ASSESSMENT OF WETLAND RESOURCES IN MALDA DISTRICT AND ITS CONSERVATION FOR SUSTAINABLE MANAGEMENT

A Thesis submitted to the University of North Bengal

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In

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By

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December, 2019

DEDICATED TO MY PARENTS

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DECLARATION

This thesis is a presentation of my original research work. I hereby declare that the thesis entitled "**ASSESSMENT OF WETLAND RESOURCES IN MALDA DISTRICT AND ITS CONSERVATION FOR SUSTAINABLE MANAGEMENT**" has been carried out as well as prepared by me under the guidance of Prof. Subir Sarkar, Department of Geography and Applied Geography, University of North Bengal. I ensure that, no part of this thesis has been submitted elsewhere for the award of any degree or fellowship previously.

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CERTIFICATE

This is to certify that, Diyali Chattaraj has prepared the thesis entitled "**ASSESSMENT OF WETLAND RESOURCES IN MALDA DISTRICT AND ITS CONSERVATION FOR SUSTAINABLE MANAGEMENT**" for the award of Ph. D degree in Geography and Applied Geography of University of North Bengal under my guidance. She has carried out the research work at the Department of Geography and Applied Geography, University of North Bengal. The thesis has been prepared, based on extensive field study, for the collection of primary data and secondary sources of information. Neither, the thesis as a whole, nor any part of it has previously been submitted elsewhere by the candidate for the award of any degree or fellowship.

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PREFACE

Wetlands are intrinsically considered a beautiful natural resource within the Earth's complex environment, which sustains human being and other life process. Malda district in the state of West Bengal, India is conspicuously occupied by large number of wetlands, which play key role in hydrological and ecological functioning of the region as well as maintain a crucial habitat for many plant and animal species. Human benefits from the wetlands emerge in the form of provisioning (food, fibre, fresh water), regulating (flood control, water storage, waste treatment) supporting (soil formation, nutrient cycling) and cultural (aesthetic value, education, recreation) services. This significant entity of Earth's environmental system (wetlands) are impacted by human assault, in the form of water quality degradation from agricultural run-off and solid waste dumping into wetland; land use land cover alteration surrounding wetlands, wetland encroachment and resultant area shrinkage; uncontrolled exploitation of surface and ground water and wetland resources etc. The wetlands under study encounter practically every problem that a wetland system can encounter. As a consequence, wetlands are being disrupted, triggered by modern human development in Malda district. The present work attempts to analyse the conservation ethics to wetland ecosystem and recommends scientific understanding on how wetlands work and what services they provide. An attempt has also been made, to advocate sound management policies in order to enhance this rare and even unique ecosystem with special reference on its wise use and sustainable management as a part of the larger effort to our sustainable earth.

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ABSTRACT

Assessment of Wetland Resources in Malda District and Its Conservation for Sustainable Management

Wetlands are formed at the interface of the terrestrial and aquatic ecosystem and comprise the characteristics of both. Wetlands are considered one of the most productive habitats on the Earth, to support diverse kinds of life processes. The present study has been conducted in Malda district (24°40′20″ N to 25°32′08″ N latitudes and 87°45′50″ E to 88°28′10″ E longitudes), which facilitates the formation of different categories of wetlands (natural and man-made) with having unique fluvio-geomorphic set-up. The present work is an attempt to assess the wetland resources in Malda district and its conservation through wise use in order to achieve the sustainable management. Therefore, the following objectives are set:

1. Mapping of wetlands of Malda district and to monitor their behavior for the development of innovative estimation measures.
2. Classification of wetlands and estimating the geographical extent of the different types and identifying the representative wetlands for detail analysis.
3. Survey and estimate the utilization of wetlands for agriculture, aquaculture, coir rotting, gathering fruits and fiber etc. and ascertaining their socio-economic impact.
4. Preparing an inventory of flora and fauna as well as estimate the potential for wildlife vis-à-vis aesthetic and recreational uses i.e., eco-tourism activities.
5. To study the potentialities of these wetlands to provide alternative economic support to rural people through generation of gainful self-employment.
6. Impact assessment of various anthropogenic activities in wetlands to understand the various degradation processes in Malda district.
7. Planning for the conservation and appropriate management technologies of the wetland on sustainable basis.

In the present study, in order to fulfil the mentioned objectives, the methodology and database have been obtained by the researcher, which comprise geomorphological, hydrological, meteorological, biological and anthropogenic inputs. The entire study is based on both the primary data and secondary sources and information.

As per the Institute of Wetland Management and Ecological Design (IWMED, 2000) and Space Application Centre (ISRO, 2010) Malda district is occupied by a total of 562 and 502 no. of wetlands (each with $\geq$2.25 ha) respectively, in which, natural classes are mostly dominant. Wetlands of Malda district are considered the most important resources as well as play a key role in hydrological, biological and ecological functioning of the region. Here, the wetlands cover different proportion of area in three distinct physiographic divisions; namely *Tal*, (north and north-west), *Diara* (south and south-west) and *Barind* (east) depending on the existing geological and hydrological characteristics. Most of the wetlands are directly or indirectly linked with the major river systems of Malda district; namely Mahananda, Kalindri, Fulahar and Tangan. However, out of the total no. of wetlands, 4 have been selected as case studies on the basis of three selection criteria (different categories of wetlands, degree of human interference and resultant encroachment of wetland area and agro-economic and biologic potentials of wetlands) namely; Siali wetland, Chakla wetland, Naghoria wetland and Chatra wetland for further detail analysis. The area coverage of case studies vary from 18 ha to 850 ha and the water depth vary from 1.5 m during pre-monsoon to more than 3.0 m in several pockets of wetlands during monsoon and post-monsoon period.

In order to prepare the inventory of biotic components (macrophytes, icthyofauna, aquatic fauna and avifauna) within wetlands, of Malda district, field study has been conducted during March 2016 to February 2017. Diverse assemblage of aquatic macrophytes, with a total of 21 species, belonging to 21 genera and 17 families namely; *Centella asiatica, Enydra fluctuans, Eclipta alba hassk, Polycarpon prostratum, Heliotropium indicum* under emergent (growth form) water edge (habitat); *Hygrophilia auriculata*, *Ipomoea aquatic*, *Marsilea Quadrifolia* under semi-emergent water edge; *Aeschynomene aspera, Hydrilla verticillata, Potamogeton perfoliatus* etc. under open water submerged rooted; *Nelumbo nucifera*, *Nymphaea nouchali, Euryale ferox* etc. under open water rooted floating leaved; *Pistia stratiotes, Eichhornia crassipes* under free floating open water macrophytes etc. have been collected, photographed and identified with the help of “Plant systematics” of Simpson (2010) and “Plant systematics: An Integrated Approach” of Singh (2016). The dominant growth form is found emergent (28.57%), followed by free floating and rooted floating leaved (19.05%), semi-emergent and submerged rooted (14.29%). In the present study, the wetlands indicate rich icthyofaunal diversity with a total of 24 species, belonging to 21 genera and14 families. The icthyofaunal species namely; *Arius arius*, *Mystus tengara*, *Clarias batrachus*, *Labeo bata*, *Labeo catla*, *Labeo calbasu*, *Labeo rohita*, *Cirrhinus* *cirrhosis*, *Heteropneustes fossils*, *Trichogaster chuna*, *Wallago attu* etc. have been identified by the standard key of "The freshwater fishes of India….A Handbook" by K.C. Jayaram (1981). Cyprinidae is found as the most dominant and diversified family containing 11 species (45.8%). Apart from the fish fauna, aquatic fauna namely; *Teuthowenia pellucida*, *Lumbricus terrestris* etc. have also been found during field study. Moreover, the wetlands, under study are proved to be an important feeding and breeding ground for a total of 32 no. of avifaunal species, belonging to 27 genera and 17 families. The bird species namely; *Halcyon pileata*, *Alcedo atthis*, *Anas paltyrhynchos*, *Bubulcus ibis*, *Ardea alba*, *Egretta garzetta*, *Ardeola grayii*, *Ciconia ciconia*, *Melopsittacus undulates*, *Pycnonotus cafer*, *Spilopelia chinensis*, *Phalacrocorax fuscicollis* as the resident and *Anser anser*, *Anas acuta*, *Netta rufina*, *Anas poecilorhyncha*, *Porphyrio poliocephalus*, *Leptoptilos crumenifer* etc. as migrant species have been sighted as well as identified with the help of using "Pocket Guide to the Birds of the Indian Subcontinent" *(Grimmett & Inskipp, 2001);* "The book of Indian Birds" *(Ali, 1990)* and online data base *(Avibase, 2015)*. As per the IUCN red list, most of the bird species are under least concern (LC) category. Being a historical heritage, the wetlands with rich biotic diversity (aquatic flora and fauna) in association with historical structures in Malda district are potential in order to promote eco-tourism activity as well as enhance the aesthetic importance and foster a greater appreciation of the wetland habitat.

In order to assess, the ever increasing anthropogenic disturbances at wetland catchment, and resultant water quality deterioration, field survey has been carried out for a period of consecutive three years from March 2015 to February 2018, covering three seasons (pre-monsoon, monsoon and post-monsoon). At the respective sampling sites a total of 15 water quality parameters under physical (2), chemical (11) and bacteriological (2) parameters have been quantified in the laboratory, by following the BIS May, 2012; APHA, AWWA and WEF, 2017. Based on the findings, most of the water quality parameters are recorded between permissible limit especially for biological species within the wetlands. The chemical parameters of total hardness, and conductivity; and physical parameter of turbidity, are found beyond permissible limit as per BIS (2012) and APHA (2017). In order to assess variation of different physical, chemical and bacteriological parameters as well as to identify different pollution sources, one way Anova has been conducted between wetlands and between seasons. The statistical analysis records, both significant (p value $<$ α value) and non-significant (p value $>$ α value) variation at 0.05 levels in two-tailed test at 95% confidence level in different water quality parameters between the case studies (wetlands); and between seasons (pre-monsoon, monsoon and post-monsoon). The observation on the water quality parameters of case studies are further analysed with the Pearson's product moment correlation coefficient. The statistical analysis shows highly significant ($p<0.01$) positive and negative correlation between water quality parameters. Whereas, significant ($p<0.05$) positive and negative correlation have also been recorded between parameters. The statistical analysis and findings, reveal that, the wetlands of Malda district are encountered with immense challenges from diverse anthropogenic activities either in the form of land run-off from adjacent agricultural field, or are highly contaminated by municipal and domestic effluents along with solid waste dumping as well as eventually results into water quality deterioration.

In order to analyse the utilization of wetlands, by surrounding inhabitants, the habitats are categorised into two types; *1. Bed village* (at immediate vicinity of wetland) and *2. Belt village* (a bit far-off). The households, residing in bed villages are comparatively found more dependable as well as utilizing wetland water for irrigation and cultivation of diverse crops (paddy, jute, pulses, maize, makhana etc.). Moreover, the households utilize the wetlands for fish cultivation and fish catch (Bata, Kalbaush, Catla, Koi, Mangur, Prawn, Rohu, Tangra etc.), duck rearing and wetland products (macrophytes- thankuni, kalmi, hingcha; aquatic fauna- googly, mollusks etc.) gathering. The belt villagers are chiefly dependent on wetlands for the commercial purpose, especially for makhana cultivation, which is considered a flourishing aquatic commercial crop to sustain the socio-economy of the poor mass in Malda district. Moreover, the economic valuation and the net estimated benefit of wetlands (case studies) in the form of makhana cultivation, fishing and product gathering is recorded to range from Rs. 8,75,000 to Rs. 57,36,500 per annum. Apart from the mentioned utilization, the wetlands in Malda district are found highly potential in order to promote makhana, sola and paniphal cultivation on wetland bed on a large scale. Furthermore, the wetlands are potential in supporting duck rearing activities in ecologically sustainable manner in order to provide alternative economic support to the rural people through generation of gainful self-employment.

However, in spite of being occupied by fairly good number of wetlands, this natural ecosystem encounters several vulnerabilities and resultant environmental changeability in Malda district, which has been documented by analysing the satellite imagery (Landsat 5 TM & Landsat 8 OLI data), reveals conspicuous land use land cover change (in the form of mango orchard, agricultural field, brick kiln industry and built-up area), adjacent to the wetlands and resultant water area shrinkage. Therefore, along with already implemented protection laws and legislative tools at international, national and state levels, the present study recommends the conservation strategies in order to restrict the remarkable changes, which has already happened to the overall land use conversion and other associated degradation of wetlands:

1. Strict measures and continuous monitoring should be taken by appropriate authority in order to restrict further wetland alteration to non-wetland purpose (urban encroachment, agricultural land encroachment).
2. Integrated planning is to be taken in order to maintain adequate surface flow within wetlands and recharge the ground water throughout the year.
3. Wetland conservation and management strategies must be comprehensive in addressing the degrading water quality which persists from point (sewage inflow) and non-point (agricultural run-off) sources of pollution.
4. Formulating stringent legal actions are required to be taken against the overexploitation of wetland resources as well as promoting judicious utilization of wetland resources in order to enable the socio-economic development of rural mass in Malda district.

The present work concludes with the necessity to coordinate between different govt. departments and the stakeholders in order to document, measure and value the linkages between wetland ecosystem and human population in the entire district of Malda.

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MEA	Millennium Ecosystem Assessment
MOEF	Ministry of Environment and Forest
SAC	Space Application Centre
DHDR	District Human Development Report
SOI	Survey of India
PS	Police Station
LULC	Land Use Land Cover
OSM	Open Series Map
GPS	Global Positioning System
TM	Thematic Mapper
ETM+	Enhanced Thematic Mapper Plus
OLI	Operational Land Imager
CDTP	Community Development Through Polytechnics
PHE	Public Health Engineering
IWMED	Institute of Wetland Management and Ecological Design
CGWB	Central Ground Water Board
CD	Community Development
MSL	Mean Sea Level
IMD	India Meteorological Department
Cumec	Cubic metre per second
ICAR	Indian Council of Agricultural Research
NBSS	National Bureau of Soil Survey
LUP	Land Use Planning
M bgl	Meter below ground level
UNEP	United Nations Environment Programme
NWCP	National Wetland Conservation Programme
SC-B	Standing Committee on Bio resources and Environment
NWC	National Wetland Committee
NNWMS	National Natural Wetland Management System
ISRO	Indian Space Research Organization
GOI	Government of India

IRS	Indian Remote Sensing
LISS	Linear Imaging Self Scanning Sensor
DST	Department of Science and Technology
NH	National Highway
OW	Open water
WE	Water edge
SE	Semi-emergent
E	Emergent
SR	Submerged rooted
FF	Free floating
FL	Floating leaved
EG	Emergent grass
R	Resident
M	Migratory
Ln	Natural logarithm
NTU	Nephelometric Turbidity Unit
pH	Power of hydrogen/ Potential of hydrogen
BIS	Bureau of Indian Standards
APHA	American Public Health Association
AWWA	American Water Works Association
WEF	Water Environment Federation
TDS	Total dissolved solid
Mg/L	Milligrams per liter
Ppm	Parts per million
DO	Dissolved oxygen
TH	Total hardness
BDL	Below detectable limit
IPCS	International Programme on Chemical Safety
TC	Total coliform
FC	Fecal coliform
MPN	Most Probable Number
MFT	Membrane Filter Tube
SEM	Standard Error of Mean

µ.s.	Micrometres/ micron
ANOVA	Analysis of Variance
HSD	Honest Significant Difference
DF	Degrees of freedom
FAO	Food and Agriculture Organization
IWMI	International Water Management Institute
IUCN	International Union for Conservation of Nature and Natural Resources
UNEP	United Nations Environment Programme
WWF	World Wildlife Fund
CBD	Convention on Biological Diversity
COP	Conference of Parties
UNCBD	United Nations Convention on Biological Diversity
IOP	International Organization Partners
IWMI	International Water Management Institute
WWT	International Wildfowl & Wetlands Trust
NWA	National Wetland Atlas
IBD	International Day for Biological Diversity
ABS	Access and Benefit sharing
NWCMP	National Wetland Conservation and Management Programme
CC	Climate Change
CSS	Centrally Sponsored Scheme
NLCP	National Lake Conservation Plan
NPCA	National Plan for Conservation of Aquatic Eco-systems
UNESCO	United Nations Educational, Scientific and Cultural Organization
MAP	Management Action Plan
NGOs	Non-Governmental Organizations

Chapter – I

INTRODUCTION

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INTRODUCTION

1.1 Concept and definition of wetlands:

Wetlands are one of the crucial natural resources and are considered most beautiful places on the earth surface to support rich species diversity. Wetland is a generic term for water bodies of various types, and includes diverse hydrological entities, named as, marshes, swamps, bogs, wet meadows, potholes, and river overflow lands *(Tiner, 1999)*. The term wetlands refer to lowlands, which is covered with shallow and sometime temporary or intermittent waters. Wetlands have been recognized as distinct ecosystems, which is aquatic as well as terrestrial at the same time, depending on the seasonal variability and its transitional nature. "Wetland is defined as land having the water table at, near or above the land surface or which is saturated for a long enough period to promote wetland or aquatic processes as indicated by hydric soils, hydrophilic vegetation and various kinds of biological activity which are adapted to the wet environment" as defined at a workshop of the *Canadian National Wetlands Working Group*, by *Tarnocai C. (1971) (Bhattacharya et al, 2000)*. According to the definition of *Cowardin (1979)* 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 shallow water". The most generalized definition of wetlands encompassing all the aspects has been provided by the convention on wetlands of International Importance, better known as *Ramsar Convention (1971)*. The convention states that "Wetlands are areas of marsh, fen, peat land or water, whether 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" *(Chatrath 1992)*. Wetlands are shallow water bodies in which water keeps up for most part of the year and recedes below the surface level during the lean period (pre-monsoon). Wetlands are considered complex hydrological and biogeochemical systems. The Millennium Ecosystem Assessment estimates that wetland covers 7 % of the earth's surface and delivers 45 % of the world's natural productivity and ecosystem services in a conservative way *(MEA, 2005)*. However, it has universally been recognized that wetlands directly and indirectly support millions of people by performing provisioning services (provide food, fiber and fresh water), regulating services (flood control, water storage, waste treatment and shoreline stabilization), supporting services (soil formation, nutrient recycling) and cultural services (aesthetic and spiritual value, education and recreation) at a time. Wetlands prevent the surface run-off from moving swiftly and overflowing the river banks downstream. Sometimes wetlands are described as *"the kidneys of the landscape"* because of performing the functions in hydrological and chemical cycle as the downstream section receives wastes from both natural and human sources *(De & Jana, 1997)*. Now-a-days wetlands have been analyzed as *"biological supermarkets"* as of the extensive food webs and rich biodiversity they support *(Mitsch & Gosselink, 1993)*. Furthermore, the spectacular concentration of different species of animals and plants in wetlands provide opportunities for recreational activities such as photography, bird watching which increase the tourism as well as boost the local economy.

For many years, the conscious world has been alerted to the destruction of the rain forest and the degradation of the seas and oceans. Relatively less attention has been paid to the world's wetlands and resultantly, the existence of wetlands is threatened due to lack of appreciation and understanding of their roles as a sustenance provider to the millions *(Rao & Datye, 2003)*. In India, the rapidly growing human population, land use alteration, improper use of watersheds has caused a substantial decline in wetlands resources throughout the country. Neglected over the years and anthropogenic pressures are posing a serious threat to the survival of this precious ecosystem. Therefore, wetlands require a collaborated research involving natural, social, and inter-disciplinary study, which aims at understanding the various components, (monitoring of water quality, economic valuation, biodiversity, and other activities) as an indispensable tool for formulating an effective and long term conservation strategies *(Kiran & Ramachandra, 1999)*. In the present century, the wetlands have received relatively good deal of attention, which have been started with the 1st conference held in Iran i.e., Ramsar Convention, in order to safeguard the wetlands for posterity. The Government of India in a close collaboration with the state governments have started recognizing the importance of protecting wetlands from the year 1985-86, as well as have taken number of steps in order to conserve the wetlands.

1.2 Problems of study:

Malda district being situated in Ganga floodplain contains a large number of wetlands, which are considered most productive ecosystems, as well as play effective tools for maintaining the environmental sustainability. However, for decades, wetlands under study have been perceived as wasteland obstacles to the overriding need for agricultural and urban development. As a consequence, wetlands are mostly threatened and being endangered by the first target of human interferences. Overexploitation of resources and anthropogenic pressure put stress and serious threat to the survival of this precious ecosystem. Population in the wetland catchment has grown rapidly and the pressure to bring more and more land under cultivation has mounted. With the increase of human population and land demand, wetland areas are encroached for agriculture and urban construction works. Similarly, negligence over the years along with tremendous anthropogenic pressure is posing ever increasing threat to the existence of the only peri-urban wetland of this district. This water body, adjacent to urban area, acts as a natural tool for flood control as well as plays a major role to retain and detain the excess flood water from Bhagirathi and Pagla River during monsoon. Furthermore, it regulates the ground water level to a great extent especially during pre-monsoon period. Moreover, the accidental introduction of alien species (water hyacinth, water lettuce) in wetlands, results into massive eutrophication and put threat to the existing indigenous biodiversity, which eventually alter the food chain and the nutrient cycle. Further, the situation is going to be worsened, as the wetland reclamation for fishing and agriculture is going unhindered. Excessive application of toxic pesticides and fertilizers in agricultural fields in the catchments is gradually degrading the wetland water quality and associated ecosystems. Furthermore, profit oriented faulty fishing practice and over extraction of wetland resources results into rapid loss of its enormous growth potential for further economic benefit to the rural mass. However, with the growing concern on wetlands, for several human requirements as well as their ecological significance, wetland conservation is increasingly accepted as an important issue. In Malda district, the local authority and different NGOs (Malda Jolabhumi Surokhha Samiti) have started recognizing the importance of wetlands and in this regard few initiatives have been taken in order to conserve the wetland resource of economic, cultural, and recreational value. The "nexus" between water, food, and energy have been recognized as one of the most fundamental relationship and challenges for the society. But still it has been found that the conservation techniques of wetlands and required mechanism is far from the guidelines offered from the wetland conservation policy as mentioned. Several key principles are required for achieving and managing the sustainable use of wetlands and water resources of Malda district, including a harmonious relationship between human and nature is essential for the sustainability of wetlands. Furthermore, an integrated plan, and its proper implementation is required with considerable effort and focus, which can effectively contribute to the sustainable development of this district in a wider context.

1.3 Literature Review:

There is extensive literature on various bio-ecological aspects of wetlands. Here an attempt is made to discuss the works on the different aspects included in the present study.

In order to deliver the technical aspects of wetlands, related to definition and classification, L.M. Cowardin, V. Carter, F.C. Golet and E.T. LaRoe (1979) have worked together on the classification of wetlands and deep water habitats of the United States, which have made significant contributions towards the wetland classification across world. Alaska Department of Fish and Game Habitat Division have focused attention on the wetland classification, inventory and assessment methods, which has been reported by Janet Hall Schempf (1992). C.M. Finlayson and A.G. Valk, (1995) together have made a sustained contribution on the global classification and inventory of wetlands, which is essentially required for their conservation and wise use. Ralph W. Tiner (1996) has made a sustained effort in the United States. Another effort has been shaped on study of wetlands with special reference to Canadian wetland classification by the National Wetland Working Group (1997). This work is based on the wetland ecosystem, surface morphology, surface pattern etc. The United States Environment Protection Agency Health, the Ecological Criteria Division and Wetland Division, (2002) jointly have conducted a pioneering survey to assess the wetland classification. In India, a simple but elegant work on wetland classification has been made by Brij Gopal and Malavika Sah (1995) especially for the purpose of wetland mapping and inventory. Space Application Centre, ISRO, Ahmedabad (2010) with the help of Ministry of Environment and Forest (MoEF), Govt. of India has made a commendable work on wetland classification system of West Bengal as a part of the project on National Wetland Inventory and Assessment (NWIA). Moreover, Space Application Centre has made another significant contribution on NWIA (2011) and National Wetland Atlas (2013), with the help of MoEF.

Wetlands are among the most productive and optimizing ecosystems in the world and realizing the need, the overall stock taking of wetlands along with its bio resources, number of remarkable studies have been developed. A group of authors; T. Reppert, W. Sigleo, E. Slakhiv, L. Messman and C. Mayers (1979) have prepared a research report on wetland values, concepts and methods for wetland evaluation, which is surveyed by Institute of water resource of United States. Virginia Carter (1986) has focused attention on the technical aspects of wetlands, regarding its hydrology, water quality, and associated functions in the United States. Mark Brinson and Richard Rheinhardt, (1996) together have noted the role of reference wetlands in functional assessment and mitigation in the United States. Another significant work has been made by group of authors: J.W. LaBaugh, T.C. Winter, and D.O.

Rosenberry, (1998) at recognizing the hydrological functions of wetlands with particular reference to prairie region in North America. Another attempt have been made together by A. Bullock and M. Acreman, (2003) at recognizing the pioneering role of wetlands in the hydrological cycle, which present a database of 439 published statements on the water quantity functions of wetlands from 169 studies worldwide. A group of three authors namely P. Negrel, E.P. Girand & F. Sgouridis, (2005) have discussed about significance of wetlands in the water cycle for sustainable management under the Integration of European Wetland research. Further, the global wetlands, its grim significance, and consequences as expressed in the cultural, economic and biological diversity, has received attention by the team of three authors namely, S. Mitra, R. Wassmann and P.L.G. Velk, (2005). Three case studies in the People's Republic of china, the United States of America and Ethiopia on a review of wetland, (2011) have been conducted by Aaron Marti. A commendable work have been developed by K. Morris and P. Papas, (2012) who have marginally touched upon an association between wetland values and threats associated with water regime, water quality, and wetland living organisms along with management interventions. In order to assess the economic valuation of wetlands, a number of commendable works have been made by J. Parikh and H. Datye (2003); T.V.Ramachandra, R.Rajinikanth, V.G.Ranjini (2005). A remarkable study has been made by S. Mukherjee (2008) on economic valuation of West Bengal wetlands. A commendable study has been conducted on the utilization of wetland resources by the rural people of Nagoa district in Assam by S.K. Sarma and M. Saikia, (2010). Another remarkable attempt on the socio-economic valuations of wetland based occupations of lower Gangetic basin through participatory approach, have been discussed by M. Roy, P. Roy, N. Samal & A. Mazumdar (2012). The study on wetland biodiversity of Malda district in the form of wetland hydrophytes (2010) by M. Chowdhury and A.P. Das, University of North Bengal; wetland avifauna (2014), by M. Chowdhury and B. Nandi have been made.

A number of scholarly works have already been conducted and developed on wetland conservation. Among which, a remarkable study on wetlands with special reference to agricultural pesticide impacts on prairie wetland has been conducted by O'Brian and Christoffel from Iowa State University (1993). A commendable study on the federal policy on wetland conservation implementation guideline for federal land managers have effectively been analyzed by a group of authors namely P.L. Stewart, P. Neice, C. Rubec and I.K. Taylor (1996). A review of published wetland research in between 1991 to 2008 has been conducted by a group of authors: Ling Zhang, Ming – Huangwang and Yuj – Shan have effectively analyzed ecological engineering and ecosystem restoration of wetland. Other significant contribution has been tooled by R.T. Kingsford (2000), who has critically assessed an ecological impact of dam, water diversions, and river management on floodplain wetlands altering their ecology and causing poor health to aquatic biota in Australia. Another important and noticeable analysis has been developed by S. Jing, Y. Lin, D. Lee, and T. Wang (2001) on the issue of using constructed wetland systems to remove solids from highly polluted river water. A group of authors S.A. Halse, M.N. Lyons, A.M. Pinder, R.J. Shiel, (2004) have worked together on the biodiversity patterns and their conservation in wetlands of the western Australian wheat belt. R.T. Kingsford (2011) has also worked on the conservation and management of degrading rivers and wetlands, which leads to widespread threats, habitat loss, and imbalances in ecosystem. A remarkable study on hydrological impact assessment of wetlands have been prepared by Acreman and Felicity, who have emphasized on how to arrest the significant alteration and degradation of wetland functions and species composition. A commendable study on wetlands of West Bengal has been conducted by S. Bhattacharya, K. Mukherjee and J.K. Garg in Institution of Wetland Management and Ecological Design (IWMED), Kolkata (2000). Another noticeable analysis on degradation of water bodies and wetlands in west Bengal and it's interaction with the economic development have been developed by a team of four authors; T.K. Das, B. Moitra, A. Raichaudhuri and T. Jash, (2000). T.V. Ramachandra, (2001) has worked on the issue of restoration and management strategies of wetlands in developing countries in the context of world and Indian scenario, which is quite similar with the problems and degradation of the wetlands of Malda district. Besides, a group of eight authors: S.N. Prasad, T. Sengupta, A. Kumar, V. Vijayan, L Vijayan, T.V. Ramachandra, N. Ahalya and A.K. Tiwari, (2002) have worked on wetlands of India, in terms of the threats and losses of wetlands, which is highly compatible with the wetlands of Malda district. A precise study have been made on the indicators of wetland planning, monitoring, policy and the guiding principles on national wetland strategy by J. Parikh, H. Datye T.L. Raghu Ram (2003). A number of studies have dealt with the management and planning of East Kolkata Wetlands in India in 2010, where, Dr. Nitai Kundu has highlighted the role of wetland system, which plays a key role in the ecological and economic security of Kolkata as well as the entire Gangetic delta. Another contributor, Ritesh Kumar, (2010) has stressed upon the management plan for east Kolkata wetlands. A commendable study on the environment and economic development of east Kolkata wetlands has been assessed by Debaleena Saha Ghatak, (2010). Another group of authors: Manojit

Paul, Mukti Chanda and Supriya Sengupta (2011) have played a pioneering role in conducting a survey to assess the strategy and scenario for wetland conservation in India.

Realizing and emphasizing the wise use of wetlands, several scholarly articles and papers have been carried out. The history and development of Ramsar convention has been studied by G.V.T. Mathews (1993). M. Gawler (1998) has stressed upon the need for recognizing an overview of the lessons and has adapted the best practices in participatory management of both coastal and inland wetlands. Eric Baren and Ian Baird (2003) have worked together on the approaches and tools for the sustainable management of the fish resources in Mekong river basin. A remarkable study on monitoring the success of metropolitan wetland restorations including cultural sustainability and ecological function has been conducted by Joan Iverson Nassauer (2004) in the University of Michigan. The sustainable water resource development as an ability to support life has also been carried out by Warren Flint (2004). R. Mclnnes (2013) has played a pioneering role in preparing the guidance and a conceptual framework for the wise use of urban and peri-urban wetlands through Ramsar’s Scientific and Technical Review Panel (STRP). A commendable work on the management of wetlands at the local, national, and international level for biodiversity has critically been analyzed by S. Cannicci and C. Contini. K.J.S. Chatrath, (1992) in wetlands of India; J. Parikh and H. Datye (2003) in their edited volume Sustainable management of wetlands biodiversity and beyond have made a study, which is discussed with important wetlands, their associated problems, and conservation and management strategies. These articles have emphasized broad approach for conservation of wetlands and suggested some desirable actions, which have been taken into consideration for further wetland study in Malda district. Somen Acharya and Tarun Adak, (2009) have worked together on the wetland management for the sustainable development as against anthropogenic interventions. A study on the status of wetlands in India regarding the ecosystem benefits, threats, and management strategies has been developed by N. Bassi, M.D. Kumar, A. Sharma, and P.P. Saradhi (2014), which is highly relevant with the wetlands of Malda district. A remarkable study on the management regime and its impact on the wetland fisheries have been prepared in two wetlands of Assam by Ganesh Chandra, (2014). Other contribution with emphasis on the conservation of wetland resources, for sustainable livelihoods has been made by P. Lamsal, K.P. Pant, L. Kumar, and K. Atreya (2015) on the basis of economic benefits in Ghodaghodi Lake of Western Nepal.

1.4 Study Area:

Malda district is centrally located in West Bengal and has been opted as study area. It is located between 24°40′20″ N to 25°32′08″ N latitude and 87°45′50″ E to 88°28′10″ E longitude. Spreading over an area of 3,733 sq. km with population 39,88,845 (2011), the district covers 4.2 % of the total landmass of West Bengal and is the home to 4.37 % of the total state population *(DHDR, 2007; Census of India, 2011)*. As per the Institute of Wetland Management and Ecological Design, Malda district comprises 562 wetlands (≥2.25 ha), covering 29,416 ha (*Bhattacharya et al. 2000*), whereas Space Application Centre has incorporated 502 wetlands (≥2.25ha), covering 20,725 ha *(SAC, ISRO, 2010)*.

1.5 Objectives:

The full value of water and wetlands need to be recognized and integrated into decision making in order to meet future social, economic, and environmental needs. What are the roles of wetlands of the district in terms of providing wetland related ecosystem services? Though some works have been done but whether effective approaches have been successfully taken to respond to the challenges and to take account of the values of water and wetlands. Particularly in Malda district the maintenance and enhancement of the benefits of wetland is, therefore, essential to achieve a sustainable economy. Therefore, the objective of present study is to construct an integrated analysis for conservation and restoration of wetlands under study. The study combines the spatial analysis of wetland ecosystem as well as designs to estimate the impacts of various non-sustainable uses of wetlands and the necessary changes are required for its better use. The objectives are as follows:

1. Mapping of wetlands of Malda district and to monitor their behavior for the development of innovative estimation measures.
2. Classification of wetlands and estimating the geographical extent of the different types and identifying the representative wetlands for detail analysis.
3. Survey and estimate the utilization of wetlands for agriculture, aquaculture, coir rotting, gathering fruits and fiber etc. and ascertaining their socio-economic impact.
4. Preparing an inventory of flora and fauna as well as estimate the potential for wildlife vis-à-vis aesthetic and recreational uses i.e., eco-tourism activities.
5. To study the potentialities of these wetlands to provide alternative economic support to rural people through generation of gainful self-employment.
6. Impact assessment of various anthropogenic activities in wetlands to understand the various degradation processes in Malda district.

7. Planning for the conservation and appropriate management technologies of the wetland on sustainable basis.

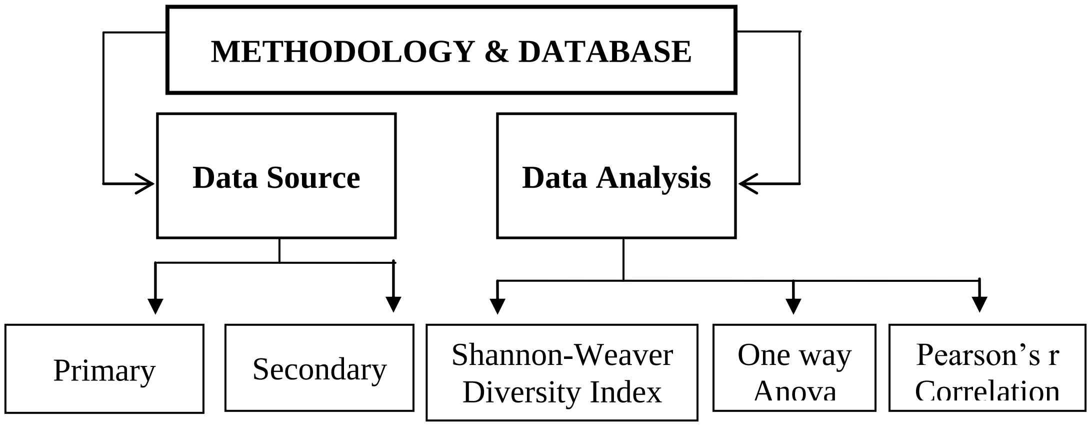
1.6 Hypotheses:

In the present study, keeping in mind the mentioned objectives, following hypothesis have been formulated:

1. Wetland ecosystem, (especially peri-urban wetland) plays a significant role in waste water treatment, flood control, ground water recharge and biodiversity conservation.
2. Wetlands of Malda district are currently utilized for agriculture, aquaculture, and coir rotting, gathering fruits and fiber etc., and also satisfying various socio-economic needs.
3. Rich biodiversity of wetlands of Malda district has potentiality for wildlife vis-à-vis aesthetic and recreational uses i.e., eco-tourism activities.
4. These wetlands have the potentiality to provide alternative economic support to rural people through generation of gainful self-employment.
5. The current piecemeal and consumption-oriented approaches affecting adversely the wetland resources.
6. The economic and environmental functions of wetland can be maintained sustainably if appropriate conservation methods and management technologies are adopted.

