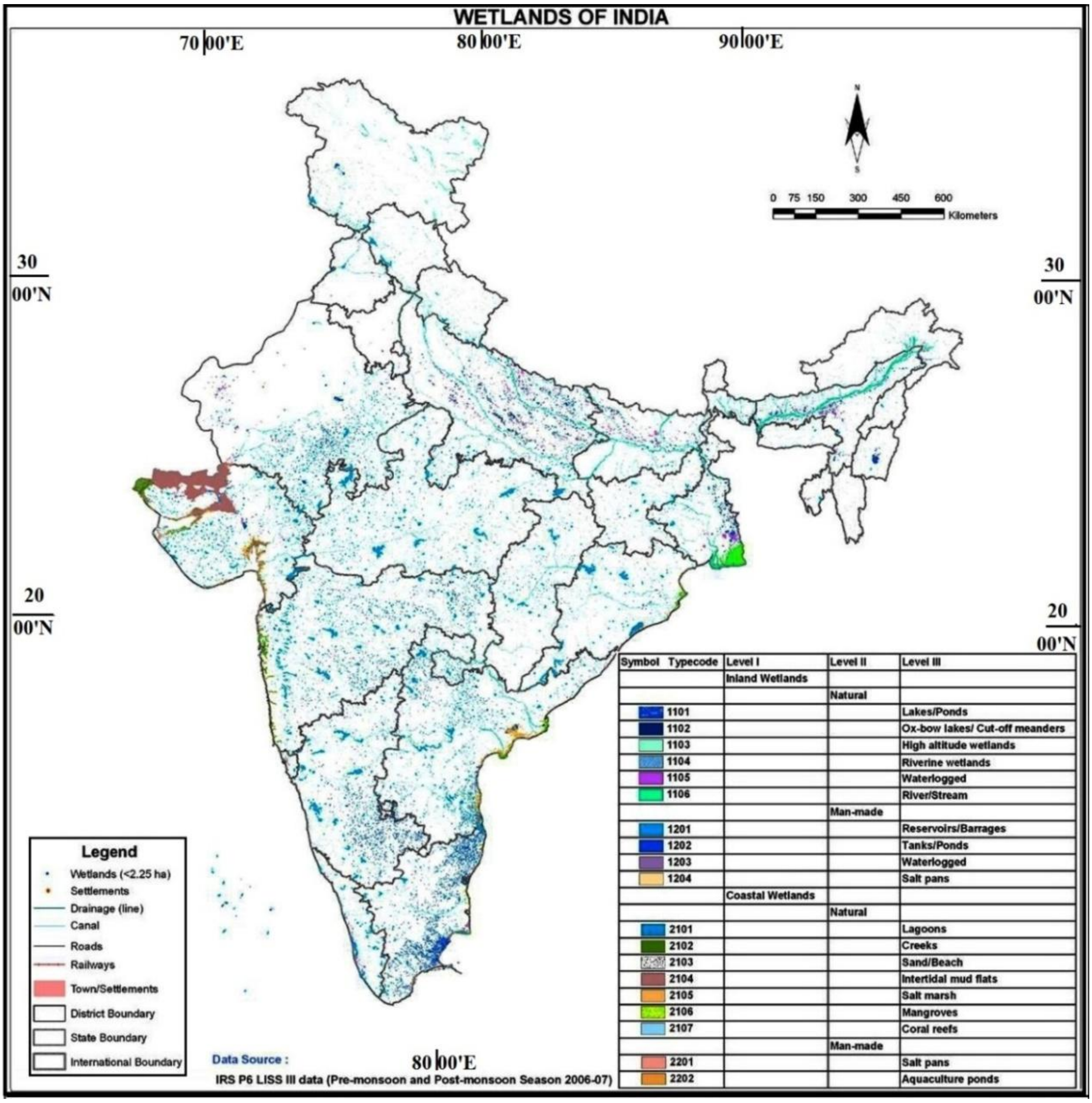
3.3. Distribution of Wetland:

3.3.1. World Distribution of Ramsar Site:

Wetlands are distributed throughout the world from tropics to the temperate zone and from plains to the glacial mountains (Chowdhury, 2009). According to Ramsar convention the highest percentage i.e., around 53% of global Ramsar sites are located in different countries of Europe followed by Asia (13%) and Africa (13%) whereas, lowest percentage is recorded nice-covered Oceania (5%). The World Conservation Monitoring Centre has estimated that about 5.7 million square kilometres i.e., roughly 6% of the earth's land surface is wetland (WCMC, *Global Biodiversity*, 1992). of this, only 2.53% belongs to freshwater wetlands and the remaining are salt water wetlands. Out of total global wetlands, 30% are bogs, 26% fens, 20% swamps and about 15% flood plains etc. (IUCN, 1999).

3.3.2. Wetland Distribution in India:

India has a rich wetland ecosystem which is distributed across various eco-geographical regions that range from the Himalayas to the Deccan plateau. Varied topography, soil and climatic regimes support and sustain diverse and unique wetland habitats in our country. Majority of the inland wetlands are directly or indirectly dependent on the major rivers systems like Ganga, Bhramaputra, Narmada, Godavari, Krishna, Kaveri, Tapti (Prasad *etal*, 2002). According to the National Wetland Atlas (ISRO), India has 757060 wetlands in total, of which 188470 are inland wetlands, 13033 are coastal wetlands and 555557 are small (<2.25 ha) wetlands (Table 3.4).



Map 3.1: Types of Wetland in India, 2011

3.3.2.1. Type-Wise Distribution of Wetlandin India:

The major wetland types in the inland category are river/stream, reservoir/barrage, tank/pond and lake/pond. In the category of costal wetlands, major types are inter-tidal mudflat, mangrove, aquaculture pond and lagoon. Type-wise area estimates are shown in Table 3.4 Among the wetland types, river/stream occupies 5.26 million hector (mha) area (34.46%),followed by reservoirs 2.48 mha (16.26%), inter-tidal mud flats2.41 mha (15.82%), tanks/ponds 1.31 mha area (8.6%) and lakes/ponds 0.73 mha area(4.78%). As far as wetland units are concerned tanks are maximum in number (122370). However, the small wetlands (< 2.25 ha) accounts for about 3.64 per cent (0.56 mha) assuming that each is of one ha (Table 3.4 & Map 3.1).

Table 3.4: Type-Wise Area Estimates of Wetlands in India (Area in Ha)

Sr. No.	Wetland code	Wetland Category	Number of wetlands	Total wetland area	% of wetland area	Open Water	
						Post-monsoon area	Pre-monsoon area
	1100	Inland Wetlands - Natural					
1	1101	Lake/Pond	11740	729532	4.78	454416	198054
2	1102	Ox-bow lake/Cut-off meander	4673	104124	0.68	57576	37818
3	1103	High altitude wetland	2707	124253	0.81	116615	109277
4	1104	Riverine wetland	2834	91682	0.60	48918	29739
5	1105	Waterlogged	11957	315091	2.06	197003	112631
6	1106	River/Stream	11747	5258385	34.46	3226238	2628182
	1200	Inland Wetlands -Man-made					
7	1201	Reservoir/Barrage	14894	2481987	16.26	2260574	1268237
8	1202	Tank/Pond	122370	1310443	8.59	916020	349512
9	1203	Waterlogged	5488	135704	0.89	85715	33822
10	1204	Salt pan	60	13698	0.09	5293	2599
		Total - Inland	188470	10564899	69.23	7368368	4769871
	2100	Coastal Wetlands - Natural					
11	2101	Lagoon	178	246044	1.61	208915	191301
12	2102	Creek	586	206698	1.35	199743	189489
13	2103	Sand/Beach	1353	63033	0.41	-	-
14	2104	Intertidal mud flat	2931	2413642	15.82	516636	366953
15	2105	Salt Marsh	744	161144	1.06	5369	2596
16	2106	Mangrove	3806	471407	3.09	-	-
17	2107	Coral Reef	606	142003	0.93	-	-
	2200	Coastal Wetlands - Man-made					
18	2201	Salt pan	609	148913	0.98	105253	94047
19	2202	Aquaculture pond	2220	287232	1.88	196514	186963
		Total - Coastal	13033	4140116	27.13	1232430	1031349
		Sub-Total	201503	14705015	96.36	8600798	5801220
		Wetlands (<2.25 ha)	555557	555557	3.64	-	-
		Total	757060	15260572	100.00	8600798	5801220

Source: National Wetland Atlas, 2011

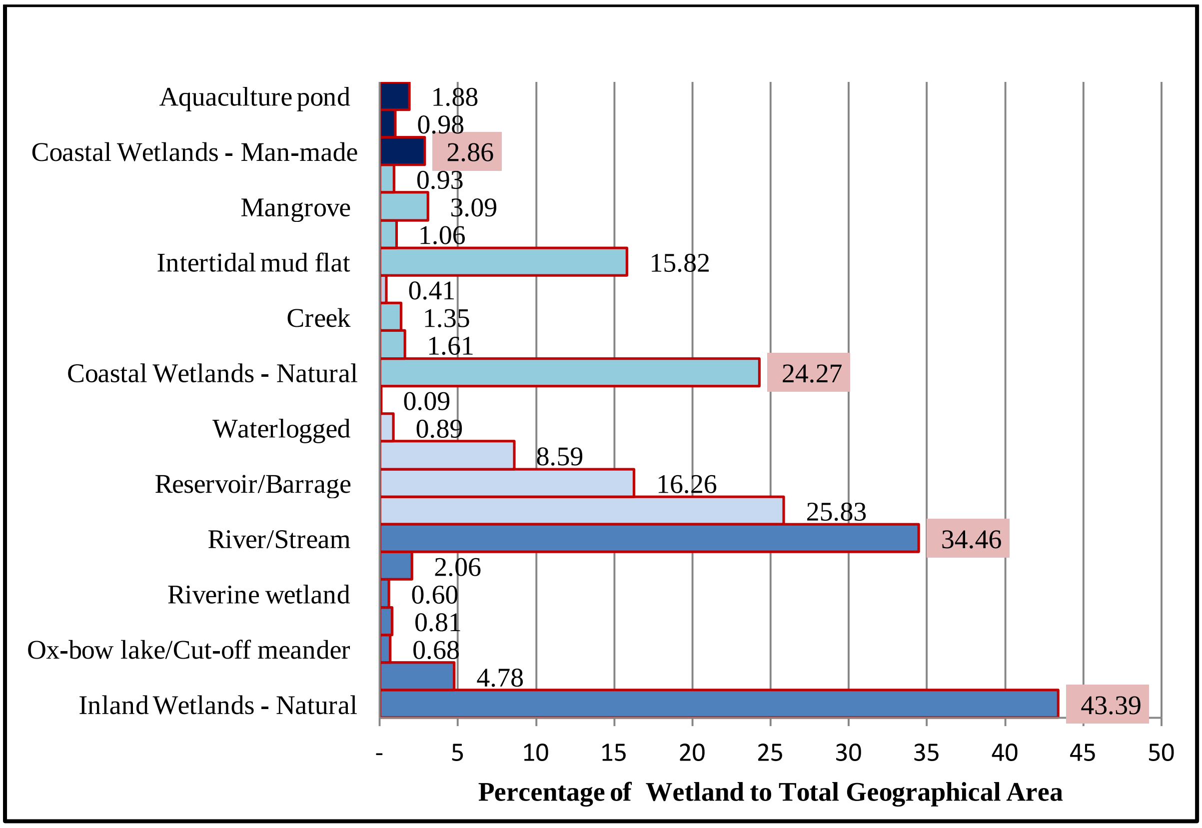


Fig 3.1: Distribution of Wetland in India, 2011

Type-wise distribution of wetlands in India is given in Table 3.4 and presented in the fig-3.1. Among the total wetland, inland made-made wetlands cover 71% followed by inland natural wetland (23%), coastal natural wetland (5%), coastal made-made wetlands (1%). Among the natural inland wetland, waterlogged area has highest number (11957) followed by river/ stream (11747), Lake/Pond (11740), Ox-bow lake/Cut-off meander (4673), Riverine wetland, (2834), High altitude wetland (2707) (fig 3.1). Among the man-made inland wetland, tank/pond have highest number (86%) followed by the reservoir (10%), waterlogged (4%) (fig 3.1). Among the man-made coastal wetland, Aquaculture pond hashighest number (78%) followed by the salt pan. Among the natural coastal wetland, Mangrovehashighest number (3806) followed by intertidal mud flat (2931) Beach (1353), Salt Marsh (744), Coral Reef (606), Creek (586) Lagoon (178). Different aspects of type-wise distribution of wetlands in India are presented in the fig 3.2 to fig 3.6.

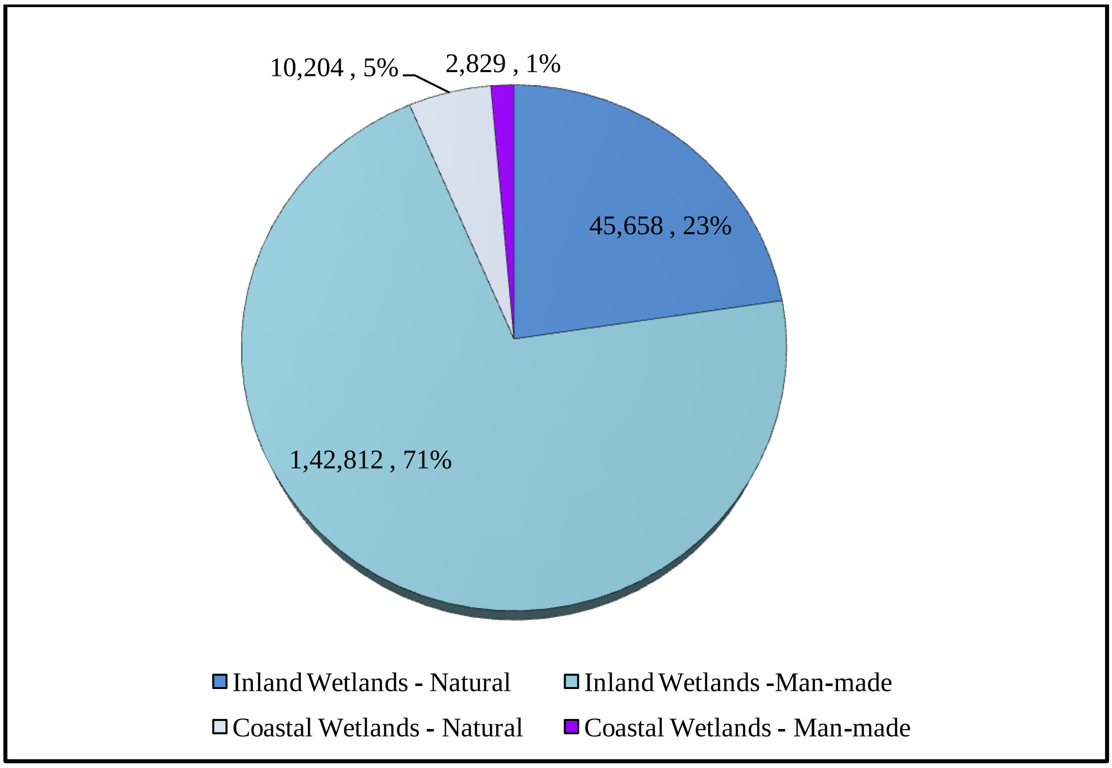


Fig 3.2: Number of Wetland in India, 2011

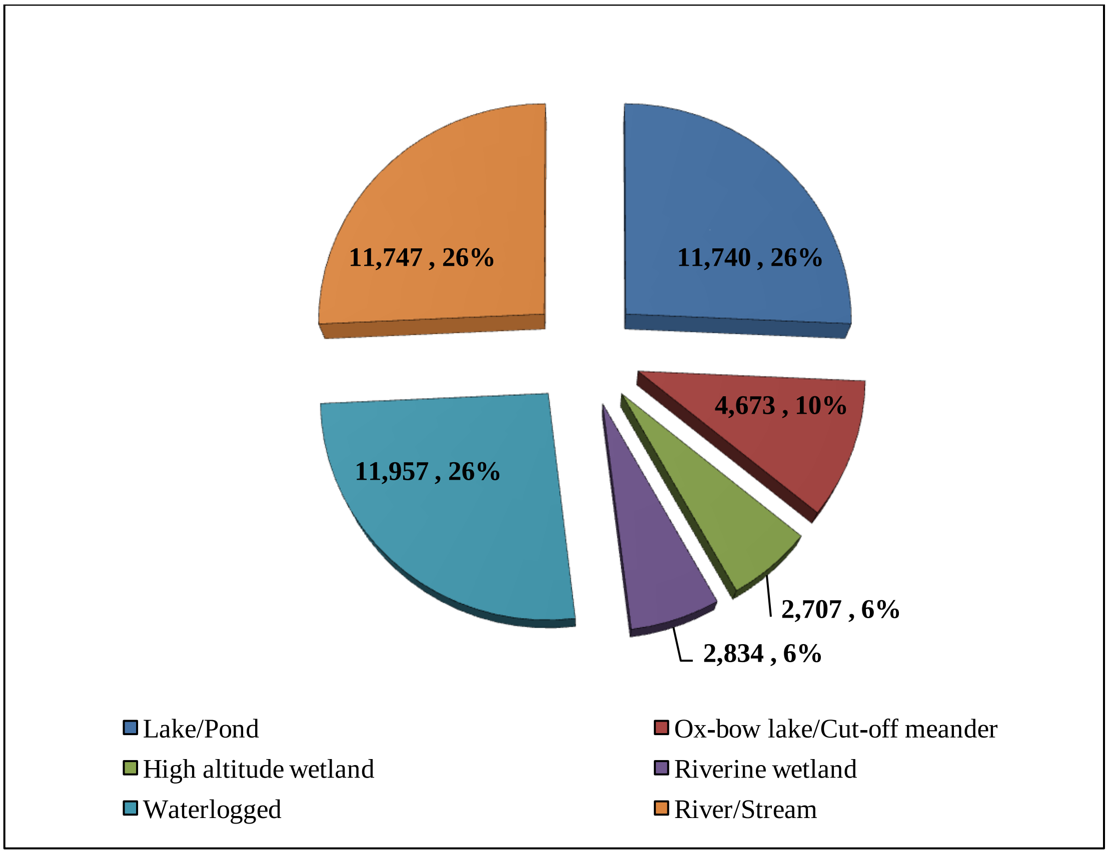


Fig 3.3: No. of Natural Inland Wetlands in India, 2011

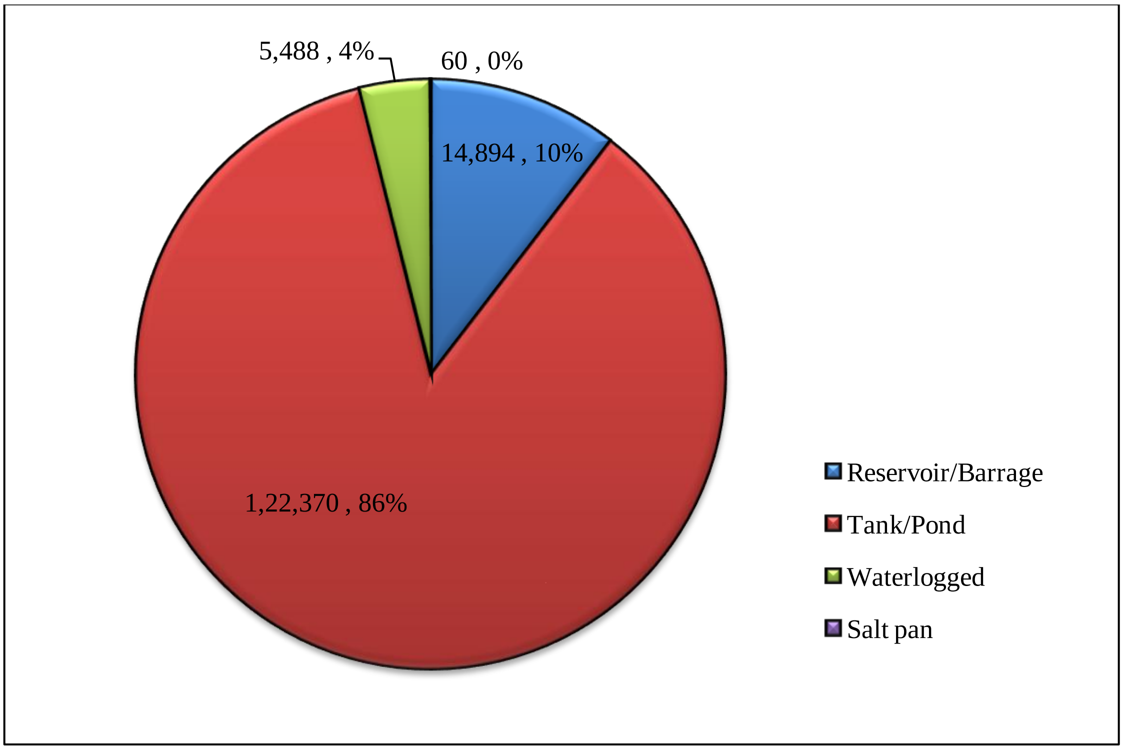


Fig 3.4: No. of Man-Made Inland Wetlands in India, 2011

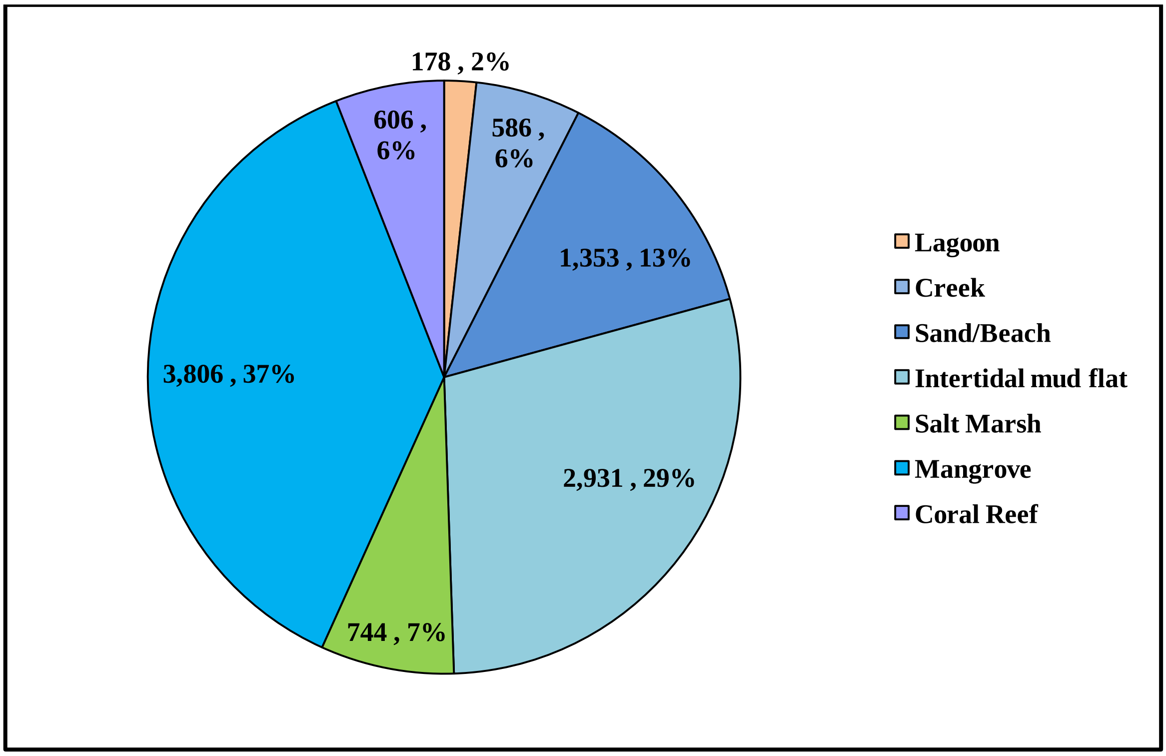


Fig 3.5: No. of Natural Coastal Wetlands in India, 2011

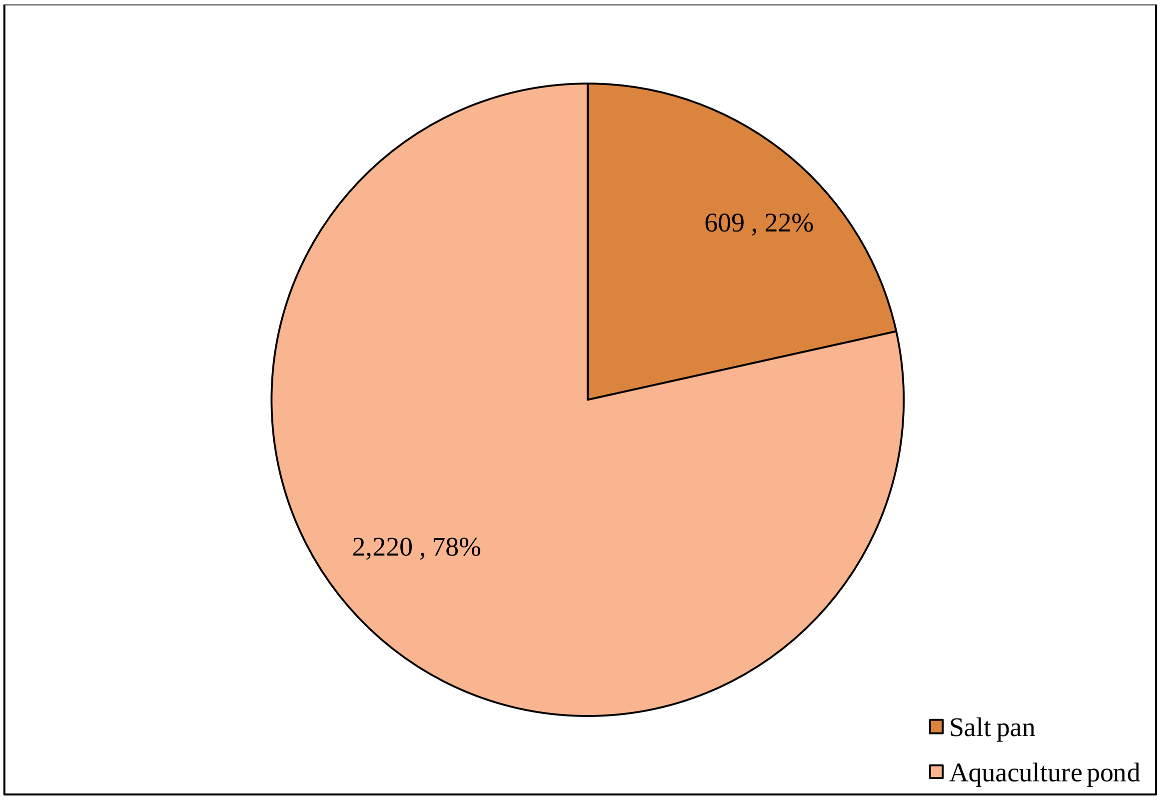


Fig 3.6: No. of Man-Made Coastal Wetlands in India, 2011

3.3.2.2. State-Wise Wetland Distribution in India:

State-wise distribution of wetlands in India shows Lakshadweep having 96.12% of its total geographic area covered under wetlands followed by Andaman & Nicobar Islands (18.52%), Daman & Diu (18.46%) and Gujarat (17.56%), which are the states having the largest extent of wetlands. Puducherry (12.88%), West Bengal (12.48%), Assam (9.74%), Tamil Nadu (6.92%), Goa (5.76%), Andhra Pradesh (5.26%), and Uttar Pradesh (5.16%) are also wetland rich states. The smallest extent (less than 1.5% of the state geographic area) have been observed in Mizoram (0.66%) followed by Haryana (0.86%), Delhi (0.93%), Sikkim (1.05%), Nagaland (1.30%), and Meghalaya (1.34%). The highest percentage of declared Ramsar Sites are situated in the state of Kerala (31%) followed by Orissa (27%) and West Bengal (2 %). (Table 3.5& fig 3.7).

Table 3.5: State-Wise Wetland Distribution in India

State code	State/UT	Wetland area in ha	% of total wetland area	% of state geographic area	Open water	
					Post-monsoon	Pre-monsoon
1	Jammu & Kashmir	391501	2.57	1.76	301818	314209
2	Himachal Pradesh	98496	0.65	1.77	69107	49245
3	Punjab	86283	0.57	1.71	36344	24386
4	Chandigarh *	350	0.00	3.07	242	225
5	Uttarakhand	103882	0.68	1.94	54221	46244
6	Haryana	42478	0.28	0.86	14216	18912
7	Delhi	2771	0.02	0.93	1282	1526
8	Rajasthan	782314	5.13	2.29	368129	158696
9	Uttar Pradesh	1242530	8.14	5.16	690216	494994
10	Bihar	403209	2.64	4.40	224655	148382
11	Sikkim	7477	0.05	1.05	7189	5035
12	Arunachal Pradesh	155728	1.02	1.78	66222	57516
13	Nagaland	21544	0.14	1.30	20938	20650
14	Manipur	63616	0.42	2.85	45304	39391
15	Mizoram	13988	0.09	0.66	13799	13778
16	Tripura	17542	0.11	1.59	9847	7023
17	Meghalaya	29987	0.20	1.34	27912	27420
18	Assam	764372	5.01	9.74	423068	390152
19	West Bengal	1107907	7.26	12.48	632450	583620
20	Jharkhand	170051	1.11	2.13	152879	103225
21	Orissa	690904	4.53	4.49	508282	419310
22	Chhattisgarh	337966	2.21	2.50	243814	173678
23	Madhya Pradesh	818166	5.36	2.65	571961	245289
24	Gujarat	3474950	22.77	17.56	1150755	732481
25	Daman & Diu *	2068	0.01	18.46	570	262
26	Dadra & Nagar Haveli *	2070	0.01	4.25	1915	1131
27	Maharashtra	1014522	6.65	3.30	796834	370357
28	Andhra Pradesh	1447133	9.48	5.26	887143	610668
29	Karnataka	643576	4.22	3.36	427921	262991
30	Goa	21337	0.14	5.76	18899	18899
31	Lakshadweep *	79586	0.52	96.12	23674	23674
32	Kerala	160590	1.05	4.13	138962	130468
33	Tamil Nadu	902534	5.91	6.92	657861	296268
34	Puducherry *	6335	0.04	12.88	4028	2535
35	Andaman & Nicobar Islands *	152809	1.00	18.52	8341	8580
	Total	15260572	100.00	4.63	8600798	5801220

Source: National Wetland Atlas, 2011 * Union Territories

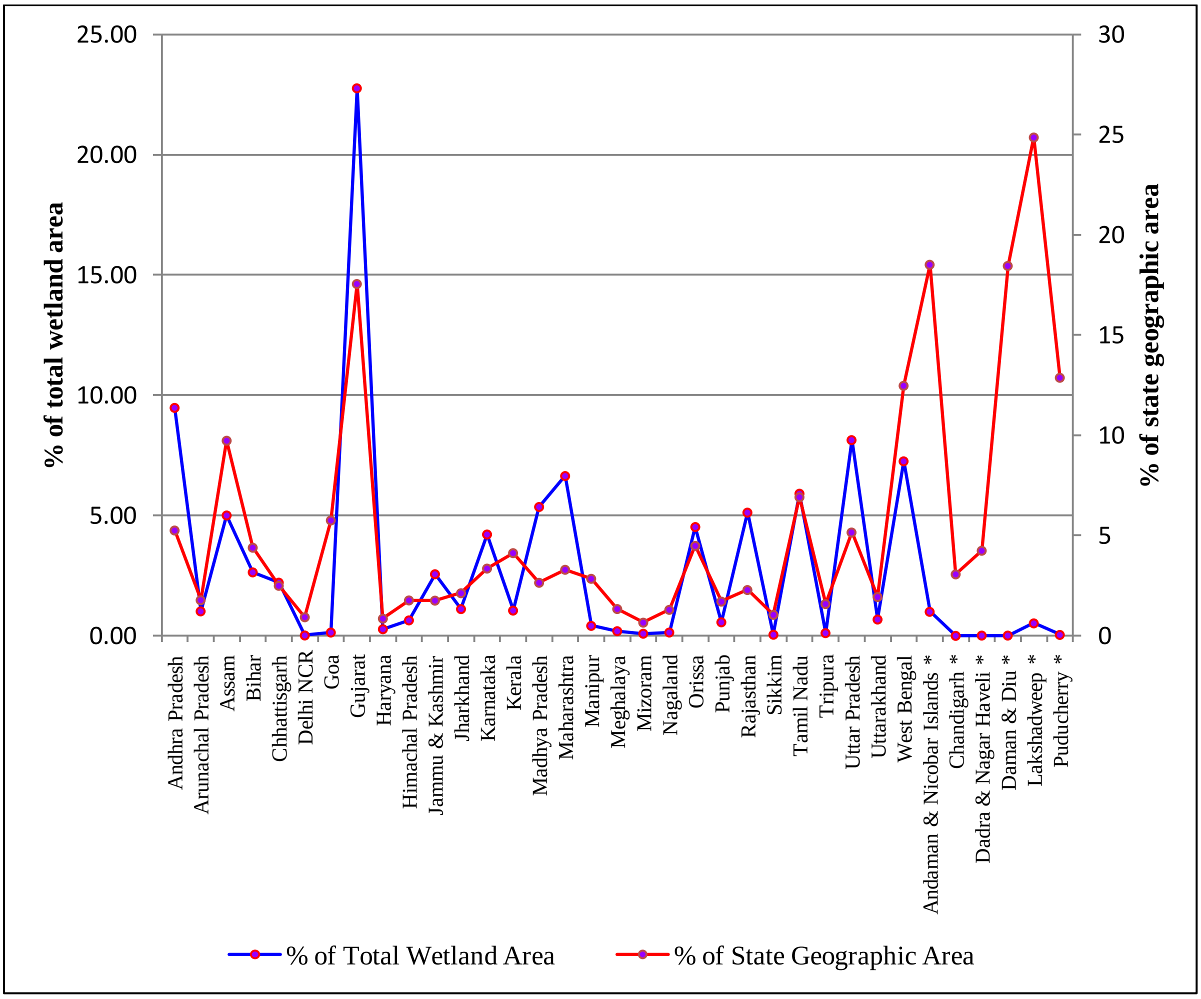
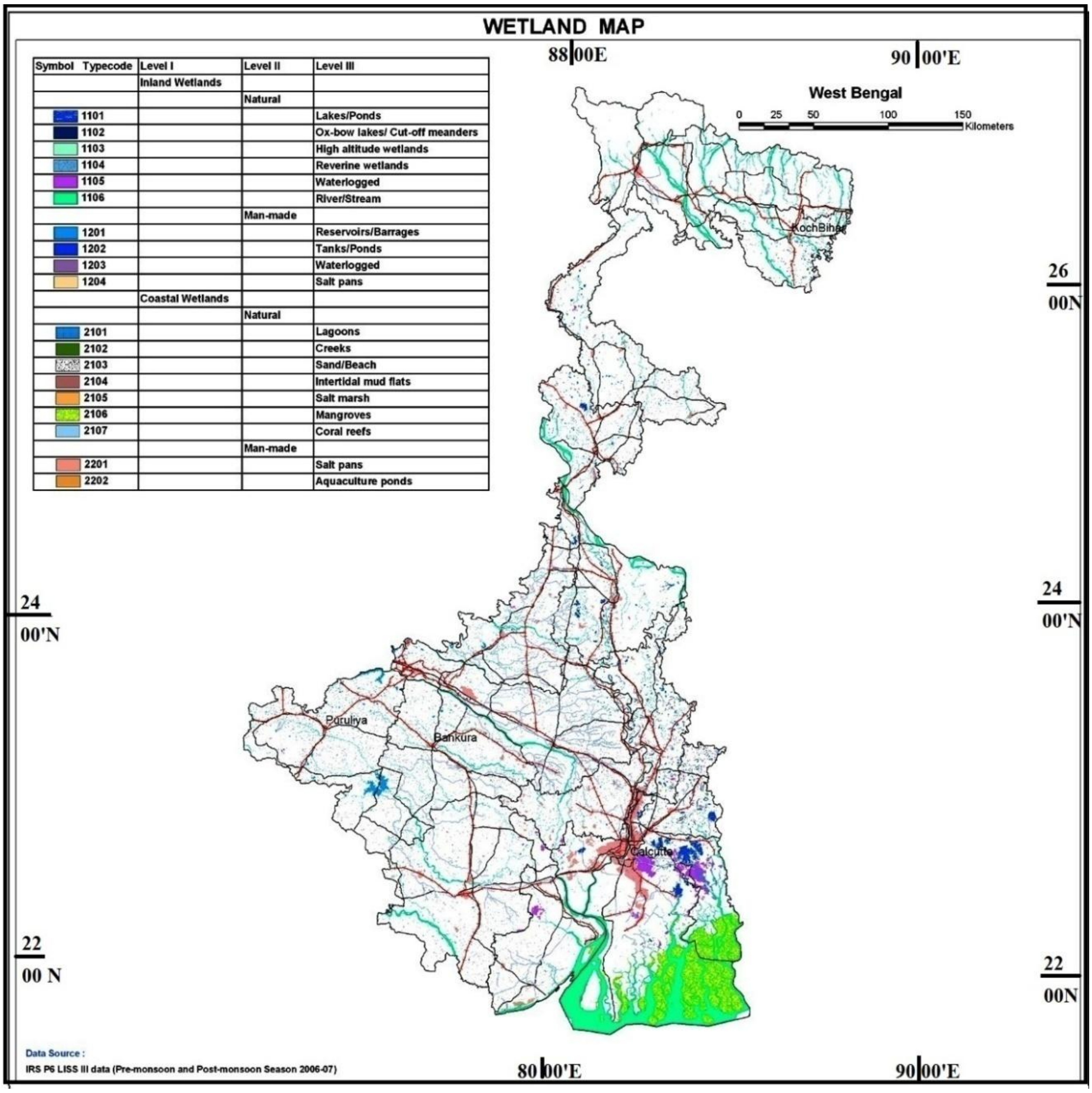


Fig 3.7: State-Wise Distribution of Wetlands in India, 2011

3.3.3. Wetland Distribution in West Bengal:

West Bengal lies in the Ganga-Brahmaputra floodplain and is blessed with the existence of several wetlands. The northern part of the state also extends into the sub-alpine hilly regions on the Singalila Range of the Eastern Himalaya. The wetlands are distributed from high altitude Darjeeling hills to the deltaic plains of South Bengal. The wetlands of West Bengal are mainly lakes, floodplains oxbow lakes, marshes, bogs and estuaries of Sunderbans (Chowdhury, 2009).



Map 3.2: Distribution of Wetland in West Bengal, 2011

3.3.3.1. Type-Wise Distribution of Wetland in West Bengal:

National Wetland Atlas (ISRO) recorded that the total area under wetlands in the state of West Bengal is 1107907 ha, accounting for about 12.47% of geographical area of the state. Total Number of wetlands in the state is 147826 including 138707 small wetlands which is less than 2.25 ha. The total number of inland wetlands are 8670 (natural 3675 and man-made -4995) and coastal wetlands are 449 (natural-421and man-made-28). The total area covering inland and coastal wetlands are 747383 ha and 221817 ha respectively. The highest wetland types are river/stream (559192 ha) followed by mangrove (209330 ha), lake/pond (58654 ha), waterlogged (56603 ha) and reservoir/barrage (22672 ha). In addition, 138707 smaller wetlands (< 2.25 ha) were also identified. Type-wise distribution of wetlands in West Bengal is given in Table 3.6 and presented in the fig 3.8. The open water in wetlands decreases during pre-monsoon (583620 ha) compared to post-monsoon (632450 ha).The area under aquatic vegetation in wetlands also increases significantly during pre-monsoon (239058 ha) compared to post-monsoon (228174 ha). Different aspect of type- wise distribution of wetlands in west bengal is presented in the fig 3.9 to fig 3.12.

Table 3.6: Type-Wise Distribution of Wetlands in West Bengal (Area in Ha)

Sl. No.	Wetland code	Wetland Category	Number of wetlands	Total wetland area	% of wetland area	Open Water	
						Post-monsoon area	Pre-monsoon area
	1100	Inland Wetlands - Natural					
1	1101	Lake/Pond	1327	58654	5.29	45374	35609
2	1102	Ox-bow lake/Cut-off meander	867	19550	1.76	15869	11063
3	1103	High altitude wetland	3	82	0.01	82	82
4	1104	Riverine wetland	490	8654	0.78	7656	6026
5	1105	Waterlogged	780	56603	5.11	47615	41337
6	1106	River/Stream	208	559192	50.47	468488	453748
	1200	Inland Wetlands -Man-made					
7	1201	Reservoir/Barrage	340	22672	2.05	20728	12744
8	1202	Tank/Pond	4581	20470	1.85	18923	15708
9	1203	Waterlogged	71	1435	0.13	1354	1076
10	1204	Salt pan	3	71	0.01	71	71
		Total - Inland	8670	747383	67.46	626160	577464
	2100	Coastal Wetlands - Natural					
11	2101	Lagoon	-	-	-	-	-
12	2102	Creek	-	-	-	-	-
13	2103	Sand/Beach	51	3338	0.30	-	-
14	2104	Intertidal mud flat	17	2726	0.25	-	-
15	2106	Mangrove	353	209330	18.89	-	-
16	2107	Coral Reef	-	-	-	-	-
	2200	Coastal Wetlands - Man-made					
17	2201	Salt pan	14	4866	0.44	4865	4865
18	2202	Aquaculture pond	14	1557	0.14	1425	1291
		Total - Coastal	449	221817	20.02	6290	6156
		Sub-Total	9119	969200	87.48	632450	583620
		Wetlands (<2.25 ha), mainly Tanks	138707	138707	12.52	-	-
		Total	147826	1107907	100.00	632450	583620

Source: National Wetland Atlas, West Bengal, 2010

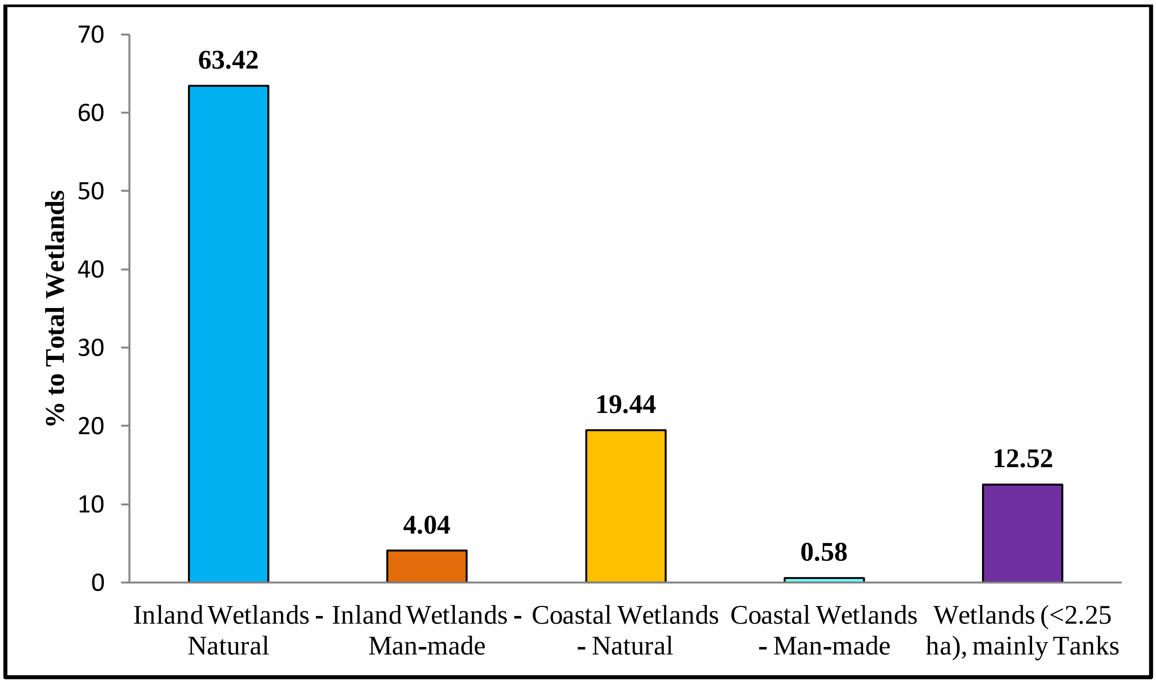
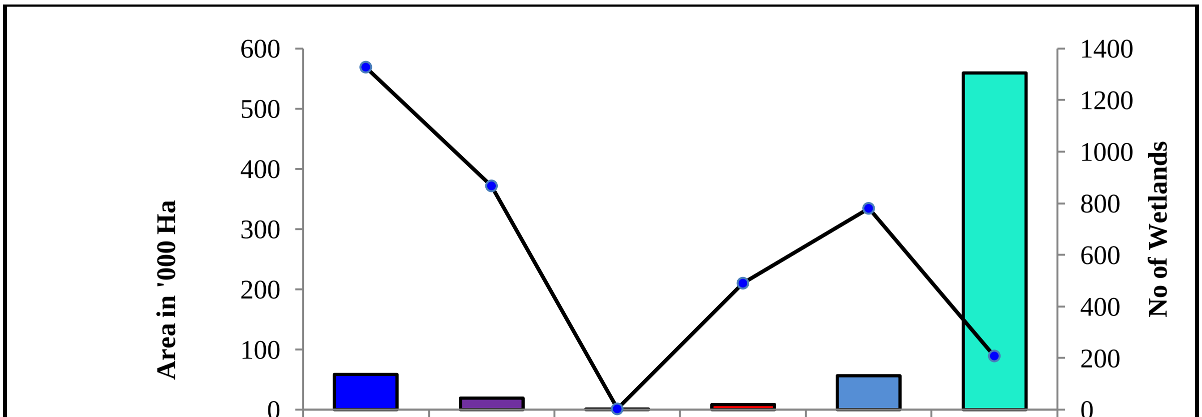
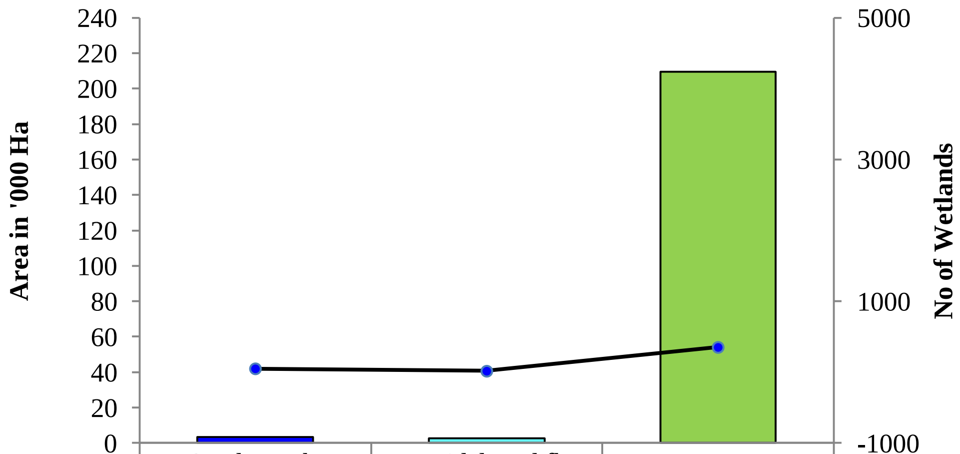


Fig 3.8: Different Types of Wetland,West Bengal, 2010



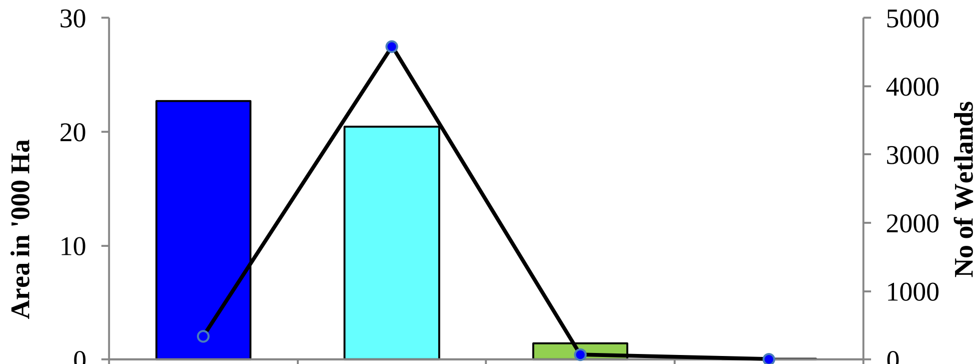
	Lake/Pond	Ox-bow lake/Cut-off meander	High altitude wetland	Riverine wetland	Waterlogged	River/Stream
Total wetland area (Ha)	58654	19550	82	8654	56603	559192
Number of wetlands	1327	867	3	490	780	208

Fig 3.9: Natural Inland Wetland (in percentage) West Bengal, 2010



	Sand/Beach	Intertidal mud flat	Mangrove
Total wetland area (Ha)	3338	2726	209330
Number of wetlands	51	17	353

Fig 3.10: Distribution of Coastal Natural Wetlands in West Bengal, 2010



	Reservoir/Barrage	Tank/Pond	Waterlogged	Salt pan
Total wetland area (Ha)	22672	20470	1435	71
340 4581 71 3	340	4581	71	3

Fig 3.11: Inland Man Made Wetlands in West Bengal, 2010

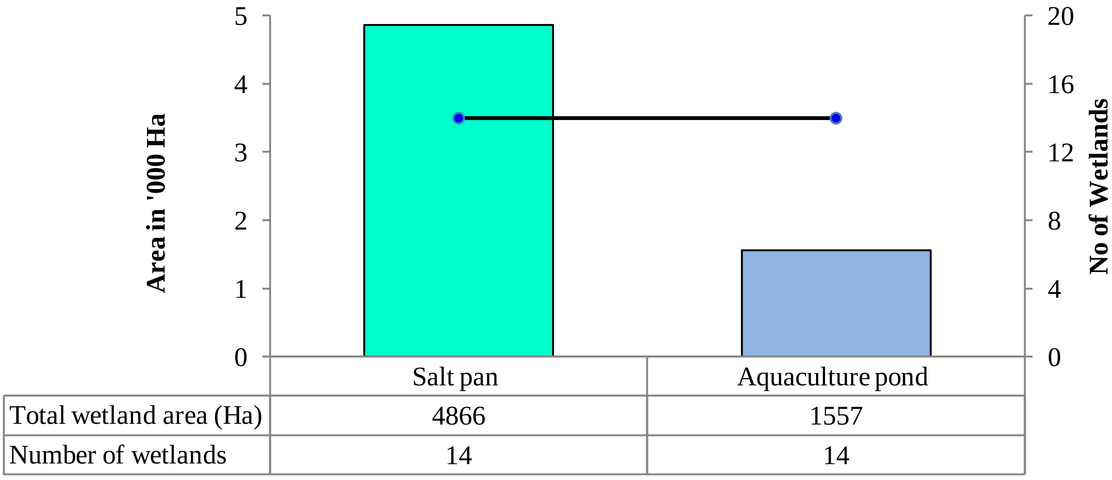


Fig 3.12: Coastal Man Made Wetlands in West Bengal, 2010

3.3.3.2. District-Wise Distribution of Wetland in West Bengal:

The wetlands comprise 11,07,907 ha of area accounting for about 12.47 % of the total geographical area of the state of West Bengal. The extent of wetlands varies from a minimum of 2.1% (Darjeeling) to maximum 58.4 % (South twenty-four Parganas) (Table 3.7 & fig 3.13). The total wetland area is small in Kolkata district (724 ha) and high in south twenty-four parganas (477151 ha). Identified wetlands In West Bengal under NWCP (as on June 26, 2009) are East Calcutta Wetland, Sunderbans, Ahiron Beel, Rasik Beel ,Santragachi, Patlakhawa-Rasomati.

Table 3.7: District-Wise Distribution of Wetland

District code	District	Wetland area in ha	% of total wetland area	% of district geographic area	Open water	
					Post-monsoon	Pre-monsoon
1	Darjiling	6395	0.58	2.08	2804	2440
2	Jalpaiguri	41520	3.75	6.67	9664	9543
3	Koch Bihar	23534	2.12	6.95	10093	8607
4	Uttar Dinajpur	12806	1.16	4.03	6558	5498
5	Daishin Dinajpur	9109	0.82	4.17	2258	1147
6	Maldah	25162	2.27	6.74	19384	15295
7	Murshidabad	41980	3.79	7.89	27924	20327

8	Birbhum	27660	2.5	6.09	8618	7692
9	Barddhaman	49542	4.47	7.05	15826	13951
10	Nadia	28189	2.54	7.18	20628	12179
11	North Twenty Four Parganas	150206	13.56	36.69	86339	82739
12	Hugli	21514	1.94	6.83	6886	5840
13	Bankura	41476	3.74	6.03	16763	12105
14	Puruliya	38122	3.44	6.09	19633	13958
15	West Medinipur*	40626	3.67	2.89	13300	10217
16	Howrah	15589	1.41	4.5	11999	11294
17	Kolkata	724	0.07	6.96	697	694
18	South Twenty Four Parganas	477151	43.07	58.45	306931	305432
19	East Medinipur	56602	5.11		46145	44662
	Total	1107907	100	12.48	632450	583620

Source: National Wetland Atlas, West Bengal, 2010

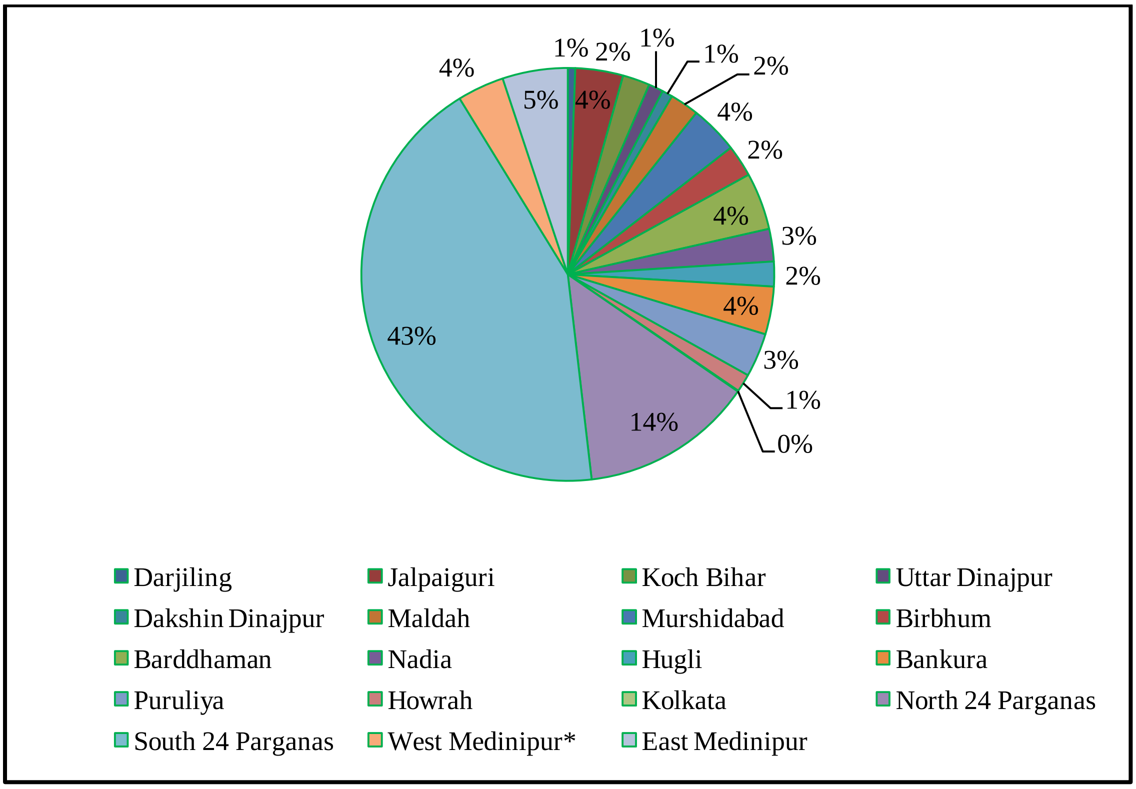
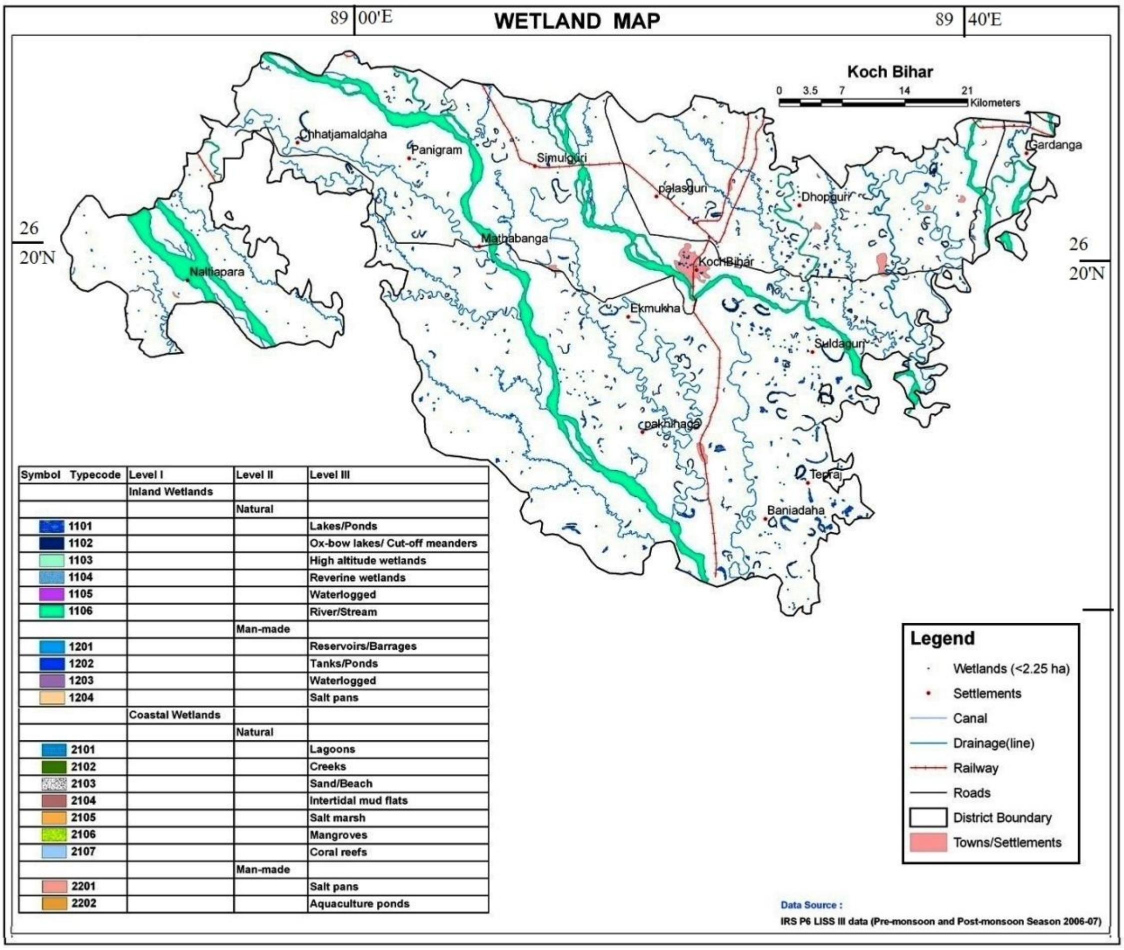


Fig 3.13: District-Wise Distribution of Wetland in West Bengal, 2010

3.3.4. Wetland Distribution in Koch Bihar:

Koch Bihar is a plain region with a slight southeastern slope. The district lies in the physiographic zone known as Terai and tall. Therefore, the majority of wetlands in Koch Bihar district are of *Palustrine* type (floodplains, seasonal waterlogged, marsh), *Lacustrine* type (Lakes) and *Riverine* type. Majority of wetlands in the district originated with the changes in the riverine system. The district has a large number of rivers and most of them change their courses very frequently, as a result, cut-off channels/ meanders or ox-bow lakes are very common. Rasik Beel and Rasomati Beel came in focus of National Wetland Conservation programme. Ox-bow Lake is the dominant category of wetlands representing 86.30 % of the total wetland area (Bandyopadhyay *et al*, 2000). Except for the Natural wetlands, there are some artificial manmade water bodies located in the district and among those few are more than four hundred years old, as a majority of Dighis in the district were dug during the *Khen* and *Coach* Dynasty. The important ponds of Koch Bihar sadar are – Sagar Dighi, Bairagi Dighi, Rajmata Dighi, Yamuna Dighi, Rajbari Jheel, Barrack Dighi, Thana Dighi (Tufanganj), Thana Dighi (Dinhata), Ful Dighi, Gopal Nagar Dighi etc.



Map 3.3: Distribution of Wetland, Koch Bihar, 2010

3.3.4.1. Type-Wise Distribution of Wetlandin Koch Bihar:

There are 390 wetlands, of which 386 are natural and 4 are man-made (Table 3.8). River/Stream ranked first in terms of area (18478 ha) accounting for 79% of wetland area (Table 3.8), followed by lakes/ponds in the district (2814 ha). Ox-bow lakes/Cut-off meanders have a significant aerial extent (1867 ha). They constitute about 8 % of wetland area. In addition, 225 small wetlands (> 2.25 ha area) are identified. Qualitative analysis showed that medium turbidity is dominant (9625 ha out of 10093 ha) for the open water features of wetlands of the district in post-monsoon.

Table 3.8: Area Estimates of Wetlands in Koch Bihar (Area in Ha)

Sl. No.	Wetland code	Wetland Category	Number of wetlands	Total Wetland Area	% of wetland area	Open Water		Change
						Post-monsoon Area	Pre-monsoon Area	(%)
	1100	**Inland Wetlands - Natural**						
1	1101	Lakes/Ponds	276	2814	11.96	1812	924	-49.01
2	1102	Ox-bow lakes/ Cut-off meanders	87	1867	7.93	1042	705	-32.34
3	1103	High altitude wetlands	-	-	-	-	-	
4	1104	Riverine wetlands	10	132	0.56	85	48	-43.53
5	1105	Waterlogged	-	-	-	-	-	
6	1106	River/Stream	13	18478	78.52	7136	6912	-3.14
	1200	**Inland Wetlands -Man-made**						
7	1201	Reservoirs/Barrages	-	-	-	-	-	
8	1202	Tanks/Ponds	4	18	0.08	18	18	0
9	1203	Waterlogged	-	-	-	-	-	
10	1204	Salt pans	-	-	-	-	-	
		Sub-Total	390	23309	99.04	10093	8607	-14.72
		Wetlands (<2.25 ha), mainly Tanks	225	225	0.96	-	-	
		Total	615	23534	100	10093	8607	-14.72

Source: National Wetland Atlas, West Bengal, 2010

3.3.4.2.Block-Wise Distribution of Wetland in Koch Bihar:

The wetlands comprise 6117.83 ha of area accounting for about 1.81% of the total geographical area of the district of Koch Bihar. The extent of wetlands varies from a minimum of 0.339% (Mekhliganj) to maximum 3.342% (Dinhata-II) (Table 3.9). The total wetland area is small in Mekhliganj block (103.77 ha) and high in Koch Bihar-I (858.17 ha). Identified wetlands In West Bengal under NWCP (as on June 26, 2009) are East Calcutta Wetland, Sunderbans, Ahiron Beel , Rasik Beel ,Santragachi, Patlakhawa-Rasomati.

Table 3.9: Block-Wise Impounded Water Area of Koch Bihar

Sl no	Block	Wetland area in Ha	% of total Wetland area	% of Block Geographic area
1	Haldibari	262.32	4.288	1.705
2	Mekhliganj	103.77	1.696	0.339
3	Mathabhanga – I	573.14	9.368	1.776
4	Mathabhanga - II	796.4	13.018	2.569
5	Koch Bihar - I	858.17	14.027	2.323
6	Koch Bihar - II	461.21	7.539	1.736
7	Tufanganj - I	527.36	8.620	1.644
8	Tufanganj - II	378.55	6.188	1.425
9	Dinhata - I	625.55	10.225	2.201
10	Dinhata - II	825.35	13.491	3.342
11	Sitai	442.2	7.228	2.750
12	Sitalkuchi	263.81	4.312	1.005
13	Total	6117.83	100.000	1.872

Source: Hand Book of Fisheries Statistics 2015-16

3.3.5. Wetland Distribution in Study Area:

Study area is blessed with water resources in the form of numerous rivers and streams and most of them have changed their courses very frequently, as a result, cut-off channels/ meanders or ox-bow lakes are very common. Among the four subdivisions of the study area,Tufanganj-I has the largest number of wetlands which alsocontributesto the highest area of the wetlands. Rasik Beel and Rasomati Beel came in focus of National Wetland Conservation programme. Except for the Natural wetlands, there are some artificial manmade water bodies located in the study area and among those, few are more than four hundred years old as the majority of dighi in the district were dug during the *Khen* and *Coach* Dynasty.

In Koch bihar district, apart from big or small rivers and streams (both narrow and wide) wetlands includes *doba, kura, chhara, beel, jheel, dighi, dabri, jampui* etc. Since Koch Bihar district is criss crossed with a number of rivers who often change their courses and there are a plethora of abandoned river basins (water-filled or dry). During the rainy season, some of these abandoned Channels re-connect themselves with the nearby rivers. During Heavy downpour some of these wetlands act as reservers of stromwater.

Though *chhara, beel and jheel* are used in the same meaning there is a simple difference among the *chhara, beel* or *jheel*. In a *beel or jheel*,there is hardly any water current visible. These are still and motionless and are not covered with aquatic plants. On the contrary, the chhara even though covered with aquatic plants have high currents during the monsoon season. Generally, in the post-monsoonperiod, all wetlands become stagnant. In the district, there lies some confusion in the correct nomenclature of Chhara and abeel or jheel among the local people. Sometimes it is observed that the water bodies which are identified as chhara by local community are nothing but beels and the vice versa. Water brimmed lowlands or a long stretch of lowlands where water accumulates only during the monsoon known as *dabri* and irrigation canals are known as *jampui.*

3.3.5.1. Block-wise Distribution of Wetland in Study Area:

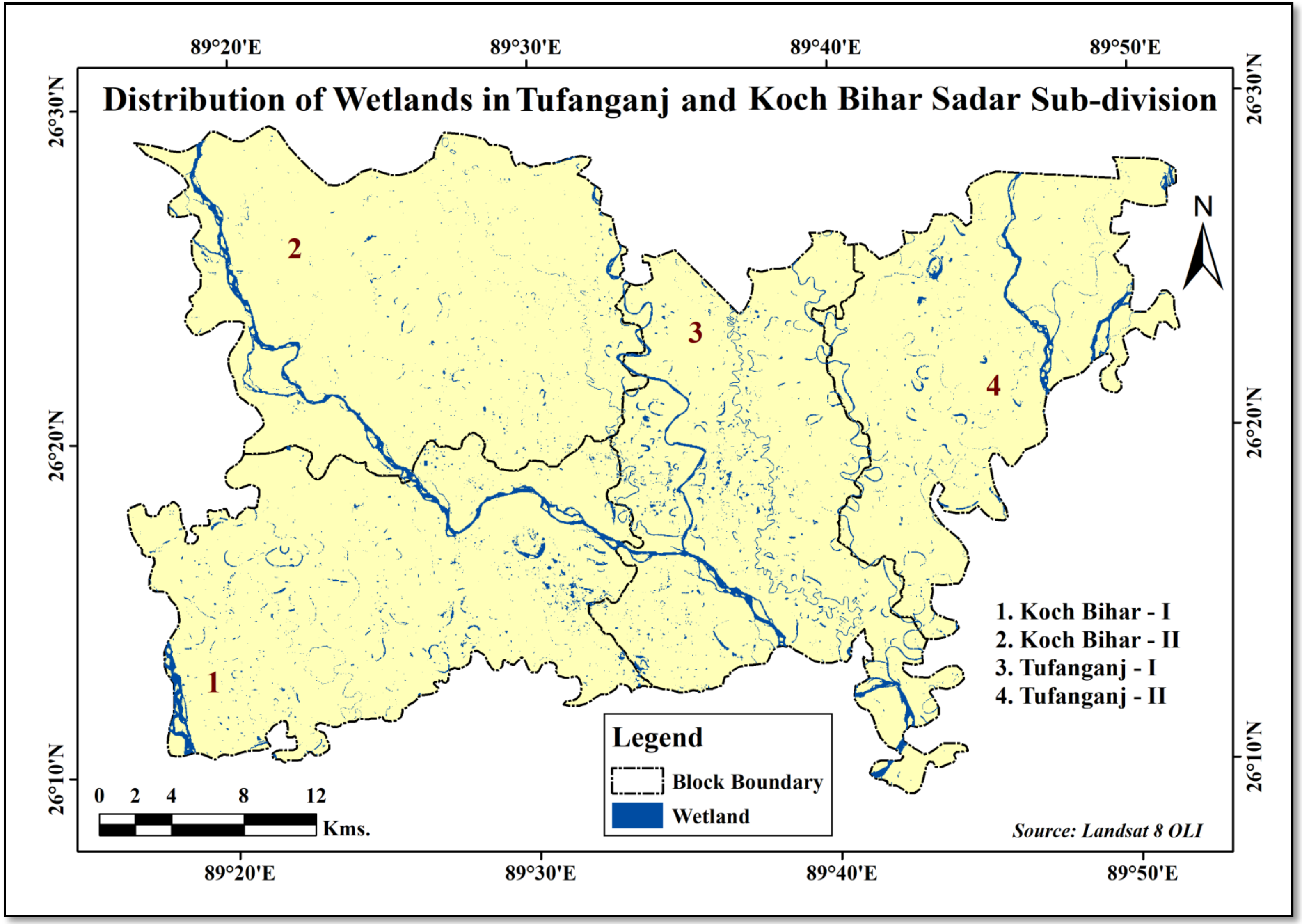
Distributions of wetlands in the study area are presented in the map 3.4 to map 3.8. In the subdivision of Koch Bihar important wetlands are: Maa-Thakurani Beel, Sonari Niktiyar Kuthi Beel, Bargila Jheel, Rasomati Jheel, Kokoyabari Chhara, Kaljani Chhara, Shoultukri Barpak Chhara, Baisguri Chhara, Pestarjhar Kura, Maranadir Kuthi Kura, Gopalpur Halongia Kura, Daldali Chhara, Daldali Jheel, Dharla Kura (Marichbari north), Marneya Kura (Marichbari north), Moamari Chhara (jheel), Moronga Beel, Chaitanya Kura, Maynaguri Kankanguri Beel, Khuniya Chhara, Pandarghat Chhara, NayaChhara, Saheberhath Chhara (Baro Nalangibari) Nakkati Chhara (Nakkati), Dayaler Chhara, Houser Dara (South Kurshamari), Bamni Chhara (Khagribari), Rajar Kura (North Kalarayer Kuthi), Daokura (North Kalarayer Kuthi), Panishala Beel, Daoyaguri Chhara, East Phalimari Chhara, Ghargharia Chhara (Talliguri), Barghoria Chhara (East Phalimari), Chhoto Atharokotha Chhara, Bamani Chhara (Kankanguri), Baiganbari Chhara (Amtali-Balabari), Chandamari Beel, Dakshin Putimari Fuleswari Beel, Barorangros Madan Kura, Sidhura Jheel, Tenganmari Kura, Kaminirghat Kura, Konamalli Pestarjhar Chhara, Jhinsidanga Chhara, Kankanguri Dara, Dhangdhingguri Dara, Kharija Naldhondra Chhara, Talliguri Chhara, Sukdhanerkuthi Kura, Bairati Chhara, Khagribari Achhiran Kura etc.

In the two blocks of Tufanganj subdivision notable wetland are: Ghunai Chhara (North Maradanga), Alodhoya Chhara (Ayrani Chitliya), Chandi Beel (do), Amlaguri Chhara, Ghunghun Dara (Bhelapeta), Ghogarkuthi Chhara, Sunfola Chhara (Andaranfulbari & Chamta), Raidak Beel (Dwiparpar), Gadadhar Chhara (Santoshpur), Dhadiyal Dabri, Rajar Kura (Dhadiyal), Dhadiyal Chhara, Bhareya Beel, Janki Chhara, Bhedaler Dara, Bhanukumari Chhara (Beel), RasikBeel, Falimari Dara, Haripur Chhara, Boyalimohan Chhara, Chandigarh Chhara, Mantani Chhara, Khorarpar Chhara, Dharshi Chhara (Ghogarkuthi), Kaljani Chhara (Dhupguri), KaljaniChhara (Beel), Shilghagri Chhara, Mugabhog Beel, Banya Beel, Urundubi Beel, Khorarparjampui (Chhatgenduguri), Ichhai Beel, Pathvaral Beel, (Pathdanga), Bhelakopa Chhara, Balarampore Chhara, Balarampore Jheel, Dwarikamari Chhara, Chhat Bhalakopa Chhara, Krishnapur Chhara, Chakchaka Beel (Nandichhechura), Siddiri Beel (Swarpasingra), Shouldhukri Beel (Balarampore no.2), Dhandhar chhara, Durlover Chhara, Burirjhar Chhara (Char Balabhut) etc.

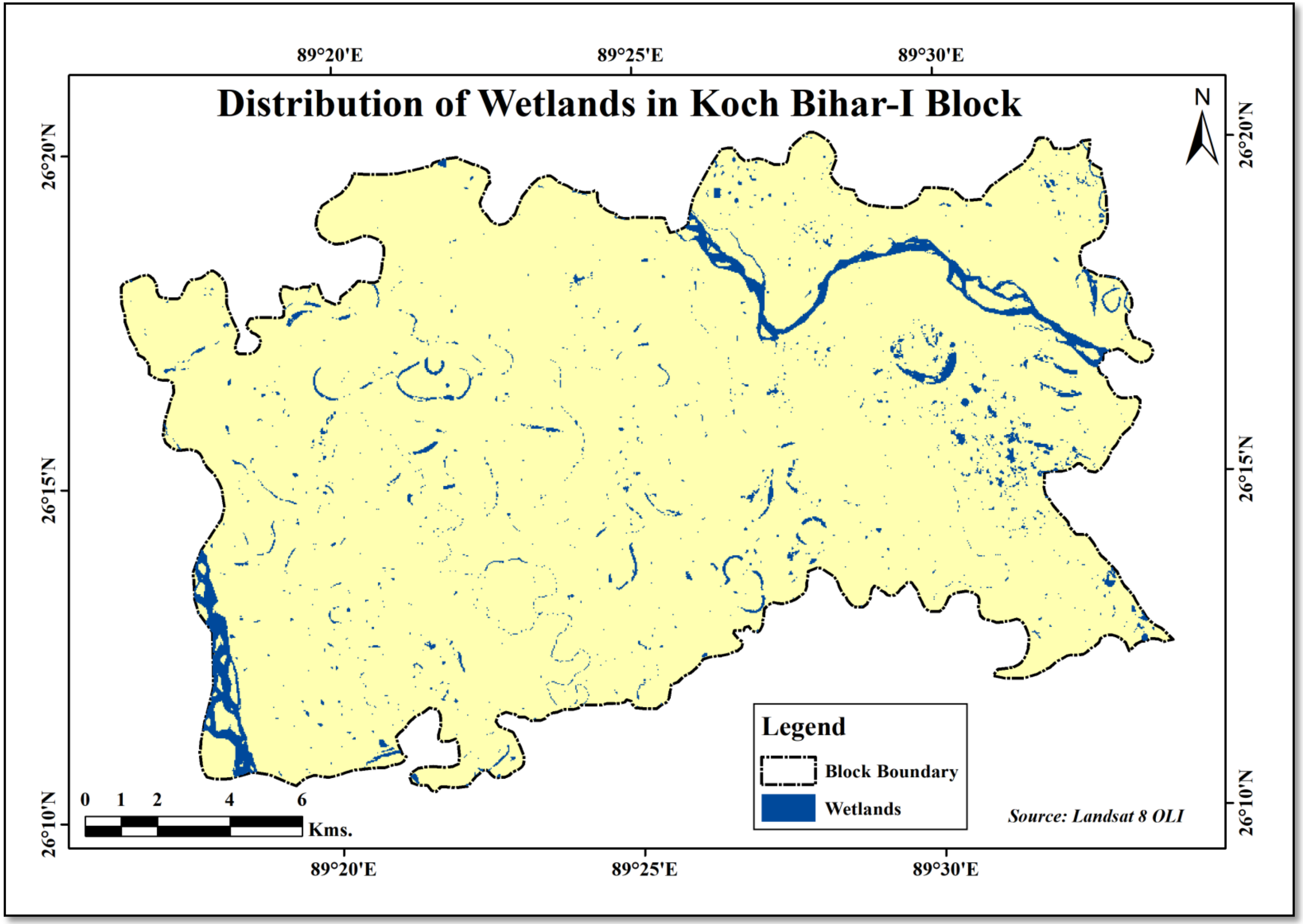
Only a few towns today have these many wetlands as Koch Bihar though it has lost its royalty. The capital city of Koch Bihar was made according to a pre-planned module supervised by many domestic or foreign sculptors, engineers and overseers. On their advice, many ponds surrounded by broad roads and shaded trees were dug even the king took the initiative to preserve and beautify these ponds. Manyghats and pavilions were constructed under the royal order of beautification of the kings. Not only the district towns but also the sub-division towns had their own share of ponds for the well-being of the citizens.

Many ponds were excavated in the Koch Bihar town, Gosanimari (the capital city of Khen dynasty),Atharokotha, Balarampore, Bhetaguri, Dhaluabari and in the subdivision towns like Tufanganj, Dinhata, Mathabhanga, Mekhliganj etc.. The kings (including the queens and king's representatives) planned to dig new dighi before establishing new towns in accordance with capital change or transfer. Thus most of the ponds were dug and beautified as a part of the plan.

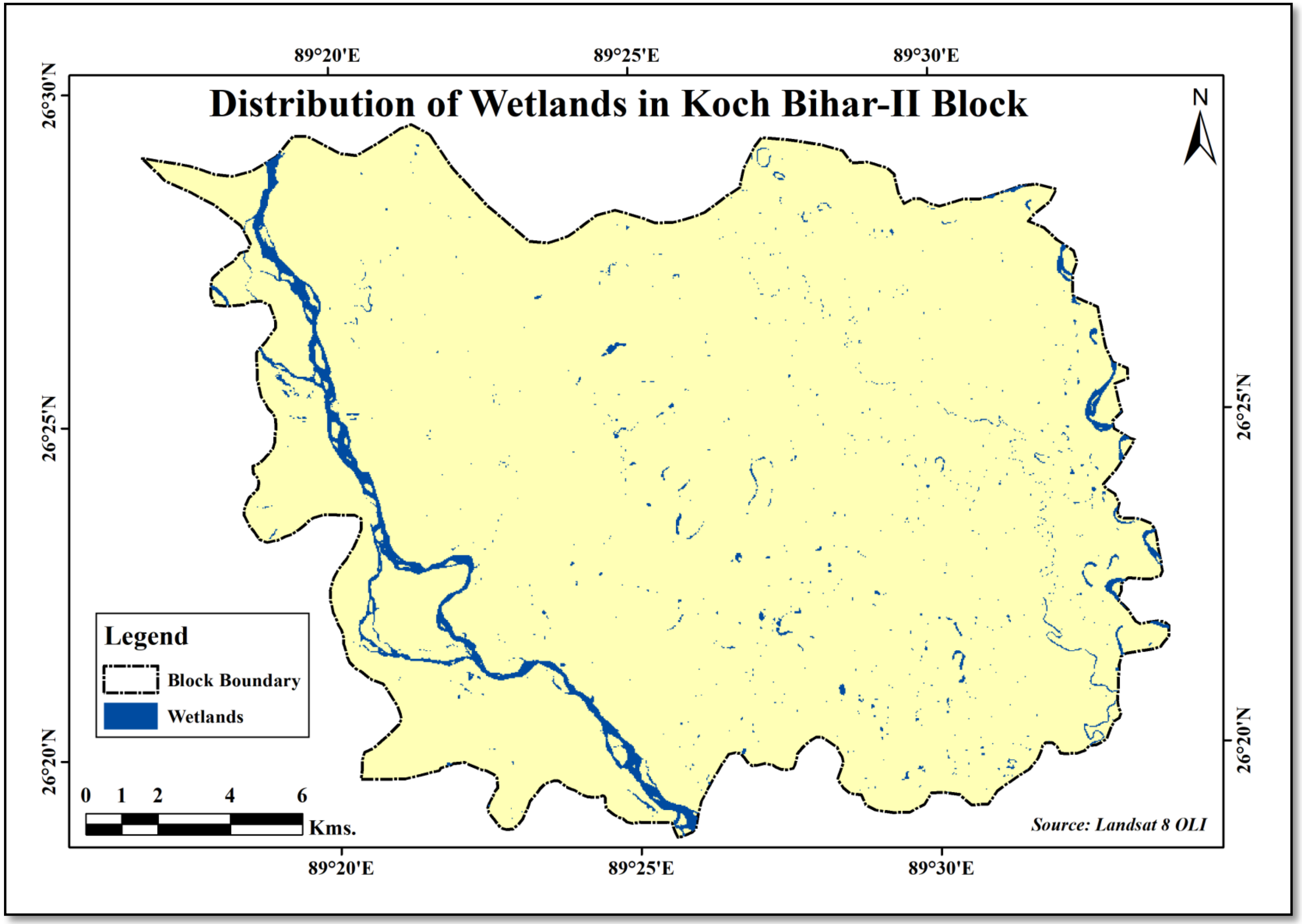
During the reign of the kings, there were approximately 27 ponds in the Koch Bihar district (vide town committee and municipality), of which Sagar Dighi is the largest. Presently some of these ponds are illegally occupied by persons, which are a burning example of greed and imprudence of the people. The ponds which are existing namely Sagar Dighi, Bairagi Dighi, Rajmata Dighi, Yamuna Dighi, Park Dighi ,Narasingha Dighi, Dangari Dighi, Kaiyan Dighi, Debibari Dighi, Rajbari Jheel, Durga Bari Dighi, Natun Bazar Dighi, Barrack Dighi etc.