1.7 Methodology & Database:

To fulfill the mentioned objectives in present study, the methodology and database have been obtained by the researcher, which comprise geomorphological, hydrological, meteorological, biological and anthropogenic inputs. The entire study is based on both the primary data and secondary sources and information that have been collected from different sources. The methodology, thus adopted, is as follows:



1.7.1 Data source:

1.7.1.1 Primary database:

In the present study, primary database has been taken in the form of sampling (randomly selected), wetland water quality parameter selection and relevant data collection, in order to fulfill the mentioned objectives.

1.7.1.1.1 Sampling:

Non-probability sampling:

The relative importance of different wetlands has been ascertained and the parameters namely; wetland categories, major functioning, agro-economic and biological potentials of wetlands, anthropogenic interference at wetland periphery and resultant level of encroachment have been taken into account for the selection of the sample wetlands. The selection criteria for the case studies have been taken into consideration, which can satisfy the following objectives of wetland categorization as well as estimating its biological and socio-economic potential along with the impact assessment of diverse anthropogenic activities. After due consideration on varied aspects (different wetland categories, degree of human interference, agro-economic and biological potentials of wetlands), case studies have been selected in Malda district, in order to detail analysis (objective no.2). Moreover, the case studies have also been selected to depict the current status as well as find out the strategies to conserve these water bodies in respect to sustainable wetland management as well as monitoring their behavior for development of innovative estimation measures.

Probability sampling:

1. The relevant data and information has been collected from field observation and interviewing the households. At household survey, random sampling (5% of universe) has been taken from surrounding households, who directly and indirectly utilize the wetlands and associated resources. The household survey has been conducted by semi-structured questionnaires in order to know the attitudes of the settlers towards the significance of wetlands. A few questions in the schedule have also been designed for noting down the inhabitants' opinion regarding the practice of agriculture, fishing and other socio-economic activities, related to these wetlands. The gram panchayat offices along with the fishing cooperative society of nearby wetlands have also been interviewed during study. The household survey has been conducted in order to satisfy the objective (no.3) of estimating the utilization of wetlands for agriculture, aquaculture, and gathering wetland products as well as ascertaining their socio-economic livelihood. Further, the objective (no.5) of household survey is to satisfy whether the sample wetlands are

potential enough to provide alternate economic support to rural people through providing gainful self-employment.

2. Another probability sampling has been done by conducting household survey by random sampling (2% of population) from adjacent English Bazar Municipality wards (no. 3, 24 and 25) surrounding the peri-urban wetland (Chatra) of Malda district. An attempt has been made through this survey, which can satisfy the objective (no.6) of identifying the causative factors that have led to the contemporary degradation of wetlands, with special emphasis on the anthropogenic effects and the changing land use.

1.7.1.1.2 Water quality parameters selection:

After collecting water samples from selected wetlands, a total of 15 water quality parameters have been opted for laboratory test: 1) Physical parameters – a. water temperature, b. turbidity; 2) Chemical parameters – a. Water pH, b. Total dissolved solid (TDS), c. Conductivity, d. Total hardness (TH), e. Dissolved oxygen (DO), f. Chloride, g. Fluoride, h. Iron, i. Arsenic, j. Manganese, k. Nitrogen and 3) Bacteriological parameters – a. Total coliform (TC), b. Fecal coliform (FC). These mentioned parameters have been taken into consideration, which can satisfy the objective (no.6) of assessing the impact of various anthropogenic activities at wetland catchment in the form of agricultural run-off, urban encroachment, brick-kiln industry, solid waste dumping etc. and understanding various degradation processes. The water quality parameters have also been selected in order to recommend appropriate conservation and management strategies of wetlands on a sustainable basis.

1.7.1.1.3 Data collection:

1. The ground survey with conventional surveying instruments along with GPS (Global Positioning System) has been used to assess the geographical dimensions of the selected wetlands. The hydrological data on wetland water level and its seasonal fluctuations throughout the study have been measured.

2. The ground survey has been done with GPS in order to identify the spatial distribution of different economic activities in and around wetlands.

3. Field study has been undertaken in 2016-17 to satisfy the objective (no.4) of preparing an inventory of diverse floral and faunal species of these wetlands through identification, collection and classification in order to assess and project the future biological potentials of wetland ecosystem. Icthyofaunal species are identified and

collected from local fishermen collections. The point count method *(Bibby et al., 2000)* has been followed for the identification of avifauna during the sunrise (04.00 – 06.00 A.M.) and sunset (04.00 – 06.30 P.M.), when various activities of bird species and their availability are found maximum. Data is collected standing at a fixed point in the study site for approximately 15 minutes. The points are selected at random with distance, which varies from 150 m to 250 m, in respective case studies and a total of 38 fixed points have been selected and repeated for the consecutive surveys in wetlands (Siali-6 points, Chakla-12 points, Naghoria-8 points and Chatra-12 points) during the study period. Bird species are observed through binoculars of different ranges as well as photographed by using Canon 1200D (55 to 250mm).

4. In order to analyse the water quality, water samples have been collected from selected wetlands during March 2015 to February 2018 covering three different seasons: pre-monsoon (April-May), monsoon (June-September), and post-monsoon (November-February). The samples have been collected in separate well-labeled disinfected polyethylene container of 250 ml from a depth of about 1 meter to 1.5 meter from randomly selected sampling sites of wetlands under case study. The physical parameter of water temperature is measured in situ at the time of sample collection with Mercury thermometer. The collected samples have been brought to laboratory within 24 hours of sample collection for testing other physical, chemical and bacteriological parameters. The water samples have been tested with the help of Community Development through Polytechnics (CDTP), Govt. of India and Public Health Engineering (PHE) Department laboratory, Govt. of West Bengal by following the Bureau of Indian Standards (BIS), 2012; American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF), 2017.

1.7.1.2 Secondary database and methodology:

1. The basic areal data have been procured from the Survey of India (SOI) topographical maps (1:63,360 and 1:50,000), Cadastral maps (1:3960), Land use / Land Cover maps (LULC) (1:50,000) of Malda district. The mapping exercise (objective no.1) has been carried out with the help of topographical maps of 1960-61; Open Series Map (OSM), of 1984-85, which is further updated in 2004-05; Cadastral map of 1974-78 and Land use map of 2010-11 in preparing detail work plan. Furthermore, the Satellite imagery of Landsat 5 TM (1990) data and Landsat 8 OLI (2018) data of November has been consulted in order to identify the variation in wetland area extension during the time

frame 1990 to 2018. The chronological assessment of the depletion of wetland resources of Malda has been estimated by comparing the surveyed information with that, available in the topographical map, open series map and land use map in order to get a comparative vignette of changing land use land cover scenario in order to fulfill the objective (no.7) of planning for conservation and management strategies of wetlands on sustainable basis.

2. The physical configurations as well as cultural modification of wetlands under study, in association with relevant data and information have been procured from different secondary sources including, Department of Fisheries, Govt. of West Bengal, Directorates of Agriculture, Govt. of West Bengal, Department of Irrigation and Waterways, Govt. of West Bengal, Public Health Engineering (P.H.E.) Department, Govt. of West Bengal, Land and Land Reforms Department, Govt. of West Bengal, Land Records and Surveys office, Govt. of West Bengal, Soil and Land use Survey of India, Directory of wetlands published by Ministry of Environment and Forest (MoEF), Institute of Wetland Management and Ecological Design (IWMED), Central Ground water Board (CGWB), Ministry of Water Resources, Govt. of India. Apart from these a number of non-government agencies like Malda Vigyan Mancha, Jalabhumi Suraksha Samiti and Centre for Ecological Engineering etc. have also been consulted.

3. In order to identify and prepare an inventory of biotic components, following books have been consulted: wetland macrophytes have been identified by “Plant systematics” of Simpson (2010) and “Plant systematics: An Integrated Approach” of Singh (2016). Wetland icthyofauna have been identified by the standard key of “The freshwater fishes of India, Pakistan, Bangladesh, Burma and Sri Lanka - A Handbook” by K.C. Jayaram (1981). The avifauna, which are sighted in and around the wetlands, have been identified with the help of “Pocket Guide to the Birds of the Indian Subcontinent” by Grimmett & Inskipp, (2001); “The book of Indian Birds” by Salim Ali, (1990) and Avibase (2015). Finally, in order to understand the structure, functions, potentials of wetlands under study and their sustainable management, all the data collected from primary and secondary sources have been analyzed and processed to develop sustainable management plan for this priceless natural ecosystem of Malda district.

1.7.2 Data analysis:

1. After preparing the inventory of biotic components, observed in and around wetlands under study, Shannon-Weaver (Shannon-Weaver) diversity index (H) *(Shannon*

& Weaver, 1964) has been used in community ecology in order to characterize the avifaunal species diversity and species evenness, sighted during the study.

- Species diversity (H) = $\sum_{i=1}^{S} - (P_i * lnP_i)$

Where:

H = Shannon-Weaver Diversity Index

P_i = Proportion of all individuals in the sample that belong to i species

S = Number of species encountered

$\sum$ = Sum from species 1 to species S

- Evenness (E_H) = $\frac{H}{lnN_i}$

Where:

E_H = Evenness Index

H = Shannon-Weaver Diversity Index

N_i = Number of individual species

2. The laboratory test result of wetland water sample has further been statistically interpreted with Mean ($\overline{X}$), Standard error of mean (SEM) and Standard deviation (σ). The variation in water quality parameters between the wetlands and the seasons has been computed by oneway Anova in order to identify different sources of pollution (point and non-point) in sample wetlands. The observation on the water quality parameters of wetlands are analyzed with Pearson product moment (r) correlation coefficient in order to know the relationship between different parameters and their impact on others.
3. The data, gathered from the household survey has been analyzed and interpreted accordingly as well as generated cartographically in order to conspicuously identify the utilization of wetlands by surrounding households.

1.8. Significance of study:

Water is a fundamental requirement for the well-being of human life and a sustainable management of water resource has become the buzzword of the present century. Being one of the most potential source regions of wetland resources, the wetlands of Malda district are subject to strong human pressure both on the water body itself and most often because of effect on wetland catchment area. Thus, conservation of existing wetlands, including its ecological character and biodiversity from the non-sustainable use and negligence is getting prioritized in the wetland and water resource management plan in Malda. Concerted efforts are awfully important for the conservation and monitoring of wetlands not only in terms of its intrinsic values and functions, but because of numerous economic activities (agriculture, fishing), which highlight the need for judicious use of this stored water resource. Therefore, the present study attempts to highlight and formulate a holistic approach for sustainable development and management of existing wetlands which is considered a robust water resource for the well-being of entire district.

1.9. Organization of work:

The present thesis contains a total of 7 chapters.

Chapter I contains the problem of study, literature review regarding the wetlands at international and national level, introduction of study area (Malda district). The objectives are set and the hypotheses are formulated keeping in mind the significance of present study. The database and methodology have been applied in order to achieve the mentioned objectives.

Chapter II includes the general description of study area (geological and hydrological set up, soil, natural vegetation, ground water) along with the spatial distribution of wetlands.

Chapter III deals with the selection of sample wetlands in Malda district on the basis of specific criteria. The precise characteristics of selected wetlands, related with their geologic formation, physiography, wetland hydrology and biotic components (macrophytes, icthyofauna and avifauna) have clearly been laid down in this chapter.

Chapter IV contains the hydrological set up of selected wetlands in terms of wetland area and depth. Further, the physic-chemical as well as bacteriological components of wetlands water sample have been analyzed in order to assess the impact of various anthropogenic activities.

Chapter V highlights the analytical insights regarding wetland utilization, which facilitate the socio-economic livelihood of human habitation. The analysis of household data has also been developed through appropriate cartographic representation.

Chapter VI deals with the problems, associated with non-sustainable utilization of wetland resources and resultant negative externalities. The concept of wetland conservation, guidelines regarding the wise use and sustainable management of wetland resources, with relevance to the study area has been discussed. Further, several action suggestions have also been recommended for the wetlands under study.

Chapter VII is the concluding one, which highlights the major findings regarding the entire study.

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Chapter – II

GEOGRAPHICAL SET UP OF STUDY AREA

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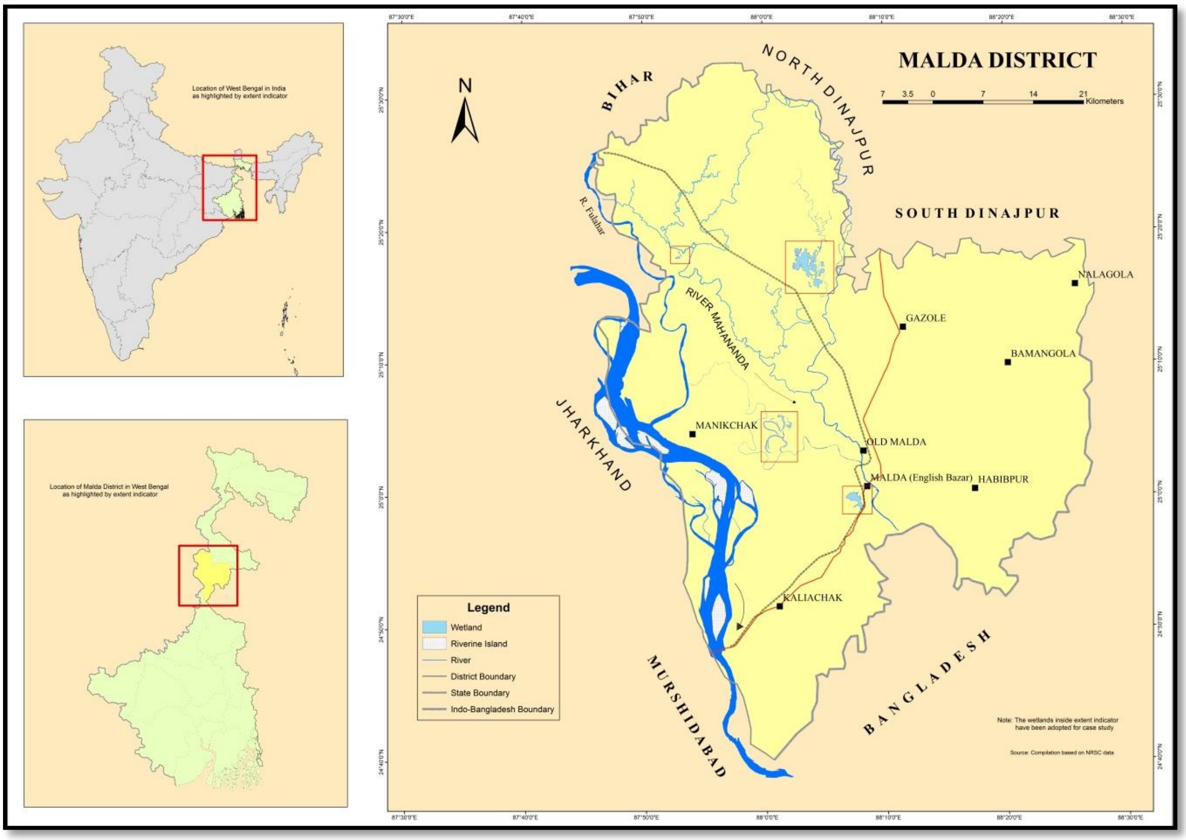
2.1 Introduction:

Malda district comprises 3,733 sq. km, and is located within 24˚40′20″ N to 25˚32′08″ N latitudes and 87˚45′50″ E to 88˚28′10″ E longitudes *(Map 2.1)*. The district is situated keeping Jharkhand in the west, Bangladesh in the east, and Murshidabad district in the south, whereas the river Ganga delineates its western boundary and the northern part shares the boundary with neighbouring district of North Dinajpur. Along with the seasonal inundation, the entire district is susceptible to the seasonal submergences. Manikchak- Gopalpur (east of river Ganga) belt is an active zone of channel migration. This belt experience frequent flood incidents as well as are associated with number of abandoned loops which are further traversed in an erratic manner by the river Kalindri. Study of satellite images of 1998, 2001, 2002, and 2003 reveal evidences of eastward channel migration as well as areal inundations. Such situation can be understood through the morphological re-arrangement of older meander scrolls.

Further territorial adjustments to the borders of Malda district had been occurred during the partition of India in 1947, when the Radcliffe award assigned several portions from its easternmost thanas to East Pakistan. The district has been reconstructed and subdivided into 10 police stations and 2 subdivisions: a) Sadar comprises it’s headquarter at English Bazar and b) Chanchal with headquarter at Chanchal. There are 15 CD (Community Development) blocks in the district namely Gazole, Bamangola, Habibpur, Old Malda, English Bazar, Manikchak, Kaliachak 1, 2 and 3, Harischandrapur 1and 2, Ratua 1 and 2, Chanchal 1 and 2. Malda district comprises total number of 29 urban centers, which are subdivided into 2 Municipality towns (Old Malda and English Bazar) and 27 Census towns.

The main urban area of Malda district is the English Bazar municipality which receives the status of town after the independence of India in 1951 with a population of 35,161 persons. The population size has reached to 205,521 persons in 2011. According to census 2011, the district ranks 11th and 9 th position in terms of population size 3,988,845 and population densities of 1,069 inhabitants per sq. km respectively in the state of West Bengal. The population growth rate over the decade 2001-2011 has been recorded 21.5% (*District Census Handbook, 2011*). However, as per 2011 census, the population of Malda is overwhelmingly rural of about 86.42 % and the urban population is 13.58 %. Thus, the burden of demographic pressure on the rural economy of this district is much heavier and the pace of urbanization is very slow. The district still continues to be a key region in the modern state of West Bengal, which connects more developed districts, located in southern part to economically backward districts, which form the northern West Bengal. Malda represents a place of great antiquity, which was once the cradle of state and society within Bengal.



Map 2.1: *Location Map of Malda District*

2.2 Geology:

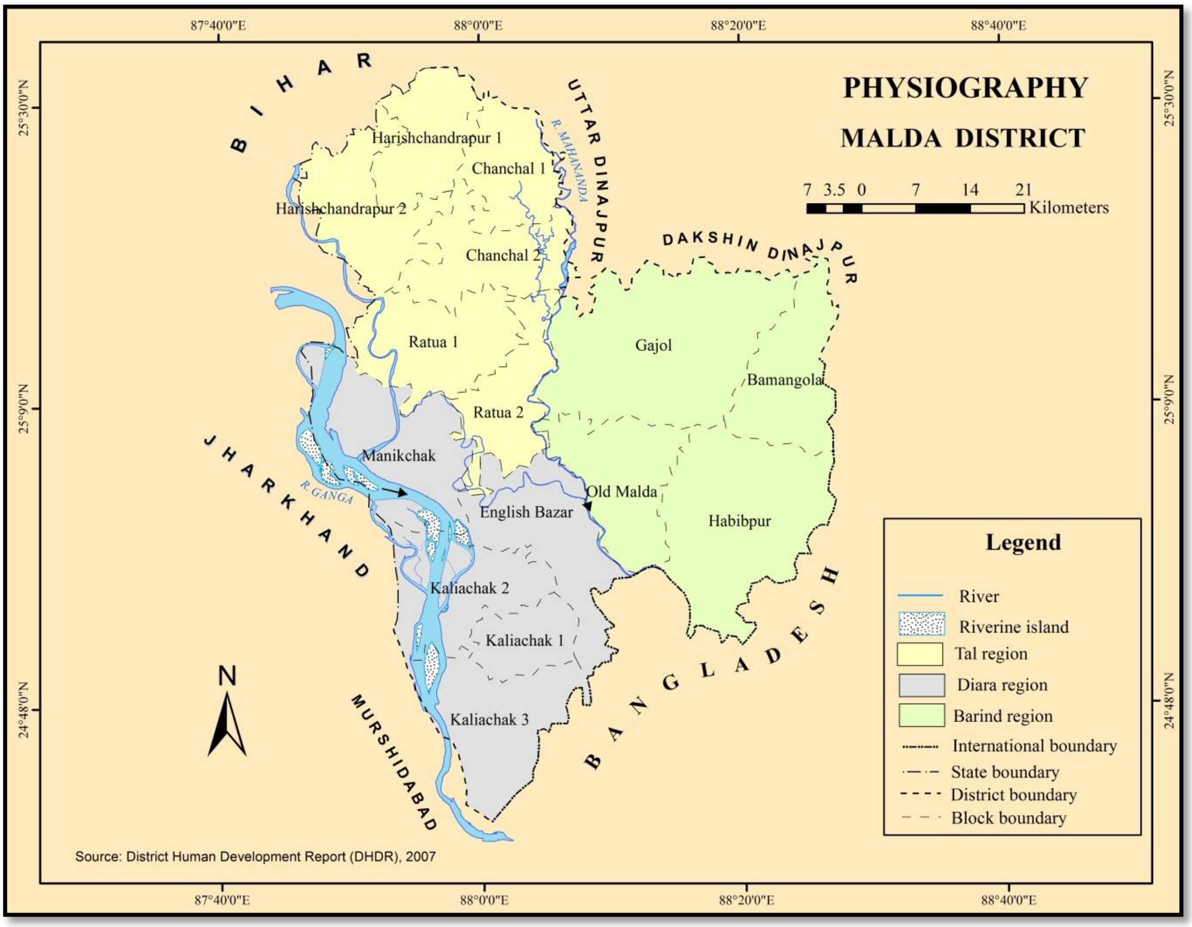
From the very outset, Malda district is a flat terrain, which is crisscrossed with the rivers as well as depicts a geological history of alluvial formation. Broadly the district is a part of Bengal basin located on the western part of the alluvium filled gap between the shields of Rajmahal in the west and Garo-Lusai-Massif of the Meghalaya plateau in the east. In the north is the alluvial fan surface of the Himalayan foothills, the piedmont alluvial plain, which is formed by the streams descending from the mountains (*Gazetteers of West Bengal, Malda, 1969*).

Bengal Basin being in the Bengal delta is located within the mio-geosyncline area *(Chakraborty, 1970)*. The fluvio-glacial deposits in the foothill of the Himalayan valleys; the elevated and crescent shaped ferallitic-lateritic materials along *Rarh* and *Barind* has shaped the complex genesis of final frame of Bengal basin. On the other hand, the Rajmahal volcanoes (during Jurassic-early Cretaceous) are the most recent evidences of lithological aggradations. Actually this area is associated with a part of the Deccan shield and is the contiguous part of the north-eastern promontory of the Deccan shield. As per the structural geology, it is separated by the alluvium of the Bengal plains and is linked with the exposures of Archaean land surface in the Meghalaya-Assam. The eastern margin of the Deccan shield is characterized by lateritic terraces of various ages as well as separates the ancient Archaean formations from very recent coastal alluviums.

2.3 Topography:

The general slope of the district is from north to south. There are no hills in this district, unless a few elevated tracts are found on the east of the Mahananda River. The highest elevation of the district above sea level is 39.7 m at Pandua, Gazole in Mahananda–Tangan river basin. Elevations ranging between 30.0 m to 39.0 m (above m.s.l.) are found in the police stations of Bamangola and Habibpur in the Tangan–Punarbhava river basin. The other places of the district fall within the elevations between 23.5 m to 38.0 m. It is a triangular shaped region, through which a number of rivers flow from north to south and the slope is gentle as is proved by the meandering courses taken by the rivers, which are flowing through the district.

The physiographic make-up of the district is obviously an outcome of the gradual infilling of the North Bengal basin. Changeable geomorphic associations, has been accelerated by the oscillation of the mighty river Ganga, and results into the spatial deformations in the physiographic make-up. Physiographically, the district is divided into three well identified parts, namely, ***Tal*** (in the north and north-west), ***Diara*** (in south and south-west) and ***Barind*** (in the east) *(Map 2.2)*. The river Mahananda flowing from north to south, bisects the district into eastern and western regions. Geographically the land to the east of the Mahananda is called the *Barind*, which covers 1331.29 sq. km (35.66 %) of district *(DHDR Malda, 2007)*. *Barind* is associated with remarkable characteristic feature of relatively high and undulating land (successive mounds and depressions). The region is composed of the red clay soil of older and unconsolidated alluvium and is considered to have been developed during Pleistocene age. The soil has developed through the accumulation of sesquioxides, which has remained unaffected subsequently by inundations and renewed silting. Organic residues in this soil are highly decomposed, and leading to non-acidic soil with 6.8 pH level and 0.54 % organic carbon content. As a consequence, overall soil fertility remains at modest level under non irrigated condition. Moreover, the hummocky terrain in the *Barind* region promotes a fair amount of runoff and the hard, impervious clayey soils, which permits little percolation.



Map 2.2: *Physiography of Malda District*

The eastern alluvium formation can readily be distinguished from the west of river Mahananda, which is further divided into two well defined parts by the river Kalindri, which is flowing from river Ganga towards east. In north of Kalindri, there is distinguishing natural feature named *Tal* land, with an area coverage of 1160.44 sq. km (31.08 %) in Malda *(DHDR Malda, 2007)*. *Tal* land is featured with full of large and small depressions, which floods deeply as the rivers rise and drains by meandering streams into swamps or into river Kalindri. *Tal* region is strewn with the innumerable marshes and ox-bow lakes and remains submerged under considerable depths of water especially during the monsoon months. South of the Kalindri lies the most fertile and populous portion of the district. The most striking natural feature of this part is *Diara*, which is located in the transitional zone between *Barind* upland

and marshy *Tal* land, and contains 1161.51 sq. km (31.11%) of Malda district *(DHDR Malda, 2007).* The region is formed due to the combined action of deposition by two rivers namely Mahananda and Ganga and probably in the Pleistocene-Holocene epoch under the Quaternary period. The word *Diara* actually means low river banks, whereas the Karara means the high bank. By extension, these terms are commonly used to indicate land below and above flood level, respectively in the later alluvium. It has been evident with the finding of the marshy red older alluvium in this region which is locally called *karkach* and also known *chama mati* meaning thereby light and shallow layer of silts i.e., older alluvium of the river Ganga. Later the river Ganga has re-shaped with the uplift of the basement of the sub-Himalayan North Bengal basin. This low land is characterized with alluvium (consists of sandy clay and sands and fine silts) along the course of the river, which are embedded with clay in the flatter parts of this plain. This alluvium is typically dark, and loosely compacted with high water content and variable but appreciable quantities of organic material (*Gazetteers of West Bengal, Malda*, *1969*). *Diara* is roughly estimated to be spread for eight to ten miles in width along the western and southern parts of the district. Its formation is the result of fluvial deposition by the river Ganga, the abandoned loops/off shoots of which can still be traced, starting from the present day course of the Bhagirathi River near Gour and extending westwards by successive stages of replenishment. This geographical entity is vulnerable to inundation during the rainy season but fortunate enough to have an excellent soil condition and irrigation facilities and is largely under the double cropping area.

2.4 Climate:

Malda district lies outside the tropics of Cancer, and is characterized by hot summer, profuse rains, and moisture in air throughout the year. The climate is significantly noteworthy because of its position and the strong effects of the south-western monsoon. Climate of Malda is dominated by three seasons i.e., hot, cold and rainy.

2.4.1 Seasons:

The hot weather begins with strong westerly winds from the month of March and continues till the middle of June. The days begin to be hot from the middle of February but night remains pleasant till the middle of April. The mean maximum temperature in April-May is about 35° C. The weather becomes oppressive during the month May to middle of September with high relative humidity ranging from 80% to 85%. Wind blows from the west during the mid-April when nor'westers sets in, sometimes in great fury. In May there are strong winds from the west, hot and interrupted squalls, generally accompanied by thunderstorms and rains which often comes with hails of great magnitude and is popularly known as *'Kalbaishakhi'*, which cause sharp drop in temperature.

Monsoon generally sets in the middle of June when the rainy seasons commence as well as continues till the end of September. The heaviest rain usually falls in July and August and sometime in even mid-June. The maximum rainfall sets in August amounting to 260 mm. Maximum rain generally occurs during the period from June to September. On an average, Malda experiences heavy showers of 76-80 numbers of rainy days. About 5-10 days experience burst of monsoon, associated with lightning.

Cold season starts from early November and continues till the end of February with mid-December to mid-January, being the coldest period. January is the coldest month in Malda amounting to 10°-12° C as average minimum temperature. In cold season on account of passages of eastern winds of western disturbances across northern India, Malda experiences unusually cold spell though for short periods. During the cold spell the minimum temperature goes down to 4° to 5° C. Winter days are bright and the air becomes crispy and clear. During cold season the district experiences very little rainfall with the exception of light showers (< 2 mm) at the end of December and a thunder shower in February. Occasional appearance of fog is also experienced in winter.

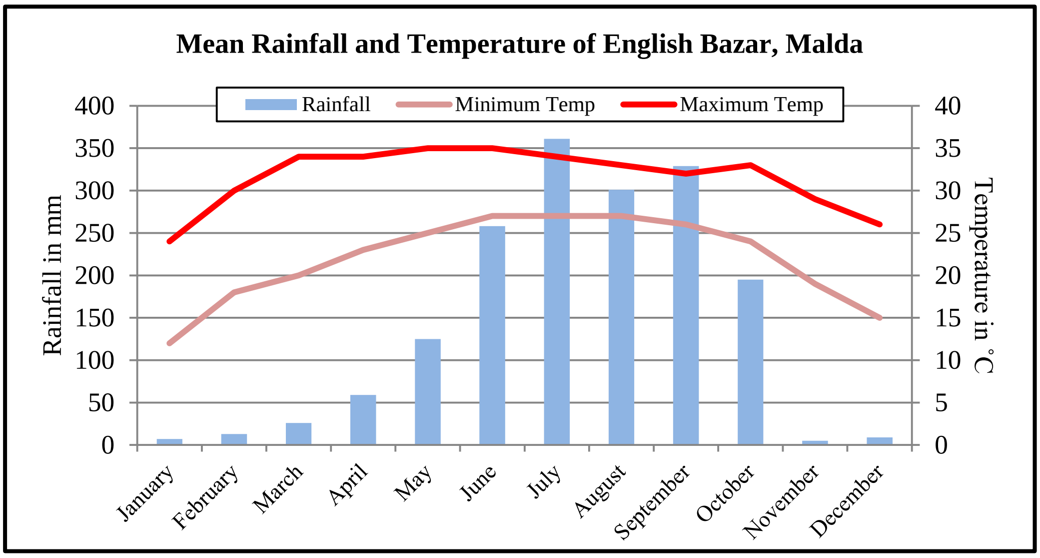


Figure 2.1: *Mean monthly temperature and rainfall of English Bazar, Malda*

2.4.2 Rainfall:

The mean annual rainfall of English Bazar is about 1500.0 mm, 75% of which fall during the monsoon months (June to September). July and August are the months, with heaviest rainfall contributing 300-360 mm followed by September (329 mm) and June (258 mm). On contrary, months from November to January are devoid of rainfall and records only 5-9 mm. Furthermore, Malda district is also mentionable for its high intensity rainstorms. Long term monthly rainfall pattern of district has been tabulated in table 2.1 and diagrammatically represented in figure 2.1.

Table 2.1 Mean monthly meteorological record of Malda district

Month	Mean Temperature °C			Humidity (%)		Rainfall (mm)	Rainy-days	Wind velocity (Km/hour)
	Max	Min	Mean	08.30	17.30			
January	24	12	18	97	52	7	1	2.5
February	30	18	24	94	42	13	1	3.0
March	34	20	27	86	36	26	2	4.6
April	34	23	28.5	84	44	59	3	6.3
May	35	25	30	87	52	125	6	7.1
June	35	27	31	92	69	258	13	7.4
July	34	27	30.5	95	81	361	16	6.5
August	33	27	30	94	81	301	14	6.2
September	32	26	29	93	83	329	12	5.0
October	33	24	28.5	90	66	195	6	3.2
November	29	19	24	94	56	5	1	2.4
December	26	15	20.5	93	55	9	-	2.4
	31.58	21.92	26.75	91.58	59.75	140.66	71.9	4.7

Source: *IMD, Govt. of India*

2.4.3 Temperature:

January is the coldest month with the mean daily minimum and maximum temperatures recorded to be 12° C and 24° C respectively *(Figure 2.1)*. During January and February, night temperature normally drops to a couple of degrees above the freezing point and frost occurs for 1-2 days in a year. Such condition with cold spells often occurs in the wake of western disturbances. The lowest ever recorded temperature was 3.0° C in 1905. Temperatures begin to rise by the beginning of March. June is the hottest months with a range of mean minimum and mean maximum temperature of 27° C to 35° C. The highest ever temperature was recorded to be 41° C, recorded in 1997. The heat during the summer is oppressive as the moisture content in the air is high. With the arrival of monsoon in mid-June the day temperature decreases by 2° or 3° C but the night temperature continues to rise (*Gazetteers of*

West Bengal, Malda, 1969). Therefore, the temperature remains extortionate and the fluctuation of day and night temperature has been recorded only 6° to 7° C (*Figure 2.1*) (*Table 2.1*). With the withdrawal of the south-west monsoon by about first week of October, both day and night temperatures drop steadily and the weather gradually becomes cooler to cold.

2.4.4 Humidity:

Atmosphere is highly humid throughout the year in this district except the period between Decembers to middle of February. Afternoons are generally less (70-75%) humid during cold and spring season while, during monsoon months humidity is found to be high (80-88%) throughout the day. Month of July records the highest relative humidity both in the morning (08:30 am) and in the afternoon (17:30) amounting to 95% and 81% respectively (*Figure 2.2*). March is the driest month when the mean humidity has been recorded to be within 50% to 65% during 08:30 and 17:30 hours respectively.

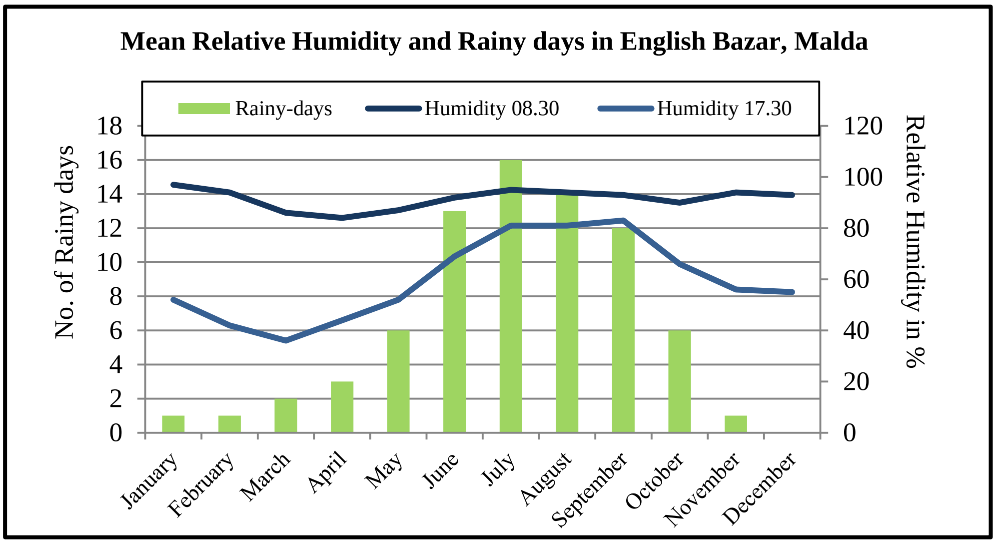


Figure 2.2: *Mean monthly relative humidity and rainy days in English Bazar, Malda*

2.4.5 Cloudiness:

In the monsoon month sky remains heavily clouded to overcast. During July and August on an average 12 days remain overcast. From October to April, the sky generally remains clear or partially clouded. Cloudiness begins to increase from May onwards.