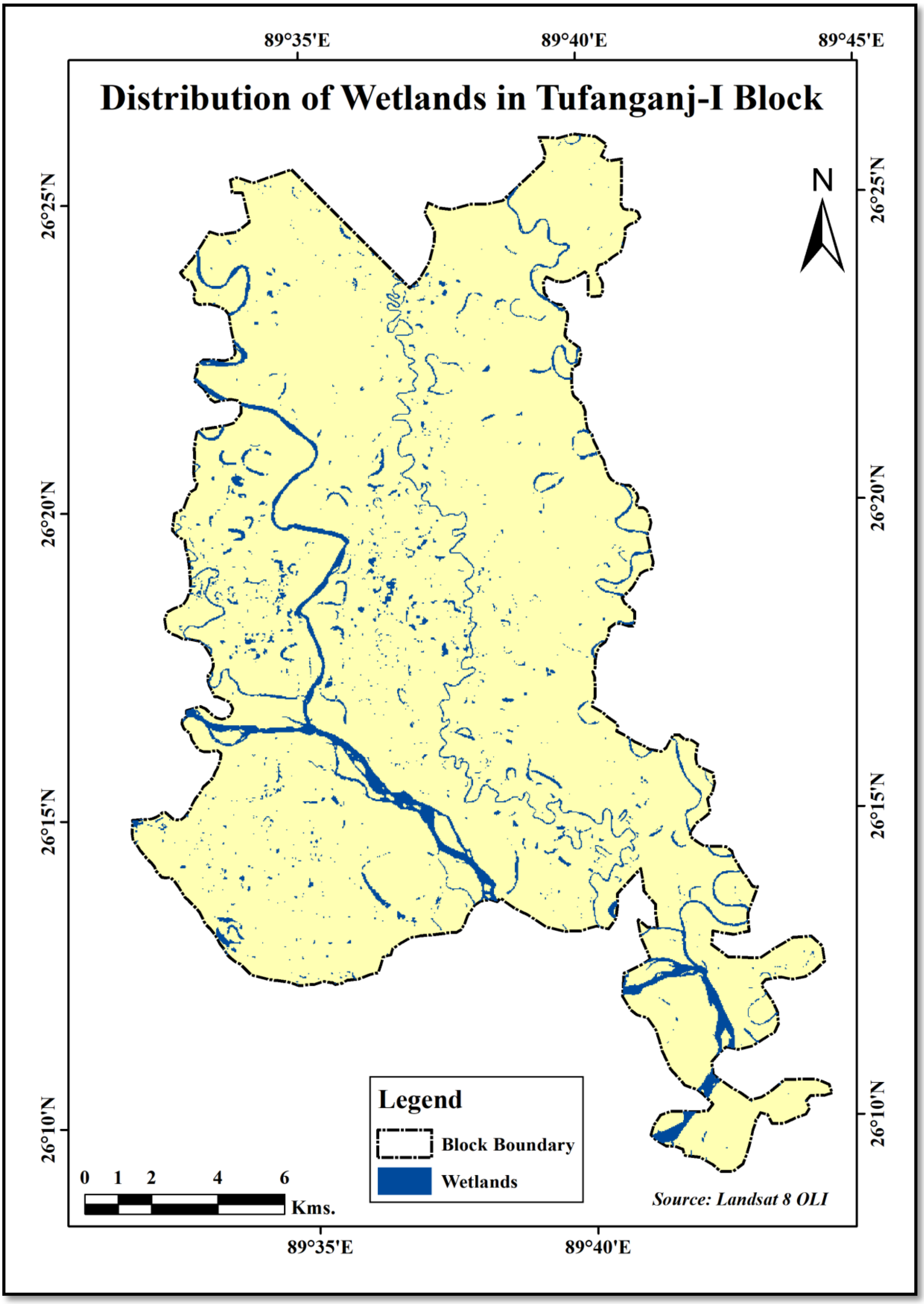
Map 3.4: Distribution of Wetland in the Study Area, 2017



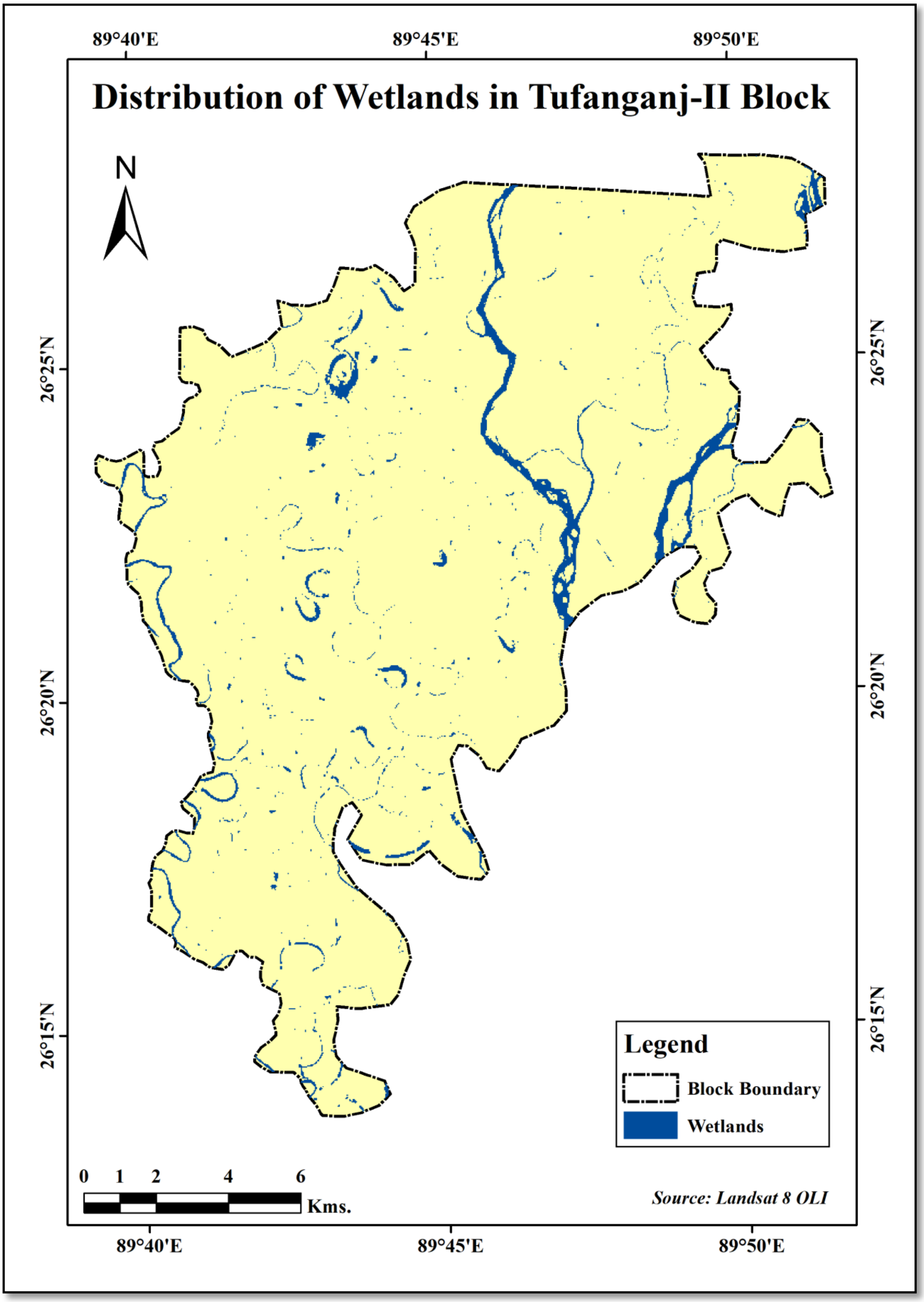
Map 3.5: Distribution of Wetland of Koch Bihar-I, 2016



Map 3.6: Distribution of Wetland of Tufanganj-II, 2016



Map 3.7: Distribution of Wetland of Tufanganj-I, 2016



Map 3.8: Distribution of Wetland of Tufanganj-II, 2016

Table 3.10:Block-Wise Water Bodies under Fish Farmers Development Agency (F.F.D.A) in the Study Area

Sl No.	Name of the Block	Area of water bodies (Ha)	No of wetlands	Average Size of wetland (Ha)
1	Koch Bihar -I	347.5281	35	9.93
2	Koch Bihar -II	145.2661	15	9.68
3	Tufanganj-I	308.217	20	15.41
4	Tufanganj-II	103.5025	15	6.90

Source: Department of Fisheries, Koch Bihar District, 2016

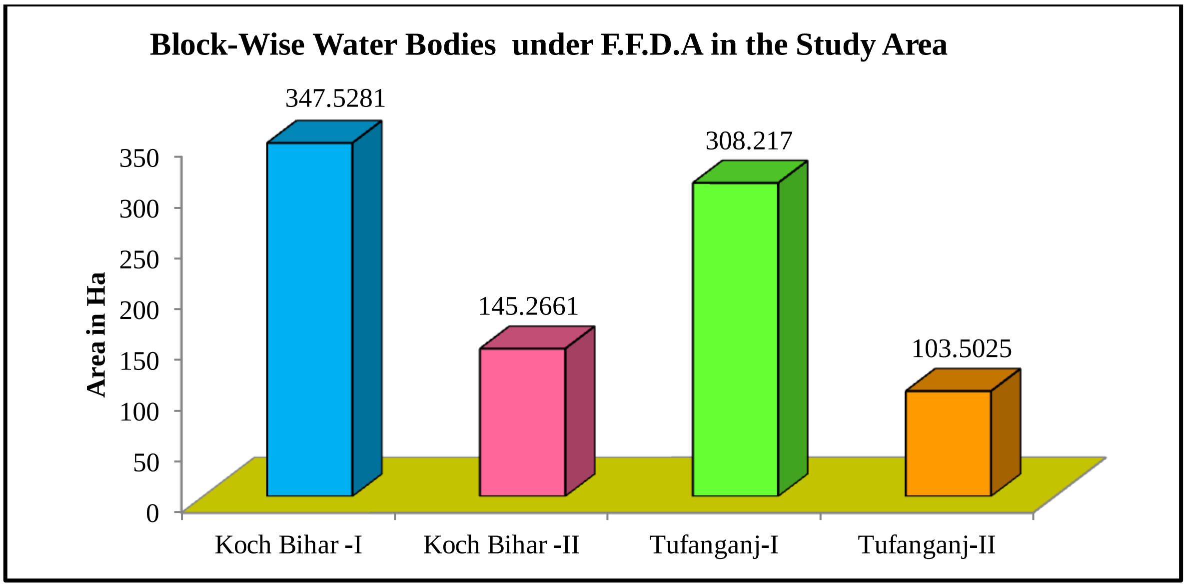


Fig 3.14:Water Bodies under Fish Farmers Development Agency (F.F.D.A) in the Study Area

Table 3.11: Block-Wise Wetland Distribution in the Study Area

Sl no	Block	Wetland area ha	% of total wetland area	% of Block geographic area
1	Koch Bihar - I	1362.13	25.53	3.69
2	Koch Bihar - II	1103.093	20.68	4.15
3	Tufanganj - I	1885.989	35.35	5.88
4	Tufanganj - II	983.7143	18.44	3.70
	Total	5334.9259	100	

Source: Landsat-8, OLI, (2017); Area Estimated by Researcher (excluding river area)

The total area of wetlands differs from block to block. It is highest in Tufanganj–I(1885.99 ha) followed by Koch Bihar–I (1362.13 ha), Koch Bihar–II(1103.09 ha) and Tufanganj-II(983.71 ha) (Table 3.11 & fig 3.14). But block-wise water area under fish farmers development agency (F.F.D.A) in the study area are shown very small than the estimated block- wise wetland area. It is highest in Koch Bihar–I (347.53 ha), followed by Tufanganj–I (308.22 ha) Koch Bihar–II (145.27 ha) and Tufanganj-II (103.50 ha) (Table 3.10 & fig 3.14).

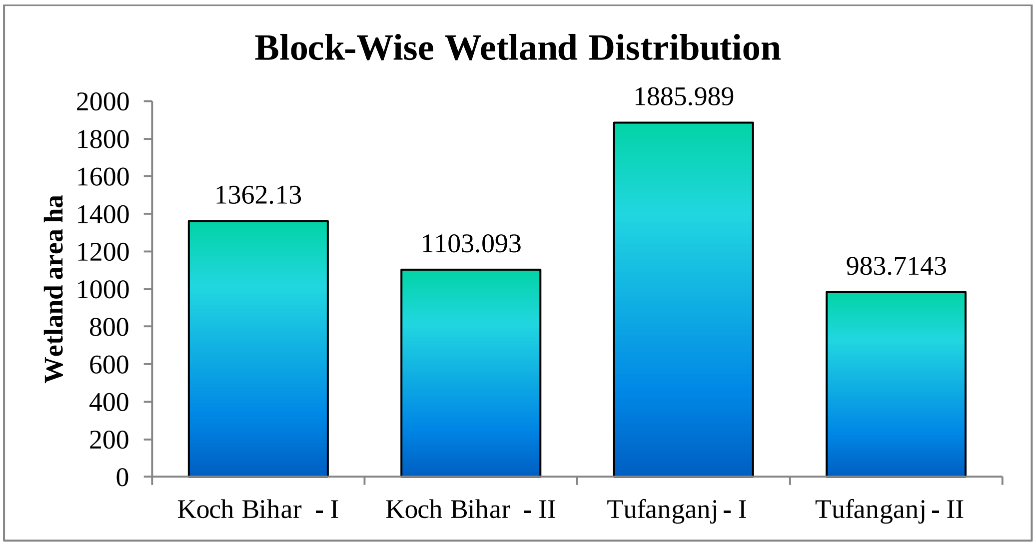


Fig 3.15: Block-Wise Wetland Distribution in the Study Area

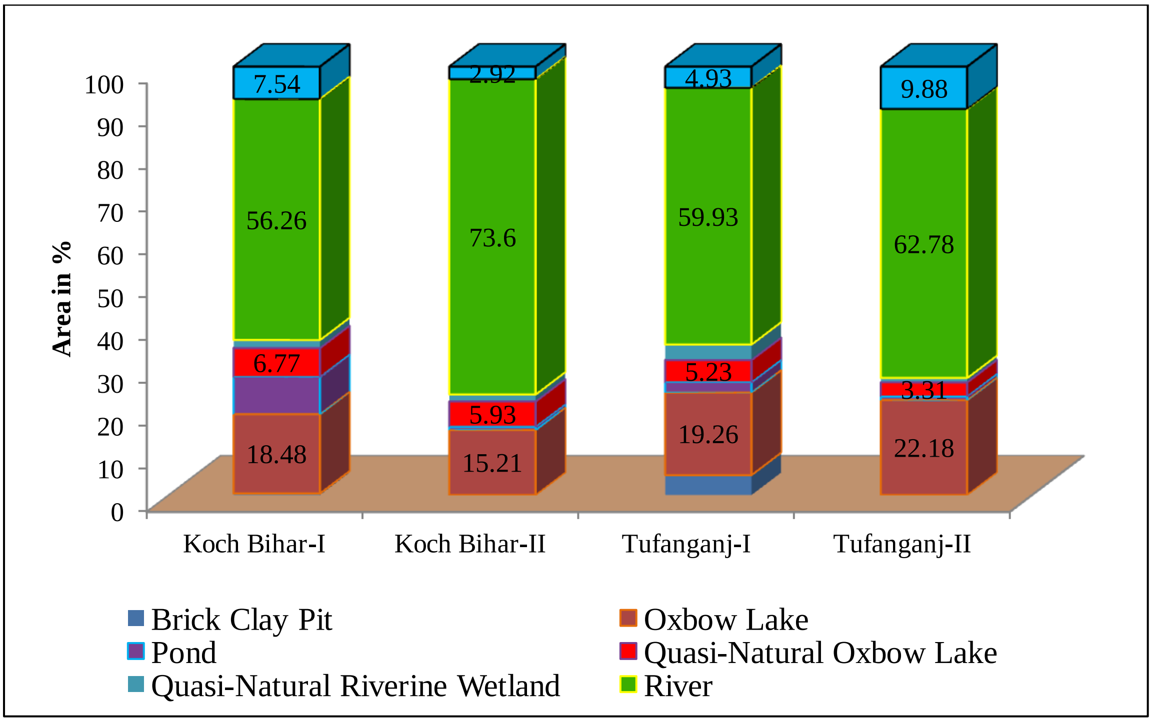


Fig 3.16: Distribution of Different Types of Wetland (Area in Ha), Koch Bihar &Tufanganj Subdivision, 2017

3.3.5.2. Type-wise Distribution of Wetland in Different Blocks of the Study Area:

Type-wise distribution of wetlands in different blocks of the study area was done with IRS P6 Resource sat 2, LISS-IV satellite image and intensive field verifications. The estimated values about type-wise distribution of wetlands in different blocks of the study area are given in the table 3.12 and presented in the figure 3.16 & map 3.9. Total area of the Wetland in the district is 7898 Ha in which River area is 4982 Ha (63.08%) followed by 1465 Ha (18.55%), Riverine Wetland 483 Ha (6.12%), Quasi-Natural Oxbow Lake 4323 Ha (5.47 %), Pond 268 Ha (3.39%), Quasi-Natural Riverine Wetland 165 Ha (2.09 %) and Brick Clay Pit 103 Ha (1.3 %).

Table 3.12: Distribution of Different Types of Wetland (Area in Ha), Koch Bihar &Tufanganj Subdivision, 2017

Block	Koch Bihar-I			Koch Bihar-II			Tufanganj-I			Tufanganj-II			Total		
Types of Wetland	No of Wetland	Area in Ha	Area in %	No of Wetland	Area in Ha	Area in %	No of Wetland	Area in Ha	Area in %	No of Wetland	Area in Ha	Area in %	No of Wetland	Area in Ha	Area in %
Brick Clay Pit	5	9	0.4	-	-	-	19	94	4.68	-	-	-	24	103	1.3
Oxbow Lake	13	412	18.48	13	318	15.21	32	387	19.26	16	348	22.18	74	1465	18.55
Pond	171	193	8.66	31	15	0.72	25	47	2.34	10	13	0.83	237	268	3.39
Quasi-Natural Oxbow Lake	7	151	6.77	9	124	5.93	17	105	5.23	4	52	3.31	37	432	5.47
Quasi-Natural Riverine Wetland	6	42	1.88	6	34	1.63	10	73	3.63	3	16	1.02	25	165	2.09
River	-	1254	56.26	-	1539	73.6	-	1204	59.93	-	985	62.78	0	4982	63.08
Riverine Wetland	28	168	7.54	15	61	2.92	25	99	4.93	21	155	9.88	89	483	6.12
Total	230	2229	100	74	2091	100	128	2009	100	54	1569	100	486	7898	100

Source: IRS P6 Resourcesat2, LISS-IV, 2017 and Field Survey

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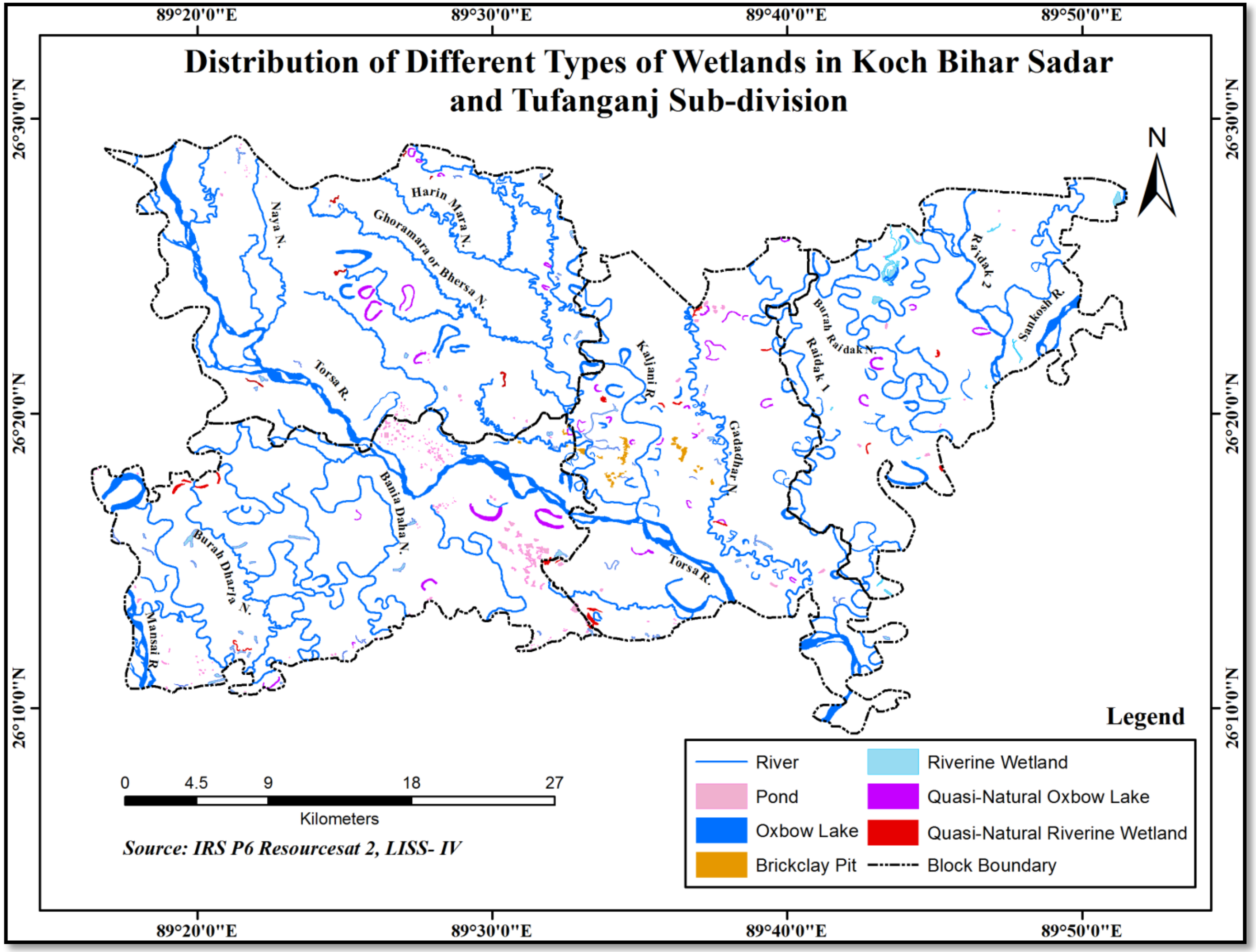


Map 3.9: Distribution of Different Types of Wetlands in Study Area, 2017

In Tufanganj-II riverine wetland share (9.88%) of the Wetland area, in Koch Bihar-I 7.54%, Tufanganj-I (4.93%) and Koch Bihar-II share 7.54%. The Quasi-Natural Oxbow Lake area observed in Koch Bihar-I (8.66%), Koch Bihar-II (5.93%), Tufanganj-I (5.23%) and in Tufanganj-II (3.31%). Highest Pond area observed in Koch Bihar-I (8.66%), only 2.43% area of Pond found in Tufanganj-I (2.34%), 0.83% in Tufanganj-II and 0.72% in Koch Bihar-II. Only 3.63% Quasi-Natural Riverine Wetland area observed in Tufanganj-I, 1.88 % in Koch Bihar-I, 1.63 % in Koch Bihar-II and only 1.02 % observed in Tufanganj-II. Brick Kiln Pit only found in Tufanganj-I (4.68 5) and only 0.4 % area observed in Koch Bihar-I (table 3.12).

3.3.5.2.1. Type-Wise Distribution of Wetlandin Koch Bihar-I:

From the fig-3.17 and map-3.10 it is clear that in Koch Bihar-I has the highest area covered by rivers (1254 hectare, 56.26 percentage) followed by oxbow lakes (412 hectare, 18.48 percentage), Ponds (193 hectare, 9.00 percentage), Riverine Wetlands (168 hectare, 7.54 percentage), Quasi-Natural Oxbow Lakes (151 hectare, 6.77 percentage), Quasi-Natural Riverine Wetlands (42 hectare, 1.88 percentage) and brick clay pits (9 hectare, 0.44 percentage) (Fig-3.17).

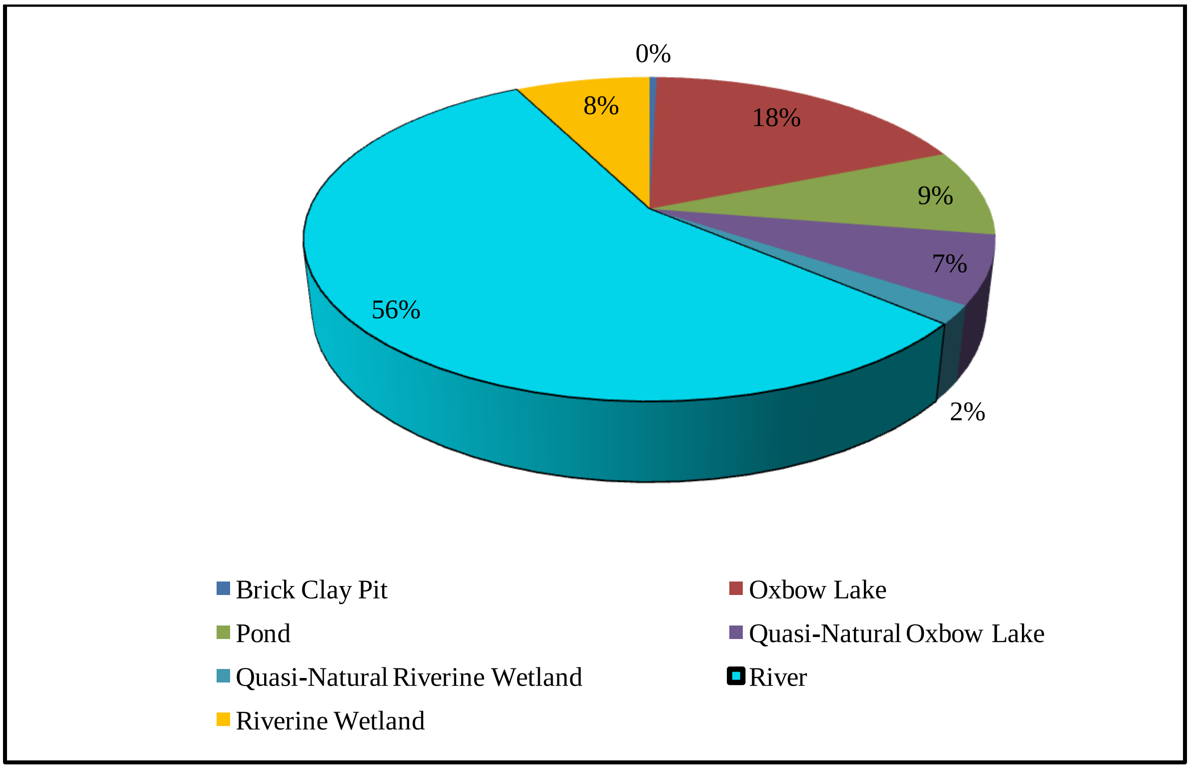
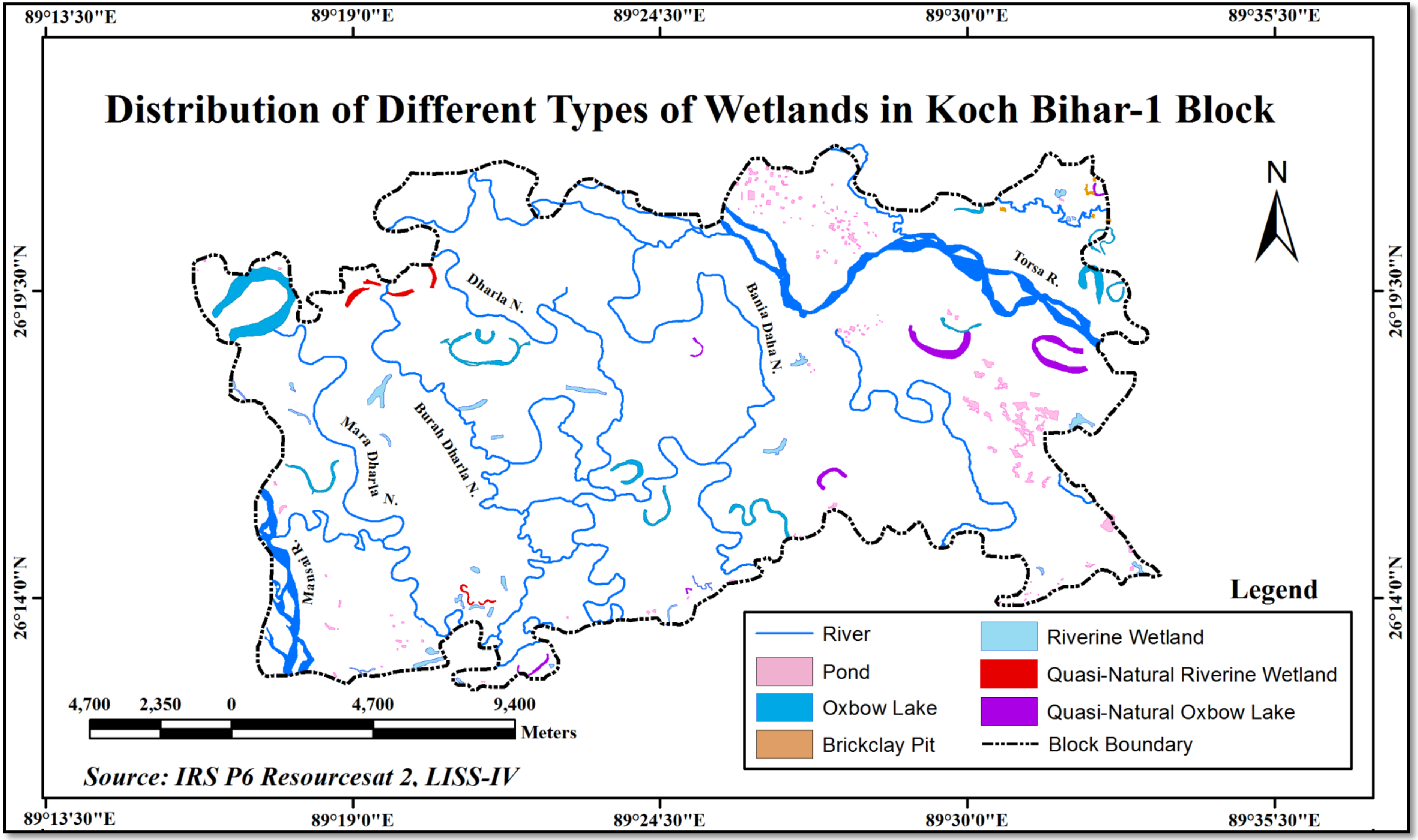
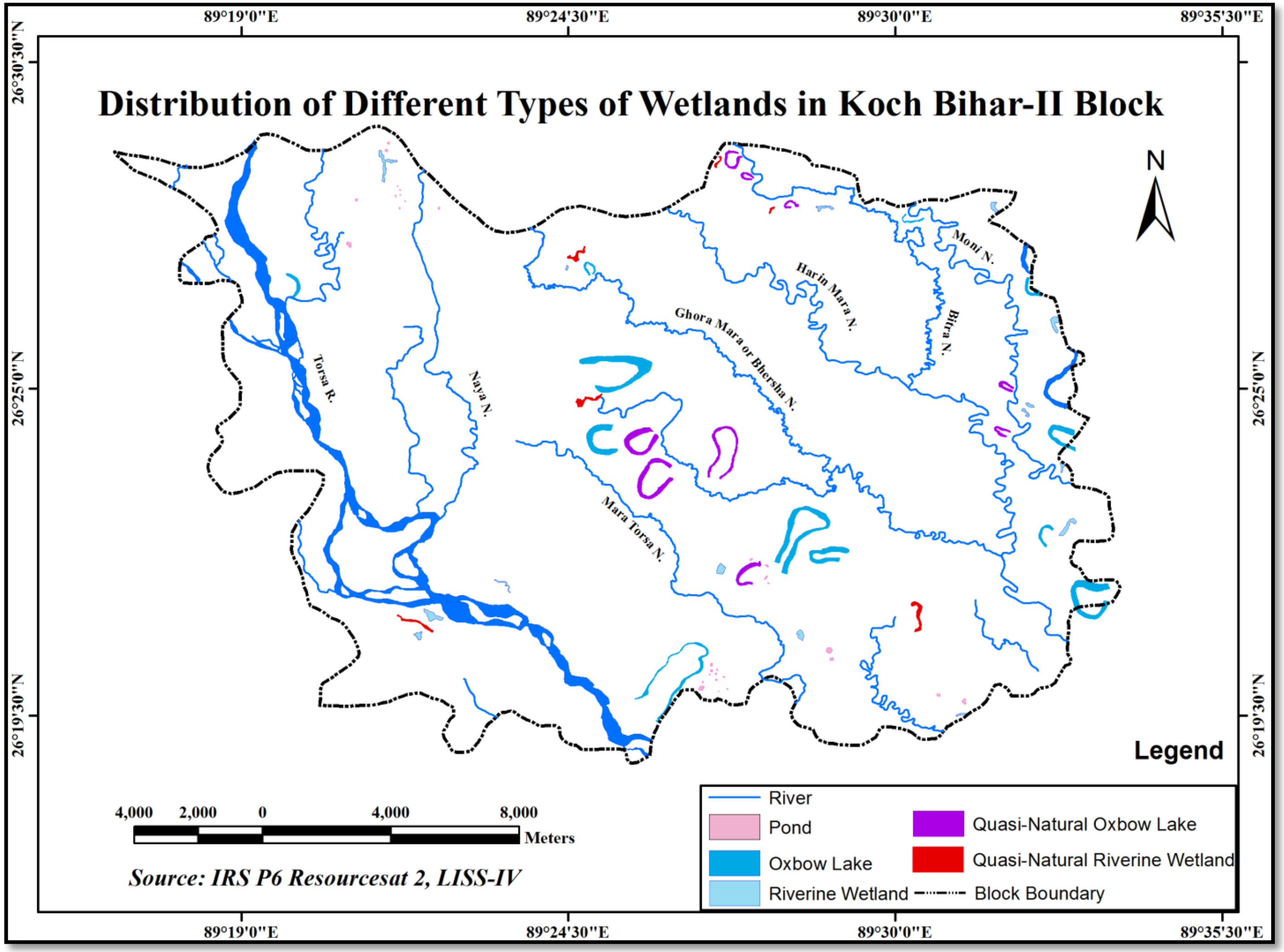


Fig 3.17: Distribution of Different Types of Wetlands in Koch Bihar-I, 2017



Map 3.10: Distribution of Different Types of Wetlands in Koch Bihar-I, 2017



Map 3.11: Distribution of Different Types of Wetlands in Koch Bihar-II, 2017

3.3.5.2.2. Type-Wise Distribution of Wetlandin Koch Bihar-II:

The fig-3.18 and map-3.11 shows that, the highest wetland area in Koch Bihar-II block is covered by Rivers (1539 hectare, 73.60 percentage) followed by Oxbow Lakes (318 hectares, 15.21 percentage), Quasi-Natural Oxbow Lakes (124 hectare, 5.93 percentage), Riverine Wetlands (61 hectare, 2.92 percentage), Quasi-Natural Riverine Wetlands (34 hectare, 1.63 percentage) and Ponds (15 hectare, 0.72 percentage).

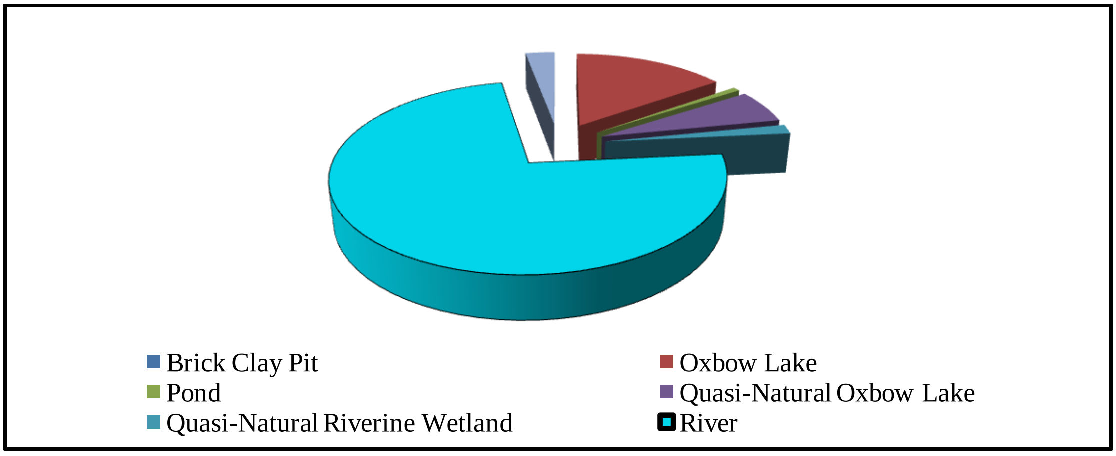


Fig 3.18: Distribution of Different Types of Wetlands in Koch Bihar-II, 2017

3.3.5.2.3. Type-Wise Distribution of Wetlandin Tufanganj-I:

In case of Tufanganj-I block 59.93 percentage area is covered by rivers (1204 hectares), followed by Oxbow Lakes (19.26 percentage), Quasi-Natural Oxbow Lakes (5.23 percentage), Riverine Wetlands (4.93), Brick Clay Pits (4.68 percentage), Quasi-Natural Riverine Wetlands (3.63 percentage), and Ponds (2.34 percentage). (Fig-3.19 and Map-3.12)

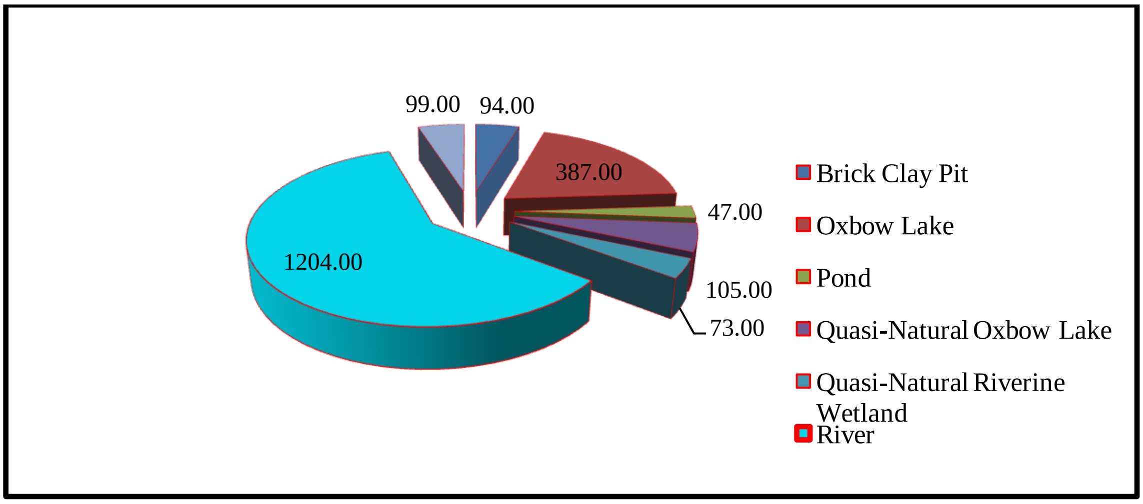
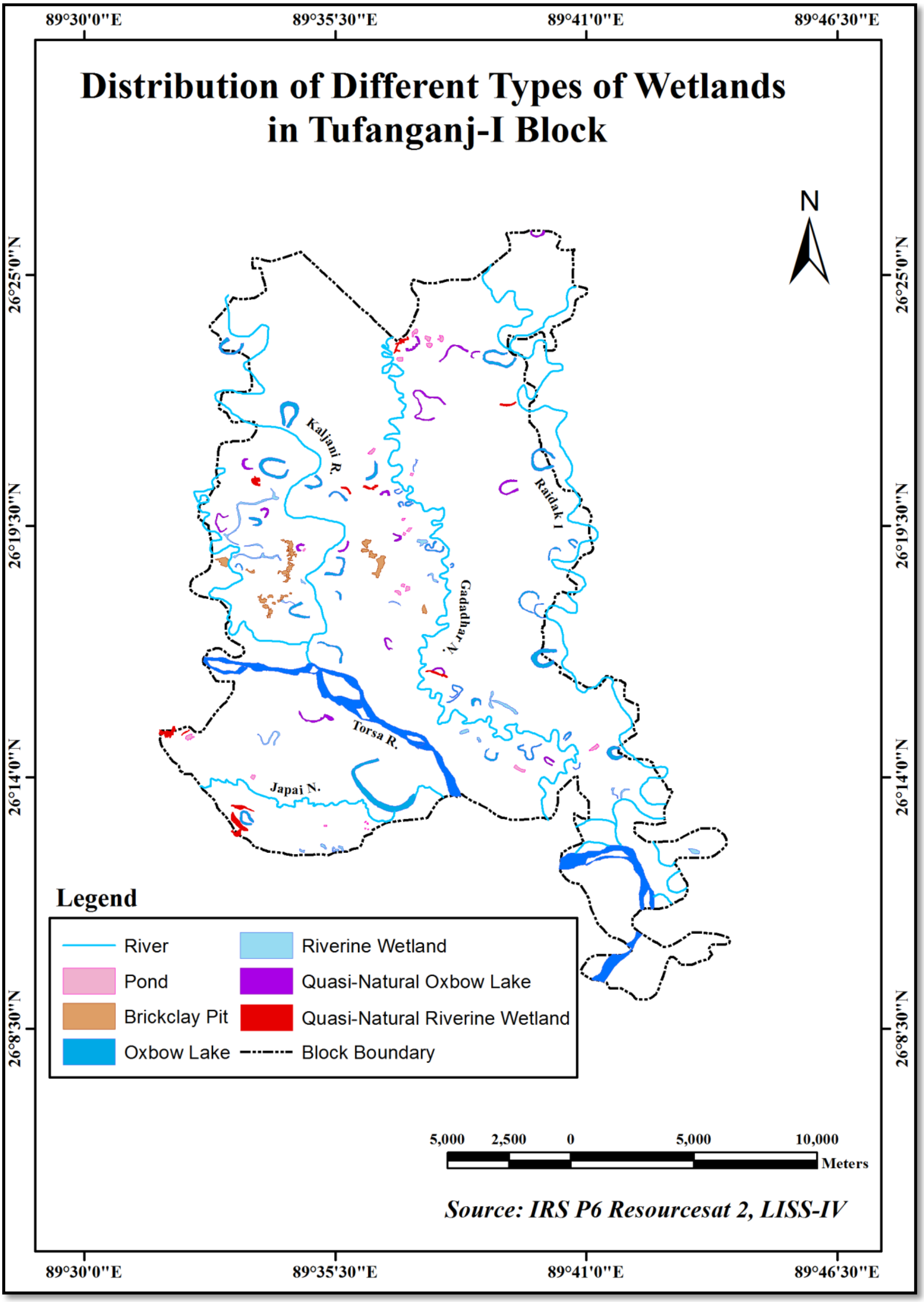
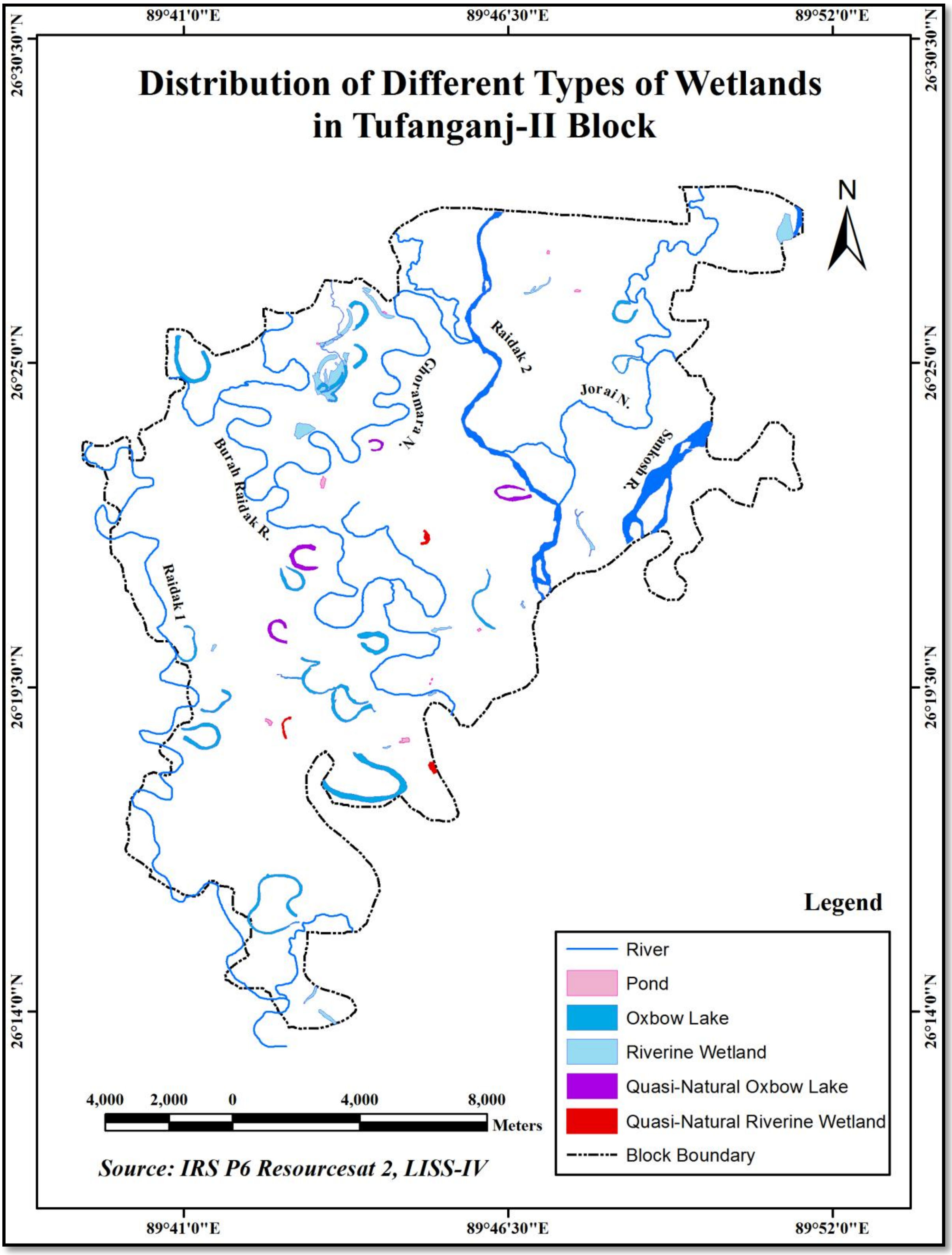


Fig 3.19: Distribution of Different Types of Wetlands in Tufanganj-I, 2017



Map 3.12: Distribution of Different Types of Wetlands in Tufanganj-I, 2017



Map 3.13: Distribution of Different Types of Wetlands in Tufanganj-II, 2017

3.3.5.2.4. Type-wise Distribution of Wetlandin Tufanganj-II:

In Tufanganj-II the highest area is shared by the rivers (62.78 percentage) followed by Oxbow Lakes (22.18 percentage), Riverine Wetlands (9.88 percentage), Quasi-Natural oxbow Wetlands (3.31 percentage), Quasi-Natural Riverine Wetlands (1.02 percentage) and Ponds (0.83 percentage). (Fig-3.20 and Map 3.13)

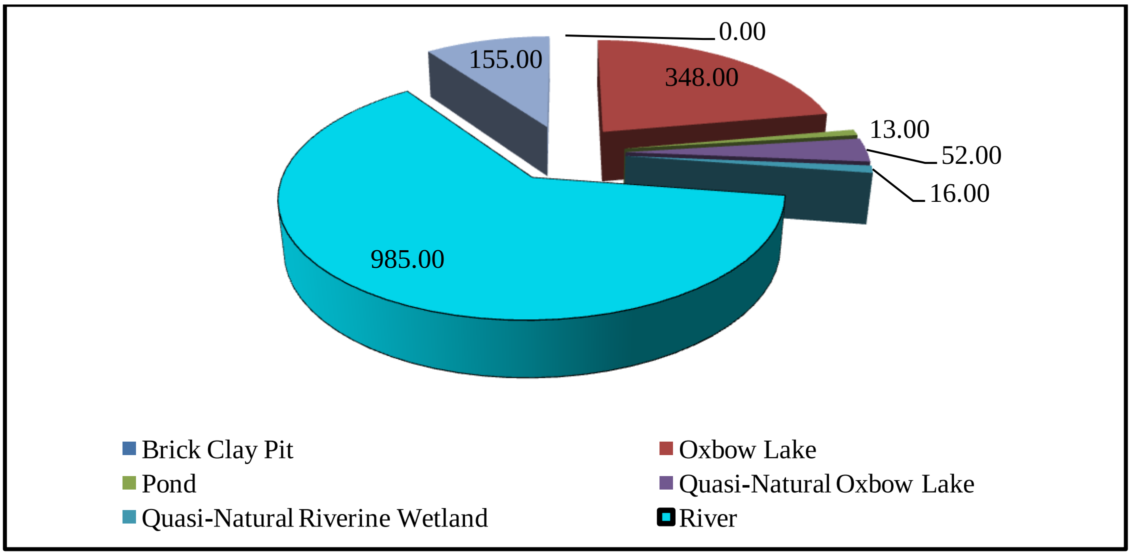


Fig 3.20: Distribution of Different Types of Wetlands in Tufanganj-II, 2017

3.3.5.3. Distribution of Wetland of the Study Area according to Nearest River:

The distance decay analysis of wetlands from the nearest rivers shows that the distribution of the wetland is very much dominated by the river systems of the area (Table 3.13). All ox-bow lakes or cut off meanders, riverine wetlands are directly created by the streams and the distributional pattern and layout of the wetlands are dominated by the nearest streams/ rivers. The variation of the distribution of wetlands is mainly due to their physiographic characteristics, the peculiar hydrological behaviour of the rivers. It is found that about 53.34% wetlands are formed within the distance of 0.5 km from the river and about 80% of the wetlands are formed within the distance of 1 km from the river (Table 3.13 & Fig 3.21). Therefore, it can be concluded that wetlands are more or less related to the river systems of the study area.

Table 3.13: Distribution of Wetland according to Nearest River

Sl. No.	River Name	Number of Wetland	Total Distance (metre)	Average distance (metre)
1	Mansai R	2	2042	1,021.00
2	Mara dharla N.	11	7191	653.73
3	Buradharla N.	13	7660	589.23
4	Dharla N.	7	3979	568.43
5	Baniadaha N.	8	6005	750.625
6	Mara mansai N.	2	2865	1,432.50
7	Jhapai N.	12	16412	1,367.67
8	Torsa N.	13	9143	703.31
9	Naya N.	1	754	754
10	Mara torsa N.	3	2886	962
11	Gadadhar N.	29	12713	438.38
12	Kaljani N.	24	12009	500.375
13	Ghargharia N.	15	7068	471.2
14	Raidak-I	25	13956	558.24
15	Burharaidak R.	18	12579	698.83
16	Raidak-II	5	2572	514.4
17	Jorai N.	2	1757	878.5
18	Buratorsa N	2	0	0
19	Sankosh R	1	0	0
20	Ghoramara R	8	5035	629.375
21	Nautara N	6	1880	313.3333
22	Mara Nautara N	7	3267	466.7143
23	Bitra N	6	1442	240.3333
24	Mone N	5	853	170.6

Source: LISS III, OLI-8

Table 3.14: Wetland Distance from River in the Study Area

Wetland Distance from the River in Metre	Number of Wetland	%
0-250	71	31.56
250-500	49	21.78
500-750	41	18.22
750-1000	19	8.44
1000-1250	15	6.67
1250-1500	9	4.00
1500-1750	13	5.78
1750-2000	7	3.11
2000-2250	1	0.44

Source: LISS III, OLI-8, 2017

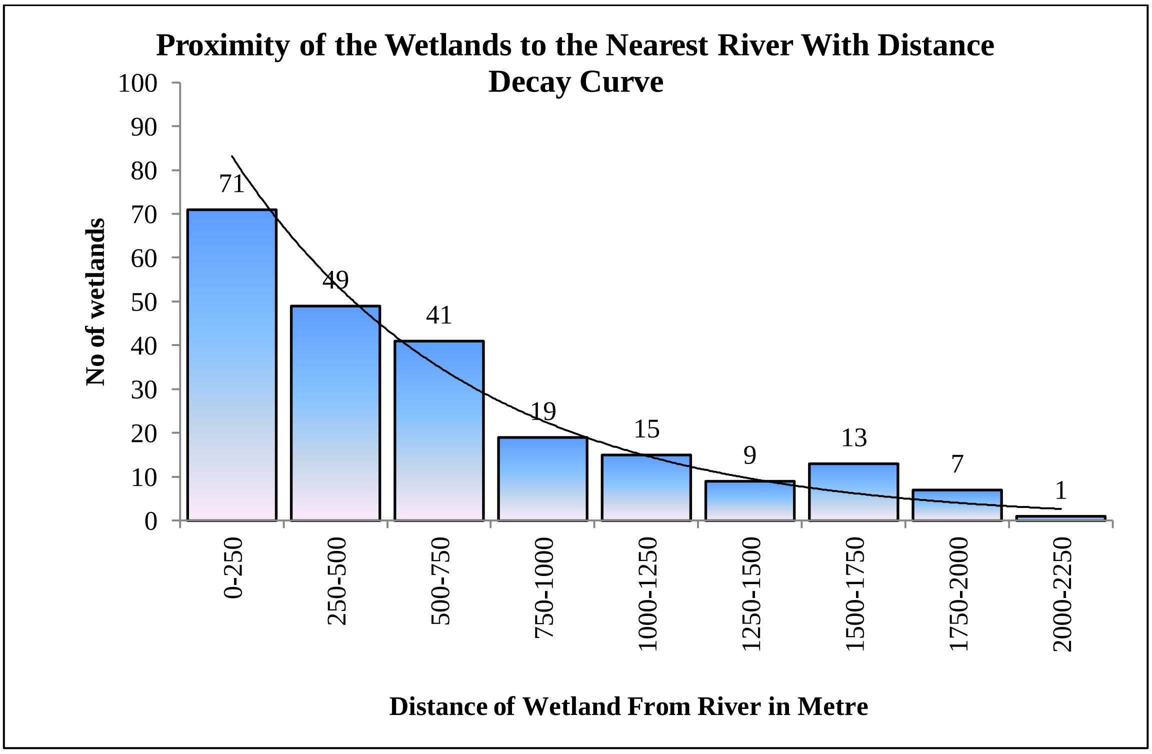


Fig 3.21: Distance Decay Analysis of Wetland

3.4. Conclusion:

There were mainly two types of wetlands, namely natural and manmade, but it is very clear from survey that most of the natural wetlands are largely modified by different anthropogenic activities, which form a new type of wetland called quasi-natural wetland. Therefore, the wetlands of the study area are divided into three broad categories. In the study area, apart from rivers (63.08%), the most dominant wetland types are oxbow lake (18.55%) followed by Riverine Wetlands (6.12%), Quasi-Natural Oxbow Lakes (5.47%), pond (3.39%), Quasi-Natural Riverine Wetlands (2.09%), Brick Clay Pits (1.3%). The wetlands are not evenly distributed in the study area. The highest wetland area is identified in Koch Bihar–I (2229 ha), followed by Koch Bihar–II (2091 ha), Tufanganj–I (2009 ha) and Tufanganj-II (1569 ha). (Table 3.12)

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CHAPTER-IV

PRESENT USE OF WETLANDS

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4.1. Introduction:

From the dawn of the human civilization, wetlands encompass all aspects of livelihood. Wetlands have been recognized as one of the key life-support systems on the earth in addition to the agricultural lands and forestlands. They form a vital element of national and global ecosystems and economies (Senaratna, 2011). Wetlands are important natural resources and significant for the biodiversity stock and its preservation. They are significant in environmental functions and important in all food chains (Rouvalis, 1998). At present wetlands are the most exploited and threatened ecosystem. The common use of wetland comprises fishing, cultivation, irrigation, jute retting, fodder collection, bathing, washing clothes and utensils, duck rearing and other household activities. The survival of these wetlands and their resources are not only important for human sustenance and economy but also perform ecological functions by preserving the endemic species.

4.2. Common Use of Wetlands in the Study Area:

The common use wetlands of the study area are summarized below-

4.2.1. Agriculture:

With the advent of 20th century, agricultural practices were marked by technological innovations; demographic changes and new varieties of crops like the boro paddy, which is now under the agricultural practice in the shallow water areas and the dry areas of the wetlands (Photo Plate 4.2). Owing to the high nutrient value of wetland soil and water, the cultivation in the wetland is a common practice (boro paddy and other dry-season crops) where farmers expect a higher yield of paddy. Cultivation starts in the month of January every year. When the wetland bed starts drying up, the farmers having ownership of the wetland bed convert them into agricultural lands. It is observed that once wetland beds are converted, they can never regain their original status. In the study area, most of the surveyed wetlands are converted into agricultural lands during pre-monsoon season for the cultivation of boro paddy. The present trend of farmers is using fertile wetland soil as seedbed for boro crops. During monsoon, these lands are engulfed by rising water of the wetlands during which essential nutrients are restored making it ready for cultivation in the next year. Among the 6 selected wetlands, Baiganbari Chhara is predominately used for agriculture during the post-monsoon period, which amounts to about 77.35% of the wetland area (Table 4.17).

Photo Plate 4.1: Seed bed of Boro Cultivation in Rasik Beel, Tufanganj-II

Photo Plate 4.2: Boro Cultivation in Baiganbari Chara, Koch Bihar-II

4.2.2. Irrigation:

The water from the wetlands are being used for irrigation in the surrounding agricultural fields and in the edges of wetland, which dry up during the pre pre-monsoon and are consequently converted into arable lands. They are irrigated mostly using the wetland water because the nutrient content of the water is comparatively higher than the ground and river water and it helps the farmers to cut down their costs on fertilizers. However, practising seasonal agriculture in and around wetlands or withdrawing larger amounts of water for irrigation risk the ecological character of the wetlands which may be altered to the point where the essential regulating and supporting services are lost. Wetlands are also used for irrigation purpose in the study area. 29 lift Irrigation were found around the Rasik Beel, 23 lift irrigation in Baigunbari Chhara and 6 lift irrigation observed in Dhangdhar Chhara (Table 4.1). A huge amount of water was withdrawn during the Boro cultivation (Winter Season).

Table 4.1: Lift Irrigation from Sample Wetland

Sample site	**No. of Lift Irrigation**
Rasik Beel wetland complex	29
Dhangdhar Chhara	6
Rasomati Jheel	0
Baiganbari Chhara	23
Chandan Dighi	0
Sagar Dighi	0
Total	58

Source: Field survey, 2017

Photo Plate 4.3: Withdrawal of Water for Irrigation, Rasik Beel, Tufanganj-II

Photo Plate 4.4: Jute Retting in Bochamari Beel, Tufanganj-II

4.2.3. Jute Retting:

Jute (White Jute –Corchours capsularis and Tossa Jute –Corchorus olitorius) is one of the most important commercial crops in the study area. During monsoon, almost all of the wetlands are used for jute retting by a large number of farmers from surrounding areas. Jute is a commercial crop, and jute sticks (*pat kathi*) are of immense value for the indigenous people, they are used for house walling, fencing, as fire wood, and also for various religious purposes. There are mainly three methods of jute retting: chemical, biological and instrumental. In the study area biological jute retting is mostly practiced due to low cost and the fact that they hardly require to pay rent to the wetland owners. Traditionally farmers use the beel water for jute retting; however, some farmers prefer to use their own pond or *Doba*. The largest area employed in jute retting, among the surveyed wetlands, is in Baiganbari Chhara (350 bigha) followed by Haripur Beel (130 bigha), Kankanguri-Naya Chhara (120 bigha), Bara Bochamari Beel (80 bigha), choto Bochamari Beel (60 bigha), Bherbheri (50 bigha) (Table 4.2).

Table 4.2: Amount of Jute Retting in Different Wetlands

Sample site	Jute retting Site	Amount in Bigha
Bara Bochamari Beel	1	80
Bherbheri	1	50
Choto Bochamari Beel	1	60
Baiganbari Chhara	1	350
Haripur Beel	1	130
Kankanguri-Naya Chhara	1	120

Source-Field Survey, 2017

4.2.4. Fish Hunting:

Koch Bihar is gifted with many water bodies commonly known as *beels/chhara* that are the only source of fish for the poor people in the surrounding villages. Historically there have been three distinct groups of people involved in organized Fish hunting in the *beels*: (i) those that fish for their daily consumption; (ii) the fishing community who depend on fishing for their livelihood; and (iii) rural entrepreneurs (leaseholders) who hardly spare fry or fingerlings of any variety in the wetlands during any season. Ordinary people usually catch fish for consumption, while fishermen are full-time operators working independently or under the lease. Fishing is very common in Rasik Beel where 86% surveyed household practice fishing followed by Baiganbari Chhara (58.75%)(Table 4.4).

Photo Plate 4.5: Fishing in Baiganbari Chara, Koch Bihar-II

Photo Plate 4.6: Fishing in Dhangdhar Chhara, Tufanganj-I

4.2.5. Pisciculture:

The breeding, rearing, and transplantation of fish by artificial means is called pisciculture or fish farming. It involves raising fish commercially in tanks, beels, dead river etc. usually for human consumption. As fish is common and important nutrient source of people, the demand for fish is much higher than the local fish supply, which makes pisciculture a profitable business. Pisciculture is practiced mainly in the ponds, quasi-natural oxbow and quasi-natural riverine wetlands in the study area. Fish species raised by the fish farms include katla, tilapia etc

Table 4.3: Particulars of Fisheries in the Blocks of Koch Bihar for the Year2012-13

Name of Block	Area available for pisciculture (Ha)	% of Area available for Pisciculture	Area under effective pisciculture (Ha)	% of Area under effective pisciculture	% of Effective Pisciculture
Koch Bihar-I	858.17	38.56	410.88	34.79	47.88
Koch Bihar-II	461.21	20.73	290.50	24.60	62.99
Tufanganj-I	527.36	23.70	297.06	25.15	56.33
Tufanganj-II	378.55	17.01	182.49	15.45	48.21
Total	2225.29	100.00	1180.93	100.00	

Source: Hand Book on Fisheries Statistics, 2015-16

Fig- 4.1 depicts Koch Bihar-I (858.17) having the highest area under pisciculture followed by Tufanganj-I (527.36 Ha). Tufanganj-II (378.55 Ha) has the least amount of area available for pisciculture. However, in terms of highest percentage of effective pisciculture, Kochbihar-II ranks the highest (62.99%).

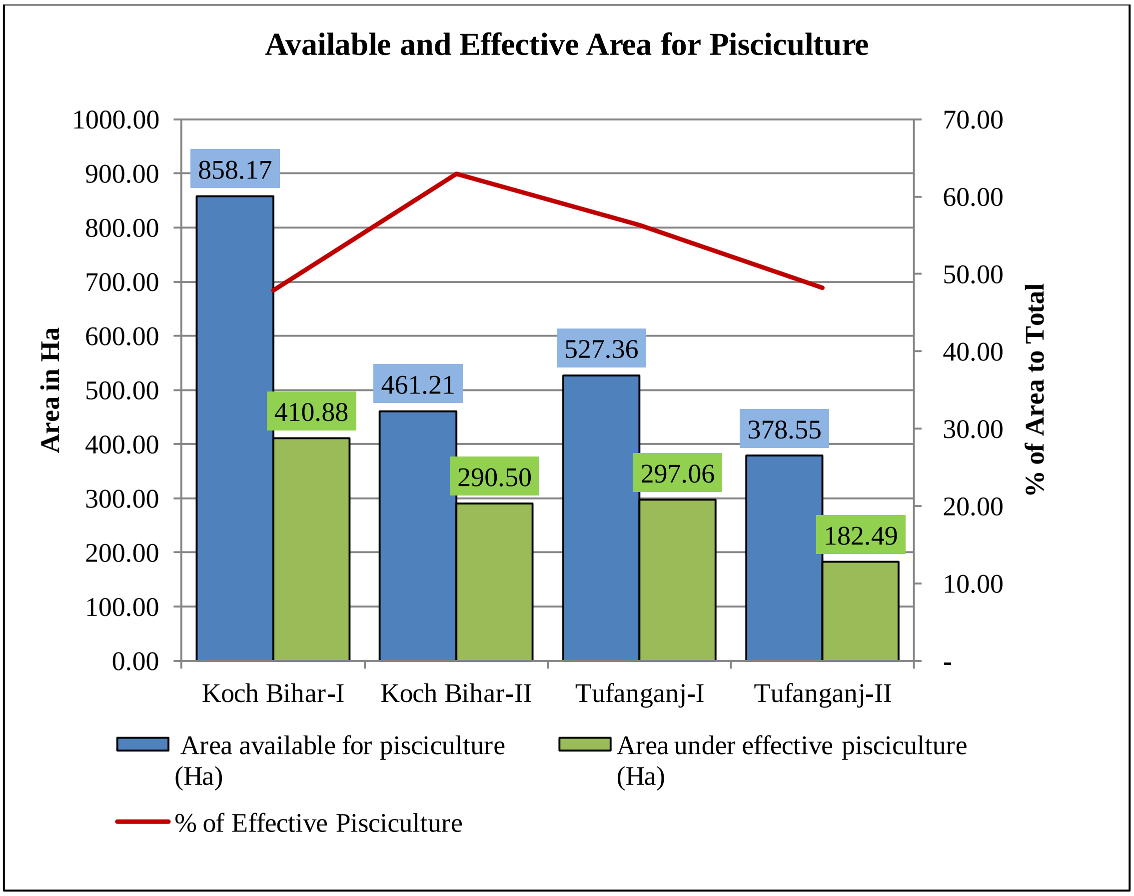


Fig 4.1: Available and Effective Area for Pisciculture

4.2.6. Fodder Collection:

Fodder collection is also an important activity in rural wetlands of the study area. Farmers collect various water-born vegetation sand supplement fodder for their livestock in monsoon and post-monsoon periods. In the dry season when the grasses dry up wetlands become the only source of fodder. Households who don't have any agricultural land collect fodder from the wetlands all throughout the year. The important fodder plants (aquatic and climber) are *Saccharum spontaneum (kash), Cynodon dectylon, Alternanthera paronychioides, Alternanthera sessilis, Coix lachryma-jobi, Eichhornia crassipes, Enydra fluctuans, Hygroryza aristata, Ipomoea aquatica, Monochoria hastate.*

Photo Plate 4.7: Fodder Collection in Rasomati Jheel, Koch Bihar-II

Photo Plate 4.8: Soil Quarrying in Baiganbari Chara, Koch Bihar-II

4.2.7. Grazing:

Grazing on wetland and wetland surrounding areas is practiced for four to twelve months in a year. Due to a low slope in the edges of the wetland and low depth of water, it becomes easy for cattle population to access grass and other fodder plants. The water level in the wetlands remains low during winter and summer season with huge spaces in and around the wetlands which makes grazing on wetlands a vital occupation. In the study area Baiganbari Chhara (56% household), Dhangdhar Chhara (34% household), Rasik Beel (23% household), and Rasomati Jheel (15% household) play a vital role for grazing (Table 4.4).

Photo Plate 4.9: Grazing in Rasomoti Jheel, Koch Bihar-II

Photo Plate 4.10: Grazing in Rashik Beel Complex, Tufanganj-II

4.2.8. Edible Plant Collection:

Apart from small fishes and various shellfishes, the surrounding households collect various edible plants *(Kalmi, Hincha, Sushni,* etc.) from wetlands for their own consumption. Collection of the edible plants for own consumption is the highest in Rasik Beel (93% household, Table 4.6) followed by Baiganbari Chhara (36% household), Rasomati Jheel (35% household) and Chandan Dighi (10% household). Discussing with the local people revealed that some households surrounding the Wetlands collect various leafy vegetables throughout the year for selling in the local market. Collection of edible plants for selling is the highest in Rasomati Jheel (5% household) followed by Rasik Beel (4% household) and Baiganbari Chhara (2.5% household) (Table 4.4).

Photo Plate 4.11: Collection of the Edible Plant in Baiganbari Chhara, Koch Bihar-II

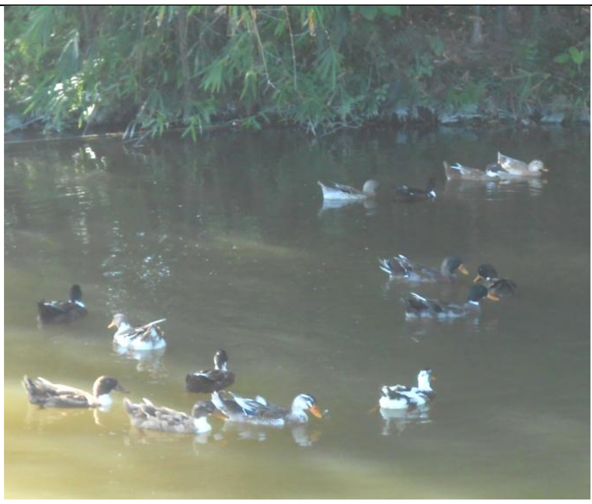


Photo Plate 4.12: Duck Keeping Dhangdhar Chhara, Tufanganj-I

Table 4.4: Use of Selected Wetlands of the Study Area

use of wetlands	Rasik Beel(N=180)		Dhangdhar Chhara (N-50)		Rasomati Jheel (N-20)		Baiganbari Chhara (N-80)		Chandan Dighi (N-20)		Sagar Dighi (N-20)	
	f	%	f	%	f	%	f	%	f	%	f	%
Wetland Cultivation:	20	11.1	NIL	Nil	NIL	NIL	32	40	NIL	NIL	NIL	NIL
Pisciculture:	Nil	Nil	3	6	NIL	NIL	7	8.75	NIL	NIL	NIL	NIL
Fishing for selling:	37	20.6	NIL	Nil	NIL	NIL	9	11.25	NIL	NIL	NIL	NIL
Fishing for Own consumption:	118	65.6	nil	Nil	2	10	38	47.5	1	5	NIL	NIL
Irrigation from Wetland:	26	14.4	6	12	NIL	NIL	17	21.25	NIL	NIL	NIL	NIL
Jute Retting:	19	10.6	19	38	NIL	NIL	19	23.75	NIL	NIL	NIL	NIL
Duck Keeping:	33	18.3	13	26	NIL	NIL	27	33.75	3	15	2	10
Fodder Collection:	82	45.6	22	44	5	25	32	40	1	5	NIL	NIL
Grazing:	42	23.3	17	34	3	15	45	56.25	NIL	NIL	NIL	NIL
Hunting	NIL	NIL	1	2	NIL	NIL	3	3.75	NIL	NIL	NIL	NIL
Collection of the edible plant for selling:	7	3.89	NIL	NIL	1	5	2	2.5	NIL	NIL	NIL	NIL
Collection of the edible plant for own consumption:	168	93.3	13	26	7	35	29	36.25	2	10	NIL	NIL
Fuel Wood Collection:	28	15.6	2	4	6	30	8	10	NIL	NIL	NIL	NIL
Collection of building and handcraft materials:	2	1.11	NIL	NIL	4	20	NIL	Nil	NIL	NIL	NIL	NIL
Bathing & Swimming:	68	37.8	24	48	NIL	NIL	28	35	NIL	NIL	14	70
Washing Clothes & Other Utensils:	11	6.11	13	26	NIL	NIL	13	16.25	1	5	5	25
Total	180	100	50	100	20	100	80	100	20	100	20	100

Source: Field Survey, 2016-17, N= No. of Household Surveyed, f= frequency

4.2.9. Duck- Keeping:

Duck keeping is a reducing practice in the study area as greater impetus is now being paid to agriculture and pisciculture owing to greater monetary returns. But duck keeping coupled with agriculture and pisciculture may give better benefit to the farmers. Duck keeping is the highest in Baiganbari Chhara (34% household) followed by Dhangdhar Chhara (26% household), Rasik Beel (18% household), Chandan Dighi (15% household) and Sagar Dighi(10% household) (Table 4.4).

4.2.10. Soil Quarrying:

Soil Quarrying is a common practice in the wetlands during the dry season when the whole or a part of wetland is dry. Clayey soil is excavated mainly by brick kiln industries and for filling up the lowland areas. Sandy soil is required mainly for creating the base of new buildings. Though soil quarrying is an illegal activity, it is increasing day by day in the study area. In the time of field survey, it has been found that a non-restricted government wetland (baiganbari Chhara) experiences more soil squaring than the restricted government wetland (Rasik Beel), whereas fully restricted government wetland (Rasomati Jheel) is free from soil quaring.

4.2.11. Bathing& Swimming:

Bathing and swimming in the wetland are the common practices of the rural and urban house holds nieghbouring the wetlands. However, pollution renders bathing and swimming impossible in the wetlands of the study area. In Koch Bihar municipality itself, out of 27 wetlands, only 14 can be used for bathing. Bathing and swimming activities are the highest in Sagar Dighi (70% household) followed by Dhangdhar Chhara (48% household), Rasik Beel(38% household) and Baiganbari Chhara (35% household) (Table 4.4).

Photo Plate 4.13: Bathing and Swimming in Sagar Dighi, Koch Bihar-I

Photo Plate 4.14: Washing of Cloth in Sagar Dighi, Koch Bihar-I

4.2.12. Dumping of Solid Waste:

Generally, wetlands are treated as unproductive landscape and inhabitants of the surrounding of the wetlands dump their waste in wetlands or on the side of the wetlands. Even the municipality or panchayet authorities dump organic and inorganic solid waste in the wetlands. Solid waste disposal has become one of the major environmental threats to the wetlands. Un-decomposed solid wastes like plastic and thermocols pose a major problem for the urban wetlands of the study area (Photo Plate 4.15).

Photo Plate 4.15: Dumping of Solid Waste in Chandan Dighi, Koch Bihar-I

Photo Plate 4.16: Washing of Cloth in Chandan Dighi, Koch Bihar-I

4.2.13. Fuel Wood:

Fuelwood collection from wetlands is an important practice in post-monsoon and winter season. Generally, female members of the family (belonging to households below poverty level) collect twigs and branches from wetland and wetland edges which are subsequently dried for firewood. Fuelwood collection is the highest in Rasomati Jheel (30% household) followed by Rasik Beel(16% household), Baiganbari Chhara (10% household), Dhangdhar Chhara (4% household) (Table 4.4).

4.2.14. Ritual Activities:

Religious rituals like cremation of dead bodies, immersion of idols, remnants and by-products of puja (wooden idol-frames, earthen pots, *diyas*, flowers etc) affect the water bodies to a great extent. Fairs like *chat puja*, *Annapurna puja*, *basantipuja* ete (Photo Plate 4.20). which are traditionally organised near the wetland thus leading to the accumulation of non-biodegradable wastes in the wetlands. On the contrary, utilizing wetland water for the marriage ceremony, first feeding ceremony *(annoprason)*, funeral and some other rituals do not have any adverse effect on wetlands; rather they protect wetland by attaching socio-cultural significance (Photo Plate 4.19).

Photo Plate 4.17: Fuel Wood Collection in Rasomati Jheel, Koch Bihar-II

Photo Plate 4.18: Fuel Wood Collection in Rashik Beel Complex, Tufanganj-II

Photo Plate 4.19:Ritual Activitiesin Dhangdhar Chhara, Tufanganj-I

Photo Plate 4.20: Basanti puja& Fair in Baiganbari Chhara, Koch Bihar-II

4.3. Specific Use of Some Selected Wetlands:

To investigate the present use of wetlands in the study area, some selected wetland shave been thoroughly examined.

4.3.1. Rasik Beel Wetland Complex:

Rasik Beel is the most important wetland included in the National Wetland Conservation Programme (updated NWCP as on June 26, 2009). Rasik Beel, one of the most potential biodiversity capitalising the study area, is a huge natural lake with a total area of 178 hectares. The Rasik Beel wetland area constitutes of water bodies of varying sizes namely Bochamari Beel, Raichangmari Beell, Nildoba Beel, Satwabhanga Nadi, Salmara Beel, Atiamochar Beel and Bherbhiri Beel that are collectively known as Rasik Beel Wetland Complex. The Rasik Beel wetland complex lies between BurhaRaidak River in the west and Ghoramara River east. It originated from different cut-off meander of Raidak River and its tributaries in course of time. Rasik Beel wetland complex was undoubtedly formed from the river Raidak now known as Bura Raidak, the oldest major Raidak River or from its tributaries the Ghoramara, and/or Satwabhanga N. The lake Bochamari is now known as Dhakeswari and Raichanmari might have been formed from the course of either Bura Raidak or Satyabhama N. But the Beel Salmara, Batikata, Satwabhanga were certainly formed from the river Satwabhanga. The position and the shape indicates that the Atiamochar Beel, Pukipara-I and Pukipara-II, and the Nildoba Beel might have been formed from the course of the river Ghoramara. All these beels except the Bochamari Beel might have been formed during the second half of the 18th century. (Das D., Sen A. and Mitra P., 2013)

According to the report of Y. S. Ahmad, IFS, DFO, Buxa Division, Bengal in 1939, "the Rasik Beel was a block under Gadarhat Reserve with sandy soil and formed due to the changes in the course of Raidak River. The block area had a number of active beels which are connected with the Chakwabha ngni Nadi, locally known as Bochamari. These beels give shelter to the enormous wild ducks in the winter season and to the wild buffaloes in summer. At that time it was principally a dense grass forest with an elephant traction the Atiamochar beat".

The Rasik Beel wetland complex is surrounded by Chengmari, Bara Salmari, Atiamochar and Takoamari protected forest. The adjacent forests of the beels are very immature, about 20-22 years old. The present distribution of forest in and around Rasik Beel under the Koch Bihar Division is given in Table-4.5.

Table 4.5: Distribution of Forest in and Around Rasik Beel

Name of Range	Beat	Mouza	J.L. No.	Total area in Ha.
Koch Bihar-I	Nagurhat	BaroSalbari	27	383.92
		Dorko	13	60.97
		ChotoSalbari	28	32.10
		Chengtimari	14	351.95
		Natabari	115	2.40
		Charalijani	35	0.88
		DebatterCharalijani	36	3.71
	Rasik Beel	Rasik Beel	26	136.38
	Atiamochar	Bansraja	55	63.20
		Part III	27	0.88
		Paglirkuti	16	30.65
		Mahiskuchi	62	33.32
		Atiamochar	15	238.47
		Madhurbasa	18	5.53
		Chat Bhalka	21	53.28
		Garbhanga	22	170.20
		Takuamari	25	254.42
		Falimari	64	67.31
		laldhoa	23	12.55
		Kharibari	17	258.33
		NajiramDeotikhata	20	46.67

Source: Zoological Survey of India, Kolkata, 2013

Among the beels of Rasik Beel Wetland Complex, five important wetlands are selected for study namely Bochamari Beel, Raichanmari Beel, Atiamochar Beel, Nildoba Beel and Satwabhanga Nadi.

Table 4.6: Number of Beneficiaries of Rasik Beel according to Use of Wetland

Different Uses of Wetland	Beneficiaries (N=180)
Wetland Cultivation:	20
Pisciculture:	Nil
Fishing for selling:	37
Fishing for Own consumption:	118
Irrigation from Wetland:	26
Jute Retting:	19
Duck Keeping:	33
Fodder Collection:	82
Grazing:	42
Hunting	NIL
Collection of the edible plant for selling:	7
Collection of the edible plant for own consumption:	168
Fuel Wood Collection:	28
Collection of building and handcraft materials:	2
Bathing & Swimming:	68
Washing Clothes & Other Utensils:	11

Source: Field Survey, 2016 & 2017, N= No. of Household Surveyed

Table 4.7: Average Wetland Service of Rasik BeelAccording to Observation Method

Wetland service	Time & duration	Degree of wetland survice
Wetland Cultivation:	Occasionally- except rainy season	*
Pisciculture:	NIL	-
Fishing for selling:	All over the year	***
Fishing for Own consumption:	All over the year	**
Irrigation from Wetland:	Pre-monsoon	*
Jute Retting:	Monsoon	*
Duck:	All over the year	*
Fodder Collection:	All over the year	*
Grazing:	All over the year	*
Hunting	NIL	-
Collection of edible plant for selling:	All over the year	*
Collection of edible plant for own consumption:	All over the year	**
Fuel Wood Collection:	Post monsoon	*
Collection of building and handcraft materials:	Post monsoon	*
Bathing & Swimming:	All over the year	*
Washing Clothes & Other Utensils:	All over the year	*
Boating and other recreational use:	Occasionally- except rainy season	**
Mining:	Pre-monsoon	*
Eco-tourism:	Occasionally- except rainy season	***
Picnic :	Occasionally- winter	**
Religious use :	All over the year	*
Cultural use:	All over the year	*
Educational use:	Occasionally- except rainy season	*
Garbage damping:	All over the year	*
The release of sewage:	All over the year	*
Morning/evening walk:	NIL	-
Burning Ghat	NIL	-

Source: Field Survey, 2016 & 2017 *N.B.:* ***= very Common, ** = Fairly Common, * = Rare(on the verge of extinction), - =not found

Table 4.8: Land Use and Land Cover of Rasik Beel and its Surroundings

Sl no.	Land use	Area in sq km	Area in %
1	Forest Area	5.02	42.76
2	Agricultural Land	2.87	24.45
3	Planted Vegetation	0.39	3.32
4	Grazing Land and Other	1.14	9.71
5	Settlement	1.11	9.45
6	Playground	0.03	0.26
7	Wetland	0.31	2.64
8	Rasik Beel	0.87	7.41

Source: Calculated by Researcher

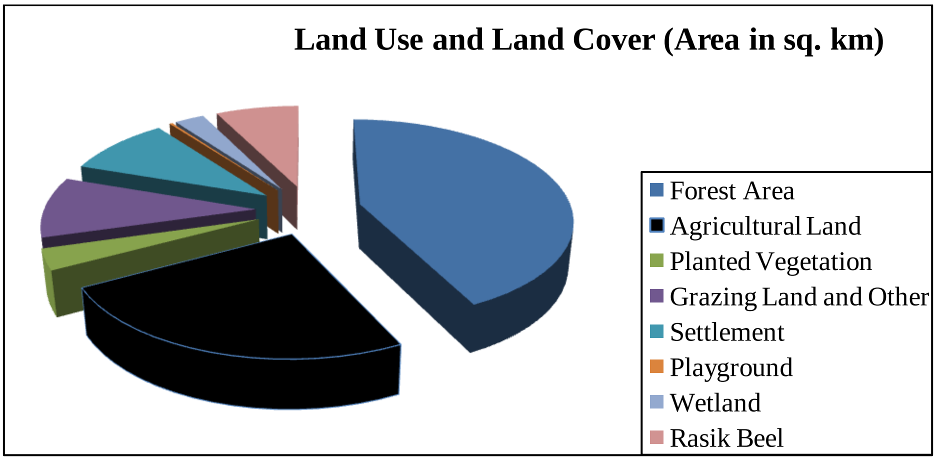
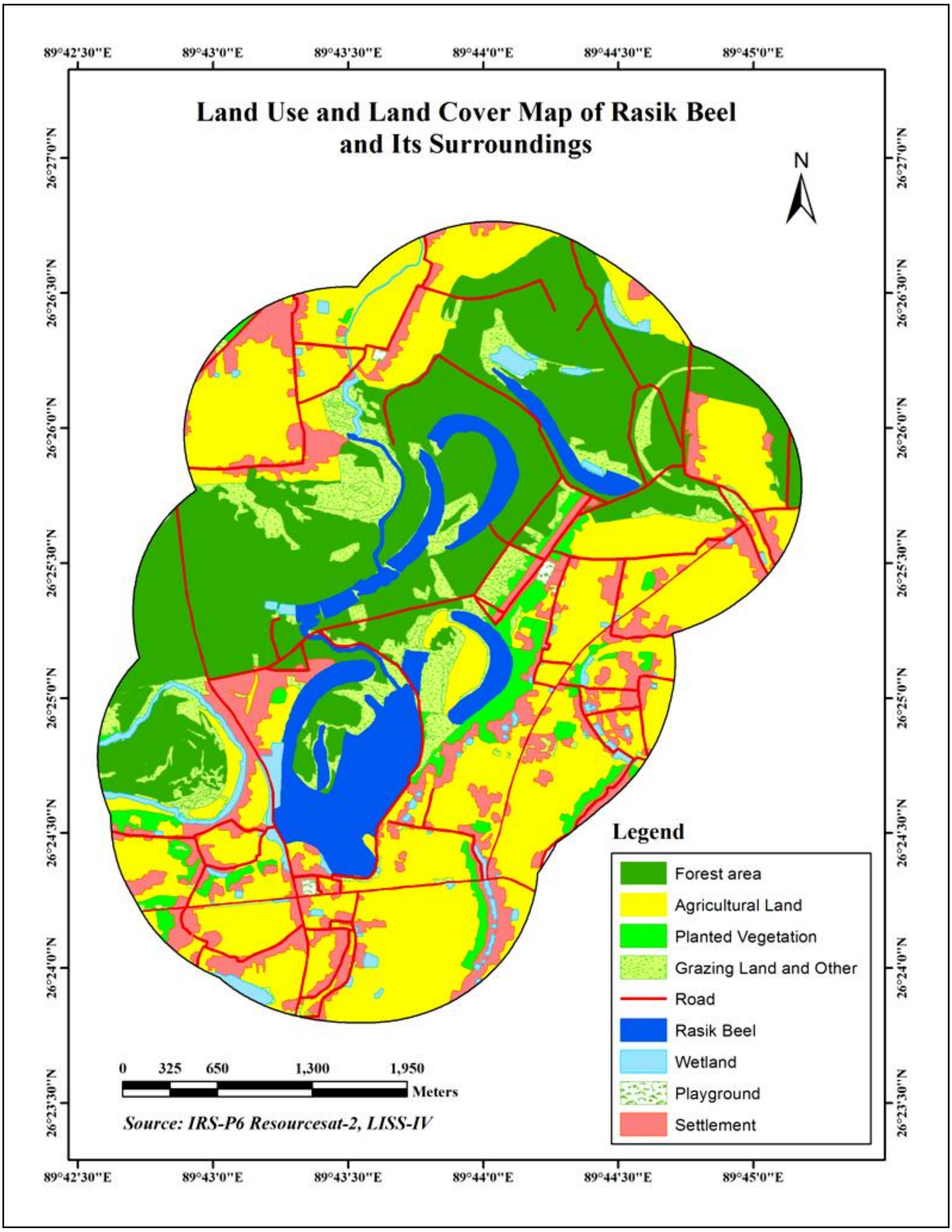


Fig 4.2: Land Use and Land Cover of Rasik Beel and its Surroundings

Land use and land cover within one km of the surrounding area of the Rasik Beel wetland complex reveal the following land use setup. The forest covers the highest area i.e.5.02 sq.km (42.76%) followed by Agricultural Land (24.45%), Grazing Land and Other (9.71%), Settlement (9.45%). Rasik Beel wetland area comprises of 0.87 sq. km and 0.31 sq. km water cover is in the surrounding area (Table 4.8). Though wetlands have a number of utility, with the passing time most of the wetland services have steadily diminished. In the Rasik Beel region fishing and eco-tourism is the important wetland service though fishing intensity and scope has goes down. The collection of edible plants for consumption, boating and other recreational uses are moderately important (Table 4.7). Other uses of Rasik Beel are rarely found there due to unavailability of the component, which provides the specific services.



Map 4.1: Land Use and Land Cover Map of Rasik Beel and its Surroundings

Source: Prepared by the Researcher on the Basis of Satellite Imagery & Field Verification

4.3.2. Dhangdhar Chhara:

Dhangdhar Chhara is situated in the brick kiln industrial zone of Maruganj Mouza of Tufanganj-I. It is the extension of Maradanga Beel which generated from Ghargharia River. It is a meander cut-off of Ghargharia River. Dhangdhar Chhara is the deepest part of the Maradanga Beel. The beel lies in between river Kaljani and River Ghargharia. This beel is partly Culturable by the Maradanga Primary Fishermen Cooperative Society. There are 9 brick kilns within the 1 km radius of the beel. It is one of the natural beels which is most affected by the industrial effluents. The industrial wastes are drained into this beel. Moreover, the beel is leased for pisciculture.

Table 4.9: Number of Beneficiaries of Dhangdhar Chhara According to Use of Wetland

Different Uses of Wetland	Beneficiaries (N=50)
Wetland Cultivation:	NIL
Pisciculture:	3
Fishing for Own consumption:	NIL
Irrigation from Wetland:	6
Jute Retting:	19
Duck Keeping:	13
Fodder Collection:	22
Grazing:	17
Hunting	1
Collection of edible plant for selling:	NIL
Collection of edible plant for own consumption:	13
Fuel Wood Collection:	2
Collection of building and handcraft materials:	NIL
Bathing & Swimming:	24
Washing Clothes & Other Utensils:	13

Source: Field Survey, 2016 & 2017

Table 4.10: Wetland Service of Dhangdhar Chhara According to Observation Method

Wetland service	Time & duration	Degree of wetland survice
Wetland Cultivation:	Pre-monsoon	*
Pisciculture:	All over the year	**
Fishing for selling:	All over the year	**
Fishing for Own consumption:	NIL	-
Irrigation from Wetland:	Pre-monsoon	*
Jute Retting:	monsoon	**
Duck Keeping:	All over the year	*
Fodder Collection:	All over the year	*
Grazing:	All over the year	*
Hunting	NIL	-
Collection of edible plant for selling:	NIL	-
Collection of edible plant for own consumption:	All over the year	*
Fuel Wood Collection:	Post-monsoon	*
Collection of building and handcraft materials:	NIL	-
Bathing & Swimming:	All over the year	**
Washing Clothes & Other Utensils:	All over the year	**
Boating and other recreational use:	NIL	-
Mining:	Occasionally- except rainy season	*
Eco-tourism:	NIL	-
Picnic :	NIL	-
Religious use :	NIL	-
Cultural use:	NIL	-
Educational use:	NIL	-
Garbage damping:	All over the year	*

Release of sewage:	All over the year	*
Morning / evening walk:	NIL	-
Burning ghat	NIL	-

Source: Field Survey, 2016 & 2017***= Very Common, ** = Fairly Common, * = Rare (on the verge of extinction), - =not found

Table 4.11: Land Use and Land Cover of Dhangdhar Chhara and its Surroundings

Sl no.	Land Use	Area in sq km	Area in %
1	Settlement	1.17	24.27
2	Agricultural Land	1.81	37.55
3	Waste Land & Other	0.43	8.92
4	Brick Kiln Industry Site	0.47	9.75
5	Planted Vegetation	0.28	5.81
6	River	0.03	0.62
7	Roads	0.04	0.83
8	Wetlands	0.54	11.20
9	Dhangdhar Chhara	0.05	1.04

Source: Calculated by Researcher

Land use and land cover within one km surrounding area of the Dhangdhar Chhara reveals the following land-use setup. The Agricultural Land covers the highest area about 1.81sqkm (37.55%) followed by Settlement area (24.27%), Brick Kiln Industrial Site (9.75%), Waste Land & Others (8.92%). Dhangdhar Chhara wetland area stretches across 0.05sq km. it also has0.54 sq. km water cover in its surrounding area (Table 4.11). In the Dhangdhar Chhara region fishing is the moderately important wetland service through the intensity and scope are rapidly reducing. Jute Retting, washing clothes and utensils, bathing & swimming are other moderately important wetland services of Dhangdha Chhara(Table 4.10).

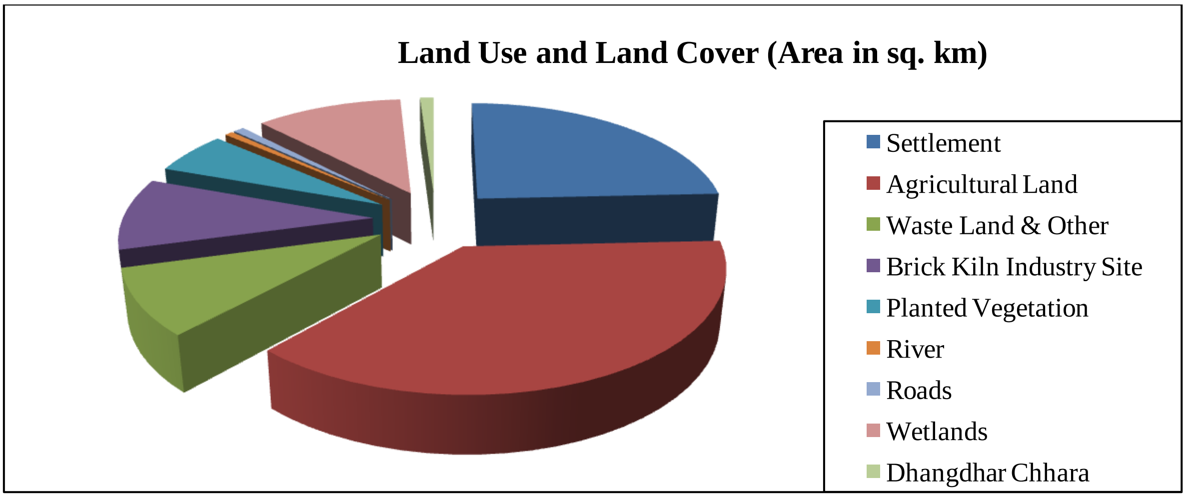
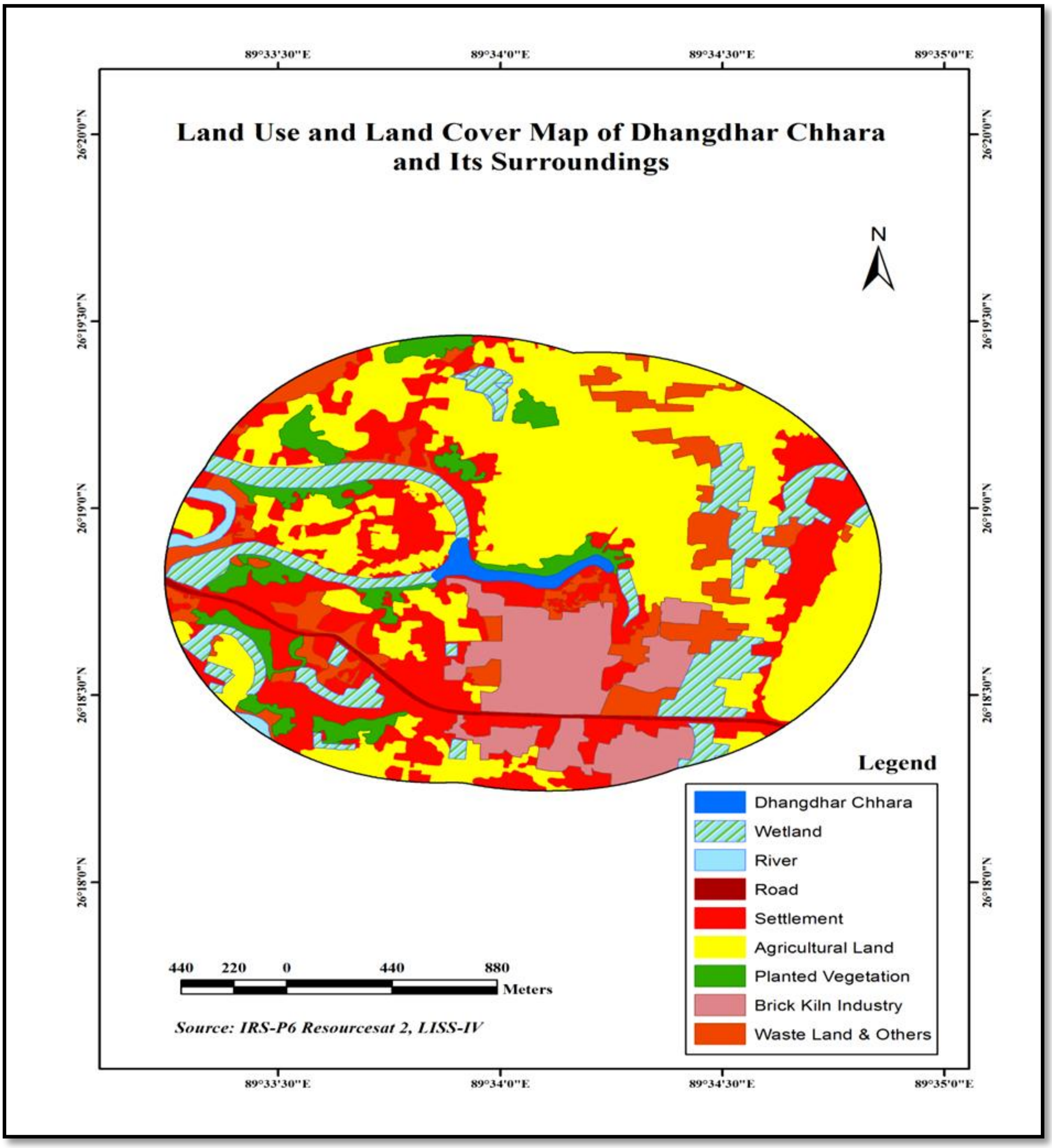


Fig 4.3: Land Use and Land Cover of Dhangdhar Chhara and its Surroundings

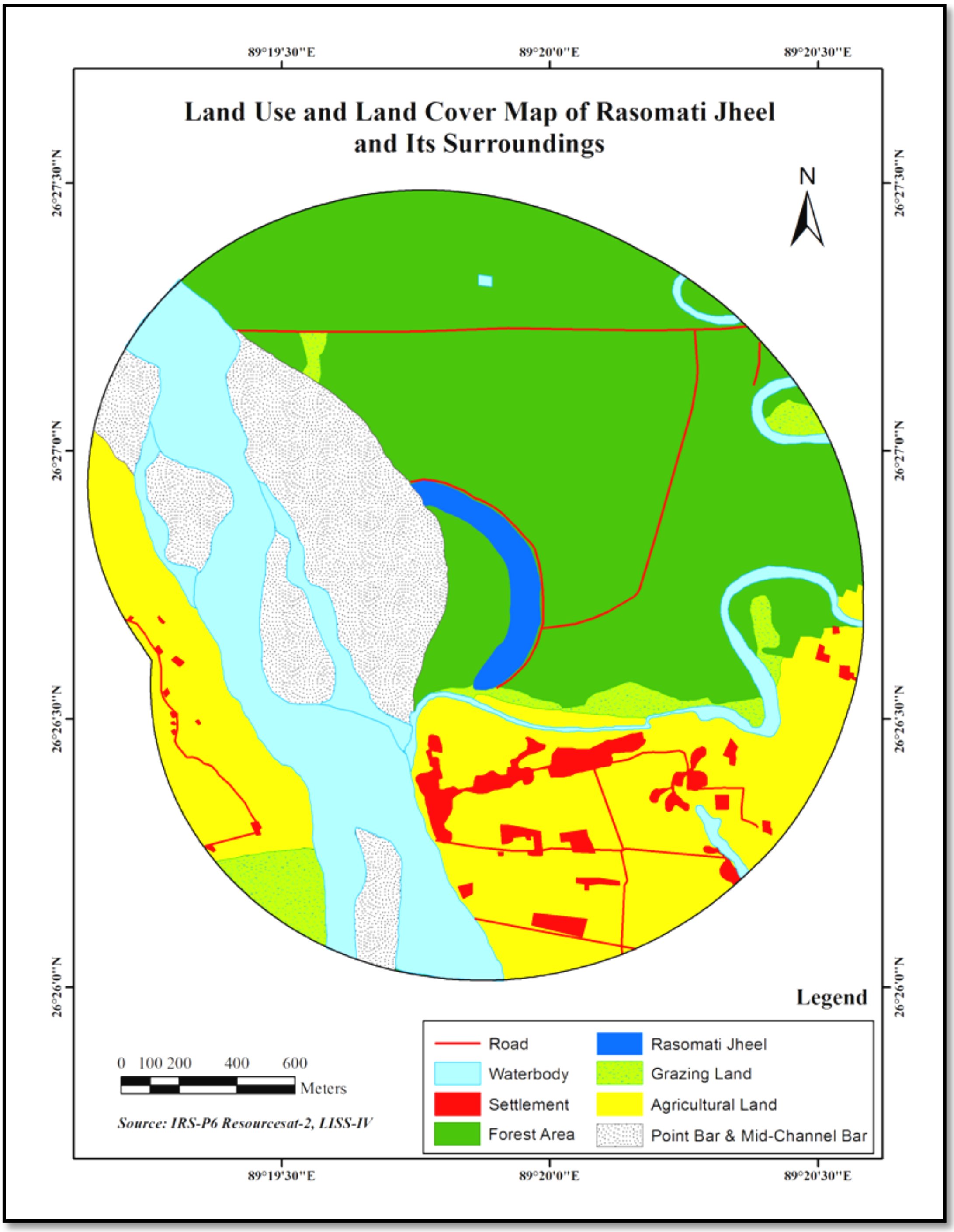


Map 4.2: Land Use and Land Cover Map of Dhangdhar Chhara and its Surroundings

Source: Prepared by the Researcher on the basis of Satellite Imagery & Field Verification

4.3.3. Rasomati Jheel:

Rasomati Jheel is the most important wetland included in the National Wetland Conservation Programme (updated NWCP as on June 26, 2009). Rasomati river originated in Torsha and also drained in it, forming a Yazoo river i.e. a tributary and also a distributary, however presently it is no longer a tributary or distributary of Torsha and has reduced into a wetland known as "Rasomati Jheel". It is disconnected from Torsha both of its source or estuary. Source of Rasomati Jheel has been closed artificially by constructing embankment on the edge of the lake and on the other hand the estuary chocked naturally by the



Map 4.3: Land Use and Land Cover Map of Rasomati Jheel and its Surroundings

Source: Prepared by the Researcher on the basis of Satellite Imagery & Field Verification

deposition of Torsa River over time. It floods during the monsoon and drains in Buri Torsha. Then the combined stream of Rasomati and Buri Torsha drains into the Torsha at Bansdaha Natibari. Every year the river bank at the estuary of Rasomati Jheel collapses which leads to the shrinkage of the area of the Rasomati Jheel. The origin of Rasomati is in Hogla forest of Patlakhawa forest. It moves towards the east and gradually arches towards the south and south-west. After covering some distance (almost 2km) the *jheel* ends in Buri Tosha at Natibari. The course of this miniature river, which is now a *jheel* mainly runs through the forest, however, after the construction of a dam at the entrance of the river along with excavation procedures to increase the depth of the river, the Government, has made the provisions for tourism and nature observation. A 'watch tower' is situated in the eastern part of the Rasomati Jheel. The beautiful dense forests of Torsha in the west are a feast for the eyes of the nature lovers.

Rasomati jeel is located 30 km from the town of Koch Bihar. It has a historic significance as it was the game reserve for the Koch dynasty. The forest consists of Sal, Sishu, Teak, Mehogany, Groundnut, Babla and Devdaru trees. It is a beautiful semi-lunar wetland flanked by lush green forests. Rasomati Jheelis an ideal place for bird watchers and photographers. Several resident bird species like hornbill, parrots, bulbul and myna are also spotted in the area. There is a 56-feet high watchtower for bird watching. Over the past several years a number of animal species have been introduced. The department's report says that Rasomati houses around 200 spotted deer, 20 leopards and six bisons. According to a forest official, Rasomati with a good forest cover is an ideal habitat for wild animals. "The Chilapata forest is 15km away and animals often walk down the banks of the Torsa to come here in search of food during the nights. We have been observing that some of these animals, particularly deer and bison, are not returning to where they came from," the official said. According to the department of forestry, three Indian one-horned rhinos will be introduced before the 2018 *durgha pujas*, making this wetland the third habitat of the mammal in the state.

Table 4.12: Number of Beneficiaries of Rasomati Jheel According to Use of Wetland

Different Uses of Wetland	Beneficiaries (N= 20)
Wetland Cultivation:	NIL
Pisciculture:	NIL
Fishing for selling:	NIL
Fishing for Own consumption:	2
Irrigation from Wetland:	NIL
Jute Retting:	NIL
Duck Keeping:	NIL
Fodder Collection:	5
Grazing:	3
Hunting	NIL

Collection of edible plant for selling:	1
Collection of edible plant for own consumption:	7
Fuel Wood Collection:	6
Collection of building and handcraft materials:	4
Bathing & Swimming:	NIL
Washing Clothes & Other Utensils:	NIL

Source: Field Survey, 2016 & 2017

Table 4.13: Wetland Service of Rasomati Jheel according to Observation Method

Wetland service	Time & duration	Degree of wetland survice
Wetland Cultivation:	NIL	-
Pisciculture:	NIL	-
Fishing for selling:	NIL	-
Fishing for Own consumption:	NIL	-
Irrigation from Wetland:	NIL	-
Jute Retting:	NIL	-
Duck Keeping:	NIL	-
Fodder Collection:	All over the year	*
Grazing:	All over the year	***
Hunting	NIL	-
Collection of edible plant for selling:	All over the year	*
Collection of edible plant for own consumption:	All over the year	**
Fuel Wood Collection:	Occasionally- winter	*
Collection of building and handcraft materials:	Occasionally- winter	*
Bathing & Swimming:	NIL	-
Washing Clothes & Other Utensils:	NIL	-
Boating and other recreational use:	NIL	-
Mining:	NIL	-
Eco-tourism:	All over the year	***
Picnic :	Occasionally- winter	**
Religious use :	NIL	-
Cultural use:	NIL	-
Educational use:	Occasionally- except rainy season	*
Garbage damping:	NIL	-
Release of sewage:	NIL	-
Morning/evening walk:	NIL	-
Burning Ghat	NIL	-

***= very Common,** = Fairly Common, * = Rare(on the verge of extinction), - =not found

Source: Field Survey, 2016 & 2017

Table 4.14: Land Use and Land Cover of Rasomati Jheel and its Surroundings

Sl no.	Land use	Area in sq km	Area in %
1	Forest Area	1.91	37.38
2	Agricultural Land	1.31	25.64
3	Grazing Land	0.17	3.33
4	Point Bar & Mid-channel Bar	0.70	13.70
5	Settlement	0.15	2.94
6	Water bodies	0.79	15.46
7	Rasomati Jheel	0.08	1.57
8	total	5.105	100

Source: Calculated by Researcher

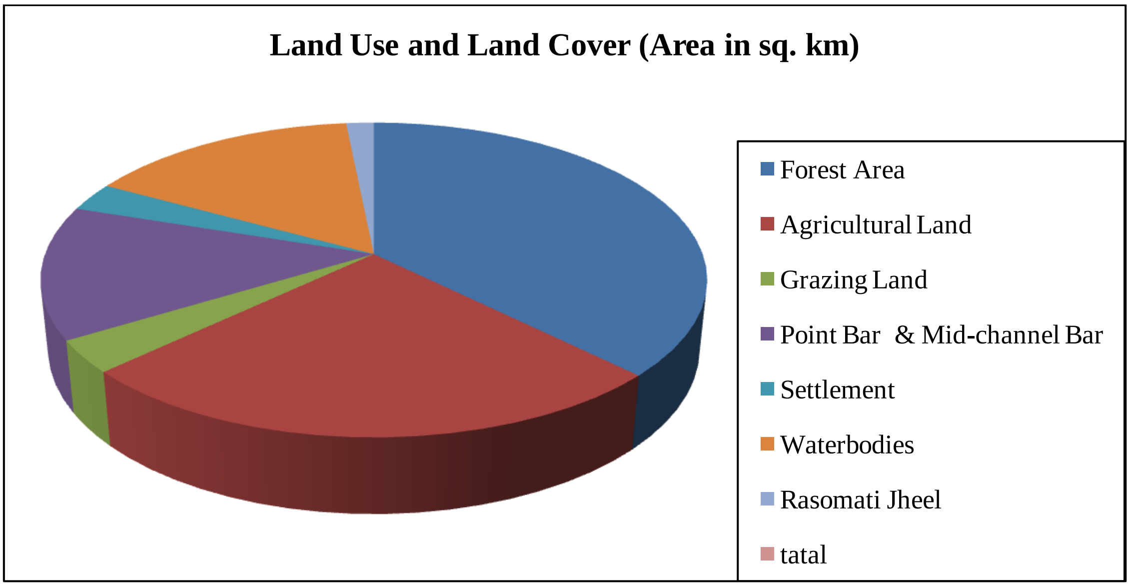


Fig 4.4: Land Use and Land Cover of Rasomati Jheel and its Surroundings

Land use and land cover of one km surrounding area of the Rasomati Jheel reveals the following land use setup. The forests cover the highest area i.e. 1.91sq km (37.38%) followed by Agricultural Land (25.64%), Water bodies (15.46%), Point Bar & Mid-channel Bar (13.70%). Rasomati Jheel wetland area stretches across0.08 sq km. and having0.79 sq. km water cover in the mapped area (Table-4.14). With the passage of time, most of the wetland services dwindled into just grazing and eco-tourism. Collection of the edible plant for local sale and consumption and monetary benefits from Picnic groups are moderately important (Table 4.13). Other services are rarely found due to unavailability of the specific component which is required for those specific services.

4.3.4. Baiganbari Chhara:

Baiganbari Chhara is located in Dewanbash Mouza of Koch Bihar-I. This beel is under the department of L.R., where fishing is done by Satmile Primary Fishermen Co-operative Society (PFCS) Ltd in 11.75 acre area of the beel. It is a meander cut-off of Mansai or Jaldhaka River. Beginning from its source to the estuary of this wetland it has various names in various places. Local senior citizens also have different opinions about the name of the wetland. Not a while ago this wetland had carried huge amounts of water but now it is reduced.

This wetland, situated in the left bank of Jaldhaka, is named as Amtali by few people, Balabari by few and Baiganbari by the rest. However is no doubt that in the downstream it is named as Baiganbari. During the monsoon through the east of Nishiganj market, a stream is seen flowing from north to south direction, but recently the upstream of the river is blocked due to a number of causes.

According to some, the tributary originated from Bura Mansai River or buri Torsha. From this point, Baiganbari Chhara is a tributary of Torsha. Now it is Mansai's abandoned channel. For different reasons, this ancient river stream is about to go extinct. In brief, it can be said that a small stream originating from the Bura Mansai flowed through chatt chhitkibari and Runibari towards the south and the east direction. There is a connection between the aforesaid stream and Paddama stream which has hardly maintained its existence in the south-western Dumniguri. Presently the connection Bura Mansai and Baiganbari Chhara have severed. Paddama chhara which originated because of the change in Bura Mansai's direction and was once connected with the so-called Amtali or the Balabari River or Baiganbari Chhara but now this connection has also severed.

In the north and mid Deoanbose this wetland meets with a local drainage stream called Houser Dara. This two combined streams then zigzags towards the south. During monsoon, a strong river current is seen in the northern part of Ashmani Ghat and Chhat Dumniguri. However, after meeting with Houser Dara it is called Baiganbari stream at Deoanbose. Most of the wetland area remains dry except in monsoon. Throughout the year, there is a low level of water mostly stagnant and motionless. But in monsoon the water level rises up, leading to flooding.

Table 4.15: Number of Beneficiaries of Baiganbari Chhara according to Use of Wetland

Different Uses of Wetland	Beneficiaries (N=80)
Wetland Cultivation:	32
Pisciculture:	7
Fishing for selling:	9
Fishing for Own consumption:	38
Irrigation from Wetland:	17
Jute Retting:	19
Duck Keeping:	27
Fodder Collection:	32
Grazing:	45
Hunting	3
Collection of edible plant for selling:	5
Collection of edible plant for own consumption:	29
Fuel Wood Collection:	8
Collection of building and handcraft materials:	NIL
Bathing & Swimming:	28
Washing Clothes & Other Utensils:	13

Source: Field Survey, 2016 & 2017

Table 4.16:Wetland Service of Baiganbari Chhara According to Observation Method

Wetland service	Time & duration	Degree of wetland survice
Wetland Cultivation:	All over the year- except rainy season	***
Pisciculture:	All over the year	**
Fishing for selling:	All over the year	***
Fishing for Own consumption:	All over the year	**
Irrigation from Wetland:	Winter	*
Jute Retting:	Monsoon and post-monsoon	***
Duck Keeping:	All over the year	**
Fodder Collection:	All over the year	*
Grazing:	All over the year	*
Hunting	Winter	*
Collection of edible plant for selling:	All over the year	*
Collection of edible plant for own consumption:	All over the year	*
Fuel Wood Collection:	Winter	*
Collection of building and handcraft materials:	NIL	-
Bathing & Swimming:	All over the year	*
Washing Clothes & Other Utensils:	All over the year	*
Boating and other recreational use:	NIL	-
Mining:	Winter	*
Eco-tourism:	NIL	-
Picnic :	NIL	-
Religious use :	All over the year	*
Cultural use:	All over the year	*
Educational use:	NIL	-
Garbage damping:	All over the year	**
Release of sewage:	All over the year	**
Morning/evening walk:	NIL	-
Burning Ghat	All over the year	**

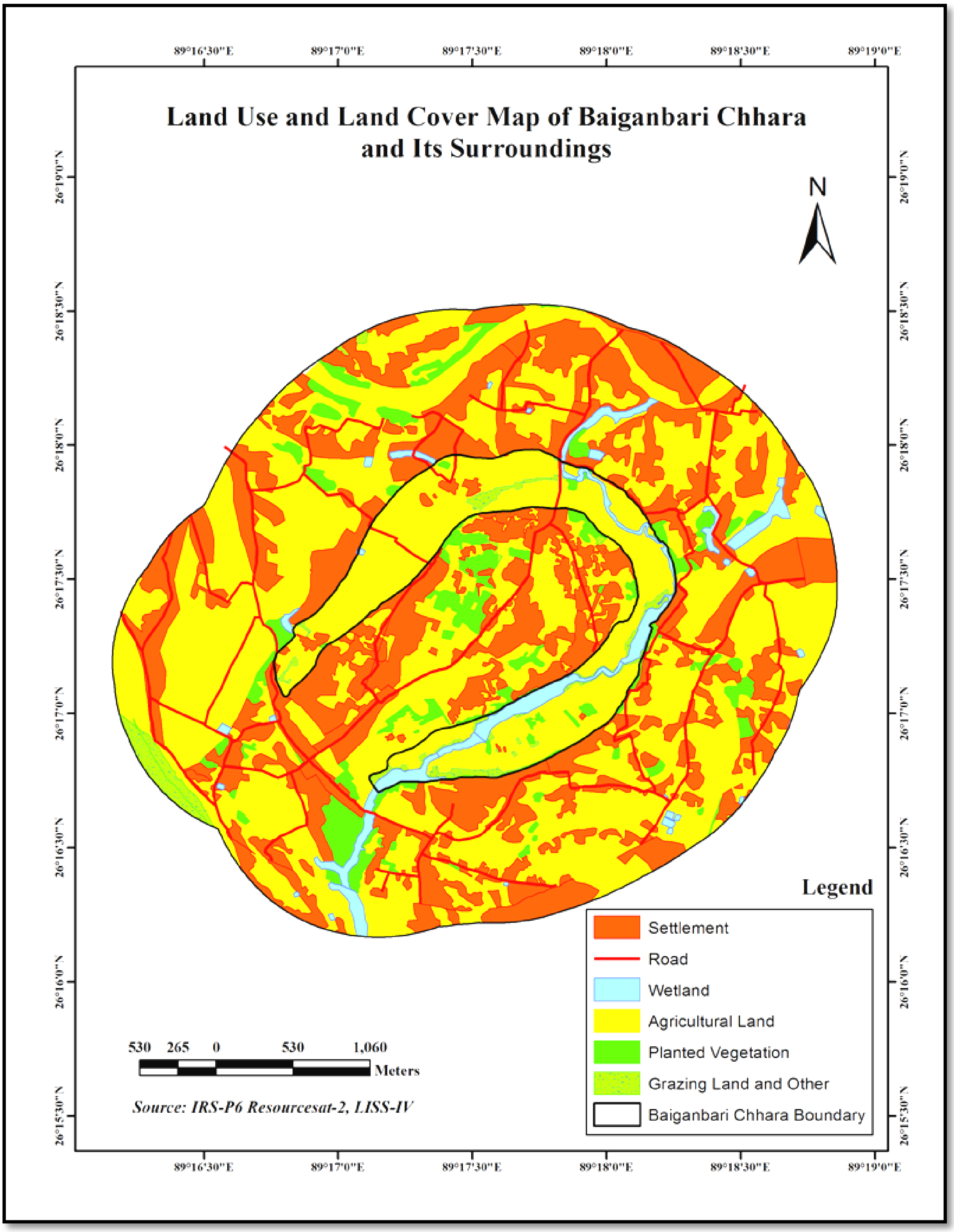
Source: Field Survey, 2016 & 2017***= Very Common, ** = Fairly Common, * = Rare(on the verge of extinction), - =not found

Table 4.17: Land Use and Land Cover of Baiganbari Chhara and its Surroundings

Sl no.	Land use	Area in sq km	Area in %	wetland area in %
1	Agricultural Land around the wetland	4.71	38.14	
2	Grazing Land and Other around the wetland	0.12	0.97	
3	Planted Vegetation around the wetland	0.72	5.83	
4	Settlement around wetland	4.77	38.62	
5	Wetlands around wetland	0.22	1.78	
6	Agricultural Land in the Wetland	1.40	11.34	77.35
7	Grazing Land and Other in the wetland	0.12	0.97	6.63
8	Planted Vegetation in the Wetland	0.05	0.40	2.76
9	Settlement in the Wetland	0.04	0.32	2.21
10	Water Cover in the Wetland	0.20	1.62	11.05

Source: Field Survey, 2016 & 2017

Land use and land cover of one km surrounding area of the Baiganbari Chhara reveals the following land use setup. It is intensively used for agriculture, grazing, settlement and pisciculture. Therefore land use pattern of Baiganbari Chhara and its surrounding areas are divided into two categories – around the wetland and in the wetland. It is very clear from the table 4.13 that during the pre-monsoon three fourth area (77.35%) of the wetland is used for cultivation mainly boro paddy, the water cover area (11.05%) is used for Fishing, 6.63% for Grazing Land and Others,2.76% for Planted Vegetation and 2.21% for Settlement. On the other hand in the surrounding area of Baiganbari Chhara, agricultural land and settlement cover 38.14% & 38.62% respectively (Table 4.17). According to the elders of Baiganbari Chhara area, this wetland was the centre of activity even in the recent past, however presently many of these wetland services are rendered useless and others steadily decreasing. While fishing, wetland cultivation and jute retting are the important wetland services their intensity and scope has been decreasing (Table 4.16). Other services of Baiganbari Chhara are rarely initiated due to unavailability of the specific component necessary for a specific service.



Map 4.4: Land Use and Land Cover Map of Baiganbari Chhara and its Surroundings

Source: Prepared by the Researcher on the Basis of Satellite Imagery & Field Verification

4.3.5. Chandan Dighi:

Chandan Dighi is situated in Koch Bihar Municipality of Sadar Koch Bihar with Plot No-5291 of Sahar Koch Bihar Mouza. It is under the Dept. of Fisheries and covers an area of 2.31 acres which is undertaken by Takagachh Fisheries Cooperative Society Ltd for pisciculture. The pond is surrounded by Koch Bihar MJN hospital in the West, Jenkins

School in the south and ABN Seal College hostel &4 houses in the East. Moreover, the pond is surrounded by more than 39 shops and commercial places in the west and north.

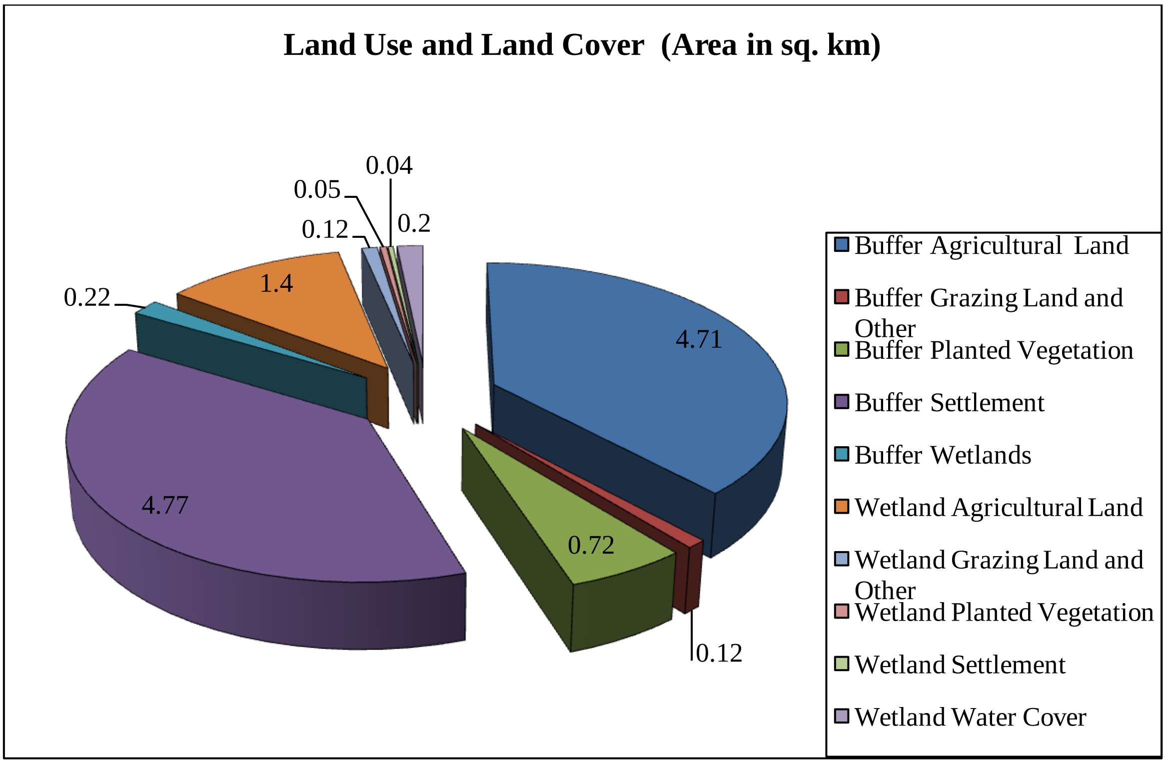


Fig4.5: Land Use and Land Cover of Chandan Dighi and its Surroundings

Table 4.18: Number of Beneficiaries of Chandan Dighi According to Use of Wetland

Different Uses of Wetland	Beneficiaries (N=20)
Wetland Cultivation:	NIL
Pisciculture:	NIL
Fishing for selling:	NIL
Fishing for Own consumption:	1
Irrigation from Wetland:	NIL
Jute Retting:	NIL
Duck Keeping:	3
Fodder Collection:	1
Grazing:	NIL
Hunting	NIL
Collection of edible plant for selling:	NIL
Collection of edible plant for own consumption:	2
Fuel Wood Collection:	NIL
Collection of building and handcraft materials:	NIL
Bathing & Swimming:	NIL
Washing Clothes & Other Utensils:	1

Source: Field Survey, 2016 & 2017

Table 4.19: Wetland Service of Chandan Dighi according to Observation Method

Wetland service	Time & duration	Degree of wetland service
Wetland Cultivation:	NIL	-
Pisciculture:	All over the year	*
Fishing for selling:	NIL	-
Fishing for Own consumption:	NIL	-
Irrigation from Wetland:	NIL	-
Jute Retting:	NIL	-
Duck Keeping:	All over the year	*
Fodder Collection:	NIL	-
Grazing:	NIL	-
Hunting	NIL	-
Collection of edible plant for selling:	All over the year	*
Collection of edible plant for own consumption:	All over the year	*
Fuel Wood Collection:	NIL	-
Collection of building and handcraft materials:	NIL	-
Bathing & Swimming:	Nil	-
Washing Clothes & Other Utensils:	All over the year	**
Boating and other recreational use:	Nil	-
Mining:	Nil	-
Eco-tourism:	Nil	-
Picnic :	Nil	-
Religious use :	Nil	-
Cultural use:	Nil	-
Educational use:	Nil	-
Garbage damping:	All over the year	**
Release of sewage:	All over the year	**
Morning/evening walk:	Nil	-
Burning Ghat	Nil	-

Source: Field Survey, 2016 & 2017***= very Common, ** = Fairly Common, * = Rare (on the verge of extinction), - =not found

Table 4.20: Land Use and Land Cover of Chandan Dighi and its Surroundings

Sl no.	Land use	Area in sq km	Area in %
1	Pond	0.0689	7.47
2	Planted Vegetation	0.1152	12.50
3	Park & Playground	0.1389	15.06
4	Chandan Dighi	0.0077	0.83
5	Fallow Land	0.0514	5.57
6	Settlement and other buildings	0.5400	58.56

Source: Calculated by Researcher

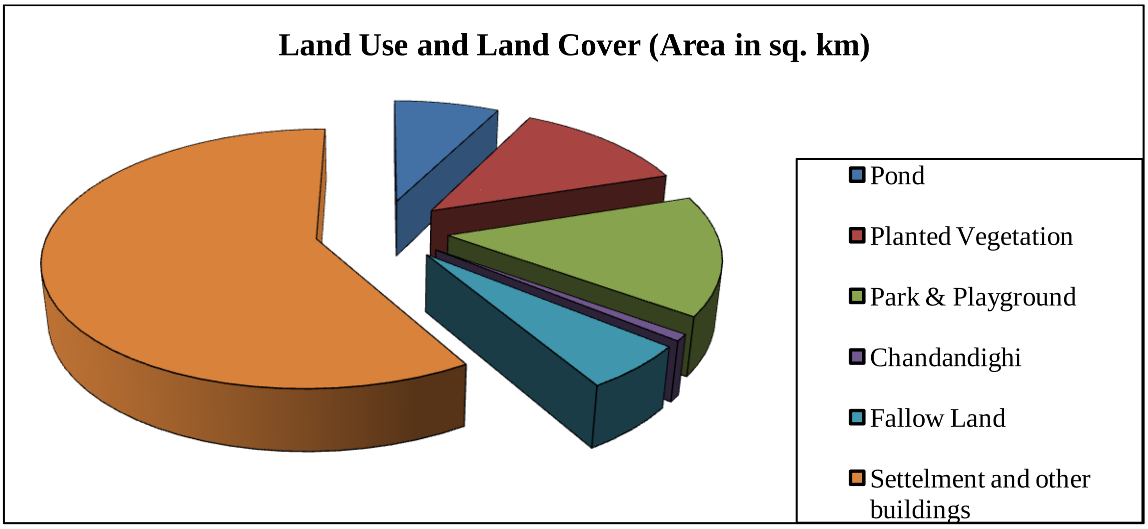
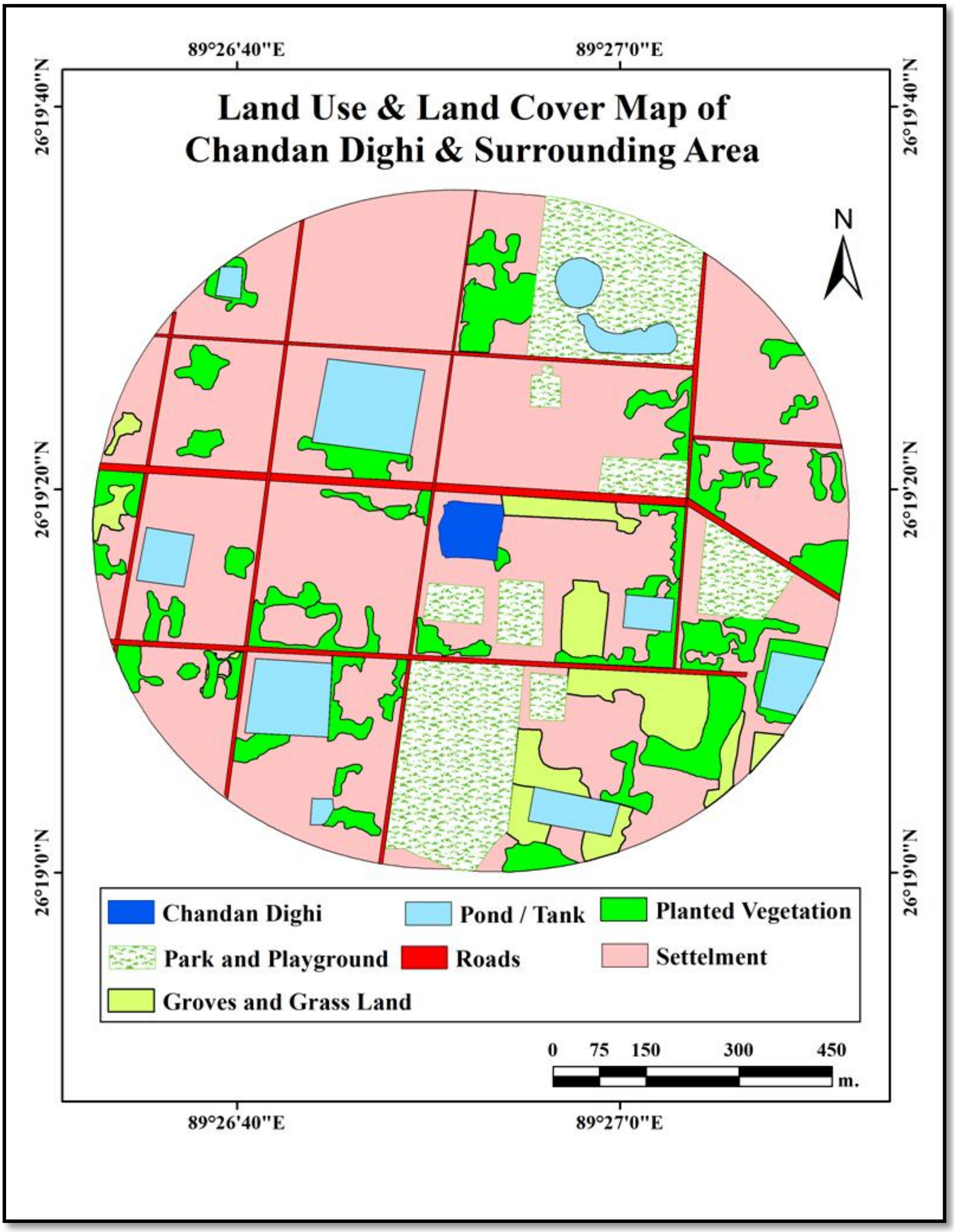


Fig4.6: Land Use and Land Cover of Chandan Dighi and its Surroundings

Land use and land cover of 500m surrounding area of the Chandan Dighi reveals the following land use setup. The Settlement and other buildings cover the highest area i.e. 0.54 sq km(58.56%) followed by Park & Playground (15.06%), Planted Vegetation (12.50%) and Fallow Land (5.57%). The total area of ofChandan Dighi is 0.0077sq. Km. and it has 0.0689 sq. km water cover in the surrounding area (Table 4.20). According to the aged locals, even 30-40 years ago the water of Chandan Dighi was very clear, generally used for drinking, bathing, swimming, washing clothes & utensils etc. However now, due to people's and administration's indifferent attitude, it has become the most degraded and polluted dighi in the Koch Bihar municipality, People treat it as a wasteland and Garbage is dumped and sewage is released by the inhabitants, hostellers, hotels, flower shops, and others. Thus, in a nutshell, it can be said that wetland service of Chandan Dighi is very less(Table 4.19).



Map4.5: Land Use and Land Cover Map of Chandan Dighi and its Surroundings

Source: Prepared by the Researcher on the Basis of Satellite Imagery & Field Verification

4.3.6. Sagar Dighi:

Koch Bihar Lake or Sagar Dighi is the most important freshwater body which is situated in the heart of Koch Behar town. It extends between 26°19'12''N to 26°19'21''N and 89°26'21''E to 89°26'28''E and the total surface area of this lake is 14.60 acres which were excavated by Maharaja Harendra Narayan in 1807 AD. It commonly attracts various migratory birds during the winter season. Among all ponds in Koch Bihar town, the most spectacular is Sagar Dighi, with grand structures arrayed all around it. These buildings built mostly between 1880 to 1920, are now offices of the district administration like Office of the District Magistrate, Administrative Building of North Bengal State Transport Corporation, BSNL Office on the West; Office of the Superintendent of Police, District Library, Municipality Building on the South, Office of the BLRO, Sate Bank of India (Koch Bihar Main Branch) etc on the East and RTO office, Foreigner's enrollment office, District Court and so on the North. Although this *dighi* was excavated for drinking water supply and flood control, now it is used for bathing, swimming, washing clothes, fishing, morning and evening walk around the lake, resting or gossiping place, boating etc. Capture Fishery or catching fish is done by leaseholder SNCADA. This pond is under the Department of Fisheries.

Table4.21: Number of Beneficiaries of Sagar Dighi According to Use of Wetland

Different Uses of Wetland	Beneficiaries (N=20)
Wetland Cultivation:	NIL
Pisciculture:	NIL
Fishing for selling:	NIL
Fishing for Own consumption:	NIL
Irrigation from Wetland:	NIL
Jute Retting:	NIL
Duck Keeping:	2
Fodder Collection:	NIL
Grazing:	NIL
Hunting:	NIL
Collection of edible plant for selling:	NIL
Collection of edible plant for own consumption:	NIL
Fuel Wood Collection:	NIL
Collection of building and handcraft materials:	NIL
Bathing & Swimming:	14
Washing Clothes & Other Utensils:	5

Source: Field Survey, 2016 & 2017

Table4.22: Wetland Service of Sagar Dighi According to Observation Method

Wetland service	Time & duration	Degree of wetland service
Wetland Cultivation:	NIL	-
Pisciculture:	All over the year	*
Fishing for selling:	NIL	-
Fishing for Own consumption:	NIL	-
Irrigation from Wetland:	NIL	-
Jute Retting:	NIL	-
Duck Keeping:	All over the year	*
Fodder Collection:	NIL	-
Grazing:	NIL	-
Hunting	NIL	-
Collection of edible plant for selling:	NIL	-
Collection of edible plant for own consumption:	NIL	-
Fuel Wood Collection:	NIL	-

Collection of building and handcraft materials:	NIL	-
Bathing & Swimming:	All over the year	***
Washing Clothes & Other Utensils:	All over the year	**
Boating and other recreational use:	All over the year	***
Mining:	NIL	-
Eco-tourism:	All over the year	**
Picnic :	NIL	-
Religious use :	All over the year	**
Cultural use:	All over the year	**
Educational use:	All over the year	*
Garbage damping:	All over the year	*
Release of sewage:	All over the year	*
Morning/evening walk:	All over the year	***
Burning Ghat	NIL	-

Source: Field Survey, 2016 & 2017 ***= very Common, ** = Fairly Common, * = Rare(on the verge of extinction), - =not found

Table4.23: Land Use and Land Cover of Sagar Dighi and its Surroundings

Sl no.	Land use	Area in sq km	Area in %
1	Settlement and Other Buildings	0.9327	67.72
2	Park & Playground	0.1611	11.70
3	Planted Vegetation	0.0561	4.07
4	Agricultural Land	0.0270	1.96
5	Wetland	0.1485	10.78
6	Sagar Dighi	0.0518	3.76

Source: Calculated by Researcher

Land use and land cover of 500m surrounding area of the Sagar Dighi reveals the following land use setup. The Settlement and other buildings cover the maximum area i.e. 0.9327 sq km (67.72%) followed by Park & Playground (11.70%), Planted Vegetation (4.07%) and Agricultural Land (1.96%). The total area of Sagar Dighi is 0.0518 sq km with 0.1485sq Km water covers in the surrounding area (Table 4.23). It is an urban wetland maintained by the Dept. of Fisheries as well as by the municipality. Comparatively, Sagar Dighi is more functional than Chandan Dighi and in the Sagar Dighi bathing & swimming, boating and other recreational activities are the important wetland service along with morning and evening walks around the cemented path surrounding the Dighi. The Eco-tourism, Religious use, Washing Clothes & Other Utensils, Cultural use are moderately important (Table 4.22). Other uses of sagar dighi are rarely found there due to unavailability of the specific component which provides the specific services.

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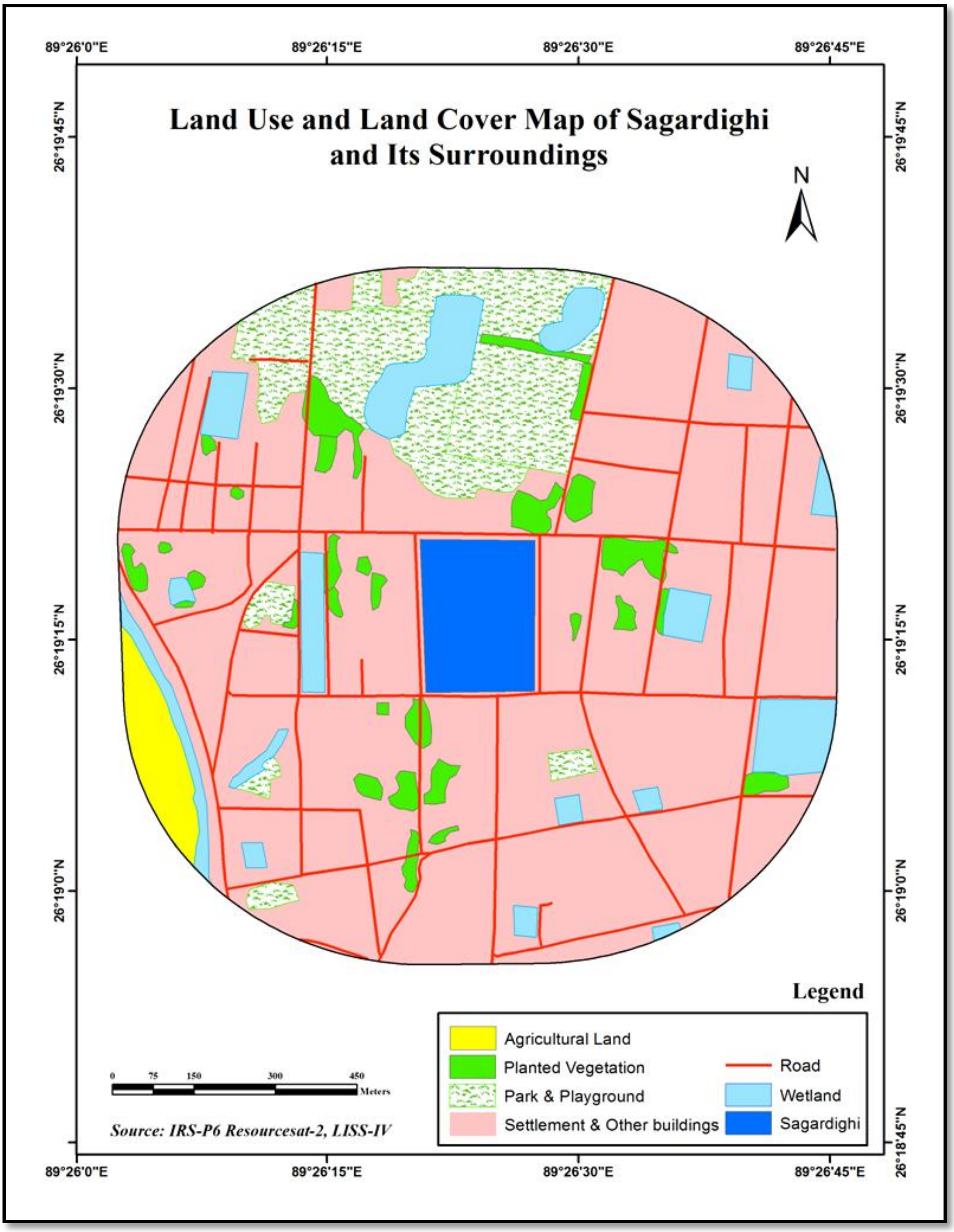

Map4.6: Land Use and Land Cover Map of Sagar Dighi and its Surroundings

Source: Prepared by the Researcher on the Basis of Satellite Imagery & Field Verification

Table 4.24: Use of wetlands

Wetland Use	Rasik Beel Complex	Dhangdhar Chhara	Rasomati Beel	Baiganbari Chhara	Chandan Dighi	Sagar Dighi	Total	%
Very Common	2	0	2	3	0	3	10	6.17
Fairly Common	4	5	3	6	3	4	25	15.43
Rare(on the verge of extinction)	17	10	4	12	4	5	52	32.10
Not Found	4	12	18	6	20	15	75	46.30
Total	27	27	27	27	27	27	162	100

Source: Computed by the Researcher on the basis of Primary Survey

Table 4.25: Chi-Square (χ^2) of the Use of Wetlands

Chi-square (Observed value)	39.917
Chi-square (Critical value)	24.996
df	15
p-value	0.0005
alpha	0.05

H0: The Each wetland's use is independent i, e. there is no difference in the use of the wetlands.

Ha: There is a link between and among the use of the wetlands.

As the computed p-value is lower than the significance level alpha (α) =0.05, the researcher rejects the null hypothesis H0 and accepts the alternative hypothesis Ha. Thus, it may be concluded that the use of different wetlands differs significantly. The risk to reject the null hypothesis H0 while it is true is lower than 0.05%.

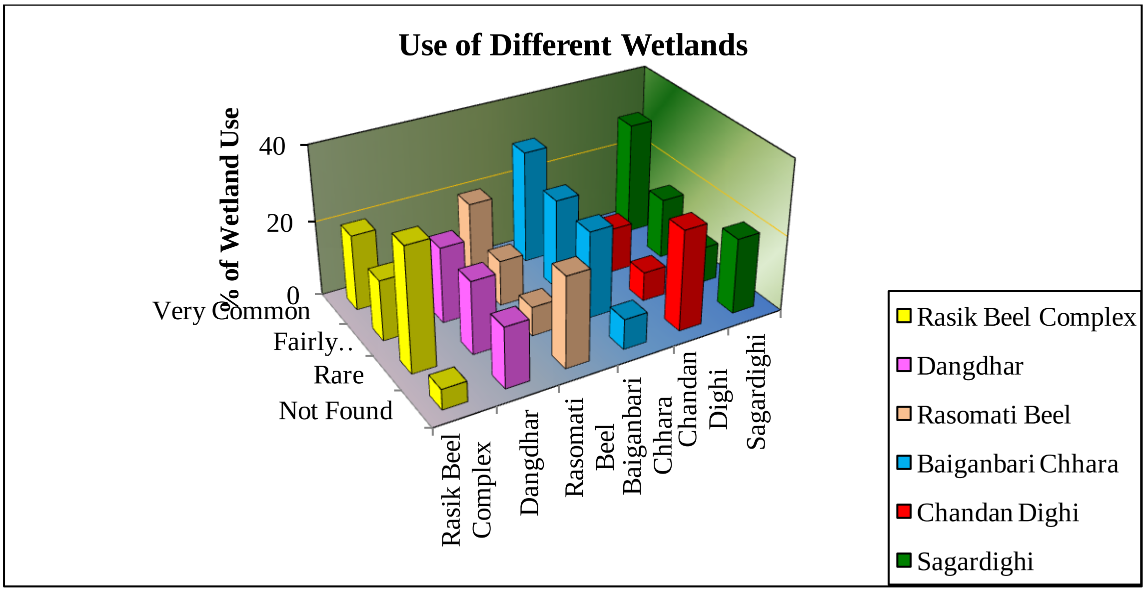

Fig 4.7: Use of selected Wetlands in the Study Area

4.4. Conclusion:

Wetlands are among the world's most productive and valuable ecosystems which directly influence human existence and well-being. Climate regulation, water supply, water purification, flood regulation, tourism and human sustenance and economic support are some of the important services provided by the wetland ecosystems. This wide range of economic, social, environmental and cultural benefits – in recent times is classified as ecosystem services (Costanzaet. al.1997). Despite covering only 1.5% of the Earth's surface, wetlands provide a disproportionately high 40% of global ecosystem services (Zedler and Kercher 2005). However, wetlands are the most threatened of all ecosystems today. A study by the Wildlife Institute of India reveals that around 70-80% of freshwater marshes and lakes in the Ganga & Brahmaputra floodplain region have been lost in the last 50 years. The intensive study of the wetlands in the study area reveals that the wetland use and services are rapidly dwindling with time. It is clear from the survey that 46.30% of the wetland services were not found, in the study area. About 32.10% of the services were on the verge of extinction, 15.43% of the services were on moderate situations (fairly common) and only 6.17% services were very common in the wetlands of the study area (Table 7.24 & fig 4.7). Both urban, as well as rural wetlands, are degrading speedily affecting the wetland utility and services to the surrounding inhabitants. From the field survey, it is obvious that though wetlands provide a great and diversified service, it is now transformed into the wasteland with a negligible importance to the surrounding inhabitants.

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CHAPTER-V

ENVIRONMENTAL STATUS OF WETLANDS

CHAPTER-V

ENVIRONMENTAL STATUS OF WETLANDS

5.1. Introduction:

Wetland environment is synonymous with wetland ecosystem and therefore is a combination of two different component- Biotic component and Abiotic component, which works as an interconnected system or a complex network. Wetlands are the richest ecosystems subsequent to the tropical rain forests of the world (Chowdhury, 2009). Wetlands, which are covering aquatic, marshy and terrestrial habitat, have been considered as ecotonal habitat (Mitsch and Gosselink, 1993). These obviously show their capacity to hold rich biodiversity that supports aquatic, marsh and land flora and fauna. It is a transition zone of pressure between two or more communities (Clark, 1954; Odum, 1959).

5.1.1. Abiotic Component:

In wetlands, the abiotic compounds consist of H_2O, O_2, CO_2, N, P, Ca and Amino Acid. A small part of the nutritional element is found blended with water in an acceptable condition for the aquatic animals but the larger part of it is reserved in the solid objects of animals' body. Sunlight, heat and air are included in this component.

5.1.2. Biotic Component:

Biotic components that include living animals and plants has been divided into three different parts such as-

5.1.2.1. Autotrophs or Producers:

All the floating, semi-submerged, submerged plants, phytoplankton which have the ability to manufacture their food, are known as Autotrophs.

5.1.2.2. Consumers:

Several kinds of insects, larva, fish, animals, planktons, reptiles, are depended on the producers for their foods are called as consumers.

5.1.2.3. Decomposers:

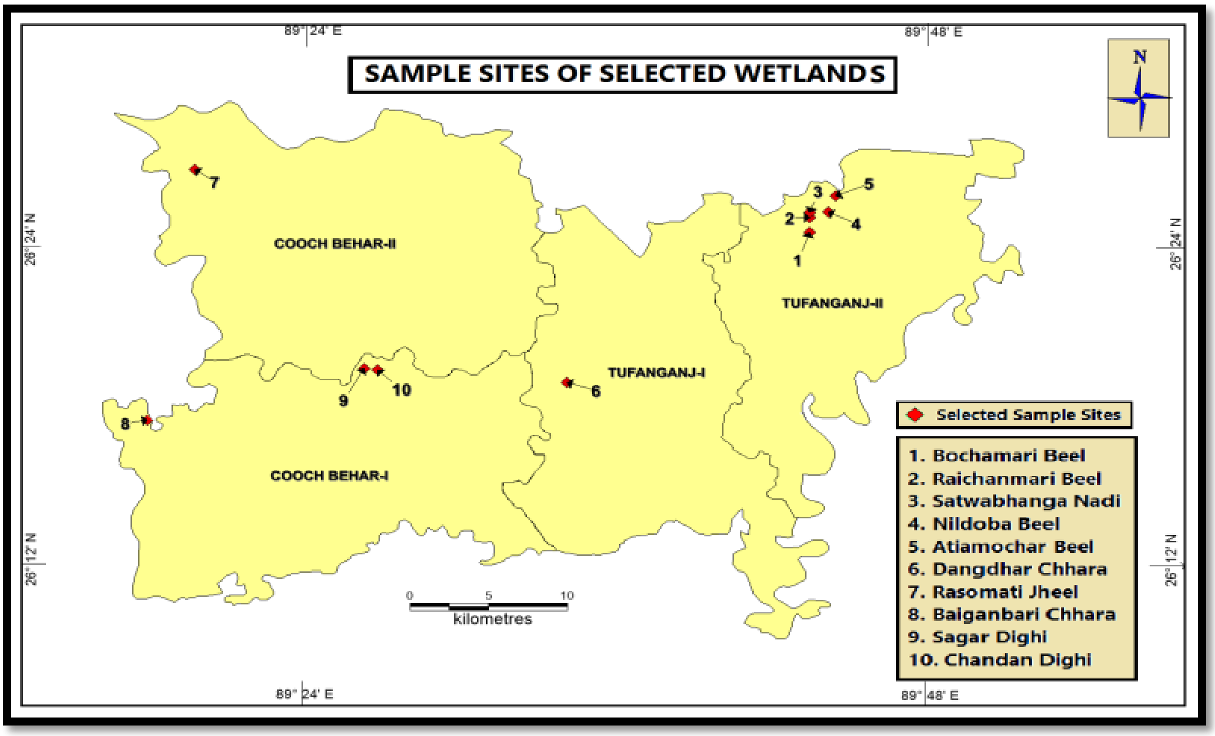
Aquatic bacteria, fungi, etc that are spread across the whole water body are included in the group of a decomposer. They decompose the dead plants and animal remains in the wetland waters.

5.2. Environmental Status of Wetlands of the Study Area:

The present status or condition of water, soil and biotic resources of wetlands are carefully investigated since water and soil quality; floral and faunal diversity are the major indicators of the overall health, well-being and environmental status of a wetland. To inquire into the soil and water conditions of the study area 10 wetlands, which are representative of the whole study area, have been selected. The wetlands are Bochamari Beel, Raichanmari Beel, Satwabhanga Nadi, Nildoba Beel, Atiamochar Beel, Dangdhar Chhara, Rasomati Jheel, Baiganbari Chhara, Sagar Dighi and Chandan Dighi (Table 5.1).

Table 5.1: Description of the Sample Sites of Selected Wetlands

Site No.	Site Name	Sample Site	(Block/ Municipality)
1	Bochamari Beel	26°24´30´´N, 89°43´15´´E	Tufanganj-II
2	Raichanmari Beel	26°25´03´´N, 89°43´21´´E	Tufanganj-II
3	Satwabhanga Nadi	26°25´13´´N, 89°43´21´´E	Tufanganj-II
4	Nildoba Beel	26°25´14´´N, 89°44´02´´E,	Tufanganj-II
5	Atiamochar Beel	26°25´51´´N, 89°44´19´´E	Tufanganj-II
6	Dangdhar Chhara	26°18´48´´N, 89°34´07´´E	Tufanganj-I
7	Rasomati Jheel	26°26´51´´N, 89°19´56´´E	Koch Bihar-II
8	Baiganbari Chhara	26°17´24´´N, 89°18´13´´E	Koch Bihar -I
9	Sagar Dighi	26°19´21´´N, 89°26´24´´E	Koch Bihar Municipality
10	Chandan Dighi	26°19´18´´N, 89°26´54´´E	Koch Bihar Municipality



Map 5.1: Sample Sites of Selected Wetlands

To inquire into the present flora and fauna the above mentioned ten wetlands are widely and relatively studied along with the other important wetlands associated to this selected wetland of the study area. The differences in water and soil quality of various wetlands depend on their geographical location, the extent of the water body, geo-chemical nature of the wetland basin rocks, natural vegetation in and around the wetlands and human activities. The present condition of the different wetlands in terms of availability of different flora and fauna are investigated.

5.2.1. Water Quality:

The study of water quality includes the estimation of physical, chemical and biological parameters of water. All these parameters are interrelated in such a way that a slight change in any of the parameters may trigger changes in others. From various studies, the wetland waters are found to be extremely rich in nutrients and have immense production potential which is reflected in soil and water quality. (Jhingran and Pathak,1987). All the characteristics of water, which influence the growth, production and reproduction of fishes, are collectively termed as water quality (CIFRI, 2000). The water quality analysis had been carried out on selected wetlands of the study area to understand the present status of wetlands. The parameters considered for assessing water quality are roughly divided into three categories i.e. - biological, physical and chemical. These parameters affect the overall health of a water body. The physical parameters include- Temperature, pH, Total Solid (TS), Total Suspended Solid (TSS), Turbidity and Electrical Conductivity (EC) of water. The chemical parameters cover- Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Free CO_2, Chloride, Carbonate, Bi-carbonate, Hardness, Iron, Alkalinity, etc.

The water quality also may vary from season to season owing to the large volumes of water inflow from the connecting rivers and wetland catchment area, especially during monsoon season. In order to assess the water quality of wetlands, 13 physico-chemical parameters are selected for the tests. All the tests were carried out following standard methods for water and Waste Water Analysis (A.P.H.A. 1985) which are described in detail in the methodology section.

Table 5.2: Water Quality of Different Wetlands in the Study Area

Name of Wetland	Year	Season	Water Temperature (°C)	pH	TA (mg/L) as $CaCO_3$	EC (µS/ Cm)	TDS (mg/L)	Free CO_2 (mg/L)	Iron(as Fe, mg/L)	Chloride (mg/L)	Carbonate (mg/L)	Bi-Carbonate (mg/L) ($HCO3^-$)	TH (mg/L)	DO mg/L	BOD mg/L
Bochamari Beel	2016	Pre-M	31.6	7.8	178	61	31	44	0.22	39	0	216	46	6.3	37.8
		Post-M	25.0	7.2	143	93	46	25	0.20	25	0	173	42	8.6	21.6
	2017	Pre-M	30.1	7.7	178	67	32	43	0.32	37	0	217	46	8.2	24.8
		Post-M	26.2	6.9	178	96	47	26	0.30	22	0	216	46	8.3	19.6
Satwabhanga Nadi	2016	Pre-M	30.3	7.5	330	148	72	29	0.45	40	0	302	66	7.5	16.3
		Post-M	25.3	7.1	214	140	69	26	0.30	23	0	260	61	9.8	14.2
	2017	Pre-M	30.2	7.7	357	145	68	33	0.48	42	0	320	68	7.6	18.6
		Post-M	25.7	7.2	178	138	70	28	0.28	22	0	216	62	9.7	12.9
Atiamochar Beel	2016	Pre-M	30.2	7.8	107	9	4	27	0.18	31	0	130	17	5.5	40.1
		Post-M	25.2	6.6	125	8	4	22	0.20	21	0	151	16	7.3	32.6
	2017	Pre-M	30.3	7.9	125	8	4	24	0.21	32	0	152	18	5.6	39.2
		Post-M	25.1	6.5	107	8	4	20	0.25	18	0	129	14	7.9	28.6
Nildoba Beel	2016	Pre-M	30.0	7.2	107	23	10	25	0.33	50	0	129	27	6.9	33.8
		Post-M	25.1	6.6	143	26	12	21	0.31	26	0	174	23	7.6	29
	2017	Pre-M	30.1	7.1	143	21	9	20	0.38	48	0	170	20	8.8	24.2
		Post-M	24.0	6.8	143	19	9	44	0.36	20	0	174	14	12.5	13.5
Raichanmari Beel	2016	Pre-M	30.1	7.1	214	68	31	35	0.06	50	0	264	32	6.1	42.1
		Post-M	26.8	7.3	178	52	27	41	0.07	28	0	217	26	7.8	28.7

Contd…….

	2017	Pre-M	30.3	7.2	250	55	26	36	0.08	49	0	305	30	7.2	37.3
		Post-M	25.9	6.8	143	58	29	46	0.06	22	0	175	28	7.3	32.2
Rasomati Jheel	2016	Pre-M	29.8	8.2	285	311	149	17	0.02	24	0	235	118	6.9	19.7
		Post-M	25.0	7.8	446	402	207	19	0.01	20	0	286	51	12.2	13.6
	2017	Pre-M	30.3	8.1	321	298	139	16	0.02	26	0	220	140	7.8	28.6
		Post-M	25.2	7.6	455	429	219	20	0.01	18	0	245	42	13.8	11.5
Baiganbari Chhara	2016	Pre-M	30.8	8.1	179	82	39	25	0.30	28	0	214	67	6.8	42.6
		Post-M	25.6	7.9	179	179	86	16	0.22	25	0	218	38	8.9	32.7
	2017	Pre-M	31.2	7.8	143	68	33	22	0.34	26	0	172	48	7.4	39.6
		Post-M	24.6	7.5	214	192	91	18	0.28	26	0	260	26	8.6	33.5
Dhangdhar Chhara	2016	Pre-M	32.2	8.2	250	226	102	28	0.91	45	0	304	36	3.8	81
		Post-M	29.0	7.5	178	124	61	16	0.78	26	0	214	14	6.2	52.3
	2017	Pre-M	31.9	8.1	286	208	97	22	0.88	39	0	248	33	4.6	67.2
		Post-M	28.2	7.4	143	111	55	16	0.84	24	0	172	14	7.5	45.6
Chandan Dighi	2016	Pre-M	31.0	7.4	286	399	188	72	0.20	75	0	249	96	1.8	76.2
		Post-M	25.3	7.9	214	266	126	59	0.10	57	0	185	79	4.6	40.5
	2017	Pre-M	33.3	7.7	286	314	149	54	0.30	78	0	260	88	1.9	86.9
		Post-M	24.3	7.8	250	253	122	68	0.10	48	0	190	68	4.4	43.5
Sagar Dighi	2016	Pre-M	30.2	9.2	230	78	36	0	0.25	38	150	120	62	4.6	40
		Post-M	26.3	8.6	250	62	29	0	0.12	22	150	90	22	8.6	18.7
	2017	Pre-M	30.9	8.9	235	75	35	0	0.27	36	150	95	58	4.7	36.2
		Post-M	28.1	7.8	255	60	31	0	0.14	20	150	90	24	7.2	23.6
Average		Pre-M	30.7	7.8	224.5	133.2	62.7	28.6	0.31	41.65	-	216.1	55.8	6.0	41.61
		Post-M	25.8	7.3	206.8	135.8	67.2	26.55	0.25	25.65	-	191.75	35.5	8.44	27.42
Average			28.27	7.6	215.7	134.5	65.0	27.6	0.28	33.7	-	203.9	45.7	7.2	34.5
SD			2.74	0.60	84.88	118.24	57.85	16.76	0.23	14.59	-	61.09	29.21	2.46	18.06

Source: Tested by Researcher during 2016 and 2017,N.B. - Pre-M =Pre-Monsoon, Post-M= Post-Monsoon

5.2.1.1. Physical Parameters:

The various physical factors affect the overall health of a water body. The following parameters are included as physical parameters (Table 5.1) i.e. Water Temperature, pH, Total Dissolved Solid (TDS), and Electrical Conductivity (EC).

5.2.1.1.1. Water Temperature:

Temperature is one of the most important parameters for the aquatic environment because it governs all physical, chemical and biological properties of waters. The rise in temperature leads to the speeding up of the chemical reaction in water and reduces the solubility of gases. In no case, the temperature of wetland water is lowered to freezing point or exceeds 40°C, which is dangerous to the aquatic life (Sharma, 1993). Distribution of aquatic organisms and other life forms greatly depend on water temperature. Temperature also relates to other physical parameters such as pH, Conductivity, Saturation of gases etc. which, have an overall influence on the biota of a water body.

From the Table 5.2, it is revealed that the mean temperature of the various wetlands varies from 25.8^{o}C to 30.7^{o}C. The average temperature is 28.27^{o}C with SD ±2.74^{o}C. Most of the wetland's temperature was higher than the average during pre-monsoon period (fig. 5.1). The study reveals that the preserved wetland (Rasomaoti jheel) has the least deviation of temperature. On the contrary, the wetlands which are dug up by man and are confined within urban commercial places or undergo rampant modification of natural wetlands have a higher negative variation of Temperature (Chandan Dighi, and Raichanmari Beel). The temperature of the water has a positive role in determining the other parameters of the water quality.