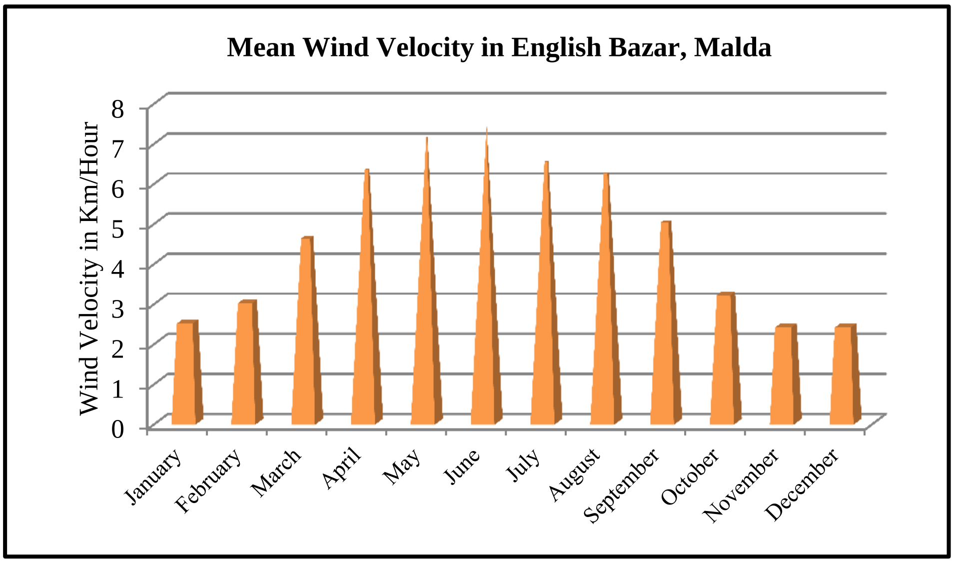


Figure 2.3: *Mean monthly wind velocity in English Bazar, Malda*

2.4.6 Wind:

Wind is generally light, except for a short spell of thunderstorms during the period between months of March to May. Mean monthly wind velocity of Malda district is shown in figure 2.3. Some of the cyclones and depressions that originate from the Bay of Bengal during south-west monsoon and post-monsoon seasons move in a northerly direction and affect the district and its neighborhood as well as causes widespread heavy rain and high wind. Thunderstorms during the months of April and May generally occur in afternoons, which are occasionally associated with squall and hail. Fog occurs in the winter months.

2.5 Drainage:

The rivers of Malda district are mostly of Himalayan and sub Himalayan origin and flow generally in southerly direction. The district is drained by major rivers namely the Ganga, the Kalindri, the Mahananda, the Tangan and the Fulahar *(Map 2.3)*. There are also other rivers like Punarbhava, Brahmani, Pagla, Buri Ganga, Chota Bhagirathi, Behula, Jalangi, Baromasia etc. situated in the district.

2.5.1 The Ganga:

The river Ganga runs through the blocks of Manikchak, Kalichak 2 and 3 and forms the south-western boundary of Malda district. The river touches the Sakrigali ghat opposite to Sahibganj of Bihar. Being obstructed by the Rajmahal massifs, it takes a southward sweep turn and follows the Garo-Rajmahal Gap of Bengal Basin as well as enters in the district at Gaduri of Bhutni char (Manikchak) under *Diara* region with a length of about 15 miles (24.2 km) (*Gazetteers of West Bengal, Malda, 1969*). Further downstream, it meets with the river

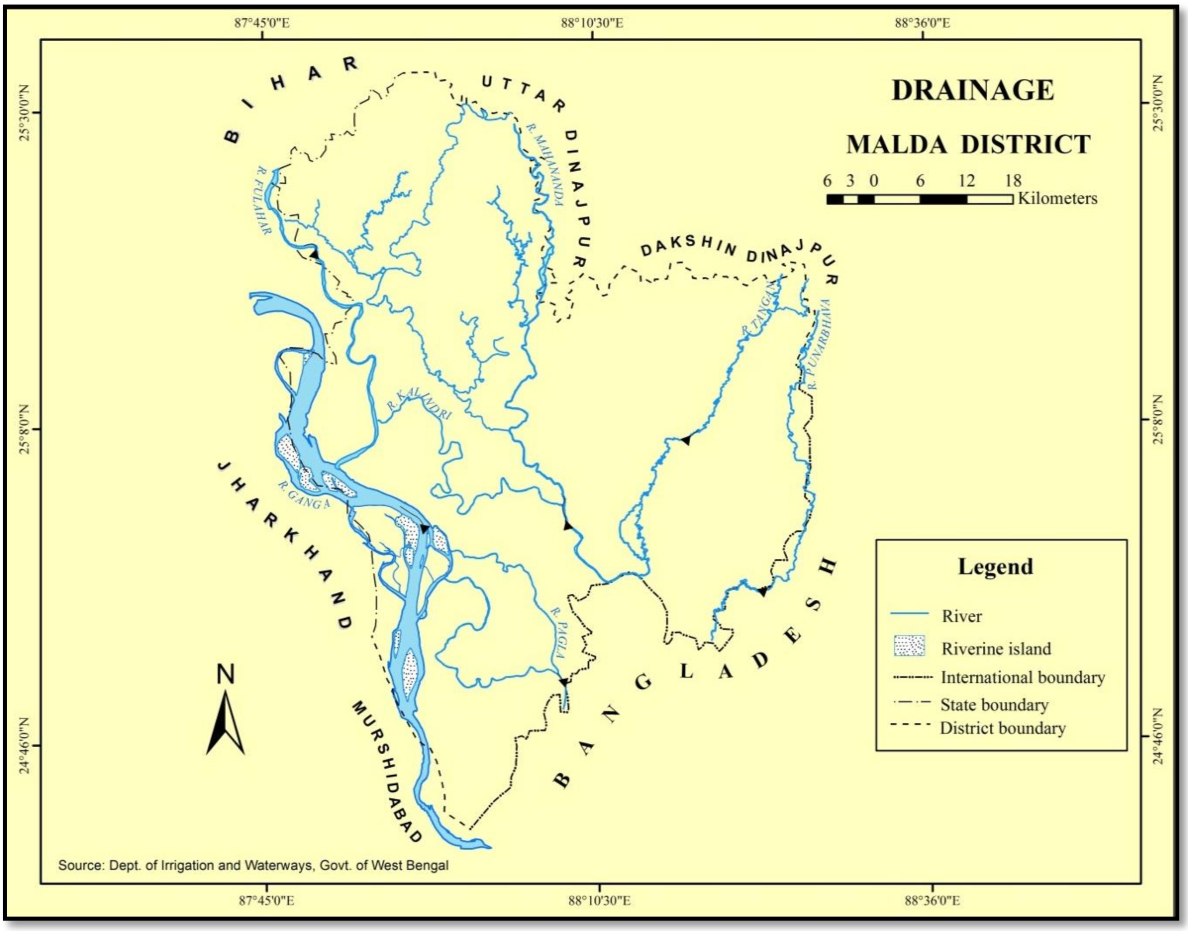
Kalindri, though now the opening has been dried up as the river has receded to the west. Hamilton, understood that the lower part of the Kalindri between this junction and the town of English Bazar as a zigzag branch course of the Ganga. About 3 km below Rajmahal, the Ganga throws off a small stream named Chota Bhagirathi, which is also presumably an old bed of Ganga. It runs first to the east and later to a southerly direction, bordering for about 20 km of the ruins of the famous Gaur dynasty. Possibly during 1700 A.D. onwards the Ganga had changed its course and shifted towards its present course.

2.5.2 The Mahananda:

The Mahananda is a trans-boundary river, flows through the Indian states of West Bengal, Bihar and Bangladesh. The river rises in the lower slopes of the Himalayas from Mahaldhiram hill near Kurseong at an elevation of 2100 m and flowing southwards. It enters in Malda district from the extreme north-west corner. It then flows eastwards, approximately along the district boundary through Kharba, where it turns south and flows more or less straight through the central part of the district, covering the blocks of Gajole, Old Malda and English Bazar. It receives the water of Kalindri on its right bank, and from Tangan and the Punarbhava on the left before it falls into the Ganges at Godagari near Nawabganj district in Bangladesh. The total length of Mahananda River is 55 miles (88.6 km) in Malda district (*Gazetteers of West Bengal, Malda, 1969*). Being conjugated with river Kalindri, it suddenly widens to about 200-600 m and it acts as boundary line between the physiographic divisions of *Tal* and *Barind*. During the last century, changes have taken place in its course, but between the dates of Rennel's map it was flowing through the present Mara Mahananda along the western boundary of Kharba police station. At the North of old Malda, the river becomes narrower and shallower, as it is above the junction with the Kalindri.

2.5.3 The Kalindri:

The river Kalindri is simply an offshoot of the eastern branch of Ganga, but actually it is a branch of the river Mahananda, and renamed as Fulahar. Bypassing through the district of Purnea, it enters in Malda district near Mihaghat, from where it is known as River Kalindri. It took off about 3 km north-west of Ratua and following a winding course in south easterly direction through the blocks of Harishchandrapur 2, Ratua 1, 2, Manikchak and Old Malda and ultimately debouches into the Mahananda at Nimasari (the northern boundary of English Bazar municipality) after traversing through an irregular course. It empties itself into the river Mahananda during rainy months but in dry seasons it looks like discontinuous pool of water. The total length is 53 miles (85.33 km) in Malda district (*Gazetteers of West Bengal, Malda,* *1969*). In the north, it receives its tributaries like the Kali kosi, Kankhor, Kosa and Baromasia, four small streams which drain the entire *Tal* area. The bank is high and steep, where erosion has taken place with resulting into red clay or sandy soil. The river is navigable in the rainy seasons and fordable in hot weather. During dry season the reach between Ratua and Chandipur becomes almost dry and is worth to even foot crossing. Between Mirjadpur and Araidanga the channel retains some water. But the Milki-Amriti reach is again remains dry.



Map 2.3: *Drainage map of Malda District*

2.5.4 The Fulahar:

The river Fulahar extends itself for about 100 km since its take-off from old Mahananda or Mara Mahananda near Bagjob. Actually the river has been traversed through Purnea of Bihar and near Miaghat of Harischandrapur. The confluence of Fulahar and Ganga is now at Narayanpur of Manikchak block. At the beginning of this century the river used to follow through the abandoned channel of Kalindri and emptied itself into Kalindri. The river system between Mihaghat and Shankartola has been named as Fulahar–Kalindri system.

Teljana, Kankhar, Baromasia, Kush, Kalkosh etc. are the main tributaries of Kalindri, which contribute to river Fulahar.

2.5.5 The Tangan:

River Tangan is an important tributary of Mahananda. The source area of the river has been destructed by the natural calamities. Being originated from Jalpaiguri district, it has passed through Panbari of Bangladesh as well as crossing Thakurgaon and Pirganj area. The river has again entered to Hemtabad of North Dinajpur district and then flows downstream over the plains of Banshihari and Gangarampur of South Dinajpur district. It has entered into Malda district at the boundary of Bamangola and Gazole police stations. The length of this river in the district is nearly 40 miles (64.4 km) (*Gazetteers of West Bengal, Malda, 1969*). The paleo-channels of the Tangan had been found for more than the miles named Mara Tangan in the Gazole block, whereas the Chunakkhai nala of Old Malda block is the abandoned cut off of the Tangan. Floods in Tangan River are associated with the floods in the Mahananda.

2.5.6 The Punarbhava:

River Punarbhava is the important off shoot of Teesta and the other two are Karotoya and Atreyee. These three make the form of Teesta meaning thereby three streams i.e., *'trisrota'* and Punarbhava is the southern/western most off stream from Teesta, with a length of about 40 miles (64.4 km). The Punarbhava forms the boundary for a few miles between Tapan in West Dinajpur and the police station of Bamangola in Malda district (*Gazetteers of West Bengal, Malda, 1969*). The river contains steep banks; particularly where it passes through the *Barind* formation. Floods in this river is also associated with the Mahananda, and during 1787 at the time of the great avulsion of the Teesta, the river Punarbhava started to be suffering from regular flow of water.

2.5.7 The Pagla:

Few miles downstream of Gaur, one of the eastern distributaries of mighty Ganga has been originated and designated as river Pagla. The river Chota Bhagirathi has been embodied with Pagla and performs an annular or semi-circular drainage pattern. During the period of 2003 flood, the watershed between Pagla and Ganga has totally been obliterated as well as has been captured by the grasps of river Ganga.

2.6 Soil:

In Malda district, there is variability in the soil morphology and its physical and chemical properties, which depends upon the geomorphic situations, moisture regime and degree of profile development. The district is enriched with alluvial Soil. North-east of the district is occupied by older alluvium soil and the south-west by deep to very deep newer alluvial soil, which is comparatively more fertile. Alluvium association of soil has an immature profile. Chemical and morphological observations show that one or two sandy layers are often found in the profiles examined. These soils are rich in calcium. Free calcium carbonate occurs over most of the area either in the surface soil or within 2 to 3 ft. in the profile.

2.6.1 Taxonomic Classification of Soils of Malda District:

The first modern classification of soil of West Bengal was initiated during the middle of twentieth century by the rapid reconnaissance survey based on 9.6 km grid system with the launching of Stwarart Scheme by the Department of Agriculture, Government of West Bengal in collaboration with I.C.A.R. *(National Commission on Agriculture, 1976)*. National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) in co-operation with the Department of Agriculture, Government of West Bengal has published Soil Map of West Bengal in four sheets in 1991. This is perhaps the most comprehensive and descriptive map of West Bengal's soil. The present discussion has mostly been based on the above mentioned study. The following table 2.2 and map 2.4 represent the major Taxonomic Order, Sub-order, and Great Groups which have been identified in Malda district. **Two** taxonomic soil Orders, **four** Sub-orders, **four** Great groups and **six** Sub-Groups have so far been identified.

2.6.1.1 Entisols:

These soils have little or no evidence of pedologic profile development either due to short duration or receiving of new deposits of alluvial at frequent interval from the higher tracts *(Sarkar, 1996)*. The only evidence of pedogenic alteration in these soils is a small accumulation of organic matter in the upper 30 cm of soil profile. Entisols may have an ochric or anthropic epipedon. A few that are sands have an albic horizon. The Entisols of Malda district have mostly ustic soil moisture and temperature regime. The order Entisols comprises an area of 1167.8 sq. km or 31.3% of the total geographical area of Malda district (*Map 2.4*). Two Sub-orders: Fluvents and Orthents have so far been identified in the district.

2.6.1.1.1 Fluvents:

These are mostly light brownish to reddish soils that are formed in recent water-deposited sediments mainly on flood plains. The Fluvents are flooded frequently unless dams or levees protect them. Stratification of the materials is normal. Most alluvial sediments came from eroding soils or stream-banks and contain an appreciable amount of organic carbon that is mainly in clay fraction. Strata of clayey or loamy materials commonly have more organic carbon than overlying more sandy strata. Thus, the percentage of organic carbon decreases irregularly with depth if the materials are stratified. The Fluvents of Malda district have been identified as Ustifluvents.

Table 2.2 Major Taxonomic Orders, Sub-order and Great Groups of Soil in Malda District

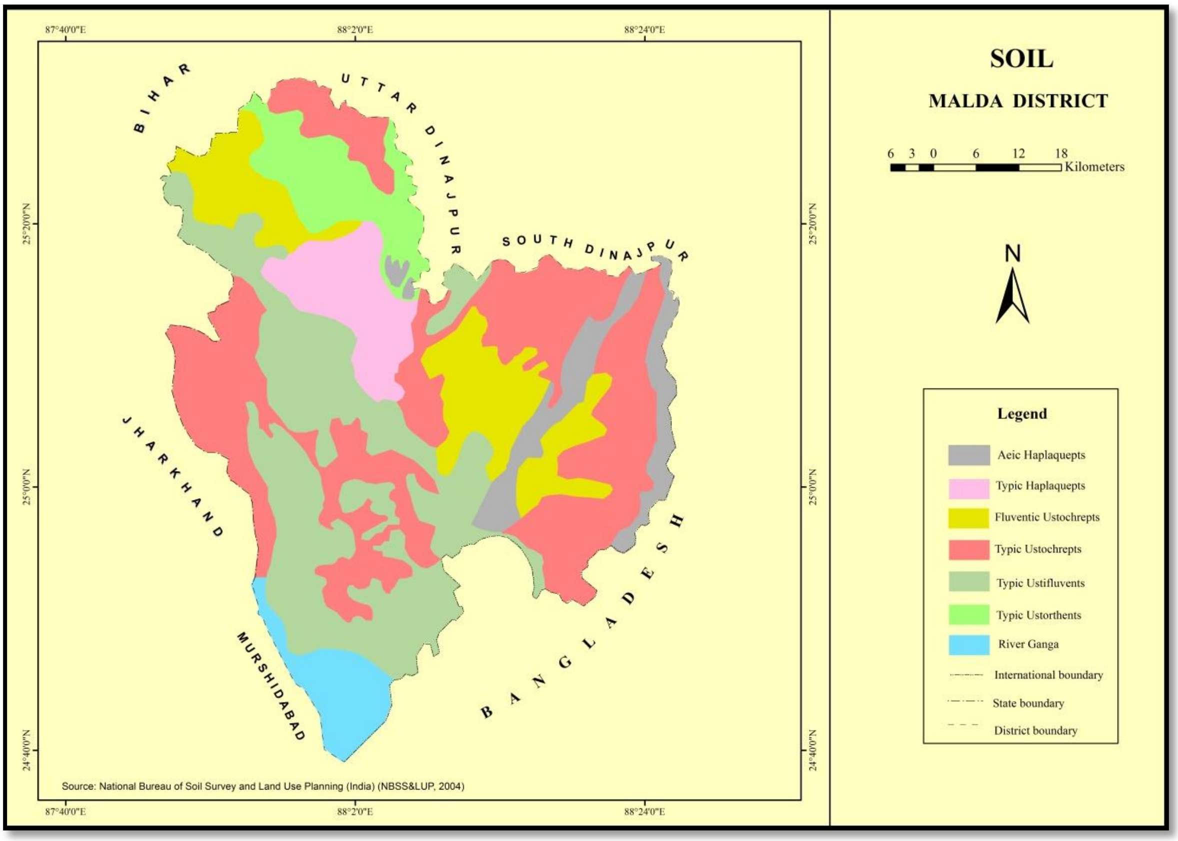
<table>
<tr><th>Orders</th><th>Sub-Orders</th><th>Great Groups</th><th>Sub-Groups</th><th>Area (sq. km.)</th><th>Area (%)</th></tr>
<tr><td rowspan="2">Entisols</td><td>Fluvents</td><td>Ustifluvents</td><td>Typic Ustifluvents</td><td>919.3</td><td>24.6</td></tr>
<tr><td>Orthents</td><td>Ustorthents</td><td>Typic Ustorthents</td><td>248.5</td><td>6.7</td></tr>
<tr><td rowspan="4">Inceptisols</td><td rowspan="2">Aquepts</td><td rowspan="2">Haplaquepts</td><td>Aeic Haplaquepts</td><td>217.9</td><td>5.8</td></tr>
<tr><td>Typic Haplaquepts</td><td>230.6</td><td>6.2</td></tr>
<tr><td rowspan="2">Ochrepts</td><td rowspan="2">Ustochrepts</td><td>Typic Ustochrepts</td><td>1661.3</td><td>44.5</td></tr>
<tr><td>Fluventic Ustochrepts</td><td>455.4</td><td>12.2</td></tr>
</table>

2.6.1.1.1.1 Ustifluvents:

These are the Fluvents that have an ustic soil moisture and isomesic to isothermic soil temperature regime. These soils are found on flood plains and are found flooded regularly during monsoon. The soils are previously known as alluvial soils and occupy 919.3 sq. km or 24.6% of the total geographical area of Malda district. The Ustifluvents are best developed in recent alluvial materials of Mahananda flood plain. They are very deep, well drained, dark yellowish brown coloured, moderately fine textured and neutral in reaction. **A** horizon is often underlain by layer of sandy deposit i.e. **C** horizon. Abundant mica particles are present throughout the soil profile. Within the subgroups of Entisols, Ustifluvents have higher soil organic carbon stock than other subgroups *(NBSS & LUP, 2004)*.

2.6.1.1.2 Orthents:

These are primarily Entisols on recent erosional surfaces, where the former soil has completely or partially been removed or so truncated that the diagnostic horizons for all other orders are absent. The great groups have been identified in as Ustorthents.



Map 2.4: *Soil map of Malda District*

2.6.1.1.2.1. Ustorthents:

These are the Orthents that have ustic soil moisture and thermic to isomesic soil temperature regime. The Ustorthents commonly occur in very recently exposed regolith, mostly in soft sedimentary deposits. Ustorthents occupy 248.5 sq. km or 6.7% of the total geographical area of Malda district. These soils are best represented by the *Amra series*, which develops on granite or gneissic parent rocks and has moderately to very steep slope. These are shallow to very shallow well-drained soils and have brown and dark brown colour, slightly acidic in reaction and have gravelly clay loamy **A** horizon over stones and pebbly **C** horizon.

2.6.1.2 Inceptisols:

These soils occur mostly in the plain and also in the lower topographic situation in a hydromorphic (aquic moisture regime) environment in West Bengal *(NBSS & LUP, 2004)*. Inceptisols have altered horizons that have lost bases or iron and aluminum but retain some weather able minerals, they do not have an illuvial horizon enriched either with silicate clay that contains aluminum or with an amorphous mixture of aluminum and organic carbon. The common diagnostic horizons may have an umbic or ochric epipedon, a cambic horizon, a fragipan and a duripan. Inceptisols develop mainly in the fine textured parent materials. These are the most common soils in Malda district covering 68.7% (2565.2 sq. km) of total geographical area of the district as well as mostly utilized for paddy cultivation. Two Sub-orders have so far been identified: Aquepts and Ochrepts.

2.6.1.2.1 Aquepts:

These are the wet Inceptisols. Their natural drainage is poor or very poor and if they have not been artificially drained, ground water stands close to the surface at some time during each year but not at all seasons. They mostly have grey to black surface horizon and mottled grey subsurface horizon. Most Aquepts are found in younger deposits i.e., in depressions, very flat plains, or flood plains. Most of them have cambic horizon, and some have fragipan. Aquepts of Malda district have been identified to be Haplaquepts Great group.

2.6.1.2.1.1 Haplaquepts:

These are sodic soils and have shallow ground water level and have a season in which capillary rise and evapo-transpiration bring sodium or other salts to or near the surface. The Haplaquepts normally are grey and mottled from the surface down ward or from a depth near the surface. Nearly, all these soils are level and are in Holocene alluvium. The vegetation, generally are hedges and salt-tolerant grasses and shrubs, but some of them have partially drained and are now irrigated for crops. Two Sub-Groups have so far been identified in Malda district (i) Aeic Haplaquepts and (ii) Typic Haplaquepts. Aeic Haplaquepts occupies an area of 217.9 sq. km. (5.8%) and are mostly identified in Gajole, Bamangola, Habibpur and Old Malda blocks of Malda district. Typic Haplaquents occupies 230.6 sq. km. or 6.2% area of the district and are identified in Chanchal 2 and Ratua 2. These soils are very deep, imperfectly drained and have light brownish grey to olive grey in colour, slight acidic in reaction, sandy loam to loamy **A** horizon, light grey, loamy **C** horizon. The cation exchange capacity is 8 to 16 m.e. /100gm of soil.

2.6.1.2.2 Ochrepts:

Ochrepts are of light colour, brownish, more or less freely drained Inceptisols. They have been formed on undulating or sloping ground of late Pleistocene or Holocene age. Ochrepts have an ochric epipedon and a cambic horizon. Ustorchrepts as the only Great group of Sub-order Ochrepts has so far been identified in Malda district.

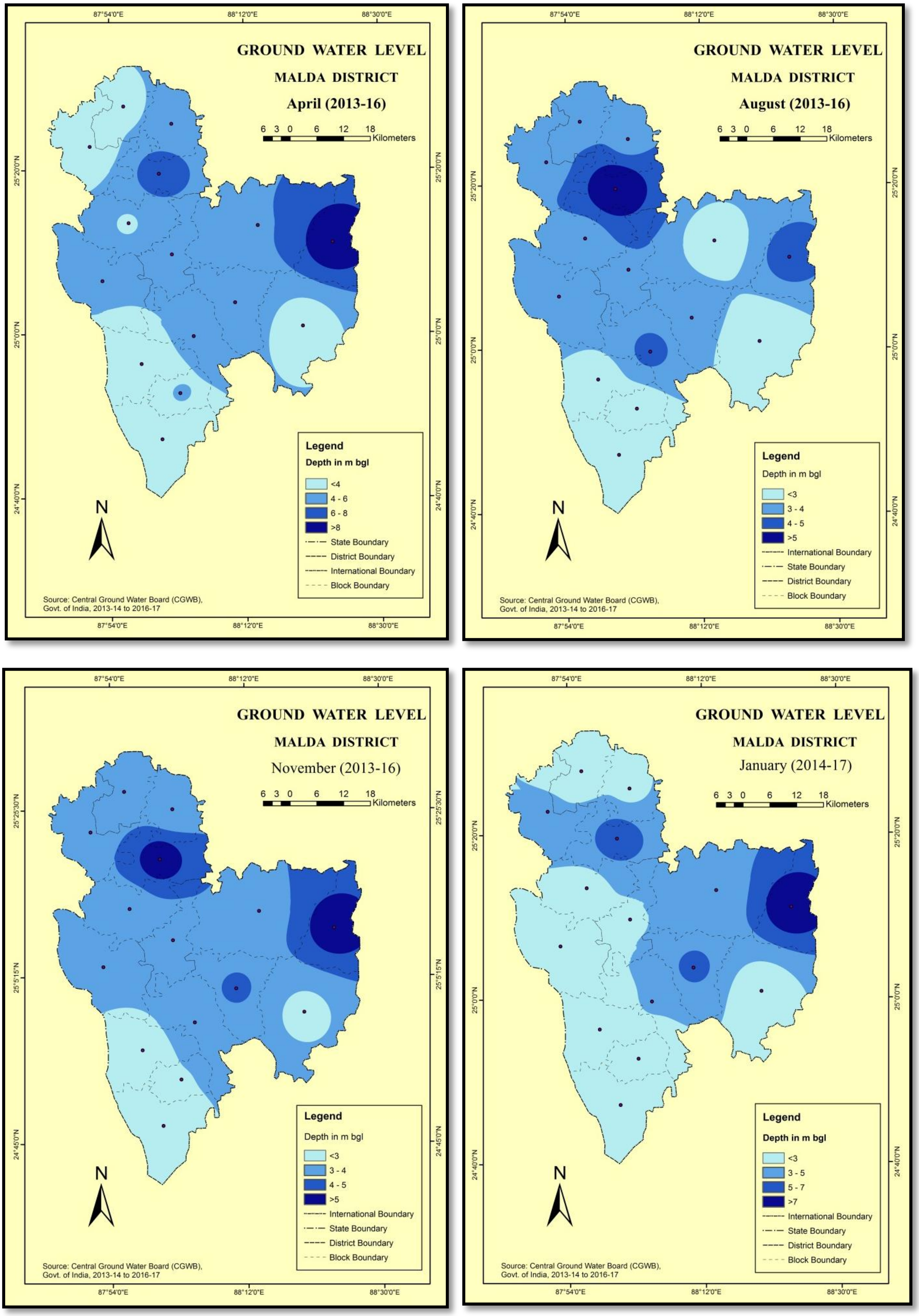
2.6.1.2.2.1 Ustorchrepts:

These are the reddish or brownish ochrepts, found in Holocene deposits. Ochrepts of ustic soil moisture regime (Ustorchrepts) are the most common soils found in Malda district covering an area of 2116.7 sq. km or 56.7% of the total geographical area of the district. These soils are developed on colluvial deposits and are very deep, imperfectly drained and have yellowish brown colour. The **A** horizon is slightly acidic in reaction and loamy in texture while the **B** horizon is characterised by yellowish brown in colour and neutral in reaction.

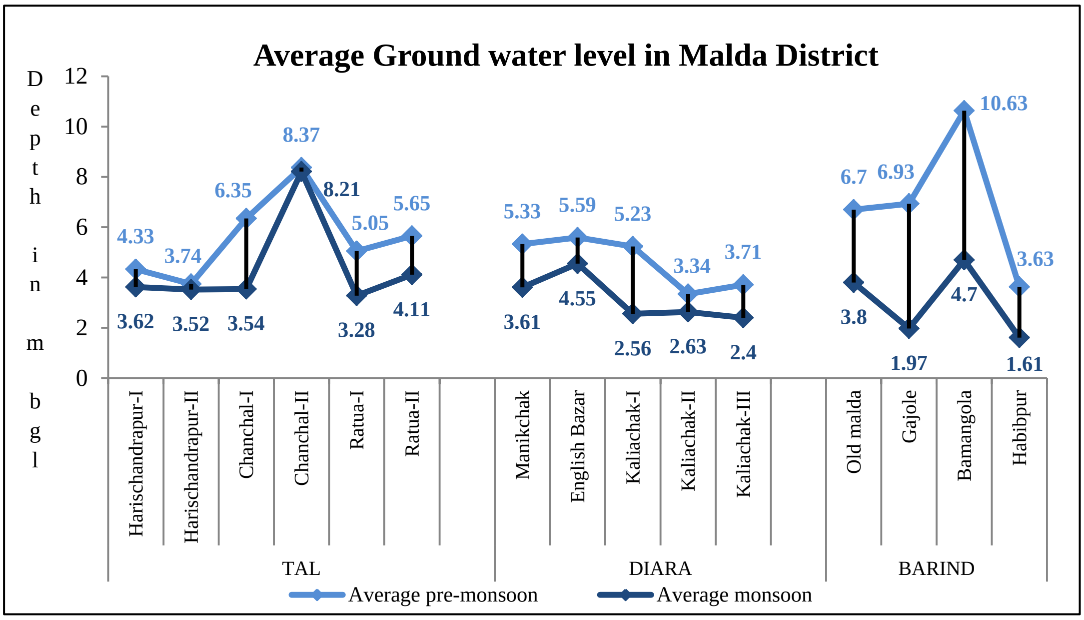
2.7 Ground water:

The ground water table is very effective and technically feasible alternatives for storing substantial quantity of monsoon run off. The geological formations of these sub-surface reservoirs may be considered as "warehouse" for storing water that come from the sources, which are located on the land surface (*CGWB, 2000*). There are several pockets in Malda district, where water table is either high or low, which is determined by the local slope, soil texture, and soil structure, rainfall and permeability factor. Within the three natural regions of district *Tal*, being centrally depressed region, as well as characterized by lack of gradient and consequent runoff, remains submerged under considerable depths of water especially during the monsoon rains.

Diara is a well-drained flat land. Thus the ground water level in both *Tal* and *Diara* is moderate to high throughout the year. *Barind* tract, being featured with hummocky and undulating terrain, suffer from low ground water table especially during pre-monsoon period. However, the ground water level of Malda district, covering four seasons namely pre-monsoon, monsoon, post-monsoon and winter, are displayed in map 2.5 *(Appendix-1)*. The ground water level (m bgl) between pre-monsoon, monsoon, post-monsoon and winter during 2013-17 has been shown *(Map 2.5)* in order to delineate the impact of rainfall and resultant ground water development on the ground water regime in district. The seasonal fluctuation in water level between pre-monsoon and monsoon is dominated by a rising pattern *(Figure 2.4)*. Normal rainfall in the mentioned year has resulted into rise in water level in almost each block in Malda district. The *Tal* region (Harischandrapur 1 & 2, Chanchal 1 & 2, Ratua 1 & 2) record an average water level ranging from 3 m to 8 m bgl throughout the year. With exception, Chanchal 1 and 2 record low to moderate water table throughout study period, which is attributed to lack of village level data. However, introduction of boro paddy cultivation in a large scale is another important factor for declining trend of water level.



Map 2.5: *Ground water levels (m bgl) in Malda District during 2013-17*



Source: *Central Ground Water Board, Ministry of Water Resources, Govt. of India, 2013–2017*

Figure 2.4: *Average ground water level during 2013-17 in Malda District*

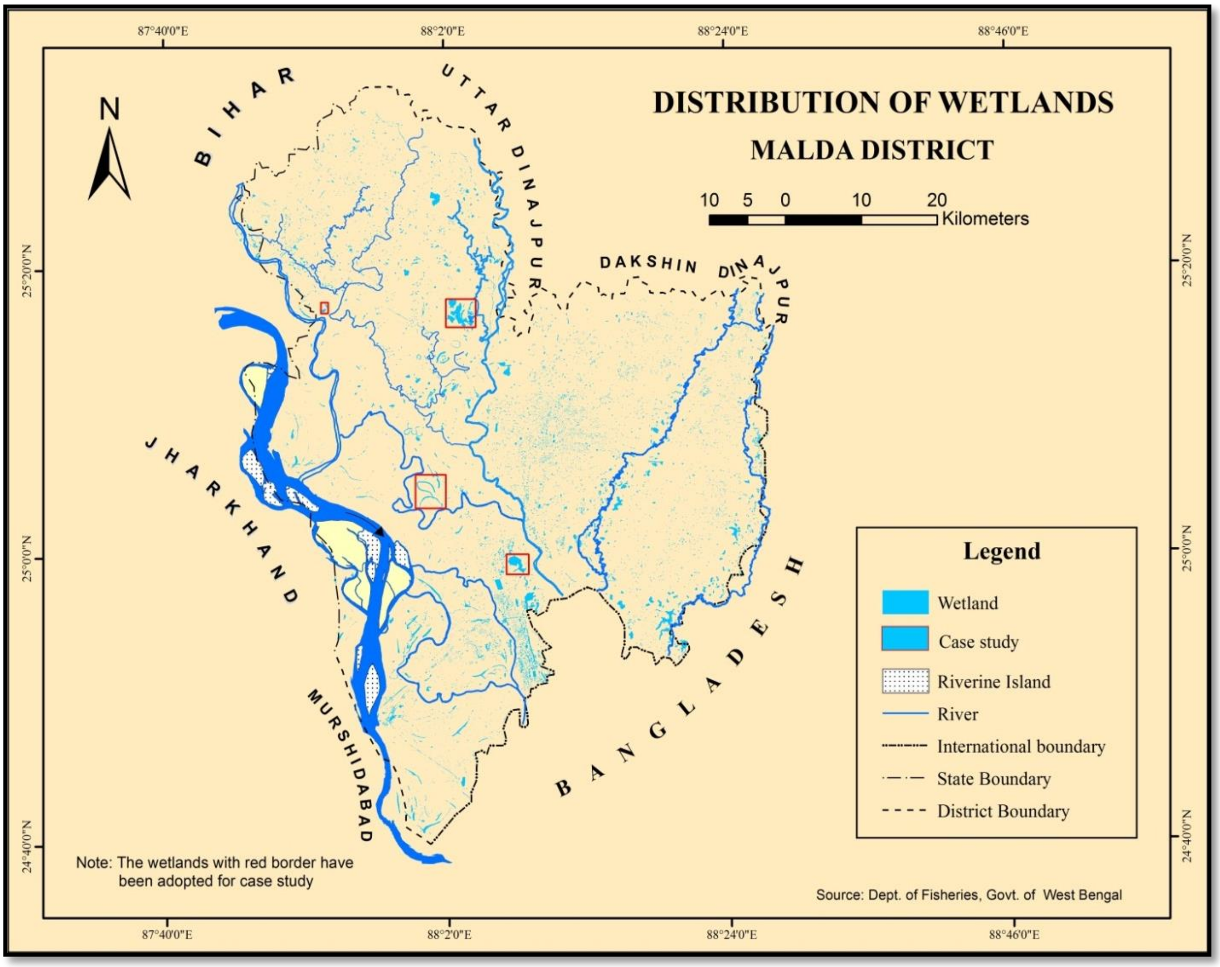
Barind region (Old malda, Habibpur, Gajole, Bamangola) records much fluctuating water level with noticeable rise from average 4 m to 10 m bgl during 2013-17 study period. Bamangola block along with Gajole with highest elevation in district record a maximum rise in water level from pre-monsoon to monsoon *(Figure 2.4)*. *Diara* region (English Bazar, Kalichak 1, 2, 3 and Manikchak) exhibits a steady rise ranging from 2.5 to 5 m bgl from pre-monsoon to monsoon *(Appendix-I) (Figure 2.4)*.