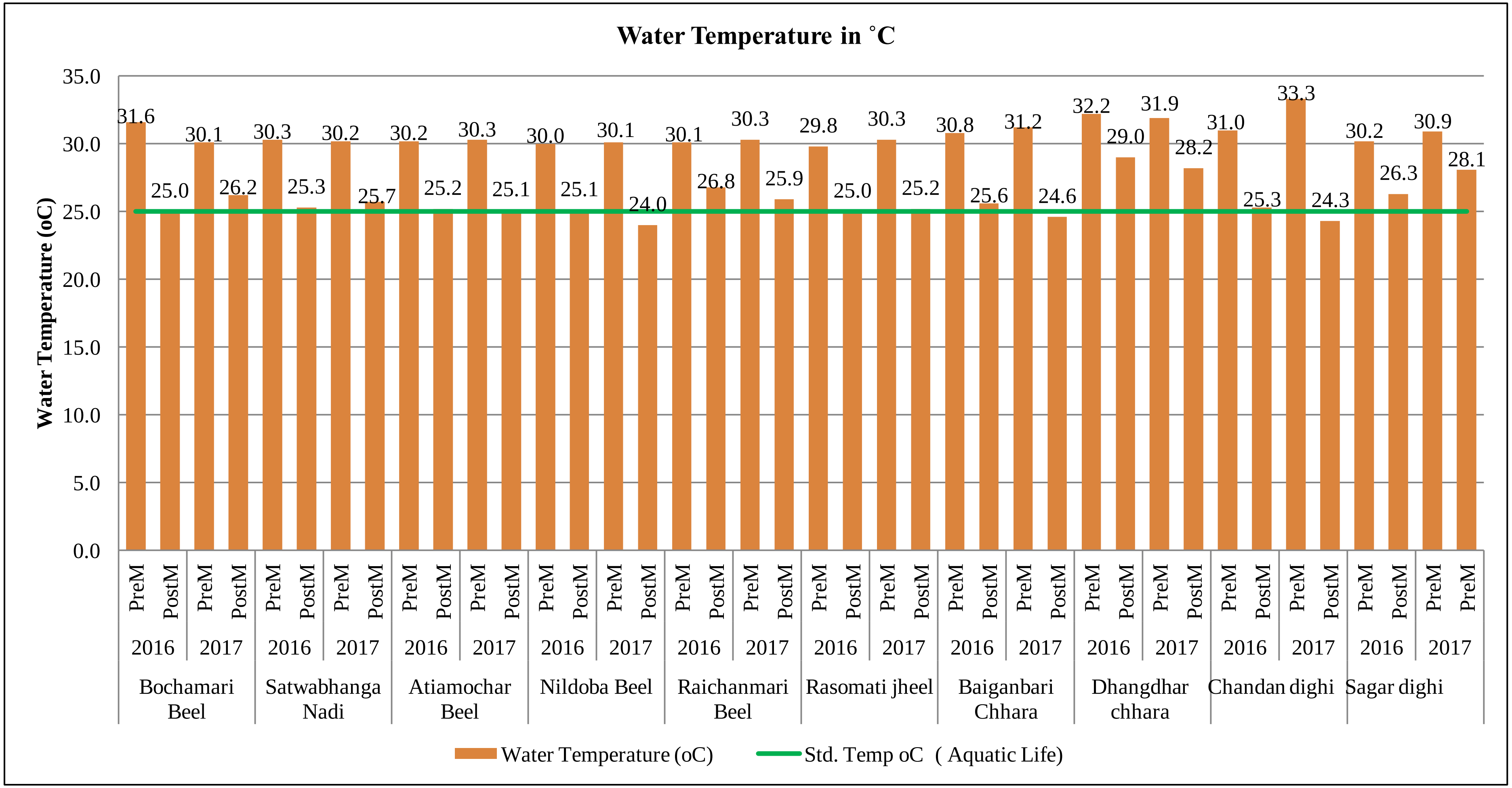


Fig 5.1: Temperature of Water in Different Wetlands, Koch Bihar & Tufanganj Subdivision, 2016 &2017, N.B. Pre-M =Pre-Monsoon, Post-M= Post-Monsoon

5.2.1.1.2. pH:

In water chemistry, measurement of pH is most important because it indicates overall water environment. It is the indicator of acidity and alkalinity of water. It is determined by the presence of H^+ ion and OH^- ion in a substance. The pH follows logarithmic scale, which ranges from 1 to 14 where pH 7 is neutral. The solubility and availability of nutritional elements such as Phosphorous, Nitrogen and Carbon depend on pH. Further, the heavy metals, which make the water toxic, are soluble in low pH. Natural waters are usually alkaline due to the presence of sufficient quantities of carbonate. However, pH of the water gets changed with time due to exposure to air and biological activities due to seasonal and diurnal variations. Industrial wastes also bring about significant changes in pH of a water body. The optimal range of pH for aquatic life or biodiversity is 6.5 – 9.0 (Bhatnagar & Devi, 2013) and for irrigation, it is 7.0 – 8.5 (WHO & BIS, 1991). It is clear that the pH is the simplified way to measure the H^+ ion concentration of a particular solution. The change of H^+ ion of any given solution imparts the inverse change of the pH of a solution. The temperature has an inverse relation with the pH. The rise in temperature causes the increase of molecular vibration in the solution and causes the rise of H^+ ion due to the decreased tendency of forming hydrogen bonds and finally, it reduces the water pH.

The average pH of the water was 7.8 and 7.3 during pre and post-monsoon period. Overall mean pH was 7.6 with SD ± 0.61. The other wetlands have a slight deviation of water pH. It is revealed that the pH of water during the post-monsoon period was slightly lower as much rainfall occurred during the monsoon period (fig 5.2). Except for Sagar Dighi, all other beels have the pH within normal limit of pH as prescribed by WHO, BIS as well as Bhatnagar & Devi, 2013. Thus, it may be concluded that except Sagar Dighi the pH of water is safe for aquatic as well as agricultural practice.

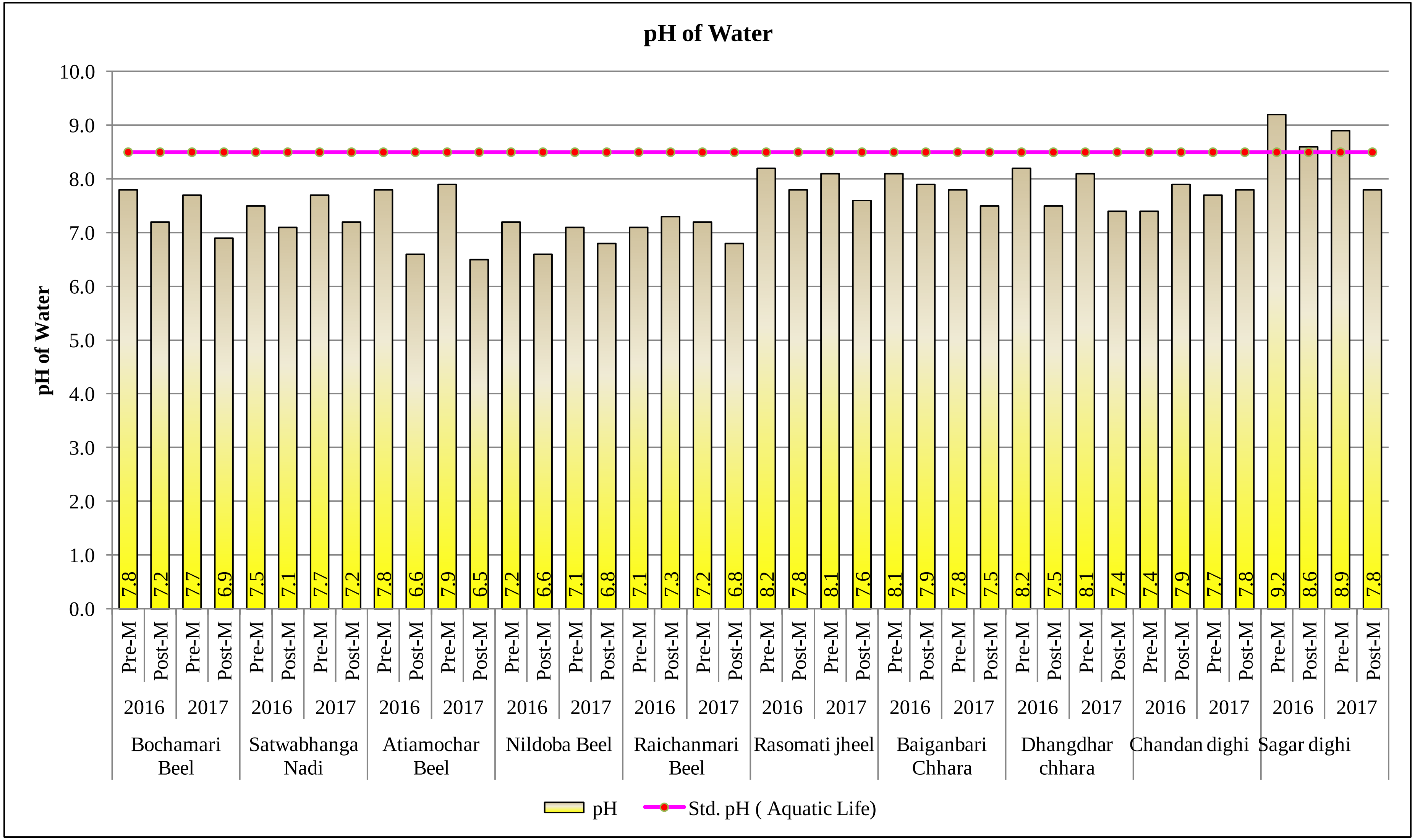


Fig 5.2: Availability of pH in Water of Different Wetlands, Koch Bihar & Tufanganj Subdivision, 2016 &2017, N.B. Pre-M =Pre-Monsoon, Post-M= Post-Monsoon

5.2.1.1.3. Total Dissolved Solid (TDS) and Electrical Conductivity (EC):

Total Dissolved solids (TDS) are the aggregated amount of floating, suspended, settleable and dissolved solids present in water samples. The solids may be organic or inorganic in nature. In another word, TDS is the measurement of inorganic salts (CaCO3, $MgCO_3$, NaCl, KCl, $MgSO_4$etc), organic matter, cations and anions dissolved in water. Organic solids in wetland waters are responsible for changes in taste, colour, odour and cause gas and biological problems.TDS is proportional to the degree of pollution. At the same time, water with a very low TDS concentration may be corrosive, the variation of TDS in the water may occur due to ionic composition of water. The factors like rainfall and biota cause changes in their concentrations. TDS is measured by the following equation:

TDS (mg/L) = 0.5 x EC (μs/cm) where 0.5 is the conversion factor of NaCl of the instrument

The EC value is an index to represent the total concentrations of soluble salt in surface water. Electrical conductivity (EC) is defined as the capacity of an aqueous solution to carry electric current.EC of water generally depends on the presence and concentration of ions, their mobility and temperature of water. So it is directly related to the concentration of salts dissolved in water i.e. TDS. A higher value of EC means higher concentrations of inorganic ions due to mineralization, use of inorganic fertilizers viz. K, Cl, $(NH_4)_2$, SO_4, NH_4NO_3 etc. The maximum tolerance limit of Electrical Conductance is $1000x10^{-6}$. Moreover, the conductivity is highly dependent upon temperature. No significant health hazard is linked with conductivity. However, it is an important criterion in determining the suitability of water for irrigation purposes.

Total Dissolved Solids (TDS) and Electrical Conductivity are related to each other. As a general rule TDS is the half of EC though they are measured in mg/L and μS/cm respectively. TDS (mg/L) = 0.5x EC (μS/cm) where 0.5 is taken as the conversion factor of NaCl of the instrument. The average TDS of the water was 62.7 and 67.2 during pre and post-monsoon period. Overall mean TDS was 65.0 with SD ± 57.85. On the other hand the average EC of the water was 133.2 and 135.8 during pre and post-monsoon period. Overall mean EC was 134.5 with SD ± 118.24. EC and TDS are the most common parameters for determining the water quality. EC determines the concentration of dissolved salts in the water. Thus, higher is the salinity, the higher is the EC. BIS prescribed as standard EC for aquatic life is 1000 µS/cm. On the other hand, BIS suggested the standard value of TDS 500 mg/L for aquatic life of water. It is observed from the study that none of the wetlands has crossed the standard value of TDS and EC for aquatic life (fig 5.4). The higher value of TDS and EC in the Rasomati Jheel may be due to the least interference and for being surrounded by the forests. On the other hand, Chandan dighi is one of the worst polluted wetlands. It is the dumping ground of the sewage of the adjacent shops. Moreover, the washer man uses the pond rigorously.

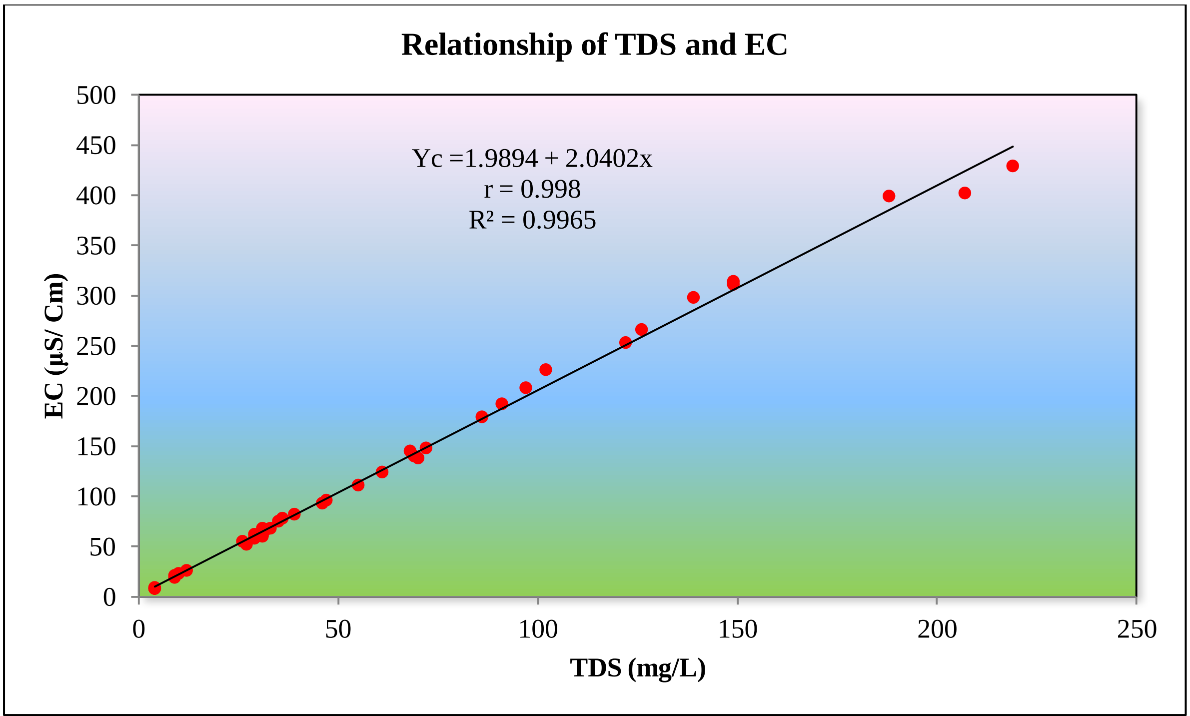


Fig 5.3: Relationship of TDS & EC in Water of Different Wetlands, Koch Bihar & Tufanganj Subdivision, 2016 &2017

The TDS and EC are positively related to each other. Pearson's coefficient correlation was a strong positive relation{r = (-)0.998} with a coefficient of determination: R^2= 0.9965(fig 5.3). The value of R^2 indicates that 99.65% data were explained by the dependent variable. It indicates the concurrent of relationship. It indicates that the increase of TDS increases the EC.

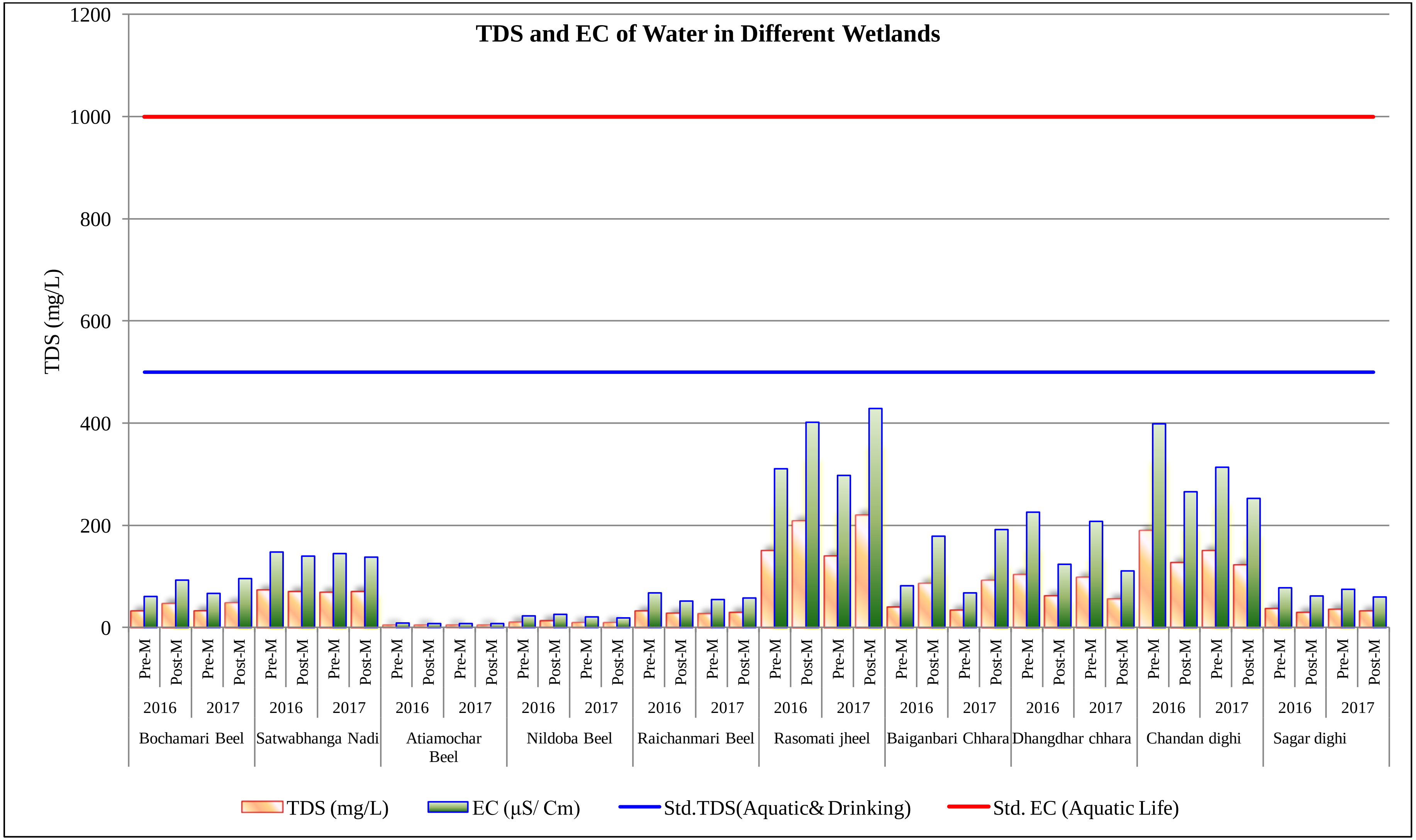


Fig 5.4: Availability of TDS & EC in Water of Different Wetlands, Koch Bihar & Tufanganj Subdivision, 2016 &2017, N.B. Pre-M =Pre-Monsoon, Post-M= Post-Monsoon

5.2.1.2. Chemical Parameters:

The chemical composition of wetland water depends on a variety of complex factors. However, three basic mechanisms that control water chemistry of wetlands- viz. precipitation, evaporation and nature of the basin. The ionic composition of water is chiefly determined by the rain and composition of macrophytes and phytoplankton. At present human activities related to industry, agriculture and urbanization play an important role in determining the chemical quality of water. The local people mainly for bathing, irrigation and fishing purposes use almost all the wetland waters. Therefore, following parameters are considered for the chemical analysis of wetland waters. The parameters are- Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chloride (Cl), Iron (Fe), Free CO_2, Carbonate, Bi-carbonate, Total Alkalinity, Total Hardness etc (Table 5.1) .

5.2.1.2.1. Dissolved Oxygen (DO):

All Living organisms are dependent on oxygen for growth and production. The D.O content shows the health and ability of the wetlands to purify itself through bio-chemical processes. Natural surface water is normally saturated with DO. However, it can rapidly decrease due to the discharge of oxygen-demanding wastes such as H_2S, Ammonia, Nitrate, Iron etc. from industries and agricultural land. Low DO concentration is generally associated with heavy contamination of organic matters. The low level DO in water bodies adversely affects the fish and other aquatic life, because without sufficient oxygen no animals can survive. The anaerobic micro-organisms produce various substances like ammonia, nitrite, ferrous iron, H_2S into the water when the concentration of DO is low. The aerobic organisms cannot oxidize these reduced substances. So, low concentration of DO and high concentration of reduced substances are harmful to the aquatic ecosystem. When the DO level drops below approximately 5 pm, some fish species like trout and brass leave such waters. Only the coarse type of fishes is found in such waters. In wetland waters having DO less than 2 pm, fishes disappear and the environment shifts towards anaerobic species (Trivedi et al, 1989). In general, the DO level is higher during the monsoon season.

Dissolved Oxygen is a significant factor for the aquatic as well as drinking water. It determines the quality of water. Bureau of Indian Standard (BIS, 1991) specifies the standard value of DO for aquatic life as 4.0 mg/L. In the present study, it is revealed in the fig-5.4 that Chandan dighi and Dangdhar Chhara are the worst in terms of the availability of dissolved oxygen. Such a situation is prevalent because of the dumping of organic and in-organic wastes & lacking proper management as seen in Chandan dighi and Dangdhar Chhara. The average DO of the wetlands in the study area was 6.0 mg/L in pre-monsoon period and 8.44mg/L during post-monsoon period. The overall mean DO was 7.2 mg/L with SD 2.46 mg/L. The values of both the seasons were high than the standard value (fig 5.5). The maximum concentration of DO has been observed in the Rasomati Jheel (13.8 mg/L) and Nildoba beel (12.5 mg/L).

Photo Plate 5.1 Recording of Water Quality Data at Baiganbari Chhara

Photo Plate 5.2: Soil sample collection from Rasomati Jheel

Photo Plate 5.3: Water Test in Laboratory

Photo Plate 5.4: Soil Test in Laboratory

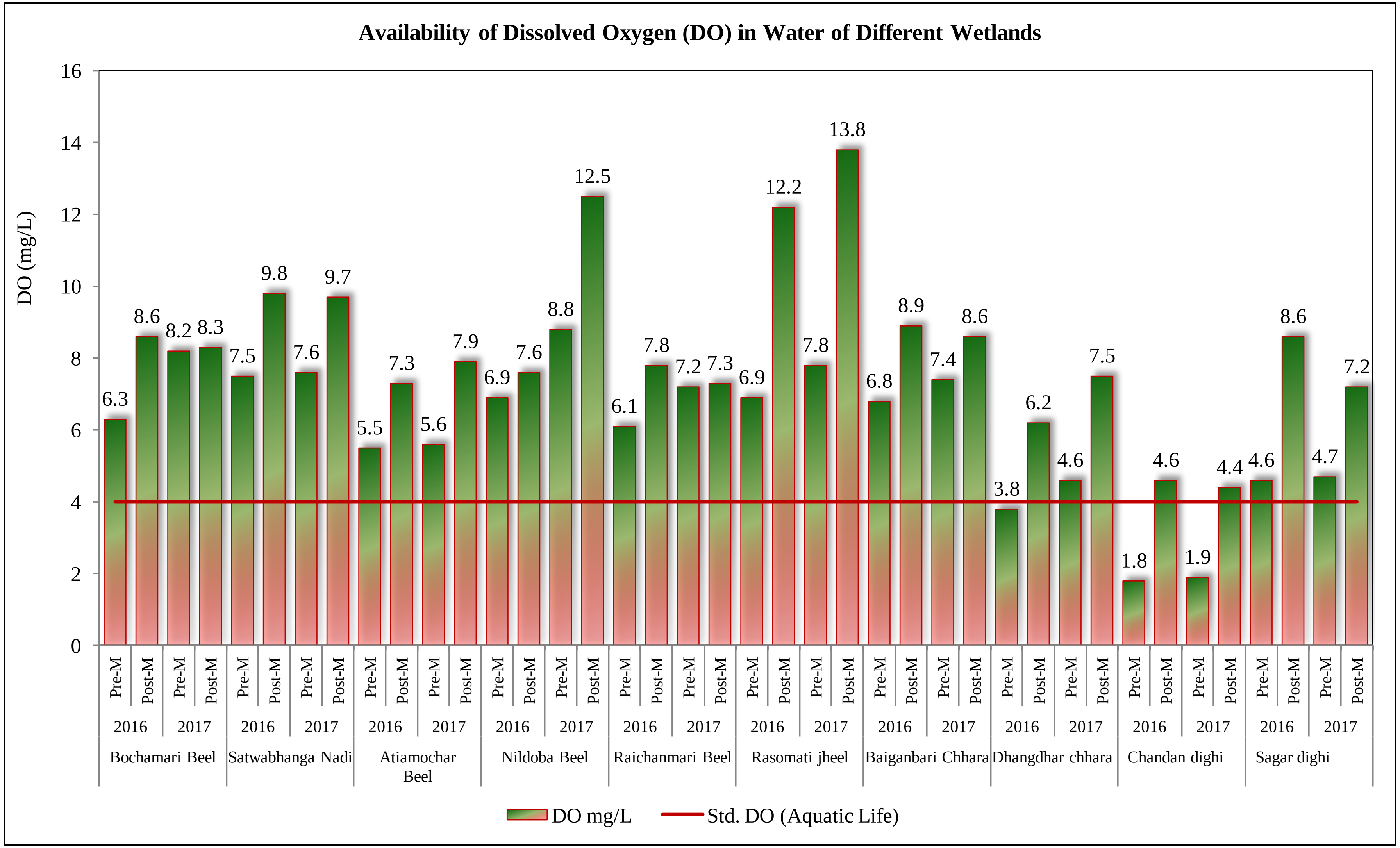


Fig 5.5: Availability of Dissolved Oxygen (DO) in Water of Different Wetlands, Koch Bihar & Tufanganj Subdivision, 2016 &2017, N.B. Pre-M =Pre-Monsoon, Post-M= Post-Monsoon

5.2.1.2.2. Biological Oxygen Demand (BOD):

The amount of oxygen utilized by micro-organisms in stabilizing the organic matters is BOD. BOD shows the intensity of bio-degradable matters present in the water of the wetlands. It shows the amount of molecular oxygen required by the bacteria to oxidise the organic materials. In other words, BOD measures the oxygen consumed by living organisms from wetland waters while utilising the organic matter. BOD values, in general, give a qualitative index of organic substances which are degraded quickly in a short period of time.

Biological Oxygen Demand (BOD) is another indicator of the health of the wetland. The suitability of the living organism in the water body mainly depends on the availability of BOD. Boyd has specified the optimum value for the aquatic life as 3-20 mg/L. The average BOD in the wetlands was 41.61 and 27.42 mg/L during the pre-and post-monsoon period. The overall mean availability of BOD was 34.5 mg/L with SD±18.06 mg/L. The higher value of standard deviation indicates that there is a significant variation of BOD in different wetlands (Fig 5.7).

The DO and BOD are inversely related to each other. Pearson's coefficient correlation was strongly negative {r =(-)0.83} with a coefficient of determination R^2= 0.6813.The value of R^2 indicates that 68.13 % data was explained by the dependent variable. It indicates that the lowering of the DO increases the BOD (fig 5.6).

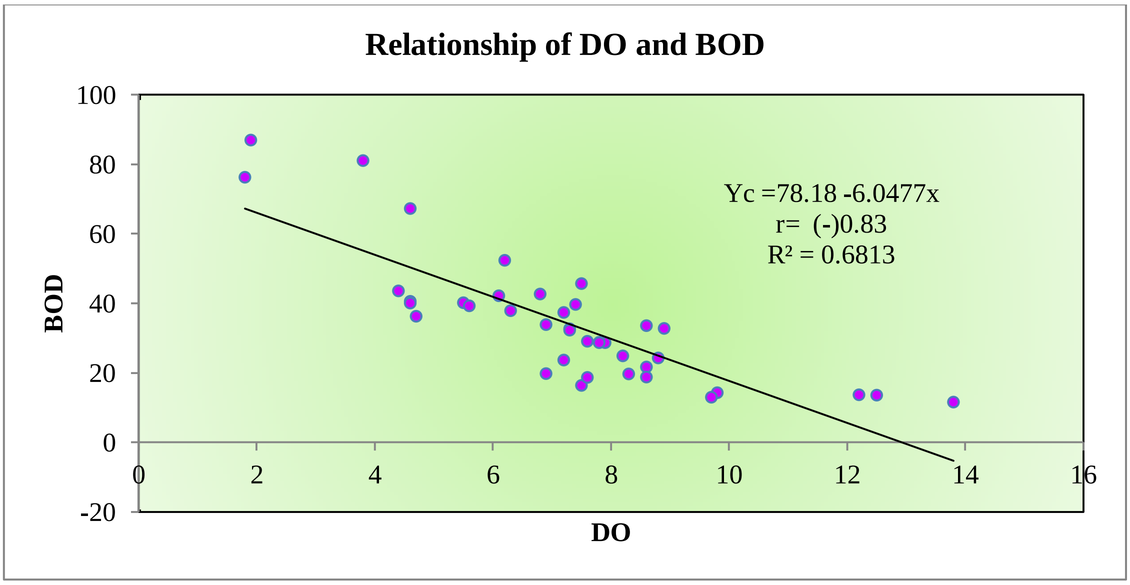


Fig 5.6: Relationship of DO and BOD

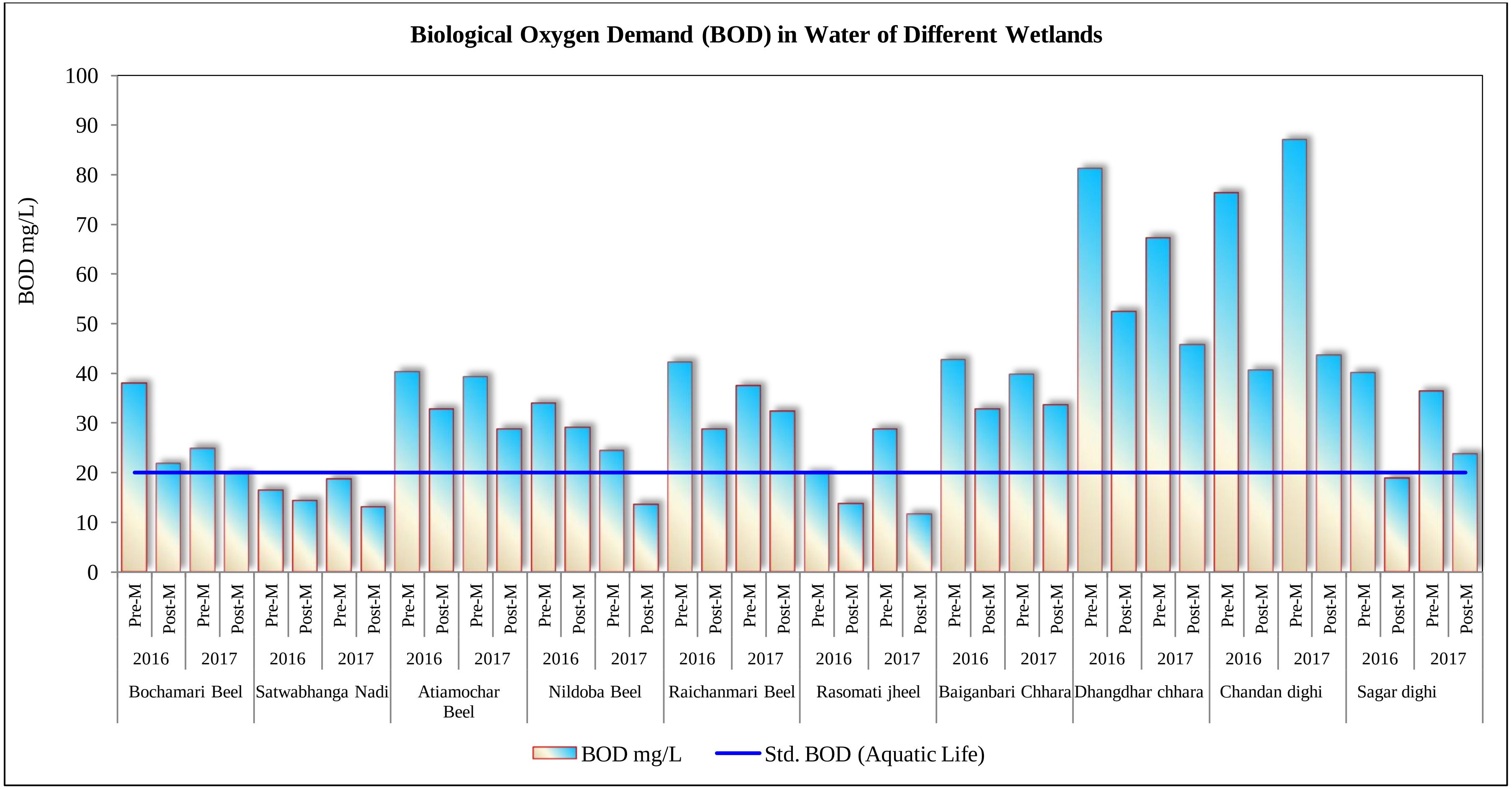
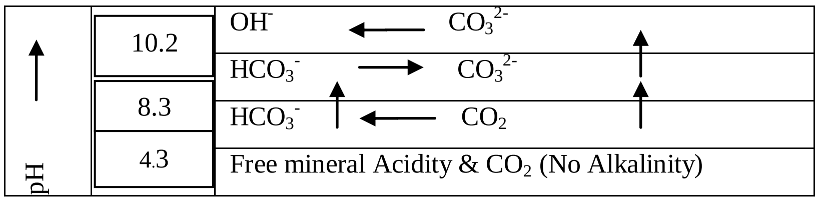


Fig 5.7: Availability of Biological Oxygen Demand (BOD) in Water of Different Wetlands, Koch Bihar & Tufanganj Subdivision, 2016 &2017, N.B. Pre-M =Pre-Monsoon, Post-M= Post-Monsoon

5.2.1.2.3. Total Alkalinity:

The alkalinity of water is an important parameter, which determines the amount of chemical to be added in water treatment. It maintains the pH of water. Alkalinity is an anionic phenomenon. All anions such as carbonate, bi-carbonate, hydroxyl, phosphate, silicate etc. contribute to alkalinity in water. Higher alkalinity is responsible for rising pH in water. Natural alkalinity helps for the growth of fish and other aquatic lives. H_2CO_3, HCO_3^- and CO_3^{2-} are the three carbonate elements which control the total alkalinity and it depends on the pH of water and water temperature. Thus, pH and total alkalinity are interrelated.



At pH below 4.3 = No Alkalinity

4.3 to 8.3 = CO_2 starts to convert HCO_3^-

8.3 = Only HCO_3^- present

> 8.3 = HCO_3^- is being converted to CO_3^{2-}

10.2 = All HCO_3^- have been converted to CO_3^{2-}

> 10.2 = CO_3^{2-} is converted to OH^- ion

Thus, higher the alkalinity, the higher is the pH or vice-versa. The minimum requirement of TA for fish culture is 20 mg/L whereas the normal range of TA is 50-200 mg/L (Bhatnagar, A. & Deve, P. 2013). Very low alkalinity (<100 mg/L) increases the pH and makes the water acidic.

It is observed from the present study in two different seasons during 2016 and 2017 that the average alkalinity was 215.7 mg/L as $CaCO_3$ with SD ± 84.88 mg/L as $CaCO_3$.The Satwabhanga Nadi (178-357 mg/L) and Rasomati Jheel (285-455 mg/L) have the maximum concentration of TA as because these are natural Ox-Bow Lakes with least human interference. Chandan dighi, Sagar Dighi and Dangdhar Chhara also show moderate total Alkalinity. The Dangdhar chhara is located in the vicinity of the brick kilns and Chandan dighi is the most neglected pond and therefore shows an increase in the Alkalinity. Atiamochar and Nildoba beels show the least TA as they have high pH. It is also evident that the TA has weakly positive relation with the water pH. Very low alkalinity makes the water acidic. From the Fig 5.9 it is observed that Rasomati Jheel has a higher concentration of TA as compared to the BIS standard of aquatic life.

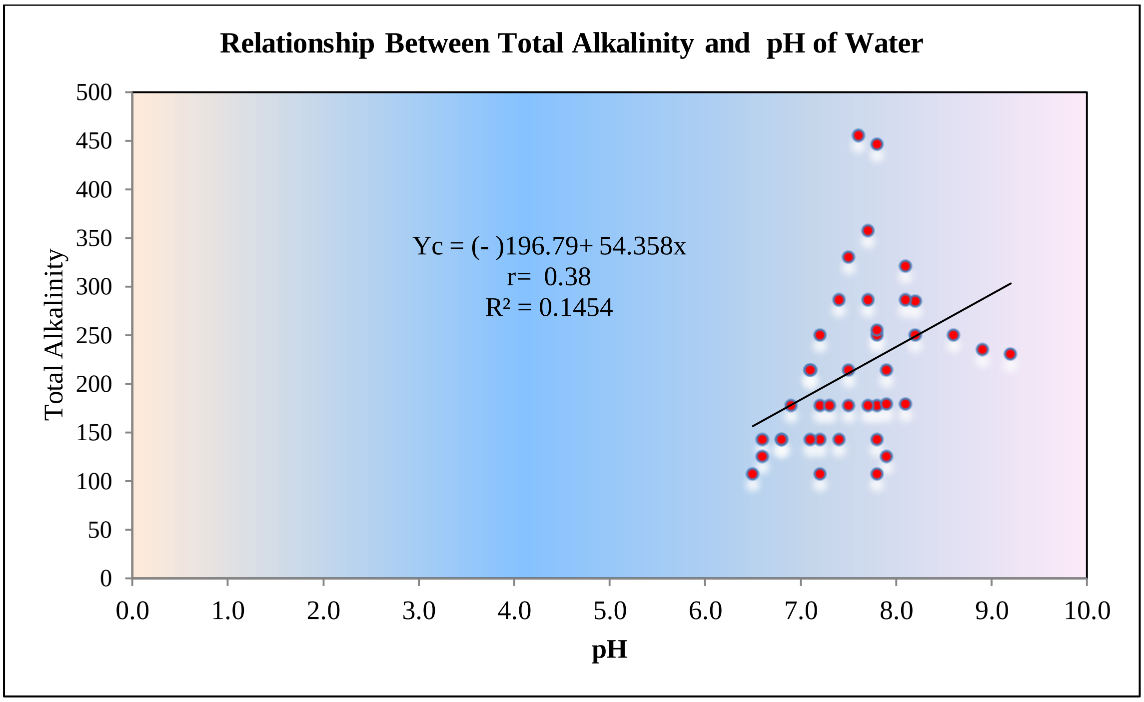


Fig 5.8: Correlation between TA and pH of Water in Different Wetlands, Koch Bihar & Tufanganj Subdivision, 2016 &2017

The total alkalinity and pH are positively related to each other. Pearson's coefficient correlation was very weak positive {r =(-)0.38} with a coefficient of determination: R^2= 0.1454. The value of R^2 indicates that 14.54 % data was explained by the dependent variable. It indicates that the increase of the DO increases the BOD (fig 5.8).

5.2.1.2.4. Total Hardness:

The hardness of water indicates high mineral content. In hard water minerals primarily consists of calcium (Ca^{2+}) and magnesium (Mg^{2+}) metal cations and sometimes other dissolved compounds such as bi-carbonates and sulphates. Calcium usually enters the water as carbonate or magnesium carbonate, while calcium carbonate (C_aCO_3) comes in the form of limestone and chalk, the predominant source of magnesium is dolomite ($MgCO_3$).

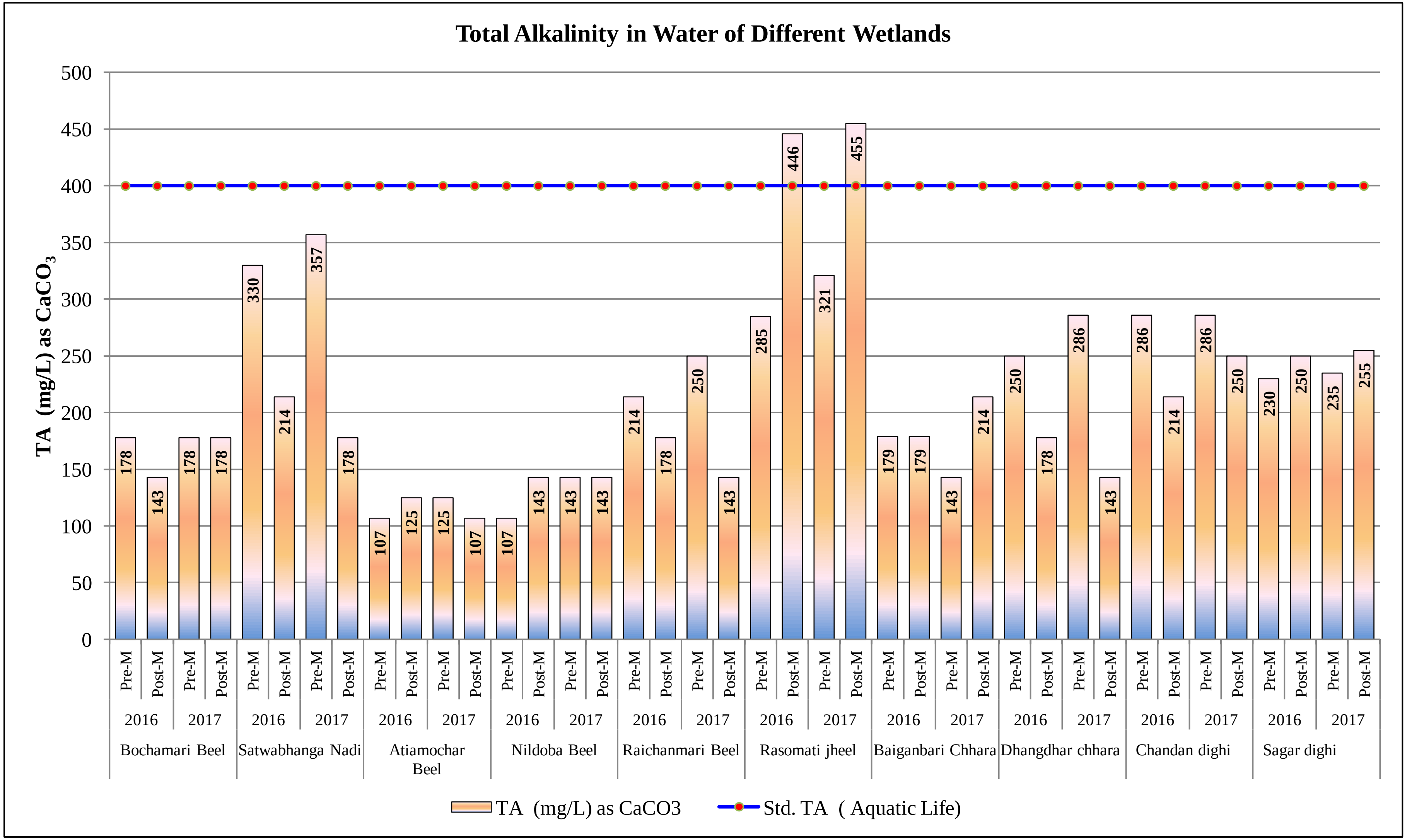


Fig 5.9: Availability of Total Alkalinity in Water of Different Wetlands, Koch Bihar & Tufanganj Subdivision, 2016 &2017, N.B. Pre-M =Pre-Monsoon, Post-M= Post-Monsoon

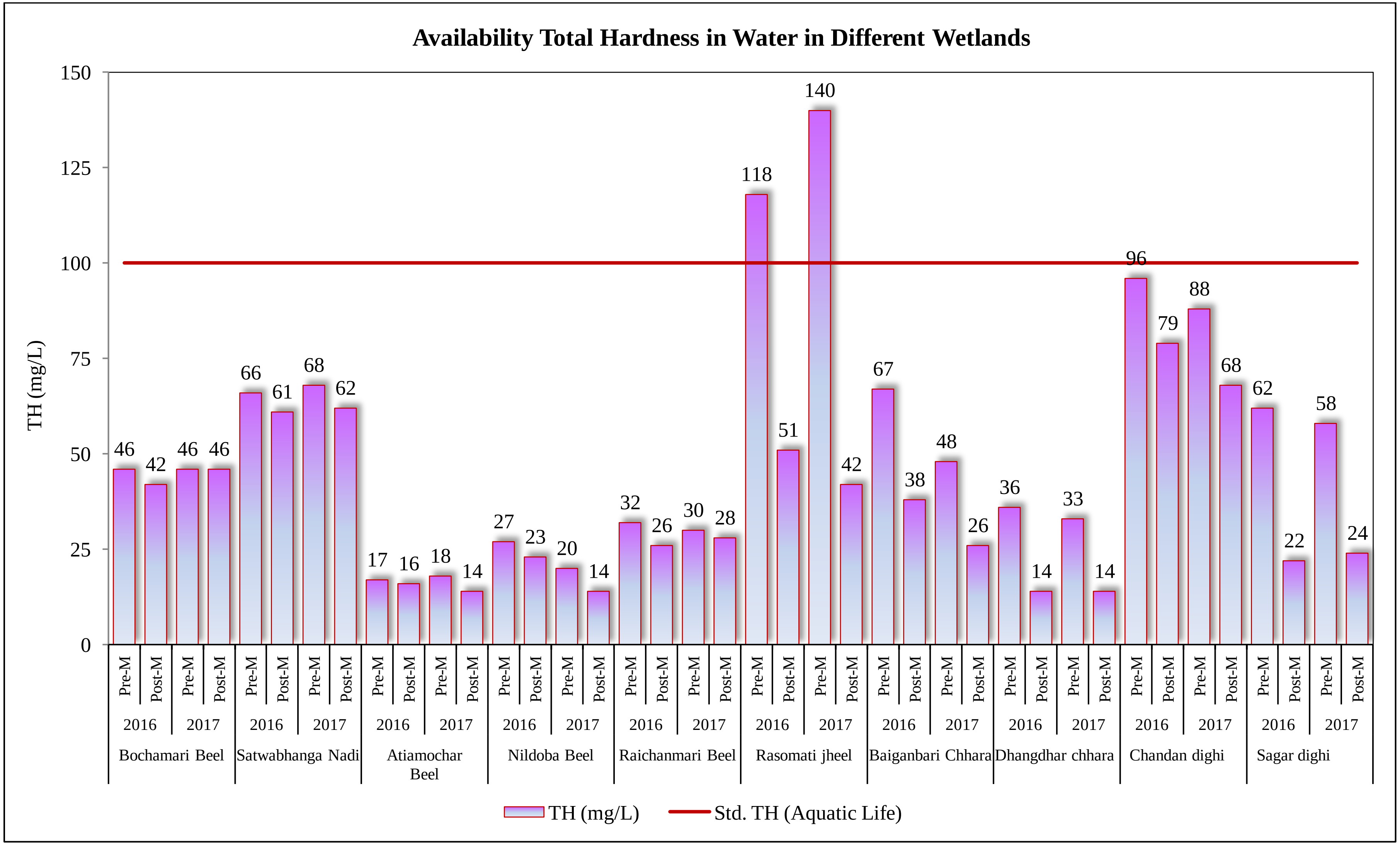


Fig 5.10: Availability of Total Hardness in Water of Different Wetlands, Koch Bihar & Tufanganj Subdivision, 2016 &2017, N.B.Pre-M =Pre-Monsoon, Post-M= Post-Monsoon

The World Health Organization stated that ‘there does not appear to be any convincing evidence that water hardness causes adverse health effects in humans’ (World Health Organization Hardness in Drinking Water, 2003). But it may affect the aquatic life. The TH in the surface fresh water ranges between 10 mg/L to 500 mg/L depending on the climate. Total hardness is classified as- < 50 mg/L = Soft, 50-150 mg/L = Moderately Hard, 150-300 mg/L = Hard, > 300 mg/L = Very Hard (Reynolds and Richard, 1996). WHO prescribed the standard limit of TH for aquatic life to be as 50-100 mg/L.

The Rasomatibeel has the maximum concentration of TH (118 and 140mg/L) in pre-monsoon period during 2016 and 2017 due to the presence of high concentration of dissolved minerals like calcium and magnesium from the forested land. As Chandandighi (88 to 96 mg/L) is highly polluted, it also shows the moderate-high concentration of total hardness. All the other wetlands have hardness in the range of permissible limit of standard value for aquatic life (fig 5.10).

5.2.1.2.5. Carbonate and Bi-Carbonate:

Carbonate (CO_3^{2-}) and bi-carbonate (HCO_3^-) are the salt of carbonic acid (H_2CO_3) which is an important parameter of water chemistry. The concentration of Carbonate and Bi-Carbonate depends on the pH of water. In less than 4.3 pH, there is no trace of CO_3^{2-} or bi-carbonate (HCO_3^-) anions. At pH level 8.3 all CO_2 converts to HCO_3^- and beyond pH 8.3, the HCO_3^- starts converting into CO_3^{2-}. CO_3^{2-} and HCO_3^- combined with Ca^+ and Mg^+ form $CaCO_3$ and $MgCO_3$ which increases the total alkalinity and pH. This may reduce the toxicity of water by removing lead and cadmium. If the amount of HCO_3^- and CO_3^{2-} levels are high (> 120 mg/L and 15 mg/L), these anions combined with Ca^+ and Mg^+ cations form insoluble $CaCO_3$ and $MgCO_3$ resulting in the rise of alkalinity. From Table 5.2 it is evident that average CO_3^{2-} in the Sagar Dighi was 150 mg/L and in other wetlands, carbonate was 0 mg/L as $CaCO_3$ because other sample sites show the pH lowers than 8.3. The HCO_3^- and CO_3^{2-}anions have a direct and significant relationship with temperature, pH, alkalinity and negative relationship with free CO_2 and chloride. Post-monsoon period shows a higher concentration of HCO_3^- in all wetlands because the agricultural and inorganic constituents waste and ash gets accumulated in the low lying water bodies by runoff. The average bi-carbonate in the wetlands was 216.1 and 191.75 mg/L during the pre-and post-monsoon period. The overall mean availability of bi-carbonate (HCO_3^-) was 203.9 mg/L with SD±61.09 mg/L (fig 5.11).

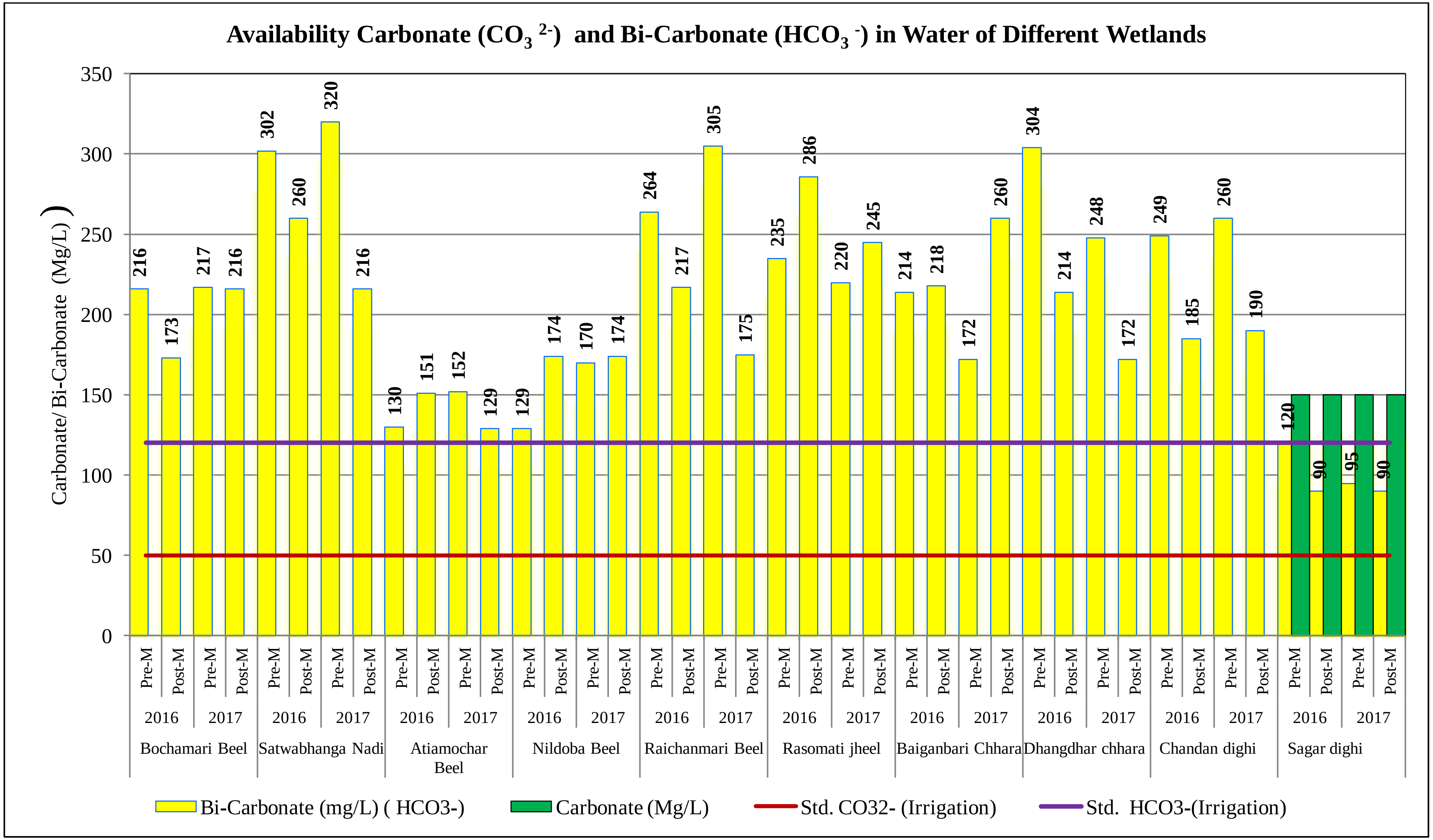


Fig 5.11: Availability Carbonate (CO_3^{2-}) and Bi-Carbonate (HCO_3^-) in Water of Different Wetlands, Koch Bihar & Tufanganj Subdivision, 2016 &2017, N.B. Pre-M =Pre-Monsoon, Post-M= Post-Monsoon

5.2.1.2.6. Free CO_2:

CO_2 is soluble in water and is present as dissolved CO_2. It is abundant in water because of its solubility which is about 200 times more than that of oxygen. The respiration of living organism in water, decomposition of organic matter and CO_2 of the atmosphere are the sources of free CO_2 in water. The photosynthesis of aquatic plants depends on CO_2 and HCO_3^-. The concentration of CO_2 is related to water temperature, pH and total alkalinity (TA). At pH 4.3-8.3, the free CO_2 starts to convert HCO_3^- and increases the alkalinity. Carbon is not appreciably toxic to fishes, most fish will survive for several days in water containing up to 60mg/lit, provided that the dissolved oxygen is plentiful. Carbon-di-Oxide concentrations are normally quite high when dissolved oxygen concentration is low; this is because CO_2 released in respiration is utilized in photosynthesis. When dissolved oxygen is low, photosynthesis does not proceed rapidly because of the relationship of carbon-di-oxide to the respiration and photosynthesis. Carbon-di-Oxide concentration usually increases during the night and decreases during the day. The particularly high concentration of CO_2 occurs in ponds after phytoplankton dies off after the loss of thermal stratification and during cloudy weather. The normal limit of free CO_2 in water is 6 (CPCB) beyond of which it is lethal to aquatic life.

The free CO_2 value of the water bodies in the urban site (Chandan dighi) varies between 54-72 mg/L, whereas in Rasomati jheel the free CO_2 was 16-20 mg/L (fig 5.12). During the pre-monsoon period due to the increase of water temperature the concentration of free CO_2 rises up to 72 mg/L in Chadandighi. The CO_2 is inversely related to water temperature, pH and TA. The free CO_2 of Raichanmari beel (35-46 mg/L) also show high concentration. The stress level of free CO_2 for aquatic life is 6mg/L (CPCB). Rasomati Beel and Baigonbari Chhara are the most suitable in terms of free CO_2. A higher level of free CO_2 is very much harmful to aquatic life. The Sagar Dighi has no free CO_2 as its pH is more than 8.3. The free CO_2 is, thus, converted to Carbonate (CO_3^{2-}).

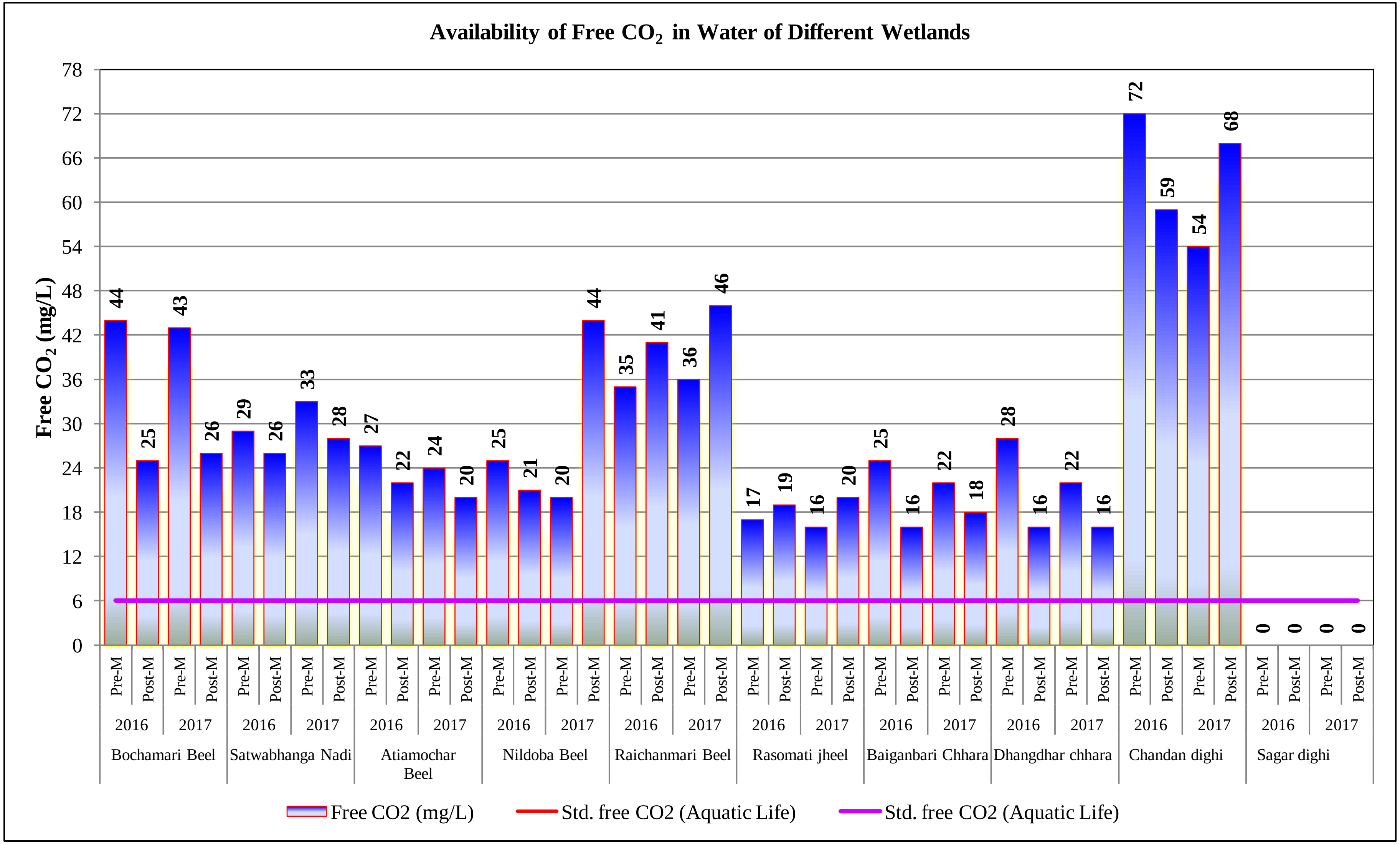


Fig 5.12: Availability of Free CO_2 in Water of Different Wetlands, Koch Bihar & Tufanganj Subdivision, 2016 &2017, N.B. Pre-M =Pre-Monsoon, Post-M= Post-Monsoon

5.2.1.2.7. Chloride (Cl):

Chloride is one of the major inorganic anions in water and waste water (Garg, 2003).Chloride content increases in water bodies due to organic matter decomposition. Chloride content is usually high in waste water, the main sources of chloride in water are municipal wastes, sewage effluent, chemical fertilizers, coal ash, high rate of evaporation, animal wastes etc. The main forms of chlorides are NaCl, KCl, $CaCl_2$ and HCl in surface and underground water. In natural fresh water,however, its concentrations remain quite low. The chloride concentration serves as an indicator of pollution. Chlorine (Cl^-) is a toxic element but when it receives one electron or combines with other cations, it forms chloride which becomes very essential to living organisms. Sreenivasan (1965) pointed out that a concentration 4-10 mg/L of chloride indicates the purity of water. Chloride is very much related to PH, TA, EC, TDS, Free CO_2 and bi-carbonates. High concentration of chlorides is harmful to human as well as aquatic life as it decelerates the growth and reproduction process. The normal range of chlorides in rivers and other fresh waters ranges between 15-35mg/L (Bhatnagar, A. & Deve, P. 2013).Fig 5.12.shows that the maximum concentration of chloride is found in Chandan Dighi (48-78 mg/L) which is most polluted wetland in the study area. Use of softener by the washer man and discharge or swage contaminates the water of Chandan dighi result high chlorides content. The high concentration of chloride in Nildoba beel and Raichanmari beel during pre-monsoon period varies from 48-50 mg/L. The range of Chloride varies 22-39 mg/L in Bochamari beel, 22-40mg/L in Satwabhange Nadi. (fig 5.13) This high concentration of chloride is due to anthropogenic source of fertilizer made with potash (K) which is accumulated from agricultural wastes. The concentration of chloride in Dangdhar Chhara was 24-45 mg/L. due to various chemicals used as dye for making the bricks red colour. The brick kiln industry effluents are the source of chloride in Dangdhar Chhara. The wetlands having less anthropogenic interference are within the threshold limit of chloride such as Atamochar beel (18-32 mg/L), Baigonbari chhara (25-28 mg/L), Rasomati Jheel (18-26 mg/L).

5.2.1.2.8. Iron (Fe^{3+}):

Iron is of the important parameter of water quality. Iron exists in two forms, soluble ferrous iron (Fe^{2+}) and insoluble ferric particulate iron (Fe^{3+}).In most aquaculture systems there is a high oxygen concentration, and all iron present in the water is in the form of insoluble ferric iron. Variations of iron profoundly influence the structure and function of lake ecosystems (Shaked, Y., Erel, Y. and Sukenik, A., 2004). Therefore, iron biogeochemistry and its environmental impacts in freshwater lakes are important. The permissible limit of Iron in potable water is 0.3mg/l, while the excessive limit is 1.0mg/l. The high concentration of Iron is harmful to fish and other aquatic lives.

The presence of Iron (Fe) content has been presented in the fig 5.13. It is revealed that iron content is very insignificant in the Rasomati Jheel (0.01-0.02ppm) as it is very much less affected by the human interference. On the contrary, Dangdharchhara (0.78-0.91 ppm) shows the maximum concentration of iron as it is one of the worst natural wetland which is located near the brick kiln industry. The industry wastes are drained to the Dangdharchhara. The Satwabhanga Nadi (0.28-0.48 ppm) also has a heavy concentration of the iron next to the Dangdhar Chhara. The urban wastes and sewerage of Kamakhyaguri may be the cause of heavy concentration of iron in Satwbhanga Nadi. Whatever may the form heavy concentration of iron creates a nuisance for the aquatic life as well as to the human health. The standard value of iron suitable for aquatic life has been specified as 1.0mg/L for aquatic life by Environmental Protection Agency (EPA, 1986). Iron concentration of all the wetlands was within the standard value i.e. 1.0 mg/L. Thus, it is clear from the Fig. 5.12 that iron concentration in the surface water has minimal effect on the water quality.

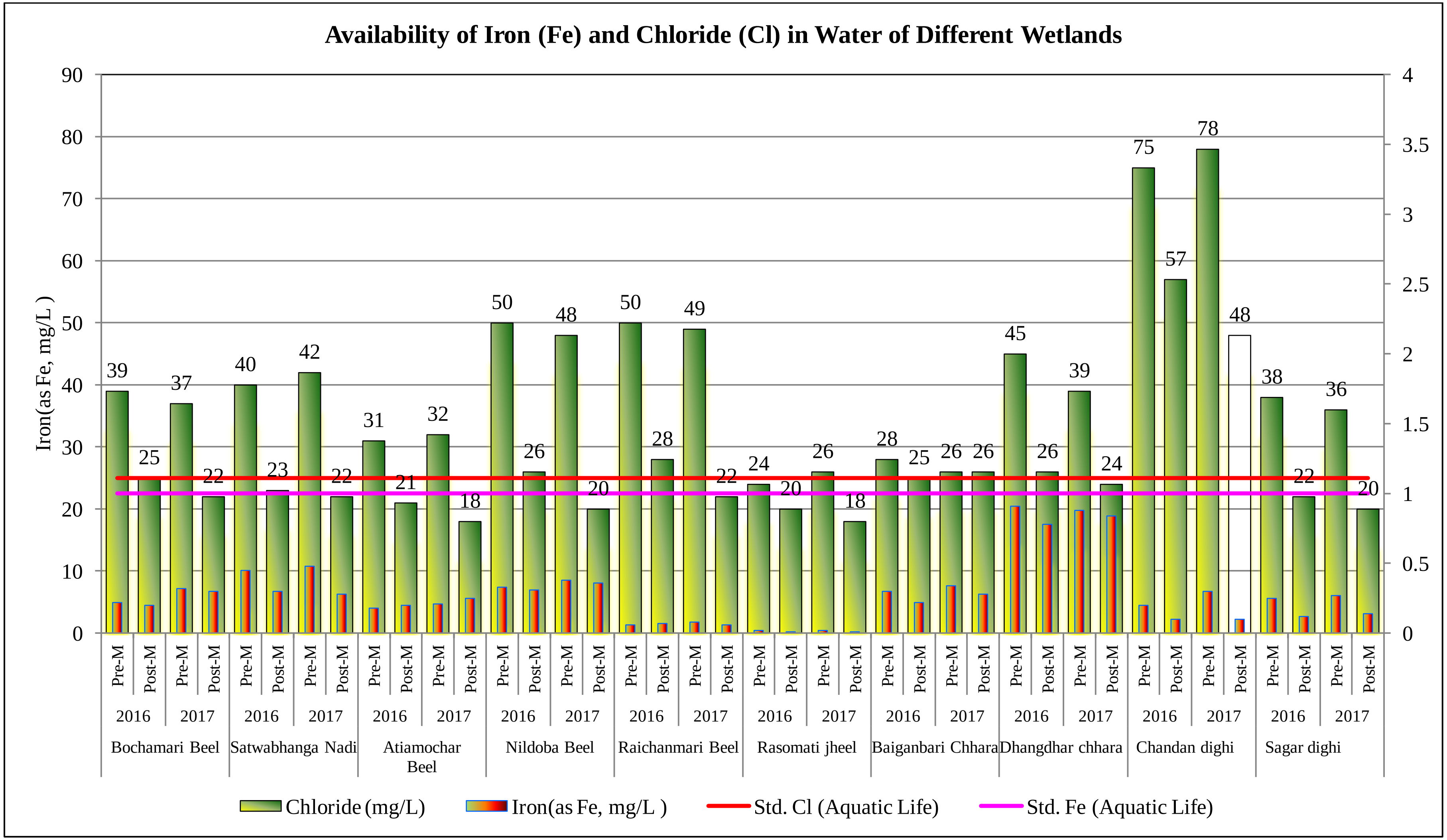


Fig 5.13: Availability of Iron (Fe) and Chloride (Cl) in Water of Different Wetlands, Koch Bihar & Tufanganj Subdivision, 2016 &2017, N.B. Pre-M =Pre-Monsoon, Post-M= Post-Monsoon

5.2.2. Soil Properties:

The property of soil of the selected wetlands is analysed in the laboratory for a proper understanding of the wetland environment in the study area (Table 5.3). However, in some wetlands, soil properties vary significantly due to the influence of factors like vegetation cover, cropping, irrigation, land drainage, runoff pollution, pesticide, insecticide, herbicide use, waste deposal from urban, sub-urban areas, and industries. The soil is vital in maintaining the productivity of any water body. Soils provide shelter and food to the benthic fauna and flora, which play a significant role in maintaining the nutrient status of overlaying water. Soils of the flood plain wetlands receive organic matter, inorganic minerals, silt and clay. Most of the flood plain wetlands abound in aquatic vegetation. Heavy accumulation of dead plant materials at the bottom of the wetlands is decomposed.

5.2.2.1. Soil pH:

The soil pH is meant to express the acidity or alkalinity of the soil. The pH determines the availability of nutrients, the physical condition of the soil and the microbial activity. The soil pH ranges from 5.00 to 8.5and can support almost all the plants. Along with application of Nitrogen fertilisers and acid forming parent materials, soil pH gradually decrease towards the periphery of the wetland water. In other words, the acidity of soil is less towards the permanent water bodies. Some acid-forming materials yield H^+ ions. The concentration of H^+ ions in the parent materials may be responsible for the occurrence of acidic soils in wetlands. pH determination is useful for soil classification on the basis of acidity or alkalinity. pH is a measure on logarithmic scale ranging from 1-14, where < 4.5- Extremely Acidic, 4.6 to 5.2- Strongly Acidic, 5.3 to 6.0- Moderately Acidic, 6.1 to 6.5 - Slightly Acidic, 6.6 to 7.0 – Neutral, 7.1 to 7.5 - Slightly Alkaline, 7.6 to 8.3 -Moderately Alkaline, 8.4 to 9- Strongly Alkaline, > 9- Extremely Alkaline. Use of chemical fertilizers in the agricultural fields may also increase the soil pH in the wetland soil because unutilized chemical fertilizers finally drain into the wetlands through rain water.

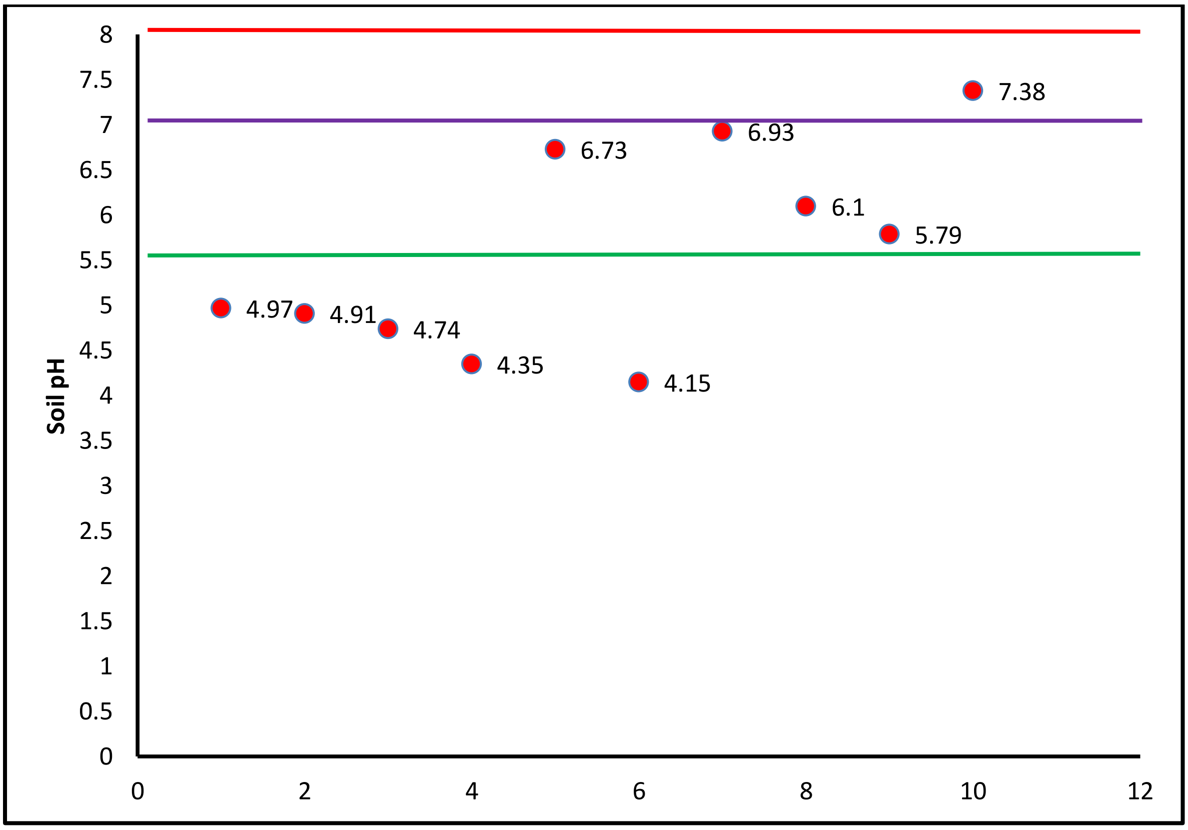
The soil samples of wetlands are found to be moderately acidic. The average soil pH of wetland soil is 5.6. The range of pH value varies from 5.1 to 5.9. Table-5.3 shows that except Sagar Dighi (7.38) all samples are acidic in nature (below 7).The highest pH value is recorded in Sagar Dighi (7.38) followed by Rasomati Jheel (6.93), Naldoba Beel(6.73), Baiganbari chhara (6.1), Chandan Dighi (5.79), Bochamari Beel (4.97), Satwabhanga

Table 5.3: Value of Soil Properties of Selected Wetlands with Soil Quality Rating Standard

SL. No.	Soil Quality Properties	Soil Quality Rating Standards					Soil Properties of Selected Wetlands										Mean	SD
		Class-I (Prime)	Class-II (Good)	Class-III (Medium)	Class-IV (Marginal)	Class-v (Unsuitable)	Bochamari Beel	Satwabhanga Nadi	Atiamochar Beel	Raichanmari Beel	Nildoba Beel	Dhangdhar Chhara	Rasomati Jheel	Baiganbari Chhara	Chandan Dighi	Sagar Dighi		
1	pH		<5.5	5.5 - 7.0	7.0 - 8.0		4.97	4.91	4.74	4.35	6.73	4.15	6.93	6.1	5.79	7.38	5.605	1.14
2	Org.C mg/kg		<1.7	1.7 - 2.6	>2.6		4.95	3.61	2.59	1.67	1.48	1.47	4.57	2.28	2.4	1.03	2.605	1.35
4	N mg/kg	>300	200-300	100-200	50-100	<50	90.94	294.78	398.27	137.98	156.8	131.26	62.72	37.63	282.24	90.94	168.356	117.61
5	P mg/kg	>250	180-250	100-180	50-100	<50	46.92	25.74	84.28	33.26	64.24	34.22	49.43	36.22	48.52	57.86	48.10	17.39
6	K mg/kg	>300	175-300	100-175	50-100	<50	518.56	257.6	174.72	105.28	94.68	98.68	794.08	608.16	296.8	159.04	310.7	245.84

Source: Field Survey 2017, Adapted from FAO 1992; Roming, et al., 1995; Mc Grath et al., 2001

Nadi (4.91), Atiamochar Beel(4.74), Raichanmari Beel (4.35), and Dhangdhar Chhara(4.15). The acidic pH indicates the soil was subjected to more soil organic matter content and high microbial activity which results in high acidic production. As presented in the table, the soil pH also revealed concentration that is consistent with good to marginal quality rating. Five wetlands have a good rating standard and four wetlands fall in medium class and one wetland i.e. Sagar Dighi is recorded in Marginal class (fig 5.14).

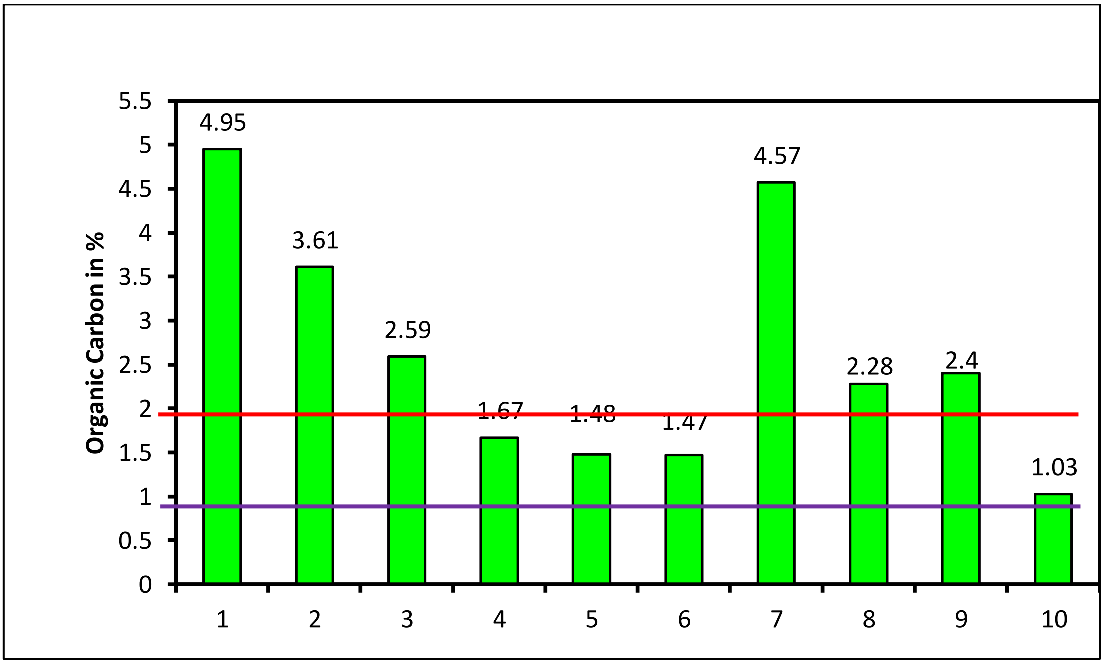


1= Bochamari Beel, 2= Satwabhanga Nadi, 3= Atiamochar Beel, 4= Raichanmari Beel, 5= Nildoba Beel, 6= Dhangdhar Chhara, 7= Rasomati Jheel, 8= Baiganbari Chhara, 9= Chandan Dighi, 10= Sagar Dighi.	(<5.5) (7 to 8) (>8)	(<5.5)Good (5.5 to 7) Medium (7 to 8) Marginal

Fig 5.14: Present Status of pH in Selected Wetlands, Adapted from FAO 1992; Roming, et al., 1995; Mc Grath et al., 2001

5.2.2.2. Soil Organic Matter:

Soil organic matter contains living and dead microbial cells. They are the source of plant nutrients. Organic matter has a favourable effect on soil's physical properties. Organic matter also contains the exchangeable sodium in the soil. The determination of organic carbon in soil serves indirectly as the measure of available nitrogen. Humus in soil has an influence on the physical, chemical and biological activities of soil. It also increases the water holding capacity, buffer and exchange capacities besides acting as a source of energy for the development of micro-organisms. The carbon present in the organic matter is considered as total organic carbon. But it has been found low in some samples collected from the wetland areas. It is low either due to washing out by rain water or due to conversion into organic acids upon decomposition of organic matter in course of time. As a whole study area wetland water records a wide range of organic carbon (OC) variation. This variation is mainly depended on the number of macrophytes present in the wetlands and their magnitude of decomposition. Due to high deposition of organic matters at the bottom, wetlands, in general, are rich in the benthos. Owing to the high rate of accumulation of nutrients, macrophytes compete with phytoplankton and under macrophyte-dominated conditions; phytoplanktons do not get enough nutrients for their growth (Boyd, 1970). It is observed that the macrophytic vegetations cover a major part of the wetlands, thereby leaving no room for the fishes to take shelter for growth.



1=Bochamari Beel, 2=Satwabhanga Nadi, 3= Atiamochar Beel, 4= Raichanmari Beel, 5= Nildoba Beel, 6= Dhangdhar Chhara, 7= Rasomati Jheel, 8= Baiganbari Chhara, 9= Chandan Dighi, 10= Sagar Dighi	(2.6) (1.7)	(> 2.6) Marginal (1.7 to 2.6) Medium (<1.7) Good

Fig 5.15:Present Status of Organic Carbon in Selected Wetlands, Adapted From FAO 1992; Roming, Et Al., 1995; Mc Grath Et Al., 2001

Table 5.3 shows the present status of organic carbon in the study area. The table indicates that the wetlands of Koch Bihar and Tufanganj are rich in organic carbon. Natural lakes have a higher amount of organic carbon concentration than a man-made wetland. The average soil organic carbon of wetland soil is 2.605. The range of organic carbon value varies from 4.95 to 1.03. Table-5.4 shows that the highest Organic Carbon value found in Bochamari Beel (4.95 per cent) followed by Rasomati Jheel (4.57 per cent), Satwabhanga Nadi (3.61 per cent), Atiamochar Beel (2.59 per cent), Chandan Dighi (2.4 per cent), Baiganbari Chhara(2.28 per cent), Raichanmari Beel (1.67 per cent), Naldoba Beel (1.48 per cent), Dhangdhar Chhara(1.47 per cent). Out of the total 10 wetlands four wetland (Raichangmari Beel, Naldoba Beel, Dhahgdhar Chhara and Sagar Dighi) was recorded in good rating standard, 3 wetlands (Atiamochar Beel, Baiganbari Chhara and Chandan Dighi) fall under medium rating standard and rest of the 3 wetlands(Bochamari Beel, Satwabhanga Nadi and Rasomoti Jheel) was recorded in Marginal rating standard (fig 5.15). Higher organic carbon produces higher pH value.

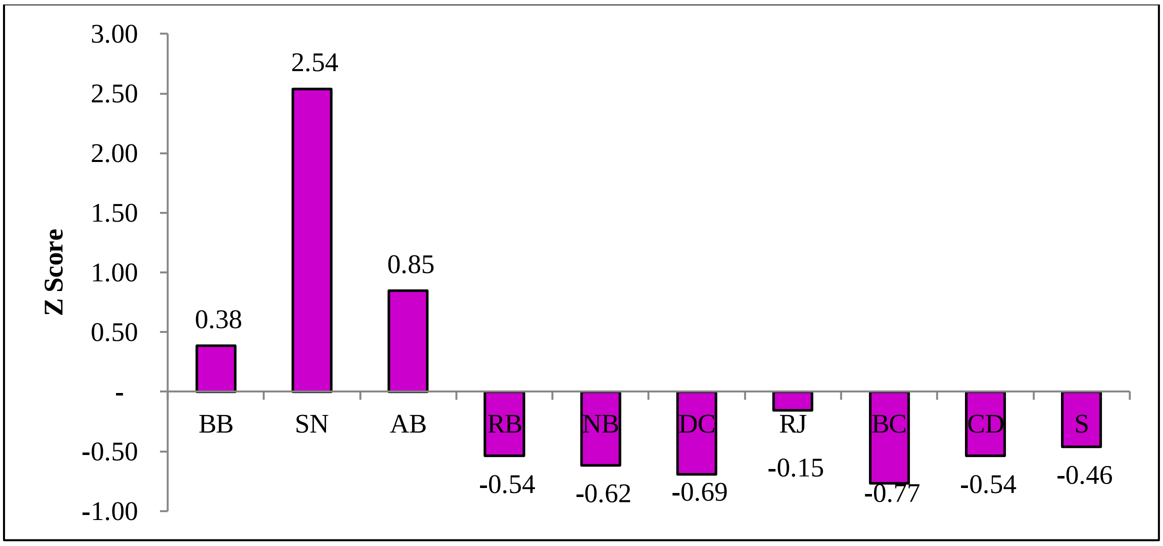
5.2.2.3. Electrical Conductivity (EC) of Soil:

The conductivity of the soil is the specific conductivity at 25ºC of water extract obtained from a mixture of soil and water with the definite ratio. It is measured by a conductivity meter and normally measured in dS/m or millimhos/cm and the value gives information of the total amount of the soluble salts present in the soil, i.e. on the degree of salinity. Salted soils are classified on the basis of two criteria, one is on the basis of Total Soluble Salts (TSS) content and another is Exchangeable Sodium Percentage (ESP) or more recently Sodium Absorption Ratio (SAR).

Table 5.4: Present Status of EC of Different Wetlands, Koch Bihar and Tufanganj, 2016 & 2017

Sample site	Sample Location	EC (Dsm-1)	Z= (X-Mean)/SD
Bochamari Beel	**Sample Site**	**0.35**	**0.38**
Satwabhanga Nadi	26o24´30´´N, 89o43´15´´E	0.63	2.54
Atiamochar Beel	26o25´03´´N, 89o43´21´´E	0.41	0.85
Raichanmari Beel	26o25´13´´N, 89o43´21´´E	0.23	-0.54
Nildoba Beel	26o25´14´´N, 89o44´02´´E,	0.22	-0.62
Dhangdhar Chhara	26o25´51´´N, 89o44´19´´E	0.21	-0.69
Rasomati Jheel	26o18´48´´N, 89o34´07´´E	0.28	-0.15
Baiganbari Chhara	26o26´51´´N, 89o19´56´´E	0.2	-0.77
Chandan Dighi	26o17´24´´N, 89o18´13´´E	0.23	-0.54
Sagar Dighi	26o19´21´´N, 89o26´24´´E	0.24	-0.46
Mean=0.3, SD= 0.13			

Source: Field Survey, 2016 & 2017



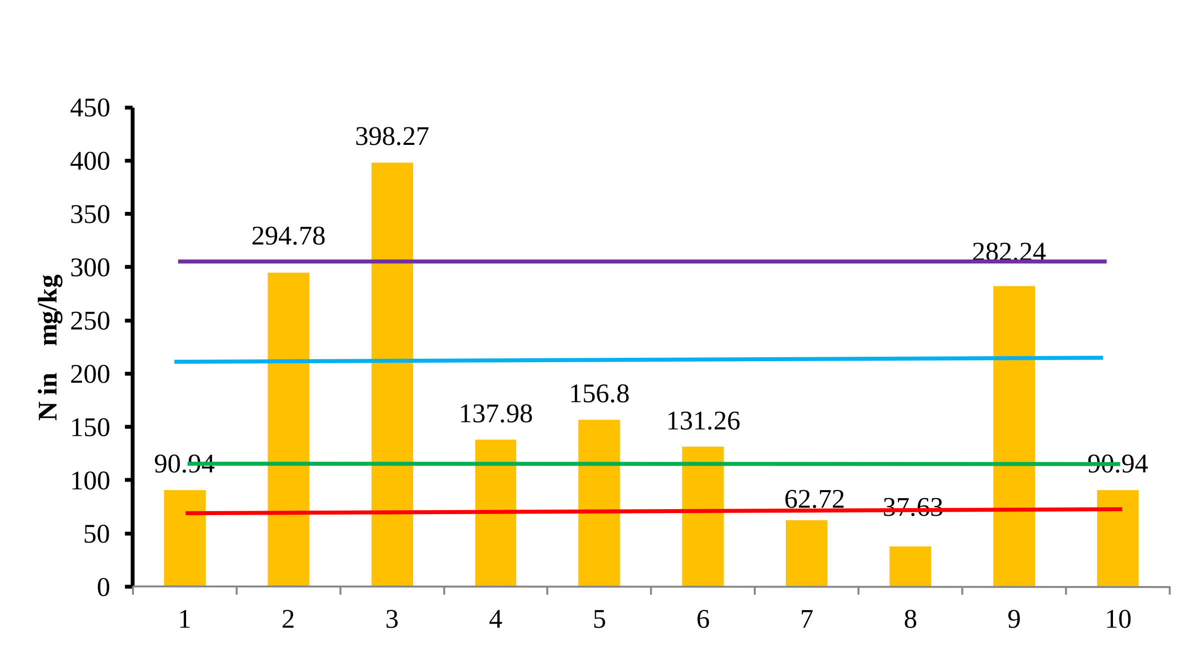
BB=Bochamari Beel, SN=Satwabhanga Nadi, AB= Atiamochar Beel, RB= Raichanmari Beel, NB= Nildoba Beel, DC= Dhangdhar Chhara, RJ= Rasomati Jheel, BC= Baiganbari Chhara, CD= Chandan Dighi, S= Sagar Dighi

Fig 5.16: Z-Score for Showing the Present Status of EC of Selected Wetlands

The table 5.4 indicates that the EC of different wetlands of Koch Bihar and Tufanganj highly differ from each other. The average EC of the wetland soil is 0.3 and the SD is 0.13. The range of EC is 0.2 to 0.63. Table 5.6 shows that the highest EC found in Satwabhanga Nadi to be 0.63 and the lowest EC identified in Baiganbari Chhara is 0.2.In Atiamochar Beel the EC is 0.41 followed by Bochamari Beel (0.35), Rasomati Jheel (0.28), Sagar Dighi (0.24), Raichanmari Beel & Chandan Dighi(0.23), Naldoba Beel(0.22). Out of the total 10 wetlands, 30 per cent show higher positive Z score and 70 per cent show negative ratio. The negative value indicates that these 7 wetland's EC to be less than average organic carbon value. The highest positive Z score was observed in Satwabhanga Nadi (+2.54) and lowest Z score was observed in Bochamari Beel (-0.77) (Fig 5.16).

5.2.2.4. Available Nitrogen:

Available Nitrogen is defined as nitrogen in a form that can be readily absorbed by plants. Nitrogen is of special importance because plants need it in rather large amounts, it is expensive to supply, and it is easily lost from the soil. Plants take up simple inorganic Nitrogen compounds from the soil. The functions of nitrogen in plant and animal life are numerous. Essentially all life processes depend directly on it. The most important forms of available nitrogen are NH_4^+, NO_3^- and certain simple organic compounds, principally free amide or amino groups. Available Nitrogen is the mineral form which is available by mineralization of organically bounded materials. About 98 % of Nitrogen is present in the soil or a plant in organic form and only 2 % Nitrogen is released as a mineral form in the ions e.g. Nitrate and Ammonium.



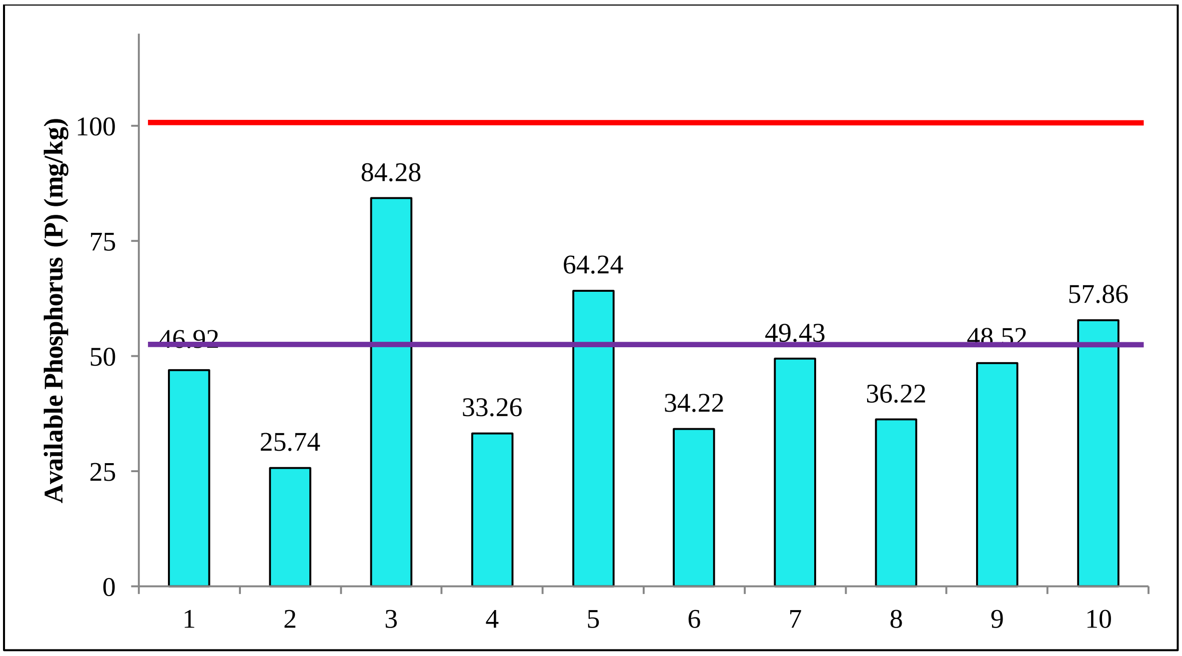
1=Bochamari Beel, 2=Satwabhanga Nadi, 3= Atiamochar Beel, 4= Raichanmari Beel, 5= Nildoba Beel, 6= Dhangdhar Chhara, 7= Rasomati Jheel, 8= Baiganbari Chhara, 9= Chandan Dighi, 10= Sagar Dighi	Index Mark	Soil quality rating standard
	50 mg/kg	(<50) Unsuitable
	100 mg/kg	(50-100) Marginal
	200 mg/kg	(100-200) Medium
	300 mg/kg	(200 - 300) Good
		(>300) Prime

Fig 5.17: Present Status of Soil Nitrogen in Selected Wetlands, Adapted From FAO 1992; Roming, Et Al., 1995; Mc Grath Et Al., 2001

The fig 5.17 indicates that the nitrogen of selected wetlands of Koch Bihar and Tufanganj subdivision highly differ from one another. The average nitrogen value of the wetland soil is 168.356 and the SD is 117.61. Fig 5.17 shows that the highest nitrogen concentration is observed in Atiamochar Beel (398.27mg/kg). and the nitrogen value of wetlands are Satwabhanga Nadi (294.78 mg/kg), Chandan Dighi (282.24 mg/kg), Naldoba Beel (156.8 mg/kg), Raichanmari Beel (137.98 mg/kg), Dhangdhar Chhara (131.26 mg/kg), Sagar Dighi (90.94 mg/kg), Rasomati Jheel (62.72 mg/kg) and the lowest nitrogen concentration is observed in Baiganbari Chhara (37.63) mg/kg. It is presented by the figure that the Nitrogen concentration ranges prime to unsuitable soil quality (Adapted from FAO 1992; Roming, et al., 1995; Mc Grath et al., 2001). Unsuitable Nitrogen concentration was recorded in Baiganbari Chhara (37.63 mg/kg). Marginal nitrogen concentration was observed in Rasomati Jheel (62.72 mg/kg), Sagar Dighi(90.94 mg/kg) and Bochamari Beel(90.94mg/kg). Medium quality of Nitrogen was recorded in Dhangdhar Chhara (131.26 mg/kg), Raichanmari Beel (137.98 mg/kg) and Nildoba Beel (156.8 mg/kg). Good quality of Nitogen was recorded in Satwabhanga Nadi (294.78 mg/kg), Chandan Dighi(282.24 mg/kg) and Prime quality Nitrogen observed in Atiamochar Beel (398.27 mg/kg).

5.2.2.5. Phosphorous:

Phosphorous is the essential element in influencing plant growth. Among the more significant functions and qualities of plants on which phosphorous has important effects are: i) Photosynthesis, ii) Nitrogen fixation, iii) Crop maturation–flowering and fruiting including seed formation, iv. Root development, v. Protein synthesis. Thus, it is essential to calculate the available phosphorous present in the soil. Phosphorous concentration largely depends on soil pH. Phosphorous is very high in some wetlands. It is more than 50 kg P_2O_5 per hectare. Only in a few soil samples, available phosphorous is of medium quantity i.e. between 20 to 50 kg per hectare. High phosphorous concentration in the soil is the indicator of high productivity of fishes.



1=Bochamari Beel, 2=Satwabhanga Nadi,	Index Mark	Soil quality rating standard
3= Atiamochar Beel, 4= Raichanmari Beel, 5= Nildoba Beel, 6= Dhangdhar Chhara, 7= Rasomati Jheel, 8= Baiganbari Chhara, 9= Chandan Dighi, 10= Sagar Dighi	50 mg/kg 100 mg/kg	(<50) Unsuitable (50-100) Marginal (100-180) Medium (180 - 250) Good (>250) Prime

Fig 5.18: Present Status of Phosphorous in a Selected wetland, Adapted from FAO 1992; Roming, Et Al., 1995; Mc Grath Et Al., 2001

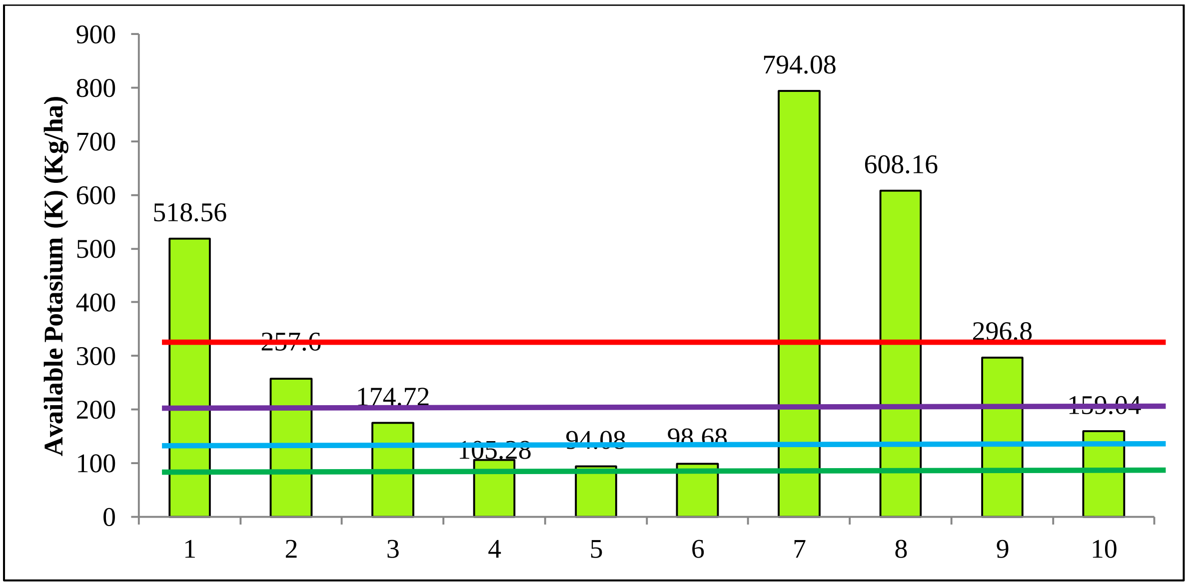
Table 5.3 shows the present status of Phosphorous in the study area. The average soil Phosphorous (P) of wetlands land is 48.069 (mg/kg). The range of Phosphorous (P) value varies from 25.74 to 84.28 ((mg/kg). Table5.6 shows that the highest Phosphorous (P) value was found in Atiamochar Beel (84.28 mg/kg) followed by Nildoba Beel (64.24 mg/kg), Sagar Dighi (57.86 mg/kg), Rasomati Jheel (49.43 mg/kg), Bochamari Beel (46.92 mg/kg), Baiganbari chhara (36.22 mg/kg), Dhangdhar Chhara (34.22 mg/kg), and Satwabhanga Nadi(25.74 mg/kg).

Except three wetlands, soil phosphorous of remaining wetland is in unsuitable category. Atiamochar Beel (84.28 mg/kg), Naldoba Beel (64.28 mg/kg), and Sagar Dighi(57.86 mg/kg) fall into the Marginal category. Rest of the seven wetlands :Rasomati Jheel (49.43 mg/kg), Bochamari Beel (46.92mg/kg), Satwabhanga Nadi (25.74 mg/kg), Raichanmari Beel (33.26mg/kg), Dhangdhar Chara (34.22 mg/kg), Baiganbari Chhara (36.22mg/kg) and Chandan Dighi(48.52 mg/kg)fall into unsuitable category (fig 5.18).

5.2.2.6. Potassium:

Potassium is also an essential ingredient that influences the productivity of the soil as well as the important element of plant growth. It activates the considerable number of enzymes responsible for plant growth. Potassium is essential for photosynthesis, protein synthesis, starch formation and translocation of sugars. It also exerts a balancing effect on the effect of both nitrogen and phosphorous. Thus, it is essential to calculate the available potassium present in the soil. Purpose of potassium determination is to determine available potassium content in given soil. Potassium is shown in kg per ha. The lowest potassium content is found in the soils of Nildoba (94.08 mg/kg) while it is the highest in samples of Rasomati (794.08 mg/kg) (Table-5.4)

The highest Potasiumis observed in Rasomati Jheel (794.08 kg/ha) followed by Baiganbari Chhara (608.16 kg/ha), Bochamari Beel (518.56 kg/ha), Chandan Dighi (296.8 kg/ha), Satwabhanga Nadi (257.6 kg/ha), Atiamochar Beel (174.72 kg/ha), Sagar Dighi (159.04 kg/ha), Raichanmari Beel (105.28 kg/ha), Dhangdhar Chhara (98.68 kg/ha), and Naldoba Beel (94.08 kg/ha) (fig 5.19).



1=Bochamari Beel, 2=Satwabhanga Nadi, 3= Atiamochar Beel, 4= Raichanmari Beel, 5= Nildoba Beel, 6= Dhangdhar Chhara, 7= Rasomati Jheel, 8= Baiganbari Chhara, 9= Chandan Dighi, 10= Sagar Dighi	Index Mark	Soil quality rating standard
	50 Kg/ha	(<50) Unsuitable
	100 Kg/ha	(50-100) Marginal
	175 Kg/ha	(100-175) Medium
	300 Kg/ha	(175-300) Good
		(>300) Prime

Fig 5.19: Present Status of Potassium in Selected Wetlands,Adapted from FAO 1992; Roming, Et Al., 1995; Mc Grath Et Al., 2001

On the basis of FAO, 1992 wetland soil quality classification, Marginal(100 mg/kg) potassium concentration is observed in Nildoba Beel(94.08 Kg/ha), and Dhangdhar Chhara(98.68 Kg/ha). Medium quality of soil is recorded in Raichanmari Beel(105.28 Kg/ha), Atiamochar Beel(174.72 Kg/ha) and Sagar Dighi (159.04Kg/ha). Good quality of potassium concentration is observed in Satwabhanga Nadi (257.6 Kg/ha) and Chandan Dighi (296.8 Kg/ha) and Prime quality of soil (Potassium) is recorded in Bochamari (518.56 Kg/ha), Rasomati Jheel (794.08 Kg/ha)and Baiganbari Chhara (608.16Kg/ha).

5.2.3. Biotic Component:

Biotic component of a wetland is a vital part of wetland environment. Wetlands are valued for their peculiar aquatic environment, which provides ideal habitat for feeding, nesting and breeding of different types of fish, birds and animals. Gopal (1995) prepared a list of over 1200 plant species and a partial list of animal those are found in Indian aquatic and wetland systems. Numerous varieties of fish found in these wetlands are the source of livelihood for a large section of the rural poor. Most of the wetlands are lentic waterbodies i.e.land locked and their water differs from the lotic systems in respect to physical, chemical and biological characteristics. Temperature, pH and nutrient content also vary from wetland to wetland. As such wetlands support a wide range of flora and fauna. The study of these aquatic lives is indispensable for a proper understanding of the wetland environment.

5.2.3.1. Flora:

The flora found in the wetlands of Koch Bihar is similar to those found in other wetlands of the state. However, the most common flora is the water hyacinth. It was introduced in India first by a European woman in 1898, who brought it from Brazil for its beauty. Unfortunately, this plant spread in the wetlands throughout the country and at present causes a major problem in such water bodies. Such mats enlarge their sizes in course of time and fill in the open surface area. With the high rate of accumulation of nutrients, the water hyacinths compete with phytoplankton and dominate them by increasing their growth. As a result, phytoplanktons, in general, are found in lesser amount in the wetland waters (Byod, 1970). The growth of such plant is so high that they restrict the reproduction of fish and growth of other plants. Published research on the flora and fauna of the wetland ecosystem are rather very few in number and mostly of recent date. Summarizing the findings of various studies already done in line and with extensive field observation from the present study, the common aquatic vegetation type in the wetlands of the study area can be grouped as follows-

Photo Plate 5.5: Field Survey, Baiganbari Chhara

Photo Plate 5.6: Field Survey, Dhanghdhar Chhara

Photo Plate 5.7: Field Survey, Rasomati jheel

Photo Plate 5.8: Field Survey, Rasik Beel

Table 5.5: Abundance Status of Aquatic Plants in Selected Wetlands, Koch Bihar & Tufanganj Subdivision

Macrophytes	Common Name	Scientific Name	Abundance Status
Open water	Water hyacinth / Kochuripana	Eichornia sp.	***
	Water cabbage / Topapana	Pistia sp.	***
	Water fern	Azolla sp.	*
	Esthwaite waterweed / Kureli	Hydrilla verticillata	*
	Bladder worts / Jhaji	Utricularia sp.	**
	Tape grass / Pata Sheola	Vallisneria spiralis	*
	Water Fern / Kariba weed	Salvinia cucullata	*
	Water caltrop / Paniphal	Trapa natans	*
	Brittle water nymph	Najas sp.	*
	Water Lily / Shaluk	Nymphaea sp.	**
	Water snowflake	Nymphoides indica	*
Water edges	Water spinach / Kalmi	Ipomoea aquatica	**
	Hincha/ Helencha	Enhydra fluctuans	**

	Edible fern/dheki sak	Diplazium esculentum	**
	Indian pennywort	Centrella asiatica	**
	Water-primrose / Kesara-dam	Ludwigia adscendens	*
	Aquarium plant / Jangli dal	Hygroryza aristata	*
	Jatropha /Varenda	Jatropha gossypifolia	*
	Nal Khagra	Arundo donax	*
	Pundi	Alpinia nigra	*
	Corndog grass / Hogla	Typha elephantina	*
	Nata or Note	Amaranthus viridis	*
	Binna or Bena	Andropogon squarrosus	*
	Sushni Shak	Marsilea quadrifolia	*
	Bhet	Nymphaea lotus	**
Bank & Marsh area	Vati or Vat	Clerodendron infortunatum	**
	Dhutura	Datura fastuosa	*
	Kashia or Kush	Eragrostis cynosuroides	*
	Dumur	Ficus cunia	*
	Tear-thumb / Pakul Mul	Polygonum pulchrum	*
	Marsh pepper/packur mul	Polygonum hydropiper	*
	Dwarf umbrella-sedge / Namuti	Cyperus platystylis	*
	Holud / Haldi	Curcuma zedoaria	**
	Ghoksha	Ficus hispida	*
	Bilbo or Bel	Aegle marmelos	*
	Chamghas or Kharkon	Typhonium trilobatum	**
	Dandakalas or Setdron	Leucas aspera	**
	Zangli Kachu	Colocasia antiquorum	***
	Bathua	Chenopodium album	**
	Ulu	Imperata cylindrica	*
	Khagra	Saccharum spontaneum	*
	Khar	Saccharum arundinaceum	*
	Nal	Phragmites Roxburghii	*
	Akando	Calotropis gigantean	*
	Letaguti	Caesalpinia bonducella	*
*** = Common ** = Fairly Common * = Rare (On the Verge of Extinction)			

Source: Field Survey, 2013-2017

Table 5.6: Abundance Status of Flora of the Study Area

Abundance of Flora			
Abundance Status	Common	Fairly Common	Rare (On the Verge of Extinction)
Number	3	12	30
%	6.67	26.67	66.67

Source: Field Survey, 2013-2017

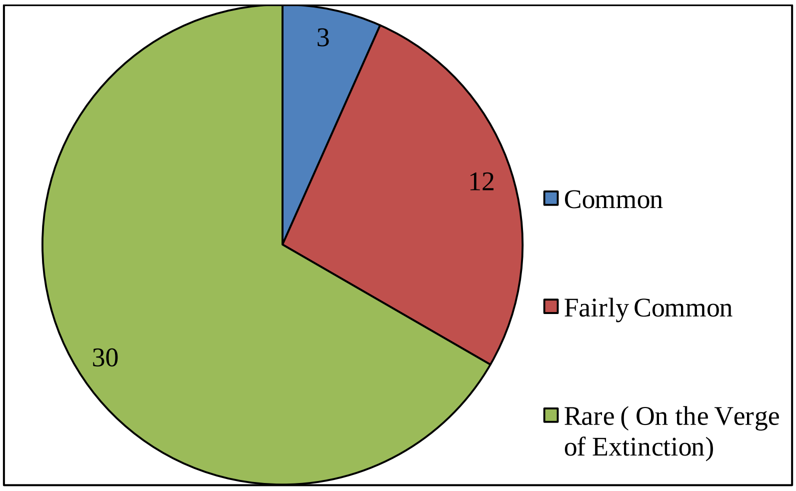


Fig 5.20: Population of Flora in Selected Wetlands of Study Area

From the extensive field survey, it is clear that most of the aquatic and semi-aquatic plant is in the critical condition. Fig 5.20 shows the present status of flora in the study area. There are only 45 wetland floral species are identified from the selected wetland and surrounding wetland of the study area. Among them only three species namely Kochuripana (Eichornia sp.), Topapana (Pistia sp.) and Zangli Kachu (Colocasia antiquorum) are very common, 12 species are fairly common and 30 species are on the verge of Extinction. Some species are so rare that they are found in some specific parts of a unique wetland e.g. Nal (Phragmites Roxburghii) Ulu (Imperata cylindrical) (Table 5.6).

5.2.3.2. Fauna:

Plants provide a niche for with the animals to feed upon the plants, use them as their home, pollinate them, disperse them or destroy them (Misra, 1980). In the wetlands, various types of flora provide habitat for innumerable fauna and form a unique ecosystem. Gentle slope, moist and fertile soil results in the luxuriant growth of grass and reeds in the surrounding areas of wetlands. These grasses, reeds and other vegetation along with the floating mats of the wetlands become the shelter for different species of fish, crabs, water snakes, migratory birds, frogs, beetles, mussels, bugs and various zoo-planktons. This environment provides an ideal habitat for feeding, nesting and breeding of various types of birds. Hence it attracts migratory birds like teals, wild duck, storks, tern and swans. The birds also fertilise the wetland water through their droppings.

Table 5.7: Abundance Status of Common Varieties of Fishes Found in Selected Wetlands, Koch Bihar & Tufanganj Subdivision

Common / Local Name	Scientific Name	Abundance Status
Balia / Beley	Glossogobiusgiuris	*
Bata	Labeo bata	**
Batashi / Tinkata	Batasiobatasio	*
Bheda / Meni	Nandusnandus	*
Boal	Wallagoattu	*
Botya	Botia Dario	*
Chanda	Chandanama	**
Chang	Channaorientalis	***
Chapila / Korti / Khoira	Gudusiachapra	**
Chela	Laubucalaubuca	*
Chital	Chitalachitala	*
Chunakholisha	Colisasota	*
Darika	Esomusdanricus	*
Fali / Folui	Notopterus notopterus	*
Gili-puthi	Puntius gelius	*
Guchi / Bam	Macrognathusaculeatus	*
Guchi / Goichi / Bam	MastacembelusaLMatus	*
Kalbaus	Labeocalbasu)	**
KanchanPuthi	Puntiusconchonius	*
Kankley / Kakley	Xenentodoncancila	*
Katla / Katal	Catla catla	*
Khalisha / Kholsa	Colisafasciatus	*
Khaura / Gharua	Clupisomagarua	*
Khorkey / khorika-poia	Acanthocobitisbotia	*
Koi	Anabustestudineus	*
Kuchia	Monopteruscuchia	*
Kucho-koi	Ctenopsnobilis	*
Kucho-tengra	Rama chandramara	**
Kursa / Kurchi / Goni	Labeogonius	*
Lal-chanda / Ranga-chanda	Pseudambassisranga	*
Magur	Clariasbatrachus	**
Maurala	Amblypharyngodonmola	*
Mowa / Mourla / Chanda	Osteobramacotiocotio	**
Mrigal	Cirrhinuscirrhosus	*
Pabda	Ompokpabda	*
Pankal / Pakal	Macrognathuspancalus	*
Poia / Poa	Lepidocephalichthysguntea	*
Ranga-kholisha / Kholsa	Colisalabiosus	*
Ruhi / Rui/ Rohu	Labeorohita	**
Sar-puthi / Saral-puthi	Puntiussarana	**
Sati / Taki /Lata	Channa punctata	***
Shal	Channa marulius	*
Shol	Channa striata	***
Singi / Sing	Heteropneustesfossilis	*
Tengra	Mystusvittatus)	**
Tepa / Tayapa	Tetraodoncutcutia	*
Teri-puthi	Puntiusterio	*
Tita-puthi / Tit-puthi	Puntiusticto	**
*** = Common ** = Fairly Common * = Rare (On the Verge of Extinction)		

Source: Field Survey, 2013-2017

Table 5.8: Abundance Status of Insect in Selected Wetlands, Koch Bihar & Tufanganj Subdivision

Common / Local Name	Scientific Name	Abundance Status
Water Scorpion	Ranatra filifoLMis	**
Giant Water Bug	Lethocerus indicus	*
Common Black Cricket	Gryllus assimilis	**
Water Beetle	Laccophilus sharpi	*
Whirligig Beetle	Dineut usunidentatus Aube,	*
Fresh Water Prawn	Macrobrachium lamarrei	*

Source: Field Survey, 2013-2017

Table 5.9: Abundance Status of Water Bird in Selected Wetlands, Koch Bihar & Tufanganj Subdivision

Common Name	Scientific Name	Abundance Status
Little Grebe	Tachybapyus ruficollis	**
Great Cormorant	Phalacrocorax carbo	*
Little Cormorant	Phalacrocorax niger	**
Indian Pond Heron	Ardeola grayii	***
Median Egret/Intermediate Egret	Mesophoyx intemedia	*
Little Egret	Egretta garzetta	**
Cattle Egret	Bubulcus ibis	***
Asian Openbill-Stork	Anastomus oscitans	**
Lesser Whistling-Duck	Dendrocygna javanica	***
Northern Pintail	Anas acuta Linnaeus,	*
Common Teal	Anas crecca Linnaeus,	**
Ferruginous Poachard	Aythya nyroca	**
Black Kite	Milvus migrans	*
White-breasted Waterhen	Amaurornis phoenicurus	**
Common Moorhen	Gallinula chloropus	**
Bronze-winged Jacana	Metopidius indicus	*
Grey-headed Lapwing	Vanellus cinereus	**
Northern Lapwing	Vanellus vanellus	**
Common Sandpiper	Actitis hypoleucos Linnaeus,	**
Wood Sandpiper	Tringa glareola Linnaeus,	**
Common Snipe	Gallinago gallinago	*
Pintail Snipe	Gallinago stenura	*
Eurasian Collared-Dove	Streptopelia decaocto	*
Spotted Dove	Streptopelia chinensis	***
Rose-ringed Parakeet	Psittacula krameri	*
Alexandrine Parakeet	Psittacula eupatria	**
Indian Cuckoo	Cuculus micropterus Gould,	**
Brainfever Bird/ Common Hawk Cuckoo	Hierococcyx varius	**
Asian Koel	Eudynamys scolopaceus	**
Barn Owl	Tyto alba	*
Spotted Owlet	Athene brama	**
Asian Palm-Swift	Cypsiurus balasiensis	***
Small Blue Kingfisher	Alcedoatthis	*
Stork-billed Kingfisher	Halcyon Pelargopsis capensis	*
Common kingfisher	Alcedo atthis	**
White-breasted Kingfisher	Halcyon smyrnensis	**
Lesser Pied Kingfisher	Ceryle rudis	*
Blue-throated Barbet	Megalaima asiatica	**
Coppersmith Barbet	Megalaima haemacephala	*

Lesser Golden-backed Woodpecker	Dinopium benghalense	**
Rufous-backed Shrike (blackheaded)	Lanius schach tricolor	*
Brown Shrike	Lanius cristatus Linnaeus,	*
Black-headed Oriole	Oriolus xanthornus	**
Black Drongo	Dicrurus macrocercus Vieillot,	***
Chestnut tailed Starling	Sturnus malabarica	*
Asian Pied Starling	Gracupica contra	***
Common Myna	Acridotheres tristis	**
Jungle Myna	Acridotheres fuscus	***
Red-whiskered Bulbul	Pycnonotus jocosus	**
Red-vented Bulbul	Pycnonotus cafer	*
Jungle Babbler	Turdoides striata	***
Grey-headed Flycatcher	Culicicapa ceylonensis	*
White-throated Fantail-Flycatcher	Rhipidura albicollis	**
Common Tailor Bird	Orthotomus sutorius	**
Oriental Magpie-Robin	Copsychus saularis	*
Citrine Wagtail	Motacilla citreola Pallas,	*
House Sparrow	Passer domesticus	***
Eurasian Tree Sparrow	Passer montanus	**
Baya Weaver	Ploceus philippinus	***
Spotted/ Scaly breasted Munia	Lonchura punctulata	**
*** = Common ** = Fairly Common * = Rare(On the Verge of Extinction)		

Source: Zoological Survey of India, Kolkata-2013 and Field Survey, 2013-2017

Table 5.10:Abundance Status of Freshwater Snails in Selected Wetlands, Koch Bihar & Tufanganj Subdivision

Common / Local Name	Scientific Name	Abundance Status
Shamuk / Googli	Bellamya bengalensis	*
Apple snail / Shamuk	Pila globosa	*
Mud Snail / Faucet Snail	Bithynia tentaculata	*
Snail	Digoniostoma cerameopoma	*
Fresh Water Snail	Thiara scabra	*
Fresh Water Muscle / Jhinuk	Lamellidens marginalis	*
*** = Common ** = Fairly Common* = Rare (On the Verge of Extinction)		

Source: Field Survey, 2013-2017

Table 5.11: Abundance Status of Other Vertebrates in Selected Wetlands, Koch Bihar & Tufanganj Subdivision

Common / Local Name	Scientific Name	Abundance Status
Common Indian Toad/kuno bang	Duttaphrynus melanostictus	*
Indian Bull Frog /sona bang	Haplobatrachus tigerinus	*
Tree Frog/ gaso bang	Polypedates maculatus	**
*** = Common ** = Fairly Common * = Rare (On the Verge of Extinction)		

Source: Field Survey, 2013-2017

Table 5.12: Abundance Status of Reptiles in Selected Wetlands, Koch Bihar & Tufanganj Subdivision

Common / Local Name	Scientific Name	Abundance Status
Oriental Garden Lizard / Girgiti	Calotes versicolor	*
Common Grass Skink / Anjani	Eutropis carinata	*
Common Monitor / Goshap	Varanus bengalensis	*
Oriental Rat Snake / Daras	Ptyas mucosus	**
Checkered Keelback / Jaldhora	Xenochrophis piscator	**
Spectacled Cobra	Najanaja	*
Common Wolf Snake	Lycodonaulicus	**
Stripped Keelback	Amphiesmastolatum	*
Black Krait	Bungarusniger	*
Wall's Sind Krait	Bungaruswalli	*
Banded krait	Bungarusfasciatus	**
Painted Bronzeback Tree Snake	Dendrelaphispictus	**
Vine Snake	Ahaetullanasuta	*
Brahminy Worm Snake	Ramphotyphlopsbraminus	*
*** = Common ** = Fairly Common * = Rare (On the Verge of Extinction)		

Source: Field Survey, 2013-2017

Table 5.13: Check List of Mammals in Selected Wetlands, Koch Bihar & Tufanganj Subdivision

Common / Local Name	Scientific Name	Abundance Status
Indian Flying Fox / Badur	Pteropusgiganteus	*
Indian Pigmy Bat / Chamchika	Pipistrellustenuismimus	*
Common Otter / Bhondor / Ud	Lutralutra	*
Toddy Cat / Bhum / Khatas	ParadoxurusheLMaphroditus	*
Small Indian Mongoose / Beji / Neul	Herpestesauropunctatus	**
Indian Mole-Rat / Metho-indur	Bandicotabengalensis Gray	**
Bandicoot Rat / Dhereindur	Bandicotaindica	**
*** = Common ** = Fairly Common* = Rare (On the Verge of Extinction)		

Source: Field Survey, 2013-2017

Table5.14: Abundance Status of Fauna in Selected Wetlands, Koch Bihar & Tufanganj Subdivision

Name of Fauna	Common	Fairly Common	Rare (On the verge of Extinction)
Fish	3	11	34
Water Bird	11	28	21
Reptile	---	5	9
Mammals	--	3	4
Vertibrate	--	1	2
Snail	--	--	6
Insect	--	2	4
Total	14	50	80
%	9.72	34.72	55.56
Grant Total		144	

Source: Field Survey, 2013-2017

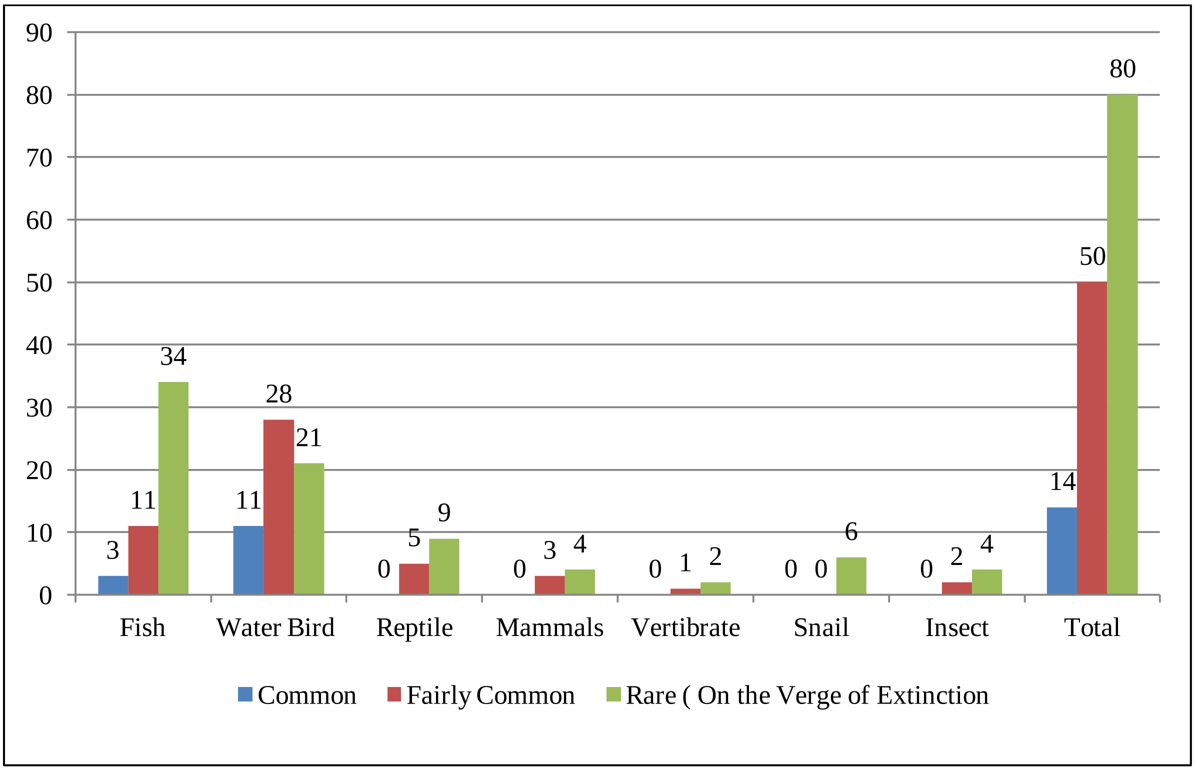


Fig 5.21: Abundance Status of Fauna in Selected Wetlands, Koch Bihar & Tufanganj Subdivision

From field observation survey it is clear that most of the fauna live in wetland or are dependent on wetland in the critical condition as their numbers are decreasing very rapidly. Fig 5.21 shows the present status of fauna in the study area. The main varieties of fish found in the wetlands in the study area can be broadly classified into three types: carps, cat fishes and feather backs. Only 48 varieties of fish are found in the wetlands of the study area(Table 5.7). Among them only three species namely Chang (Channa orientalis), Shol (Channa striata) and Sati (Channa punctata) are very common, 11 species are fairly common and 34 species are on the verge of extinction. Not only fish almost all community lives and depend on wetland which is in critical condition. Among 60 species of water bird, only 11 species are very common, 28 species are fairly common and 21 species are on the verge of extinction(Table 5.9). Among 14 species of reptile, only five species are fairly common and nine species are on the verge of extinction (Table 5.12). Among seven species of mammals, only three species are fairly common and four species are on the verge of Extinction (Table 5.13). Among three species of vertebrate, only one species are fairly common and two species are on the verge of extinction (Table 5.11). Among six species of insect, only two species are fairly common and four species are on the verge of extinction (Table 5.8). Snails are in very critical condition as only six species are on the verge of extinction (Table 5.11).

5.3. Conclusion:

Degradation of water and soil quality, loss in biological diversity is the main indicator of ecosystem degradation of the wetlands of the study area. Wetlands sustain highly productive ecosystem with a potential supply of nutrients in and around the areas. The total biodiversity (flora and fauna) of wetlands is high in comparison to terrestrial ecosystems. Wetlands provide protective cover and essential feeding, breeding and maturation areas for a wide range of invertebrates as well as cold and warm-blooded vertebrates. Wetland provides a refuge for migratory birds. It is clear from the above discussion that numbers of birds, fishes and aquatic animals (snails, frog and other insects), a variety of vegetation cover of wetlands and its surrounding areas have been steadily dwindling each year. On the other hand, overall water and soil quality are in an alarming condition which is very clear from the result of water quality index of the beels. It is clear from the survey that 66.67% of the floral species are on the verge of extinction, 26.67% of the floral species are on moderate situations and only 6% are in good condition or in overgrowth condition (Table 5.6). The abundance status of fauna is also very alarming condition. This is a common phenomenon in all the surveyed wetlands in the study area. It is clear from the survey that 55.56% of the faunal species are on the verge of extinction, 34.72% of the faunal species are on moderate situations and only 9.72% are in satisfactory condition or in overgrowth condition (Table 5.14).

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CHAPTER-VI

CAUSES AND CONSEQUENCES OF DEGRADATION OF WETLAND

CHAPTER-VI

CAUSES AND CONSEQUENCE OF DEGRADATION OF WETLAND

6.1. Introduction:

Wetlands though have immense potential for development, are the most threatened of all ecosystems today. In spite of covering only 1.5% of the Earth's surface, wetlands provide a disproportionately high (40%) of global ecosystem services (Zedler and Kercher 2005). It is estimated that freshwater wetlands alone carry 20 % of the known range of biodiversity in India (Deepa and Ramachandra, 1999). A study by the Wildlife Institute of India reveals that around 70-80% of freshwater marshes and lakes in the gangetic floodplain region has been lost in the last 50 years. The Wildlife Institute of India's survey reveals that wetlands are disappearing at a rate of 2% to 3% every year. Sometimes the damages to wetlands are unavoidable due to increasing pressure on land owing to high population growth. But in most of the cases, the true values of wetlands are misunderstood by the government, politicians, engineers, as well as common people. Just a few decades ago, wetlands have been considered as mosquito breeding zone, muddy, dangerous, and unhealthy place. The wetlands are used for agricultural activities. These are filled for the construction of houses, establishment of industrial complexes. The wetdans are sometimes used as dumping sites of household, commercial and biomedical wastes. However, it is fortunate that scientists have discovered wetlands as the most valuable of all the ecosystems. The contemporary status of the wetlands is not satisfactory; degradation and conversion of wetlands are increasing by many folds with time.

Wetlands are being an unseen storehouse of nature's bounty and a gift of nature to mankind which act as regulators and reservoirs for rivers (Raju, 2012). But, the area of wetlands has been declining in every country due to the invasion of the population and exploitation of natural resources which are non-environmental friendly (Smoktonowicz, 2005). People think that wetlands are unproductive areas free for filling and use of developmental needs (Kilborn 1991). Their ecological and economic functions are undermined for the last decades. The discharge of pollutants, land filling, overpopulation and unrestricted exploitation of wetland resources are threatening the very existence of these environmentally fragile habitats (Squillace, 2007).

As human population and social, religious, commercial and economic activities in and around the wetland have grown extremely, the magnitude of eco-degradation and pollution have also increased. As a result, the environment of the wetlands has been affected adversely. Thus, the wetland has been receiving threats to its survival due to a mass of geo-environmental problems. The geo-environmental problems of the wetlands may result from a number of problems like garbage dumping, pollutant inflow, human encroachment and areal shrinkage, siltation, weed infestation, eutrophication, overexploitation of wetland resources, and modern agricultural and piscicultural practices etc.

6.2. Causes of Degradation of Wetland:

The wetlands provide an ideal habitat for feeding, nesting and breeding of a large number of fishes, birds and aquatic animals. Therefore, these wetland ecosystems need proper conservation and management strategies to protect them from further degradation. The basic causes of degradation of wetland are same worldwide through the causes of degradation vary from place to place. The main causative factors responsible for the degeneration of wetlands of the study area are identified as follows:

6.2.1. Sedimentation:

The organic and inorganic remains, sand, silt, pebbles, dead and decomposing matter, and house hold wastes from the wetland catchment area drain into the Wetland through rainwater or run-off, which leads to sedimentation in wetlands.

Siltation is the accumulation of sand, silt, pebbles and other inorganic materials on wetland bottom. Siltation is a common problem associated with almost all the wetlands and in most of the cases, it depends on land use and land cover patterns of the surrounding areas. The wetlands serve as natural reservoirs and can reduce the impact of floods. But during the rainy season, the sediment load carried by the rivers is deposited in the wetlands ultimately settling down at the bottom. At the same time, sediment loaded runoff from the wetland catchment area finds its way to the wetlands. Thus the depth of the wetlands is reduced to a great extent as a result of inundation by floods. Though Siltation is a natural process of filling up of the wetlands, the anthropogenic activities like agriculture, grazing, sand mining from the river bed, earth quarrying, contraction of roads, railways, houses, commercial and residential complexes etc in the catchment of a wetland also accelerates the process. So the natural process coupled with anthropogenic activities lead to shrinkage and loss of many wetland habitats in the study area. But the source of sediment is difficult to identify because it comes from non-point sources.

Table 6.1: Thickness of Mud in Wetland Bed

Sample site	Min depth (feet)	Max. depth (feet)	Average
Bochamari Beel	1.5	2.5	2.0
Khottimari Beel	1.0	2.0	1.5
Batikata Beel	1.0	2.0	1.5
Chotojan Beel	0.2	0.5	0.4
Barojan Beel	1.0	2.0	1.5
Raichanmari Beel	2.0	3.0	2.5
Bherbheri Beel	3.0	5.0	4.0
Salmara Beel	4.0	6.0	5.0
Nildoba Beel	3.0	4.0	3.5
Atiamochar Beel	0.5	0.8	0.7
Dhangdhar Chhara	2.0	3.5	2.8
Rasomati Jheel	2.0	4.0	3.0
Baiganbari Chhara	1.0	2.0	1.5
Chandan Dighi	2.0	4.0	3.0
Sagar Dighi	0.3	0.5	0.4

Source: Field Survey, 2017

In the study area, bottom deposition varies from wetland to wetland. It is highest in the Salmara Beel (5ft) followed by Bherbheri Beel (4 ft) and Nildob Beel a (3.5 ft). Bottom deposition is very thin in Chotojan and Sagar Dighi(0.4ft) followed by Khottimari Beel (1.5ft), Batikata Beel (1.5ft), Barojan etc (Table 6.1 & fig. 6.1).

Table 6.2: Organic Carbon Concentration in the Different Wetland

Sample site	Organic Carbon (%)
Bochamari Beel	4.95
Satwabhanga Nadi	3.61
Atiamochar Beel	2.59
Raichanmari Beel	1.67
Nildoba Beel	1.48
Dhangdhar Chhara	1.47
Rasomati jheel	4.57
Baiganbari Chhara	2.28
Chandan Dighi	2.4
Sagar Dighi	1.03

Source: Field Survey, 2017

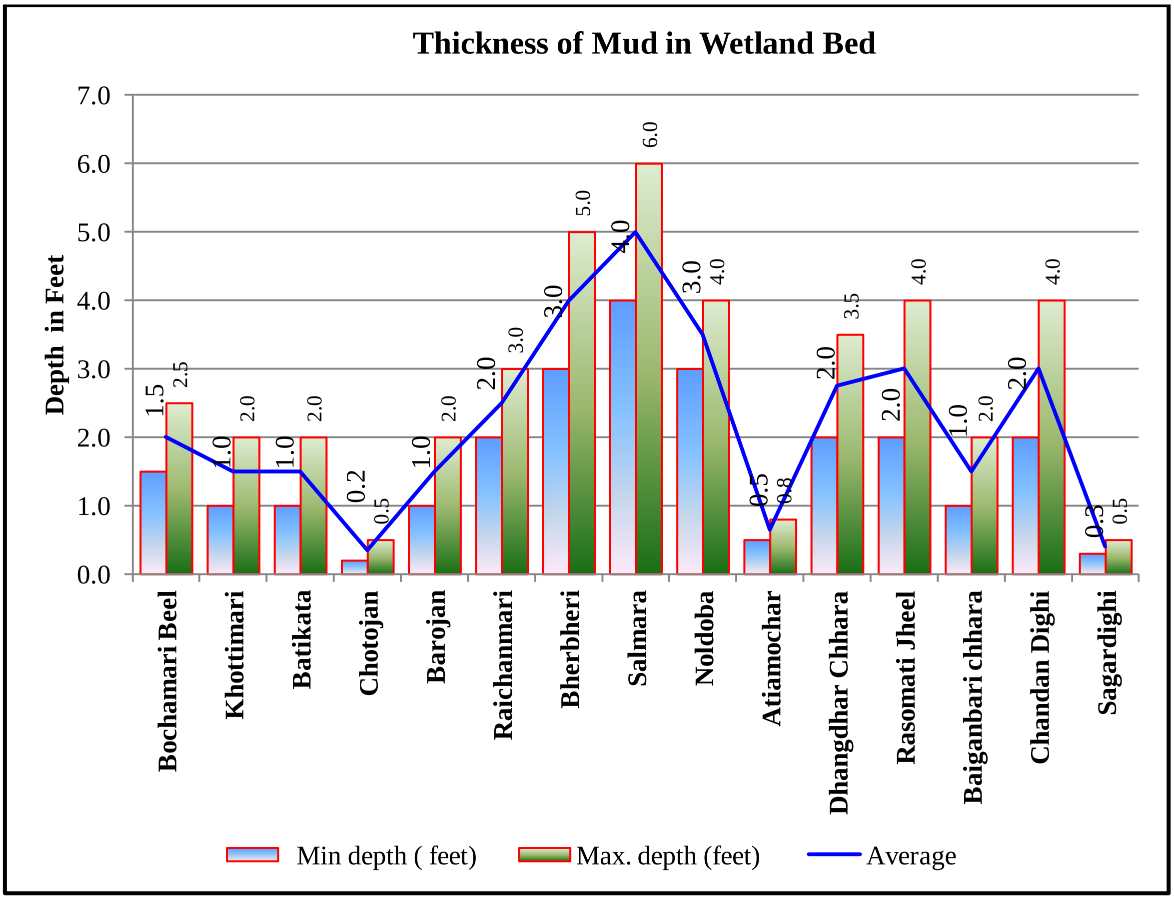


Fig 6.1: Thickness of Mud in Bed of Different Wetlands

It is observed from the field survey that most of the wetlands of the study area are covered with macrophytes. The growth of these macrophytes is normally very fast in the shallow wetlands. Multiplication of floating mats reduces the open water area of wetlands and helps in eutrophication. As soon as these macrophytic plants die and decompose, they are deposited at the bottom of wetlands. This process of accumulation of organic deposit over the years has to lead to degeneration of wetlands in the study area. But the amount of degeneration varies from wetland to wetland depending upon the amount of macrophytic vegetation available in them. Very high organic carbon content of the Beel denotes the organic bottom deposition. The organic carbon content of the soil is very high in Bochamari Beel (4.95%), followed by Rasomati jheel (4.57%), Satwabhanga Nadi (3.61%) etc (Table-6.2 & fig. 6.2).

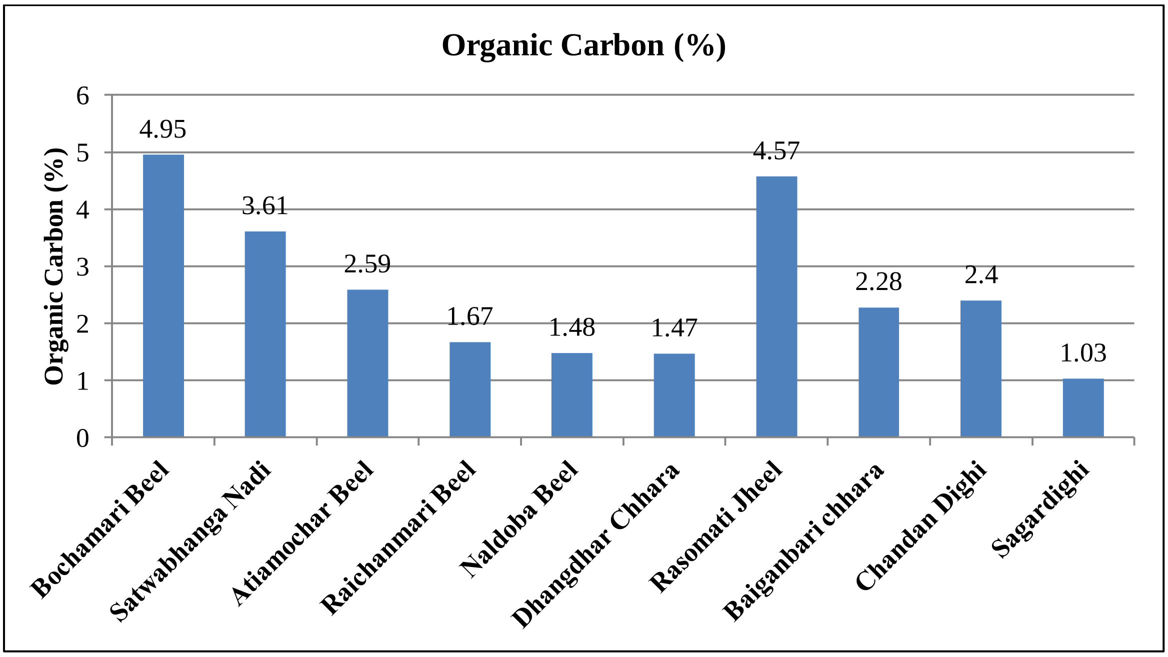


Fig 6.2: Organic Carbon Concentration in the Different Wetland

6.2.2. Blockage of Feeder Channel:

The feeder channels can be called as the life-line of wetlands. Wetlands may have one or more feeder channels which regulate the water regime and water quality of the wetlands. The productivity of fish in the wetlands and growth of macrophytes is largely determined by the connection of feeder channels with the wetlands. But due to blockage of feeder channels wetlands are degenerate (Deka D. M. 2011). The young fishes enter into the wetlands during the monsoon when the nearby rivers are connected to them; the larger fishes also enter the wetlands for breeding. Auto stocking of these young and brood fishes determine the productivity of fish in the wetlands. The channels regulate the water level of these wetlands during the rainy season. They also help in keeping the wetlands clean from overgrowth of macrophytes and pollutants drained into it from nearby industries, urban centres and agricultural fields. But the feeder channels connecting the wetlands with the nearest river are sometimes blocked by road, railways, embankments and other structures (for example Haripur Beel in the Tufanganj-II) (Photo Plate 6.1). The blockage of feeder channel may be caused due to natural siltation by the river in the mouth of wetland (for example Rasomati Beel in the Koch Bihar-II). The embankments act as physical barriers to the migration of fish and the free flow of water between rivers and wetlands. As a result, these barriers hamper the natural cleaning process of wetlands. In some feeder channels, sluice gates are provided for flow of water as well as for fish migration. But these gates are found to be ineffective in most of the areas, as they are mainly designed for prevention of flood water rather than fish migration. From field survey, it is observed that more than 65% of the sluice gates are out of order. As a result productivity of fish is reduced, water quality declines, the rate of accumulation of organic deposits on the bottom of the wetlands increases at a faster rate, thereby leading to degeneration and even death of the wetlands.

6.2.3. Construction of Engineering Structures and other Obstacles:

The engineering constructions in and around the wetlands causes a serious threat to the wetlands. These engineering structures include roads, railways and *Calvert* across the wetlands, houses and other commercial structure. In the study area, roads and railways act as barriers and cause ecological problems in the wetlands. 4765 km of road and 109 km of railway are criss-crossed in the study area (Table 6.3 & fig. 6.3). At many places, roads and railways pass through the wetlands and invariably block the free flow of water and macrophytes. A considerable part of the materials used in the construction of roads, railways and buildings in the vicinity of wetlands are washed into the wetlands by storm water, thereby reducing the wetland depth. Morpho-ecological changes are brought about by the engineering structures constructed in and around the wetlands and thereby converting them into stagnant water bodies.

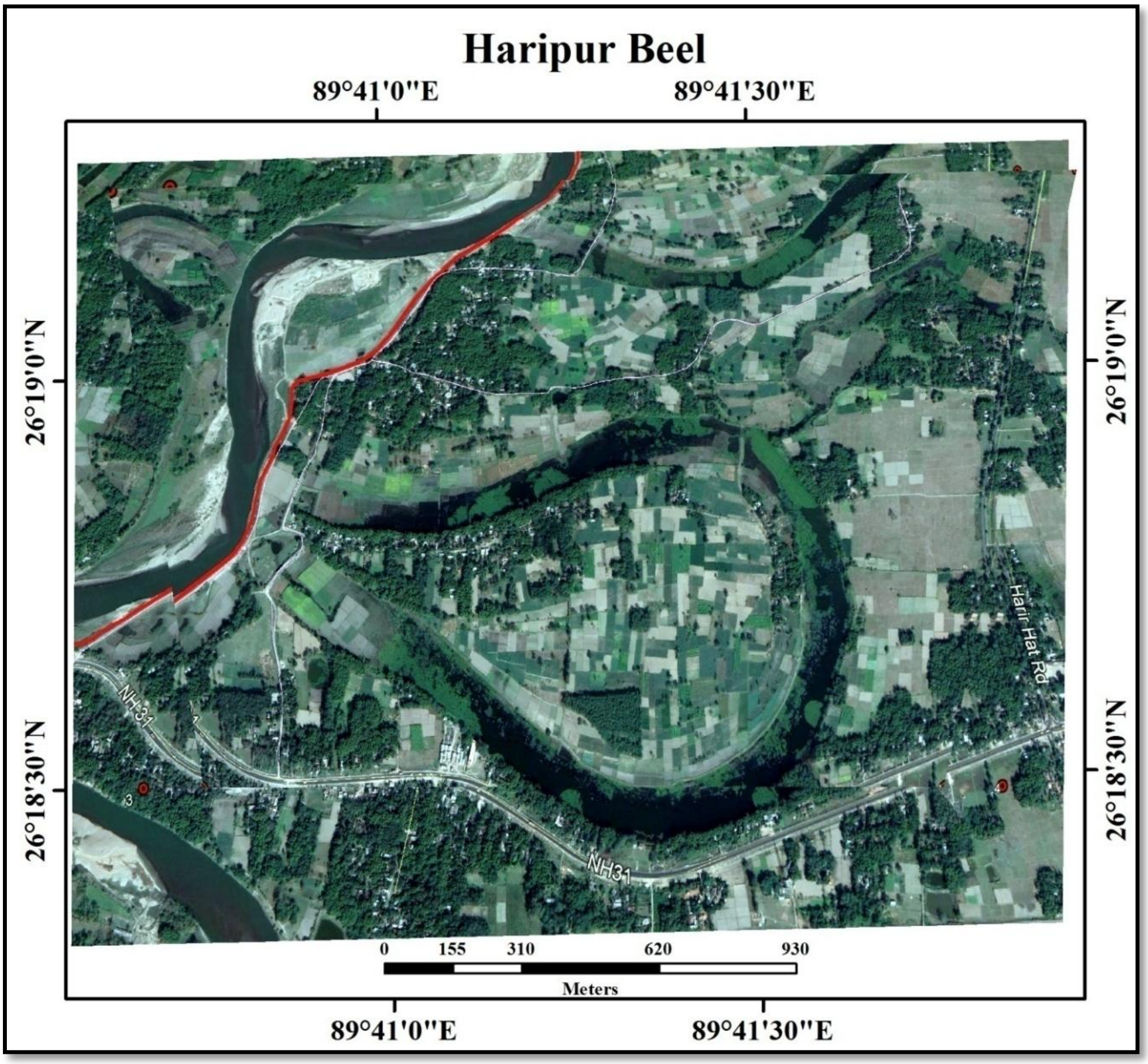


Photo Plate 6.1: Blockage of Feeder Channel of HaripurBeel

A large number of fishing obstacles constructed across the wetlands hinder the free flow of water and floating macrophytes and destroy the breeding grounds of fishes. Normally, shallow littoral areas of the wetlands are submerged after rain. Such gentle slopping areas in the littoral zone are the breeding ground of most of the fishes found in the wetlands. Slight movement of water i.e. 0.3 to 0.5 km per hour is suitable for breeding of both migratory and non-migratory species of fishes. In most of the rivers, water current is much more than this. Therefore, the shallow areas of wetlands, with active feeder channels are found to be the best breeding ground for many varieties of fish. But now the shallow areas of wetlands are now being used for agriculture and the water gets stagnant due to the construction of embankments and roads & railways and hence the breeding grounds for fishes are progressively being lost in the wetland of the study area like Kakribari Beel, Kankanguri Chhara.

Table 6.3: Length of Roads Maintained by Different Agencies in the Study Area, 2010-11

	P.W.D.	Zilla Parishad		Gram Panchayat & Panchayat Samity		PMG Sarak Yojana
	Surfaced	**Surfaced**	**Unsurfaced**	**Surfaced**	**Unsurfaced**	**Surfaced**
Koch Bihar-I	95.05	31.49	11.15	88.86	1267.46	102.02
Koch Bihar-II	93.98	34.09	8.60	48.38	824.90	116.90
Tufanganj-I	78.74	19.60	9.41	43.80	555.44	42.56
Tufanganj-II	72.72	21.64	4.83	39.70	1061.18	92.44
Total	340.49	106.82	33.99	220.74	3708.98	353.92
Grand total	4764.94					

Source: Field Survey, 2017

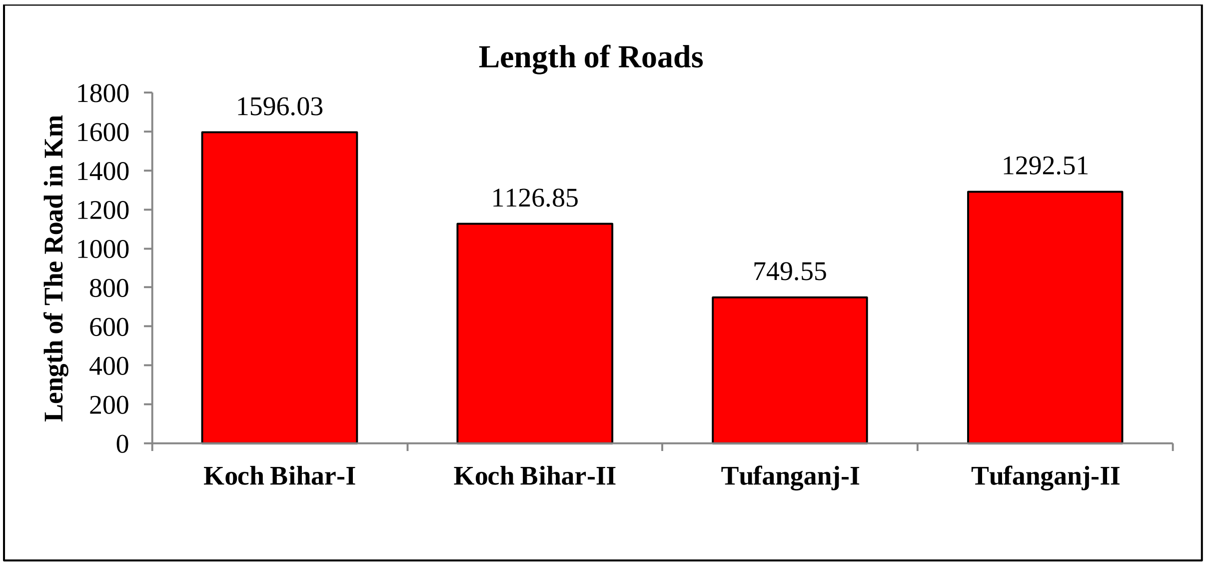


Fig6.3: Length of Roads Maintained by Different Agencies in the Study Area, 2010-11

6.2.4. Encroachment:

People consider wetlands to be of no value or wastelands. So in order to make such lands productive, they encroach for agriculture, construction of houses for private and public use, urban expansion and other such purposes. Most of the wetlands of the study area are now in a deplorable and degraded condition. The major socio-economic factors responsible for Encroachment and Areal Shrinkage are as follows:

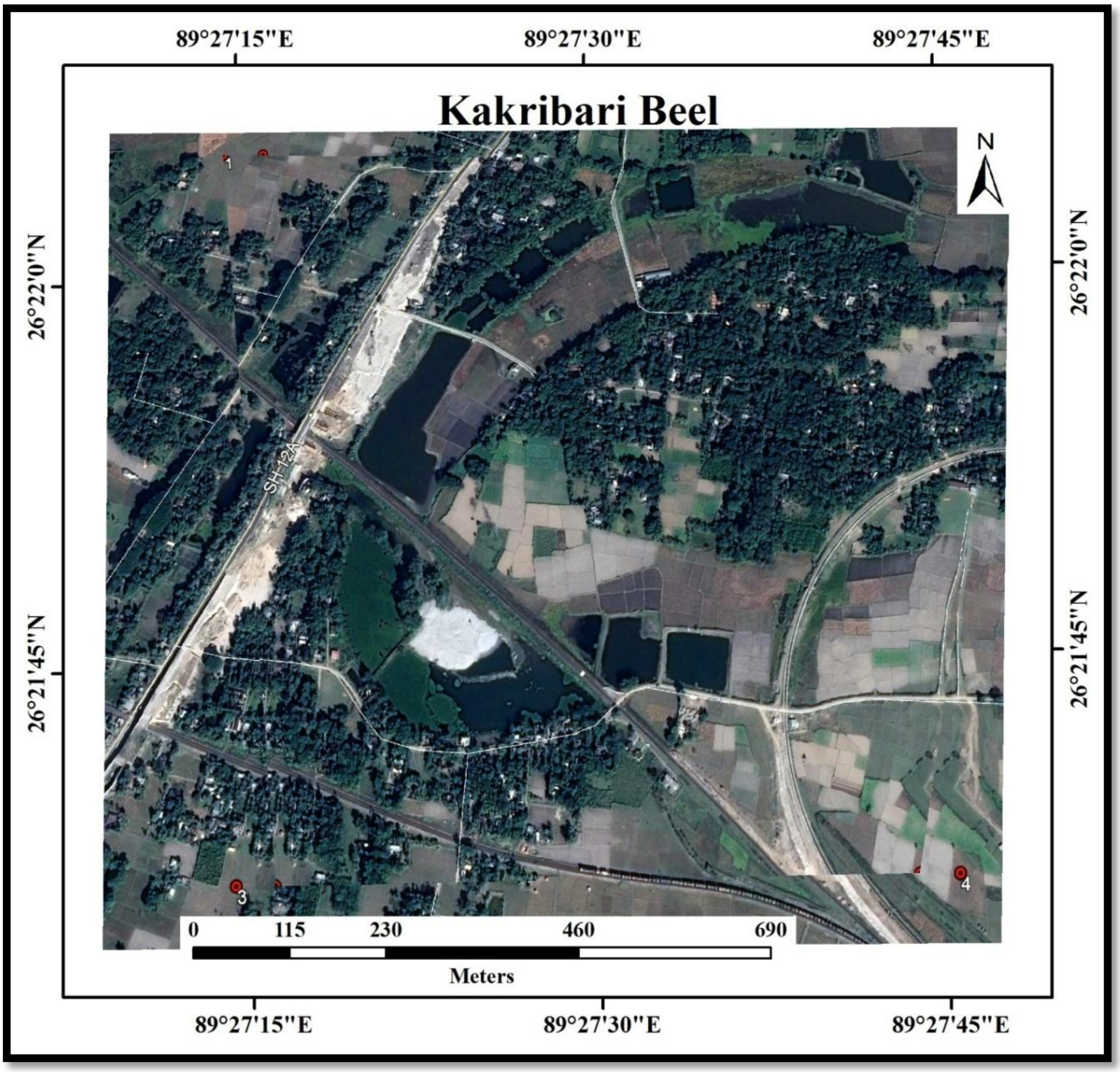


Photo Plate 6.2: Road and Railway as Obstacles in Kakribari Beel

(i) As soon as the flood water recedes, some parts of the wetlands dry up which are extremely fertile and offer the possibility of growing a type paddy popularly called the 'Boro paddy' it is a variety of rice mainly grown in winter. However with the increasing population pressure in the study area, the farmers are now facing acute scarcity of land and in order to find a fertile soil they turn to the wetlands, but the wetlands which have been converted once; can never regain their original status. In baiganbari Chhara 77.35% of wetland area is converted to agricultural land for boro paddy cultivation (Table 6.4 & fig. 6.4).

(ii) Apart from agriculture, the wetlands have other uses like the construction of houses and buildings for industrial and commercial use. The houses constructed in the wetland areas are generally of semi-kaccha type but sometimes schools, Temples, Mosques; club etc. may even have permanent concrete structures in these areas. Recently it is seen that concrete constructions are built by filling up the edges of wetlands; as evident in the edges of Chandan Dighi and Dhangdhar Chhara which are progressively filled up.

(iii) Sometimes shrinkage of wetland area in study area takes place due to natural processes like siltation and river engulfment. While siltation is a common phenomenon, which takes place almost in all the wetlands of the study area, river engulfment is most prominent in the Rasomati Jheel where the Northen side is engulfed by Mansai River.

Table 6.4: Land Use and Land Cover of Baiganbari Chhara and its Surroundings

Sl no.	Land use	The area in sq km	Area in %	wetland area in %
1	Agricultural Land around the wetland	4.71	38.14	
2	Grazing Land and Other around the wetland	0.12	0.97	
3	Planted Vegetation around the wetland	0.72	5.83	
4	Settlement around wetland	4.77	38.62	
5	Wetlands around wetland	0.22	1.78	
6	Agricultural Land in the Wetland	1.40	11.34	77.35
7	Grazing Land and Other in the wetland	0.12	0.97	6.63
8	Planted Vegetation in the Wetland	0.05	0.40	2.76
9	Settlement in the Wetland	0.04	0.32	2.21
10	Water Cover in the Wetland	0.20	1.62	11.05

Source: Calculated by Researcher

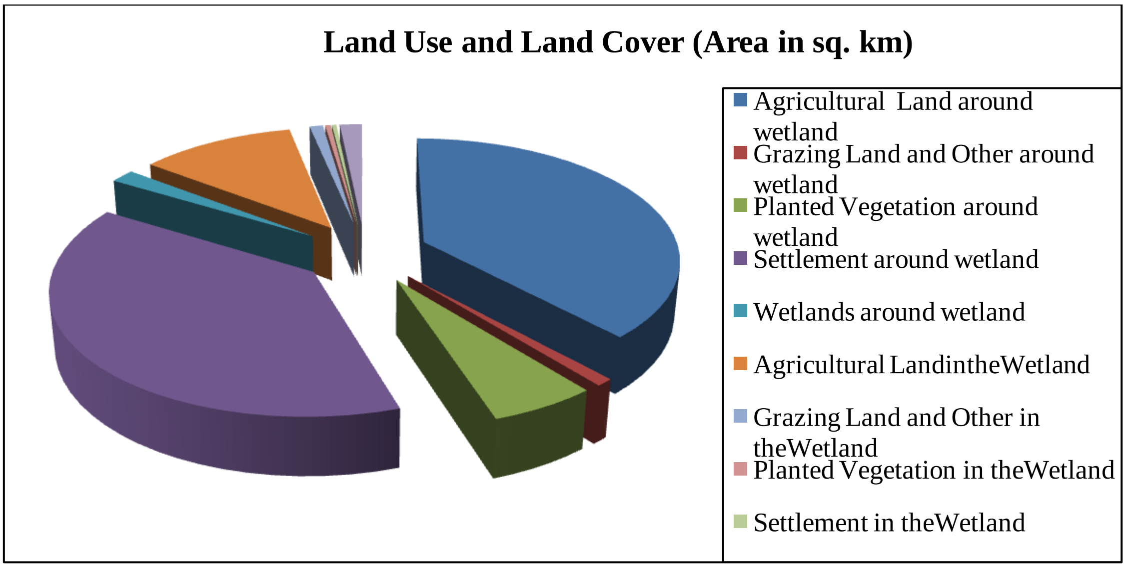


Fig 6.4: Land Use and Land Cover of Baiganbari Chhara and its Surroundings

6.2.5. Agriculture:

The greatest agent of Wetland degradation is agriculture, through nutrient and sediment pollution. Organic and inorganic fertilizers containing nitrogen and phosphorus are carried to wetlands through runoff which causes major problems like the excess growth of aquatic plants. At the same time utilization of Wetland for Boro paddy (Photo Plate 6.3)cultivation during winter and aquaculture of Water caltrop *(jalsigara)* and taro *(solakachu)* during rainy season further degrades the wetlands. According to Williams and Ehrenfeld & Schneider (1991), drainage and other disturbances associated with agriculture are the main contributors to wetland loss and modification**.**

Photo Plate 6.3: Boro Cultivation in Baiganbari Chara, Koch Bihar-II

Photo Plate 6.4: Irrigation for Boro Cultivation in Rasik Beel, Tufanganj-II

The recent practices of farmers which include using wetlands as seed-bed for boro crops adversely affect the wetland ecosystem as huge quantities of biocides (insecticides and pesticides) and herbicides are drained into the wetlands through runoff. With agricultural modernization, the farmers in the study area use intensive agricultural practices, which coupled with the motive of greater profit drive them to use huge amounts of organic and inorganic fertilizers, pesticides, insecticides, herbicides, modern machinery to generate higher levels of productivity from relatively smaller areas. Application of high input technology also has an adverse effect on the water quality of the wetlands as the success of high input modern technology depends on the usage of irrigation, chemical fertilizers, insecticides, pesticides etc. However, the run-off water transporting the residues of hazardous chemical inputs finally finds their way into the wetlands thus undermining the water quality. Again, the accumulating fertilizers in the neighbouring wetlands promote irrepressible organic growth reducing the oxygen content and increasing the biological oxygen demand. This disrupts the lifecycle of all inhabiting species in wetland ecosystems.

6.2.6. Irrigation:

The water from the wetland is being used for irrigation in the surrounding agricultural fields. Farmers are more inclined to the withdrawing water from wetlands (Photo Plate 6.4) than other sources like groundwater or nearby rivers since wetland water being more nutrient-rich yields more agricultural produce. Withdrawing large amounts of water from wetlands is hazardous to wetland ecosystem. Koch Bihar and Tufanganj subdivision have an abundance of wetland which is one of the important sources of irrigation during the boro paddy cultivation in the study area. Total 24 River lift irrigation from wetlands (RLI) was observed in Koch Bihar &Tufanganj subdivision which serves 226 ha irrigated area (2006-07). Out of 24 RLI, 18 RLI were observed in Koch Bihar subdivision and rest 6 RLI were identified in Tufanganj subdivision (Table 6.5). Out of 4 blocks, Koch Bihar-I has the highest irrigated area (70.80 per cent) followed by Tufanganj-I (19.03 per cent) and Koch Bihar-II (10.18 per cent). On the other hand, Tufanganj-II has 2 RLI which is out of order and thus serves zero irrigated area **(Fig 6.5)**.

Table 6.5: No. of Lift Irrigation (Govt.) and Irrigated Area (Ha) from Wetlands of Koch Bihar Sadar &Tufanganj

Name of the Blocks	Lift Irrigation	Irrigated area (Ha)
Koch Bihar-I	7	160
Koch Bihar-II	11	23
Tufanganj-I	4	43
Tufanganj-II	2	0
Total	24	226

Source: Minor Irrigation Census (2006-07)

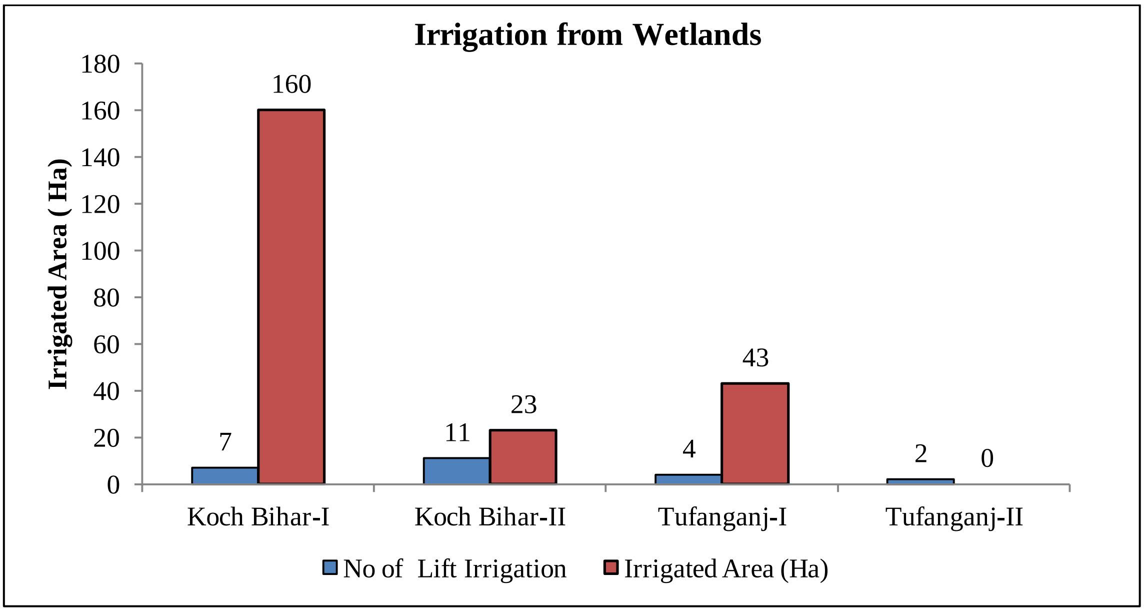


Fig 6.5: Irrigation from Wetlands of Koch Bihar &Tufanganj

A field survey was conducted during the boro paddy cultivation in 2017; it is found that wetlands are the important source of irrigation. Total 58 Lift Irrigation systems were found in the selected wetland of study area (Fig 6.6). Farmers'response suggests that they prefer wetland water over any another source of irrigation as wetland water is an admixture of nutrients which boost the production of crops. Out of 58 Lift Irrigation, 29 Lift Irrigation are found in Rasikbeel wetland complex, 23 in Baiganbari Chhara, and 6 in Dhangdhar Chhara. Sagar Dighi and Chandan Dighi, located in the Urban area and Rasomati jheel, located in the forested area are not utilised for irrigation since agricultural practices do not exist there.