2.8 Natural Vegetation:

In Malda district, the area under forest is 20 sq. km which is only 0.54% of total area, containing 8 and 5 sq. km under reserve and protected forests respectively and 7 sq. km under un-classed state forest *(State Forest Report, Govt. of West Bengal, 2011-12)*. The largest protected forest is locally known as Kariali Forest, which still contents a remnant of the natural forest vegetation. Adina is another forested tract, which is close to English Bazar. Scattered small section under forest areas is located in Old Malda, Harishchandrapur and Gajole blocks. The most abundant vegetation is *Bambusa vulgaris* (Bamboo), *Ficus benghalensis* (Banyan), *Ficus religiosa* (Peepal), *Delonix regia* (Krisnachhura) and *Vachellia nilotica* (Babul). The forest comprising of natural species like *Shorea robusta* (Sal), *Barringtonia acutangula* (Hijol.), *Dalbargina sisso* (Sisso), *Bombax ceiba* (Cotton), *Azadirachta indica* (Neem), *Albizzia lebbeck* (Siris), *Neolamarckia cadamba* (Kadam), *Tamarindus indica* (Tetool) etc. The Deciduous types of vegetation such as *Cocos nucifera* (Coconut), *Litchi chinensis* (Litchi), *Tectona grandis* (Sagwan/ Teak), *Toona ciliata* (Toon) etc. are also found in this district. Among the fruits grown in the district, Mangifera indica (mango) is the most famous. The mango orchards are distributed all over the district, especially in west of River Mahananda, with the exception of a strip along River Ganga. The existence of the following fruit species can still be noticed in the district such as *Artocarpus heterophyllus* (jack-fruit), *Phoenix dactylifera* (date-palm), *Annona reticulate* (custard apple), *Cucumis melo* (marsh melon), *Citrullus lanatus* (water melon) etc.

2.9 Wetland status:

Malda district represents a mature geomorphic process with strong evidences of complex hydrological activities in the form of recurring shifting of river channels, massive bank erosion along with often dereliction of rivers etc. The unique fluvio-geomorphic set-up facilitates the formation of natural inland wetlands like cut-off meanders, seasonal waterlogged areas, lakes, and marsh etc. The district is occupied by 562 wetlands (≥2.25 ha) according to IWMED *(Bhattacharya, et al., 2000)* and 502 wetlands (≥2.25 ha) according to Space Application Centre *(SAC, ISRO; 2010)*. The wetlands of this region are generally palustrine (floodplains, seasonal waterlogged, marsh), lacustrine (Lakes) and riverine types. All these wetlands are directly or indirectly connected with the different river systems namely Ganga, Mahananda, Kalindri, Tangan, Punarbhava and Pagla. In terms of the spatial extents of different wetland categories, inland natural wetlands in the form of riverine wetlands, waterlogged seasonal are mostly dominant followed by natural lakes/ ponds, marshy lands and man-made wetlands in Malda district. Moreover, a considerable portion of the district is occupied by cut-off meander/ ox-bow lakes. Out of the well identified physiographic regions, *Tal* tract, being full of large and small depressions, exhibits maximum number of wetlands, followed by *Barind* and *Diara* tracts. *Diara* region, which is a low bank of river, floods deeply. As a consequence, extensive and frequent flooding in this vulnerable geographical entity drastically expunges the possibility to identify the individual wetlands. On the other hand, in spite of promoting a fair amount of run-off, *Barind* tract of high and undulating terrain restrict widespread flooding. Therefore, the individual wetlands with their specific characteristics are easily identifiable (*Map 2.6*).



Map 2.6: *Distribution of wetlands in Malda District*

2.10 Conclusion:

Malda district is crisscrossed with plentiful rivers, which are flowing through the well-defined physiographic divisions. The district is occupied by number of river linked wetlands, each with specific characteristics. Most of the wetlands throughout this district is treated as an efficient wealth as well as have great significance in terms of ecological and socio-economic benefits. Being highly productive and rich in biological diversity, these wetlands provide a vast range of ecosystem services i.e. food, fiber, waste assimilation and water purification, flood mitigation and recharging the ground water. Further, most of wetlands in Malda district are being used for paddy cultivation *(Bhattacharya, 2000)* and are potential to promote gainful self-employment and tourism activity for being a part of the cultural heritage.

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Chapter – III

CLASSIFICATION AND

CHARACTERISTICS OF WETLANDS

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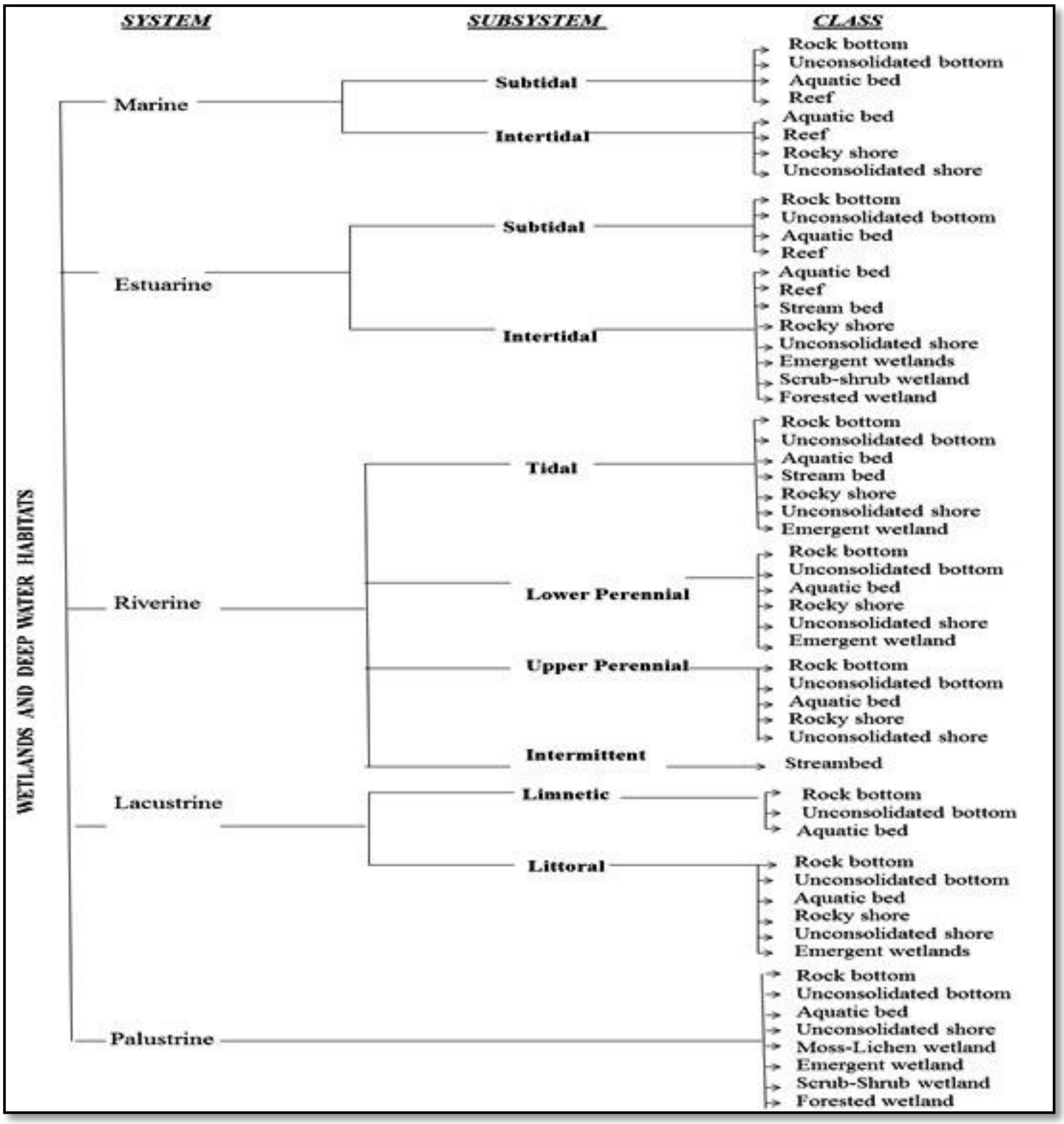
CLASSIFICATION AND CHARACTERISTICS OF WETLANDS

3.1 Introduction:

Wetlands are functional part of the local or district water cycle and are at the heart of the nexus. Malda district has a spectacular combination of different categories of wetland. A fairly good portion especially the depressions (*Tal* and *Diara*) are occupied by wetlands and water courses in the study area. The spatial distribution of wetlands varies in the areal extent. The importantce of these wetlands lie in the fact that their unique ecological features provide a range of regulatory, provisioning, supporting, and cultural services for environmental sustainability of the entire district.

3.2 Classification of wetlands:

Classification of wetland types is a very in-depth and a complicated process as the more one considers the variations in wetland characteristics; the more categorizations can be created *(Marti, 2011)*. Wetland classification refers to the system or method which categorizes wetlands and water bodies according to their similar physical characteristics in the form of hydrology, existing vegetation etc. and where the values and functions of wetlands are not apparently considered. The adoption and development of wetland classification is necessary to impose the boundaries on natural ecosystems for the purpose of inventory, evaluation and for better management. The purpose of wetland classification is to standardize and define the terms, being used to describe the various wetland types *(Cowardin et al., 1979).* A variety of classifications have already been developed for wetlands on the basis of hydrology and geomorphology such as wetland sources (riverine/surface runoff/ground water), wetland location (inland/coastal), salinity (fresh water/salt water) and commonly recognized vegetation cover of wetlands. The most widely used comprehensive classification systems have been developed for the United States Fish and Wildlife Service *(Cowardin et al., 1979) (Figure 3.1)*. The structure of Cowardin system is hierarchical, progressing from systems (5), sub-systems (10), classes (56), sub-classes along with a series of water regime, chemistry and soil modifiers. This classification of wetland and deep water habitat has categorized the wetlands into five major systems: 1. Marine, 2. Estuarine, 3. Riverine, 4. Lacustrine, and 5. Palustrine; each with their own specific subdivisions, based on their hydrological, ecological and geological characteristics. Being thorough and extensive, Cowardin's system of wetland classification is appropriate for an ecologically based understanding of wetland definition. Another wetland classification scheme was suggested by Dugan, which is similar to Cowardin's classification.



Source: *Cowardin et al., 1979*

Figure 3.1 *Classification hierarchy of wetlands and deep water habitats, showing Systems, Sub-systems and Classes*

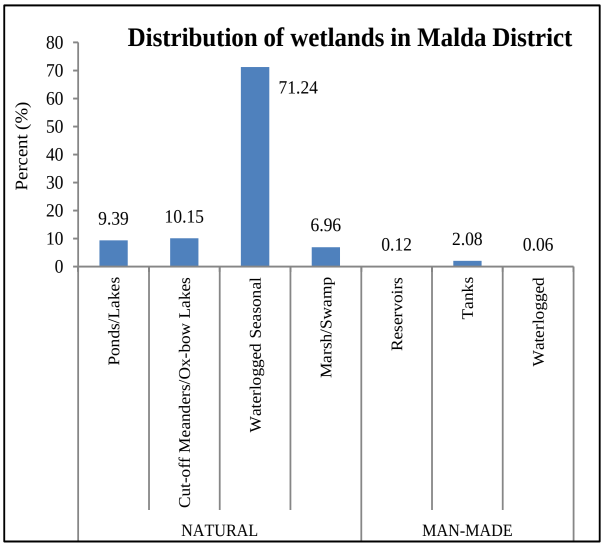
Dugan has classified the wetlands into three major systems: 1. Salt water wetlands, 2. Freshwater wetlands and 3. Man-made wetlands. These systems are further subdivided into twelve types and ten sub-types, based on the hydrological characteristics *(Dugan, 1990)*. Later Canadian Wetland Classification system has provided alternative schemes, which has recognized three hierarchical levels: 1. Class, 2. Form, and 3. Type. Five classes are recognized on the basis of the overall genetic origin of wetland ecosystems. Forms are differentiated on the basis of surface morphology, surface pattern, water type and morphology of underlying mineral soil. Types are classified according to vegetation physiognomy *(Warner & Rubec, 1997)*. The Ramsar classification system comprises three main wetland habitats, namely 1) Marine / Coastal wetlands, 2) Inland wetlands and 3) Human-made wetlands. These categories are further subdivided into a total of 42 wetland types *(Convention on Biological Diversity, UNEP, 2003)*. Ramsar wetland classification is approved by Recommendation 4.7 and amended by Resolutions VI.5 and VII.11 of the Conference of Contracting Parties.

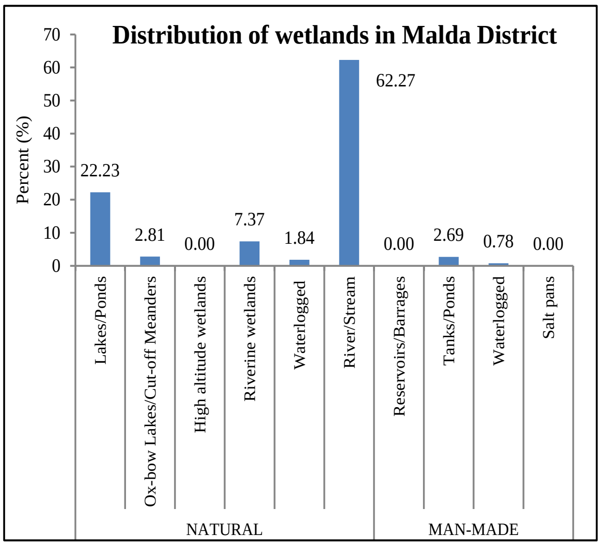
India has a wealth of wetland ecosystems, covering the whole range of ecosystem types which is enriched with inland and coastal wetland habitats and which is distributed across diverse eco-geographical region. According to the Directory of Asian wetlands in 1989, a total of 27,403 wetlands have been identified, of which 23,444 are inland and 3,959 are coastal wetlands *(NWCP, 2009)*. In addition to the natural wetlands, a substantial number of man-made wetlands have also been resulted from the need of socio-economic services and eventually been added to the country's wetland wealth. A preliminary survey has been conducted to assess the wetland resources in 1980s by the Ministry of Environment and Forests (MoEF). Based on the collected information, a Directory of Wetlands has been published by Ministry of Environment and Forest, India in 1990. According to the directory, a total of 2,167 natural and 65,253 man-made wetlands have been identified, occupying 4.1 million ha *(Rao & Datye, 2003)*. A separate classification system using remotely sensed data has been prepared for discussion in the Standing Committee on Bioresources (SC-B) and Environment in 1991, which has further been revised. The classification system for preparing national inventory of wetland has been conducted under the guidance of National Wetland Committee (NWC) with the support of National Natural Wetland Management System (NNWMS) and the Ministry of Environment and Forests, Government of India in March 1992 *(Bhattacharya et al., 2000; Prasad et al., 2002)*. The Classification System for Wetlands in India has been evolved and completed in 1997 under the Space Application Centre (SAC), Indian Space Research Organization (ISRO) Ahmedabad, in association with state remote sensing application centres, sponsored by Ministry of Environment and Forests, Government of India. SAC has identified and mapped 19 wetland classes at 1:25,000 scales in the mainland and islands using the visual interpretation of coarse resolution satellite data *(Prasad et al., 2002)*. These wetland classes are organized under a Level III hierarchical system. Level I have two wetland classes: 1. Inland and 2. Coastal, these are further bifurcated into two categories in Level II as: a. natural and b. man-made *(Murthy et al., 2013)*. A detail analysis on survey and mapping indicates the total wetland area of 7.6 million ha out of which 3.6 million ha is inland and the rest is coastal wetland *(Rao & Datye, 2003)*. Another framework for inclusion of wetland classes follow the definition, devised by the Ramsar convention, according to which, most of the natural water bodies (such as rivers, lakes, coastal lagoons, mangroves, peat land, coral reefs) and man made wetlands (such as ponds, farm ponds, irrigated fields, sacred groves, salt pans, reservoirs, gravel pits, sewage farms and canals) in India constitute the wetland ecosystem *(Bassi et al, 2014)*.

In the context of West Bengal, having a spectacular combination of diverse physiographic province, varied types of wetlands do exist here. The physiographic backdrop seems to be totally different so as to apply the Cowardin's classification system, which is considered one of the mostly accepted worldwide. Keeping the systems of wetland classification, which is prescribed under Ramsar Convention on Wetlands, a wide variety of wetlands are found in West Bengal including the freshwater inland wetlands like rivers and lakes, marshes and swamps and also coastal wetlands like mangroves, tidal flats, swamps etc. Furthermore, innumerable human-made wetlands dot the landscape of West Bengal in the form of fish and shrimp ponds, farm ponds, irrigated agricultural land, reservoirs; borrow pits, sewage farms, and canals. Institute of Wetland Management and Ecological Design (IWMED), established by Government of West Bengal, have initiated a project for mapping and inventorying the wetlands of West Bengal. Detail maps of these wetlands have been prepared on 1:50,000 scale through utilizing the Remote Sensing technology and using IRS 1B LISS II multi-temporal, synoptic FCC data of 1992-93, followed by the Survey of India topographic sheets *(Bhattacharya et al., 2000)*. Similarly, inventory and assessment of different categories of wetlands have also been conducted by Space Application Centre (SAC), ISRO, using GIS layers of wetland boundary, water spread, aquatic vegetation and turbidity. The layers have been derived from LISS III data *(SAC, ISRO, 2010)*.

In the study area of Malda district, the spatial distribution of wetlands varies in numbers as well as in area extent. The classification system, adopted by IWMED, incorporates all wetlands, along with other impoundments such as reservoirs, tanks, waterlogged marsh/swamp etc. Malda district is occupied by a fairly good portion (no. 562, each with ≥2.25ha) of around 20,956.49 ha area by waterlogged seasonal of natural class *(Appendix-2)* *(Figure 3.2)*. This natural class covers more than 71.23 % of total wetland area under the entire district. Out of total number (235) under this particular class (natural waterlogged seasonal), 11 water bodies have area greater than 100 ha. Another type of wetland in the form of cut-off meander/ ox-bow lakes (no. 190) is next in abundance, which covers 10.15% of the total wetland area. Inland natural lakes/ponds (no. 22) and marshy lands (no. 20) are also present in Malda district and have covered almost 9.38 % and 6.95 % of the total wetland area respectively. Under the man-made classes, tanks (no. 90) occupy a considerable portion of 2.08% of total wetland area *(Appendix 2) (Figure 3.2)*. Man-made reservoirs and waterlogged cover negligible portion of wetland area in this district *(Bhattacharya et al., 2000).*

As per the Space Application Centre (SAC), ISRO, Malda district contains 502 inland natural and man-made wetlands, which cover an area of 20,725 ha (each with ≥2.25 ha). The inland natural wetland category is dominant, in which river/stream (no. 32) ranks first with a total area of 12,906 ha. The district is occupied by large number of riverine wetlands (no. 148), with an area coverage 1,527 ha, followed by natural lakes/ponds (no. 123) with 4,608 ha, waterlogged (no. 48) with 382 ha and ox-bow lakes/ cut-off Meanders (no. 31) with 582 ha. Out of the man-made wetlands, tanks/ ponds (no. 105) occupy 558 ha area *(SAC, ISRO, 2010) (Appendix-3) (Figure 3.3).*





Source: *Institute of Wetland Management and Ecological Design (IWMED) (Bhattacharya et al., 2000)*

Source: *Space Application Centre (ISRO),*

Figure 3.2: *Distribution of Inland wetlands in Malda District (after IWMED)*

Figure 3.3: *Distribution of Inland wetlands in Malda District (after ISRO)*

3.3 General overview of wetlands in Malda district:

Wetlands of Malda district are considered the most important resources as well as play a key role in hydrological, biological and ecological functioning of the region. Here, the wetlands cover different proportion of area in three distinct physiographic divisions, depending on the existing geological and hydrological characteristics. Flat to basin like topography together along with the meandering nature of the rivers contribute to the formation of these types of natural inland wetlands (*Bhattacharya et al., 2000*). The wetlands of Malda district posses some common characteristics including their origin, dimensions, existing hydrological and biological properties.

1. Most of the wetlands are directly or indirectly linked with the river system of Malda district. The major rivers along with their tributaries discharging the wetlands are Mahananda, Kalindri, Fulahar and Tangan. These wetlands are generally seasonally waterlogged and some are perennial. Significant seasonal variability has been observed almost in all the wetlands in terms of open water extension and water depth in the pre-monsoon, monsoon and post-monsoon. Across all categories of wetlands, the water spread area from post monsoon to the peak of pre-monsoon reduces significantly, which indicates the practice of wetland water use throughout the year. This has major implications for the total water availability of these wetlands and the various functions that they perform in different seasons, round the year. Overall, the seasonal status of water spread area of wetlands varies from a few ha to more than 500 ha. The seasonal variability is also noticeable in wetland water depths, which varies from 2 to 3.5 meter throughout the year in Malda district *(Plate 4.1b)*.
2. Malda district is covered by a good number of wetlands; whose individual area is up to 10 ha. Out of the total number of wetlands, near about 20 wetlands are considered big with an approximate size of about more than 100 ha. Most of the wetlands are within 10 to 100 ha in Malda district *(Bhattacharya et al., 2000)*.
3. As far the shape is concerned, the wetlands of Malda district differ from one another depending on several geographical factors such as the existing topography, hydrological and soil characteristics, frequent shifting of river courses etc. Majority of the wetlands are of irregular shape. Moreover, circular, rectangular, and elongated shaped wetlands along with some isolated cut-off channels are also present here.
4. From the view point of biodiversity, the wetlands and water bodies of entire district maintain a stable aquatic ecosystem by having both the floral and faunal diversity. Aquatic biodiversity is chiefly dependent on the hydrological regime of wetland and its geological condition. Although, the wetland sites, located in *Tal* physiographic region are considered to be the repositories of diverse species of aquatic plants, fishes, birds, insects, and amphibians because of having an auxiliary ecological environment. These

biological resources not only maintain the ecological equilibrium of the environment, but also are responsible for the socio-economic upliftment of adjacent habitat.

- In the present study, the wetlands host diverse macrophytes, containing six types of growth forms, falling under two categories of habitats. The macrophytes include the growth forms namely, Semi-emergent (SE), Emergent (E), Submerged rooted (SR), Rooted floating leveaved (RFL), Free floating (FF) and Emergent grass (EG), under the habitats of a) Open water (OW) and b) Water edge (WE). The wetlands of Malda district assume its importance for harbouring large number of macrophytes of more than 30 species, including open water and water edge vegetation. The variety of plant specimens have been found from deep to shallow water covered areas of different wetlands from the study area. The free floating macrophyte Kachuripana, grow rapidly as well as form a dense mat in the open water of wetlands. Kachuripana is the major macrophyte commonly found in all the wetlands of this district. The wetland edge is generally dominated by the macrophytes namely Hatisur, Hingcha, Hygrophilia, Thankuni, Ghima and Sushni etc. The common open water macrophytes, found in these wetlands are Padma, Saluk, Water fern, Paniphal, Kachu, and Makhana etc. Some of these aquatic vegetations such as Thankuni, Kulekhara, and Hingcha possess known medicinal properties as well as provide revenue sources to the peripheral local communities. The notable feature of those wetlands, located in the geographical region of *Tal* and *Diara* is the presence of makhana cultivation. The calorific value of makhana correspond well with staple food materials and other carbohydrate rich cereals, as it is highly rich in vitamin and protein but low in fat and cholesterol. Most of the wetland macrophytes are utilized in day today life of local settlers. Being an essential component as producer in the wetland ecosystem, aquatic macrophytes are used as food for different aquatic animals, especially fishes and birds *(Chowdhury & Das, 2010)*.
- From the field visit, it has been noticed that, the wetlands of Malda district constitute a major inland fresh water fishes of around 35 to 40 species, belonging to different families. The dominant fish species are Rohu, Ar, Bata, Catla, Mrigel, Boal etc. Furthermore, the commercial species found in the wetlands are Mangur, Mourala, Kalbaush, Tangra, Prawn, Koi etc. The diverse fish species through fish culture and fish catch in wetland water act as the livelihood support to thousand of riparian poor fisher folks at the vicinity, over the decades.

- The wetlands of Malda district are deliberated as important source of food, spawning ground and nursery for fishes, besides offering feeding and breeding ground to a variety of bird species including both the resident and migratory. From the field study as well as interviewing the local people, it is known that around 40 to 50 species of avifauna have been observed annually in which, majority are of common resident and few are migratory species. The wetlands and riparian zone are encountered with the common resident species namely Cattle egret, Spotted doves, Flycatcher, Cormorant, Koel, Heron, Woodpecker, Kingfisher etc. The wetlands and adjacent tract of Malda district act as the staging site of migratory flyways and some of the large concentrations of aquatic birds are sighted every year especially during post-monsoon (November to February). The wetlands host a significant number of migratory birds such as Greylag goose, Pintail, Shovellor, Spot bills etc.

In Malda district, majority of wetlands are located in a close proximity with the villages, under several mouzas. Some wetlands are positioned near the urban centre. The land use surrounding the wetlands and catchment area are dominated by agricultural field, mango orchards, and brick kilns etc. Furthermore, urban sprawl (built-up area) dominates the wetland catchment area especially near the town.

3.4 Case studies of selected wetlands:

After analyzing the status of wetlands in Malda district as well as identifying the emerging needs, several criteria have been taken into consideration for the selection of case studies (wetlands). Four (4) wetlands have been selected as representative wetlands from Malda district *(Map 2.1 & 2.6)* for further detail analysis; namely:

1. ***Siali wetland***, under the block of Harishchandrapur 2
2. ***Chakla wetland***, under Chanchal 2 and Ratua 2
3. ***Naghoria wetland***, under English Bazar and Ratua 2
4. ***Chatra wetland***, under English Bazar

The area extension of selected wetlands has been measured with satellite images of TM (1990) and OLI (2018), which make difference with the record of Dept. of Fisheries, Govt. of West Bengal, because of no proper delineation in measuring this natural entity (wetland). However, the selection criteria of wetlands are as follows:

A. Different categories of wetlands:

The above mentioned wetlands have been selected for detail analysis, which contains different categories, as proposed by IWMED (2000) and SAC (2010). Out of the case studies, Siali and Chakla wetlands are under riverine category (wetlands, connected with rivers and lie adjacent to rivers and streams), which are connected by small tributaries of the major rivers namely Mahananda, Fulahar and Kalindri, flowing through Malda district from north to south direction. Whereas, Naghoria wetland is formed in flat, low lying plains (*Diara* region), as a cut off meander, which fall under the category of ox-bow lakes and is fed by River Kalindri, a tributary of River Mahananda. The last one is Chatra wetland, which is considered an isolated natural waterlogged, as well as a unique representation of fresh water wetland ecosystem.

B. Degree of human interference and resultant encroachment of weland area:

The location of wetland often has important connections with the adjacent land use practices. Out of the case studies, Siali, Chakla and Naghoria wetlands are located at the rural periphery as well as experience the human interferences in the form of land use land cover change especially, continuous wetland area conversion to commercial land utilization. The land use land cover around Siali and Chakla wetland encounter the maximum extension of agricultural land, whereas, the catchment of Naghoria wetland has drastically been converted into mango orchards during the last few years. On the other, Chatra wetland, being a peri-urban water body (located adjacent to urban centres) encounter non-sustainable conversion of wetland area into construction work, under the newly formed municipal wards.

C. Agro-economic and biological potentials of wetlands:

Out of the case studies, Siali and Chatra wetland provide immense potential for makhana, sola and paniphal cultivation, which are considered commercially beneficial in order to sustain the socio-economy of rural mass of Malda district. Chakla wetland promotes commercial fish cultivation, organized by the fishing cooperative societies. On the other, Naghoria wetland acts as the ample water source in order to irrigate surrounding agricultural fields as well as to increase the productivity of paddy (aush, aman and boro), pulses and vegetables. Further, the wetland is economically potential for promoting duck rearing activities. Moreover, the wetlands, under case study are enriched with biodiversity potential as well as host diverse assemblage of aquatic macrphytes, aquatic fauna along with bird species.

From the view point of biodiversity as well as to prepare the inventory of biotic components, found in the wetlands under study, field study has been undertaken during March 2016 to February 2017. The diverse species of macrophytes (aquatic plants) have been collected, photographed and taken to laboratories for further identification and are kept into record. Wetland macrophytes have been identified by "Plant systematics" of Simpson (2010) and "Plant systematics: An Integrated Approach" of Singh (2016). In the present study, diverse icthyofaunal species have also been collected as well as recorded, which are belonging to different families. The fishes are collected with the help of local fishermen and peripheral settlers and have been identified by the standard key of "The freshwater fishes of India….A Handbook" by K.C. Jayaram (1981). During the field study especially in post-monsoon, further observation has been done in order to record the bird assemblages, which are affected significantly by food availability, size of the water body and, the diverse ecological condition. In order to prepare an inventory of avifauna, a total of 15 consecutive surveys through point count method *(Bibby et al., 2000)* have been executed in the wetlands, with major surveys during post-monsoon (November-February), where the availability of migratory bird species are recorded maximum. Bird species are observed by binoculars of different ranges as well as photographed by using Canon 1200D (55 to 250mm) and identified by using "Pocket Guide to the Birds of the Indian Subcontinent" by Grimmett & Inskipp (2001); "The book of Indian Birds" by Salim Ali (1990) and online data base namely Avibase, (2015). Furthermore, the Shannon-Weaver diversity index (H) *(Shannon & Weaver, 1964)* has been used in community ecology for the wetlands under case study, to characterize the species diversity and species evenness, present in the community.

3.5 Characteristics of selected wetlands:

3.5.1 Siali wetland

3.5.1.1 Introduction:

Siali wetland is located within 25˚18´ N to 25˚19´ N latitudes and 87˚53´ E to 87˚54´ E longtitudes, in Harischandrapur 2 block under Chanchal subdivision of Malda district. The nature of this water body is a unique representation of natural fresh water wetland system. In the pre-monsoon period, the wetland is divided into three fragmented water bodies, which are locally known as a) Kachua beel, b) Pajoa beel and c) Siali beel. The wetland is also locally known as 'Monla beel'. During the rainy season all the three parts merge into one and take a huge shape. Siali wetland is appeared from a definite irregular shape. Siali wetland is under the jurisdiction of Harishchandrapur Police Station and Bhaluka Gram Panchayat. The wetland is surrounded by the following mouza namely; Talgachi (J.L. No. 171); Jagannathpur (J.L. No. 172); Fatepur (J.L. No. 173); Par bhaluka (J.L. No. 174); Bhaluka (J.L. No. 175); Degun (J.L. No. 176) and Kariali (J.L. No. 177).

3.5.1.2 Topographic configuration:

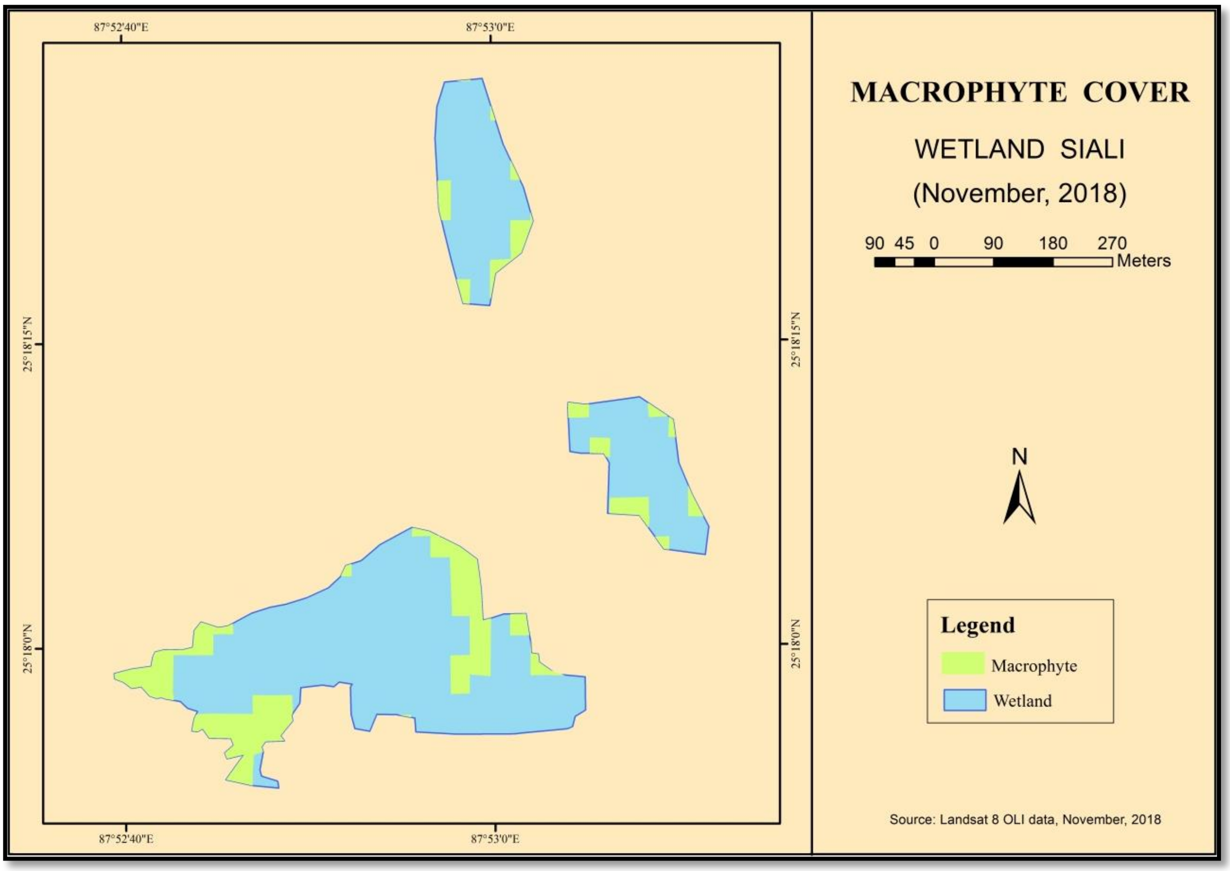
Out of the earlier mentioned physiography (*Tal, Diara* and *Barind*) of Malda district, Siali wetlandis located in *Tal* region, which lies to the west of the river Mahananda and to the north of the river Kalindri. This physiographic region is mostly composed of bog lands, which are formed in many marshy pockets around vestigial inland drainages, including innumerable marshes and ox-bow lakes. *Tal* region is practically a low lying area which floods deeply as the rivers rise and drains by meandering streams into swamps or into River Kalindri. It gradually slopes south of the Kalindri down towards the south and south-west and merges with the *Diara* region. Because of their combination of low gradients and the resulting sluggishness in their water flow, all the local rivers are prone to inundate the region during the monsoon season. However, the hydrology of Siali wetland is mainly controlled by surface run off, feeding rivulets and streams. Moreover; the region gets enough rainfall with an ultimate result of flash run off. And the presence of ground water regime has also been noticed during the field study. Siali wetland is fed by two tributaries of river Baramasia, namely; Kankhor and Kali kosi, through which the inflow of water into this wetland is controlled especially during monsoon. Two outlets are connected with this wetland namely; Kokra Bridge and Elangi canal, which are located in the eastern part of wetland and through which the excess water drains out from this water body. These inlets and outlets, connected with Siali wetland play a significant role in maintaining the hydrology of the wetland throughout the year. The area extent of Siali wetland is recorded 18.74 ha, which has been synchronized during last thirty years (1990-2018) along with distinct seasonal fluctuations. The average water depth in this wetland varies from 2 to 3 meter throughout the year. The pre-mosoon records an average water depth of 1.5 meter. During the rainy season, particularly from the month of August, the total area of this wetland gets filled up with the water, the depth of which varies from 2.5 to 3.0 meter *(Appendix-4)*. Because of the lack of gradient and resultant regular runoff, most of the tract remains submerged under considerable depths of water during the monsoon rains.

3.5.1.3 Biotic components:

Observations on the aquatic macrophytes and pisci faunal occurances along with their distribution of at the sample wetlands are carried out through frequent field surveys at seasonal intervals. From the bio-diversity point of view, Siali wetland comprises rich floral and faunal composition. Aquatic macrophytes exhibit a feeding relationship with the faunal species including fishes, as well as bird species and their diversity is positively correlated with the richer vegetation covering the wetland and water surface.