Table 6.6: No. of Lift Irrigation (Private) from Sample Wetland

Sample site	No. of Lift Irrigation
Rasik Beel wetland complex	29
Dhangdhar Chhara	6
Rasomati Jheel	0
Baiganbari Chhara	23
Chandan Dighi	0
Sagar Dighi	0
Total	58
Source: Field survey, 2016	

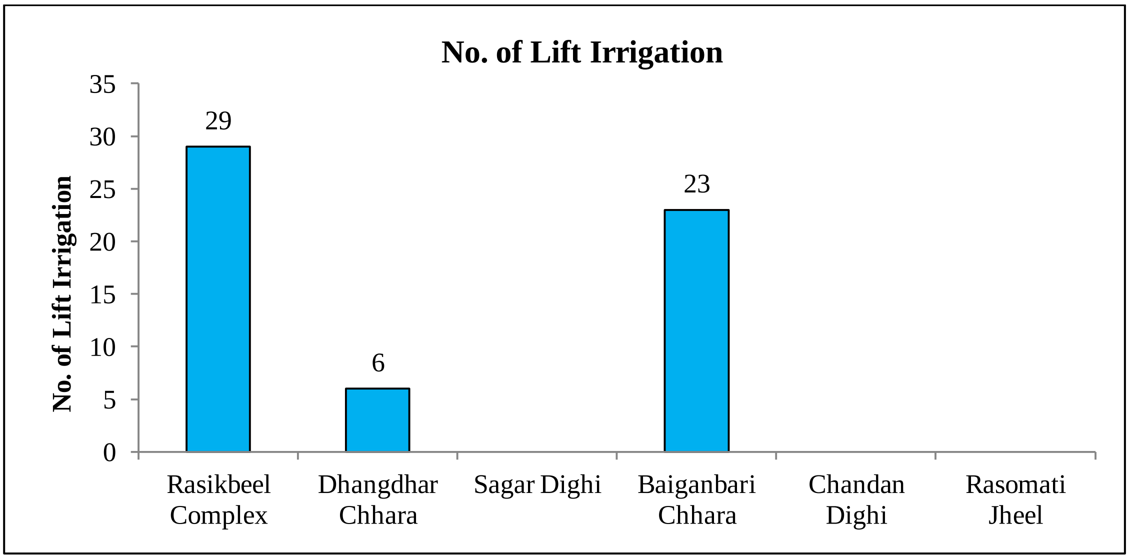


Fig6.6: No. of Lift Irrigation (Private) from Sample Wetland

6.2.7. Garbage Dumping:

Garbage dumping is a common phenomenon undertaken by individuals, municipality, panchayat as well as other authorities. It is the main cause of wetland degradation in urban areas. Garbage dumping is directly related to the level of cultural development and aesthetic sense of the people involved in it. In urban areas, garbage is produced from household and commercial activities which need to be disposed of off to a safer site than in the nearby wetlands. This should also be an important subject of concern for the municipal authority as it relates to planning and management of urban ecology. But in the study area, the municipal and panchayat authorities are not concerned in the proper management of the garbage generated in their area. They are haphazardly dumped in the so-called no man's land or vacant Govt. land that is often in the vicinity of a wetland, thus creating huge physical and ecological problems in the wetlands. This problem is very acute in the wetlands (dihgi) under the Koch Bihar municipality namely Chandandighi, Marwari Dighi, Lamba dighi, Laldighi, etc(Table 6.7).

Table 6.7: Nature of Garbage Dumping

Sample Site	No. of dumping point	Nature of materials	Amount
Rasomati jheel	0	NA	NA
RasikBeel Complex	2	Organic	Nominal
Dhangdhar Chhara	3	Inorganic	Nominal
Haripur Beel	4	Mixed (Both)	Nominal
Sagar Dighi	4	Inorganic	Huge

Chandan Dighi	7	Inorganic	Huge
Marwari Dighi	8	Mixed (Both)	Huge
Lamba Dighi	10	Inorganic	Huge
Baiganbari Chhara	12	Organic	Huge
Kankanguri-Nayachhara	14	Inorganic	Huge

Source: Field Survey, 2017

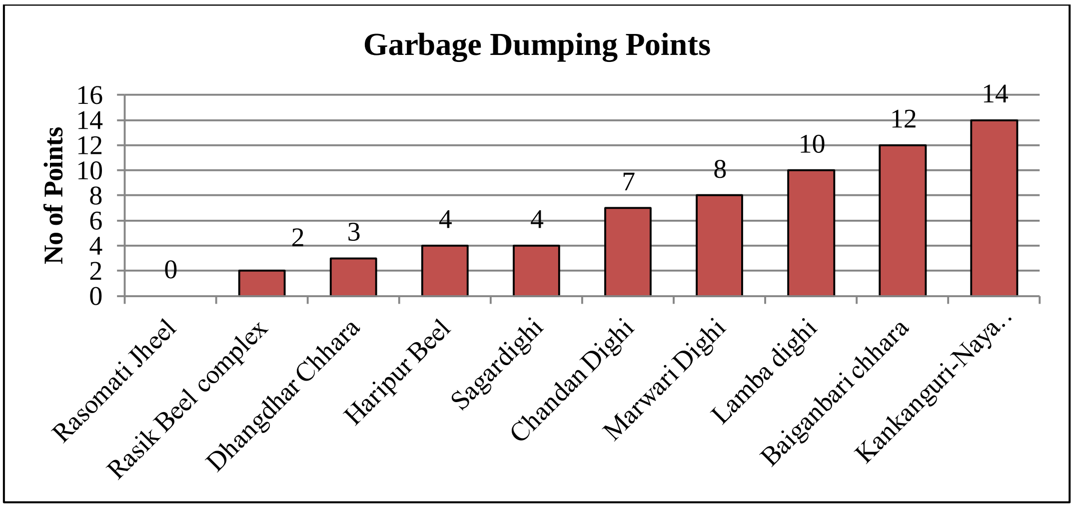


Fig 6.7: Garbage Damping Points

Photo Plate 6.5: Garbage dumping in Marwari Dighi, Koch Bihar-I

Photo Plate 6.6: Pollutants Inflow in Baiganbari Chara, Koch Bihar-II

6.2.8. Pollutants Inflow:

The drains coming from urban industrial and commercial areas as well as runoff from agricultural fields bring effluents and pollutants to the wetlands. The organic and inorganic wastes drained into the wetlands have an adverse effect on the wetland environment. Wastes that are seen floating in the wetland waters are plastic bottles, shoes, sandals, plastic bags, useless household goods etc. As many of these are non-biodegradable, they remain floating and block the natural flow of water in the wetlands. As many tea-stalls and hotels are situated in the close proximity of the wetlands, all the wastes generated from them find their way to the wetlands. The organic wastes also increase the nutrient content of water thereby making the water unsuitable for living species.

Household Sewage creates vital problems in the wetland environment. Households Sewage including wastes from the toilet of the houses located in the vicinity of the wetland directly flow into the wetlands and disrupt the wetland environment. The municipal authorities hardly take any measures like sewage treatment or sewage diversion for prevention of pollution in the wetland waters. Among the surveyed wetlands 67% wetlands have pollutant inflow and 33% wetlands are free from pollutant inflow (Table 6.8).

Table 6.8: Source of Pollutant Inflow

Sample site	**Pollutant Inflow found(Yes/No)**	**Source**
Bochamari Beel	Yes	Kamakhyaguri Municipality
Satwabhanga Nadi	Yes	Agricultural
Atiamochar Beel	No	NA
Raichanmari Beel	Yes	Agricultural
Nildoba Beel	No	NA
Dhangdhar Chhara	Yes	Industrial
Rasomati Jheel	No	NA
Baiganbari Chhara	Yes	Agricultural & Market
Chandan Dighi	Yes	Municipality
Sagar Dighi	No	NA
Haripur Beel	Yes	Agricultural
Kankanguri-Naya Chhara	Yes	Agricultural
Count of Yes	8	67%
Count of No	4	33%

Source: Field Survey, 2017

Pollutant's Inflow in the Wetlands

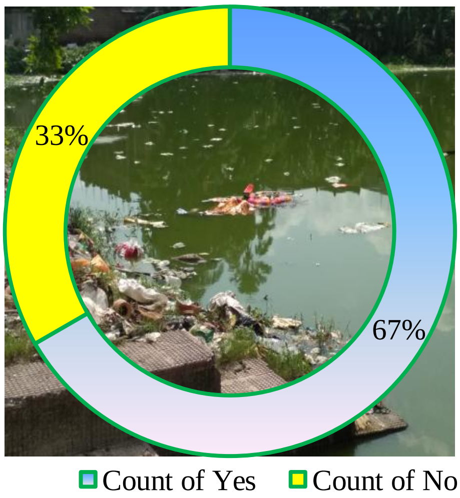


Fig 6.8: Pollutant's Inflow in the Wetlands

6.2.9. Eutrophication:

The wetlands which have a large supply of nutrients are called eutrophic. On the other hand, wetlands with a small supply of such nutrients are termed as oligotrophic (Edmonson, 1975). Wetlands usually support a high rate of biological production. Therefore, the term eutrophication is used to specify the rate of nutrient supply. As in the case of many fresh water lakes, the term eutrophic is used to describe wetlands that generate the dense development of plants or algae. The growing rate of eutrophication is the main cause of deterioration of wetland ecosystem.

Low depth of wetlands, high rainfall with moderately high temperature and low sunshine are the main reasons for the widespread growth of aquatic macrophytes. As long as the wetlands remain deep and have a considerable volume of water they remain in equilibrium. Aquatic species like *Eichornia crassipes* and *Ipomea aquatica* infestation is a common problem in the study area. Weed concentration in a water body severely restricts plankton production, limits the living space for fish and disturbs the equilibrium of physico-chemical qualities of water. It also causes imbalances in DO budget and promotes accumulation of dead weeds in the wetland bed. Most of the wetland is, however, almost fully covered in aquatic weeds, which include Eichhornia, Pistia, Spirodela, Lemea, Wolfia, Typha, Phrognules, Cyperus, Colocasia, Ipomosa etc. In winter as the water level drops down, these weeds dry and decompose leading to an increase in the nutrient content of water and eutrophication and also alters the ecological functions of wetlands.

In the state of eutrophication, the wetlands develop large quantities of organisms per unit area and ultimately it becomes filled up completely and is covered by aquatic and land vegetation. In this way, some wetlands in the study area have degenerated into swampy and muddy landforms comparable to waste lands. At present they are neither suitable for fish production nor for crop cultivation nor grazing by the household animals. In the Rashik Beel wetland complex, there are some portions which have become very muddy and are locally named as *bhershi*. Table 6.9 deals with vegetation cover of the study area.

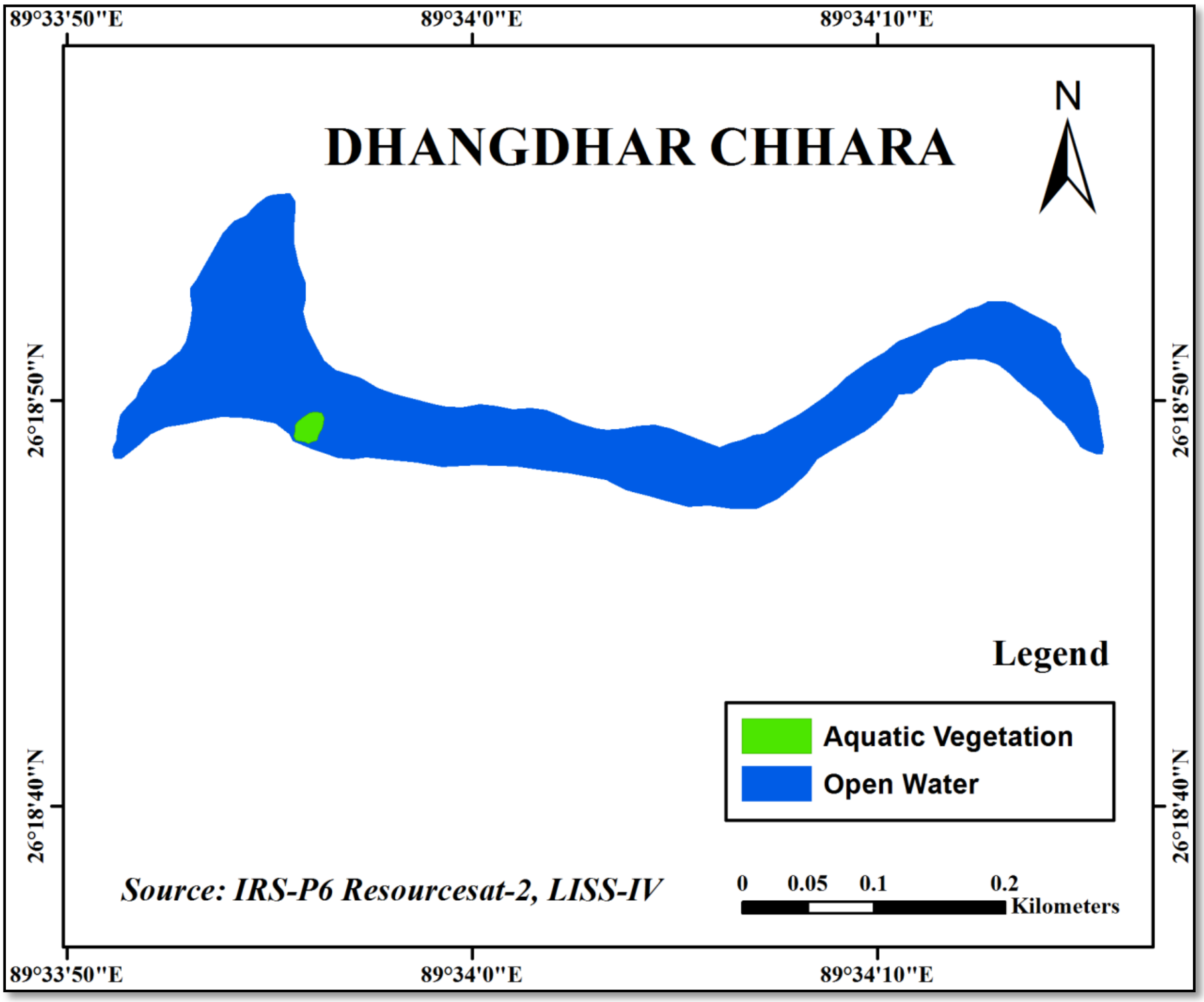
Table 6.9: Vegetation Cover and Open Water Share in Selected Wetlands of the Study Area

Wetlands		**Area of Wetlands in ha**				
		Total area	**Open water**	**Open water in %**	**Aquatic vegetation cover**	**Aquatic vegetation cover in %**
Rasik Beel Wetland Complex	Bochamari Beel, Chotojan&Barojan	62.9175	17.8259	28.33	45.0916	71.67
	Raichanmari Beel	9.4435	3.5509	37.60	5.8926	62.40
	Nildoba Beel	11.0721	2.8557	25.79	8.2164	74.21
	Satwabhanga Nadi	6.6301	2.8135	42.44	3.8166	57.56
	Atiamochar Beel	10.7145	3.3641	31.40	7.3504	68.60
	Bherbheri Beel	13.2263	5.0332	38.05	8.1931	61.95
	Salmara Beel	14.7974	NIL	0.00	14.7974	100.00
Dhangdhar Chhara		4.0858	4.0501	99.13	0.0357	0.87
Sagar Dighi		5.1758	5.1758	100.00	NIL	0.00
Chandan Dighi		0.5848	NIL	0.00	0.5848	100.00
Rasomati Jheel		6.6809	0.3740	5.60	6.3069	94.40
Baiganbari Chhara		18.7328	5.4740	29.22	13.2588	70.78

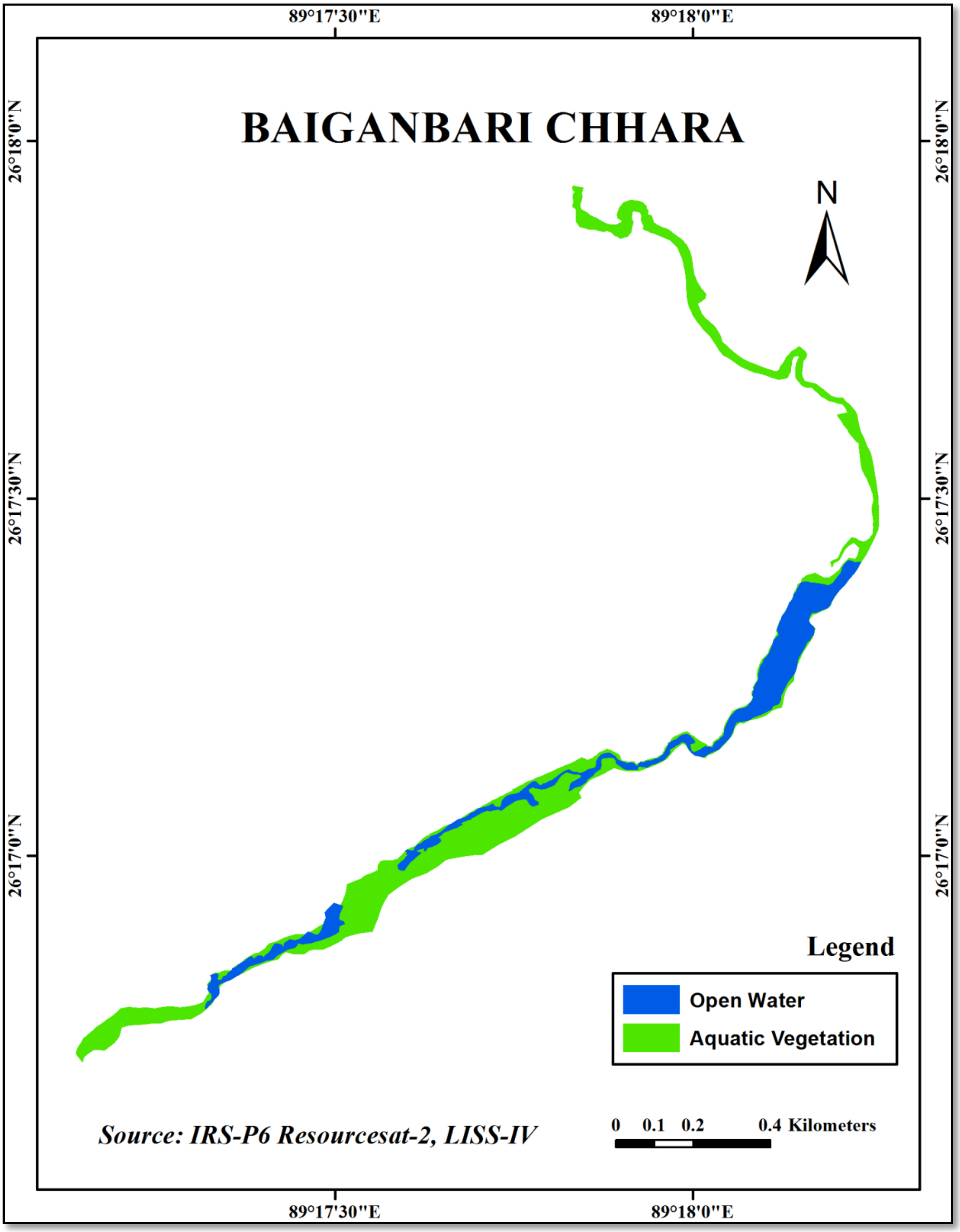
Source: IRS-P6 Resourcesat-2, LISS-IV

Table 6.9 reveals that 100% aquatic vegetation cover is observed in Chandan Dighi and Salmara Beel followed by Rasomoti Jheel (94.4%), Nildoba Beel (74.21%),Bochmari Beel(71.67%), Baiganbari Chhara (70.78%), Atiamochar Beel (68.60%), Raichangmari

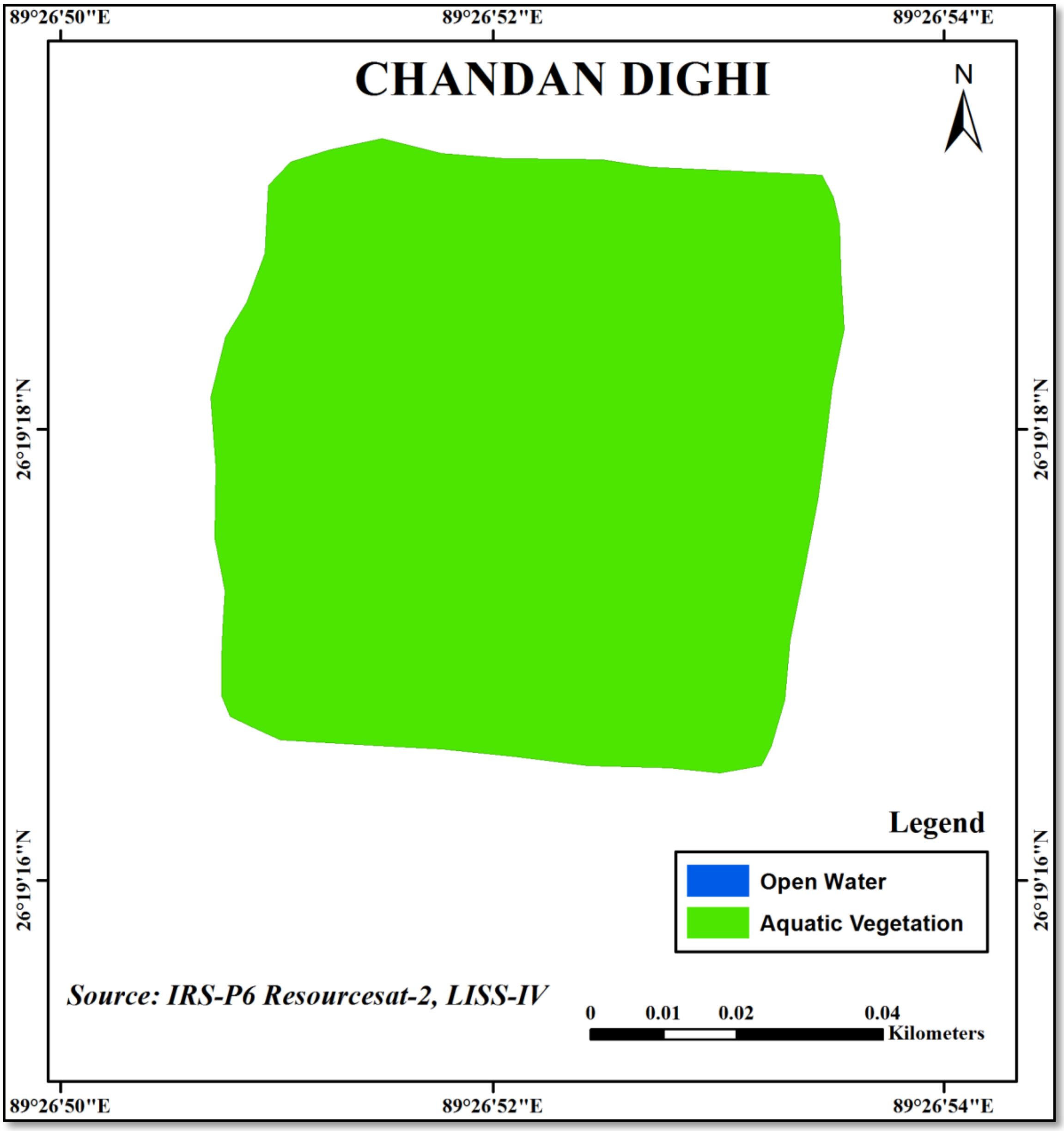
(62.40%), Bherbheri (61.95%) and Satwabhanga Nadi (57.56%) and only 0.87% aquatic vegetation cover observed is in Dhangdhar Chhara and 100% open water observed in Sagrdighi. In Dhangdhar Chhara 99.13% area is covered with open water followed by Satwabhanga (42.44%), Bherberi (38.05%), Raichanmari (37.60%), Atiamochar (31.40%), Baiganbari Chhara(29.22) and in Rasomati jheel (5.6%).



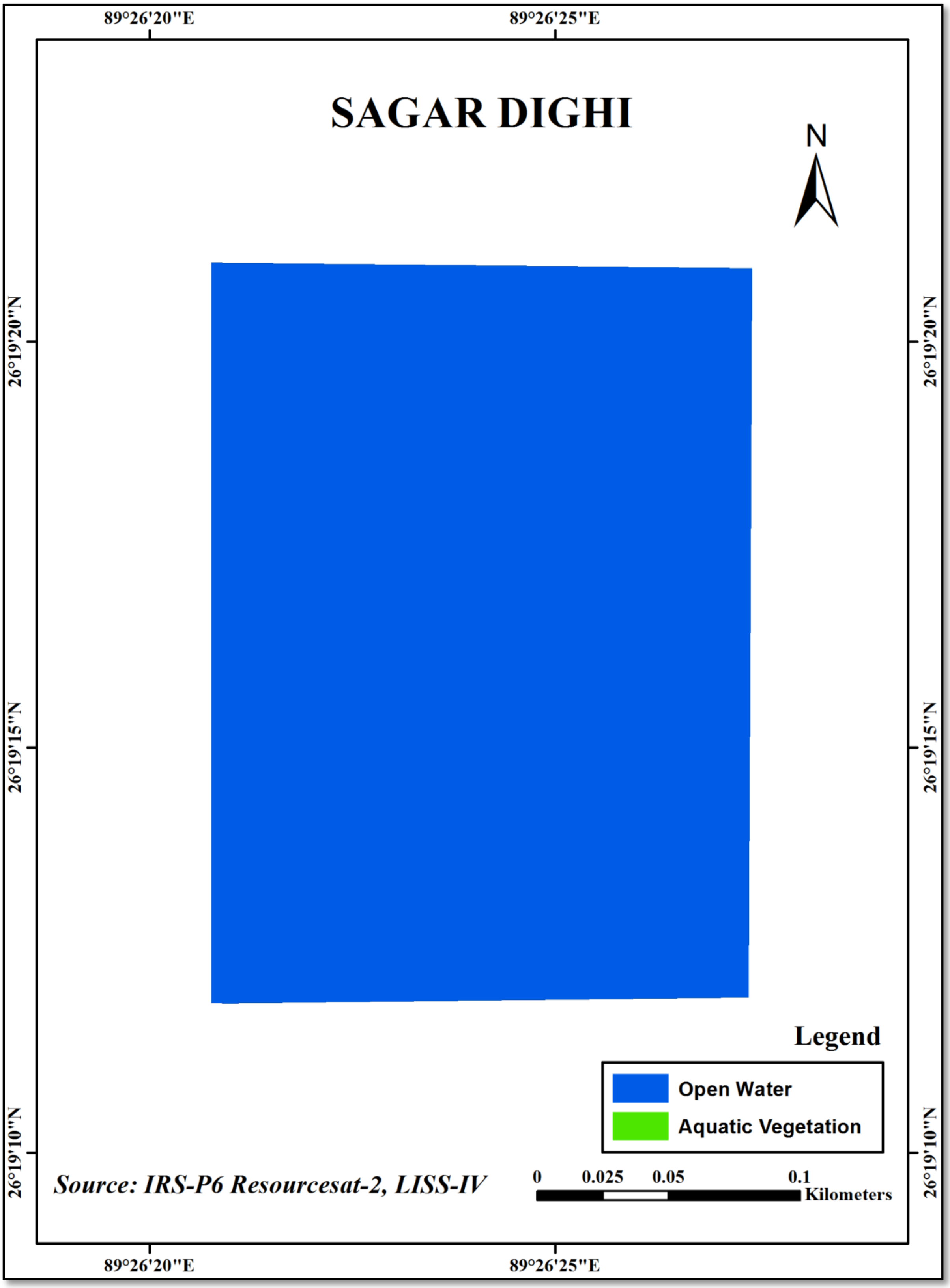
Map 6.1: Vegetation Cover and Open Water Share in Dhangdhar Chara, November 2017



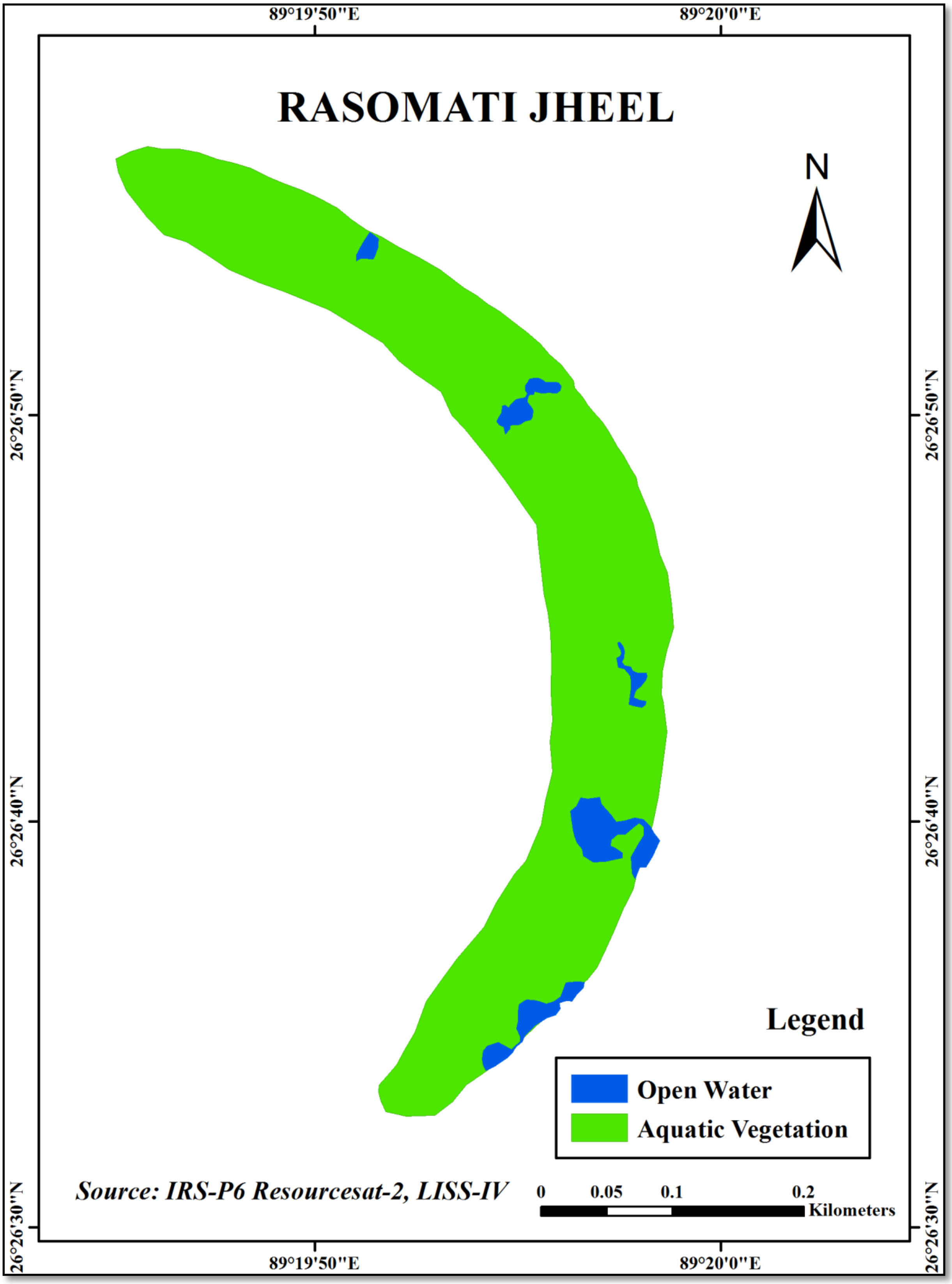
Map 6.2: Vegetation Cover and Open Water Share in Baiganbari Chhara, November 2017



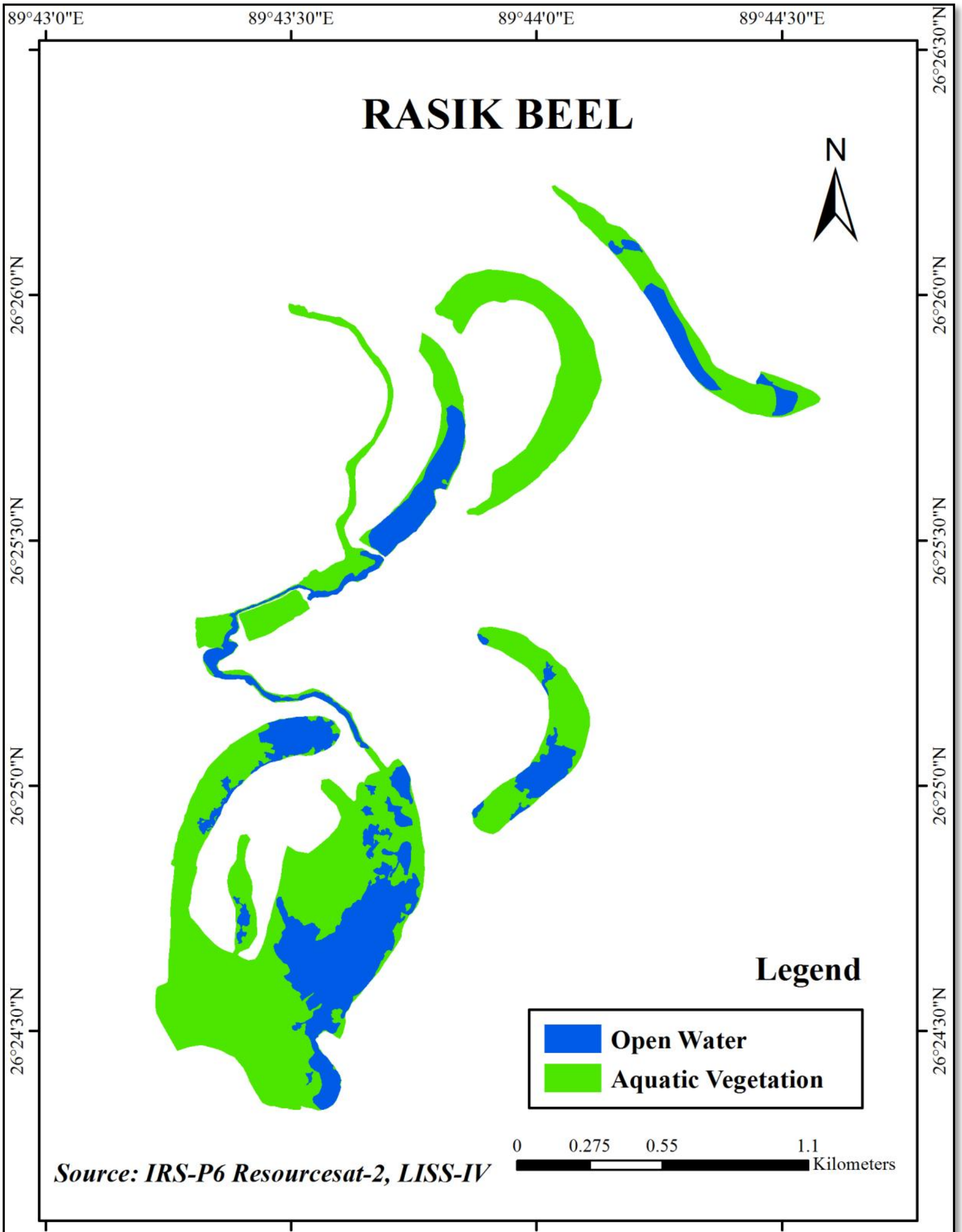
Map 6.3: Vegetation Cover and Open Water Share in Chandan Dighi, November 2017



Map 6.4: Vegetation Cover and Open Water Share in Sagar Dighi, November 2017



Map 6.5: Vegetation Cover and Open Water Share in Rasomati Jheel, November 2017



Map 6.6: Vegetation Cover and Open Water Share in Rasik Beel Wetland Complex, November 2017

6.2.10. Indiscriminate Fishing:

One of the most harmful man-made activities in the wetlands is indiscriminate fishing especially the gravid fishes. During the breeding season, large quantities of gravid fishes with eggs are sold at high prices in the local markets, completely disregarding the existing fishery rules and with no moral consideration for the future productivity of fishes. Indiscriminate fishing with traditional gears is also responsible for the low productivity of the wetlands. The mesh size of the nets used for fishing capture is generally smaller than the Permissible size. As a result, fishes of all sizes are captured, including the fry and fingerlings. Consequently, the fish count and variety decreases which render the wetlands unproductive over time.

Production from wetlands largely depends on the gears and devices employed for fishing (Lagler, 1978). Many locally designed gears and indigenous methods are used for capturing fishes from the wetlands in the study area. The gears and devices can be broadly divided into three categories (i) Nets, (ii) hooks and lines and (iii) traps. Nets used here are of various types and their mesh sizes vary ranging from less than 5mm to more than 110 mm. With the help of nets like '*Tanajal*' (mesh size 10 to 20mm) ,*'Jhakijal/Chapijal'* (mesh size 8mm to 15 mm) , ' *Langijal*', (mesh size 8 mm to 15 mm),'*Masarijal*' (mesh size 5mm to 8 mm) , fishes of all sizes are captured including the brooding fishes. This type of indiscriminate fishing reduces the productivity of wetlands to a great extent. Indiscriminate fishing utilizing different fishing methods along with fishing by drying up or draining wetlands is very harmful to the wetland ecosystems. These practices are prevalent in Chotojan Beel, Barojan Beel, Dhangdhar, Baiganbai, Haripur Beel and Kankanguri-Naya Chhara.(table 6.10)

Table 6.10: Indiscriminate Fishing Status

Sample site	All over the year	Fishing by Dried up
Bochamari Beel	yes	
Khottimari Beel	yes	
Batikata Beel	yes	
Chotojan Beel		fully
Barojan Beel		fully
Raichanmari Beel	yes	
Bherbheri Beel	yes	
Salmara Beel	yes	
Nildoba Beel	yes	

Atiamochar Beel	yes	
Dhangdhar Chhara	yes	partly
Rasomati jheel	yes	
Baiganbari Chhara		Fully
Chandan Dighi	yes	
Sagar Dighi	yes	
Haripur Beel	yes	partly
Kankanguri-Naya Chhara	yes	partly

Source: Field Survey, 2016-17

Secondly, it has been found that the traditional gears are inefficient for fishing in the wetland waters, as a result, the bottom-dwelling fishes which are carnivorous in nature (due to the heavy deposition of silt, mud and petrified matters on the wetland bed over the years) are spared. And when these fishes are left uncaught, they disturb the balance in the wetland ecosystem. It is found that in almost all the wetlands only bottom-dwelling fishes dominate.

In addition, the shallow wetlands are drained using motor pump set during the dry season for catching the remaining fishes thus killing the last parent species of flora and fauna existing in a wetland, this adversely affects the productivity of wetland in the coming year.

6.2.11. Flood:

A flood is a natural event. But flood becomes a disaster due to the interference of various engineering structures like embankments, sluice gates, roads, railways etc. It is learnt from various field visits that people of different localities now demand demolition of such man-made structures to be relief from the floods. Several cases are recorded so far in the study area, where the villagers cut the roads or embankments to release or redirect the flood water blocked in their locality, thereby creating havoc in other areas. Due to roads, railways, embankments etc. the wetlands retain the flood waters for longer periods than usual. The sediment-loaded waters finally settle the dissolved clay and silt in the wetlands decreasing their depth, on the contrary when the strong water currents break off the roads and embankments, the flood water carries away many fishes and floating aquatic plants which in turn disrupt the wetland ecosystem.

6.2.12. Weed Clearance:

Weed clearance is a common practice in the wetlands. After clearance, the weeds are dumped in the littoral areas thus reducing the effective wetland area. Moreover, some portions of decomposed weeds get deposited in the bottom of wetland by rain and storm water further reducing the depth. Secondly, Lots of flora and fauna are also removed along with the weeds of which some may be of the rare variety. Clearance of the weeds **(**Photo Plate 6.7 & 6.8) exposes the camouflage of many species including fishes that then become an easy prey to the predators and fishermen. Many birds also nest in them and with the clearing of weeds, their nests along with the eggs get destroyed thus affecting their population. Among the surveyed wetland 10 wetlands have been cleared at least once in a year. And on the other hand, 7 wetlands have not been cleared regularly (Table 6.11).

Photo Plate 6.7: Weed Clearance in RasikBeel, Tufangang-II

Photo Plate 6.8: Weed Clearance by Fire in BaiganbariChara, Koch Bihar-II

Table 6.11: Weed Clearance Status of the Study Area

Sample Site	Whether Clearance of Weed is Done or Not	Frequency of Weed Clearance in a Year	Summary of the Data	Count
Bochamari Beel	No	0	Count of Yes	10
Khottimari Beel	No	0	Count of No	7
Batikata Beel	No	0	No Clearance	7
Chotojan Beel	Yes	1	One time Clarence	4
Barojan Beel	Yes	1	2 times of Clearance	5
Raichanmari Beel	Yes	2	3 times of Clearance	1
Bherbheri Beel	No	0		
Salmara Beel	No	0		
Nildoba Beel	No	0		

Atiamochar Beel	Yes	3		
Dhangdhar Chhara	Yes	2		
Rasomati Jheel	No	0		
Baiganbari Chhara	Yes	2		
Chandan Dighi	Yes	1		
Sagar Dighi	Yes	1		
Haripur Beel	Yes	2		
Kankanguri-Naya Chhara	Yes	2		

Source: Field Survey, 2017

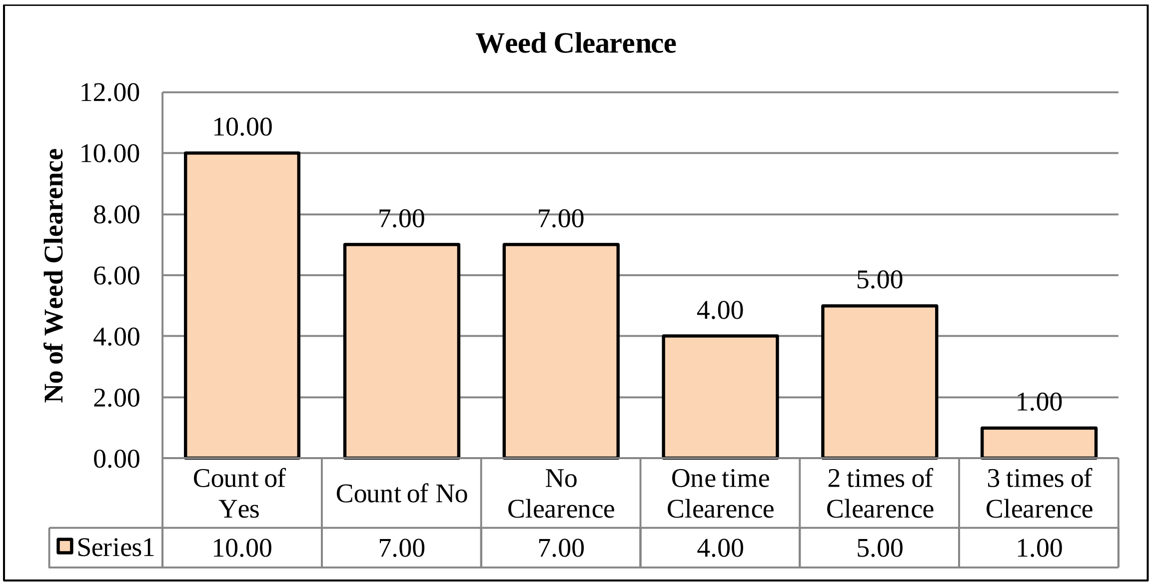


Fig 6.9: Weed Clearance

6.2.13. Fragmentation of Wetlands:

Fragmentation or division of wetlands the main hydrological and ecological problem for the wetland degeneration in the study area. Division of wetlands mainly occurs in shallow oxbow lakes. Almost all oxbow lakes and riverine wetlands are more or less fragmented by owner and lease holders of the wetlands. The oxbow lakes and riverine wetlands whose physical appearances have changed by 50% or more by anthropogenic activities are categorized as Quasi-Natural oxbow lake and Quasi-Natural riverine wetlands. Total 37Quasi-Natural oxbow lakes and 25 Quasi-Natural riverine wetlands are identified. The Quasi-Natural Oxbow Lake area observed in Koch Bihar-I is 8.66 %, Koch Bihar-II is 5.93 %, Tufanganj-I is 5.23 % and in Tufanganj-II is 3.31 %. Highest Pond area observed in Koch Bihar-I is 8.66 %, Tufanganj-I is 2.34 %, 0.83 % in Tufanganj-II and 0.72 % in Koch Bihar-II. Only 3.63 %Quasi-Natural Riverine Wetland is observed in Tufanagnaj-I, 1.88 %

in Koch Bihar-I, 1.63 % in Koch Bihar-II and only 1.02 % are observed in Tufanganj-II. In the study area, the wetlands with private ownership gradually face fragmentation due to a number of factors like disputes over ownership among partners or fragmentation due to inheritance, selling or buying etc. due to which the basic property of a wetland is lost. Moreover, the lack of vigilance and stern preventive measures of the wetlands under Government ownership is to face Fragmentation. For example, Ado beel (Photo Plate-6.9), Panisala Beel, Chatrampur Beel, Dhairhat Beel face this problem.

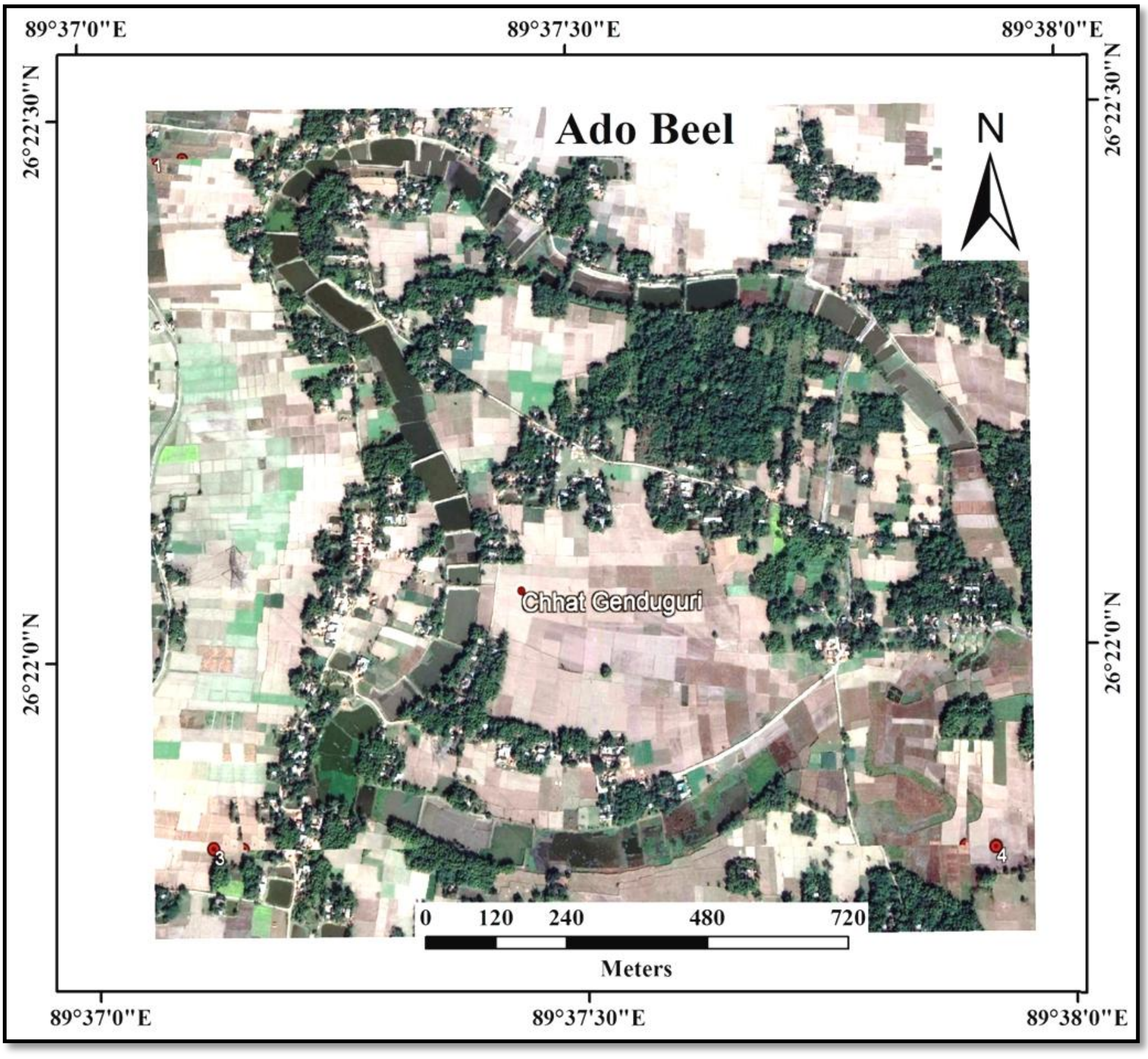


Photo Plate 6.9: Fragmentation of Wetlands in Ado Beel

6.2.14. Jute Retting:

Jute is one of the most important cash crops in the study area (Table 6.12). Jute retting tremendously affects the water quality of a wetland. In the study area almost all wetlands are used more or less for retting of jute and consequently, the water quality deteriorates so much that many organisms die irrespective of their species during jute retting. Therefore there is an urgent need to abandon the traditional process of jute retting which can be replaced with many alternative procedures like replacing mud or clay with that of plastic or defibrating the jute stems and then storing the fibers in a hole or a large drum and treating them with chemicals that induce retting. Amount of jute retting in the surveyed wetland is high in Baiganbari Chhara(350 bigha) followed by Haripur Beel(130 bigha), Kankanguri-Naya Chhara (120 bigha), Bara Bochamari Beel (80 bigha), Choto Bochamari Beel (60 bigha), Bherbheri Beel (50 bigha), (Table 6.13).

Table 6.12: Area, Production and Yield in the Blocks (Jute), 2011

Block	Area (Ha)	Production ('000 Ton)	Yield (Kg/Ha)
Coochbehar-I	11558	123.324	10.67
Coochbehar-II	5197	69.588	13.39
Tufanganj-I	3780	33.113	8.76
Tufanganj-II	1774	15.789	8.90

Source: District Statistical Hand Book

Table 6.13: Amount of Jute Retting in Different Wetland

Sample Site	Jute retting Site	Amount in Bigha
Bara Bochamari Beel	1	80
Khottimari Beel	-	0
Batikata Beel	-	0
Chotojan Beel	-	0
Barojan Beel	-	0
Raichanmari Beel	-	0
Bherbheri Beel	1	50
Salmara Beel	-	0
Nildoba Beel	-	0
Atiamochar Beel	-	0
ChotoBochamariBeel	1	60
Rasomati jheel	-	0
Baiganbari Chhara	1	350
ChandanDighi	-	0
Sagar Dighi	-	0
HaripurBeel	1	130
Kankanguri-Naya Chhara	1	120

Source: Field Survey, 2017

6.2.15: Over Utilization of Wetland Resources:

From the survey, it is evident that the wetland resources are over exploited. Fishing, edible plant collection, fodder collection, soil or silt quarrying, over grazing, crab and snail collection etc. negatively affect the biodiversity in the wetlands and degrades the wetlands.

6.2.16: Socio-Cultural Causes:

The wetlands play an important role in the socio-cultural (Table 6.14) life of people (marriage, grain initiation or *annaprashan)* which indirectly helps in the conservation of wetlands. However, some socio-cultural activities degrade the wetlands like pujas or fairs surrounding the wetlands pollute the water bodies. The wastes which generate from crematory grounds or from the immersion of idols in water release many submergible or floating bio-degradable or non-biodegradable wastes which play a major role in the pollution of wetlands.

Table 6.14: Socio-Cultural Activities in and Around Wetlands

Sample Site	Taking water for Cultural Activities	Fairs	No. of Crematory Grounds	Immersion of Idols
RasikBeel Complex	yes	no	Nil	yes
Dhangdhar Chhara	yes	no	1	yes
Rasomati jheel	no	no	Nil	yes
Baiganbari Chhara	yes	yes	4	yes
Chandan Dighi	no	no	Nil	yes
Sagar Dighi	yes	no	Nil	yes
Haripur Beel	yes	yes	2	yes
Kankanguri-Naya Chhara	yes	yes	3	yes

Source: Field Survey, 2017

6.2.17. Lack of Awareness:

Lastly one of the major causes of wetland degradation which paves the path for other causes is the indifference and lack of awareness in people. People who are directly or indirectly depend on wetlands fail to realize their importance. During the survey, to test the level of awareness of the wetland-dependent people, a scale called five-level-Likert scale was used and a shocking discovery was made that the majority of these people (93%) were ignorant about the importance of wetlands and how to conserve them. From the survey it is also evident that neither the Government nor any NGO has taken any initiative towards building up the awareness among people through festoons, posters, street plays or rally thus projecting the over-all indifference.

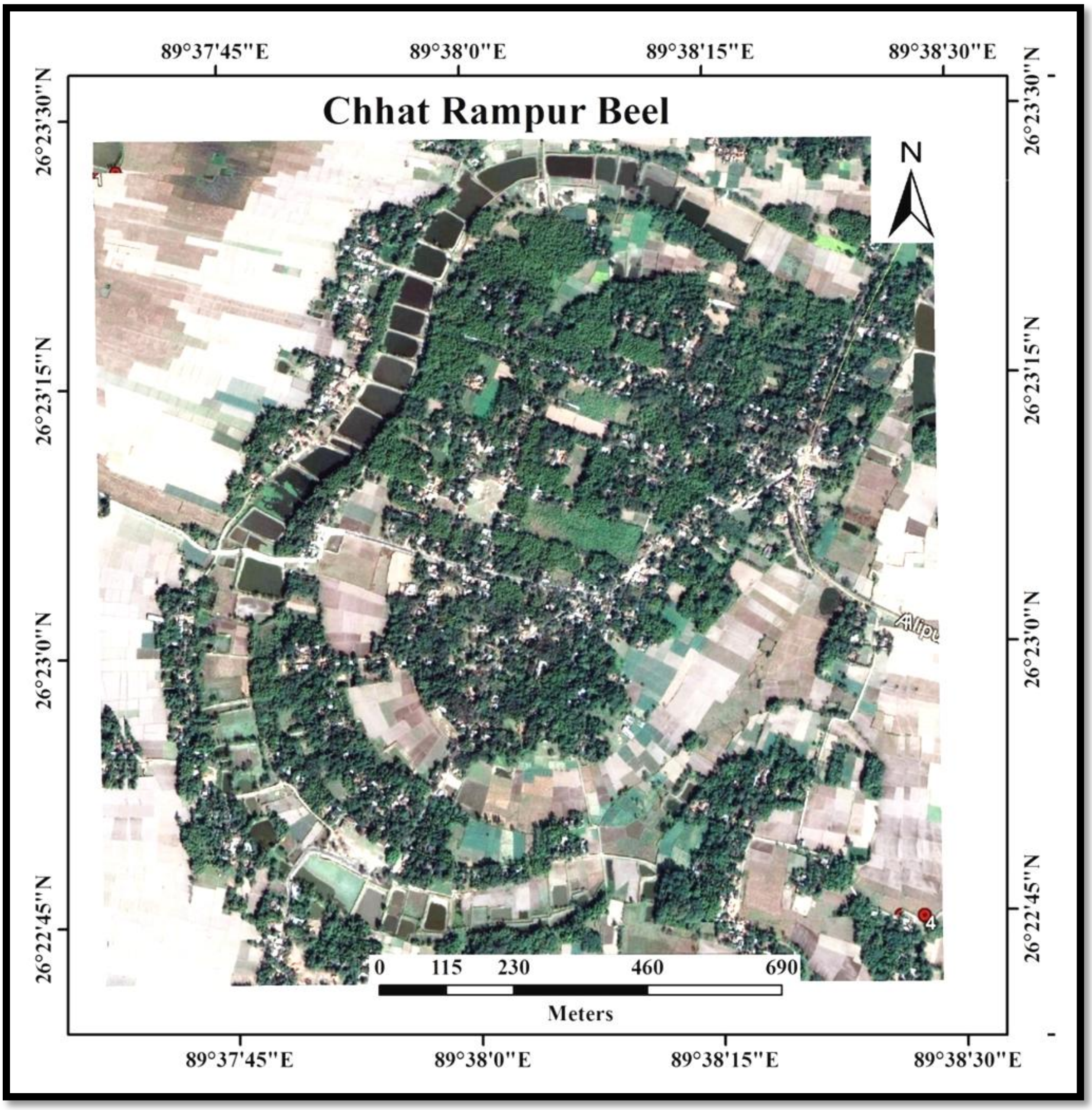


Photo Plate 6.10: Modification of Chat Rampur Beel

6.3. Consequences of Wetland Degradation:

Wetland is an indispensable part of an ecosystem. In a complex ecosystem or biosphere, wetlands irrespective of their size play an important role. It can also be said that every wetland is an ecosystem in itself and as a unique ecosystem; wetlands are one of the most productive of ecosystems. The paramount importance of Wetlands as an ecosystem received impetus only after the 70's through the Ramsar convention; however, presently it is one of the most threatened of ecosystems. This is primarily because the people are hardly aware of the true value of wetlands and over-exploit, pollute or eradicate wetlands. The degradation of wetlands over time, paves the way for environmental degradation, the major effects of wetland degradation in the study area is manifested through the following indicators-

6.3.1. Water Quality:

The most eminent indicator of wetland status is the water quality. The wetlands serve as a habitat for a number of flora and fauna species, and a minor change in the water quality negatively impacts most of the wetland dependent species, especially the water birds. Water quality refers to the different physical, chemical and biological characteristics of water (Diersing, N. 2009).and to correctly determine the water quality of the wetlands of the study area, W.Q.I. (water quality Index) is used. Evaluating the water quality from a large number of samples, each containing concentrations for many parameters is very difficult (Almeida, C. A., Quintar, S.,Gonzalez, P., and Mallea, M. A. 2007)A Water Quality Index (WQI) is a compilation of a number of parameters that can be used to determine the overall quality. Numbers of water quality indices have been formulated all over the world which can easily judge the overall water quality within a particular area promptly and efficiently. For example, US National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), British Columbia Water Quality Index (BCWQI), and Oregon Water Quality Index (OWQI). (Diersing, N. 2009; Bharti N, Katyal.D,2011; Debels, P., et al 2005; Kannel, P. R., et al, 2007)

Brown et al. (1970) developing a common scale and assigning weights for which elaborate Delphic exercises were performed (Bharti N, Katyal.D, 2011). This effort was supported by the National Sanitation Foundation (NSF) and that is why it also referred to as NSFWQI. This work seems to be the most comprehensive and has been discussed in various papers. It is a measure of the condition of water relative to the requirements of one or more biotic species or to any human need or purpose (Johnson D. L., Ambrose S. H., et al, 1997).

A Water Quality Index (WQI) is a compilation of a number of parameters that can be used to determine the overall water quality. Here the calculation of the WQI was done using weighted arithmetic water quality index which was originally proposed by Horton (Horton, R. K., 1965) and developed by Brown et al (Brown, R. M., Mc Lelland, N.I., Deininger, R.A. and O'Connor, M.F., 1972) in the following form-

$$WQI = \Sigma Q_iW_i / \Sigma W_i$$

Further, the quality rating scale (Qi) for each parameter is calculated according to Brown et al (1972) by using the following equation:

$$Qi = 100 \{(Va-Vi)/ (Vs-Vi)\}$$

Where,

Va = actual value of the water quality parameter obtained from laboratory analysis.

Vi = ideal value of the water quality parameter can be obtained from the standard tables. All the ideal values (Vi) are taken as zero except pH and dissolved oxygen. For pH, the ideal value is 7.0 and for dissolved oxygen, the ideal value is 14.6 mg/l.

Vs = recommended standard value of i^{th} parameter.

The unit weight for each water quality parameter is calculated by a value inversely proportional to recommended standard (Vs) for the corresponding parameter using the following expression.

$$Wi = K / Vs$$

Wi is the Unit weight of the factor

K is proportionality constant.

Values of K were calculated as $K = \frac{1}{\Sigma(1/Vs)}$

The water quality status (WQS) according to WQI is shown in Table 6.17.

Table 6.16 below shows a classification of water quality, based on its quality index due to Brown et al (1972) Chatterji and Raziuddin (ChatterjeeC. and Raziuddin M., 2002)etc.

Table 6.15: Classification of Water Quality Based on Weighted Arithmetic WQI Method

WQI	STATUS
0 - 25	Excellent
26 - 50	Good
51 - 75	Poor
76 - 100	Very Poor
Above 100	Unsuitable

Source: Brown et al (1972), Chatterji and Raziuddin (2002)

Table 6.16: Standard for Drinking Water and Aquatic Life

Sl. No	Parameters	Unit	Aquatic Life	
			Standard	Recommended Agency
1	BO	mg/l	3-20	BOYD,2003
2	Chloride	mg/l	25	Bhatnagar & Debi
3	Conductivity	µs/cm	1000	CPCB
4	Iron	mg/l	1	EPA, 1986
5	Dissolved O2(DO)	mg/l	4	CPCB
6	pH	Unit	6.5 - 8.5	CPCB
7	Total Alkalinity	mg/l	10-400	piper et al,1982
8	Total Dissolved Solids(TDS)	mg/l	500	Bhatnaga r& Debi
9	Total Hardness as CaCO3	mg/l	50-100	WHO, 2003
10	Free CO2	mg/l	6	CPCB
11	Water Temperature	°C	20-25	FAO,2006

Table 6.17: Water Quality Index for Aquatic Life in Bochamari Beel during Pre-Monsoon 2016

SL. NO	Parameter	Unit	Ideal Value (Vi)	Standard values (Vs) for Aquatic life	1/Vs	Observed Value (Va)	Unit Weights (Wi)	Quality Rating (Qi)	WiQi
1	Water Temperature (oC)	mg/L	0	20-25	0.040	31.6	0.024	126.400	3.010
2	pH	mg/L	7	6.5-8.5	0.118	7.8	0.070	53.333	3.735
3	Total Alkalinity (mg/L) as CaCO3	mg/L	0	10-400	0.003	178	0.001	44.500	0.066
4	EC (µS/ Cm)	mg/L	0	1000	0.001	61	0.001	6.100	0.004
5	TDS (mg/L)	mg/L	0	500	0.002	31	0.001	6.200	0.007
6	Free CO2 (mg/L)	mg/L	0	6	0.167	44	0.099	733.333	72.759
7	Iron(as Fe, mg/l)	mg/L	0	1	1.000	0.22	0.595	22.000	13.097
8	Chloride (mg/L)	µs/cm	0	25	0.040	39	0.024	156.000	3.715
9	TH (mg/L)	mg/L	0	50-100	0.010	46	0.006	46.000	0.274
10	DO	mg/L	14.6	4	0.250	6.3	0.149	78.302	11.653
11	BOD	mg/L	0	3-20	0.050	37.8	0.030	189.000	5.626
				Total	1.680	Σwi	1.00	ΣWiQi	113.946
				K=	0.595				
				WQI=	113.95				

Table 6.18: WQI for Aquatic Life in Selected Wetland during Post-Monsoon & Pre-Monsoon of 2016 & 2017

Name of Water Body	Year	Season	WQI for Aquatic Life
Bochamari Beel	2016	Pre-Monsoon	113.95
		Post-Monsoon	70.90
	2017	Pre-Monsoon	112.84
		Post-Monsoon	77.10

Satwabhanga Nadi	2016	Pre-Monsoon	96.71
		Post-Monsoon	75.24
	2017	Pre-Monsoon	106.45
		Post-Monsoon	77.71
Atiamochar Beel	2016	Pre-Monsoon	83.81
		Post-Monsoon	66.06
	2017	Pre-Monsoon	80.95
		Post-Monsoon	63.51
Nildoba Beel	2016	Pre-Monsoon	85.58
		Post-Monsoon	70.52
	2017	Pre-Monsoon	75.52
		Post-Monsoon	102.54
Raichanmari Beel	2016	Pre-Monsoon	88.03
		Post-Monsoon	92.64
	2017	Pre-Monsoon	89.00
		Post-Monsoon	98.54
Rasomati Jheel	2016	Pre-Monsoon	54.63
		Post-Monsoon	45.97
	2017	Pre-Monsoon	52.95
		Post-Monsoon	43.92
Baiganbari Chhara	2016	Pre-Monsoon	87.71
		Post-Monsoon	61.77
	2017	Pre-Monsoon	82.16
		Post-Monsoon	67.27
Dhangdhar Chhara	2016	Pre-Monsoon	140.99
		Post-Monsoon	100.21
	2017	Pre-Monsoon	125.04
		Post-Monsoon	100.21
Chandan Dighi	2016	Pre-Monsoon	172.99
		Post-Monsoon	136.22
	2017	Pre-Monsoon	152.47
		Post-Monsoon	150.36
Sagar Dighi	2016	Pre-Monsoon	52.11
		Post-Monsoon	30.66
	2017	Pre-Monsoon	51.05
		Post-Monsoon	33.60
Average	2016-17	Pre-Monsoon	95.25
		Post-Monsoon	78.25
Average	2016-17	Both Season	86.74

Source: Tested and Calculated by the Researcher

Table 6.19: Classification of Water Quality Based On Weighted Arithmetic WQI Method

WQI	Status	Aquatic Life	Aquatic Life
		No of wetland	%
0 - 25	Excellent	0	0
26 - 50	Good	5	12.5
51 - 75	Poor	9	22.5
76 - 100	Very Poor	14	35
Above 100	Unsuitable for Aquatic Life	12	30
	Total	40	100

Source: Calculate by the Researcher, Reference: Brown et al (1972), Chatterji and Raziuddin (2002)

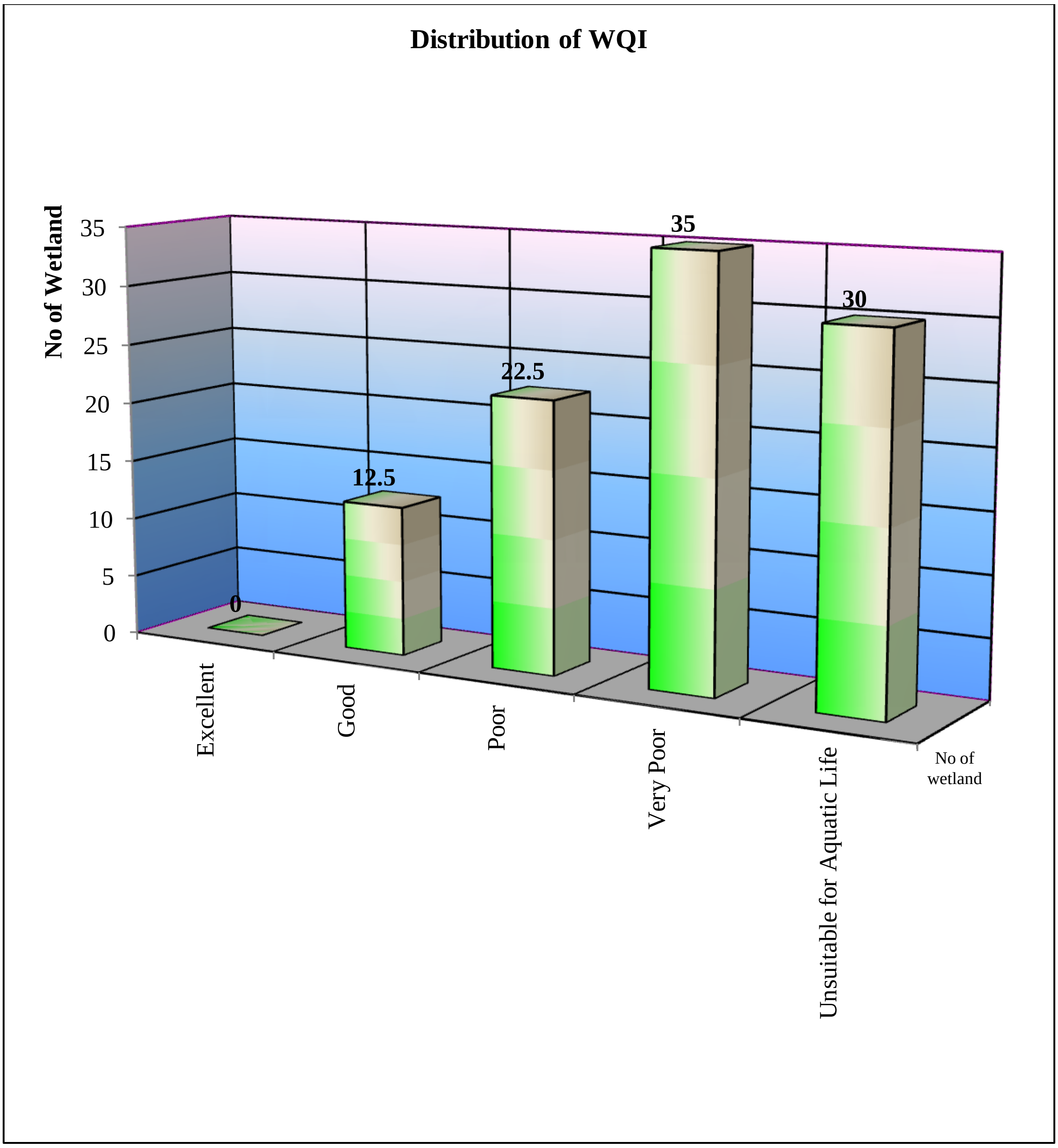


Fig 6.10: Distribution for WQI in Different Beels

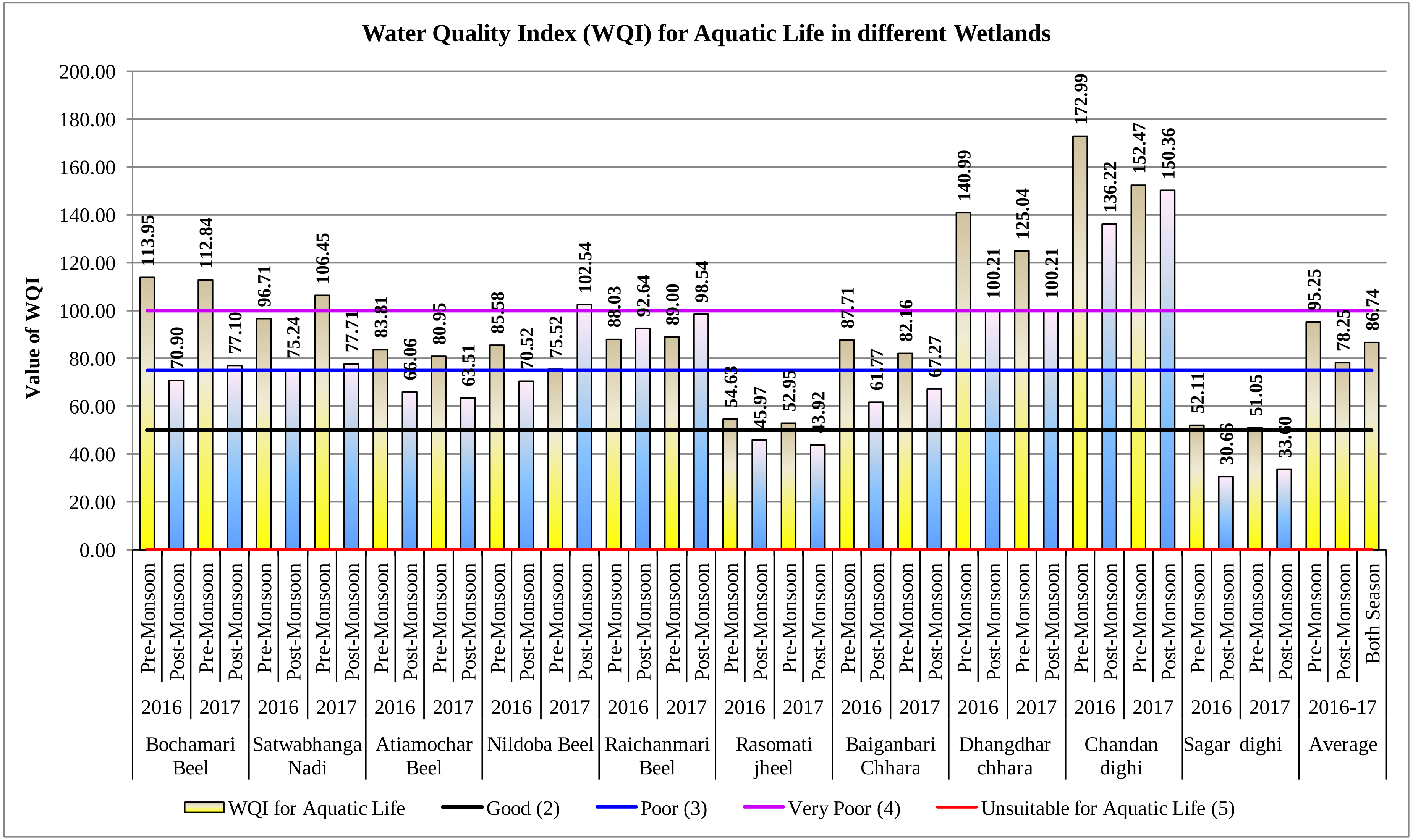


Fig6.11: WQI for Drinking Water and Aquatic Life

The WQI of Rasomati jheel and Sagar Dighi shows excellent quality whose value lies between 30.66 -48.97 during post Monsoon. In pre-monsoon period they also show the near about excellent quality for aquatic life. The quality of water in Chandan Dighi is the worst followed by Dangdhar Chhra. In both seasons these two wetlands are unsuitable for aquatic life. The researcher during his field survey identified dead fish in Dandhar Chhara (Photo Plate 6.12). Again, the researcher hardly found any fish or aquatic species in Chandan Dighi. Pre-Monsoon period is more vulnerable to deteriorating of water quality. The water of Bochamari Beel, Satwabhnga Nadi, and Nildoba Beel were not suitable for aquatic life during pre-monsoon period. The value of WQI exceeds the range 100 in these wetlands (Table 6.20). The quality of water in Nildoba and Raichanmari Beel was higher during post-monsoon period. The probable cause may be the draining of urban wastes from the nearest town through Satwabhanga Nadi.

Table 6.20: WQI Variance and Standart Error

Name of the Wetland	Summary	Count	Sum	Average	Variance	Standard Error
Bochamari Beel	Pre-Monsoon	2	226.79	113.39	0.61	0.55
	Post Monsoon	2	148.00	74.00	19.19	3.10
Satwabhanga Nadi	Pre-Monsoon	2	203.16	101.58	47.41	4.87
	Post Monsoon	2	152.95	76.47	3.04	1.23
Atiamochar Beel	Pre-Monsoon	2	164.76	82.38	4.10	1.43
	Post Monsoon	2	129.58	64.79	3.25	1.27
Nildoba Beel	Pre-Monsoon	2	161.11	80.55	50.65	5.03
	Post Monsoon	2	173.06	86.53	512.84	16.01
Raichanmari Beel	Pre-Monsoon	2	177.03	88.51	0.48	0.49
	Post Monsoon	2	191.17	95.59	17.43	2.95
Rasomati Jheel	Pre-Monsoon	2	107.59	53.79	1.41	0.84
	Post Monsoon	2	89.89	44.94	2.11	1.03
Baiganbari Chhara	Pre-Monsoon	2	169.86	84.93	15.40	2.78
	Post Monsoon	2	129.03	64.52	15.10	2.75
Dhangdhar Chhara	Pre-Monsoon	2	266.03	133.01	127.33	7.98
	Post Monsoon	2	200.43	100.21	0.00	0.00
Chandan Dighi	Pre-Monsoon	2	325.46	162.73	210.46	10.26
	Post Monsoon	2	286.58	143.29	99.92	7.07
Sagar Dighi	Pre-Monsoon	2	103.16	51.58	0.56	0.53
	Post Monsoon	2	64.26	32.13	4.34	1.47
	2016	20	1726.71	86.34	1191.07	
	2017	20	1743.19	87.16	1043.32	

Table 6.21: Calculation of ANOVA Statistic

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	41324.53	19	2174.98	36.61	0.00000	2.17
Columns	6.79	1	6.79	0.11	0.74	4.38
Error	1128.86	19	59.41			
Total	42460.18	39				

An ANOVA without replication has been applied to assess whether the WQI is equal in different wetlands in different seasons. Thus,

H_0: There is no significant variation of the WQI of aquatic life in different seasons among different wetlands

H a: There is a significant variation of the WQI of aquatic life in different seasons among different wetlands

As the computed p-value is lower than the significance level alpha=0.05, the present researcher rejects the null hypothesis H_0 and accepts the alternative hypothesis Ha.
Thus, it may be concluded that the WQI of different wetlands varies in different seasons during 2016 and 2017. Further, it is observed that there is no significant variation in the water quality for aquatic life in different years (2016 and 2017) as P- value is lower than the level of significance i.e.0.05.

6.3.2. Effect on the Water Cycle:

Wetlands affect the water cycle in two different ways namely evaporation and recharge of ground water. Though the annual rate of evaporation or groundwater recharge can't be correctly estimated, it is evident that both are proportional to the carrying capacity or water reserve of the wetlands. Siltation and eutrophication of the wetlands over time reduce the depth of water as well as the carrying capacity of the wetlands which in turn reduce the amount of water that evaporates and infiltrate the groundwater reserve. This results in a decreased precipitation in one hand and a lowering of the ground water level on the other hand. Through the field survey and interviewing the elders and fishermen of the study area,

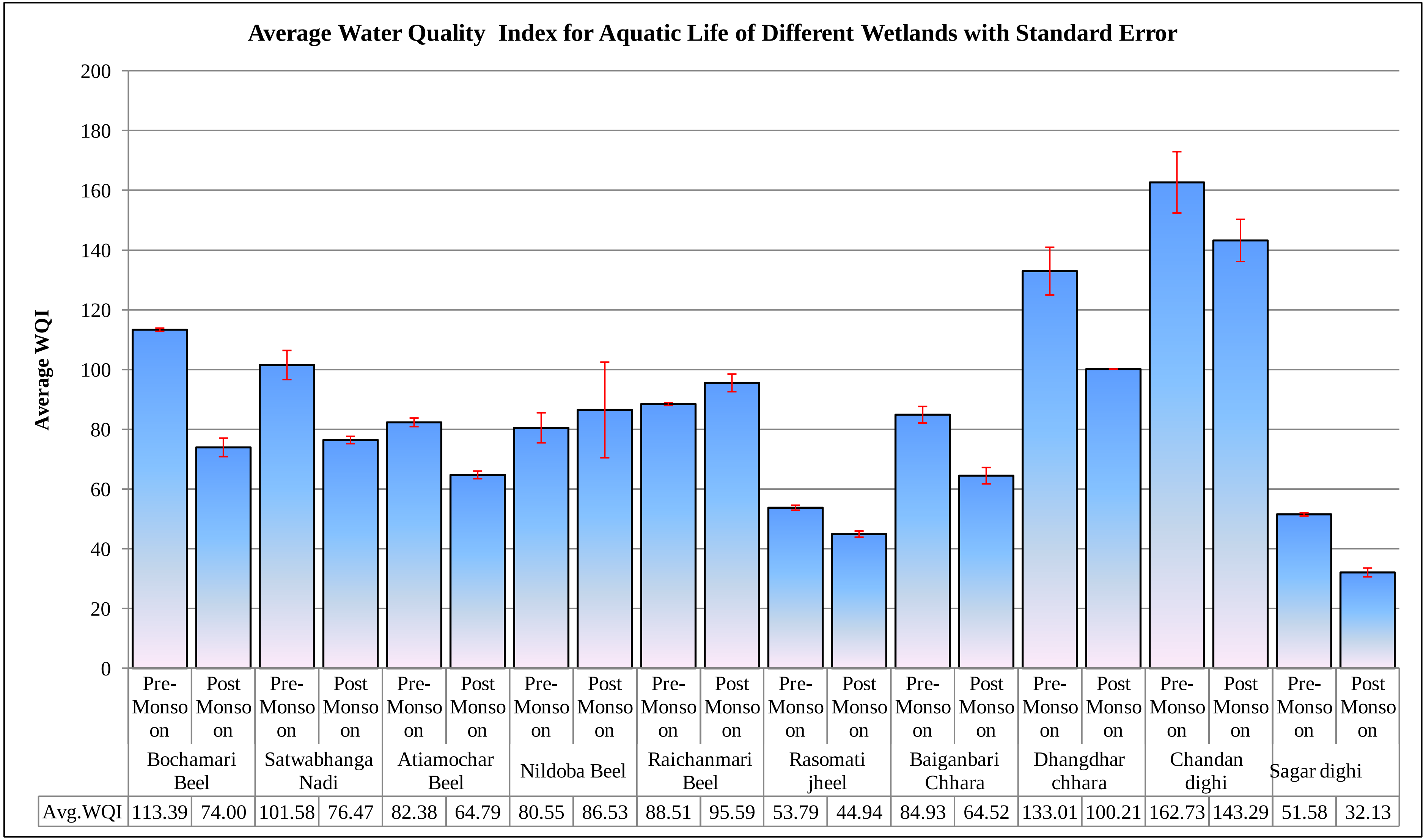


Fig 6.12: Average Value of WQI and Standard Error

it is found that more or less all the wetlands have undergone shallowness. The tables 6.22 describe the depth of water in the studied wetland in monsoon and summer season. In the studied wetlands, Batikata Beel has the highest (18-19ft) depth of water followed by Sagar Dighi (14-18ft) and Atiamocher Beel (13-14ft). Shallow water depth is observed in Chotojan Beel and Barojan Beel shallow (4-5ft) water during monsoon season. During winters, While Batikata has the highest (12-14ft) depth of water followed by Atiamoche Beel r (7-10ft) and Sagardighi (5-12ft), Chotojan Beel and Barojan Beel dry up fully(Table-6.22).