3.5.1.3.1 Macrophytes:

Macrophytes, as a component of fresh water ecosystem, play an important role in the structure and functioning of the aquatic ecosystems. Siali wetland provides habitat for a diverse assortment of macrophytes, which depends upon several environmental factors and biological interactions. This wetland contains a good assesmblage of emergent, submerged rooted, rooted floating leaved and free floating plants, found in the open water and wetland water edge and occupy a significant area of 3.59 ha (19.18%) out of total wetland water extension *(Map 3.1)*. In the pre-monsoon, due to recession of the monsoon water, large mud flats are exposed and sometimes are associated with these numerous floral compositions. The plants such as water hyacinth and other floating, rooted and emergent macrophytes duly cover these mud flats, which remain submerged during monsoon. In all, 11 species of aquatic flora belonging to 11 genera and 10 families are identified from the field survey. The open water habitat holds 5 species namely, *Hydrilla verticillata* (SR), *Euryale ferox* (RFL), *Eichhornia crassipes* (FF), *Azolla ceae* (FF), *Salvinia cucullata* (FF) belonging to 4 families and the water edge contains 6 species namely, *Hygrophilia auriculata* (SE), *Centella asiatica* (E), *Enydra fluctuans* (E), *Heliotropium indicum* (E), *Polycarpon prostratum* (E), *Hygroryza aristata* (EG) belonging to 6 families *(Appendix-5)*. In Siali wetland the composition of different plant groups comprise 4 species of emergent, 3 species of free floating, and 1 species each in rooted floating leved, semi-emergent, submerged rooted and emergent grass. Both the open water and water edge macrophytes constitute an indispensible component of entire ecosystems. The most distinctive plants *Helio Tropium*, *Hygrophila auriculata*and *Eichhornia Crassiper* are in abundance in all the four parts of Siali wetland.



Map 3.1: *Distribution of Macrophytes in Siali wetland*

The macrophyte composition in and around Siali wetland gradually shift in different seasons throughout the year. The free floating macrophytes such as, *Euryale ferox* are the most luxuriant group during post-monsoon period, immediately after the monsoon, whereas, *Eichhornia Crassiper* is found mostly dominant during pre-monsoon and starts reducing down during monsoon, with maximum surface water influx within wetland. On contrary, the emergent water edge macrophytes such as *Centella Asiatica*, *Hygrophila auriculata* and *Enydra fluctuam* are observed to develop best at the pre-monsoon season, when the water level is relatively low. Furthermore, the plants namely Thankuni, Kulekhara, Hingcha (locally called) possess known medicinal properties to the surrounding households. These medicinal plants are collected and sold in the nearby market, which supplement the household economy to some extent for the people living in the vicinity of the wetland. These large aquatic plants are the important source of food, fodder, herbal medicine, and domestic household materials for the people residing in its peripheral villages of Siali wetland. In this wetland, water hyacinth infests the open water bodies although they have been in some cases, periodically cleared by the fishermen. This infestation is a major threat because they cause eutrophication as well as extinction of other species. In some cases, there is thick film of blue and green algae, which causes a noxious effect on existing fish composition. At the bank, helophytic species (those terrestrial species that can tolerate complete submergence) are abundant. Among the wetland macophytes, *Euryale ferox* (Makhana) is a unique aquatic plant similar to lotus in open water habitat, which is covered with numerous spines or thorns on all surfaces. It is a rooted plant, with attached rosette of floating leaves.

3.5.1.3.2 Icthyofauna:

Fish diversity depends upon many physical parameters of aquatic environment as well as represents a rich blending of applied and fundamental ecology, which is achieved by the intersections among fishery science, ichthyology, and ecology *(Hasan et al., 2017)*. In the present study, Siali wetland hosts a wide range of fish species, which are considered to have immense socio-economic and cultural importance to the people of the peripheral area. From the field survey, about 10 species of fish fauna namely; *Arius arius* , *Clarias batrachus Labeo bata, Labeo catla* , *Labeo rohita* , *Cyprinus carpio, Cirrhinus cirrhosis* , *Hypophthalmichthys molitrix, Heteropneustes fossils, Ophiocephalidae Punctatus* belonging to 8 genera and 5 families are identified. These are mainly fresh water species and some of them are commercially very important *(Appendix-6)*. Carnivorous air-breathing fishes i.e., live fishes like, Lata, Mangur, Shingi are fed on carp fry, fingerlings, and other unwanted fish species. The fish fauna in this wetland namely Ar, Katla, Mrigel, and Koi are cultivated for the commercial purposes. Fish are the good source of food for piscivorous bird species and also for other higher vertebrates like frogs, snakes, fishing cats, the presence of which has been reported by the local people during field study. Pisciculture is one of the many occupations of the surrounding region. In Siali wetland, the fishing practice is done on lease basis under the Bhaluka fisheries cooperative society. The local villagers are not allowed to catch fish during the lease time period. But, people belonging to the wetland periphery are used to catch *Teuthowenia pellucida (Gugli)* local oysters/mollusks, tortoises and other available fishes for their personal consumption and income.

3.5.1.3.3 Avifauna:

Siali wetland contains high nutritional value and productivity, which supports congregation of diverse species of avifauna in the form of both migratory and residents. This wetland is considereda unique place in terms of providing a broad based ecological spectrum of aquatic life. It attracts thousands of water birds during the post-monsoon months especially, from November to February. Altogether, a total of 10 avian species, belonging to

10 genera and 9 families have been identified at the time of field survey. Out of the total species, 7 are found residents namely; *Gyps indicus*, *Alcedo atthis, Ardeola grayii, Phalacrocorax fuscicollis, Melopsittacus undulates, Pycnonotus cafer, Leiopicus mahrattensis* belonging to 7 families and 3 are migrants namely, *Anser anser, Netta rufina, Leptoptilos crumenifer* belonging to 2 families (*Figure 3.4 & 3.5*) *(Appendix-7).* The variation in the bird density and the species richness are observed according to the seasonal changes, whereas the maximum concentration of both resident and migratory bird species is recorded during post-monsoon. Siali wetland along with its periphery provides ecological security to the wetland dependent birds. The field study depicts that this wetland is occupied by the resident birds during the major part of the year. However, during the winter mostly in January, February and March the wetland is equally utilized by the resident and migratory birds, because of having an optimum water storage, availability of abundant food like small fish fauna, *Lumbricus terrestris* (Earthworm), increased vegetation as well as suitable weather condition. This wetland is considered a suitable wintering site for a number of migratory water fowl species which is one of the most remarkable components of global biodiversity and range from larger ducks to geese. They obtain food, usually small invertebrates like, insects, worms, larvae and mollusks by wading in the shallow water or probing into the mud. The resident and migratory bird populations such as *Phalacrocoracidae fuscicollis, Ardeola grayii*, *Pycnonotus cafer*, *Leiopicus mahrattensis, Netta rufina* nestle in the bush along the peripheral areas of vegetation in association with reeds and trees surrounding this water body. Besides this ornithological importance, Siali wetland provides habitat to other diverse life form as it is used to be a famous spot for supporting the wild birds and ducks of all kinds including the migratory water fowls in winter. Moreover, Siali wetland hosts variey of insects, which constitute the major faunal component of wetland ecosystem and play crucial role in the trophic structure of wetland. Besides, snakes, frogs and turtle species are found in the wetland water and mainly feed on insects and small fish species.

3.5.1.3.3.1 Shannon-Weaver Diversity Index:

The Shannon Diversity index has been applied in order to know the avifaunal species diversity as well as evenness in and around Siali wetland. High value of H represents more diverse communities. The recorded species are evenly distributed in and around this wetland as the H value is high. So the H value allows knowing not only the number of species but how the abundance of the species is distributed among all the species in the community *(Table no. 3.1)*.

Table 3.1 Avifaunal species diversity in and around Siali wetland

Selected points	No. of sightings	Species	N_i	P_i	In P_i	$-(P_i$*ln $P_i)$
6	1	Bengal vulture	2	0.03	-3.51	0.11
	9	Cormorant	15	0.21	-1.56	0.33
	6	Parakeet	14	0.19	-1.66	0.32
	1	Pond heron	2	0.03	-3.51	0.11
	5	Red vented bulbul	22	0.31	-1.17	0.36
	1	Small blue kingfisher	2	0.03	-3.51	0.11
	1	Yellow crown woodpecker	2	0.03	-3.51	0.11
	4	Grey leg goose	10	0.14	-1.97	0.28
	2	Red-crested spotbill	3	0.04	-3.22	0.13
	1	Marabou stork	1	0.01	-4.29	0.06
		∑	73			1.86

- Species diversity index (H) = 1.86
- Evenness (E_H) = 0.43

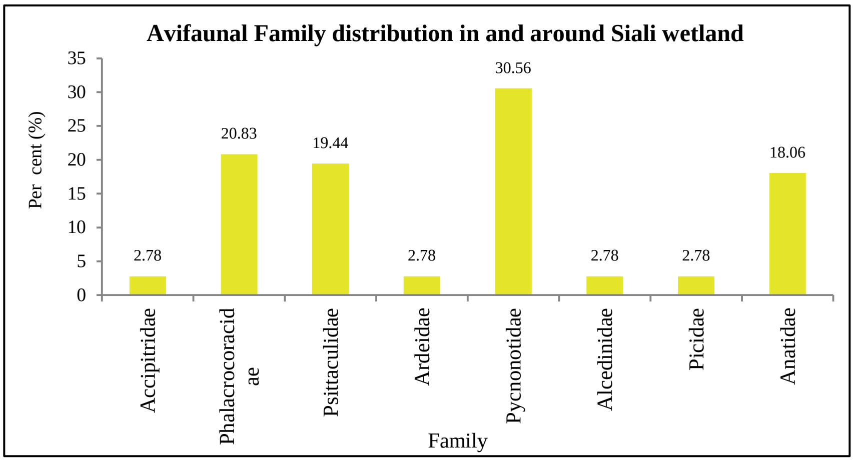


Figure 3.4: *Avifaunal family distributions in and around Siali wetland*

Siali wetland is bordered by several concrete residences in the direction of north and east bank of the wetland, namely villages of Jagannathpur, Degun, Fatehpur, Talgachi, Bhaluka etc. A dense mixed jungle, named as Kariali Protected Forest is located in the north-east direction of the water body. Agricultural lands in the vicinity are irrigated by the water of the perennial wetland and in the southern location the wetland is bounded by plentiful mango orchards. As reported by the villagers during field study, the northern part of wetland area, which was covered by forest till the end sixties (as shown in SOI topographical map, 1957), has been destroyed to set up a new village and the maximum portion of the forest has already been converted into cultivated land.

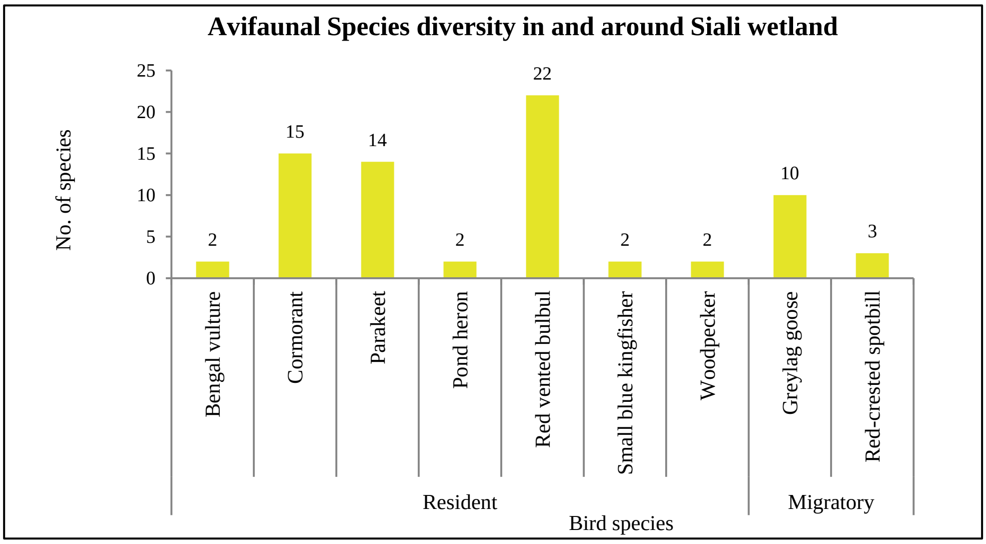


Figure 3.5: *Avifaunal species diversityin and around Siali wetland*

3.5.2 Chakla wetland

3.5.2.1 Introduction:

Chakla wetland is located in Chanchal 2 block, under *Tal* physiography of Malda district. This natural water body is located within 25°16´ 30˝ N to 25˚ 18´ 30˝ N latitude and 88° 02´ 20˝ E to 88˚ 04´ 30˝ E longitude. Similar with Siali wetland, Chakla wetland is also divided into several fragmented water bodies especially during the pre-monsoon period. Some of its parts include: a) Singhra, b) Khanpur and c) Chakla wetland etc. Singhra beel falls under Gopalpur Mouza and appears to be the largest water body within this wetland complex. Chakla wetland lies in the north-east of Singhra and is relatively isolated than the other two wetlands. Khanpur wetland is located in the south-east of Chakla wetland. Chakla wetland is appeared from irregular to semi-circular shape. The lower portion of this wetland is seasonal as well as water logged immediately after monsoon and the upper portion is perennial and a considerable water spread area is maintained. During the monsoon and post-monsoon months, these isolated parts merge together into one water body and takes a huge shape. The wetland is under the jurisdiction of Samsi police station and following mouzas namely; Gangadebi (J.L. No. 112); Gopalpur (J.L. No. 113); Damipur (J.L. No. 114); Shimultala (J.L. No. 118); Hazaratpur (J.L. No. 185); Jalalpur (J.L. No. 186) and Khanpur (J.L. No. 191).

3.5.2.2 Topographic configuration:

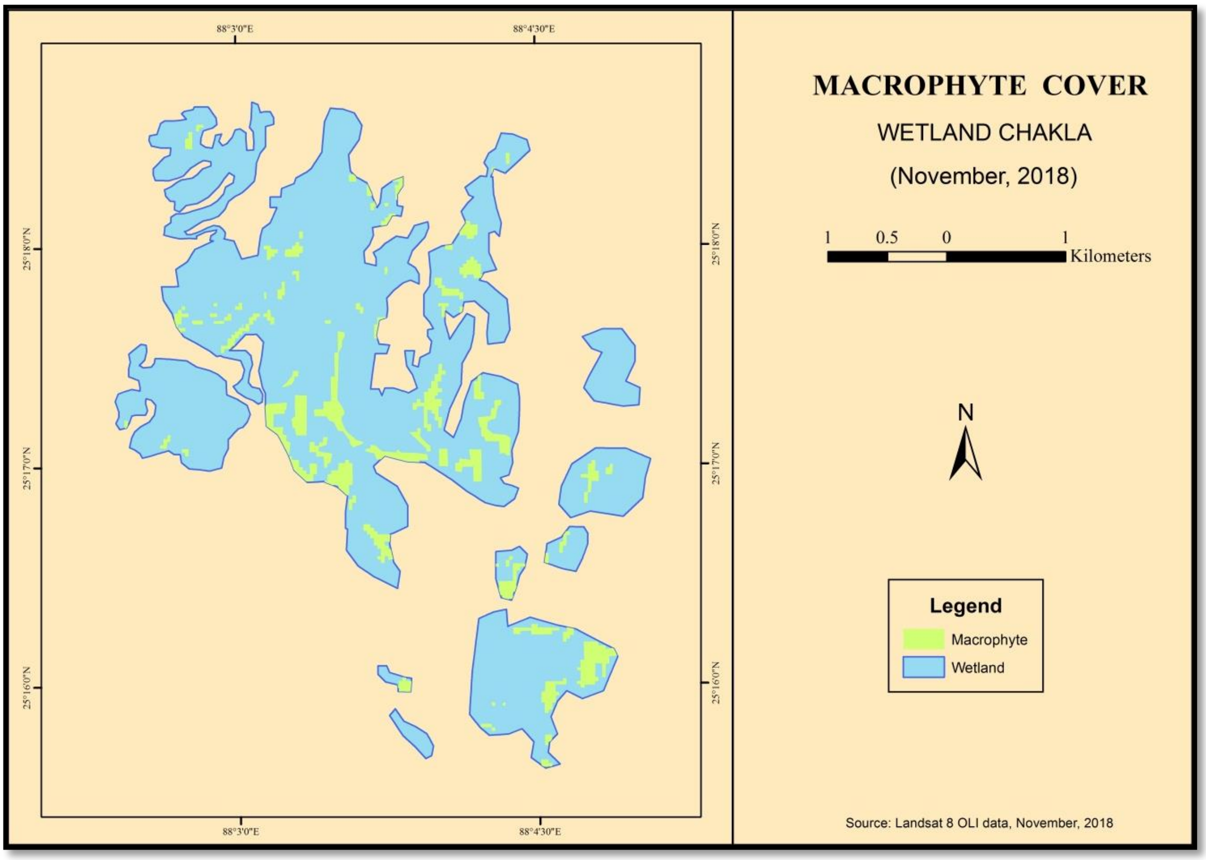
Chakla wetland is also a part of *Tal* depression. The entire wetland complex is a low lying plain, which is covered with a succession of village sites with their adjacent fields and swampy tracts. The formation of Chakla wetland complex is the result of century's fluvial action by the old channels; out of which Mara Mahananda still exists. The general slope is from north-west to the south-east. The slope is gradual, as is proved by the meandering course taken by the Mara Mahananda River, which flows through south-west portion of this wetland and on the west by River Mahananda. The hydrology of this wetland complex is mainly run-off feeding. The catchment area of Chakla wetland is large and it gets enough rainfall with an ultimate result of flash run off. Moreover, Nuna river in the north and Bhoga river in south are two tributaries of Mahananda River, which chiefly control the inflow of water during the pre-monsoon and check the outflow during the monsoon with its southern flow in Chakla wetland. The Mahananda River is flowing just 8 km away from the eastern side of this water body. There exist fluctuations in the water level as well as the spatial extent in each of these wetlands during the pre-monsoon, monsoon, and post-monsoon seasons. In the present study, as per satellite image (1990), the wetland area is found 1137.13 ha, which has been synchronized to 842.50 ha (2018). In the pre-monsoon period the water spread area of the wetland is reduced, but in post monsoon it fills out at a peak. Chakla wetland is basically shallow one and the average depth of water is recorded 2.5 meter during monsoon and maintains up to post-monsoon season. The depth of water within this water body goes down to less than 2.0 meter during pre-monsoon season *(Appendix-4)*.

3.5.2.3 Biotic components:

Chakla wetland possesses a higher diversity of macrophytes, similar with Siali wetland. This wetland reveals a heterogeneous assemblage of plant type which facilitates in maintaining the overall ecological balance. Apart from the aquatic plants, this wetland supports number of other life forms, in the form of diverse fish fauna and avian species.

3.5.2.3.1 Macrophytes:

Chakla wetland provides diverse assortments of macrophytes, which vary from free floating to anchor with floating leaves, submerghed rooted and emergent growth forms. The macrophyte coverage in Chakla wetland is recorded 84.71 ha (10.05%) *(Map 3.2)* to the wetland area. An inventory of all the aquatic plants largely present in Chakla wetland has been prepared through spot visit by identifying 10 species, which are belonging to 10 genera and 10 families. Out of the total collected species, the wetland is infested with 4 members of open water macrophytes namely, *Salvinia cucullata* (FF), *Nymphaea nouchali* (RFL), *Eichhornia crassipes* (FF) *and Nelumbo nucifera* (RFL) belonging to 4 genera and 4 families and 6 members of wetland water edge species such as *Hygrophilia auriculata* (SE), *Eclipta alba hassk* (E), *Heliotropium indicum* (E), *Polycarpon prostratum* (E), *Marsilea Quadrifolia* (SE) *and Hygroryza aristata* (EG) belonging to 6 genera and 6 families *(Appendix-5)*. The aquatic macrophytes comprise 3 species of emergent, 2 species each in free floating, rooted floating leaved and semi-emergent and 1 species of emergent grass.



Map 3.2: *Distribution of Macrophytes in Chakla wetland*

In the pre-monsoon period, due to recession of the wetland water, large mud flats appear in between Chakla and Khanpur wetland and it widely appears in the north of the Gangadebi village. These aquatic macrophytes are observed to play substantial role in the local socio-economy i.e., edible plants, medicinal values, feed for livestock, green manure, and thatch cordage. Macrophytes like hingcha, kulekhara, and thankuni are also used most efficiently for the medicinal purposes to the peripheral settlers. Many of them such as kalmi, sushni, ghima become essential in day to day human diet for its healthy consumption. Though these plants are mostly sensitive to the seasonal fluctuation of water level, no appreciable variation in their occurrences is observed during spot visit. It has been found that, none of the collected macrophytes are considered to be threatened as such. However, Chakla wetland is fully associated with the infestation of water hyacinth in open water bodies. Due to excessive nutrient enrichment (eutrophication) over utilization of agro-chemicals, accelerated by agricultural run-off, domestic sewage has been posing serious threat to the very existence of the water quality of this wetland, and is getting deteriorated beyond any kind of use or animal consumption.

3.5.2.3.2 Icthyofauna:

Chakla wetland is a typical example of middle Ganga wetlands and one of the very important water bodies of Malda district especially for the availability for fish fauna. It provides food and shelter to a large number of aquatic fauna and harbors many fresh water fish species. In the present study, the investigation has been undertaken to study as well as assess the biotic potential of this wetland with special emphasis on diverse icthyofaunal composition. The field study records that Chakla wetland is endowed with rich faunal diversity of around 13 species namely; *Labeo catla*, *Labeo rohita*, *Wallago attu*, *Cirrihinus cirrhosis*, *Amblypharyngodon mola*, *Chanda nama*, *Labeo calbasu*, *Pethia ticto*, *Clarius batrachus*, *Ctenopharyngodon idella, Tetradon cutcutia, Trichogaster chuna, Hypophthalmichthys molitrix, Ctenopharyngodon idella*, belonging to 11 genera and 6 families *(Appendix-6)*. These icthyofaunal species are considered the most abundant fish species, found from this wetland round the year. The major carps like Catla, Rohu, and Mrigel are mostly dominant due to seed stocking. These species are cultivated as well as used for the economic and commercial purposes. Chakla wetland experience fishing practice, which has bee developed on lease basis under the fisheries cooperative society of Malda Zilla Parishad. People belonging to the wetland periphery are used to catch local oysters, tortoises and other available aquatic fauna for their own consumption along with the small income.

3.5.2.3.3 Avifauna:

Chakla wetland is considered an important area for breeding, wintering and staging of water birds. Moreover, this vast natural water body harbours favourable surroundings for diverse bird species (residents and migrants) to be amalgamated during winter. Near about eighteen (18) species of residential and migratory birds are sighted in this wetland area. The water edge and the adjoining grassland of this wetland are crowned by large association of residents namely; *Alcedo atthis, Anas paltyrhynchos, Dendrocygna javanica, Bubulcus ibis, Ardea cinerea, Ardea intermedia, Egretta garzetta, Ardeola grayii, Ciconia ciconia, Phalacrocorax fuscicollis.* A total number of 10 residential bird species belonging to 9 genera and 5 families have been sighted. Along with residents, 6 migratory species namely; *Anas acuta, Anas clypeata, Anas poecilorhyncha, Aythya nyroca, Botaurus lentiginosus, Actitis macularius* belonging to 5 genera and 3 families have been observed during October to March as well as identified at field investigation and by interviewing the local settlers *(Figure 3.6 & 3.7) (Appendix-7)*. The wetland open water act as the feeding ground of large population of fish eating water fowls as well as residential birds like *Phalacrocorax fuscicollis*, *Ardeola grayii*, *Bubulcus ibis*, *Anas paltyrhynchos*. The wetland hosts a very large population of *Ciconia ciconia*, found in many pockets of the wetland, but mostly at the water edge. The Small blue kingfisher is frequently observed in this wetland to hunt fishes from the wetland or to rest in nearby shrubs and trees. Among the different growth forms studied, floating and submerged vegetation occupy a significant position to support the avian diversity. In winter, the wetland open water is covered with flocks of winter visitors of *Dendrocygna javanica*, Pintails and Pochards, which are abundant. One can also find White-eyed pochard, Spot billed ducks in the open water as unique migrants. All these feed upon small fishes, frogs, insects, small reptiles etc. Four species of Heron and three kinds of storks have also been sighted during the field survey. Other than these, the common water fowls are Bitterens, Whitling teals, Sandpipers and resident ducks which consume the seeds of the wetland plants. The major water fowl population occupies the water edge of wetland complex. Other than these, amphibians are represented by different species of frogs and toads. These mainly feed on insects and small fish species. They serve as food for different birds and reptiles.

3.5.2.3.3.1 Shannon-Weaver Diversity Index:

The Shannon Diversity Index has been applied in Chakla wetland, which has shown higher species diversity as well as higher evenness, which records H value 2.36 (*Table no. 3.2*).

Table 3.2 Avifaunal species diversity in and around Chakla wetland

Selected points	No. of sightings	Species	N_i	P_i	In P_i	$-(P_i*\ln P_i)$
12	6	Cattle egret	17	0.13	-2.04	0.27
	8	Cormorant	21	0.16	-1.83	0.29
	4	Grey Heron	13	0.10	-2.30	0.23
	2	Intermediate egret	6	0.05	-2.30	0.12
	3	Black capped Kingfisher	6	0.05	-2.30	0.12
	2	Little egret	5	0.04	-3.22	0.13
	2	Pond heron	5	0.04	-3.22	0.13
	1	Storks	2	0.02	-3.91	0.08
	3	Whistling teals	7	0.05	-2.30	0.12
	16	Resident ducks	27	0.21	-1.56	0.33
	3	Pintail	5	0.04	-3.22	0.13
	2	Shovellor	3	0.02	-3.91	0.08
	2	Spot bills	5	0.04	-3.22	0.13
	1	White eyed pochards	3	0.02	-3.91	0.08
	1	Bitterens	2	0.02	-3.91	0.08
	1	Sandpipers	1	0.008	-4.83	0.04
		∑	128			2.36

- Species diversity index (H) = 2.36
- Evenness index (E_H) = 0.49

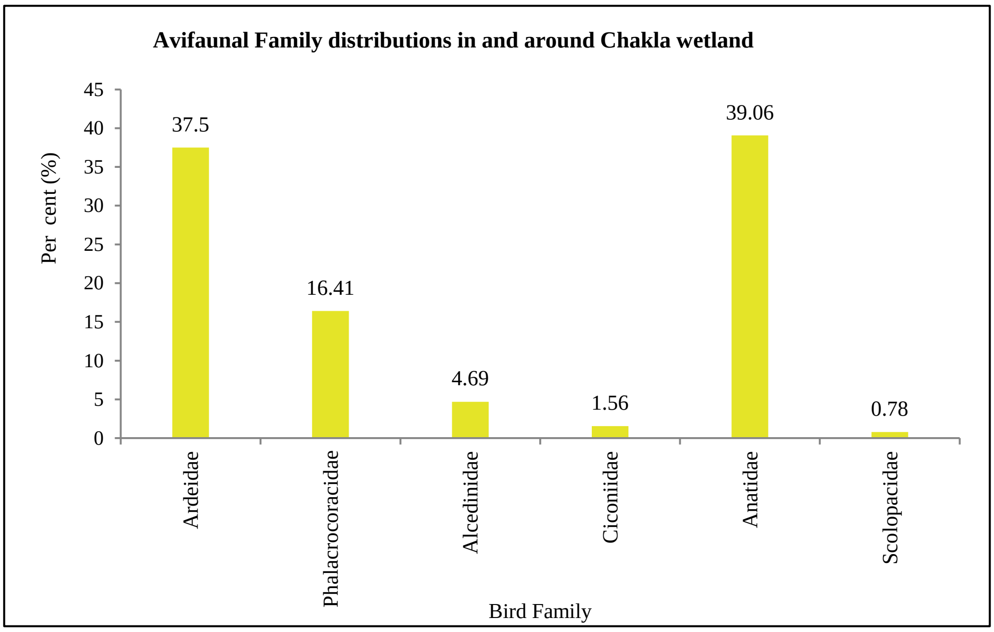


Figure 3.6: *Avifaunal family distributions in and around Chakla wetland*

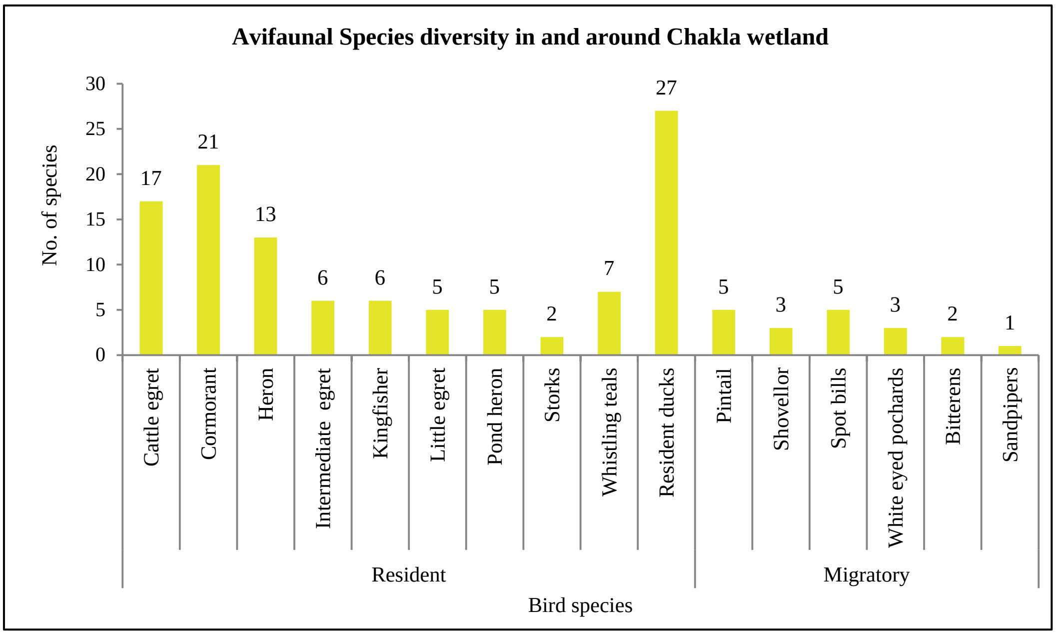


Figure 3.7: *Avifaunal species diversity in and around Chakla wetland*

Chakla wetland is surrounded by several concrete residences in the form of villages namely Hazaratganj, Kaliganj, Damaipur, Shimultala, Khanpur and Gangadebi. The peripheral agricultural land is irrigated by the water of the perennial wetland and in the southern and south western location the wetland is bounded by some cultivated lands including scattered vegetation. The nearby markets are located at Samsi, Gajole and Malda town. This wetland complex is about 5 km away from the Gazole Samsi road. The approach road has now been made metalled by Prime Minister Rojgar Yojana from Jorgachi more. The National Highway 81 and Northern Frontier Railway of Katihar Singhabad section have been developed along the south western flank of the wetland complex.

3.5.3 Naghoria wetland

3.5.3.1 Introduction:

According to the Oxford Dictionary, Oxbow lake is a river cut off due to high degree of bend and nearness of meander’s limb is very closer to each other. Oxbow lakes usually form in flat, low lying plains, close to where the river empties into another body of water and these plains are often associated with wide meandering rivers. Naghoria wetland is a cut off meander, which is fed by the Kalindri River, a tributary of Mahananda. The extreme bend of the Kalindri River has cut off from main stream and rejected channel forms an oxbow lake as well as a wetland, which appears to be Naghoria wetland. The wetland is placed in the extreme end of the northwestern part of English Bazar block; 12 km away from the Malda town and 1.5 km away from the Malda Manikchak road. The wetland is situated between geographical coordinates 25°01´ 30˝ N to 25°05´ 45˝ N latitude and 87° 59´ 45˝ E to 88° 04´ 30˝ E longitude. Naghoria wetland is a cut off meander, comprises larger area and have developed an ecological set up with the surrounding natural systems. The wetland is well situated on the northern side of the Kalindri River, which follows near about 110 meters apart from the water body and is taken as an offshoot of the eastern branch of the Ganges. But actually it is branch of River Mahananda and renamed as Fulahar, which passes through the district of Purnea in Bihar. It enters into Malda district near Mihaghat in Harischandrapur police station, from where it is known as River Kalindri. It flows mainly in the south-eastern direction to its confluence with the Mahananda at Nimasarai, near Old Malda block. Water volume and circulation of this cut off wetland is directly related to the Kalindri River, which shifts its course at number of times. The Kalindri River has long been considered a dynamic river because of having frequent changes in its entire course, including a number of paleo channels and ox- bow lakes. It has been recorded that River Kalindri has changed its course towards the south in recent years. Administratively Naghoria wetland is located under the jurisdiction of following mouzas namely; Phulbaria (J.L. No. 24); Nagharia (J.L. No. 25); Lakshmighat (J.L. No. 26) and Uttar Lakshmipur (J.L. No. 41) of English Bazar and Ratua 2 block in Malda District.

3.5.3.2 Topographic configuration:

The Kalindri River flows mainly eastward and divides the western part of the district into two distinct portions. As mentioned earlier, the portion to the north of this river has been distinguished as *Tal* land and the portion to the south as *Diara*. Naghoria wetland is situated in the *Diara* physiographic tract, and is formed due to abrupt change of river course by Kalindri, which is very commonly found in the plains of West Bengal. The overall topographic set up is just like a wide alluvial plain spreading out like an inland delta, with channels diverging out like distributaries, to fall ultimately into the water from north-east to south running Mahananda River, near Old Malda. The making of the Naghoria wetland is a product of fluvial action and is formed by excessive silting of Kalindri River. The maximum portion of this region is a part of active flood plain, which is covered by immature and loosely compacted alluvium of recent origins. This alluvial is typically dark, loosely compacted with a high water and organic material content. The general slope of the wetland region is towards east and south-east and is perceptibly gentle. The main support of its drainage is rain water, along with the inlet and outlet of Kalindri River. The Kalindri River receives water from small inlets namely Kali koshi, Kankhor, and Baromasia. In Naghoria cut-off, water enters through these inlets during monsoon and drains out in another wing through the outlet. As per the field visit and satellite imagery, the area extension of Naghoria wetland is recorded 228.13 ha, which has been reduced down by 56.49 ha during last three decades. The depth of water in this wetland keeps on varying during different seasons with an average depth of 2.0 meter in pre-monsoon, during the month of March to end of May, and indicates the dry phase of summer season. The water level increases with an average 2.7 meter during monsoon and 2.5 meter in post-monsoon *(Appendix-4)* as the surface run off from the vast catchment area enters into this cut off by Kalindri River and through Nurpur connection via Nurpur barrage from Ganga River. Loss of either inlet or outlet of this oxbow lake has converted the flowing lake into stagnant wetland. The wetland generally swells up by the end of July and the water recedes gradually from the mid October to its previous position. Naghoria wetland experiences fluctuation in the water level and in the spatial extent throughout the year.