Table 6.22: Depth of Water in Feet

Sample site	Depth in monsoon season (ft)	Depth in the winter season (ft)
Bochamari Beel	10-11	5-7
Khottimari Beel	9-10	4-6
Batikata Beel	18-19	12-14
Chotojan Beel	4-5	Nil
Barojan Beel	4-5	Nil
Raichanmari Beel	8-9	4-5
Bherbheri Beel	5-7	1-3
Salmara Beel	5-10	2-5
Nildoba Beel	7-11	3-6
Atiamochar Beel	13-14	7-10
Dhangdhar Chhara	7-11	3-5
Rasomati jheel	11-13	3-6
Baiganbari Chhara	10-12	2-3
Chandan Dighi	6-8	2-5
Sagar Dighi	14-18	5-12

Source: Filed Survey, 2017

6.3.3. Effect on the Soil Quality:

The soil quality is heavily affected by the degradation of wetlands, for example, eutrophication increases the amount of organic carbon in the soil of the wetlands, and results in massive proliferation of aquatic plants, and similarly, siltation decreases the depth of wetlands by increasing the amount of sand in the water bed. Dumping of organic or inorganic wastes in the wetlands also affect the soil quality, wastes like plastic are non-degradable which mix with soil and cause health hazards to the wetland dependent organisms including humans.

The urban wetlands of the study area like Marwari dighi, Chandhan Dighi and Lal Dighi show a greater level of pollution caused by plastic items like carrying bags, shoes, bottles and thermocol. On the other hand, the wetlands in the rural areas show comparatively fewer pollution levels with an exception to the wetlands in the vicinity of markets (kankanguri Chhara, Houser Derra), where the pollution level is high and the soil quality is at its degraded condition.

6.3.4. Effect on Flora:

The loss and degradation of wetlands directly affect the flora of the region. The organic and inorganic remains, dead and decomposing matter, chemical fertilizers and house hold wastes from the wetland catchment area drain into the Wetland through rainwater or runoff, which disrupt the physio-chemical composition and balance of the Wetland waters. This results in massive proliferation of a few invasive species like the water hyacinths (Eicchorni crassipes) which engulf the total available area of the wetlands and eliminate the native species of aquatic plants. Moreover, the endemic medicinal plants and edible plants face extinction due to over-exploitation. All these disrupt the ecosystem balance and have a negative impact on the economy of the area. Currently, the wetlands like Baiganbari Chhara, Dhangdhar Chhara, Chandan Dighi, Lal Dighi etc. face these problems. In the wetlands of the study are 66.67% (Table 5.6) flora and 55.56 % fauna (Table 5.14) may on the verge of Extinction.

6.3.5. Effect on Fauna:

The loss of wetlands poses a major existential threat to the inhabiting fauna, of which water birds, wetland-dependent mammals, fresh water fishes, amphibians, and reptiles, are affected the most.

Photo Plate 6.11: Death of Earth Worms in BaiganbariChara, Koch Bihar-II

Photo Plate 6.12: Death of Fish in RasikBeel, Tufanganj-II

Based on the survey in the selected wetlands which includes the interview of the elders and fishermen of the area, it has been found out that a few decades ago, these wetlands were inhabited by a variety of fauna like different local fishes, water birds, turtles, *gharials* or alligators and crocodiles. But presently none of them exists. The major causes of the extinction or elimination of these species within a short time frame are i) Water pollution ii) shallowing of the Wetland depth iii) Eutrophication iv) Habitat loss for endemic species v) Exploitation of the Wetland resources, like fishing hauls, lumbering etc. The present status of the water bird is represented through table no.6.23. From the report of Zoological Survey of India, Kolkata, it is very clear that number water bird has declined rapidly in the year 2010(-38.45%) and 2011(-9.74%) (Table 6.23).

Table 6.23: Total Number of Each Water bird Species Recorded at Rasik Beel Wetland Complex

Survey Year With Month	Total No. of Water birds	Yearly Decrease Rate
Jan 2009	5105	N.A
Feb 2010	3142	-38.45
Feb 2011	2836	-9.74

Source: Zoological Survey of India, Kolkata, 2013

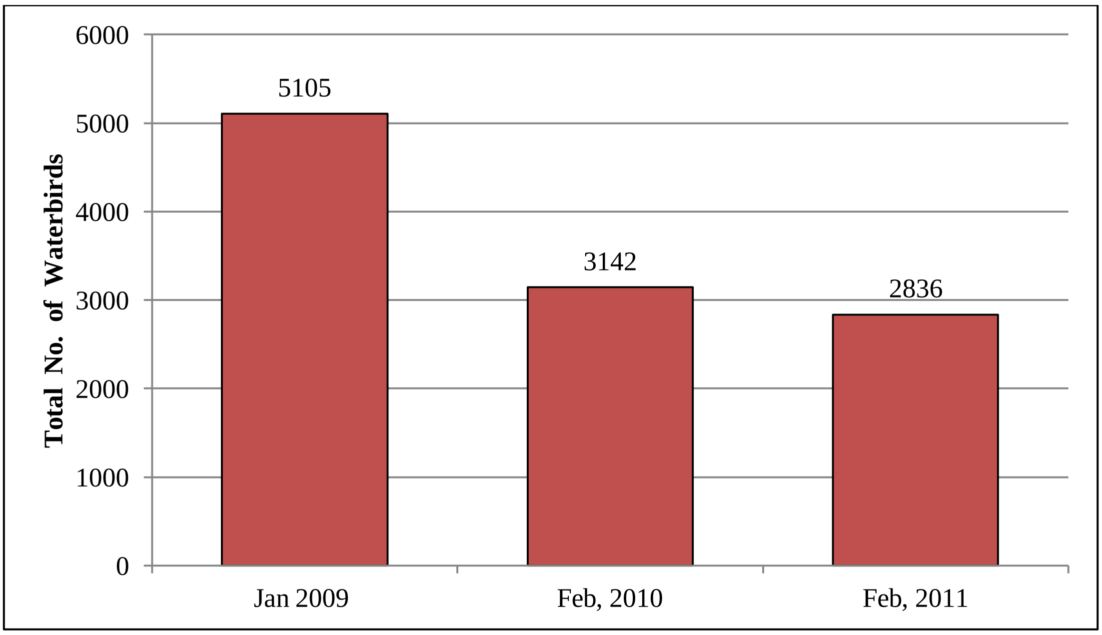


Fig 6.13: Variation in the Number ofWater birds during (2009 – 2011)

6.3.6. Shrinkage of Area:

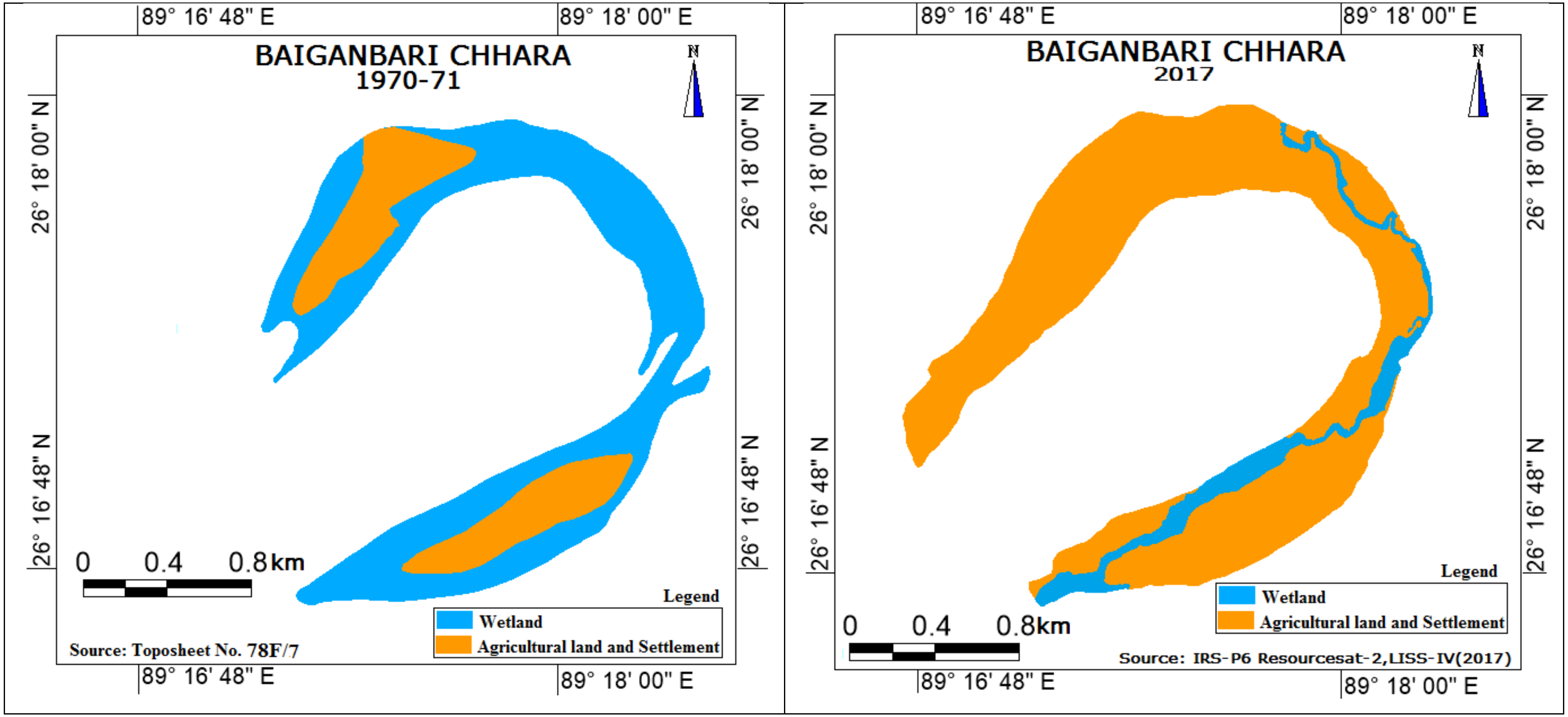
The major cause of wetland loss is shrinkage of the total area due to encroachment and wetland degradation. Those parts of the wetland areas that have temporarily or permanently been converted for more productive uses (Agricultural and piscicultural activities) are indicative of the loss of wetland area. The field survey has revealed that the major cause of wetland conversion in a rural area is organic & inorganic bottom deposition and agriculture practices in wetland bed, spacially the Boro Paddy cultivation. Causes of wetland conversion in the urban area especially in Kock bihar Sadar is filling up the Wetlands for construction of houses, shops etc which led to the disappearance of many water bodies named as *dighi*. During the reign of the kings, there were approximately 27 ponds in the Koch Bihar district (vide town committee and municipality), of which Sagardighi is the largest. But in the town, 12 to 15 ponds have disappeared, according to the field survey, which are Marapora Dighi, Newtown Kalubabur Dighi, HazraDighi, Ismail Miyar Dighi, Masjid Barir Dighi, Jamidar Shital Chakrabortir Dighi, Subhash Pally Dighi, Patakura Venus Square Dighi etc. Some ponds are partly filled namely Mustafa Dighi, Lal Dighi, Chandan Dighi, Shib Dighi, Dhobi Dighi, Marwari dighi etc.

Almost all wetlands faced the problem of areal Shrinkage. Temporal changes of selected wetlands in the study area are described below (Table 6.24). The highest negative change (-84.03 %) of wetland area was identified in Baigunbari Chara (Table 6.24. and Map 6.14). In 1970-71 the area of this wetland was 117.299 ha, but in 2017 it was only 18.73 ha, followed by -34.74% change observed in Dhangdhar Chhara, -12.39% change in Rasik Beel and -7.01% in Rasomati jheel. Sagar Dighi with no negative change of wetland area (+1.6 %) is a man-made wetland preserved by fisheries department (Table 6.24).

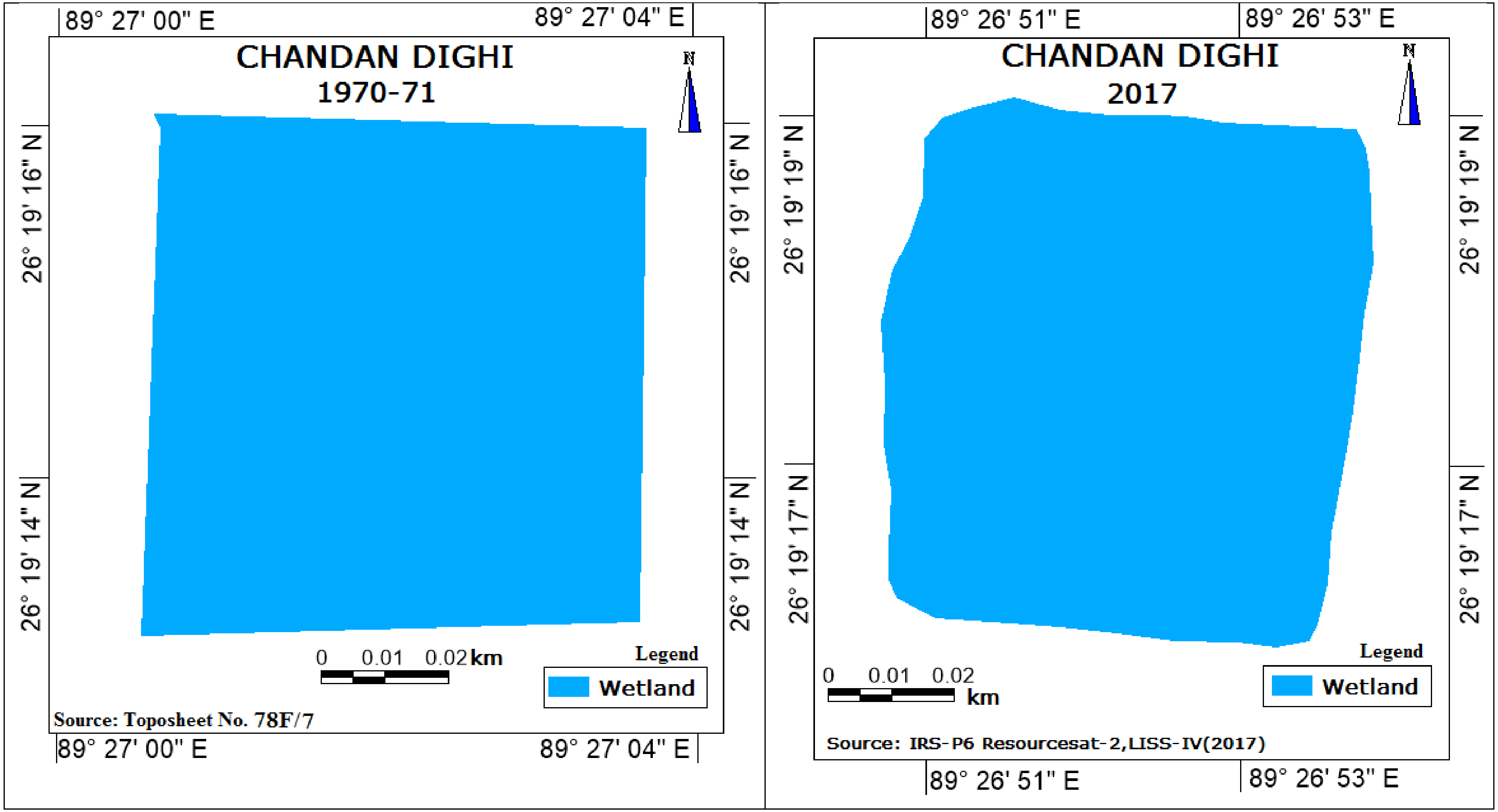
Table 6.24: Temporal Change of Selected Wetlands in the Study Area

Name of the Wetland	Area of Wetlands in Ha		Change in Ha	Change in %
	1970-71	2017		
Rasik Beel	105.5222	92.4456	-13.0766	-12.39
Dhangdhar Chhara	6.261	4.0858	-2.1752	-34.74
Sagar Dighi	5.0941	5.1758	+0.0817	+1.60
Chandan Dighi	0.6221	0.5848	-0.0373	-6.00
Rasomati Jheel	7.1849	6.6809	-0.504	-7.01
Baiganbari Chhara	117.299	18.7328	-98.5662	-84.03

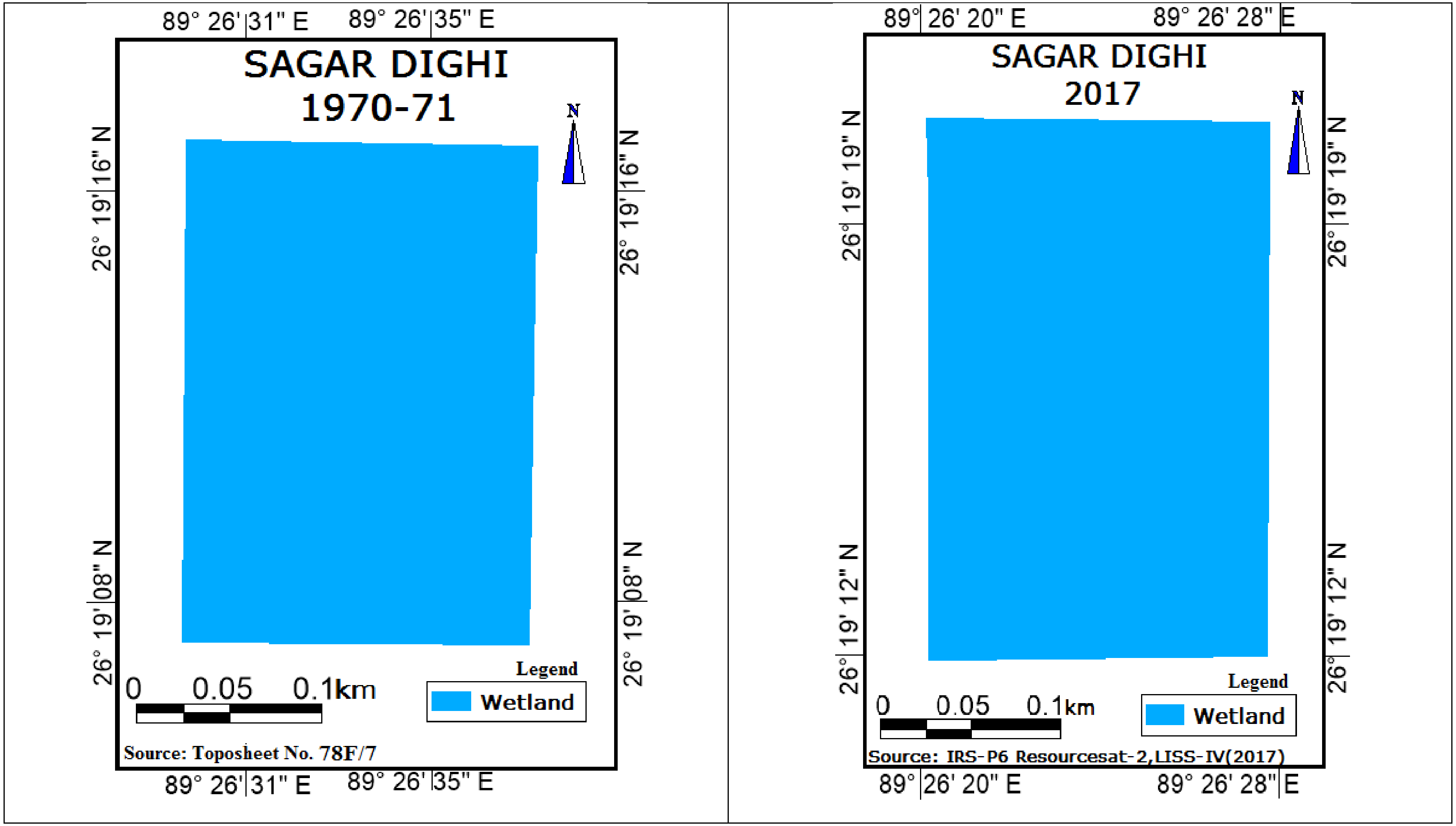
Source: Sourvey of India Topographical sheet & IRS-P6 Resourcesat-2, LISS-IV (2017)



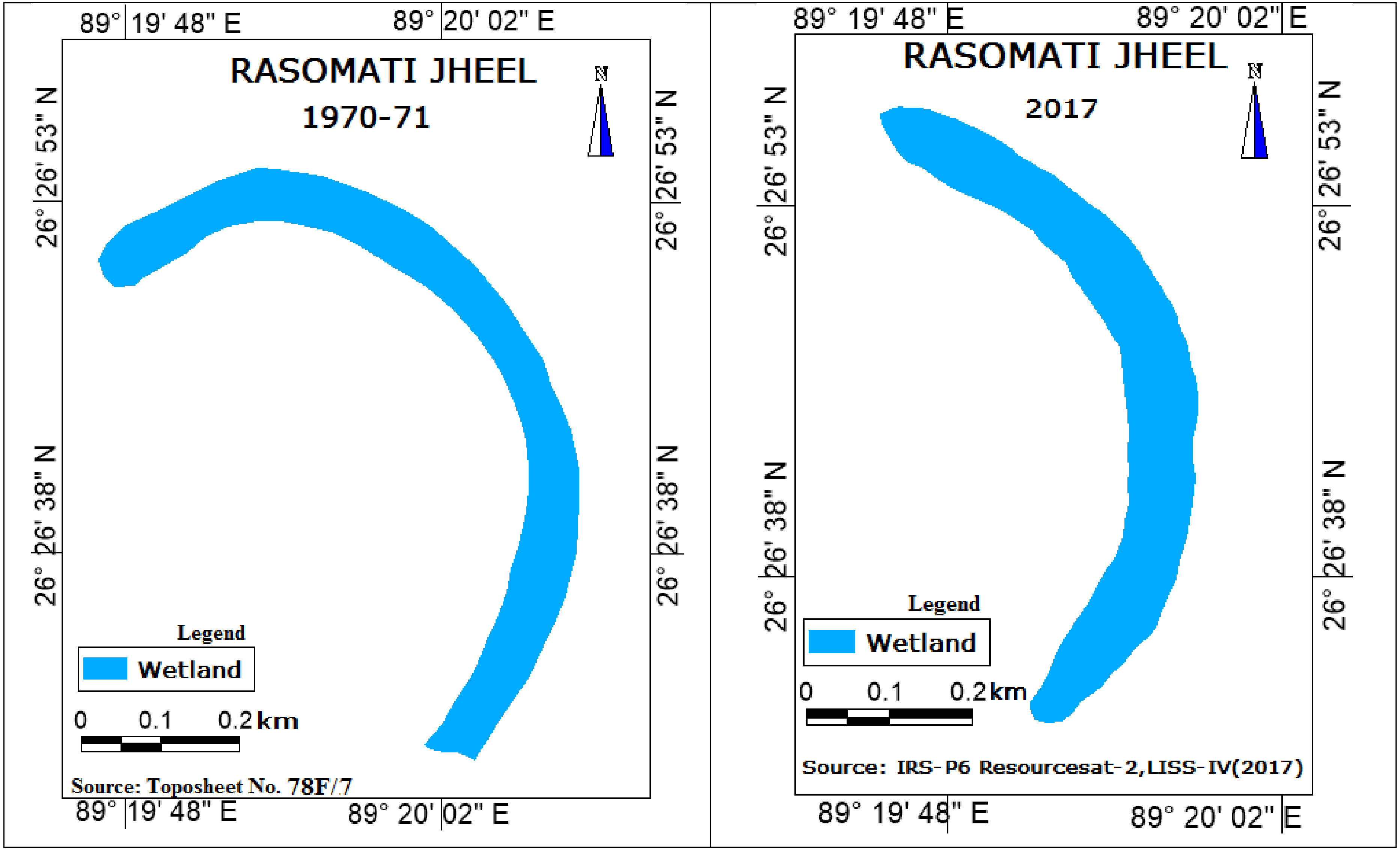
Map 6.7: Temporal Change of Wetland Area of Baiganbari Chhara



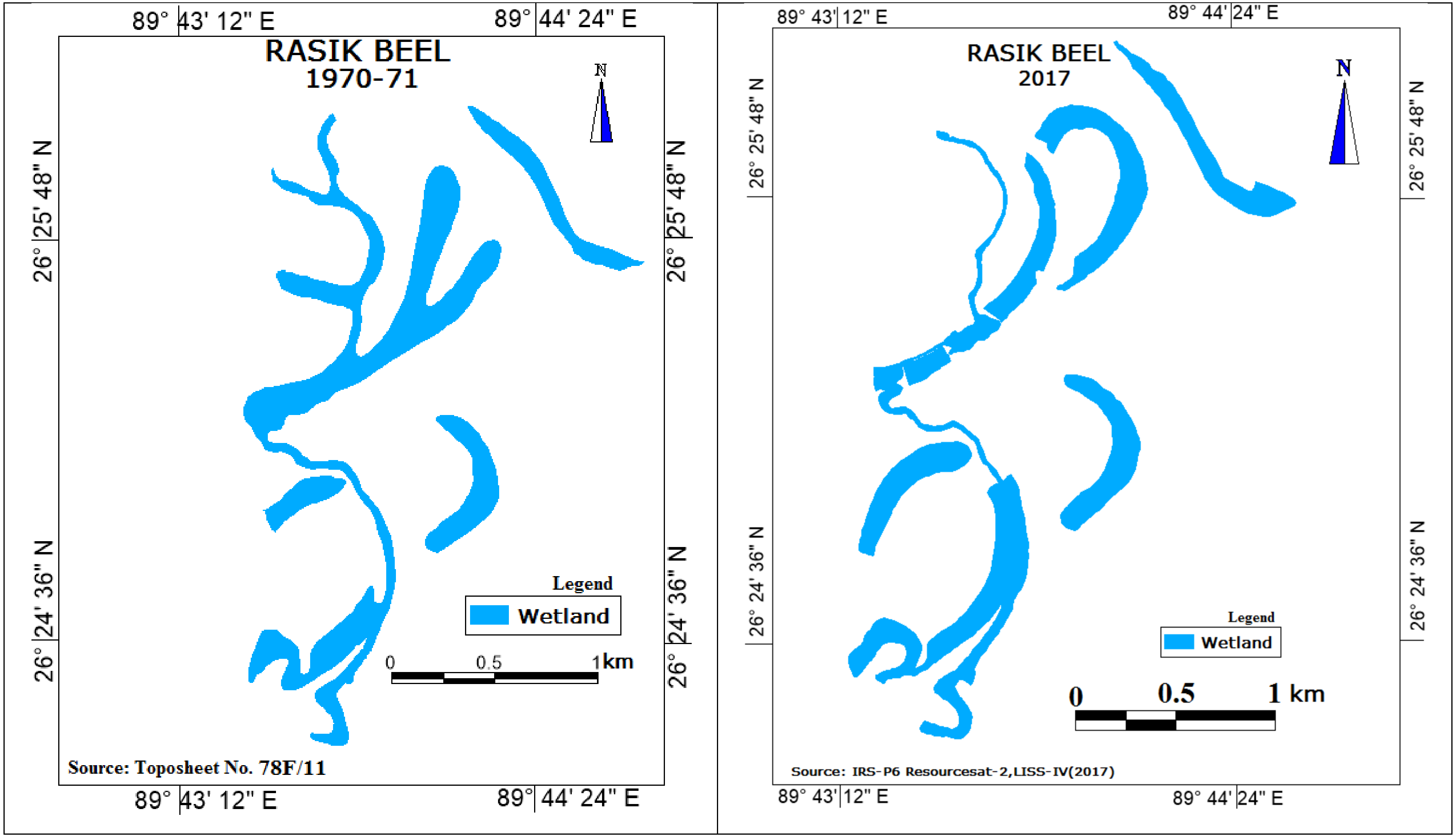
Map 6.8: Temporal Change of Wetland Area of Chandan Dighi



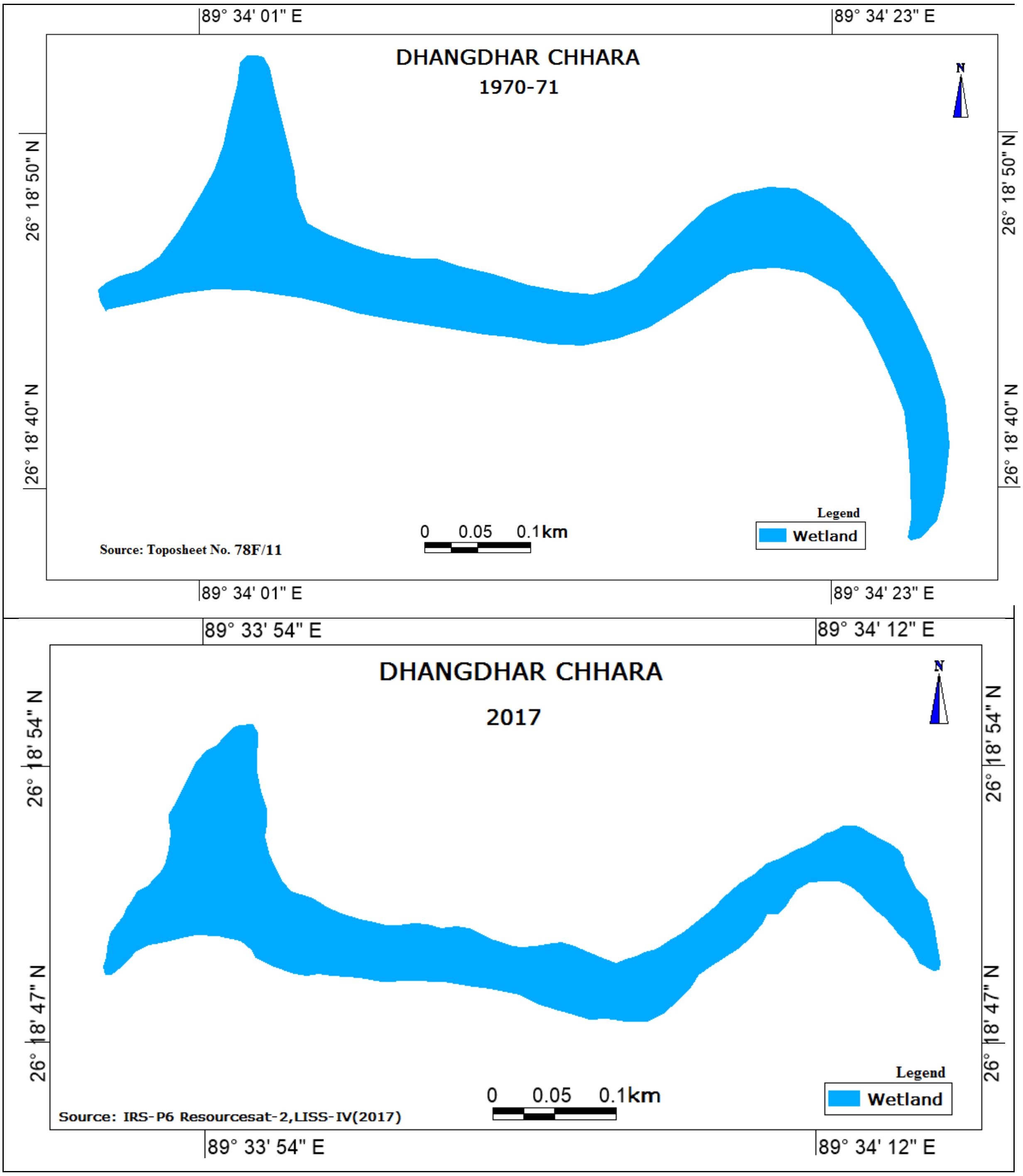
Map 6.9: Temporal Change of Wetland Area of Sagar Dighi



Map 6.10: Temporal Change of Wetland Area of Rasomati Jheel



Map 6.11: Temporal Change of Wetland Area of Rasik Beel



Map 6.12: Temporal Change of Wetland Area of Dhangdhar Chhara

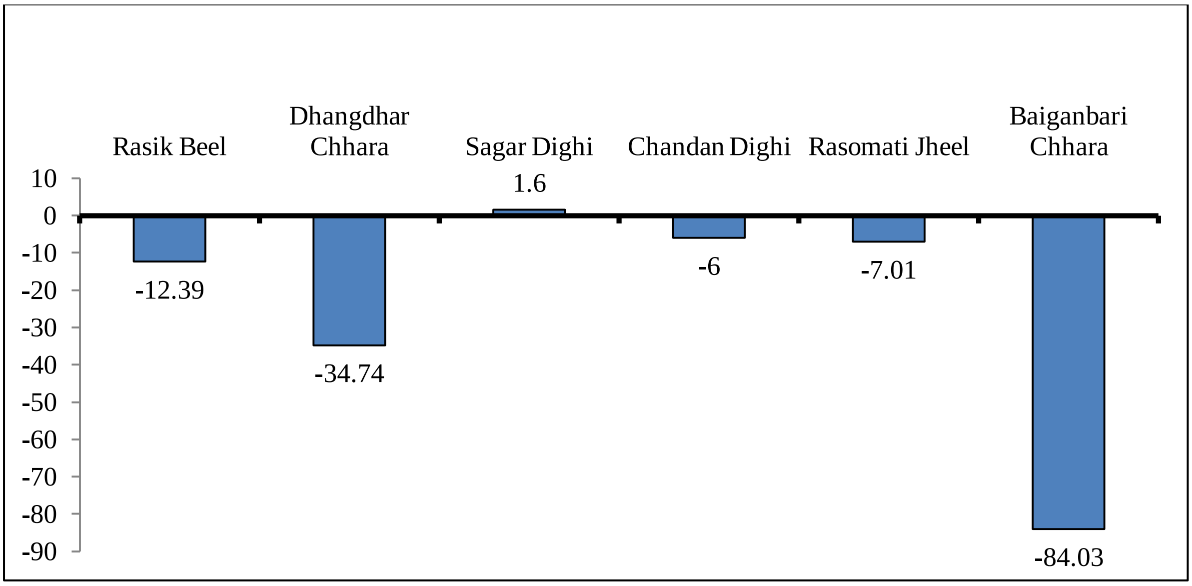


Fig 6.14: Temporal Change of Selected Wetlands in the Study Area

6.3.7. Effect on the Local and Regional Economy:

Wetland degradation has an adverse effect on the economy of the local people and the dependent population of the wetland. The negative effects of agricultural modernization, pisciculture, urbanisation, industrialization are often ignored by the people of the study area. These are also harmful to the wetland centric occupations and the local economy. Due to modernization, wetlands lose their importance and the traditional occupations like fishing, edible plant collection, fodder collection fade away and the people connected with them are rendered unemployed. The medicinal plants endemic to an area mostly choose the wetlands as their habitat, however, the loss of wetlands and their minimization lead to elimination and disappearance of these plant species which in turn eliminates the livelihood of traditional healers who are then forced to abandon their age-old tradition and turn to new professions. Fisherman and edible plant collector of wetlands of the study area face unemployment due to degradation of wetlands. In the study area 17% fisherman of Rasik Beel complex, 26% of Baiganbari Chhara, 15% of Kankanguri-naya Chharaand 50% edible plant collectors of Rasik Beel complex, 36% of Rasomati Jheel have changed their occupation (Table 6.25).

Table6.25: Change of Occupation During 15-20 Years

Wetland	Fisherman (%)	Edible Plant Collector (%)	Other Wetland Related Occupation (%)
Rasik Beel complex	17	50	12
Dhangdhar Chhara	8	19	Nil
Rasomati Jheel	NA	36	95
Baiganbari Chhara	26	5	35
Haripur Beel	12	5	20
Kankanguri-Naya Chhara	15	10	15

Source: Filed Survey, 2017

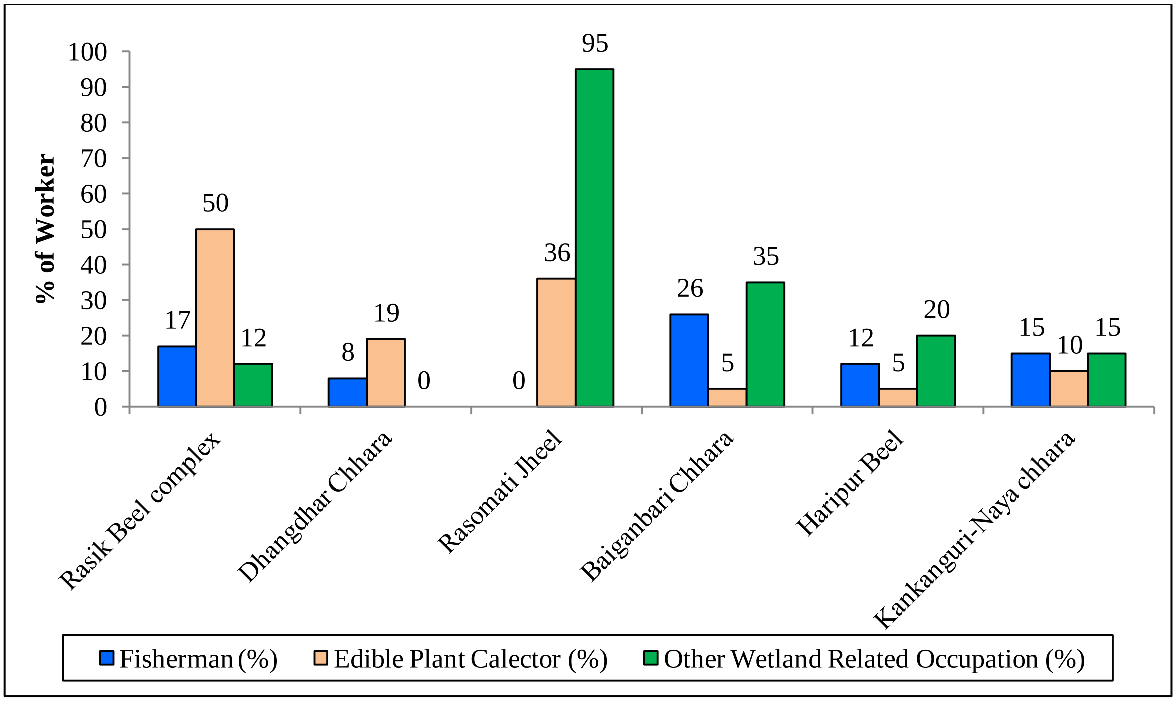


Fig 6.15: Change of Occupation during 15-20 Years

Apart from this, economically backword families living in vicinity of the wetlands directly depend on the wetlands for their food (small fishes, crabs, oysters, shrimps, edible plants) and daily needs (firewood, fodder collection) and with the loss of wetlands their very life resource; nutritional food and health security is lost.

6.4. Conclusion:

It is concluded that all the developmental & economic activities in and around the wetlands pose a serious threat to the wetland ecosystems. The chemical fertilizers and biocides (insecticides and pesticides) are used in massive quantities in the agricultural fields in the vicinity of the nearby wetlands and also in some wetland-converted agricultural lands resulting in the disturbance of the wetland ecosystem. Other agricultural activities like irrigation and jute retting disturb the hydrology of the wetland ecosystem. Fragmentation of wetlands due to the construction of roads, railways, embankments etc., organic and inorganic bottom deposits, filling up of wetlands are the major causes of wetland degradation. Similarly, garbage dumping, eutrophication, over exploitation of wetland resources, lack of awareness destroy the equilibrium in the wetland ecosystem by changing the physicochemical characteristics of wetland waters and loss of biodiversity. This, in turn, affects the economic well-being of wetland dependent individuals.

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CHAPTER-VII

FINDINGS, CONSERVATION POLICIES AND MANAGEMENT STRATEGIES

CHAPTER-VII
FINDINGS, CONSERVATION POLICIES AND MANAGEMENT STRATEGIES

7.1 Introduction:

During the past few decades, conservation of Wetlands has received a great impetus worldwide since all types of wetlands have been confronting different geo-environmental problems due to natural and anthropogenic factors. Anthropogenic factors play a more prominent role in wetland degradation and generate a lot of problems for the wetland dependent population. Depending on their locational and socio-economic characteristics the wetlands are likely to face different environmental problems of varying dimension. Previously, the Wetland's self-purifying system protected them against the deteriorating effects of age old traditional human activities, but now a host of environmental problems are created as the increasing modern human activities have rendered the purifying system ineffective. Thus, the wetlands situated in and around the cities and towns are threatened by fast growing urbanization and associated high magnitude human activities. On the other hand, wetlands situated in the rural areas undergo numerous problems owing to agricultural and pisciculture practices in and around the wetlands. It is astonishing that even the wetlands situated in the heart of the reserved forest, are also under threat due to illegal anthropogenic activities. In view of the ever increasing multidimensional problems, it is an urgent need to make an all-round effort to save these important wetlands from further degradation and decay by reinforcing the existing conservation policies and legislation in India. In this regard, some measures have been suggested for more effective management and conservation of the wetlands of the study area.

7.2. Existing Conservation Policies and Legislations in India:

Before the attainment of independence, India had no specific policies except 'The Indian Fisheries Act, 1857' and 'The Indian Forest Act of 1927' for protecting the environment. Indian constitution is tacit about the term 'Environment' and there is no such provision about the environmental conservation. However, in 42nd Amendment Bill in 1976, the Government made an effort to ensure the environment protection. The Article 48A declares that "The State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country". Article 51-A (g) states that "It shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures."The above mentioned articles safeguard the wetlands. It is the duty of the State as well as the citizens to implement preventative measures for the environment which has already been degraded or is polluted. The Indian constitution has three lists: Union, State and Concurrent but there is ambiguity regarding the responsibility of framing the laws encompassing the matters of environmental protection. Although the State List discusses about public health and sanitation, agriculture, water supply, irrigation and drainage and fisheries, the Article 253 empowers the Parliament to legislate on any matter. The Concurrent List highlights the Forestry. At present conservation and wise utilization of wetlands are being ensured through following legal instruments:

7.2.1. Legislations:

• The Indian Fisheries Act, 1857

• The Indian Forest Act, 1927

• Wildlife (Protection) Act, 1972

• Water (Prevention and Control of Pollution) Act, 1974

• Water (Prevention and Control of Pollution) Rules, 1975

• Territorial Water, Continental Shelf, Exclusive Economic Zone and other Marine Zones Act, 1976

•Water Cess Act, 1977

• Forest (Conservation Act), 1980

• Maritime Zone of India (Regulation and fishing by foreign vessels) Act, 1980

• Environmental (Protection) Act, 1986

• Water (Prevention and Control of Pollution) Cess (Amendment) Act, 1991

• Biological Diversity Act, 2002

• Water (Prevention and Control of Pollution) Cess (Amendment) Act, 2003

• Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights)Act, 2006. In addition to these, there are some Policies, Plans and Project

7.2.2.Policies:

•National Forest Policy, 1988

• National Conservation Strategy and Policy Statement on Environment and Development, 1992

• The National Water Policy, 2002

• National Environment Policy, 2006A
• Wetlands (Conservation and Management) Rules, 2010
• Wetlands (Conservation and Management) Rules, 2017

7.2.3. Plans:

National Biodiversity Action Plan, 2008

7.2.4. Project:

National Wetland Inventory and Assessment (NWIA) Project, 2011

Besides these, some acts like National Environment Tribunal Act of 1995 and National Environment Appellate Authority Act of 1997 have been codified. The Government of India has propounded National Water Policy in September 1987. The Bill was reviewed in 2002 and updated in 2012. It aims to ensure thoughtful use of water resources like monitoring the wise use of ground water to encourage rain water harvesting and checking the loss of runoff, it also imposes restrictions on over withdrawal of water for irrigation. The Government of West Bengal enacted the 'West Bengal Inland Fisheries Act' in 1984 for protecting and conserving the environment.

7.2.5. Important Acts of West Bengal Government:

Some relevant statues enacted by the Government of West Bengal are listed below:

a. The West Bengal Panchayat Act, 1973
b. The West Bengal Town and Country (Planning and Development) Act, 1979 (As amended by West Bengal Act 18 of 2001)
c. West Bengal Inland Fisheries (Amendment) Act, 1993 & 2008
d. West Bengal Ground Water Resources (Management, Control and Regulation) Act, 2005
e. The West Bengal Land Reforms (Amendment) Act, 2005
f. West Bengal Trees (Protection and Conservation in Non-Forest Areas) Act, 2006
g. The East Kolkata Wetlands (Conservation and Management) Act, 2006. Among these only three important programme and policy are discussed below-

7.2.6. Important Wetlands Conservation Acts:

7.2.6.1. National Wetlands Conservation Programme, 1985:

In the year 1985-86 the Government of India implemented the 'National Wetlands Conservation Programme (NWCP)' in close collaboration with the State/UT Governments. Under this programme, about115 wetlands all over India have been identified till June 2009 by the Ministry of Environment and Forests, Govt. of India which requires urgent conservation and management interventions. The list includes six wetland situated in the state of West Bengal among which the district of Koch Bihar houses two wetlands namely Rasik Beel and Rasomati Jheel which are also located in the study area. These wetlands are eligible for 100% financial assistance on grant basis to the concerned State Governments for undertaking activities like survey and demarcation of wetland, catchment area treatment, weed control, conservation of biodiversity, pollution abatement, livelihood support, creation of minor infrastructure, capacity building of various stakeholders, educational awareness, and community development.

7.2.6.2. National Environment Policy (NEP, 2006):

National Environment policy, introduced on May 19, 2006, distinguishes the various ecological uses of wetlands. NEP identifies the causes of degradation of wetlands due to drainage from agriculture and human settlements. The policy was set up to create an enforceable regulatory mechanism to identify the valuable wetlands, to protect those from degradation and also to enhance the conservation of wetlands. It is observed that sometimes the economic returns from wetlands is weighed much higher than the environmental services and benefits derived from wetlands, giving way to the environmental degradation of wetlands. Except for Ramsar Convention (1971) there is no other wetland regulation at International level. To cope up with this issue, it is an urgent requirement to form some specific policies to regulate the casual linkage between natural entities and human interference on the wetland. To meet this purpose Government of India formulated the National Environment Policy in the year 2006.

7.2.6.3. Wetlands (Conservation and Management) Rules, 2017:

The Ministry of Environment, Forests and Climate Change put forward new Wetland (Conservation and Management) Rules on September 26, 2017, for decentralization of the management of wetlands among the states/ Union Territories and identified about 2 lakh wetlands where the illegal activities that trigger degradation and deterioration of the wetlands are to be prohibited. The wetlands are described in the rule as the "vital parts of the hydrological cycle, (that) are highly productive ecosystems which support rich biodiversity and provides a wide range of ecosystem services such as water storage, water purification, flood mitigation, erosion control, aquifer recharge, micro-climate regulation, aesthetic enhancement of landscapes while simultaneously supporting many significant recreational, social and cultural activities, being part of our rich cultural heritage."The rule also mentioned that the wetlands are under severe threat and are degraded by blockage of drainage and pollution made by human beings. This causes the disruption of the hydrological cycle, loss of Biodiversity and interruption in the ecosystem.

The rule is applicable to the wetlands categorized as Ramsar Sites and also to the wetlands identified by the Central, State and Union Territory administration in different acts such as Indian Forest Act, 1927, the Wild Life (Protection) Act, 1972, the Forest (Conservation) Act, 1980, the State Forest Acts, and the Coastal Regulation Zone Notification, 2011 etc.

The States and the UTs will set up 'State Wetland Authority' by including the MIC, Environment, and Government Officials, expert in the related fields such as hydrology, planning, fisheries, socio-economists and wetland ecology. The Central Government has also constituted the 'National Wetlands Committee' with the Government Officials and experts in the related fields. The authority will formulate 'wise use principle' of wetlands so that conservation, sustainable use and proper management of the wetlands can be attained. The rule also aims at decentralization of powers.

7.3. Major Findings of the Study:

The study investigates the geo-environmental status of wetlands of Tufanganj and Koch Bihar Sadar sub-division in Koch Bihar District, West Bengal, India. Here'geographical status' of a wetland means an insight into the distribution and classification of the wetlands in the study area. To determine the 'Environmental Status' of the wetlands, investigation on the utilization pattern of the wetlands, soil & water quality, floral and faunal status of wetlands has been conducted. In order to propose some Management strategies for the Wetlands, the findings of the different chapters are summarized below:

1. In the study area, a thorough investigation on nature and the modifications of the wetlands were made and then categorized into three broad divisions namely Natural wetland, Quasi-natural wetland and man-made wetland, of which natural wetlands have 3 sub-divisions namely River/ Stream, Oxbow lake and Riverine wetland. The quasi-natural wetland has 2 sub-divisions namely Quasi-natural Oxbow Lake and Quasi-natural Riverine wetland. On the other hand, the Man-made wetland has also 2 sub-divisions namely Brick/Clay/sand pit and Pond/ Tank. Among the different types of wetland, river has highest percentage (63.08%) followed by oxbow lake (18.55%), Riverine wetland (6.12%), Quasi-natural Oxbow Lake (5.47%), pond (3.39%), Quasi-natural Riverine wetland (2.09%) lastly Brick/Clay/sand pit (1.30%).

2. The researcher has identified 486 wetlands that cover a total area of 7898 ha, which are unevenly distributed in the study area. Of all the blocks in the study area, Koch Bihar-I has highest number of wetlands (230) with highest wetland area of 2229 hectare followed by Tufanganj-I (128) with 2009 hectare area, Koch Bihar-II(74) has 2091 hectare area, and Tufanganj-II (54) has1569 hectares area. In the study area74 oxbow lakes have been identified, the majority of which is in Tufanganj-I (32) followed by Tufanganj-II (16) and the rest 26 i.e 13 each in Koch Bihar-I and Koch Bihar-II. Riverine wetlands are 89 in number; of which 28 are in Koch Bihar-I, 15 in Koch Bihar-II, 25 in Tufanganj-I and 21 in Tufanganj-II. Quasi- Natural oxbow lakes are 37 in number; 17 in Koch Bihar-I, 9 in Koch Bihar-II, 7 in Tufanganj-I and 4 in Tufanganj-II. The Quasi-Natural Riverine Wetlands are 25 in number, 10 of which are situated in Tufanganj-I, 6 each; 12 in Koch Bihar-I and Koch Bihar- II and 3 in Tufanganj-II. Apart from these 237 ponds have been identified in the study area of which 171 are in Koch Bihar- I, 31 in Koch Bihar-II, 25 in Tufanganj-I and 10 in Tufanganj- II. Brick/ Clay pits re 24 in number, a majority of 19 pits are located in Tufanganj-I, and the rest 5 in Koch Bihar- I.

3. The usability of a wetland depends on the nature, location, and environmental status of the wetlands. It also depends on the factors like ownership of the wetland, the degree of restriction imposed by the government, the economic status of the dependent people of wetland, the extent of awareness etc. Through the survey conducted, it is revealed that with an exception of few, the wetlands of the study area provide about 27 types of services or uses. The most important uses of the wetlands of the study area are in agriculture, pisciculture, grazing, fodder & edible plant collection, construction for

settlement & commercial purpose, dumping of organic and inorganic wastes. Generally, wetlands provide a range of different services, but from the field survey it is observed that on an average 46.8% of wetland services are not found, 32.10% are rarely observed, 15.43% wetland services are occasional and only 6.17% wetland services are commonly observed. Of all the wetlands, a sharp decline in the number of services is observed in Chandan Dighi (20) and Rasomati Jheel (18) on accord of being the most degraded wetland in the study area and a protected wetland respectively.

4. Based on the results, it can be said that none of the wetlands are indicative of a balanced ecosystem. The pH value of all selected wetlands except Sagar Dighi (9.2) are below the standard limit for aquatic life though the TDS, EC and Iron parameters of water were at the permissible limit for aquatic life. The dissolved oxygen (DO) level, required for a healthy aquatic life is very low in Dangdhar Chhara (3.8 mg/L) and Chandan Dighi(1.8 mg/L & 1.9 mg/L) since Dangdhar Chhara is located in the vicinity of brick kiln industry and Chandan Dighi is the most neglected wetland, which is converted into a dumping site of waste materials. The BOD level was also high in most wetlands, but the highest was in Dangdhar Chhara (81mg/L) and Chandan Dighi (86.9 mg/L). Only Satwabhanga Nadi had BOD at the permissible limit in all season. The value TA and TH of water was at the permissible limit in all the selected wetlands except Rasomati Jheel. The free CO_2 of water is much higher than the standard value in all the selected wetlands except Sagar Dighi.

`The pH of the soil in the wetland bottom was at permissible limit except Sagar dighi. The Organic Carbon levels are much higher than the standard levels in Bochamari Beel (4.95 percent), Rasomati Jheel (4.57 percent), Satwabhanga Nadi (3.61 percent). Due to the higher nutrient value of the wetland soil, the growth and reproduction of aquatic plants are much higher, thus destroying the ecosystem balance. The lowest nitrogen concentration is found in Baiganbari Chhara (37.63 mg/kg).

From the survey, a continuous decline in the aquatic life and extinction of many endemic species is observed. In the wetlands under study, 66.67% flora and 55.56 % fauna may be on the verge of Extinction. For example, indigenous reptiles like Gharials and turtles, amphibians like Bull Frog (RanaTigerina) etc cease to exist now.

5. In total 16 causes are identified for wetland degradation in the study area, out of which 6 are major causes. They are i) sedimentation in wetland bed ii) clogging of feeder channel iii) construction of engineering structures and fishing obstacles in the wetlands. iv) encroachment of wetland v) over-exploitation of wetland resources like excessive fishing, irrigation, agriculture, Jute retting v) fragmentation of the wetlands vi) garbage dumping & pollutants inflow in wetlands. The indifference of the Government and the NGOs towards building awareness also causes degradation of wetlands.

6. Consequences of the degradation of wetlands and their effect on the environment and economy of the individuals in the vicinity of wetlands are identified by water quality index (WQI), soil quality standard, flora and faunal status, areal shrinkage of wetland and effect on the local and regional economy. In the study area, all selected wetlands are unsuitable for aquatic life except Sagar Dighi (WQI=30.66) and Rasomati Jheel (WQI=43.92). The water area of the wetlands in the study area is steadily declining as observed between the years 1971 to 2017. Baiganbari Chhara has witnessed the maximum negative change (-84.03%) followed by Dhangdhar Chhara (-34.74%), Rasik Beel (-12.39%), Rasomati Jheel (-7.01%), Chandan Dighi (-6.0%). The wetland degradation affects the occupation and economy of the surrounding inhabitants and about 13% of fishermen and 20.83% of edible plant collectors had to change their occupation

7.4. Recommendations and Management Strategies of the Wetlands:

Based on the major findings of the study and a brief review of the existing wetland conservation policies and legislations in India and West Bengal, the following recommendations and management strategies are proposed:

1. No decision-making is complete without the active participation of local people who are dependent on the wetland resources for their livelihood. Surrounding people have been using wetlands since time immemorial. Therefore there is a need to blend both traditional and latest scientific technologies if long-term conservation goals are to be achieved. Wise use of the wetland resources should be assured and local people’s participation must be ensured in wetland management. The dependent community should involve themselves in maintaining the environmental integrity of the beels or wetlands.

2. Surrounding villagers and wetland dependent population should be made aware of the conservation and sustainable management of wetlands. In this regard, government agencies and NGOs should play a vital role to create as well as boost up awareness among the common people. Various environmental awareness campaigns such as workshops, rally, folk dances, and street theatres should be initiated. Various publicity materials on wetland conservation like handbills, leaflets, banners, training/awareness programmes, posters and hoardings should be created utilizing print and electronic media.

3. Setting up of a Rasik Beeland Rasomati Beel Development Authority for collecting reliable data on the biodiversity of the Rasik Beel and Rasomatibeel and its surrounding forest areas and publishing biodiversity atlas of these Wetlands and undertaking necessary action for declaration of Ramsar site.
4. The restriction should be imposed on picnic parties since they, disturb the environmental equilibrium in a number of ways like littering the area with non-eco-friendly materials such as thermocol (Expanded Polystyrene is a non-biodegradable synthetic aromatic polymer, plastic and also by playing loudspeaker indiscriminately in the wetland areas. To mitigate this, hoardings should be hanged in the picnic areas and leaflets mentioning all the Do's & Don'ts in details should be distributed at the time of entrance. Simultaneously spot fine system should be introduced for violating the rules in the wetland areas.

5. It is necessary to cut down the overgrowth of floating and submerged vegetation, without the use of any chemicals because chemical elimination of weeds not only harms the aquatic vegetation but also affects the aquatic animals to a great extent. In this view, traditional knowledge should be employed to generate revenue from weeds by converting weeds into compost and mineral recycling agents.

6. Wetlands may be re-connected with the feeder channel by removing the blockage in connecting portion between the wetland and the feeder channel for maintaining the proper flow in the rainy season.

7. Most of the wetlands lack proper boundary. Proper demarcation of the wetland boundary would be helpful in curbing encroachment in the wetland and fringe areas. In this regard, the Land and Land Revenue department must take some initiatives to settle wetland-boundaries. All types of illegal settlement should be vacated from the wetland areas. If it is not possible the existing wetland areas should be strictly protected from further encroachment.

8. Unwise future constructions of engineering structures like roads, bridges, railway lines, irrigation canals and road cum embankment across the wetland constructed by various departments should be stopped. It must be ensured that all the necessary constructions should be made only after proper consultation and co-ordination among the concerned departments since the construction of various roads and railways across the wetlands and its surrounding is a threat to the wetlands. If it is unavoidable, necessary slope analysis should be made before proper construction of the roads and a sufficient number of bridges must be constructed over all the outlets in order to maintain the natural flow of the water.
9. Community fishing in the dry season by withdrawing and draining water is common almost in all the wetland areas which is very harmful. In many places, local inhabitants make merry/observe a special festive occasion during which all the villagers fish together in the wetland which makes the water so muddy and polluted that later on a good amount of small fish and other aquatic animals face death. Therefore, such practices should be stopped and the government should enforce laws against such practices rules and should build awareness in people of the surrounding areas.

10. At present, the wetlands are controlled by different departments of government. Overlapping of the management and lack of proper co-ordination among these departments, cause various problems in the effective management of these water bodies. Therefore, all the wetlands should be brought under control of a single department for their proper management and all the wetlands should be registered categorically according to their status.

11. Discharge of all sorts of runoff and effluents from industries, urban areas and agricultural field must be checked at the source. Agricultural activity in the catchment area of the wetland is the main source of pesticides, insecticides, herbicides, and

chemical fertilizers which are drained to wetlands causing wetland degradation. Therefore, measures should be taken to stop such inflow in wetlands and making the people aware of the harmful effects of such chemicals used in the agricultural field. Animal wastes should not be dumped in the wetlands. It is the common practices of wetland edge dwellers to sewage their toilet outlet directly into the wetland thus creating unhygienic living conditions. This practice should be stopped to facilitate the well being of the wetlands.

12. Poor infrastructure, economic and educational backwardness in the wetland areas are the other causes of degradation of wetlands. The economic condition of the wetland dependent communities is so poor that they try to earn their daily meals through all round exploitation of the wetland resources resulting in depletion of flora and fauna in the wetlands. Therefore, government, through different competent authorities should take appropriate measures to improve the people's economic condition. Moreover, emphasis should be given to the development of eco-tourism and generating other eco-friendly employment sources. In addition to this, some necessary steps should be adopted to provide alternative livelihood measures like piggery, animal husbandry, duckery, small cottage industry and edible vegetable cultivation to the people residing in and around the wetlands.

13. Poaching and hunting of residential and migratory birds in the restricted as well as unrestricted wetlands, should be stopped at any cost. Poaching of the waterfowls during the winter season is practiced in the study area by the local people causing the extinction of the birds in these areas. Such practices should be banned by building proper awareness in the local people and enforcing the government rules.

14. In the wetlands of the study area, soil quarrying and deep tillage have become a common phenomenon. It degrades the wetland environment through sedimentation on wetland beds and erosion on bank areas. In this regard, land and land revenue departments and respective Gram Panchayat Authorities should enforce laws so that people refrain from such damaging practices.

15. Most pathetic part is that wetlands have been handed over to the individual renter for pisciculture which not only deprives the local people of catching fishes but also

degrades the wetlands through the indifferent policies of the renters who are only concerned with their own benefit. Therefore, it is suggested that wetlands should be rented to the fishermen co-operative society or government involving local people and NGO’s.

16. Fishing must be restricted during the breeding period for the conservation of fish community. Fishermen should be also forbidden from using small hole fishing net and catching fingerling. The government should make arrangements for alternative occupation for the fishermen during the restricted period or special allowances should be provided to the fishermen during the lean season.

17. As many of the wetlands in the study area are infested with overgrowth of floating and submerged vegetation, which reduces their productivity, it is necessary to remove such weeds from the wetlands on a regular basis. To facilitate natural water flow of the wetland the excess organic and inorganic bottom deposition should be dragged. The govt. may perform these programmes by implementing National Rural Employment Guarantee Scheme (NREGS) and Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS). Through the implementation of this programme garbage in and around rural and urban wetland should be cleared up regularly.

18. Afforestation programme should be initiated in the wetland catchment areas as well as in the wetland edges for reducing the sediment load of runoff which drains into the wetlands. It is a vital wetland management program in the study area where the soil is mainly alluvial in nature as siltation in wetland beds reduces the life span of wetlands.

19. Paddy cultivation should be replaced by the cultivation of different wetland compatible edible plants like *Kalmi, Hincha* in dry season Water Lily etc in monsoon season for the better economic benefit and ecosystem maintenance. Commercial pisciculture should be replaced with a commercial breeding of native wetland fish like Singi, Magur etc. Fish-Duck-Paddy system with organic manure should be implemented for economic benefit and better ecosystem management in wetlands located in the rural areas. This system involves the cultivation of paddy with some native fish and duck simultaneously in the same wetland.

20. After some primary treatment of the wetland environment, Government should spare the native fingerling of these wetlands for the development of fisherman community as well as for the wellbeing of the wetland ecosystem. Accordingly, Government should also spare the indigenous snail species which are an important dietary source of different local and migratory birds.

21. Joint wetland management Committees which are expected to play an active role in conservation and management of wetlands should be formed by including the fishermen, farmers in and around the wetlands, local panchayat personnel or municipality officials, selected officers from the block and district level. NGOs and environmental experts. For this purpose co-operative system should be adopted for the betterment of the beneficiaries as well as the wetland.

22. The government should constitute a Special Protection Force for the protection of the wetland not only in the study area but for the whole of West Bengal with the help of Civic volunteer and Village Police.

23. There should be a provision in the fishery laws to restrict the use of undersized mesh in fishing nets. Until and unless the nets of smaller mesh size like "fashijal" (a type of rill net), "Mosharijal" (a type of draw net) are totally banned, particularly during the months of May to November, the multiplication of fishes in the wetlands is impossible.

24. At present, only the registered wetlands are given on lease to the fisherman co-operative society or individual only for a period of three years. During this period, the lease holders of 'wetlands' do not take any development measures, rather they aim at maximizing their profit by catching all most all the fishes in a wetland, they even do not spare fry and fingerlings of any variety. Unless the lease period is extended at least for 10 years, this malpractice cannot be stopped.

7.5. Conclusion:

The present investigation was carried out to study the geo-environmental status of wetlands of the study area including classification, distribution and use of wetlands in the study area. The impetus is also given to the water & soil quality, floral & faunal status of wetlands, causes and consequences of wetland degradation, conservation practices and management strategies for the wetlands.

The study area abounds in numerous wetlands, which include marshes, *beels*, and pools of stagnant water and tanks or ponds. These wetlands play a significant role in the environmental and economic condition of the study area. But unfortunately, they are presently facing a serious threat to their existence due to population growth and its related causes. Low man to land ratio in the study area forces the people to reclaim new land from the wetlands for agriculture, settlement and commercial use. The major uses of wetlands are agriculture, pisciculture, grazing, fodder & edible plant collection, construction for settlement & commercial purpose, dumping of organic and inorganic wastes. Generally, wetland provides a range of multivariate services, but from the field survey it is observed that on an average 46.8% of wetland services are not found, 32.10% are rarely observed, 15.43% services are occasional and only 6.17% services are commonly observed.

It is obvious from the study that physical condition of wetlands of the study area is not in the satisfactory state. Water Quality of all the selected wetlands are unsuitable for aquatic life except Sagar Dighi (WQI=30.66) and Rasomati Jheel (WQI=43.92). The pH value of all the selected wetlands except Sagar Dighi (9.2) is under the standard limit suitable for aquatic life. The dissolved oxygen (DO) level, required for healthy aquatic life is very low in Dangdhar Chhara (3.8 mg/L) and Chandan Dighi (1.8 mg/L & 1.9 mg/L). The BOD level was also so high in Dangdhar Chhara (81mg/L) and Chandan Dighi (86.9 mg/L) and only Satwabhanga Nadi had BOD at the permissible limit in all seasons. The free CO_2 of water is much higher than the standard value in all the selected wetlands except Sagar Dighi. On the other hand, soil quality of selected wetlands is in moderate condition. A continuous decline in the aquatic life and extinction of many endemic species is observed. It is estimated that 66.67% flora and 55.56 % fauna of wetlands of the study area may be on the verge of extinction. There are many causes for wetland degradation in the study area. The main causes are over-exploitation of wetland resources through fishing, irrigation, agriculture, Jute retting; sedimentation and fragmentation of the wetlands, clogging of feeder channel, construction of engineering structures, garbage dumping & pollutants inflow in the wetlands.

Due to the degradation of wetlands in the study area, it is evident that environment is deteriorated and economic conditions of the wetland beneficiaries of the are in viable. It is further noticed that different wetland services are declining day by day. About 46.8 % wetland services are not found in the study area. A considerable number of water birds (-44.45%) has been extinct during the last two years. About 66.67% flora and 55.56 % fauna are on the verge of extinction in the wetlands of the study area. Areal shrinkage is another serious concern in the study area. The present researcher observed that about 84.03 % and 34.74% water area of Baiganbari Chhara and Dhangdhar Chhara has been disappeared. The wetland degradation affects the occupation and economy of the surrounding inhabitants as 13% fisherman and 20.83% edible plant collectors are forced to change their occupation.

Thus, there is an urgent need to conserve wetlands of the study area. A joint wetland management committee should be formed by including the fishermen, farmers and selected government officials and NGOs for conservation & management of wetland and the betterment of the beneficiaries. Community fishing, poaching and hunting of residential and migratory birds in the wetlands should be stopped at any cost. The government should arrange for alternative occupation for the fishermen during the breeding period. Paddy cultivation should be replaced by the cultivation of different wetland compatible edible plants like *Kalmi, Hincha* in the dry season and *saluk* in the monsoon season. Fish-Duck-Paddy system with organic manure should be implemented for economic benefit. If the wetlands are properly managed, it may bring a change in the environmental and economic aspect of the study area.

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APPENDIX – A

Part-A

Questionnaire to Determine the Wetland Services and Land Use Pattern of the Wetland Surroundings

Section I

Interview no: 64 date 20.11.16

Name of respondent: Dhurjadhan Barman

Sex: Male [✓] Female [ ] age: 65

Present occupation: fisherman

Previous occupation (before 10-15 years): fisherman

Reasons for changing theoccupation: N. A.

Educational Qualification: V

Name of the village: Dhakhin changtimari

Name of the block: Tufanganj – I

Name of the wetland in vicinity: Rasik Beel Wetland complex (Raichanmari)

Location: latitude: 26°24'30" N longitude: 89°43'15" E

Section II

1. How long have you been staying in the village? From birth [✓] year [ ]
2. Do you derive any benefit from the wetland? Yes [✓] No [ ]
3. **Which of the following activities sums up your utilization of wetland resources?**

[X] Crop cultivation
[X] Grazing
[X] Edible plant collection
[X] Medicinal plant collection
[X] Animal remains for medicinal use
[X] Collection of building materials
[✓] Fuel wood collection
[✓] Fishing
[X] Hunting
[X] Drinking water
[X] Water for cooking

[✓] Bathing
[✓] Washing household utensils
[✗] Washing vehicles
[✗] Irrigation
[✗] Jute retting
[✗] Release of sewage
[✗] Release of effluents
[✓] Garbage disposal → Small amount.
[✓] Disposal of festival generated wastes Small amount.
[✓] Surroundings used as toilets
[✗] Urban development

4. What other benefit [redacted] derive from the wetland?

[✓] Religious use
[✓] Aesthetic value
[✓] Cultural value
[✓] Tourism
[✓] Education and awareness
[✓] Recreation (swimming, bathing, boating, other)
[✓] Livelihood dependence

5. Human Induced Activities

1. Disposal of religious waste: [✓] Yes [ ] No
   If yes, mention the occasion.. Durgha puja & Kali puja..........
2. Rubble and construction material: [ ] Yes [✗] No
   If yes, mention the type.....................N.A.......................................
3. Washing vehicles & clothes: [✓] Yes [ ] No
4. Surroundings used as toilets: [✓] Yes [ ] No
5. Catching fish &Prawns: [✓] Yes [ ] No
6. Collection of Reeds, grasses for thatch
   (a roof covering of straw) or fodder : [✓] Yes [ ] No
   If yes, provide the details.. Small amount of kashiya & some fodder.

Section III

A. AGRICULTURE

1. Do you have cultivable land? [ ] Yes [✓] No ✓.

If yes, mention the total area and type of land (in Bigha) N.A.

Years	**In wetland**	**Around Wetland**
<5		
5-10		
10-20	N.A	
20-30		
>30		

2. If your cultivable land is in wetland, how many years have been farming there?

Indicate total amount of cultivable land (in bigha) in wetland N.A.

years ago_________10years ago__________20years ago_______30years ago________

3. How many house-holds do you know to be involved in farming activity in the wetland? 20

4. Reasons for cultivation in wetland:scarcity of land [✓] more production [✓]

If other, provide the details govt. was give caltivable land for 205 S.T. People.

5. Crops cultivated in the last 3 years (fulfill the table with production amount per bigha)

year	**Year 2013-14**		**Year 2014-15**		**Year 2015-16**		**Year 2016-17**	
Season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
crop			N.A					
Production/ bigha								

6. How will you describe benefits from cultivation in the wetland during the last five years?

Increasing [ ] Decreasing [ ] No change [ ]

7. If changes have occurred explain the causes: scarcity of water [ ]

Decline in the water quality [ ] Decline in the soil fertility [ ]

If other, mention the cause____

8. Fertilizer Used

Fertilizer & pesticide used in the last year/ throughout the year							
Summer crop Aus, amon, jute, chilli, greens, vegetables, others. Winter crop Greens, chilli, ground creep, potato, wheat, vegetables, maize, oil seeds, tobacco, boro, ginger, garlic, onion, others				Chemical fertilizer: npk(10/26, 15/15) = i, urea = ii, phosphorus(ssp)= iii Potash= iv, dap =v, magnesium=vi, zinc=vii Boron= viii ,dolomite =ix ,potassium humate =x Bio- fertilizer: cow dung-a, others organic-b			
Season	Name of the crop	Fertilizer(সার)		Pesticideকীটনাশক		Herbicideউদ্ভিদনাশক	Irrigation from wetland (if yes, mention amount of withdrawal)
		Chemical fertilizer	Bio-fertilizer	Chemical	Bio-pesticide		
Summer							
			N.A.				
Winter							
Jute retting		Mention the amount of land/ coverage					
Seed-bed							

9. Determining the level of awareness on the effect of farming activities in the wetlands based on the typical five-level Likerts cale:

Statement /scale	(put √ on his response) farmers in the wetlands [ ] farmers around the wetlands[ ]				
	Strongly disagree	Disagree	Don't know	Agree	Strongly agree
Use of chemical fertilizers affects the wetlands.		✓			
Use of pesticides affects the wetland.				✓	
Use of herbicides affects the wetland.		✓			
Runoff from agricultural fields degrades the wetlands.	✓				
Deep tillage in wetlands affect the Wetland ecosystem.	✓				
Water quality is affected by agriculture.		✓			
Soil quality is affected by agriculture.	✓				
Wildlife is affected by agriculture.		✓			
Landscape change due to agriculture			✓		
Advantages of using bio-fertilizers& bio-pesticides?			✓		

B) PISCICULTURE

i. Are you engaged in pisciculture? yes[✓] no[ ]

ii. If yes, mention the type: own [✓] co-operative [ ]

iii. Particulars of pisciculture:

Chemical fertilizer: NPK(10/26, 15/15) = I, Urea = ii, Phosphorus(ssp)= iii Potash= iv, DAP =V, Magnesium=vi, Zinc=vii Boron= viii ,Dolomite =ix ,Potassium Humate =x Bio- fertilizer: Cow dung-A, Others organic-B						
Name Of The Fish Collected	Name Of Fish Spray	Fertilizer Use In Pisciculture		Pesticide Use In Pisciculture		Threatened Fish Species
		Chemical fertilizer	Bio-fertilizer	Chemical	Bio	
Bengal eel(বানমাছ), Long whiskered catfish(আইড়), Bacha (বাচা),Dwarf goonch(বাগাইর/বাঘাইর),Sind danio(বাঁশপাতা),Awaousguamensis(বাইলা),Zig-Zag eel/Tire track eel(বাইম),Balitora minnow (বালিচুরা) ,Barred baril (বারালি / বোরালি), Indian Batasi (বাতাসি), Bogalabeo (ভাঙন/ভাঙ্গন), Indian Jewfish (ভেটকী), Wallago (বোয়াল), Bengal loach (বৌমাছ/রানি), Ganges River Gizzard Shad(চাপিলা), Squarehead catfish (চেকা), Silver razor belly minnow (চেলা), Flying barb, Slender rasbora, Gangetic scissortail	Indian carp. বাটা, রুই.	X	A.	X	X	Indian catfish, Long wish-kered cat fish, Wallago

rasbora (দারকিনা), Sucker head(ঘরপোয়া), Clown knifefish (চিতল/ চেতল),Gogangraviridescens, Nangranangra (গংটেংরা), Gray eel-catfish (গংমাগুর), Largescale archerfish (গোটিপোয়া), Gangeticailia, Jamunsailia (কাজুলি), Freshwater garfish (কাকিলা), Orange-fin labeo (কালিবাউস/ কালবোশ), Butter catfish (কানিপাবদা), Glyptothoraxcavia (কানিটেংরা), Indian Carp (কাতলা), Banded gourami (লশে,/খৌলশা), Grass Carp (গ্রাসকার্প), Scribbled goby (বেলে), Burmese loach (পুয়াকুই) ,Rita (রিটা), Indian glassy fish (রাঙ্গাচান্দা / রাঙাচাঁদা), Java barb (রাজপুঁটি), ফলি, Gangetichairfin anchovy (ফাশা/ ফ্যাঁসা), Swamp barb (পুঁটি), Green pufferfish (পটকা), Mango fish/Cichlid (তপসে/তপস্বী),Olive barb (সরপুঁটি) , Ocellatedpufferfish (ট্যাঁপা), Tyangra (টেংরা), Indian Tilapia(তেলাপিয়া), Stinging catfish (শিঙি/শিঙ্গি), Snakehead murrel (শৌলু/শোল), Spotted snakehead (টাকি), Climbing perch(কৈ),Swamp eel (কুঁচে/কুচিয়া/কুইচ্চা/কুইচা),Kalabans (কুরসা),Dwarf gourami (লালখোলিশা/ খলশে),Elongate glass-perchlet (লম্বাচাঁদা), Tor Tor (মহাশোল), Bombay duck (লোটে/ল্যাটা), Walking catfish (মাগুর), Barred spiny eel (পনকালবাইম / পাঁকালবাম), Mrigal(মৃগেল/মিরগেল), GaruaBachcha (মুরিবাচা), MolaCarplet (মলা), Indian Carplet (মৌরলা), Indian catfish(পাবদা), Pomfret (চাঁদা/পমফ্রেট), Pama croaker (পোয়া), Bengal Parshey (পারশে), Yellowtail catfish (পাঙ্গাস / পাঙাশ), Indian mottled eel, Any other... [illegible]						Rasbora, Clown knifefish, Jamunsailia, Climbing Perch

10. Determining the level of awareness on the effect of fisheries or related activities in the wetlands based on typical five-level Likert scale

Statement /scale	(put √ on his response) farmers in the wetlands [ ] farmers around the wetlands[ ]				
	Strongly disagree	Disagree	Don't know	Agree	Strongly agree
Chemical fertilizers affect wetland			✓		

Pesticides use affect wetlands.	✓				
Herbicides affect wetlands.			✓		
Removal of weeds affects wetlands.		✓			
Water quality is affected by fish-farming				✓	
soil quality affect by fish-farming		✓			
wildlife affect by fish-farming		✓			
Landscape change			✓		
Advantages of using bio-fertilizer & bio-pesticides?			✓		

C) FISHING

i. Involvement in fishing: Yes[✓] no [ ] If yes,

ii. Duration of fishing in the wetland 35 years (months/years)

iii. Is fishing your main occupation? Yes [✓] no[ ]

iv. If yes mention how much you earn daily Rs. 250/- 300/-

v. Indicate the type of fishing in different time.

Indian mottled eel, Bengal eel (বানমাছ), Long whiskered catfish (আইড়), Bacha (বাচা), Dwarf goonch (বাগাইর/বাঘাইর), Sind danio (বাঁশপাতা), Awaousguamensis (বাইলা), Zig-Zag eel/Tire track eel (বাইম), Balitora minnow (বালিচুরা) ,Barred baril (বারালি / বোরালি), Indian Batasi (বাতাসি), Bogalabeo (ভাঙন/ভাঙ্গন), Indian Jewfish (ভেটকী), Wallago (বোয়াল), Bengal loach (বৌমাছ/রানি), Ganges River Gizzard Shad (চাপিলা), Squarehead catfish (চেকা), Silver razorbelly minnow (চেলা), Flying barb, Slender rasbora, Gangetic scissortail rasbora (দারকিনা), Sucker head(ঘরপোয়া), Clown knifefish (চিতল/ চেতল), Gogangraviridescens, Nangranangra (গংটেংরা), Gray eel-catfish (গংমাগুর), Largescale archerfish (গোটিপোয়া), Gangeticailia, Jamunsailia (কাজুলি), Freshwater garfish (কাকিলা), Orange-fin labeo (কালিবাউস/ কালবোশ), Butter catfish (কানিপাবদা), Glyptothoraxcavia (কানিটেংরা), Indian Carp (কাতলা), Banded gourami (লশে,/খৌলশা), Grass Carp (গ্রাসকার্প), Scribbled goby (বেলে), Burmese loach (পুয়ারুই) ,Rita (রিটা), Indian glassy fish (রাঙ্গাচান্দা / রাঙাচাঁদা), Java barb (রাজপুঁটি), ফলি, Gangetichairfin anchovy (ফাশা/ ফ্যাঁসা), Swamp barb (পুঁটি), Green pufferfish (পটকা), Mango fish/Cichlid (তপসে/তপস্বী), Olive barb (সরপুঁটি) , Ocellatedpufferfish (ট্যাঁপা), Tyangra (টেংরা), Indian Tilapia (তেলাপিয়া), Stinging catfish (শিঙি /শিঙ্গি), Snakehead murrel (শৌল/শোল), Spotted snakehead (টাকি), Climbing perch(কৈ), Swamp eel (কুঁচে/কুচিয়া/ কুইচ্চা/কুইচা), Kalabans (কুরসা), Dwarf gourami (লালখোলিশা/ খলশে), Elongate glass-perchlet (লম্বাচাঁদা), Tor Tor (মহাশোল), Bombay duck (লোটে/ল্যাটা), Walking catfish (মাগুর), Barred spiny eel (পনকালবাইম / পাঁকালবাম), Mrigal (মৃগেল/মিরগেল), GaruaBachcha (মুরিবাচা), MolaCarplet (মলা), Indian Carplet (মৌরলা), Indian catfish (পাবদা), Pomfret (চাঁদা/পমফ্রেট), Pama croaker (পোয়া), Bengal Parshey (পারশে), Yellowtail catfish (পাঙ্গাস / পাঙাশ)

Major fish collected in summer season	Major fish collected in monsoon season	Major fish collected in post-monsoon season	Major fish collected in winter season

Pama croaker, climbing perch, etc.	Mola carplet, Swamp barb.	Snakehead Murrel, Stinging catfish, Walking catfish.	Snakehead Murrel, Spotted snake-head,

VI. How will you describe the fishing productivity in the wetlands during the past five years? [ ] increasing [✓] Decreasing [ ] No change

If change has occurred explain the cause Excessive fishing, water polution, water from Khamakhagari Municipality,

VII. How many house hold do you know have involved in fishing in the wetland?

At present 150-160 2 years ago 150-160 5years ago 250 10years ago 300

In the last 2-3 years has any community/organization taken any action to mitigate the problem? If yes, explain NO

VIII. To test the extent of knowledge on the negative effects of fishing in the wetlands based on a typical five-level Likert scale

Statement /scale	(put √ on his response) Farmers in the wetlands [ ] Farmers around the wetlands[ ]				
	Strongly disagree	Disagree	Don't know	Agree	Strongly agree
Excessive fishing affects wetland.				✓	
Catching tench affect thefish population & fishing productivity.				✓	
Catching brooding fish affect the fish population.				✓	
Removal of weeds affect the wetland	✓				

IX. **List of endangered and protected flora and fauna of wetland (fishermen)**

Name of species		Endangered	Protected
fauna	fish	Tinkata. Gili Putki, Koi, Bam	Sali, Shol,
		Pakal, Khosa, Kuchiya	Chang.
flora		Ulu, Khagra, Binna,	Zongli kachu.