3.5.3.3 Biotic components:

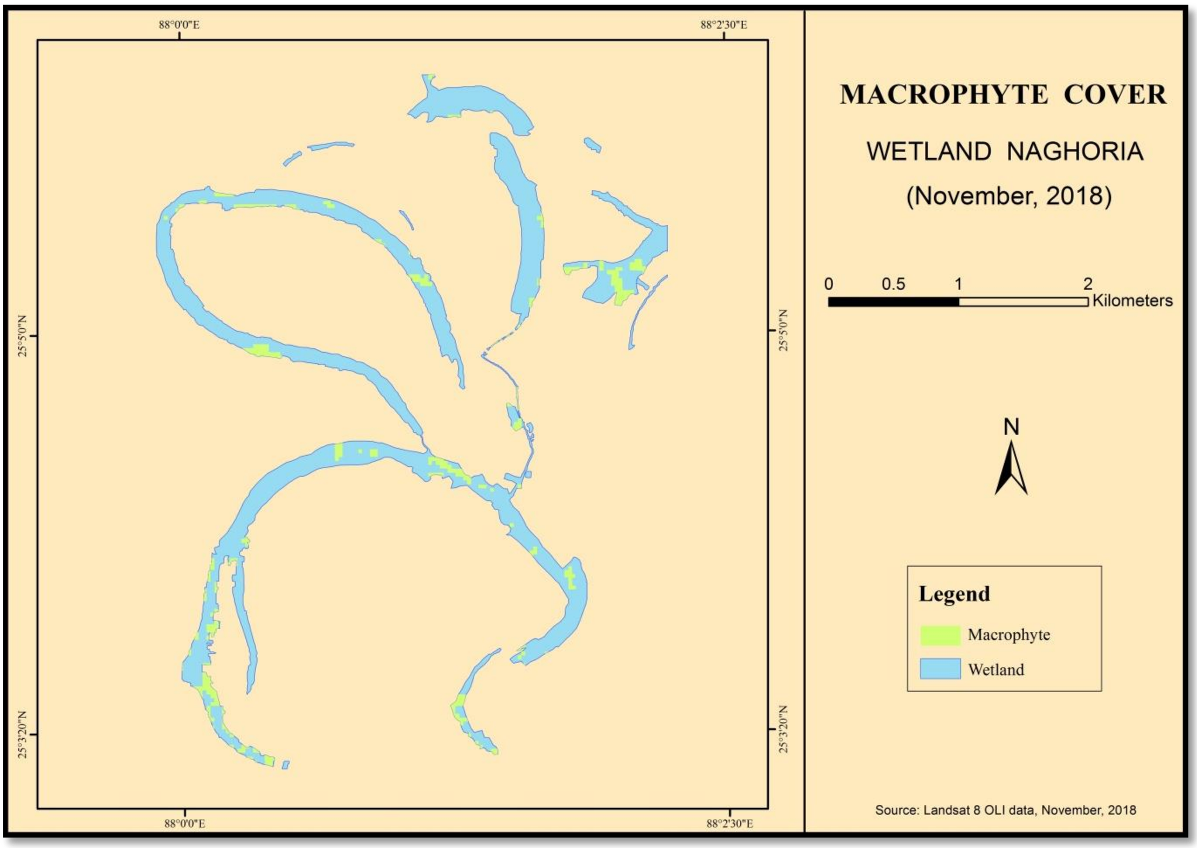
Naghoria wetland is associated with various kinds of living organisms, including floral and faunal composition. This water body is infested by large scale open water with plentiful water edge vegetation. Along with aquatic macrophytes, numerous fish species and avian diversity are sighted and identified in and around Naghoria wetland.

3.5.3.3.1 Macrophytes:

In the present study, Naghoria wetland harbours large population of free floating, semi-emergent, rooted floating leaved and emergent macrophytes. The macrophytic assemblage has covered a total of 22.86 ha (10.02%) to the total wetland area *(Map 3.3)*. A total number of 11 species, belonging to 11 genera and 10 families are identified from the filed study. The macrophytes include 4 species namely *Colcasia esculenta* (E), *Trapa natans* (RFL), *Eichhornia crassipes* (FF), *Azolla ceae* (FF), *Salvinia cucullata* (FF) belonging to 5 families under open water and 7 species namely, *Hygrophilia auriculata* (SE), *Centella asiatica* (E), *Enydra fluctuans* (E), *Heliotropium indicum* (E), *Polycarpon prostratum* (E) *and Ipomoea aquatic* (SE) belonging to 6 families under wetland water edge habitat *(Appendix-5)*. Among the different types of floral organisms, both the water edge and open water macrophytes are the important resources in supplying food webs into this wetland. The wetland fringe harbor thick assemblage of macrophytes such as *Centella asiatica*, *Hygrophilia auriculata*, which are considered the important source of herbal medicine as well as domestic household materials for those people residing in its peripheral villages of this wetland. Further, these macro vegetations are largely useful in maintaining the ecological balance of the entire ecosystem and the environment of Malda town.

3.5.3.3.2 Icthyofauna:

Icthyofauna is considered one of the important elements in the economy of the surrounding villages at the vicinity of Naghria wetland. This perennial cut off water body regularly supports substantial numbers of fish fauna, which is indicative of wetland values, productivity, and diversity. The immense aquatic biodiversity and fish resources support nutritional security and livelihoods of a large section of settlers at the vicinity of Naghoria wetland.



Map 3.3: *Distribution of Macrophytes in Naghoria wetland*

Near about 9 fish species, belonging to 6 genera and 5 families have been recorded. Among the identified fish species, majority are fresh water fish species including *Labeo bata*, *Labeo catla*, *Mystus tengara*, *Caridean shrimp*, *Macrobrachium rosenbergii*, *Cyprinus* *carpio, Clarias batrachus, Lebeo rohita* , *Labeo calbasu* (*Appendix-6*). As this wetland is well connected with River Kalindri, some of the fishes migrate between wetland and the river and many riverine fish species have amalgamated here. Moreover, it is a good breeding ground for number of commercially important fishes like, *Clarius batrachus, Mystus tengara, Macrobrachium rosenbergii* and *Caridean shrimp*. Other than icthyofauna, amphibians are represented by different species of frogs and toads and these are mainly fed on insects and small fish species. They serve as food for different birds and reptiles. People belonging to the wetland periphery are used to catch *Teuthowenia pellucida*, local oysters/ mollusks, tortoises and other available aquatic fauna for their self-consumption and income.

3.5.3.3.3 Avifauna:

The diversity of life form in and around Naghoria wetland is due to the presence of auxilliary ecological condition. The wetland provides an excellent habitat by providing quantities of food in the form of micro flora (aquatic plankton species), meso flora (aquatic vegetations), micro fauna (small microscopic animals), meso fauna (fishes, insects and small animals) etc. in the wetlands *(Datta et al., 2011)*.This water body acts as a transitory stopover for migratory birds, besides large number of residential birds. However, at the time of investigation and interviewing the local people, near about 15 species of residents belonging to 11 genera and 8 families; 4 species of migratory birds, belonging to 3 genera under single family have been sighted *(Figure 3.8 & 3.9)*. It has commonly been observed that the migratory bird species appear during the peak winter season, from November and stay up to February. A large number of water birds ranging from Leh, Ladakh and other parts of Himalayas, to Siberia, Afghanistan, spend a part of their winter sojourn in this wetland. Among the avifauna, the migratory birds occupy a significant position, which ranges from Pintail to considerably large number of ducks and geese. The major traditional wintering grounds for *Anas acuta*, *Anser anser*, *Anas clypeata* are located in this wetland. Besides Pintail, this cut-off meander provides wintering and passage sites for *Aythya nyroca*, *Aythya fuligula*, *Netta rufina*, which migrate from central and west Asia, and Europe. The basic requirements of migratory water fowls at their wintering ground are adequate food supply and security, which are properly fulfilled by this wetland as it is encircled with the fertile patches of agricultural fields, for feeding and resting. The density and species richness of birds are expected to be highest during winter when migratory population arrive and minimum during pre-monsoon when the migratory populations leave the area. The resident species, including *Falco amurensis*, *Leiopicus mahrattensis*, *Spilopelia chinensis*, *Ciconia ciconia*, *Alauda gulgula*, *Halcyon pileata, Alcedo atthis, Bubo zeylonensis, Egretta garzetta, Eudynamys scolopaceus, and Terpsiphone paradise* are engaged in the nesting activities and are commonly found round the year. The resident ducks also congregate in this water body *(Appendix-7)*.

3.5.3.3.3.1 Shannon-Weaver Diversity Index:

The application of Shannon Diversity index shows that the species diversity (H=2.58) along with species evenness (E_H=0.57) are recorded high in Naghoria wetland (*Table no. 3.3*). This water body records an abundance of bird species especially during the winter months (November to February).

Table 3.3 Avifaunal species diversity in and around Naghoria wetland

Selected points	No. of sightings	Species	N_i	P_i	In P_i	- (P_i*ln P_i)
8	1	Black capped kingfisher	4	0.044	-3.124	0.137
	2	Brown fish owl	3	0.033	-3.411	0.113
	1	Falcon	2	0.022	-3.817	0.084
	6	Flycatcher	19	0.211	-1.556	0.328
	2	Grey heron	5	0.056	-2.882	0.161
	2	Indian small skylark	4	0.044	-3.124	0.137
	1	Koel	4	0.044	-3.124	0.137
	1	Little egret	2	0.022	-3.817	0.084
	1	Yellow crown woodpecker	1	0.011	-4.510	0.050
	1	Small blue kingfisher	2	0.022	-3.817	0.084
	3	Spotted doves	14	0.156	-1.858	0.290
	6	White stork	13	0.144	-1.938	0.279
	3	Grayleg goose	7	0.078	-2.551	0.199
	2	Pintail	3	0.033	-3.411	0.113
	1	Shovellor	1	0.011	-4.510	0.050
	1	Red crested Spot bill	2	0.022	-3.817	0.084
	1	Tuffed pochard	2	0.022	-3.817	0.084
	1	White eyed pochard	2	0.022	-3.817	0.084
		∑	90			2.498

- Species diversity index (H) =2.498
- Evenness index (E_H) = 0.547

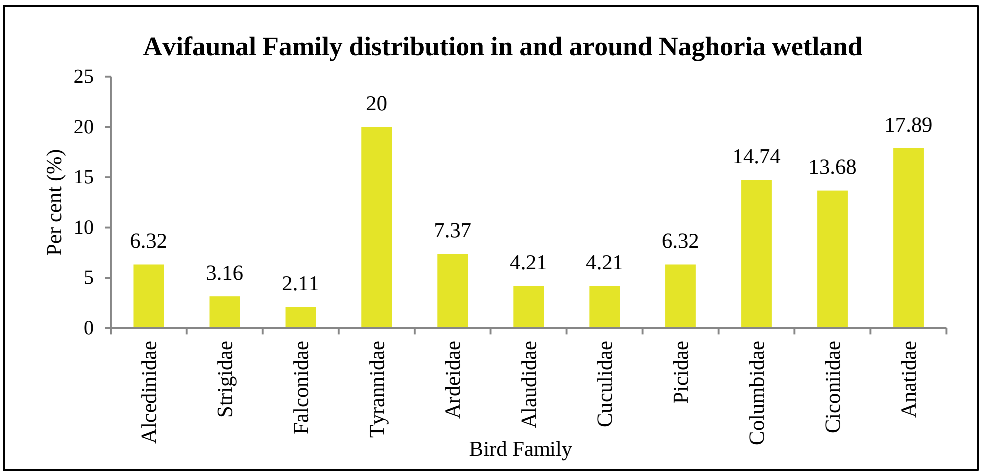


Figure 3.8: *Avifaunal family distributions in and around Naghoria wetland*

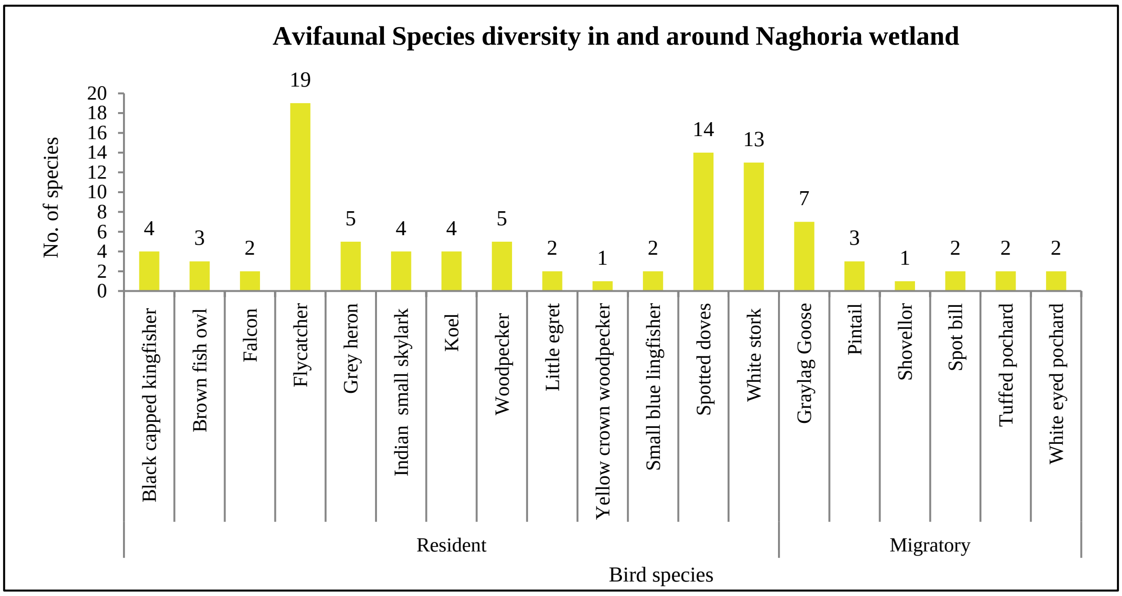


Figure 3.9: *Avifaunal species diversity in and around Naghoria wetland*

There are five villages in and around Naghoria wetland namely, Naghoria, Lakhshmighat and Uttar Lakshipur, Phulbaria and Kolamari villages. During the last few decades, eastern portion of this wetland catchments area has already been transformed into mango orchards, especially near Koklamari village. In the southern side, large portion of wetland area, adjacent to the Phulbaria village has been converted into cultivated land. Being located near Malda town, the physical accessibility of Naghoria wetland is relatively better than Siali and Chakla wetland.

3.5.4 Chatra wetland

3.5.4.1 Introduction:

Peri–urban wetlands are located in the areas adjacent to cities and towns. Chatra wetland is a peri-urban water body and is considered the only one of this specific type in the entire the North Bengal. This natural wetland has great ecological and environmental importance. It is located in the south-east of English Bazar block and at the south-western fringe of English bazar municipality. Chatra wetland is located between 24˚ 58´ 30˝ N to 25°00́ 30˝ N latitudes and 88°06´ E to 88˚ 08´ E longitudes. The wetland is is attached with National Highway (NH) 34 and the Eastern Railway track, connecting North Bengal with the South Bengal. The formation of this peri-urban wetland is new, as it has not been identified in the topographical map of 1949-51 and 1968-69 by SOI. The wetland first came out as a part of huge water body of 'Bhatiar beel', which is located in the eastern side of the NH 34 along with the eastern railway line. Later on, with the extension of double railway track, Chatra wetland got partially separated from the Bhatiar beel, except the Godrail bridge connection on NH 34 and railway line connects it. Presently, Chatra wetland is considered a separate water body, which has detouched from bhatiar beel. The nature of this per-urban wetland is a unique representation of the fresh water wetland system, and its shape and size has also been changed substantially. Excessive downpour, including massive flood occurrence during 1998 had dumped huge quantity of water in this wetland and finally caused spatial extension of the wetland area and rise of average water level. Administratively this wetland is located adjacent to municipal wards no. 3, 23, 24 and 25. Furthermore, several mouzas namely; parts of Pirojpur (J.L No. 69); Arazi Dilalpur (J.L. No. 70); Abhirampur (J.L. No. 91); Gabgachi (J.L. No. 90) & Uttar Jadupur (J.L. No. 88) encircle this wetland. Along with mitigating the flood risk, this natural water logged area acts as kidney of landscape by filtering the city's sewage, which is entering into this water body from adjacent municipal wards through the recovery of nutrients in an effective manner. Moreover, this wetland contributes to the well-being of the community by performing urban green space, as well as provides aesthetic appeal, landscape diversities and recreational opportunities.

3.5.4.2 Topographic configuration:

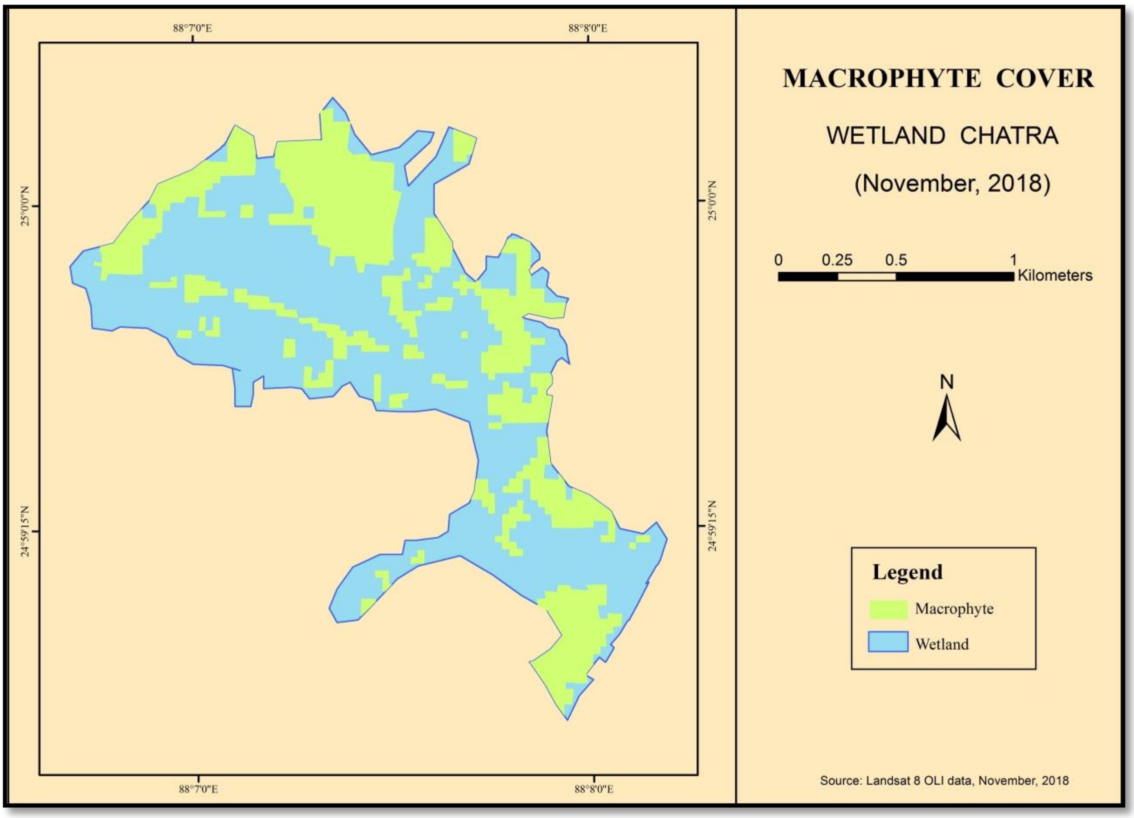
Similar with Naghoria cut off, Chatra wetland is a part of *Diara* physiographic unit. The Kalindri and Mahananda River are flowing from north-west to south-east direction and the meeting point is in a very close proximity, just 1.6 km away from the northern side of this wetland. The slope of Chatra wetland is gentle, from north to the south. Regular supply of municipal sewage flow, including the surface discharge water is the permanent source of water inflow of this wetland. Chatra wetland is connected with several inlets from the adjacent municipality wards (no. 3, 23, 24 and 25) in the north-east, east and south-eastern flank, which carry sizeable quantity of water from the surrounding areas into this wetland. Its outlet point is very narrow and quite elevated from the normal bed level of the wetland. This unique low land track performs very significant role for allowing the flood water to pass through and also excessive rain water into Bhatiar Beel through the only Godrail bridge connection as well as protects the entire town and the adjacent areas. In the present study, the area extension of Chatra wetland is recorded 295.73 ha in satellite image (1990), whereas, the area has been encroached chiefly with urban construction and is presently recorded 234.54 ha (2018). The depth of the water keeps on varying during the course of the year and records an average 1.8 meter in pre-monsoon and 3.0 meter during monsoon and post-monsoon *(Appendix-4)*. The water depth fluctuates in different periods, but not in large scale because of regular supply of municipal sewage inflow into this wetland from several points. Hence, this peri-urban wetland receives substantial amount of water round the year. During the monsoon, it plays a vital role in controlling the flow of flood water from Bhagirathi and Pagla River, which otherwise can flood the adjacent areas, and being located in the low-lying area, it has the capacity to a great extent to retain and detain excess flood water. Further, the process of water retention and detention act as a very effective tool to regularize the ground water level and enable high water table of Malda town by discharging gradually the water during the pre-monsoon period. The natural facility of Chatra wetland for the sewage treatment is next best to East Kolkata wetland (EKW). Hence it acts as the city's 'lung', which performs a substantial, hydrological and ecological role by maintaining sufficient water level throughout the year. In recent time, the hydrology of wetland has partially been hampered due to construction of approximate 3 km long Bandh road, including the NH 34, connecting Siliguri and Kolkata.

3.5.4.3 Biotic components:

Chatra peri-urban wetland reveals a heterogeneous assemblage of living forms including floral and faunal diversity. The macrophytes constitute the principal source of food in the food chain of aquatic animals and play a crucial role in the structure and functioning of the aquatic ecosystem. Further, macrophytes in and around wetlands provide shelter to various aquatic fauna as well serve as a breeding ground for associated faunal species.

3.5.4.3.1 Macrophytes:

Numerous herbaceous plant species such as free floating, anchored and rooted emergent and submergent plants occupy different niches in the eastern, northern and southern parts of this water body. The wetland is substantially covered with macrophytes amounting to 82.92 ha (35.35%) to the total wetland area *(Map 3.4)*. The water edge and the open water species in the form of emergent, free floating and rooted floating leaved macrophytes are found at different seasons without any appreciable variation in their occurrence as per the field study.



Map 3.4: *Distribution of Macrophytes in Chatra wetland*

A total of 11 species, belonging to 11 genera and 9 families are identified by spot visit. The open water habitat contains 7 species namely, *Colcasia esculenta* (E), *Pistia stratiotes* (FF), *Aeschynomene aspera* (SR), *Euryale ferox* (RFL), *Nymphaea nouchali* (RFL), *Eichhornia crassipes* (FF) *and Potamogeton perfoliatus* (SR) belonging 5 families and water edge contains 4 species namely *Hygrophilia auriculata* (SE), *Enydra fluctuans* (E), *Heliotropium indicum* (E) *and Polycarpon prostratum* (E) belonging to 4 families *(Appendix-5)*. Chatra wetland is infested with more pollution tolerant aquatic plants. The species assemblage depends on the availability of water and the vegetation type, which gradually shifts in different seasons of the year. Traditional uses of aquatic medicinal plants of Thankuni, Hingcha, and Kulekhara are novel and are collected and sold, thus supplementing the household economy to some extent for the people living in the vicinity of this peri-urban wetland. Furthermore, Chatra wetland hosts most important hydrophytes of Makhana. In the earlier nineties, for the first time this geoplant had been seen in Harischandrapur block and by slowly spreading out, it got introduced in Chatra wetland from the year 2003. Makhana cultivation has recently been increased in last few years, which supports to meet the great demand for fish and vegetables of fast growing town population. It has high nutritional value. The indiscriminate application of huge chemical insecticides, fertilizers and other agrochemicals, deteriorate the water quality of Chatra wetland, and make it beyond any kind of consumption. General survey in different seasons of the area indicates that *Eichhornia Crassipes* (Water hyacinth) and *Pistia stratiotes* (Water lettuce) are the dominant macrophytes. Kachuripana with the submerged roots and aerial leaves along with Potamogeton perfoliatus (Bara-pana) spread considerably at a higher speed and has roofed several pockets of this wetland. The riotous growth of water hyacinth and resultant declining fish production is one of the serious problems in this peri-urban wetland, as reported by the fishermen and local people during filed study.

3.5.4.3.2 Icthyofauna:

Fishes are one of the important components in the economy of Malda district, as they have been a stable item in the diet of so many people as well as corroborate the livelihood and nutritional security of many more local fishers of Malda district. Chatra wetland was once one of the region’s finest repositories of fish resources, which has been minimized rapidly. Presently, this water body exhibits a moderate ichthyofaunal diversity which is mainly fresh water species and some of them are commercially very important. A total number of 10 species of fish fauna namely, *Chanda nama, Badis badis, Clarias batrachus, Ophicephalus gachna, Labeo rohita, Pethia ticto, Trichogaster chuna, Mastacembelus pancalus, Macrobrachium rosenbergii, and Tilapia sparrmanii* belonging to 10 genera and 8 families are collected and identified from field study *(Appendix-6)*. The economically important fish species like Rohu, Bot koi, Khalisa, Mangur etc. are found moderately in this wetland. The declining fish diversity is attributed to unorganized fish catch and makhana cultivation. Apart from mentioned biodiversity, snakes and frogs commonly feed on shellfishes, leeches and other worms, insects etc. At the time of observation and investigation, the presence of several insects and invertebrates like Diatoms have been identified and reported by the local settlers around the wetland.

3.5.4.3.3 Avifauna:

Study on avifaunal diversity is an essential ecological tool which acts as an important indicator to evaluate different habitats both qualitatively and quantitatively (*Bilgrami, 1995*). During the field observation and interviewing the household, a total of 9 avifaunal species, belonging to 9 genera and 7 families are sighted. Out of this, 6 are residents such as; *Alcedo atthis, Ardea alba, Ardea cinerea, Spilopelia chinensis, Phalacrocorax fuscicollis,* and *Terpsiphone paradise* belonging to 5 families and 3 migrant species namely; *Anser anser Anas acuta Porphyrio poliocephalus* belonging to 2 families are recorded to be sighted during winter in order to utilize this water body as stopover and resting place *(Figure 3.10 & 3.11) (Appendix-7)*. The water edges and the agricultural fields adjacent to this wetland is crowded by the large number of *Ardea cinerea*, *Ardea alba*, *Spilopelia chinensis* and *Terpsiphone paradise* etc. throughout the year whereas, *Phalacrocorax fuscicollis* and *Alcedo atthis* are mostly common in open water. Chatra wetland is mostly dominated by the resident birds during major part of the year. The residents are dependent upon the surrounding areas, especially the grassy patches, agricultural fields for feeding and resting. The density and species richness of birds are expected to be high during the winter when resident species are engaged in the nesting activities for breeding and other purposes during the monsoon period. Migratory water birds, one of the most remarkable components of global biodiversity are good indicators and useful models for studying variety of environmental problems. In earlier, this wetland was enriched with large number of migrant bird population, arrived this particular wetland to find abundant supply of food in the form of fish fauna, *Lumbricus terrestris* including a peaceful and friendly environment. The study area, under the present investigation encounters immense challenges from the gradual decline in the migratory bird population over the years, which is documented by interviewing local people and perception study *(Appendix-11) (Figure 6.3)*. Therefore, it is vital to understand the underlying cause for the decline in species diversity in order to prevent the loss of key components of biodiversity of wetland habitats.

3.5.4.3.3.1 Shannon-Weaver Diversity Index:

The field study records relatively less number as well as less diversity in the avifaunal species throughout the year. The migratory population is recorded to be declining, in relation with other wetlands in Malda district which is attributed to polluted water, non-availability of food and immense human interference. The species diversity (H) is recorded 1.93 and species evenness (E_H) is 0.43, which is relatively lower than other wetlands under study (*Table no. 3.4*).

Table 3.4 Avifaunal species diversity in and around Chatra wetland

Selected points	No. of sightings	Birds	N_i	P_i	In P_i	$-(P_i*\ln P_i)$
12	6	Cormorant	16	0.17	-1.77	0.30
	3	Spotted Dove	10	0.11	-2.24	0.24
	3	Great egret	8	0.09	-2.46	0.21
	7	Flycatcher	20	0.21	-1.55	0.33
	10	Grey heron	17	0.18	-1.71	0.31
	2	Small blue Kingfisher	3	0.03	-3.44	0.11
	3	Grayleg goose	9	0.10	-2.35	0.22
	5	Pintail	4	0.04	-3.16	0.13
	3	Grey headed swamphen	7	0.07	-2.60	0.19
		∑	94			2.05

- ❖ Shannon-Weaver diversity index (H) =2.05
- ❖ Evenness (E_H) = 0.45

Chatra wetland, located adjacent to Malda town is encircled by both the rural and urban residences, in north-eastern and south-western side respectively. Malda-Karbenigram metalled road restricts the northern boundary of this wetland. In its east, there is Eastern railway track and Bandh road, which starts from Malanchapalli towards north and gradually curves to further northwest, meeting Malda-Manikchak road.

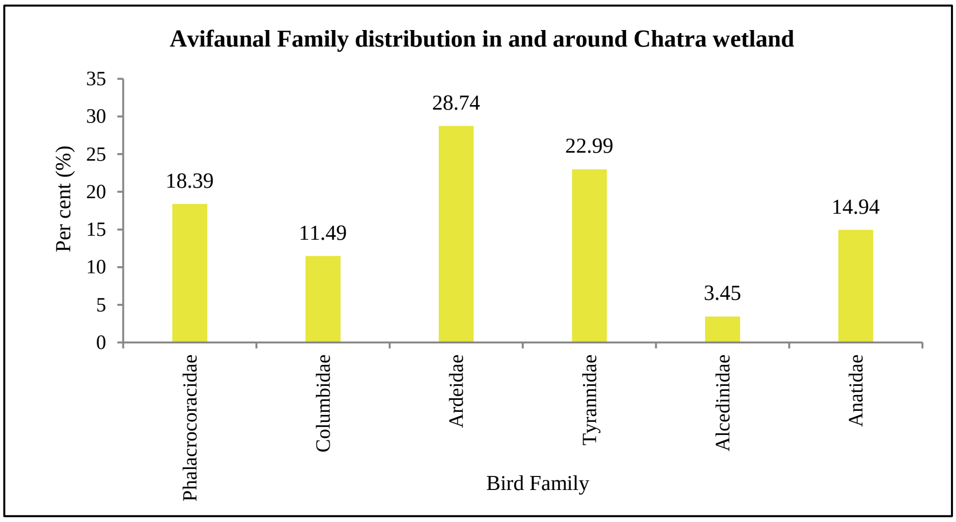


Figure 3.10: *Avifaunal family distributions in and around Chatra wetland*

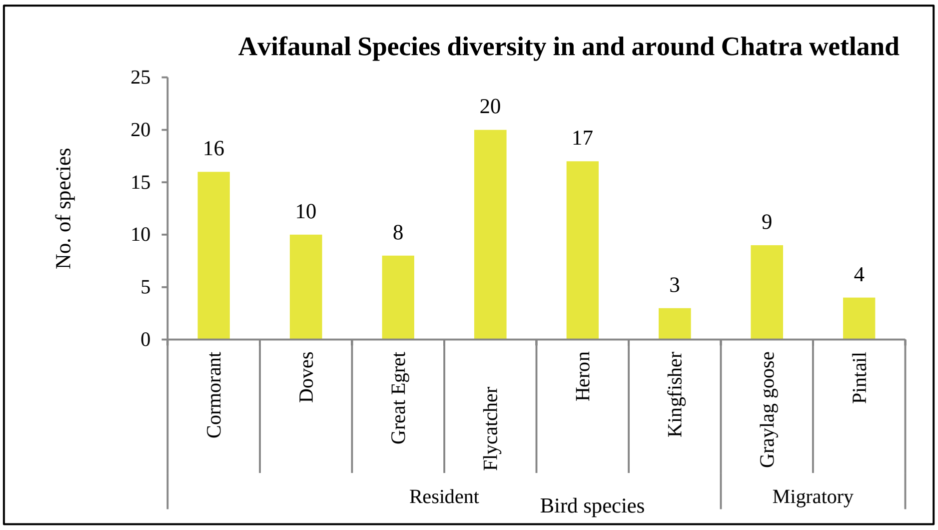


Figure 3.11: *Avifaunal species diversity in and around Chatra wetland*

3.6 Inventory of flora and fauna in selected wetlands:

3.6.1 Macrophytes:

Earlier study has been made at Chanchal sub-division of Malda district, which has recorded 32 species, belonging to 28 genera and 29 families *(Some & Mukherjee, 2018)*. Another study has identified 45 macrophytic species, belonging to 39 genera and 28 families in tribal dominated zone of Malda district *(Biswas & Das, 2011)*. Moreover, early study on ethnobotanical survey has recorded 115 species of edible plants which are of medicinal importance in Bamangola block of Malda district *(Ghosh, 2017)*. However, in the present study, adequate field trips are followed, which represents unique assemblage of entire biotic components in the form of aquatic plants, icthyofauna and avifauna (resident and migratory) in these wetlands. A total of 21 species of macrophytes, belonging to 21 genera and 17 families have been identified and collected from the wetlands (*Acanthaceae-1, Apiaceae-1, Araceae-2, Asteraceae-2, Boraginaceae-1, Caryophyllaceae-1, Convolvulaceae-1, Fabaceae-1, Hydrocharitaceae-1, Lythraceae-1, Nelumbonaceae-1, Marsileaceae-1, Nymphaeaceae-2, Poaceae-1, Pontederiaceae-1, Potamogetonaceae-1*and *Salviniaceae-2) (Figure 3.12)*.

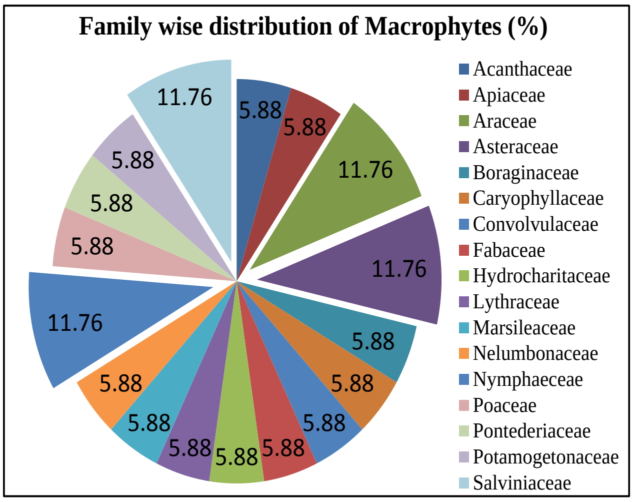


Figure 3 .12: *Family wise distribution of macrophtes in selected wetlands*

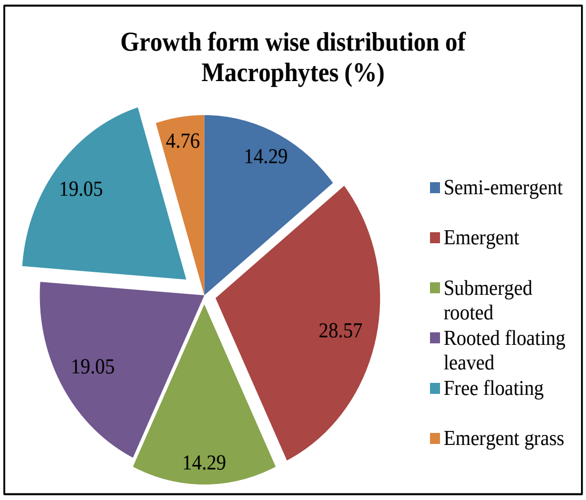


Figure 3.13: *Growth form wise distribution of macrophytes in selected wetlands*

The aquatic macrophytes of these wetlands are grouped into six growth forms namely, Semi-emergent (SE), Emergent (E), Submerged rooted (SR), Rooted floating leaved (RFL), Free floating (FF) and Emergent grass (ER) which are identified in open water (OW) and wetland water edge (WE) *(Figure 3.13) (Appendix-5) (Plate 3.1)*. The dominant growth form is found emergent (28.57%), which is represented by *Centella asiatica*, *Colcasia esculenta (Plate 3.1f)*, *Enydra fluctuans (Plate 3.1c)*, *Eclipta alba hassk*, *Heliotropium indicum (Plate 3,1g)*, *Polycarpon prostratum* etc; followed by rooted floating leaved (19.05%) in the form of *Trapa natans*, *Nelumbo nucifera*, *Euryale ferox (Plate 3.1b & i)*, *Nymphaea nouchali;* free floating (19.05%) in the form of *Pistia stratiotes (Plate 3.1e)*, *Eichhornia crassipes (Plate 3.1a & d)*, *Azolla ceae*, *Salvinia cucullata*. The other growth forms are followed by submerged rooted (14.29%) in the form of *Aeschynomene aspera*, *Hydrilla verticillata*, *Potamogeton perfoliatus;* semi-emergent (14.29%) like *Hygrophilia auriculata*, *Ipomoea aquatica*, *Marsilea Quadrifolia* and emergent grass (4.76%) like *Hygroryza aristata*. Some of the emergent macrophytic species are used in the systems of medicine.

Plate 3.1a: *Eichhornia crassipes, Chatra wetland*

Plate 3.1b: *Euryale ferox, Siali wetland*

Plate 3.1c: *Enydra fluctuans, Naghoria wetland*

Plate 3.1d: *Eichhornia crassipes, Chakla wetland*

Plate 3.1e: *Pistia stratiotes, Chatra wetland*

Plate 3.1f: *Colcasia esculenta, Naghoria wetland*

Plate 3.1g: *Heliotropium indicum, Siali wetland*

Plate 3.1h: *Marsilea Quadrifolia, Chakla wetland*

Plate 3.1i: *Euryale ferox, Chatra wetland*

Plate 3.1j: *Hygrophilia auriculata, Chakla wetland*

Plates 3.1: *Macrophytes observed in the wetlands under study*

3.6.2 Icthyofauna:

Earlier study has been conducted on fish faunal biodiversity of Malda district, which has identified and collected 32 species of fishes belonging to 27 genera and 13 families *(Hasan et al., 2017)*. In the present study, the wetlands indicate rich icthyofaunal diversity. The collected fish groups comprise a total of 24 species, belonging to 21 genera and 14 families *(Ambassidae-1, Ariidae-1, Badidae-1, Bagridae-1, Caridea-1, Clariidae-1, Cyprinidae-11, Crangonidae-1, Heteropneustidae-1, Mastacembelidae-1, Ophiocephalidae-1, Osphronemidae-1, Siluridae-1 and Tetraodontidae-1) (Appendix-6) (Plate 3.2)*. Cyprinidae is found as the most dominant and diversified family containing 11 species (45.8%) whereas other fish families comprise 1 species each (4.2%). *Labeo rohita and Labeo catla are found most dominant fish species, followed by Labeo bata (Plate 3.2b & c), Mystus tengara (Plate 3.2d), Arius arius, Labeo calbasu, Cirrhinus cirrhosis, Clarias batrachus, Tilapia sparrmanii (Plate 3.2a & g) Chanda nama, Trichogaster chuna etc under Cyprinidae.*

Plate 3.2a: *Tilapia sparrmanii, Chakla wetland*

Plate 3.2b: *Labeo bata, Siali wetland*

Plate 3.2c: *Labeo bata, Naghoria wetland*

Plate 3.2d: *Mystus tengara, Naghoria wetland*

Plate 3.2e: *Heteropneustes fossils, Siali wetland*

Plate 3.2f: *Macrobrachium rosenbergii, Chatra wetland*

Plate 3.2g: *Tilapia sparrmanii, Chatra wetland*

Plate 3.2h: *Macrobrachium rosenbergii, Chatra wetland*

Plates 3.2: *Icthyofauna observed in the wetlands under study*

3.6.3 Avifauna:

Chowdhury and Nandi have identified 62 bird species, belonging to 21 families in wetlands under different physiography of Malda district *(Chowdhury & Nandi, 2014)*. Another study has been made on the faunal structure in the wetlands of Malda *(Chowdhury & Das, 2013)*. In the present study, all the wetlands, under study are occupied by large number of residents and migratory species. The avifaunal diversity is recorded more during post-monsoon and winter months as there is optimum water storage, availability of abundant food and increased vegetation *(Bhat et al., 2009)*. In the present study, the wetlan are proved to be the important feeding ground for a total of 32 bird species, belonging to 27 genera and 17 families *(Accipitridae-1, Alaudidae-1, Alcedinidae-2, Anatidae-9, Ardeidae-7, Ciconiidae-1, Columbidae-1, Cuculidae-1, Phalacrocoracidae-1, Picidae-1, Ploceidae-1, Psittaculidae-1, Pycnonotidae-1, Strigidae-1 and Scolopacidae-1, Monarchidae-1, Falconidae-1) (Figure 3.14).* Out of total sighted species, 23 species are recorded residents and 9 species are migrants. The wetlands are almost equally utilized by residents and migratory species during winter but are recorded relatively less number as well as less diversity of bird population during pre-monsoon due to water recession. Among the identified bird families, Ardeidae (21.87%) and Anatidae (28.13%) are considered most commonly observed and represented by 7 species and 9 species respectively *(Appendix-7) (Plate 3.3)*.

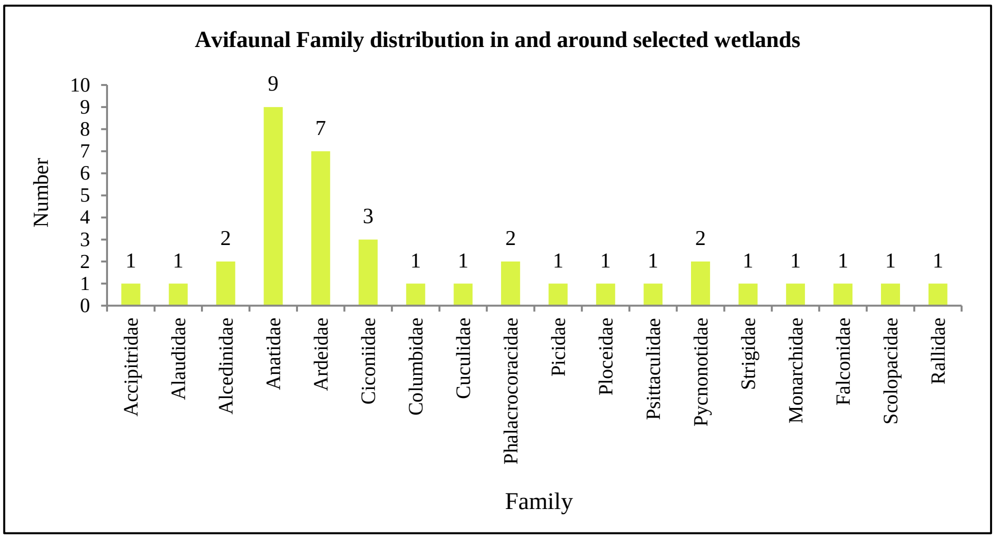


Figure 3.14: *Avifaunal family distributions in and around wetlands under study*

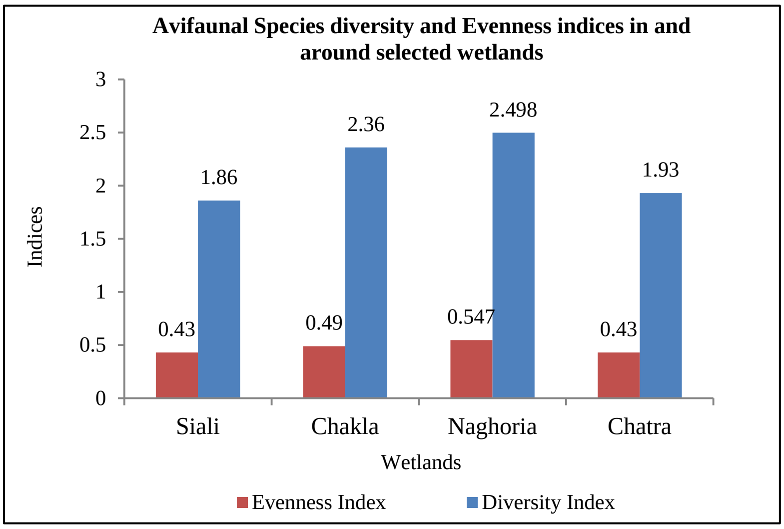


Figure 3.15: *Avifaunal species diversity (H) and Evenness index (E_H) in and around wetlands under study*

The residents namely, *Ardea alba (Plate 3.3c)*, *Ardeola grayii (Plate 3.3p)*, *Bubulcus ibis (Plate 3.3a & l)* under Ardeidae family; *Alcedo atthis (Plate 3.3r)*, *Halcyon pileata (Plate 3.3e)* under Alcedinidae family (6.25%) are found in remarkable number in and around the wetlands of Malda district. The migratory species namely, *Anser anser, Netta rufina, Anas poecilorhyncha (Plate 3.3i),* etc. under *Anatidae* family; *Leptoptilos crumenifer (Plate 3.3o)* under Ciconiidae family (3.13%) congregates in considerable flocks especially on the larger wetlands, and are exclusively observed during winter period. The other bird families are followed by *Pycnonotidae, Psittaculidae, and Columbidae* etc *(Figure 3.14).*

Plate 3.3a: *Bubulcus ibis, Chakla wetland*

Plate 3.3b: *Ciconia ciconia, Chatra wetland*

Plate 3.3c: *Ardea alba, Chatra wetland*

Plate 3.3d: *Melopsittacus undulates, Siali wetland*

Plate 3.3e: *Halcyon pileata, Naghoria wetland*

Plate 3.3f: *Bubo zeylonensis, Naghoria wetland*

Plate 3.3g: *Microcarbo niger, Chatra wetland*

Plate 3.3h: *Pycnonotus cafer, Siali wetland*

Plate 3.3i: *Anas poecilorhyncha, Chakla wetland*

Plate 3.3j: *Pycnonotus leocotis, Naghoria wetland*

Plate 3.3k: *Ciconia ciconia, Chatra wetland*

Plate 3.3l: *Bubulcus ibis, Siali wetland*

Plate 3.3m: *Phalacrocorax fuscicollis, Chakla wetland*

Plate 3.3n: *Porphyrio poliocephalus Chatra wetland*

Plate 3.3o: *Leptoptilos crumenifer, Siali wetland*

Plate 3.3p: *Ardeola grayii, Chakla wetland*

Plate 3.3q: *Aythya colony, Naghoria wetland*

Plate 3.3r: *Alcedo atthis, Chakla wetland*

Plates 3.3: *Avifauna (Resident & Migratory) sighted in the wetlands under*

The species diversity and species evenness of wetlands has been calculated by applying the Shannon-Weaver Diversity Indices *(Figure 3.15)*. The species diversity is recorded maximum during post-monsoon months because of large assortment of migratory species. The avaialibility of bird species starts gradually declining with the arrival of pre-monsoon, due to lowering down the water level along with food supply. High species diversity indicates increasing species evenness, as both are positively correlated. Therefore, applying the diversity indices to the case studies, Naghoria wetland records maximum species diversity (H=2.58) and species evenness (E_H= 0.57), which is attributed to conducive environment for the amalgamation of avifaunal species, in the form of availability of food, shelter etc. along with less human interferences. Naghoria wetland is followed by Chakla (H=2.36) (E_H= 0.49), Chatra (H= 1.93) (E_H= 0.43) and Siali wetland (H= 1.86) (E_H= 0.43) *(Figure 3.15)*. Siali wetland records relatively low species diversity and species evenness which is attributed to small size of wetland area. On the other, in spite of being a large water body, Chatra wetland is subjected to unlawful anthropogenic pressure from last few decades, which eventually results into relatively low migratory species diversity and evenness, than the wetlands under study. However, as per the most authoraitative guide to the status of biological diversity, International Union for Conservation of Nature and Natural Resource (IUCN version 2019-2) Red list has recognized most of the sighted species in and around wetlands are under Least concern (LC) category, except some avifaunal species namely; *Mycteria leucocephala* (Painted Stork) as resident and *Aythya nyroca* (White eyed pochard) as migrant species under Near threatened (NT) category and *Gyps indicus* (Bengal vulture) under Critically endangered (CR) category. In the present study, all the wetlands are considered a storehouse of diverse assemblage of biotic resources, in the form of macrophytes, icthyofauna and avifauna (residents and migratory), as proved by the field observation and application of diversity indices. Therefore, the wetlands act as 'biological supermarket' is potential to provide biodiversity conservation in Malda district.

3.7 Conclusion:

The present study reflects the presence of topographic and biological diversity of wetlands in Malda, which is represented by the case studies. The wetlands under study maintain the density and the diversity of bird species and are considered important feeding grounds for the resident and migratory species. The field study reveals the importance of entire wetland ecosystem as potential for promoting eco-tourism, which deals with the interaction with biotic resources of natural environment. Moreover, being a historical heritage, different rulers from ancient period, with assorted origin, religion and dynasty (Maurya, Gupta, Pala, Sen, Delhi and Bengal Sultanate etc.) had left their imprints of respective kingdom on the earth of Malda district, along with digging of wetlands, in order to ensure the availability and conservation of water. The architectural structure and ruins in the form of mosques (Qadam Rasool, Choto Sona, Tantipara, Gunmant, Chamkati, Lattan, Khania Dighi), gateways (Gumti, Lukachori, Baisgazi wall), tombs (Do-chala, Rohanpur Octagonal), few storeyed towers have been formed along side small, medium and large sized wetlands in several centuries back. The wetlands and water bodies with rich biotic diversity (aquatic flora and fauna) in association with historical structures are potential in order to promote eco-tourism activity as well as enhance the aesthetic importance and foster a greater appreciation of the wetland habitat. 'Based known secrets' of the district is had the wetlands been utilized a little bit better organized manner, the district economy would have been much better. However, wetlands though have tremendous potential for developments, are yet most threatened of all ecosystems today. There is a strong correlation between loss of biodiversity and erosion of socio-cultural diversity and Malda district is not an exception in this regard. Being a delicate life supporting system, any kind of anthropogenic stress through direct and indirect modification and non-sustainable utilization of wetlands would result into an adverse impact over the entire district. For a successful wetland management in any situation, immediate conservation strategies as well as a participatory and integrated approach should essentially be framed and implemented. Simultaneously, it is also very essential to make the stakeholders aware of the causes of present crisis, effects and possible preventive measures with proper knowledge, so that their participation can conserve these water bodies and associated ecosystem. And lastly, further research works should be carried out in order to understand the intricacies of the events, extent of damages on the wetland ecology, so that the effective steps can be taken to redress the damages.

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Chapter – IV

HYDROLOGICAL SET UP OF WETLANDS

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HYDROLOGICAL SET UP OF WETLANDS

4.1 Introduction:

The hydrological set up is an integral part of evaluation of health of any wetland ecosystem. The hydrology employs the influences upon the diverse assemblage of biotic components, and consequently gives a picture of environmental suitability of water in order to maintain various life forms. The water quality (physico-chemical and bacteriological parameters) study of wetlands is also a part of its hydrology. The changes in the quality of water certainly affect the distribution and survival of different organisms in and around wetlands *(Sylas & Sankaran, 2014)*. Consideration of water quality is important in wetland habitat evaluation because a host of interacting physical and chemical factors can influence the levels of primary productivity and resultantly influence the trophic structure as well as the total biomass throughout the aquatic food web *(Wetzel, 1975)*. Therefore, the water quality monitoring is an ideal tool for establishing the baseline data for assessing the pollution status as well as for the conservation and management of wetlands, specifically where the water resource is not well managed as in case of Malda district.

4.2 General study on wetland hydrology and water quality of Malda district:

The database, that has been generated as the outcome of present research is capable to prove that the wetlands in Malda district have the potential to control flood and recharge the ground water for further usage throughout the year. In the present study, most of the wetlands, in Malda district are linked with the major rivers (Mahananda, Fulahar, Kalindri, Tangan) and act as a buffer for excess rain. By soaking excess water like sponge, the wetlands are potential to mitigate the frequent flood hazard in Malda district and replenish the ground water recharge. Generally, wetland has two types of water storage: 1. Static wetland water storage that remains almost same over long period; and 2. Dynamic wetland water storage, which is considered as the difference between pre-monsoon and monsoon water level. Out of the total depth of dynamic storage, few amounts gets evaporated, few amount is infiltrated below the ground to replenish the ground water and remaining amount is used for agricultural purpose for the land, surrounding the respective wetlands. In Malda district, no such data is found regarding evapotranspiration, but the neighbouring district of Dakshin Dinajpur records an average 0.9 meter of water to be evaporated during 16 years, from 2000 to 2016 *(Paul, 2017)*. Within the remaining portion of dynamic wetland water storage, 40 % is utilized for agricultural purpose, whereas, 60 % of water is infiltrated and recharge the ground water.

The wetlands of Malda district contain some specific physical, chemical and bacteriological components through analyzing which the water quality study is made. A general survey of the physico-chemical factors of wetland water such as water temperature, pH, turbidity, total dissolved solids, conductivity, total hardness, dissolved oxygen, chloride, fluoride, iron content etc. along with bacteriological components namely; total and fecal coliform have been made.

4.2.1 Description of physico-chemical and bacteriological parameters of wetland water:

The physico-chemical components of the wetland water are found significantly fluctuating with the seasonal variability in Malda district.

4.2.1.1 Physical parameters:

1. ***Water temperature*** is an essential physical parameter, which influences the physical, chemical and biological behavior of aquatic life. Temperature alters the dissolve oxygen concentration in water body, and make oxygen less available for the respiration and metabolic *(Tank & Chippa, 2013; Jalal & Sanalkumar, 2012)* and physiological activities of aquatic organisms including their life processes like feeding, reproduction, movements and distribution *(Rani et al., 2012)*. The standard temperature for sustaining the aquatic life varies between 28° C to 30° C *(Weldermeriam, 2013)*. The wetlands in Malda district record more or less identical water temperature with maximum during pre-monsoon, followed by monsoon and post-monsoon season. Wetland water temperature ranges from 20° C to 25° C during post monsoon to 29° C to 33° C during pre-monsoon period.
2. ***Turbidity*** is a key component of water quality measurement. Turbidity is the measure of light, scattered by suspended particles such as clay, silts, finely divided organic matter, plankton and other microscopic organisms *(Verma et al., 2012)* that are generally invisible to the naked eye. These suspended particles absorb more light and results in rising of the water temperature. In the wetlands of Malda district, the turbidity is recorded within the permissible range between 5 to 10 NTU (Nephelometric turbidity unit). Turbidity is observed to be highest during the monsoon, followed by post-monsoon

and pre-monsoon season. High turbidity in the wetlands of Malda district signifies the presence of large amount of suspended solids, which eventually results into eutrophication and thereby decreases the dissolved oxygen level.

4.2.1.2 Chemical parameters:

3. The ***pH*** ("Potential of hydrogen"/"Power of hydrogen") measures the concentration of hydrogen ion in water *(Verma et al., 2012)*. At a given temperature the intensity of the acidic or basic character of water is indicated by its pH value. All the biochemical activities and retention of physico-chemical attributes of the water greatly depend on pH of the surrounding water *(Jalal and Sanalkumar, 2013)*. The pH measurements range on a scale from 0 to 14, with 7.0 considered to be neutral. Solutions with a pH value below 7.0 are considered acidic and above 7.0 are considered alkaline. In the present study, the pH value is found relatively lower in post-monsoon and slightly higher during pre-monsoon which maintains a consistent record above 7.0 almost in all the wetlands under study. The hard water may be detrimental to the vital biological process and can cause several aesthetic problems and hazards. The lower pH during the monsoon may be due to dilution of alkaline substances (household products). However, the pH level within the wetlands under study is restricted between the recommended range (6.5 – 8.5) for human use and it can be termed safe to the aquatic life as per BIS (2012) and APHA (2017).

4. ***Conductivity*** is a measure of ions. Conductivity estimates the total amount of dissolved solids in the wetland water *(Tank & Chippa, 2013)*. Electrical conductivity depends on the concentration and nature of the ionized substances dissolved in water, representing the total ion content *(Zacheus & Martikainen, 1997)*. The dissolved salts in association with solutions of most inorganic compounds such as alkalis, chlorides, sulfides and carbonate are relatively good conductors. The permissible range of conductivity is restricted to 400 µ.s. In the present study the conductivity of wetland water is consistently recorded to be higher during pre-monsoon and relatively lower in post-monsoon season but within the permissible range. Relatively high values of conductivity within wetlands of Malda district could be due to high ionic concentration, pollution status, trophic levels, presence of domestic effluents and other organic matter present in water.

5. Another component of water quality measurement is ***Total dissolved solids*** (TDS.), which signifies the inorganic pollution load in the wetland water. Its

concentration is the sum of cations (positively charged) and anions (negatively charged) in the water. It refers to the total amount of ions, including minerals, salts or metals, dissolved in a given volume of water (mg/L), and also referred to as parts per million (ppm). Being an indicator for rapid plankton growth and sewage contamination, TDS evaluates the fitness of wetland water. Further, the quantity of TDS determines the colour and electrical conductivity of the water body. In the study area, dissolved solid is found to be fluctuating markedly with the seasonal variation in almost all the wetlands with higher value during pre-monsoon, followed by monsoon and post-monsoon season. The wetlands, adjacent to urban area in Malda district records consistently high level of dissolved solids throughout the year.

6. ***Dissolved oxygen*** (DO) is regarded as one of the best indicators in order to assess the health of wetland and water body *(Edmondson, 1965)*. It is a measure of the amount of oxygen available for the biochemical activity in a given amount of water. It plays a key role in the waste-water treatment process and at the same time it has large effects on chemical and biological processes in wetland ecosystem. The concentration of dissolved oxygen is highly dependent on temperature, salinity and biological activity in the water column. Oxygen content is important for direct needs of many organisms and affects the solubility of many nutrients and therefore the periodicity of aquatic ecosystem *(Wetzel, 1983)*. The adequate presence of dissolved oxygen is necessary for aerobic biological activities and it indicates healthy aquatic life within the wetland system *(Maurya & Singh, 2016; Yadav & Yadav, 2017)*. In the present study, the wetlands record high amount of dissolved oxygen during monsoon and post-monsoon whereas, relatively lower amount has been recorded during pre-monsoon period, when the water level is low. The depletion of oxygen during pre-monsoon indicates the presence of high organic loads in the form of free floating macrophytes, which prevent light penetration into water, and results in the lower rate of photosynthesis by phytoplankton. Simultaneously high amount of dissolved oxygen in the wetlands under study, which is noticeable during monsoon and post-monsoon period, is possibly a contribution of brisk photosynthesis by submerged and floating aquatic plants.

7. ***Total hardness*** (TH) is a complex mixture of cations and anions *(Qureshimatva et al., 2015)*. Hardness is a measure of the capacity of water to precipitate soap. Soap is precipitated chiefly by calcium and magnesium ions, present in the surface and ground water mainly as carbonates and bicarbonates *(Tank & Chippa, 2013; Mandal, 2012)*. Therefore, total hardness can be equivalent to the total calcium and magnesium hardness,

expressed in milligrams per liter (mg/L). Some cations like iron, strontium, magnesium and anions, such as carbonates, bicarbonates, sulphate, chloride, nitrate and silicates contribute to hardness in the aquatic ecosystem. In the wetlands of Malda district, hardness is found to be fluctuating with seasonal variation, and records maximum during pre-monsoon, followed by monsoon and post-monsoon. Recorded hardness is within the permissible level (600 mg/L). The wetlands adjacent to the urban area in the entire district records high level of hardness round the year and is considered hard water (>100 mg/L), which is considered as pernicious as soft water for the human consumption.

8. ***Chloride*** is considered as one of the most important inorganic anion in water. The primary sources of chloride content in water body include wastewater from industries and municipalities, agricultural runoff, produced water from gas and oil wells etc. Chloride concentrations in freshwater is generally taken as an indicator of sewage pollution *(Wetzel, 1966)*. High chloride content in wetland water indicates the pollution of animal origin *(Munawar, 1970)*, through runoff load from peripheral area. In the present study, the chloride content is noted to be more or less same in almost all the water bodies of Malda district throughout the year. Maximum chloride concentration in wetland water is found during the post-monsoon season. Higher concentration of chloride may be attributed to increase the organic waste of human origin along with the runoff water.

9. ***Fluoride*** is an essential naturally occurring compound derived from fluorine. Fluoride is found negligible within the wetlands and somewhere it is recorded below detectable limit in Malda district.

10. In the present study, the ***iron*** and ***manganese*** are found to be fluctuating and somewhere almost negligible. The water bodies record maximum iron content during post-monsoon, followed by monsoon and pre-monsoon. Some of the wetlands under study represent iron content beyond the permissible limit (0.3 mg/L). The manganese content is almost below detectable limit throughout the entire study period in all the wetlands.

11. ***Arsenic*** is introduced into the wetland and water body through the dissolution of rocks, minerals and ores, from the industrial effluents, including mining wastes, and via atmospheric deposition *(IPCS, 1981; Hindmarsh & McCurdy, 1986)*. The main adverse effects reported to be associated with long-term ingestion of inorganic arsenic by humans are cancer, skin lesions, developmental effects, cardiovascular disease, neurotoxicity and diabetes *(IPCS, 2001)*. West-Bengal is one of the worst arsenic affected areas in the

world arsenic scenario. Malda district, especially the low land region *(Diara)* containing blocks namely English Bazar, Manikchak, Kaliachak 1, 2, 3 encounter immense health hazards from various types of skin manifestations and other arsenic toxicity such as Melanesia, keratosis, hyperkeratosis, and cancer. However, in the present study arsenic content is recorded very less in wetland water, especially during the pre-monsoon, whereas monsoon and post-monsoon record somewhere below detectable limit.

12. ***Nitrogen*** in wetland water is necessary to sustain biotic production in the wetlands. Surface water contains the amount of nitrate due to leaching of nitrate with the percolating water *(Gopalkrushna, 2011)*. Nitrates are contributed to the fresh water through various natural sources and due to human activities such as, runoff of nitrate rich fertilizers and animal manure into the water supply. From the present investigation, it is noted that the nitrate concentration is found consistently below detectable limit across all the seasons in wetlands under study.

4.2.1.3 Bacteriological parameters of wetland water:

In addition to the physico-chemical water quality indicators, bacteriological parameters of the wetland water have also been tested in laboratory. From the biological perspective, coliform counts have been taken into consideration for water quality measurement. Coliforms are bacteria that are always present in the digestive tracts of animals, including humans, and are found in their wastes. They are also found in plant and soil material. The presence of these bacteria indicates that whether the water is contaminated with feces or sewage, and has the potential to cause disease. Water pollution, caused due to fecal contamination is a serious problem due to the potential for contracting diseases from pathogens (disease causing organisms). So, testing of coliform bacteria in the wetland water sample is considered as a reasonable indication of whether other pathogenic bacteria are present or not. Coliform bacteria are generally of two kinds: 1. Total coliform and 2. Fecal coliform.

1. ***Total coliform gives*** the information about coliform bacteria *(Jalal & Sanalkumar, 2012)* that are found in the soil, water that has been influenced by surface water, and in human or animal waste.

2. ***Fecal coliforms*** are the group of the total coliforms that are considered to be present specifically in the gut and feces of warm-blooded animals. The origins of fecal coliforms are more specific than the total coliform group of bacteria, where the former is considered to be much accurate indication of animal or human waste than the later one. In the present study, the coliform content is found to be fluctuating within wetlands

which record maximum count of total and fecal coliform during post-monsoon season, followed by monsoon and pre-monsoon period in the wetlands under study.

4.3 Analysis of physico-chemical and bacteriological parameters of selected wetlands:

For the determination of physico-chemical and bacteriological quality of wetland water, field survey has been carried out for a period of consecutive three years from March 2015 to February 2018, covering three seasons viz. pre-monsoon (March-May), monsoon (June-September) and post-monsoon (October-February). During field study, the water samples have been collected in separate disinfected polyethylene cans from a depth of about 1.0 to 1.5 meter from the selected wetlands *(Plate 4.1a & c)*. At the respective sampling sites *(Map 4.4)* a total of 15 water quality parameters have been quantified in the laboratory, by following the BIS May, 2012; APHA, AWWA and WEF, 2017, presented in table no. 4.1 *(Appendix-8).*

Plate 4.1a: *Water sample collection during monsoon*

Plate 4.1b: *Water level measurement during post-monsoon*

Plate 4.1c: *Water sample collection during pre-monsoon*

Plate 4.1: *Wetland water level measurement and water sample collection during study*

4. 1 Details of wetland water components, instruments used, unit of measurement and permissible limit during study period

Sl. No.	Wetland water quality parameters	Instrument used	Unit of measurement	Permissible limit (BIS)	Remark
			A. Physical parameters		
1.	Water temperature	Mercury thermometer	°C		APHA 2550
2.	Turbidity	Turbidity Meter	Nephelometric turbidity unit (N.T.U.)	5	APHA 2130
			B. Chemical Parameters		
1.	Ph	pH Meter	-	6.5 – 8.5	APHA 4500-H^+
2.	Conductivity	Conductivity Meter	µ.s.	400	APHA 2510
3.	Total Dissolved Solid	Conductivity Meter	Parts per million (ppm)	200	APHA 2540
4.	Dissolved Oxygen	DO Meter	mg/L	18	APHA 4500-O
5.	Total Hardness	Titration method	mg/L	600	APHA 2340
6.	Chloride		mg/L		APHA 4500-Cl
7.	Iron		mg/L		APHA 3500-Fe
8.	Fluoride		mg/L		APHA 4500_F^-
9.	Arsenic		mg/L		APHA 3500-As
10.	Nitrate		mg/L		APHA 4500-NO_3^-
11.	Manganese		mg/L		APHA 3500-Mn
			C. Bacteriological parameters		
1.	Total coliform	MPN – Most probable number	MPN/100 ml	Shall not be detectable in any 100 ml sample	APHA 9222
2.	Fecal coliform	MFT – Membrane filter tube	MPN/100 ml	Shall not be detectable in any 100 ml sample	APHA 9222

Source: *BIS May, 2012; APHA, AWWA & WEF, 2017*

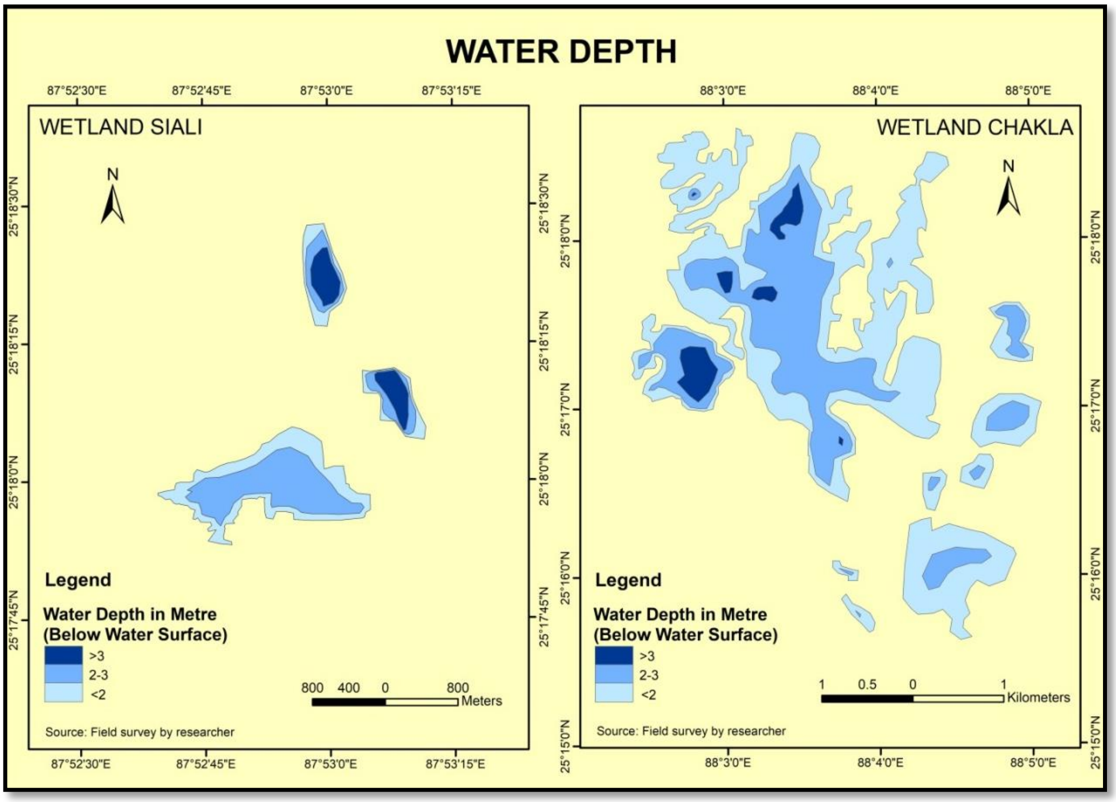
4.3.1 Siali wetland

4.3.1.1 Wetland hydrology:

Siali wetland is fed by the surface drainage of the catchment area and is well connected with Kankhor and Kali koshi, two tributaries of River Baramasia, which ultimately meets River Mahananda. The water level records minimum depth of < 2 meter, whereas the monsoon and post-monsoon record peak water level of 3.5 and 3.0 meter respectively in certain portion of this water body *(Map 4.1)*. Shallow water depth is recorded in the south, whereas maximum water depth is recorded in the north of Siali wetland. Large sections of wetland region turn into mud banks/ mud flats during the dry season, while the many marshy pockets remain become shallow. Siali wetland exerts a significant influence on the hydrological cycle. This water body initially alters the flood flows, and subsequently recharges the ground water table. The field study reveals that, this wetland is capable to store 3.5 meter water as extra amount during monsoon seasons, which is amounted to volume 554,358 m^3 of water. Therefore, Siali wetland plays the role to reduce down the flood peak of River Fulahar. Moreover, the dynamic water storage of this particular wetland is recorded 1.7 meter during the study, in which 0.9 meter gets evaporated *(Pal, 2017)*. Out of the remaining portion (0.8 meter) of dynamic water storage, approximately 60 % gets infiltrated as ground water recharge through Siali wetland.

4.3.1.2 Physico-chemical and bacteriological parameters:

For assessing the water quality of Siali wetland, certain relevant parameters have been analyzed from the sample water collection. All the parameters are displayed in mean value of data along with Standard Error of Mean (SEM) and Standard Deviation *(Table no. 4.2) (Appendix-8)*. The seasonal variation of these parameters has been presented in the following figure 4.1 (a, b), 4.2 (a to h) and 4.3 (a, b).



Map 4.1: *Water depth of wetland Siali and Chakla in meter (below water surface)*

4.3.1.2.1 Physical parameters:

In the present study, seasonal variability of water temperature has been observed maximum during summer, comparatively less during monsoon and minimum during post-monsoon season. In Siali wetland the ***water temperature*** generally ranges from 24°C ($\bar{X}$=24.43; σ=0.38) to 32.5°C ($\bar{X}$=31.77; σ=0.64) throughout the year. Water temperature records small variations from pre-monsoon (31.77°C) to monsoon (28.40°C) and post-monsoon (24.43°C) season *(Table 4.2) (Figure 4.1a).*

The ***turbidity*** of Siali wetland water is moderate to high and found within the permissible limit of 5 N.T.U. Turbidity value ranges from 1.51 N.T.U. ($\bar{X}$=2.18; σ=0.58) to 4.86 N.T.U. ($\bar{X}$=4.54, σ=0.59), with maximum concentration during monsoon (4.89 N.T.U.), and minimum during pre-monsoon (1.51 N.T.U.) *(Table 4.2) (Figure 4.1b)*. Turbidity reduces the light penetration into wetland water which eventually affects the photosynthesis process of phytoplankton as well as reduces the productivity of the entire wetland ecosystem *(Abujam et al., 2012).*

4.3.1.2.2 Chemical parameters:

The ***pH*** of this wetland water ranges from 7.01 ($\bar{X}$=7.17; σ=0.14) to 7.62 ($\bar{X}$=7.53; σ=0.11) throughout the study period. In Siali wetland, the pH is recorded high during the pre-monsoon (7.62), followed by monsoon (7.32) and post-monsoon (7.04) period *(Table 4.2) (Figure 4.2a)*. The pH is somewhat alkaline during pre-monsoon, which may be associated with active photosynthesis. Water pH has been recorded declining during monsoon which may be due to the higher run off from the adjacent catchment area *(Map 4.2)*, having slightly acidic soil or due to the luxuriant growth of emergent macrophytes.

During the entire study period, covering three years in Siali wetland ***conductivity*** records from 120.9 µ.s. ($\bar{X}$=125.17; σ=3.97) to 146.9µ.s. ($\bar{X}$=143.87; σ=3.01). Conductivity is found seasonally fluctuating with its peak value during pre-monsoon (146.907µ.s), followed by monsoon (126.80µ.s) and post-monsoon period (120.90µ.s) *(Table 4.2) (Figure 4.2c)*.