Overall fish yield during the last 5-10 years

No Change [ ] Decreased (%) [✓] Increased (%) [ ]

Any incidence of mortality of fish or birds in the wetland in the recent past? If so yes.

provide details fish.

Mention the flora which is less seen during the last 5 years ——

Do you think conservation of wetland is necessary? No Answer.

D. EDIBLE PLANT COLLECTION

I. Involvement in the collection of edible plant: Yes [ ] No [✓] if yes,

II. Duration of collection of edible plants from the wetland: N.A. (months/years)

III. How many house hold do you know to be involved in this activity in the wetland? 10-15

Indicate the type of Edible plant collected in different time

Edible Plant	Niche of Plant	Summer Season	Monsoon Season	Winter Season
Water spinach(Kulmi)				
Buffalo Spinach (Hincha)				
Suluk				
Fiddleheads (Dhekisak)				
Colocasiaesculenta (Kachusak)		NA		
Water caltrop (Jalsingara)				
zongasak				
Others.........				

IV. Is the collection of wild plant your main occupation? Yes [ ] No [X]

If yes mention the daily income ______________________

V. How will you describe the prospect of collection of wild plants as an income source in the past five years? [ ] Increasing [ ] Decreasing [X] No change

If change has occurred explain the cause ______________________

VI. Are you aware of the impact of edible plant collection on the wetland?

Yes [ ] No [ ]

NA

E. LIVESTOCK

I. Does your livestock graze in the wetlands? Yes [ ] No [✓]

II. Livestock has been grazing the wetland since ______________(months/years)

III. How many household you know to be involved in grazing the livestock in the wetland?

Mention the data of total livestock grazing in the wetlands during different times of the year

Livestock	No.	Summer Season	Monsoon Season	Post Monsoon Season	Winter Season
Cattle					
Goat					
Sheep					
duck					
Other…… …………				NA.	

IV. Do you cut grass or bushes to feed your livestock? Yes [ ] No [ ]

V. If yes mention time……………..why…………………………………………

VI. Is the animal husbandry and fodder collection your main occupation?

Yes [ ] No [✓]

VII. How will you describe the changes in fodder collection during the past five years?

[ ] Increasing [ ] Decreasing [ ] No change

VIII. If there is a change explain the cause ______________________

IX. Are you aware about impact of collection of grazing on wetland?

Yes [ ] No [ ]

F. **COLLECTION OF BUILDING MATERIALS**

I. Do you in in collection of building material?

Yes [ ] No [✓] If yes

II. How long have you been involved in the collection of building materials from the wetland? N.A.

III. How many house hold do you know to be involved in collection of building materials the wetland? NO

IV. Indicate the type of building material extracted from the wetlands at different times of the year:

Building material (mention name)	Area of collection	Summer Season	Monsoon Season	Post Monsoon Season	Winter Season
Plant			N.A		
Grass					
Mud					
Sand					
Stone					

V. Is the collection of building material your main occupation? Yes [ ] no[✓]

VI. If yes mention your daily earnings N.A.

VII. How will you describe the changes in building material extraction from the wetland in the past five years?

Increasing [ ] Decreasing [ ] No Change [ ] N.A.

VIII. If change has occurred explain the causes N.A.

IX. Are you aware of the impact of collection of building materials on wetland?

Yes [ ] No[✓]

G. **COLLECTION OF FIRE WOOD**

I. Do you involved in collection of collection fire wood? yes[✓] no [ ] if yes

II. How long have you been involved in collection of fire wood from the wetland? Very long

III. How many house hold do you know to be involved in this activity in the wetland? 35-50

Indicate the collection pattern of fire wood at different times of the year.

Fire wood(mention plant name)	Niche of plant	**Summer Season**	**Monsoon Season**	**Post Monsoon Season**	**Winter Season**
Baro Kalmi	edges	X	X	✓	✓

Branch of Tree	edgs.	✓	✗	✗	✓

V. Is the collection of fire wood your main occupation? Yes [ ] No [✗]

V. If yes, mention your daily earnings ✗

VI. How will you describe the changes in the firewood collection in the wetland during the past five years?

Increasing [ ] Decreasing [✓] No change [ ]

VII. If change has occurred explain the causes ____________________

VIII. Are you aware of the impact of firewood collection on wetland?

Yes [ ] No [✓]

H. **HUNTING**

I. Are you involved in hunting? Yes [ ] No [✓]

If yes, How long have you been involved in hunting in the wetland? ____________ (month/year)

II. How many house hold do you know to be involved in hunting in the wetland?

Indicate the type of hunting at different times.

Hunting(mention bird/animal name)	Niche of animal	Summer Season	Monsoon Season	Post Monsoon Season	Winter Season
		N.A			

III. Hunting your main occupation? Yes [ ] No [ ] N.A.

IV. If yes mention how much you daily earnings

V. How will you describe the monetary returns from hunting in the wetlands during the past five years?

[ ] Increasing [ ] Decreasing [ ] No change N.A.

If change has occurred explain the causes

VI. Are you aware of the negative impacts of hunting on wetland? Yes ✓ no ____

I. WATER USE

J. Mention the quantity of water for the following activities:

Water for	Quantity of collection per day/season	Frequency of collection	Number of people/other	Cause of use
Irrigation	For Boro Production	one.	20-25	More Production
Drinking water supply	X	—	—	—
Water for cooking	X	—	—	—
Bathing	yes.	whole year.	—	—
Washing household utensils	yes.	All over the year.	—	—
Washing of cloths & vehicles	yes.	All over the year.	—	—
Other	—	—	—	—

II. How will you describe the changes in the water use in the past five years?

Increasing [✓] Decreasing [ ] No change [ ]

III. If change has occurred explain the causes Boro cultivation, Population expantation.

IV. Are you aware about the negative impact of excessing pressure on water resources of wetland? Yes [ ] No [✓]

নুরমহর বেগম
Signature of Respondent

Abdul Mia 20.11.16
Signature of Researcher

Part-B

Questionnaire for Assessment of wetlands

GENERAL

1. Name of the Wetland: Rasik Beel wetland complex.

2. Location: Latitude: 26°24'30"N Longitude: 89°43'15" E

3. Lake Type: Natural Lake ✓ Man-made (Reservoir) ✗

4. Constriction/stricture (if any) for the purpose of

a) Fishery development ✗

b) Flood control ✓

c) Irrigation ✗

d) Settlement ✓

e) Road ✓

f) Other –

6. Number of roads and railways nearby the wetland: Road - 6 Railways - Nil

7. Roads and railways passing through the wetland: Road - 2

8. How many villages/ settlements are located near or on the periphery of wetland? 5

9. Land use (%):

Urban [ ] Rural [✓] Agricultural [ ] Forest [✓] Grazing [✓] Fallow [ ]

10. Fishing: Non-commercial fishing [✓] Pisciculture [✓]

11. If Urban Catchment: N.A.

Has Sewerage been provided? Yes [ ] No [ ]

13. Sewage treatment: Yes [ ] No [✓]

14. Solid waste disposal in lake (if any) [ ] yes. But small amount.

HYDROLOGY

1. Source of water(inflow): Rainfall ✓ Runoff ✓ River Drainage [ ] Wastewater drainage [✓]

2. Outflow. if any (describe): yes but blocked by sluice gate [ ]

3. Name of the feeder channel (with the time of connection) Burha Raidak & Ghoramara River.

4. Water level changes (annual) in Meters 2-4 ft. [ ]

5. Does the lake dry out completely? Every year [✓] occasionally [ ] Rarely [ ] But Partly *

6. Name of the nearby river with distance from the Beel Burha Raidak ½ km.

7. Approximate area of the Wetland 180 ha. [ ]

8. Water spread area of the Beel in rainy season all over wetland [ ]

* Chotojan & Barojan wetland are dried completly every year.

BIODIVERSITY

a. Inhabiting Flora

Population Status		
Very common	Fairly common	Rare
Kochuripana	Saluk	Zonga Sak/Kachu-
Topa Pana	Kalmi	Pani phal
Zongli Kochu	Helencha	Nal Khagra
Kalmi	Dheki Sak	Pundi
	Bhet	Hogla
	Dandokalos	Binna
		Kash
		Ulu
		Khagra
		Kher.

b. Inhabiting Fauna

Population Status		
Very common	Fairly common	Rare
Chang, Shol, Soti	Bata, Kalbous,	Sing, Pabda
Lesser whistling-Duck	Koi, Chanda, Ruhi	Paia, Kuchia
cattle Egret,	Kocho chinni,	Bam, Baal,
Spoted Dove,	common Kingfisher,	Darikina,
Block Drongo	Asian Koel,	Water Beetle,
Jungle Myna	Gaso Bang,	Black Kite
	Daras,	Jhinuk,
	Beji.	Googhi
	Metho idur.	Sona Bang.
		Goshap
		Bador
		ud.

MAJOR PROBLEMS

I. Thickness of organic & Inorganic Bottom Deposits(Mud): (Bochamari Beel)

II. Edges of the wetland [✓], 1.5 feet

III. middle of the wetland [✓], 2.5 feet

IV. Blockage of Feeder Channel by road [✓], railways [ ], embankment [ ] house

V. Encroachment and Areal Shrinkage by agriculture [✓], Local Residents [ ], Builders [ ], Government [ ],

VI. Fragmentation of wetland by road [✓], railways [ ], creation of pond [ ]

VII. Garbage Dumping

i. No. of garbage dumping points [✗]

ii. Material: organic [ ], inorganic [ ]

VIII. Major dumped materials ✗

Amount: small [ ] Moderate [ ] Huge[ ]

IX. Pollutants Inflow from market: municipality [ ] agricultural fields [✓] N.A [ ],

X. Eutrophication: vegetation cover of wetland: 100% [ ] 75% [✓] 50% [ ] 25% [ ],

XI. Indiscriminate Fishing: All throughout the year [✓], only rainy season [ ],

Only dry season [ ], fishing by dried up

XII. Every year flood affects the wetland: Yes [✓] No [ ]

XIII. Weed Clearance: every year [ ] Alternative years [ ] No [✓]

Once a year [ ], Twice a year [ ], Thrice a year [ ], four times a year [ ]

XIV. Jute retting: Yes [✓] No [ ]

XV. Approximate amount of jute retting in bigha [120],

XVI. Socio-cultural activities in and around the wetland:

Puja [ ], Fairs [ ], Crematory grounds [ ], Immersion of idols [✓]

XVII. Depth of water in feet:

In rainy season

i. Edges of the wetland [ ], 2 feet

ii. Middle of the wetland [ ], 12 feet

In summer season

i. Edges of the wetland [ ], 1 feet

ii. Middle of the wetland[ ], 6 feet

XVIII.Other information:

Reduction in area (shrinkage) [✓], Reduction in depth (Siltation) [✓], Encroachments [✓],
Algal blooms [X], Aquatic weeds [✓], Decline or Loss of fisheries [✓],
Eutrophication [✓], Organic Pollution [✓], Toxic pollution [X],

XIX. Total area of the wetland: Increased [X], Decreased [✓], Unchanged [X],

MONITORING &CONSERVATION

1. What is the present legal conservation status of the wetland?

Protected fully [ ] Protected partially [✓]
Unprotected [ ] Proposed for protection [ ]

2. If protected, please mention -

(a) The Year since when the wetland is being protected It included in wetland development Project in 2005.

(b) Protecting agency:

Forest department [✓] Irrigation department [ ]
Municipal Corporation [ ] Any other Agency [ ]

(c) Protection Status:

Fishing Prohibited or regulated [X] Hunting prohibition [✓] other [X]

Abdul Miraj 20.11.12
Signature of Researcher

Appendix – B

List of Abbreviations

ANOVA= Analysis of Variance

BIS= Bureau of Indian Standard

BLRO= Block Level Revenue Officer

BOD= Biological Oxygen Demand

CGWB= Central Ground Water Board

CGWB= Central Ground Water Board

DFO= District Forest Officer

DSH= District Statistical Handbook

DO= Dissolve Oxygen

EC= Electrical Conductivity

FAO= Food and Agricultural Organization

GSI= Geological Survey of India

GSI= Geological Survey of India

IFS=Indian Forest Service

IMD= Indian Meteorological Department

ISRO= Indian Space Research Organization

NWCP=National Wetland Conservation Programme

OC= Organic Carbon

PFCS= Primary Fishermen Co-operative Society

RLI= River Lift Irrigation

RSC= Sodium Residue Carbonate

TA= Total Alkalinity

TS= Total Solid

TSS= Total Suspended Solid

WCMC= World Conservation Monitoring Centre

WHO= World Health Organization

WQI=Water Quality Index

PPM= Parts Per Million

Appendix – C

Glossary of the terms

Annoprason = First feeding Ceremony

Chhara', 'Dara', 'Doba', 'Jheel', 'Beel', and 'Kura'= Marshy or swamp generally created by remnant channel or ox bow lake in plain region.

Dighi= Pond

Fish hunting=fish catching from wetland without fish culture.

Jampoi =Minor natural Canal from which water has been withdrawal for irrigation purpose in dry season.

Kalbaishakhi= Thunder storm accompanied by hail

Kalmi, Hincha, Sushni= Edible Plant

Koch =An indigenous mongoloid race who lived in the area from pre- historic time

patkathi= Jute sticks

Rajbanshis, Oraon, Rabha, Munda, Santal, Bedia and Garo=The native people of Koch Bihar district.

APPENDIX-D

List of Publications

1. Miraj, A. & Bhattacharya, S., K. (2017). “Changing Trends Of Some Bio –Physico-Chemical Characteristics of Sagar Dighi of Cooch Behar, West Bengal, India, Journal of Indian Research (ISSN: 2321-4155), 5(3), pp. 79-94**. (Included in the Thesis)**

2. Miraj, A. & Bhattacharya, S., K. (2017). “Assessment of Water Quality Index (WQI) and Suitability of Sagar Dighi, Koch Bihar, West Bengal, India”, International Journal of Pharmaceutics & Drug Analysis, (ISSN: 2348-8948), 5 (12), pp. 467-474. **(Included in the Thesis)**

3. Miraj, A., Pal, S., Bhattacharya, S., K. & Chakrborty, K. (2017). “Observation on the TDS and EC Values of Different Water Bodies at Cooch Behar, West Bengal, India” International Journal of Theoretical & Applied Sciences, 9(2),106-113.

4. Bhattyacharya. S., K., & Miraj. A. (2017), “Application of Remote Sensing and G.I.S in Wetland management: A Case study of Koch Bihar District, West Bengal” (Mandal. D.K. Ed), Remote Sensing and G.I.S in Environmental Management, 28-39.

Appendix – E

Copy of the Publications

Journal of Indian Research (ISSN: 2321-4155)
Vol.5, No.3, July-September, 2017, 79-94

Geography

CHANGING TRENDS OF SOME BIO-PHYSICO-CHEMICAL CHARACTERISTICS OF SAGARDIGHI OF COOCH BEHAR, WEST BENGAL, INDIA

Abdul Miraj*
Sudip Kumar Bhattacharya**

ABSTRACT

Present work was designed to study the changing trends of some important bio-physico-chemical characteristics of Sagardighi of Cooch Behar, West Bengal, India. To evaluate the water quality of the lake, bio-physico-chemical parameters (tested by West Bengal Pollution Control Board, Siliguri laboratory) were studied on the monthly basis for a period of five years between June 2011 to May 2016. There were seven physical parameters , interalia, Temperature, pH, Total Dissolved Solid (TDS), Total Suspended Solid (TSS), Total Fixed Solids (TFS), Turbidity, and Electrical Conductivity (EC); thirteen chemical parameters, interalia, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Alkalinity (TA), calcium, magnesium, chloride, sulphate, sodium, phosphate, nitrate-N, potassium, Total Hardness (TH) and two bacteriological parameters, Total Coliform(TC) and Fecal Coliform(FC). The present work provides baseline information on changing trends of bio-physico-chemical status of Sagardighi. This would facilitate sustainable management and conservation of ecosystem of this lake. The data obtained from this study reveals that the bio-physico-chemical parameters of Sagardighi of Cooch Behar are comparatively in moderate condition but almost all the parameters are prone to cross the critical pollution level, if necessary action is not taken in time.

Keywords: Bacteriological Parameters, Changing Trends, Chemical Parameters, Physical Parameters, Sagardighi.

INTRODUCTION

Ponds are useful wetlands located in and around human settlement. Ponds are generally semi-natural ecosystems constructed by man. The ponds are subjected to a range of physical,

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chemical and biological problems caused by human activities and climate change due to which a major concern has aroused as it can diminish their aesthetic beauty, recreational value, water quality and habitat suitability. Most of the ponds or lakes, especially near residential, commercial and administrative areas are polluted because of anthropogenic activities. The physical and chemical characteristics of water are important parameters as they directly or indirectly affect its quality and consequently its suitability for the distribution and production of fish and other aquatic animals (Swingle 1969).

Increased anthropogenic activities in and around the water bodies damage the aquatic ecosystems and ultimately the physico-chemical properties of water (Upadhyay *et al.* 2010). It is well established that domestic sewage and industrial effluents falling into natural water bodies change the water quality and lead to eutrophication (Shaw *et al.* 1991). The monitoring of physico-chemical parameters of a water body is vital for both long term and short term study (Wood 1995). Good water quality resources depends on a large number of physico-chemical parameters and the magnitude and source of any pollution load; and to assess that, monitoring of these parameters are essential (Reddi *et al.* 1993).

MATERIALS AND METHODS

Description of Study Area

Sagardighi has been selected for study. It is the most important freshwater body which is situated in the heart of Cooch Behar town. It extends between 26°19'12"N to 26°19'21"N and 89°26'21"E to 89°26'28"E and the total surface area of this lake is 14.60 hectare. The lake was excavated by Maharaja Harendra Narayan in 1807 AD. It attracts various migratory

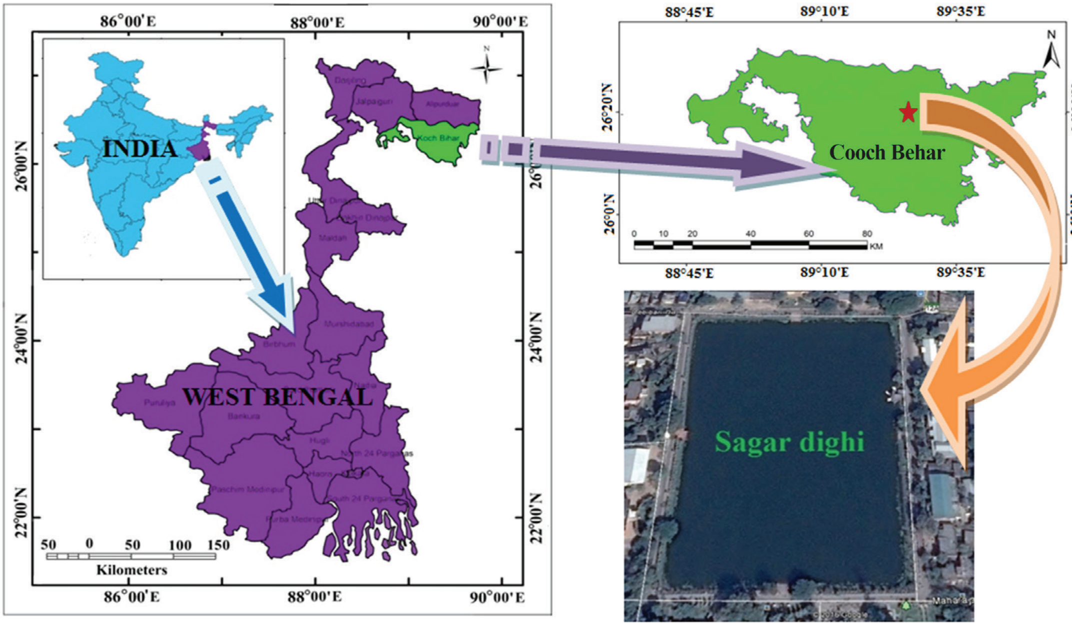

Figure 1: Locational Map of Sagardighi.

birds during the winter season. Among all ponds in Cooch Behar town the most spectacular is Sagardighi, with grand structures arrayed all around it. These buildings, built mostly between 1880 to 1920, are now offices of the district administration like Office of the District Magistrate, Administrative Building of North Bengal State Transport Corporation, BSNL Office on the West; Office of the Superintendent of Police, District Library, Municipality Building on the South, Office of the BLRO, Sate Bank of India (Cooch Behar Main Branch) and numerous other on the east and RTO office, Foreigner's enrollment office, District Court in the north. Although this lake was excavated for drinking water supply control, now it is used for bathing, swimming, washing clothes, fishing, morning and evening walk around the lake, resting or gossiping place, boating etc.

Collection of Water Parameters Data:

The study of Cooch Behar Lake or Sagardighi was conducted using secondary data of five year duration between June 2011 to May 2016 of West Bengal Pollution Control Board, Siliguri Laboratory, Siliguri in Darjeeling.

Statistical Analysis:

Statistical analysis like mean, standard deviation and correlation coefficient, correlation matrix etc. and some graphical representation have been made using Microsoft Excel (Version Windows 2007), a computer based programmer for windows.

Preparation of maps:

The locational map was prepared by using Google Earth, Global Mapper 2011 and Arc GIS v-9.3.

RESULTS AND DISCUSSION

Physical Parameters:

Temperature: It is one of the most important parameters for aquatic environment because it governs the physical, chemical and biological properties of water. The maximum water temperature (35°C) was recorded in September, 2011 and minimum (18°C) in January, 2013(Table 1). The mean temperature is gradually high from 28.58°C (2011-12) with SD 4.54 to 29.83°C (2015-16) with SD 3.59 in (Table 1 & 2).

pH: pH is an important parameter because it indicates more or less overall water environment. The intensity of acidity or alkalinity of water can be measured by taking the value of pH of water. Natural water is usually alkaline due to the presence of sufficient quantities of carbonate. Here, it ranged from 6.63 (July, 2011) to 9.54 (April, 2016) during 2011-16(Table 1). Sometime pH value exceeds the permissible limit i.e. 6.5 to 8.5.

Total Dissolved Solid (TDS): TDS consequently may have an influence on the acceptability of water in general. Water with a very low TDS concentration may be corrosive and corrosive water may lead to toxicity in water. The variation of TDS in water may occur due to ionic composition of water. The highest TDS (271 mg/l) was recorded in August, 2012 and lowest one was 22 mg/l in November 2011(Table 1).

Total Suspended Solid (TSS): The TSS is a direct measurement of the concentration of suspended material present in a water sample. TSS value varied due to ionic composition of water and the factors like rainfall and biota cause changes in their concentrations. The maximum TSS (158 mg/l) was recorded in October, 2013 and minimum (4 mg/l) in January, 2011 (Table 1).

Total Fixed Solids (TFS): Total Solids are dried, weighed, and then ignited at 500 ± 50ºC. The loss of weight by ignition at 500 ± 50ºC is a measure of the volatile solids, which are classed as organic material. The remaining solids are the total fixed solids, which are considered as inorganic (mineral) matter. In other word, the Total Solids associated with the mineral fraction are termed Total Fixed Solids (TFS). It ranged from 4 mg/l (June, 2015) to 160 mg/l (September, 2015) during 2011-16 (Table 1).

Turbidity: It is another important physical parameter which is responsible for scattering and absorption of light by water. As the turbidity obstructs light penetration, it limits production of phytoplankton growth, which in turn leads to a decrease in photosynthetic activity and depletion of oxygen content. The maximum turbidity (39.1/NUT) was recorded in May, 2013 and minimum (3.11/NUT) in February, 2016 (Table 1), whereas the permissible limit (BIS standard) of turbidity is 5/NUT.

Electrical Conductivity (EC): EC value is an index to represent the total concentrations of soluble salt in surface water. The highest EC (98.8 µS/cm) was recorded in August, 2012 and lowest one was (42 µS/cm) in November 2011(Table 1). EC showed a positive correlation with Total Alkalinity (r=0.686) (Table 2).

Chemical Parameters:

Dissolved Oxygen (DO**):** DO indicate the health of the ecosystem and refers to the volume of oxygen present in water body. It is an important water quality parameter to be measured because it prevails over biological and physicochemical attributes of surrounding water. Oxygen enters into water by aerial diffusion and as a photosynthetic byproduct of aquatic plants and algae. The DO depends upon the temperature, salinity and pressure of water. The DO value indicates the degree of pollution in the water bodies (Gopalkrushna, 2011).It ranged from 5.2 mg/l in July 2011 to 9.9 mg/l in February, 2012 during 2011-16 (Table 1).

Biochemical Oxygen Demand (BOD): It is one of the most important components for the aquatic community. It is the amount of dissolved oxygen needed (i.e., demanded) by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. The maximum BOD (7.1 mg/l) was recorded in May, 2012 and minimum (0.85 mg/l) in July, 2011(Table 1). The mean BOD is gradually low from 3.42 mg/l with SD 2.14 in 2011-12 to 2.28 mg/l with SD 0.72 in 2015-16(Table 1 & 2).

Chemical Oxygen Demand (COD): The oxygen required by the organic matters in water to be oxidized by a strong chemical oxidant which is known as Chemical Oxygen Demand (COD). Sometimes BOD cannot be determined accurately due to the presence of toxins and other such unfavorable conditions. Under such circumstances, COD plays an important role for assessment of organic matters in water. It ranged from 14.4 mg/l (October, 2011) to 78 mg/l

(July, 2011) during 2011-16 (Table 1), whereas the permissible limit (WHO standard) of COD is 10 mg/l. It showed a positive correlation with turbidity (r=0.647) (Table 2).

Total Alkalinity (TA): TA of water is an important parameter, which determines the amount of chemical needed to be added in water treatment. Alkalinity is an anionic phenomenon. The highest alkalinity value (68mg/l) was recorded in December 2012 and the lowest (15.2 mg/l) in March 2013. This shows a positive correlation with calcium (r=0.686, Table 1 and 2) and conductivity(r=0.748, Table 1 and 2).

Calcium: Calcium content is present in hard water as well as soft water. Calcium in wetland water is most essential for the growth of aquatic vegetation and lives. It ranged from 2.83mg/l (April, 2013,) to 27.25 mg/l (August, 2015) during 2011-16 (Table 1).

Magnesium: It is an important chemical component of water. It is essential for the chlorophyll bearing bacteria, algae and plants. Magnesium concentration ranged from 0.54 mg/1 to 8.75mg/l.

Chloride: It is one of the major inorganic anions in water and waste water. Chloride content increases in water bodies due to organic matter decomposition. The important source of chloride in the water is the discharge of domestic and industrial sewage. Hence, the chloride concentration serves as an indicator of pollution by sewage disposal and industrial wastes. The maximum chloride (17.61mg/l) was recorded in November, 2016 and minimum (1.96 mg/l) in May, 2016 (Table 1).

Sulphate: Sulphate is naturally occurring anions in all kinds of natural water. Industrial waste and domestic sewage are responsible for increase of its concentrations in water. The tolerance limit of sulphate in water is 200 mg/1 while, excessive limit considered is 400mg/l. Sulphate concentration ranged from 0.055mg/l in January, 2011 to 16.33 mg/l in June, 2013

Sodium: Sodium content in water is essential chemical component. The maximum sodium (1 mg/l) was recorded in March, 2013 and minimum (6mg/l) in September, 2011 (Table 1).

Phosphate: In natural water, phosphorous occurs as phosphate. It is essential for the growth of organisms and act as nutrient that limits the primary productivity of water body that stimulates the growth of photosynthesis of aquatic micro and macro organisms. The maximum phosphate (0.587mg/l) concentration was recorded in July, 2014 and minimum (0.007 mg/l) in February, 2014 (Table 1).

Nitrate-N: Nitrate-N concentration enters fresh water through discharge of sewage, industrial wastes and runoff from agricultural fields, the concentration and rate of supply of nitrate in the land use practices of the surrounding watershed. In present study, Nitrate-N concentration ranged from 0.003 mg/1 to 0.68mg/l (Table 1).

Potassium: Potassium concentration is very low (<10 mg/l) in natural waters since rocks, which contain potassium, are relatively resistant to weathering. It is usually found in ionic form and the salts are highly soluble. Though found in small quantities it plays a vital role in the metabolism of fresh water environment (Ramachandra *et al*., 2012). The maximum potassium (3 mg/l) was recorded in January, 2013 and minimum (0.78 mg/l) in September, 2013 (Table 1).

Total Hardness (TH): Total Hardness normally indicates the total calcium and magnesium salts present in water along with some other polyvalent metals such as iron, aluminum, manganese etc. It determines the suitability of water for domestic, industrial and drinking purposes. The total hardness of the water body was in the range between 14.14 mg/l in June, 2011 to 84 mg/l in December, 2011(Table 1).Total Hardness showed a positive correlation with calcium (r=0.883, Table 1 and 2) and magnesium (r=0.698, Table 1 and 2).

Bacteriological Parameters

Total Coliform and Fecal Coliform are the two bacteriological parameters considered here which indicate the presence of pathogens in water of the lake. The maximum Total Coliform (170000 MPN/100ml) was recorded in August, 2011 and minimum (1700 MPN/100ml) in April, 2013(Table 1). The maximum Fecal Coliform (27000 MPN/100ml) was recorded in August, 2011 and minimum (500 MPN/100ml) in April, 2013(Table 1), whereas the permissible limit of Total Coliform and Fecal Coliform is 500 MPN/100ml(CPCB standard) and 10-100 MPN/100ml(Malaysia standard) respectively. Total Coliform showed a positive correlation with Fecal Coliform (r=0.877) (Table 2).

Table 1a: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal

Year		2011							2012					Range	Mean	Standard Deviation
Parameters	**Unit**	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May			
BOD	mg/l	3.35	0.85	1.5	3.6	1.1	1.7	3.2	4	2.2	5.5	6.9	7.1	0.85-7.1	3.42	2.14
Calcium	mg/l	4.12	6.59	6.6	4.9	5.6	9.6	19.2	7.2	6.4	4	7.69	8	4-19.2	7.49	4.03
Chloride	mg/l	2.99	2.94	2.99	4	6.6	6.6	4.86	6.8	5.83	4.89	4.89	3.91	2.94-6.8	4.78	1.45
COD	mg/l	30	78	33.6	17.2	14.4	24.96	39.6	40	58.41	43.68	55.44	45	14.4-78	40.02	18.10
Conductivity	µS/cm	50.6	57.3	48.9	46.7	47.7	51.8	49.3	51.4	58.3	57.5	66	60	46.7-66	53.79	5.92
Dissolved O_2 (DO)	mg/l	7.8	5.2	8.2	8.1	9.8	9.2	9.8	9.8	9.9	9	9.1	8.8	5.2-9.9	8.73	1.32
Fecal Coliform	MPN/ 100ml	22000	9000	27, 000	9000	22000	7000	11000	8000	8000	1300	1700	3000	1300-27000	10750.00	8441.40
Magnesium	mg/l	0.98	1.96	0.99	1.45	4.37	1.94	8.75	1.46	4.37	1.73	3.88	2.3	0.98-8.75	2.85	2.23
Nitrate-N	mg/l	0.15	0.04	0.27	0.17	0.12	BDL	0.02	BDL	0.04	BDL	BDL	0.18	0.02-0.27	0.12	0.09
pH	Unit	7.25	6.63	7.01	7.94	6.93	7.24	7.63	7.31	6.95	7.92	6.66	7.89	6.63-7.94	7.28	0.47
Phosphate-P	mg/l	0.037	0.044	0.014	0.02	0.03	0.23	0.02	0.05	0.01	0.087	0.027	0.011	0.01-0.23	0.05	0.06
Potassium	mg/l	2	1	1	1	1	1	1	1	1	1	1	1	1-2	1.08	0.29
Sodium	mg/l	2.5	1.46	4.03	6	2.35	2.35	3.73	5.69	3.36	4.71	4.71	2.75	1.46-6	3.64	1.43
Sulphate	mg/l	0.055	0.16	NT	2.95	2.65	2.75	6.38	2.78	1.63	2.02	0.62	2.42	0.055-6.38	2.22	1.75
Temperature	^0C	32	33	31	35	32	25	25	20	23	27	30	30	20-35	28.58	4.54
Total Alkalinity	mg/l	18	20	22	20	22	24	68	30	24	32	28.5	24.7	18-68	27.77	13.36
Total Coliform	MPN/ 100ml	70000	17000	1, 70, 000	17, 000	50000	11000	14000	11000	13000	5000	2700	5000	2700-170000	32141.67	47811.42
Total Dissolved Solids(TDS)	mg/l	154	36	30	36	40	22	26	84	46	83	54	64	22-154	56.25	37.02
Total Fixed Solids(TFS)	mg/l	16	8	10	10	30	6	10	40	26	30	22	16	6-40	18.67	10.83
Total Hardness as $CaCO_3$	mg/l	14.14	24.24	20.2	18	32	32	84	24	34	16	32.69	28	14.14-84	29.94	18.36
Total Suspended Solids(TSS)	mg/l	48	42	18	38	28	4	6	4	92	30	16	142	4-142	39.00	40.70
Turbidity	NTU	17.4	28.6	7.11	8.57	17.2	10.2	13.9	9.25	22.4	12.5	19.6	10.7	7.11-28.6	14.79	6.44

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

Table 1b: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal

Year		2012							2013							
Parameters	Unit	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Range	Mean	Standard Deviation
BOD	mg/l	6.3	5.35	3.2	3.8	4.8	4.1	4.3	4.2	3.6	6.3	4.3	2.8	2.8-6.3	4.42	1.10
Calcium	mg/l	5.82	5.6	5.6	7.2	5.6	8	8	5.66	9.2	5.66	2.83	9.82	2.83-9.82	6.58	1.93
Chloride	mg/l	3.91	3.74	4.78	2.87	3.83	3.83	5.74	6.7	2.87	7.66	3.82	7.78	2.87-7.78	4.79	1.75
COD	mg/l	21.12	37.44	32.64	19.32	27.04	37.44	39.12	41.6	66.56	73	61	69	19.32-73	43.77	18.90
Conductivity	µs/cm	56	50	47	47	42	50	52	53	56	58	57	53	42-58	51.75	4.79
Dissolved O_2 (DO)	mg/l	8.6	8.6	6.4	6.5	8	8.3	8.2	8.9	8.8	8.6	7.9	7.6	6.4-8.9	8.03	0.83
Fecal Coliform	MPN/ 100ml	2300	1300	1100	3300	2700	1700	2100	2200	1300	1100	500	1400	500-3300	1750.00	790.28
Magnesium	mg/l	1.79	1.73	2.3	1.73	2.3	2.3	1.152	2.55	5.61	1.02	1.53	5.05	1.02-5.61	2.42	1.44
Nitrate-N	mg/l	0.1	0.01	0.008	0.01	0.007	0.01	BDL	BDL	BDL	0.01	0.006	0.01	0.006-0.1	0.02	0.03
pH	Unit	8.02	8	7.21	7.65	8.5	8.27	7.57	8.1	8.35	7.3	7.96	7.63	7.21-8.5	7.88	0.41
Phosphate-P	mg/l	0.026	0.021	0.019	0.021	0.034	0.049	0.063	0.058	0.075	0.061	0.083	0.062	0.019-0.083	0.05	0.02
Potassium	mg/l	1	<1.00	1	<1.00	1	<1.00	<1.00	3	1	<1.00		<1.00	1-3	1.40	0.89
Sodium	mg/l	4.71	3.36	2.75	2.35	2.75	1.88	2.85	5	2.38	1		1.13	1-5	2.74	1.27
Sulphate	mg/l	1.5	7.19	5	0.29	0.468	5.37	0.075	4.29	2.22	2.24	3.17	3.33	0.075-7.19	2.93	2.23
Temperature	^{0}C	29	32	32	29	28	30	26	18	26	28	34	31	18-34	28.58	4.12
Total Alkalinity	mg/l	20.9	19	20.9	22.8	22.8	24.7	26.6	28.5	26.6	15.2	20.9	26.1	15.2-28.5	22.92	3.80
Total Coliform	MPN/ 100ml	8000	14000	8000	22000	17000	13000	17000	14000	8000	5000	1700	8000	1700-22000	11308.33	5818.07
Total Dissolved Solids(TDS)	mg/l	88	271	115	33	43	62	74	75	26	68	64	52	26-271	80.92	64.54
Total Fixed Solids(TFS)	mg/l	16	10	10	20	28	60	88	40	24	30	18	44	10-88	32.33	22.91
Total Hardness as $CaCO_3$	mg/l	20.8	20	22	24	22	28	24	23.1	21.47	17.7	12.39	42.09	12.39-42.09	23.13	7.07
Total Suspended Solids(TSS)	mg/l	40	40	26	98	24	12	28	42	44	44	44	60	12-98	41.83	21.65
Turbidity	NTU	9.56	7.89	5.26	4.18	5.14	6.64	8.84	7.36	17.4	31.7	14.8	39.1	4.18-39.1	13.16	11.20

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

Table 1c: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal

Year		2013							2014							
Parameters	Unit	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Range	Mean	Standard Deviation
BOD	mg/l	2.2	3	3.1	3.6	2.4	1.9	2.1	3.4	3.4	2.8	1.8	4.5	1.8-4.5	2.85	0.81
Calcium	mg/l	5.6	6.4	8.8	13.6	7.2	6.4	7.2	6.4	7.2	8	9.6	12	5.6-13.6	8.20	2.44
Chloride	mg/l	6.84	10.76	10.53	8.81	2.94	3.91	6.85	4.89	5.87	4.87	7.83	15.65	2.94-15.65	7.48	3.55
COD	mg/l	53	28.52	15.84	46.72	49.28	31	26.88	24.84	42.32	31.2	36.48	49	15.84-53	36.26	11.70
Conductivity	µs/cm	51	56	50	53	50	51	51	53	56	70	74	85	50-85	58.33	11.52
Dissolved O_2 (DO)	mg/l	7.2	7.8	6.9	8.2	7.8	8.2	7.8	6.8	7.8	6.9	6.9	6.8	6.8-8.2	7.43	0.56
Fecal Coliform	MPN/ 100ml	2700	9000	8000	2200	2600	5000	2600	2200	2200	2100	1100	1700	1100-9000	3450.00	2540.76
Magnesium	mg/l	3.46	3.46	2.88	1.73	0.58	1.15	1.73	1.73	2.3	1.15	2.3	4.61	0.58-4.61	2.26	1.16
Nitrate-N	mg/l	0.008	0.02	0.008	0.05	0.02	0.007	0.007	0.02	0.008	0.005	0.19	0.68	0.005-0.68	0.09	0.19
pH	Unit	7.35	7.16	7.2	7.32	7.28	7.38	7.2	7.22	7.23	7.13	7.22	7.58	7.13-7.58	7.27	0.12
Phosphate-P	mg/l	0.055	0.051	0.042	0.031	0.039	0.033	0.035	0.057	0.007	0.041	0.029	0.123	0.007-0.123	0.05	0.03
Potassium	mg/l	<1.0	<1.0	<1.00	0.78	<1.00	<1.00	1	1	1	1	2	1	0.78-2	1.11	0.40
Sodium	mg/l	1.813	2.86	2.35	4.43	<1.00	1.35	2.75	2.75	1.34	2.35	3.29	4.37	1.34-4.43	2.70	1.04
Sulphate	mg/l	16.33	2.54	3.49	1.41	0.74	1.74	1.82	0.75	0.92	0.94	0.79	0.45	0.45-16.33	2.66	4.39
Temperature	^0C	30	31	34	35	28	26	26	22	24	30	29	30	22-35	28.75	3.82
Total Alkalinity	mg/l	20	24	24	28	24	24	26	18	22	42	36	30	18-42	26.50	6.78
Total Coliform	MPN/ 100ml	13000	16000	14000	8000	11000	11000	8000	6000	5000	6000	5000	7000	5000-16000	9166.67	3737.61
Total Dissolved Solids(TDS)	mg/l	63	92	90	65	82	64	78	48	75	75	111	47	47-111	74.17	18.43
Total Fixed Solids(TFS)	mg/l	68	32	16	16	32	16	22	12	54	20	16	30	12-68	27.83	17.17
Total Hardness as $CaCO_3$	mg/l	26	28	32	40	20	20	24	22	26	24	32	46	20-46	28.33	7.99
Total Suspended Solids(TSS)	mg/l	42	54	88	78	158	42	24	16	44	44	22	146	16-158	63.17	46.57
Turbidity	NTU	13.8	10.4	5.24	3.46	3.65	3.75	4.34	6.28	4.27	6.12	5.61	22.3	3.46-22.3	7.44	5.60

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

Table 1d: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal

Year		2014							2015					Range	Mean	Standard Deviation
Parameters	Unit	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May			
BOD	mg/l	4.5	1.7	2.8	2.1	2.6	2.2	2.4	2.6	1.6	3	1.8	2.4	1.6-4.5	2.48	0.77
Calcium	mg/l	9.6	10.92	6.72	10.08	8.4	6.72	5.92	11.2	12	11.16	11.21	10.42	5.92-12	9.53	2.08
Chloride	mg/l	3.91	4.89	10.76	7.82	3.91	7.83	6.85	4.99	7.83	4.89	16.75	4.89	3.91-16.75	7.11	3.66
COD	mg/l	41	35.36	24	22.08	44.16	28.56	18.32	24	41.28	33.16	37.44	55.12	18.32-55.12	33.71	10.80
Conductivity	µs/cm	67	69	70	66	60	71	62.7	65			92	98.8	60-98.8	72.15	12.79
Dissolved O_2 (DO)	mg/l	6.8	7.4	7.5	7.2	7.4	7.4	8.7	7.2	6.8	8.2	7.4	7.9	6.8-8.7	7.49	0.55
Fecal Coliform	MPN/ 100ml	1300	1700	9000	5000	1700	1400	2600	2700	1400	1700	1300	1700	1300-9000	2625.00	2260.78
Magnesium	mg/l	1.73	2.42	3.63	2.27	3.02	1.81	4.26	0.58	1.15	0.54	0.96	4.32	0.54-4.32	2.22	1.34
Nitrate-N	mg/l	0.05	0.02	BDL	NT	0.09	0.006	NT	0.007	0.004	NT	0.003	0.02	0.003-0.09	0.03	0.03
pH	Unit	7.6	7.12	6.96	7.57	7.33	7.89	7.75	7.56	7.49	8.8	8.5	8.73	6.96-8.8	7.78	0.60
Phosphate-P	mg/l	0.239	0.587	0.019	0.013	0.027	0.027	0.056	0.038	0.027	0.029	0.025	0.045	0.013-0.587	0.09	0.17
Potassium	mg/l			1	1	1	1	1	1	1	1	1	BDL	1-1	1.00	0.00
Sodium	mg/l		2.86	2	3	3	2.75	3	3	3.36	3	3.36	2.35	2-3.36	2.88	0.40
Sulphate	mg/l	0.68	2.17	3.38	2.5	3.71	0.14	0.66	0.97	1.94	0.95	1.67	1.09	0.14-3.71	1.66	1.12
Temperature	^{0}C	32	32	33	30	28	29	27	24	29	28	32	32	24-33	29.67	2.67
Total Alkalinity	mg/l	36	38	44	34	40	31.5	38	36	34	40	42	44	31.5-44	38.13	4.02
Total Coliform	MPN/ 100ml	8000	4000	14000	11000	7000	5000	7000	9000	8000	9000	7000	8000	4000-14000	8083.33	2609.71
Total Dissolved Solids(TDS)	mg/l	49	49	91	93	44	84	61	37	61	77	45	84	37-93	64.58	20.21
Total Fixed Solids(TFS)	mg/l	18	20	14	10	8	8	12	10			6	68	6-68	17.40	18.33
Total Hardness as $CaCO_3$	mg/l	30	35.7	29.4	23.1	31.5	23.1	29.6	30	34	30	32	44	23.1-44	31.03	5.51
Total Suspended Solids(TSS)	mg/l	24	57	46	56	16	38	56	22	24	28	64	25	16-64	38.00	16.92
Turbidity	NTU	4.57	10.2	3.44	6.16	8.27	4.67	8.76	7.07	6.58	6.14	9.12	14.1	3.44-14.1	7.42	2.91

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

Table 1e: Monthly Fluctuation of Different Bio-Physico-Chemical Parameters in Sagardighi of Cooch Behar, West Bengal

Year		2015							2016					Range	Mean	Standard Deviation
Parameters	Unit	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May			
BOD	mg/l	2.4	1.7	2	2.5	2.8	3.9	3.1	1.7	1.6	2	2.3	1.4	1.4-3.9	2.28	0.72
Calcium	mg/l	9.62	12.83	27.25	10.42	16.03	15.23	16.83	11.22	12.02	15.23	10.42	12.02	9.62-27.25	14.09	4.79
Chloride	mg/l	6.84	10.76	4.89	13.69	7.83	17.61	13.69	12.72	9.78	9.78	2.93	1.96	1.96-17.61	9.37	4.71
COD	mg/l	46.8	19.76	25	33	22	27.84	34.56	31	23	39	60.48	62.4	19.76-62.4	35.40	14.37
Conductivity	µs/cm	86.6	87.18	86.6	79.81	87.74	77.12	68.89	66.97	73.42	84.51	85.19	80.1	66.97-87.74	80.34	7.32
Dissolved O_2 (DO)	mg/l	7.1	7.9	6.8	8	8.6	8.8	8.7	7.3	7	8	8.7	7.9	6.8-8.8	7.90	0.71
Fecal Coliform	MPN/ 100ml	2200	800	2200	2700	3300	14000	2600	2100	6000	1200	1100	800	800-14000	3250.00	3670.65
Magnesium	mg/l	3.84	0.56	2.8	4.48	6.16	1.73	5.18	5.76	1.73	5.18	4.03	5.18	0.56-6.16	3.89	1.80
Nitrate-N	mg/l	BDL	0.01	0.02	0.04	0.07	0.1	0.05	0.09	0.13	0.06	0.1	0.12	0.01-0.13	0.07	0.04
pH	Unit	8.79	8.73	7.31	8.33	7.86	7.6	8.6	7.7	8.45	8.62	9.54	8.75	7.31-9.54	8.36	0.63
Phosphate-P	mg/l	0.139	0.029	0.027	0.089	0.114	0.083	0.184	0.023	0.055	0.047	0.12	0.015	0.015-0.184	0.08	0.05
Potassium	mg/l	2	2	1	1	1	BDL	BDL	2	1	2	BDL	BDL	1-2	1.50	0.53
Sodium	mg/l	3	5	3	3	3	BDL	1	4	3.36	3.36	3	5	1-5	3.34	1.10
Sulphate	mg/l	2.96	2.13	4.29	4.38	5.49	4.08	5.16	6.56	BDL	6.12	0.88	2.38	0.88-6.56	4.04	1.78
Temperature	^{0}C	32	34	30	33	31	30	26	22	26	30	34	30	22-34	29.83	3.59
Total Alkalinity	mg/l	46	42	52	46	60	46	48	34	62	48	40	44	34-62	47.33	7.83
Total Coliform	MPN/ 100ml	11000	3000	5000	7000	5000	33000	7000	6000	17000	3300	2600	3300	2600-33000	8600.00	8702.25
Total Dissolved Solids(TDS)	mg/l	70	49	35	59	84	41	64	73	91	93	90	23	23-93	64.33	23.48
Total Fixed Solids(TFS)	mg/l	4	30	20	160	10	12	26		54	86	18	6	4-160	38.73	46.92
Total Hardness as $CaCO_3$	mg/l	48	34	78	42	62	36	60	48	36	56	40	48	34-78	49.00	13.06
Total Suspended Solids(TSS)	mg/l	48	22	24	38	52	20	84	28	26	94	22	20	20-94	39.83	25.42
Turbidity	NTU	24.3	6.28	10.2	11.4	4.18	11.5	7.18	5.04	3.11	10.2	8.39	10.4	3.11-24.3	9.35	5.51

Source: West Bengal Pollution Control Board. BDL= Below Detectable Level

Table 2: Correlation Matrix of Bio-Physico-Chemical Parameters of Sagardighi of Cooch Behar, West Bengal

Parameters	BOD	Calcium	Chloride	COD	Conductivity	Dissolved O2(DO)	Fecal Coliform	Magnesium	Nitrate-N	pH	Phosphate-P	Potassium	Sodium	Sulphate	Temperature	Total Alkalinity	Total Coliform	Total Dissolved Solids(TDS)	Total Fixed Solids(TFS)	Total Hardness as CaCo3	Total Suspended Solids(TSS)	Turbidity
BOD	1	-0.273	-0.142	0.148	-0.271	0.319	-0.212	-0.120	0.122	0.002	-0.075	-0.098	0.160	-0.082	-0.063	-0.318	-0.062	0.208	0.000	-0.273	0.151	0.136
Calcium		1	0.340	-0.098	0.563	-0.049	-0.133	0.378	0.041	0.229	0.130	-0.023	0.043	0.172	0.029	0.748	-0.215	-0.247	0.029	0.883	-0.013	-0.087
Chloride			1	-0.219	0.440	-0.042	-0.014	0.166	0.219	0.084	0.047	0.142	0.013	0.184	0.040	0.339	-0.028	-0.030	0.232	0.305	0.187	-0.002
COD				1	0.069	0.025	-0.264	0.191	0.027	0.063	0.034	0.011	-0.152	0.009	0.031	-0.158	-0.264	-0.098	0.098	-0.009	0.120	0.647
Conductivity					1	-0.178	-0.303	0.247	0.189	0.484	0.165	0.195	0.106	-0.054	0.259	0.686	-0.328	-0.056	0.121	0.527	0.038	0.028
Dissolved O_2 (DO)						1	0.229	0.269	-0.012	0.133	-0.023	-0.036	0.251	0.092	-0.295	0.027	0.114	-0.008	0.075	0.071	-0.099	0.093
Fecal Coliform							1	-0.024	0.252	-0.382	-0.128	-0.042	0.011	-0.017	0.097	-0.131	0.877	-0.067	-0.151	-0.091	-0.112	0.092
Magnesium								1	0.142	0.171	0.057	0.057	-0.045	0.370	-0.057	0.448	-0.109	-0.161	0.151	0.698	0.060	0.277
Nitrate-N									1	-0.015	0.028	0.051	0.392	-0.155	0.082	-0.004	0.112	-0.084	-0.073	0.081	0.322	0.167
pH										1	0.019	0.297	0.157	0.057	0.107	0.404	-0.229	0.060	0.215	0.232	-0.035	-0.113
Phosphate-P											1	0.067	-0.116	-0.010	0.088	0.143	-0.123	-0.137	-0.006	0.125	0.028	0.062
Potassium												1	0.218	0.257	-0.197	0.053	0.166	0.348	0.127	0.048	0.011	0.043
Sodium													1	-0.071	-0.062	0.128	-0.132	-0.025	-0.102	0.031	-0.132	-0.205
Sulphate														1	0.006	0.146	-0.049	0.152	0.240	0.286	-0.085	0.001
Temperature															1	0.017	0.090	0.127	-0.049	0.016	0.141	0.115
Total Alkalinity																1	-0.215	-0.138	0.093	0.763	-0.143	-0.185
Total Coliform																	1	0.164	-0.040	-0.198	-0.034	0.127
Total Dissolved Solids(TDS)																		1	0.033	-0.232	0.060	-0.167
Total Fixed Solids(TFS)																			1	0.087	0.030	0.060
Total Hardness as $CaCO_3$																				1	0.010	0.074
Total Suspended Solids(TSS)																					1	0.104
Turbidity																						1.000

(Values are shown as r = coefficient correlation)

CONCLUSION

The bio-physico-chemical parameters of Sagardighi are within the tolerance limits except pH, COD, Turbidity, Total Coliform and Fecal Coliform. Among them, value of COD, Total Coliform and Fecal Coliform were always above permissible limit. Therefore, we generally say that the water quality of Sagardighi is moderately suitable for bathing and swimming as well as for the growth of aquatic fauna and flora. However, fluctuations in bio-physico-chemical parameters, if they continue, would result in imbalance in the ecosystem in long run. After detailed study of bio-physico-chemical data of Sagardighi for five years (2011-2016), it is revealed that water quality is comparatively in moderate condition but almost all the parameters are prone to cross their critical pollution level. Therefore an urgent effort must be taken to develop ecosystem-based management strategies with inputs from scientists, resource managers, policy makers, government and non-government organizations and environmentalist to save this heritage water-body.

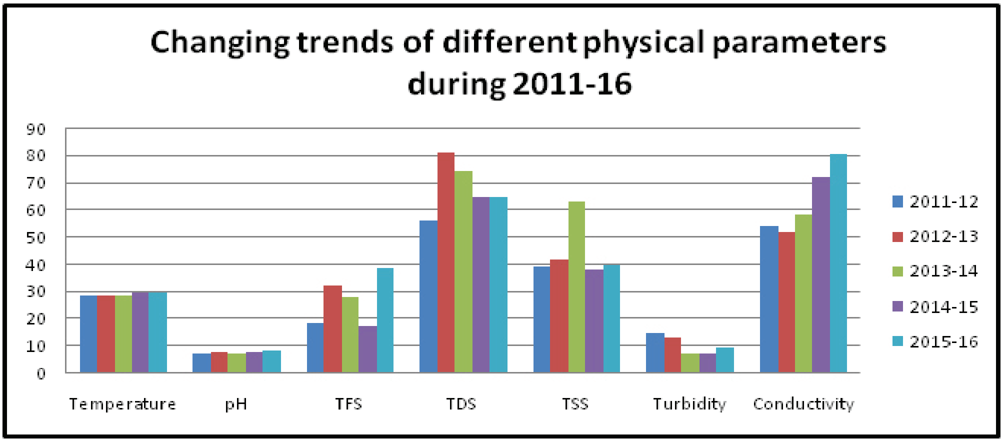

Figure 2: Changing Trends of Different Physical Parameters (Yearly Mean) of Sagardighi of Cooch Behar, West Bengal (2011-16)

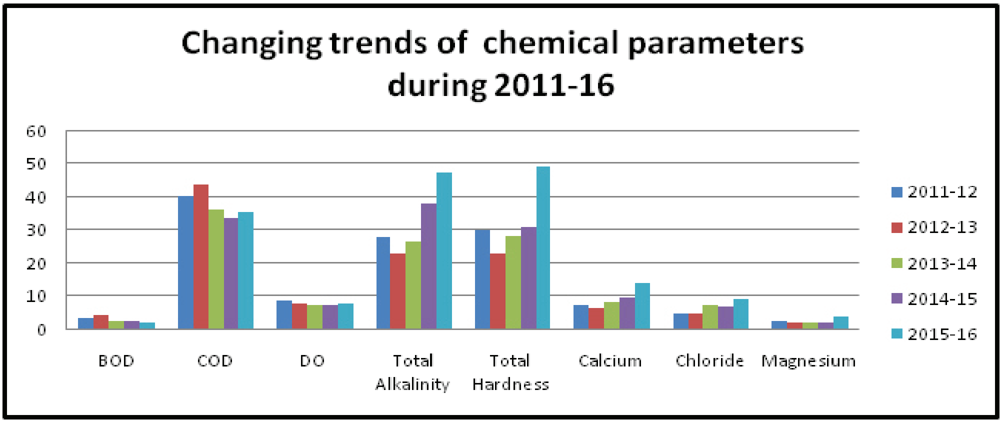

Figure 3: Changing Trends of Different Chemical Parameters (Yearly Mean) of Sagardighi of Cooch Behar, West Bengal (2011-16)

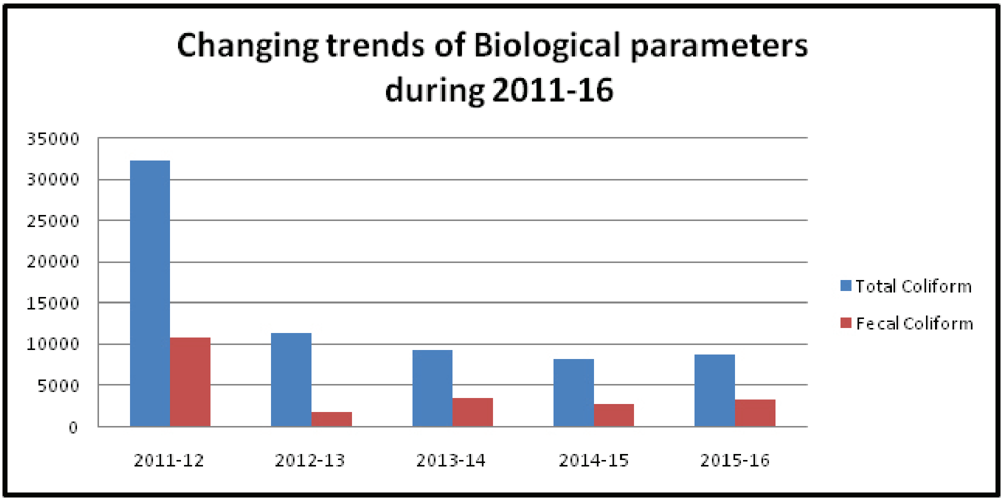

Figure 4: Changing Trends of Different Biological Parameters (Yearly Mean) of Sagardighi of Cooch Behar, West Bengal (2011-16)

Table 3: Changing Trends of Different Bio-Physio-chemical Parameters (Yearly Mean) of Sagardighi of Cooch Behar, West Bengal (2011-16)

Parameters	**Mean**						**Standard Deviation**
	Unit	2011-12	2012-13	2013-14	2014-15	2015-16	
BOD	mg/l	3.42	4.42	2.85	2.48	2.28	0.860755
Calcium	mg/l	7.49	6.58	8.2	9.53	14.09	2.949876
Chloride	mg/l	4.78	4.79	7.48	7.11	9.37	1.951904
COD	mg/l	40.02	43.77	36.26	33.71	35.4	4.044251
Conductivity	µs/cm	53.79	51.75	58.33	72.15	80.34	12.42199
Dissolved O_2 (DO)	mg/l	8.73	8.03	7.43	7.49	7.9	0.522858
Fecal Coliform	MPN/100ml	10750	1750	3450	2625	3250	3630.238
Magnesium	mg/l	2.85	2.42	2.26	2.22	3.89	0.695895
Nitrate-N	mg/l	0.12	0.02	0.09	0.03	0.07	0.041593
pH	Unit	7.28	7.88	7.27	7.78	8.36	0.456815
Phosphate-P	mg/l	0.05	0.05	0.05	0.09	0.08	0.019494
Potassium	mg/l	1.08	1.4	1.11	1	1.5	0.218449
Sodium	mg/l	3.64	2.74	2.7	2.88	3.34	0.412068
Sulphate	mg/l	2.22	2.93	2.66	1.66	4.04	0.889112
Temperature	^{0}C	28.58	28.58	28.75	29.67	29.83	0.616336
Total Alkalinity	mg/l	27.77	22.92	26.5	38.13	47.33	10.02211
Total Coliform	MPN/100ml	32141.67	11308.33	9166.67	8083.33	8600	10293.15
Total Dissolved Solids(TDS)	mg/l	56.25	80.92	74.17	64.58	64.33	9.594407

Total Fixed Solids(TFS)	mg/l	18.67	32.33	27.83	17.4	38.73	9.058688
Total Hardness as $CaCO_3$	mg/l	29.94	23.13	28.33	31.03	49	9.82244
Total Suspended Solids(TSS)	mg/l	39	41.83	63.17	38	39.83	10.60562
Turbidity	NTU	14.79	13.16	7.44	7.42	9.35	3.377465

FUTURE SCOPE

On the basis of our present observation and detailed data base of important bio-physico-chemical characteristics of Sagardighi of Cooch Behar, West Bengal, India, we feel that further time-series analysis of quality of water of this water body and a detailed study of these parameters should be conducted.

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Research Article

ASSESSMENT OF WATER QUALITY INDEX (WQI) AND SUITABILITY OF SAGAR DIGHI, KOCH BIHAR, WEST BENGAL, INDIA

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Abstract

The aim of the study was to find out the Water Quality Index (WQI) of Koch Bihar Lake or Sagar Dighi in order to assess its suitability for drinking, bathing and swimming purposes. Water sample were collected in three bottles, two glass bottles with the capacity of 100 ml each and one large PVC (1 litter capacity) bottle for laboratory analysis. Total 20 bio-physico-chemical parameters were used for WQI calculation for drinking purpose and six physico-chemical parameters were used for WQI calculation for bathing and swimming purposes. The calculation of the WQI was done using weighted arithmetic water quality index which was originally proposed by Horton (1965) and developed by Brown et al (1972). The WQI of Sagar Dighi obtained for drinking and Bathing/ recreational use indicates Unsuitable for drinking and poor quality for humans uses respectively. We therefore strongly recommend that an urgent effort must be taken to develop ecosystem-based management strategies.

Key words: Bio-Physico-Chemical Parameters, Weighted Arithmetic Index Method, Water Quality, Water Quality Index, Sagar Dighi.

INTRODUCTION

The district of Koch Bihar is situated in the Himalayan Tarai Region of West Bengal. A number of artificial wetlands (ponds) are present in Koch Bihar town, most of which were created at the time of 'Koch dynasty' for drinking water. The most important is Sagar Dighi which situated in the middle of the town. Now it is used by surrounding dwellers and daily workers of the town for bathing, swimming, washing and other domestic purposes. Runoff from surrounding, solid waste by the visitor and tourist directly disposes to this pond. As a result the Water quality of the pond water is gradually changing. So the monitoring of water quality is very essential. Water quality refers to the different physical, chemical and biological characteristics of water [13]. Evaluating the water quality from a large number of samples, each containing concentrations for many parameters is very difficult [2]. A water quality index (WQI) summarizes large amounts of water quality data into simple terms (e.g., excellent, good, bad, etc.) for reporting to managers and the public in a consistent manner [4]. A water quality index provides a single numerical value that expresses overall water quality at a certain location and time, based on several water quality parameters. In general WQI can give an indication of water health. The objective of the study therefore was to calculate the Water Quality Index (WQI) of Sagar Dighi in order to assess its suitability for drinking, bathing and swimming.

Materials and Methods:

Description of Study Area:

Koch Bihar Lake or Sagar Dighi is selected for study. It is the most important freshwater body which is situated in the heart of Koch Behar town. It extends between 26°19'12''N to 26°19'21''N and 89°26'21''E to 89°26'28''E and the total surface area of this lake is 14.60 hectare which was excavated by Maharaja Harendra Narayan in 1807 AD. It commonly attracts various migratory birds in the winter season. Among all ponds in Koch Bihar town the most spectacular is Sagar Dighi, with grand structures arrayed all around it. These buildings, built mostly between 1880 to 1920, are now offices of the district administration like Office of the District Magistrate, Administrative Building of North Bengal State Transport Corporation, BSNL Office on the West; Office of the Superintendent of Police, District Library, Municipality Building on the South, Office of the BLRO, Sate Bank of India (Cooch Behar Main Branch) etc on the East and RTO office, Foreigner's enrollment office, District Court and so on the North. Although this lake was excavated for drinking water supply and flood control, now it is used for bathing, swimming, washing clothes, fishing, morning and evening walk around the lake, resting or gossiping place, boating etc.

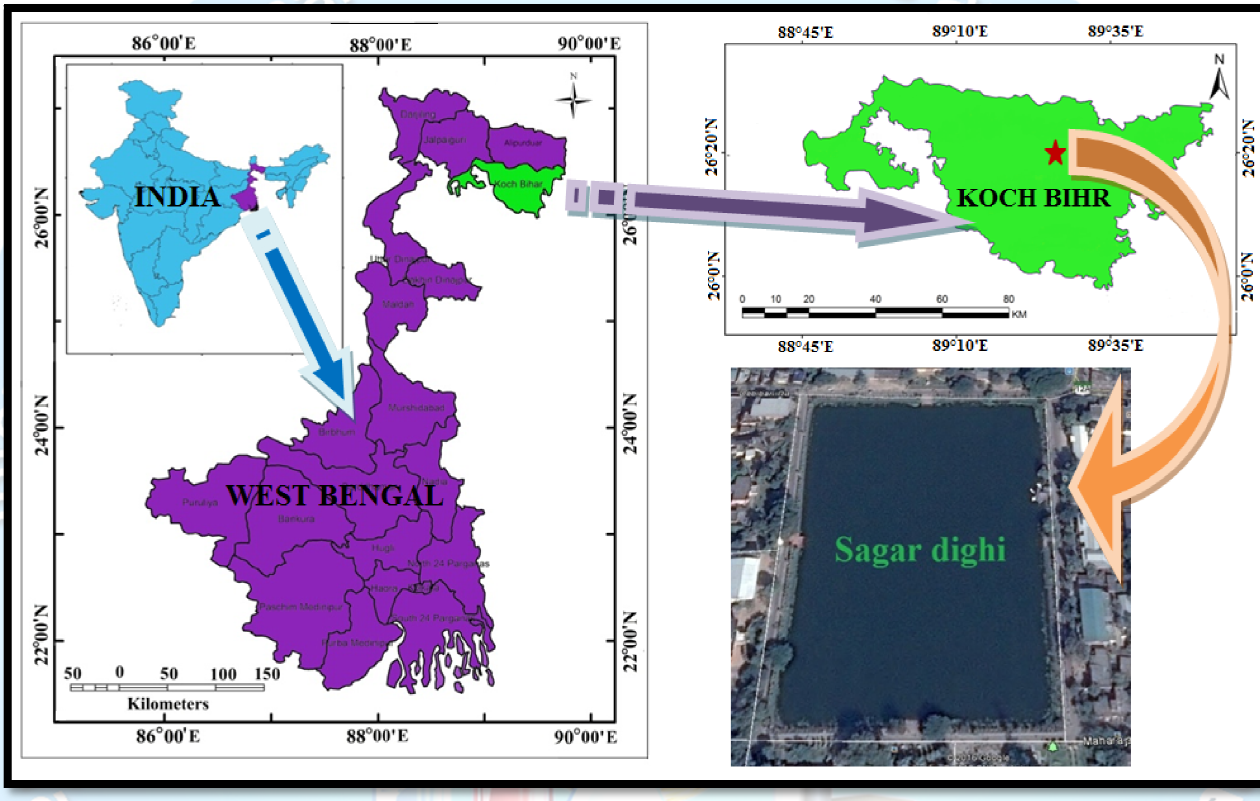

Fig1: locational map of sagar dighi.

Mode of Study:

Water Quality Parameter data is derived by three modes. Water PH, Total dissolved solids, Electrical Conductivity are measured in situ by digital instrument. Dissolved O2(DO) , BOD, FREE CO_2,Chloride ,Total Hardness , Bicarbonate, Total Alkalinity are analysed from collected water sample in laboratory and other Water Quality Parameter are collected from secondary source i.e. West Bengal Pollution Control Board. (Table-1).

Sample Collection: Water samples were collected in 2nd weak of pre-monsoon (June, 2017) and post-monsoon (September, 2017) period from selected site of the study area. Collection of samples took place within 9:30 am by dipping well labeled sterilized plastic and glass containers at the approximate depth of 1.00 ft. All water sample were collected in three bottles , two glass bottles sinking it in the water carefully and slowly so that no air bubbles were introduced with the capacity of 100 ml each (among them in one glass bottle 2ml of $MnSO_4$ followed by 2ml alkaline iodide solution is added)and one large PVC (1 litter capacity) bottle. Physicochemical parameters were analysed in the laboratory in the same day as early as possible except BOD.

Water Analysis Methods:

Physical and chemical analysis of the samples was done according to Standard Methods as per APHA[3], 1995. Methods used and Source of Data for physical and chemical analyses of water are shown in below mentioned in Table 1.

Water quality Standards:

The values obtained were compared with standards prescribed by BIS[5], WHO[22] and CPCB[18]. The following table reveals the parameters, with their units which are evaluated, in water samples. The water quality index is calculated by using the standard of drinking water and Bathing/ Recreational Use of Water quality prescribed by the World Health Organization, Bureau of Indian Standards and Central Pollution Control Board(Table 2). In calculation BDL (Below Detectable Level) treated as zero(0)

Water Quality Index Calculation:

A Water Quality Index (WQI) is a compilation of a number of parameters that can be used to determine the overall quality. In order to keep the health of any aquaculture system at an optimal level, certain water quality indicators or parameters must be monitored and controlled. A numbers of water quality indices have been formulated all over the world which can easily judge out the overall water quality within a particular area promptly and efficiently. For example, US National Sanitation Foundation Water Quality Index (NSFWQI) [5], Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI) [5], British Columbia Water Quality Index (BCWQI), and Oregon Water Quality Index (OWQI)[12, 17, 1].

Brown et al. (1970) developed a paying great rigor in selecting parameters, developing a common scale, and assigning weights for which elaborate Delphic exercises were performed [5]. This effort was supported by the National Sanitation Foundation (NSF) and that is why also referred as NSFWQI. This work seems to be the most comprehensive and has been discussed in various papers [8]. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose [10].

Here the calculation of the WQI was done using weighted arithmetic water quality index which was originally proposed by Horton (1965)[15] and developed by Brown et al (1972)[8] in the following form:

$WQI = \Sigma QiWi / \Sigma Wi$

Further, the quality rating scale (Qi) for each parameter is calculated according to Brown et al (1972)[8] by using the following equation:

$Qi = 100 \{(Va-Vi)/ (Vs-Vi)\}$

Where,

Va = actual value of the water quality parameter obtained from laboratory analysis.

Vi = ideal value of the water quality parameter can be obtained from the standard tables. All the ideal values (Vi) are taken as zero except pH and dissolved oxygen [16] For pH, the ideal value is 7.0 and for dissolved oxygen, the ideal value is 14.6 mg/l.

Vs = recommended standard value of i^{th} parameter.

The unit weight for each water quality parameter is calculated by a value inversely proportional to recommended standard (Vs) for the corresponding parameter using the following expression.

$Wi = K / Vs$

Wi is Unit weight of factor

K is proportionality constant.

Table 3 shows a classification of water quality, based on its quality index due to Brown et al (1972)[8], Chatterji and Raziuddin (2002) [9]etc.

Results and Discussions

Table 4, 5, 6 & 7 deals with calculation of the water quality index (WQI) of the of Sagar Dighi for drinking and Bathing/ recreational use of water in pre-monsoon period (June, 2017) and post-monsoon period (september, 2017) using the weighted arithmetic index formula as follows: $WQI = \Sigma QiWi / \Sigma Wi$.

Table:1 Mode of Water Quality Analysis

Sl. No	Parameters	Method Adopted/Instrument/Source of Data
1	Ammonia-N	WBPCB
2	BOD	Titrimetric Method (five days incubation)
3	Boron	WBPCB
4	Calcium	WBPCB
5	Chloride	Argent metric Method
6	COD	WBPCB
7	Conductivity	HM Digitals Aquapro digital water tester (Model AP-2)
8	Bi-carbonate	Titration Method
9	Dissolved O2(DO)	Winkler's Method
10	Fluoride	WBPCB
11	Magnesium	WBPCB
12	Nitrate-N	WBPCB
13	pH	HM Digitals pH Hydrotester (Model pH-80)
14	Sodium	WBPCB
15	Sulphate	WBPCB
16	Total Alkalinity	Titration Method
17	Total Coliform	WBPCB
18	Total Dissolved Solids(TDS)	HM Digitals Aquapro digital water tester (Model AP-1)
19	Total Hardness as CaCO3	Conventional titration method.
20	Turbidity	WBPCB

N.B.:WBPCB= West Bengal Pollution Control Board

Table 2. Standard for drinking water and Bathing/ recreational use of water.

Sl. No	Parameters	Unit	Drinking Water		Bathing/ Recreational Use of Water	
			Standard	Recommended Agency	Standard	Recommended Agency
1	Ammonia-N	mg/l	0.3	WHO	--	
2	BOD	mg/l	2	CPCB	3	CPCB
3	Boron	mg/l	0.3	BIS	--	
4	Calcium	mg/l	75	BIS	--	
5	Chloride	mg/l	250	BIS	600	CPCB
6	COD	mg/l	10	WHO	--	
7	Conductivity	µs/cm	300	ICMR (1975)	--	
8	Bi-carbonate	mg/l	244	BIS	--	
9	Dissolved O_2(DO)	mg/l	6	CPCB	5	CPCB
10	Fluoride	mg/l	1	BIS	1.5	CPCB
11	Magnesium	mg/l	30	BIS	--	
12	Nitrate-N	mg/l	45	BIS	--	
13	pH	Unit	6.5 - 8.5	BIS	6.5 - 8.5	CPCB
14	Sodium	mg/l	180	BIS	--	
15	Sulphate	mg/l	200	BIS	--	
16	Total Alkalinity	mg/l	200	BIS	--	
17	Total Coliform	MPN/100ml	50	CPCB	500	CPCB
18	Total Dissolved Solids(TDS)	mg/l	500	BIS	--	
19	Total Hardness as $CaCO_3$	mg/l	300	BIS	--	
20	Turbidity	NTU	5	BIS	--	

N.B.: (--): *not indicated.*

Table 3. Classification of water quality based on weighted arithmetic WQI method

WQI	STATUS
0 - 25	Excellent
26 - 50	Good
51 - 75	Poor
76 - 100	Very Poor
Above 100	Unsuitable for use

Source: Brown et al (1972), Chatterji and Raziuddin (2002)

Table 4: Calculation of Water Quality Index (WQI) of Sagar Dighi for drinking water in pre- monsoon period (June, 2017).

Sl. No	Parameter	Unit	Standard values (Vs)	Observed Value (Va)	Unit Weights (Wi)	Quality Rating (Qi)	WiQi
1	Ammonia-N	mg/l	0.3	0.347	0.375705816	115.6666667	43.45663939
2	BOD	mg/l	2	4.4	0.056355872	220	12.39829193
3	Boron	mg/l	0.3	0.011	0.375705816	3.666666667	1.377587992
4	Calcium	mg/l	75	8.02	0.001502823	10.69333333	0.01607019
5	Chloride	mg/l	250	14	0.000450847	5.6	0.002524743
6	COD	mg/l	10	25	0.011271174	250	2.817793621
7	Electrical Conductivity	µs/cm	300	75	0.000375706	25	0.009392645
8	Bi-carbonate	mg/l	244	18	0.000461933	7.37704918	0.003407705
9	Dissolved O2(DO)	mg/l	6	7.6	0.018785291	81.39534884	1.529035298
10	Fluoride	mg/l	1	BDL	0.112711745	0	0
11	Magnesium	mg/l	30	1.73	0.003757058	5.766666667	0.021665702
12	Nitrate-N	mg/l	45	0.43	0.002504705	0.955555556	0.002393385
13	pH(6.5-8.5)	Unit	6.5-8.5	8.8	0.013260205	120	1.591224633
14	Sodium	mg/l	180	4	0.000626176	2.222222222	0.001391503
15	Sulphate	mg/l	200	0.32	0.000563559	0.16	9.01694E-05
16	Total Alkalinity	mg/l	200	28	0.000563559	14	0.007889822
17	Total Coliform	MPN/100ml	50	14000	0.002254235	28000	63.1185771
18	Total Dissolved Solids(TDS)	mg/l	500	34	0.000225423	6.8	0.00153288
19	Total Hardness as CaCO3	mg/l	300	28	0.000375706	9.333333333	0.003506588
20	Turbidity	NTU	5	9.6	0.022542349	192	4.328131001
					Σ Wi=1		**Σ** WiQi=130.6871463
WQI = ΣQiWi /ΣWi=130.6871463							

N.B.: BDL= Below Detectable Level

Table 5 : Calculation of Water Quality Index (WQI) of Sagar Dighi for Bathing/ recreational use in pre-monsoon period (June, 2017).

SlNo	Parameter	Unit	Standard values (Vs)	Observed Value (Va)	Unit Weights (Wi)	Quality Rating (Qi)	WiQi
1	BOD	mg/l	3	4.4	0.252274178	146.6666667	37.0002127
2	Chloride	mg/l	600	14	0.001261371	2.333333333	0.002943199
3	Dissolved O_2(DO)	mg/l	5	7.6	0.151364507	72.91666667	11.03699527
4	Fluoride	mg/l	1.5	BDL	0.504548355	0	0
5	pH(6.5-8.5)	Unit	6.5-8.5	8.8	0.089037945	120	10.6845534
6	Total Coliform	MPN/100ml	500	14000	0.001513645	2800	4.238206182
					Σ Wi=1		Σ WiQi=62.96291075
WQI = ΣQiWi /ΣWi=62.96291075							

N.B.: BDL= Below Detectable Level

Table 6: Calculation of Water Quality Index (WQI) of Sagar Dighi for drinking water in post-monsoon period (september, 2017).

Sl. No	Parameter	Unit	Standard values (Vs)	Observed Value (Va)	Unit Weights (Wi)	Quality Rating (Qi)	WiQi
1	Ammonia-N	mg/l	0.3	BDL	0.375705816	0	0
2	BOD	mg/l	2	4.3	0.056355872	215	12.11651257
3	Boron	mg/l	0.3	0.006	0.375705816	2	0.751411632
4	Calcium	mg/l	75	9.62	0.001502823	12.82666667	0.019276213
5	Chloride	mg/l	250	20	0.000450847	8	0.003606776
6	COD	mg/l	10	22	0.011271174	220	2.479658386
7	Electrical Conductivity	μs/cm	300	63	0.000375706	21	0.007889822
8	Bi-carbonate	mg/l	244	14	0.000461933	5.737704918	0.002650437
9	Dissolved O2(DO)	mg/l	6	6.2	0.018785291	97.6744186	1.834842358
10	Fluoride	mg/l	1	0.14	0.112711745	14	1.577964428
11	Magnesium	mg/l	30	1.15	0.003757058	3.833333333	0.014402056
12	Nitrate-N	mg/l	45	0.38	0.002504705	0.844444444	0.002115085
13	pH(6.5-8.5)	Unit	6.5-8.5	8.2	0.013260205	80	1.060816422
14	Sodium	mg/l	180	2.51	0.000626176	1.394444444	0.000873168
15	Sulphate	mg/l	200	1.18	0.000563559	0.59	0.0003325
16	Total Alkalinity	mg/l	200	22	0.000563559	11	0.006199146
17	Total Coliform	MPN/100ml	50	11000	0.002254235	22000	49.59316772
18	Total Dissolved Solids(TDS)	mg/l	500	28	0.000225423	5.6	0.001262372
19	Total Hardness as CaCO3	mg/l	300	22	0.000375706	7.333333333	0.002755176
20	Turbidity	NTU	5	13.1	0.022542349	262	5.906095429
					Σ Wi=1		Σ WiQi=75.3818317
WQI = ΣQiWi /ΣWi=75.3818317							

N.B.: BDL= Below Detectable Level

Table 7: Calculation of Water Quality Index (WQI) of Sagar Dighi for Bathing/ recreational use of water in post-monsoon period (september, 2017).

Sl. no	Parameter	Unit	Standard values (Vs)	Observed Value (Va)	Unit Weights (Wi)	Quality Rating (Qi)	WiQi
1	BOD	mg/l	3	4.3	0.252274178	143.3333333	36.15929878
2	Chloride	mg/l	600	20	0.001261371	3.333333333	0.00420457
3	Dissolved O_2(DO)	mg/l	5	6.2	0.151364507	87.5	13.24439432
4	Fluoride	mg/l	1.5	0.14	0.504548355	9.333333333	4.70911798
5	pH(6.5-8.5)	Unit	6.5-8.5	8.2	0.089037945	80	7.1230356
6	Total Coliform	MPN/100ml	500	11000	0.001513645	2200	3.330019143
					Σ Wi=1		**Σ**WiQi=64.57007039
WQI = **Σ**QiWi /**Σ**Wi=64.57007039							

N.B.: BDL= Below Detectable Level

The water quality Index for drinking obtained water in pre-monsoon (June, 2017) and post-monsoon (September, 2017) period are130.6871463 (Table 4) and 75.3818317 (Table 6) respectively. The water quality Index value (130.69) of June, 2017 indicates the Unsuitable for drinking and WQI (75.38) of September, 2017 indicate poor quality for human uses and must therefore be treated before use to avoid water related diseases.

The water quality Index for Bathing/ recreational use obtained in pre-monsoon (June, 2017) and post-monsoon (September, 2017) period are 62.96291075(Table 5) and 64.57007039(Table 7) respectively which indicate poor quality for humans uses.

Conclusion:

During the study, it is observed that the water quality of Sagar Dighi for drinking water in pre-monsoon period become unsuitable than post-monsoon period. We concluded that the water is not fit for drinking purpose without treatment (filtration, disinfection etc). Suitability of water quality for Bathing/ recreational use is become poor in post-monsoon period than pre-monsoon period. The Study show that the water of the Sagar Dighi is deteriorated very badly due to the addition of urban sewage, anthropogenic activities like washing, Bathing etc. Therefore an urgent effort must be taken to develop ecosystem-based management strategies with inputs from scientists, resource managers, policy makers, government and non-government organizations and environmentalist.

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