Siali wetland records the ***total dissolved solid*** (tds) content from 50.7ppm ($\bar{X}$=58.70, σ=7.21) to 86.7 ppm ($\bar{X}$=78.50, σ=7.71) throughout the study time *(Table 4.2) (Figure 4.2b)*. There is a marked seasonal variation in dissolved solid with the highest value during pre-monsoon (86.70ppm), followed by monsoon (65.30ppm) and post-monsoon (50.70ppm). The relatively high value of dissolved solid during rainy period may be due to addition of domestic waste water, garbage and sewage etc. in the natural surface water body *(Verma et* *al., 2012)*. The high concentration of TDS from the surrounding locality *(Map 4.2)*, where the photograph has been taken (shown by red arrow), enhances the nutrient status of water body which eventually results into eutrophication in this wetland.

Dissolved oxygen is another chemical water quality parameter, which is used as an index of water quality, primary production and pollution. Siali wetland water records the concentration of dissolved oxygen from 4.1 mg/L ($\bar{X}$=4.37; σ=0.25) to 6.7 mg/L ($\bar{X}$=6.43; σ=0.25) throughout the entire study period. Highest do is recorded during post-monsoon (6.70mg/L), followed by monsoon (4.90mg/L) and remain almost same during pre-monsoon *(Table 4.2) (Figure 4.2d)*.

In the present study, the wetland water ***hardness*** ranges from 104 mg/L ($\bar{X}$=112; σ=6.93) to 155 mg/L ($\bar{X}$=155; σ=12.28). Marked seasonal fluctuation is recorded with highest value in pre-monsoon (159mg/L), which is quite high than the normal water condition and is termed hard water. Total hardness in wetland water has gradually been reduced down in monsoon (120mg/L) and post-monsoon (104mg/L) period *(Table 4.2) (Figure 4.2e)*.

The ***Chloride*** content is recorded from 72.01 mg/L ($\bar{X}$=72.04; σ=0.02) to 78.43 mg/L ($\bar{X}$=78.43; σ=0) throughout the study period. An increasing trend of chloride from monsoon (73.17mg/L) with maximum during post-monsoon (78.43mg/L) and a declining trend in pre-monsoon (72.01mg/L) period have been recorded in this water body *(Table 4.2) (Figure 4.2f)*. The gradual increase of chloride concentration in the wetland water indicates the influence of organic waste of human origin with runoff water from the peripheral villages.

The chemical component of ***iron*** is found consistently low throughout the year, which ranges from 0.15 mg/L ($\bar{X}$=0.19; σ=0.04) to 0.69 mg/L ($\bar{X}$=0.58; σ=0.10). The obtained level of iron is significantly high during post-monsoon (0.7mg/L) and low during pre-monsoon (0.15mg/L).

Fluoride and ***arsenic*** concentration has been found very less irrespective of all the seasons. Fluoride ranges from 0.17 mg/L ($\bar{X}$=0.18; σ=0.01) to 0.30 mg/L ($\bar{X}$=0.30; σ=0.01) with maximum value during post-monsoon and minimum during pre-monsoon *(Figure 4.2h)*. Arsenic content within wetland water records 0.01 to 0.02 mg/L during the entire study period.

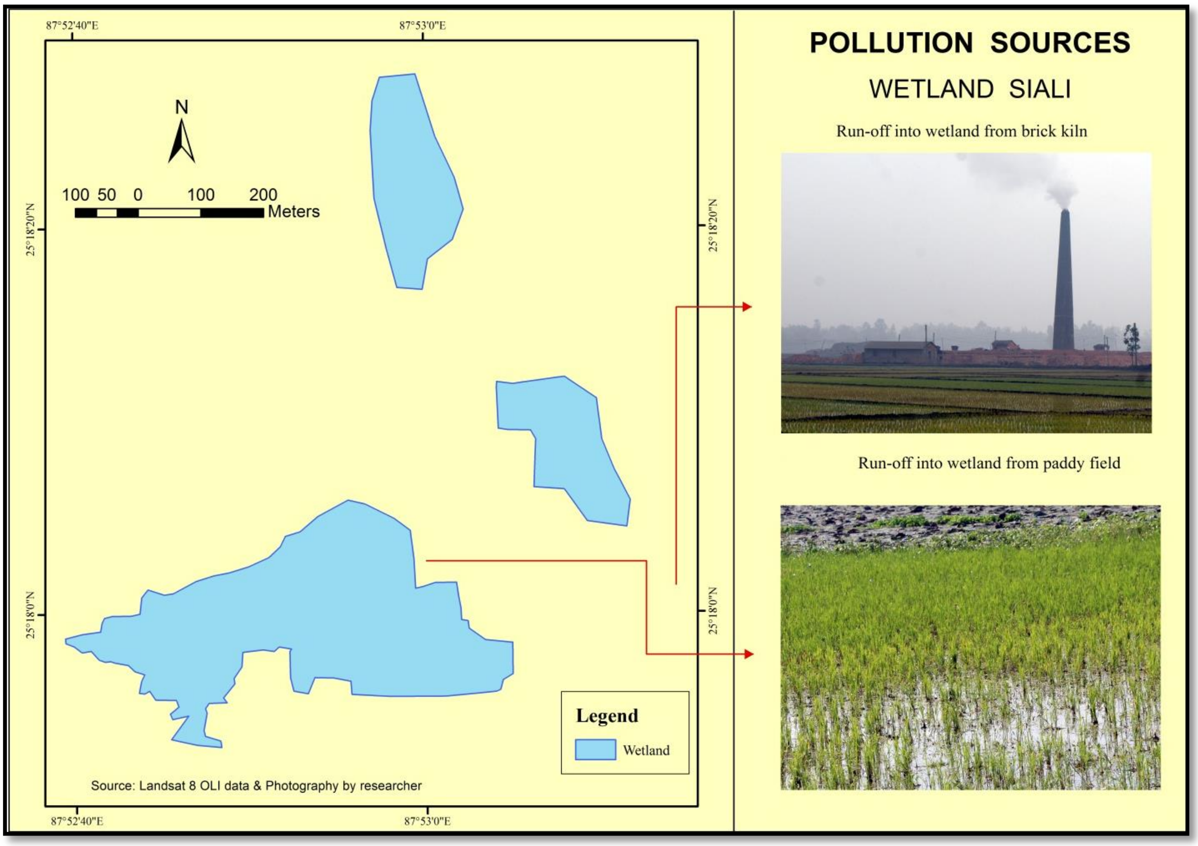
Other two chemical components ***nitrate*** and ***manganese*** are found below detectable limit throughout the entire study period.

Table 4.2 Statistical result on physic-chemical and bacteriological parameters of Siali wetland

Parameters	Pre-monsoon			Monsoon			Post-monsoon		
	Mean		Std. Deviation	Mean		Std. Deviation	Mean		Std. Deviation
	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic
Water temperature	31.77	0.37	0.64	28.40	0.60	1.04	24.43	0.22	0.38
pH	7.53	0.06	0.11	7.40	0.043	0.075	7.17	0.081	0.14
Conductivity	143.87	1.73	3.01	129.77	1.51	2.61	125.17	2.28	3.95
Total dissolved solid	78.50	4.45	7.71	67.47	1.30	2.25	58.70	4.16	7.21
Turbidity	2.18	0.33	0.58	4.54	0.34	0.59	3.48	0.30	0.51
Total hardness	150.00	7.09	12.28	126.00	3.00	5.20	112.00	4.00	6.93
Dissolved oxygen	4.37	0.15	0.25	5.37	0.29	0.50	6.43	0.15	0.25
Chloride	72.04	.013	0.023	73.17	0.100	0.17	78.43	0.00	0.00
Iron	0.19	0.02	0.035	0.43	0.015	0.025	0.58	0.057	0.098
Fluoride	0.18	0.003	0.006	0.23	0.00	0.00	0.30	0.007	0.012
Arsenic	0.01	0.002	0.003	0.00	0.00	0.00	0.01	0.002	0.003
Total coliform	4.67	0.67	1.15	7.00	0.00	0.00	12.67	0.67	1.16
Fecal coliform	0.33	0.33	0.58	1.00	0.00	0.00	2.00	0.00	0.00

Source: *1. Water sample collected from field study*

2. Water sample tested by P.H.E. Department, under Malda Polytechnic, Govt. of West Benga



Map 4.2: *Run-off from agricultural field into Siali wetland*

4.3.1.2.3 Bacteriological parameters:

The bacteriological analysis has been conducted in the laboratory to access the total coliform and fecal coliform. In the present study, ***total coliform*** counts ranges from 4 MPN ($\bar{X}$=4.67; σ=1.15) to 14 MPN ($\bar{X}$=12.67; σ=1.16) per 100 ml water. Maximum total coliform is recorded during winter months (14MPN/100 ml), followed by monsoon (7MPN/100ml) and pre-monsoon (4MPN/100ml) *(Table 4.2) (Figure 4.3 a&b)*. The present investigation reveals an increasing trend in the concentration of total coliform during the monsoon and post-monsoon period, which may be due to the large accumulation of land run-off in wetland water, and results into high bacterial population within wetland water.

Fecal coliform records as low as 0 to 3 MPN ($\bar{X}$=2; σ=0) per 100ml wetland water.

4.3.2 Chakla wetland

4.3.2.1 Wetland hydrology:

The hydrological activity of the *Tal* physiographic region is evident from the fact that, large number of perennial rivers, including mighty River Ganga, traverse through this zone. Moreover, there are strong evidence of shifting river channels, and is normally subjected to inundation regularly. By regular inflow of Nuna and Bhoga inlets (of River Mahananda) from north and south respectively, the water spread area of this wetland gets enlarged. Due to favourable slope condition and consequent run-off, most of the tract remains submerged under considerable depths of water during the monsoon rains. The water level significantly varies from < 2 meter during pre-monsoon to > 3.5 meter during monsoon season in several parts of this vast water body *(Map 4.1)*. Maximum water depth is noticeable in the north and western pockets, whereas the rest of the portions display low to moderate water depth within wetland. The field study reveals that, Chakla wetland is capable to store 2.0 meter water as extra amount during monsoon period, which is amounted to volume 42,314,620 m^3 of water. Therefore, Chakla wetland, being a vast water body plays the role of buffer to soak excess water from wetland catchment as well as reduce down the flood peak of River Mahananda. Moreover, the dynamic water storage of Chakla wetland is recorded 1.25 meter during the study, in which a specific amount of water (0.9 meter) gets evaporated. Out of the remaining portion (0.35 meter) of dynamic water storage, a large amount (approximately 60 %) gets infiltrated as ground water recharge through this natural entity.

4.3.2.2 Physico-chemical and bacteriological parameters:

4.3.2.2.1 Physical parameters:

The physico-chemical and bacteriological parameters of the sample wetland water are displayed in the following table 4.3 as well as represented in figure 4.1, 4.2 and 4.3.

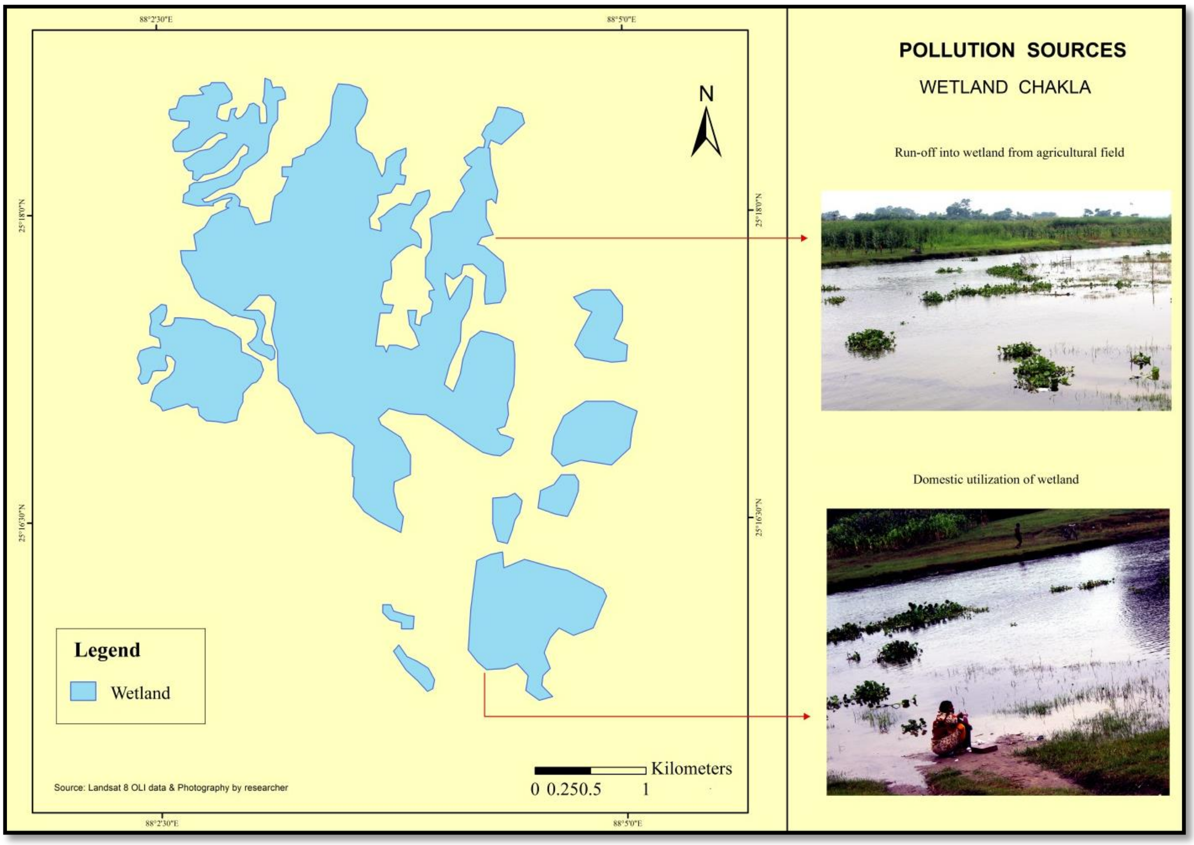
Chakla wetland records ***water temperature*** ranges from 23.5°C ($\bar{X}$=23.7; σ=0.20) to 31.7°C ($\bar{X}$=31.23; σ=0.40) throughout the year, with the highest recorded value during pre-monsoon (31.70°C), followed by monsoon (27°C) and post-monsoon (23.70°C) *(Figure 4.1a)*.

In the present study, the ***turbidity*** in wetland water ranges from 4.35 N.T.U. ($\bar{X}$=4.39; σ=0.06) to 6.92 N.T.U. ($\bar{X}$=6.53; σ=0.54) which exceeds the permissible limit of 5.00 N.T.U. as proposed by BIS and APHA. Wetland water turbidity is found maximum during the monsoon period (6.92 N.T.U.) and least turbidity is obtained during pre-monsoon (4.35 N.T.U.) *(Table 4.3) (Figure 4.1b)*. High turbidity signifies the presence of large amount of suspended solids within this water body *(Verma et al., 2012)*. This also indicates the high rate of siltation, so as to decrease the depth of this wetland complex.

4.3.2.2.2 Chemical parameters:

The water ***pH***, which is governed by the equilibrium between carbon-di-oxide, carbonate and bicarbonate ions, mostly lies within the range of 6.73 ($\bar{X}$=6.96; σ=0.20) to 7.61 ($\bar{X}$=7.54; σ=0.08) throughout the study period. The pH of Chakla wetland complex is observed to be slightly acidic (6.73) during post-monsoon; which has turned to alkaline range (7.61) during pre-monsoon. The pH record is considered to be conducive for the aquatic ecosystem in this wetland *(Table 4.3) (Figure 4.2a)*.

The recorded ***Conductivity*** of Chakla wetland is restricted between 103.5 µ.s. ($\bar{X}$=104.97; σ=2.20) to 159.8µ.s. ($\bar{X}$=138.47; σ=18.50) throughout the year with lower amount during post-monsoon (103.50µ.s.) and higher in pre-monsoon (159.80µ.s.) period *(Table 4.3) (Figure 4.2c)*. In this water body, there is a striking seasonal variation in conductivity, but confined within the permissible range of 400 µ.s (BIS and APHA).



Map 4.3: *Agricultural and domestic sewage inflow into Chakla wetland*

Table 4.3 Statistical result on physic-chemical and bacteriological parameters of Chakla wetland

Parameters	Pre-monsoon			Monsoon			Post-monsoon		
	Mean		Std. Deviation	Mean		Std. Deviation	Mean		Std. Deviation
	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic
Water temperature	31.23	0.23	0.40	27.00	0.00	0.00	23.70	0.12	0.20
pH	7.54	0.04	0.077	7.34	0.12	0.21	6.96	0.12	0.204
Conductivity	138.47	10.68	18.50	115.33	6.33	10.97	104.97	1.27	2.20
Total dissolved solid	66.87	3.52	6.10	57.00	0.58	1.00	51.57	1.27	2.19
Turbidity	4.39	0.032	0.06	6.53	0.31	0.54	5.60	0.00	0.00
Total hardness	95.33	3.33	5.77	78.00	8.00	13.86	54.00	5.03	8.72
Dissolved oxygen	4.17	0.067	0.12	5.57	0.37	0.64	6.57	0.13	0.23
Chloride	29.30	1.72	2.98	29.53	2.33	4.04	40.24	0.00	0.00
Iron	0.71	0.12	0.21	0.50	0.00	0.00	1.03	0.21	0.36
Fluoride	0.23	0.01	0.012	0.20	0.00	0.00	0.17	0.01	0.012
Arsenic	0.00	0.00	0.00	.000	0.00	0.00	0.013	0.01	0.003
Total coliform	0.00	0.00	0.00	8.33	0.33	0.58	18.00	1.00	1.73
Fecal coliform	0.00	0.00	0.00	2.33	0.33	0.58	8.67	0.67	1.155

Source: *1. Water sample collected from field study*

2. Water sample tested by P.H.E. Department, under Malda Polytechnic, Govt. of West Bengal.

Total dissolved solid in Chakla wetland ranges from 50.3 ppm ($\bar{X}$=51.57; σ=2.19) to 73.9 ppm ($\bar{X}$=66.87; σ=6.10) throughout the study period. In the present study, TDS is visibly low during post-monsoon (50.30ppm) and higher during pre-monsoon period (73.90ppm) and its concentration is well within the permissible limit *(Table 4.3) (Figure 4.2b)*. High loading of dissolved solid factor could be associated with the dissolution of ions in the water, which signifies the inorganic pollution load in wetland water *(Map 4.3)*.

Dissolved oxygen is a parameter in aquatic ecosystem, which greatly affects the physical, chemical and biological process of the wetland ecosystem. Do significantly ranges between 4.1 mg/L ($\bar{X}$=4.17; σ=0.12) to 6.7 mg/L ($\bar{X}$=6.57; σ=0.23) during the entire study period *(Table no. 4.3) (Figure 4.2d)*. The result shows that there is a gradual increase of dissolved oxygen during post-monsoon period (6.70mg/L), which is attributed to low ambient atmospheric temperature. Chakla wetland records minimum dissolved oxygen during pre-monsoon (4.10mg/L), which may be due to the presence of high organic loads in this wetland complex *(Map 4.3)*.

Total hardness in wetland water records an average value of 44 mg/L ($\bar{X}$=54; σ=8.72) to 102 mg/L ($\bar{X}$=95.33; σ=5.77), across all the seasons and considered to be soft water. Maximum water hardness is recorded during pre-monsoon (102.00mg/L), whereas minimum in post-monsoon (44.00mg/L) season *(Table 4.3) (Figure 4.2e)*.

In the present study, the ***chloride*** concentration significantly fluctuates from 27.2 mg/L ($\bar{X}$=29.53; σ=4.04) to 40.24 mg/L ($\bar{X}$=40.24; σ=0). The post-monsoon (40.24mg/L) records maximum chloride content, which remain almost same during pre-monsoon (27.58mg/L) and monsoon (27.20mg/L) *(Table no. 4.3) (Figure 4.2f)*. The chloride concentration in post-monsoon may be due to the accumulation of domestic sewages from neighboring village sites and cattle sheds, immediately after the heavy shower *(Map 4.3)*.

Iron concentration in Chakla wetland ranges between 0.47 mg/L ($\bar{X}$=0.71; σ=0.21) to 1.28 mg/L ($\bar{X}$=1.03; σ=0.36) throughout the study period. Maximum concentration of iron is recorded in post-monsoon (1.28mg/L), whereas minimum in pre-monsoon (0.47mg/L) *(Figure 4.2g)*. Iron content is directly related with the zooplankton diversity *(Pal et al., 2015)*, which is truly maintained in case of diverse faunal composition in Chakla wetland.

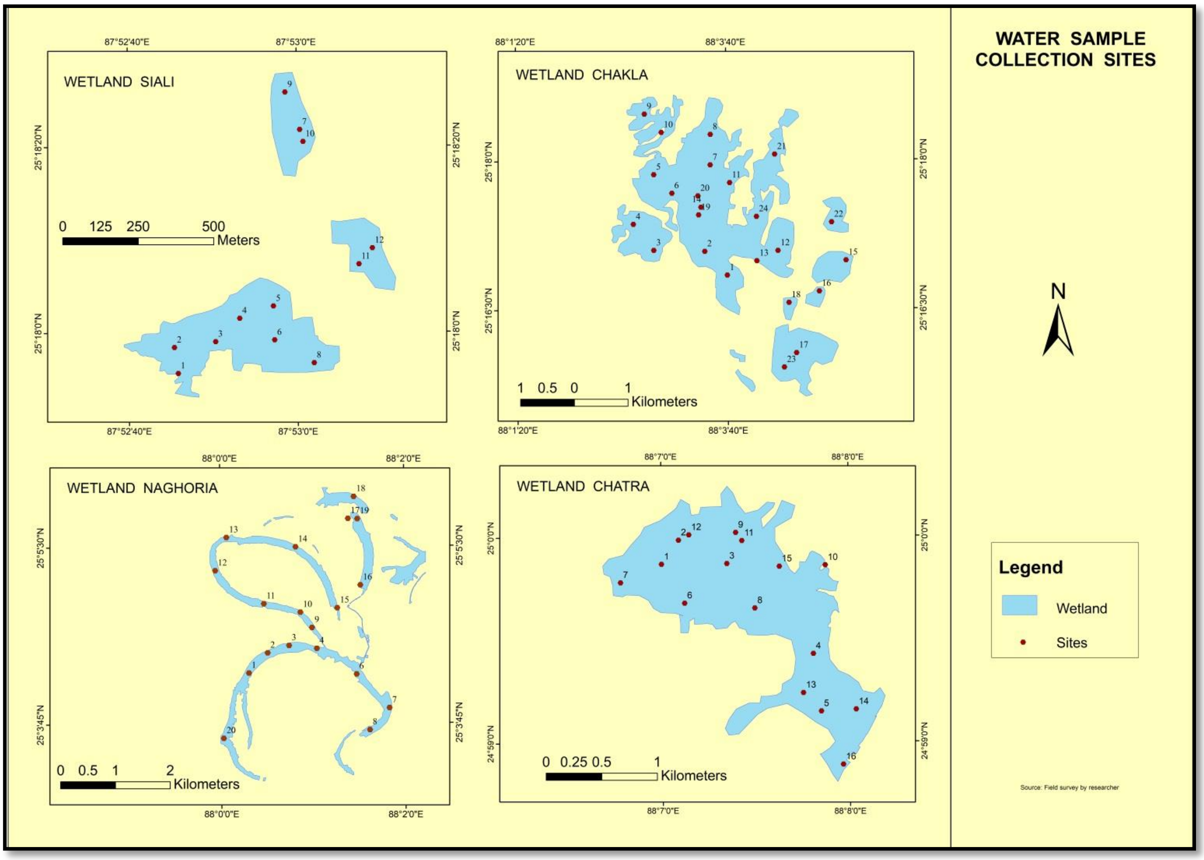
The ***fluoride*** content has been recorded very less, as well as restricted between 0.16 mg/L ($\bar{X}$=0.17; σ=0.01) to 0.24 mg/L ($\bar{X}$=0.23; σ=0.01) across all the seasons *(Figure 4.2h)*. The ***arsenic*** content is found negligible, ranges from 0 to 0.016 mg/L throughout the study period.

The ***nitrate*** and ***manganese*** are recorded consistently low across all the seasons in the surface water in spite of several agricultural practices at the periphery of wetland complex.

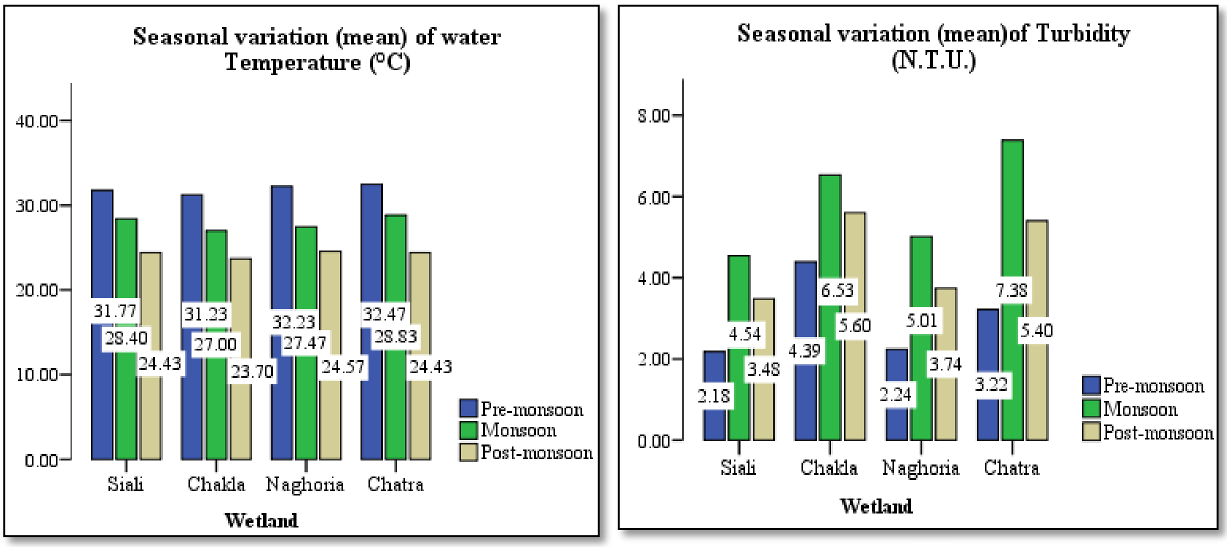
4.3.2.2.2. Bacteriological parameters:

In the context of bacteriological analysis the presence of ***total coliform*** is consistently high, and ranges between 0 to 20 MPN ($\bar{X}$=18; σ=1.73) per 100 ml water. Post-monsoon (20.00MPN/100ml) records a higher load of organic compounds in Chakla wetland, whereas pre-monsoon records 0.

Fecal coliform is found lower, ranges from 0 to 10 MPN ($\bar{X}$=8.67; σ=1.16) per 100 ml water with highest amount in post-monsoon (10.00MPN/100ml) *(Table 4.3) (Figure 4.3 a&b)*.

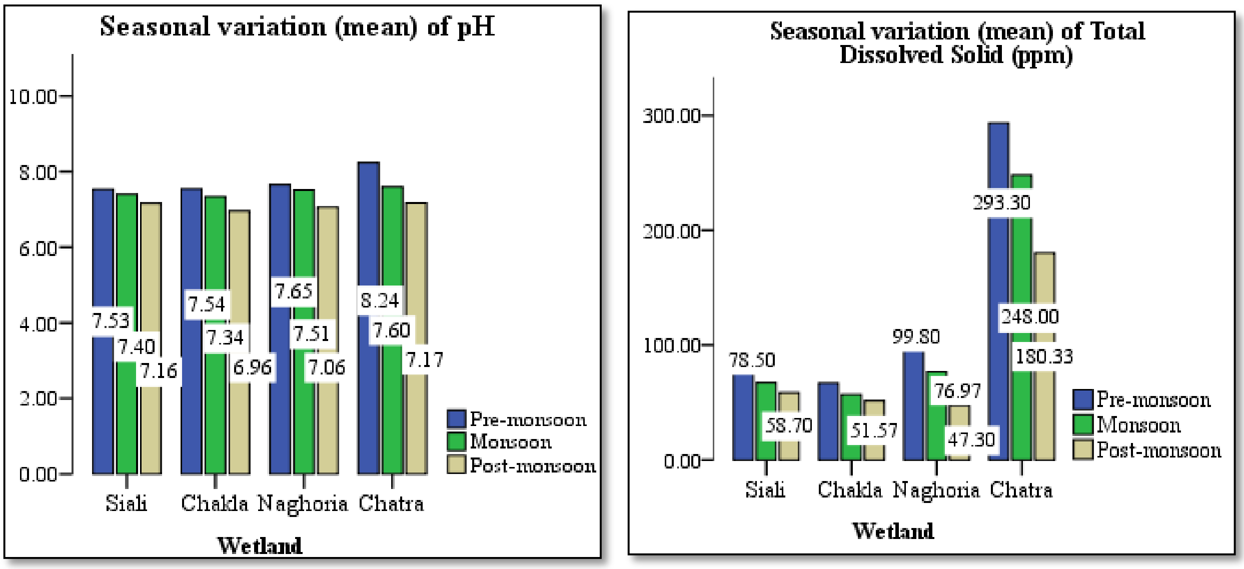


Map 4.4: *Water sample collection sites from selected wetlands*



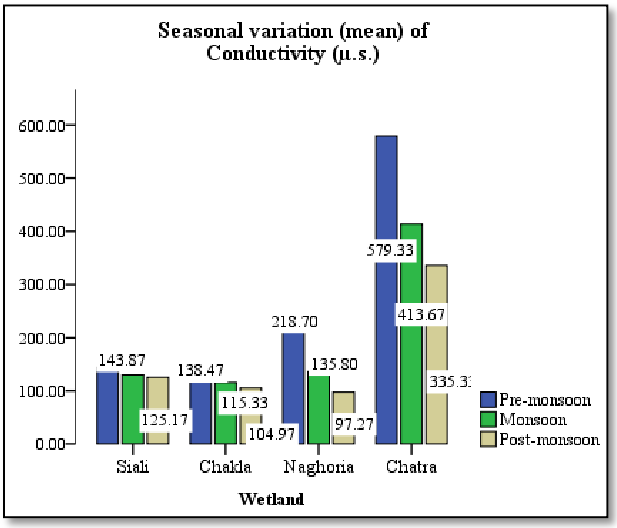
(a) **(b)**

Figure 4.1: *Seasonal variations of physical water quality parameters between selected wetlands*

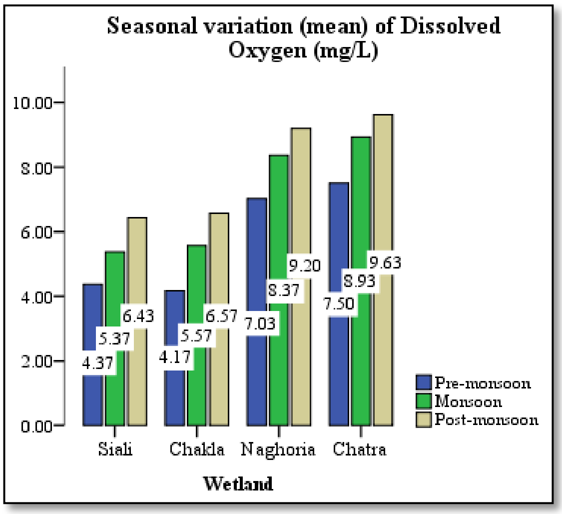


(a) **(b)**

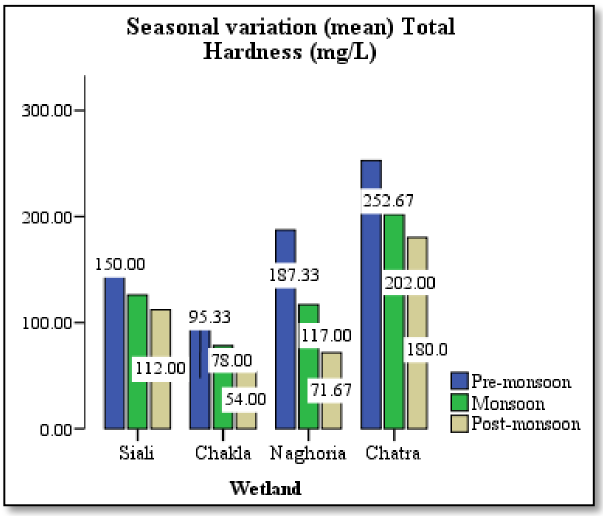
Figure 4.2: *Seasonal variations of Chemical water quality parameters between selected wetlands*



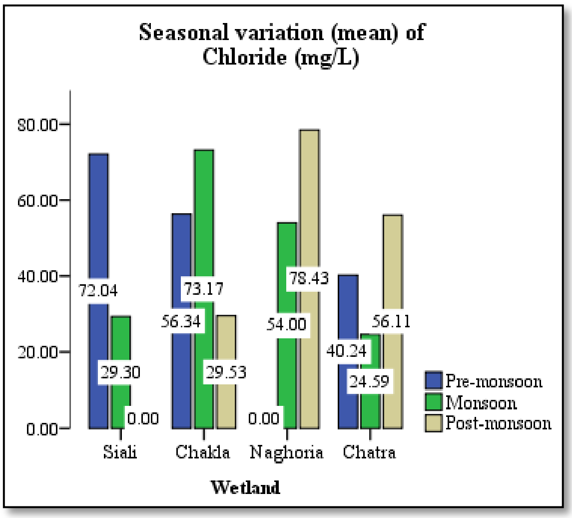
(c)



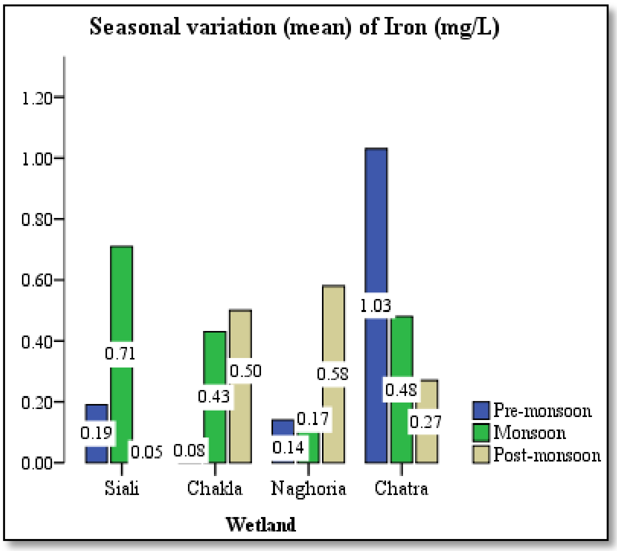
(d)



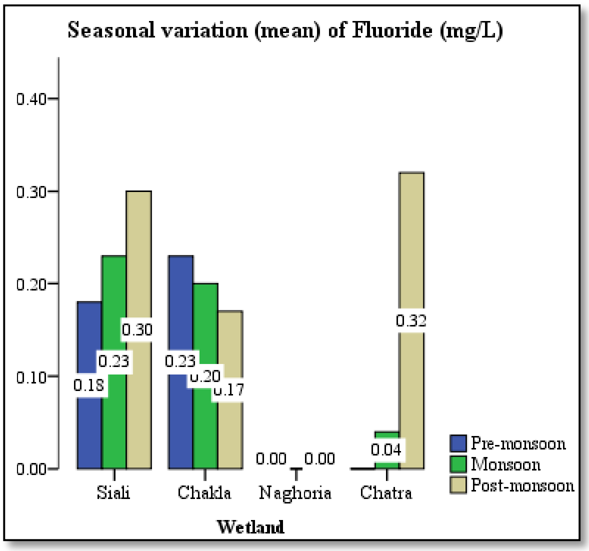
(e)



(f)

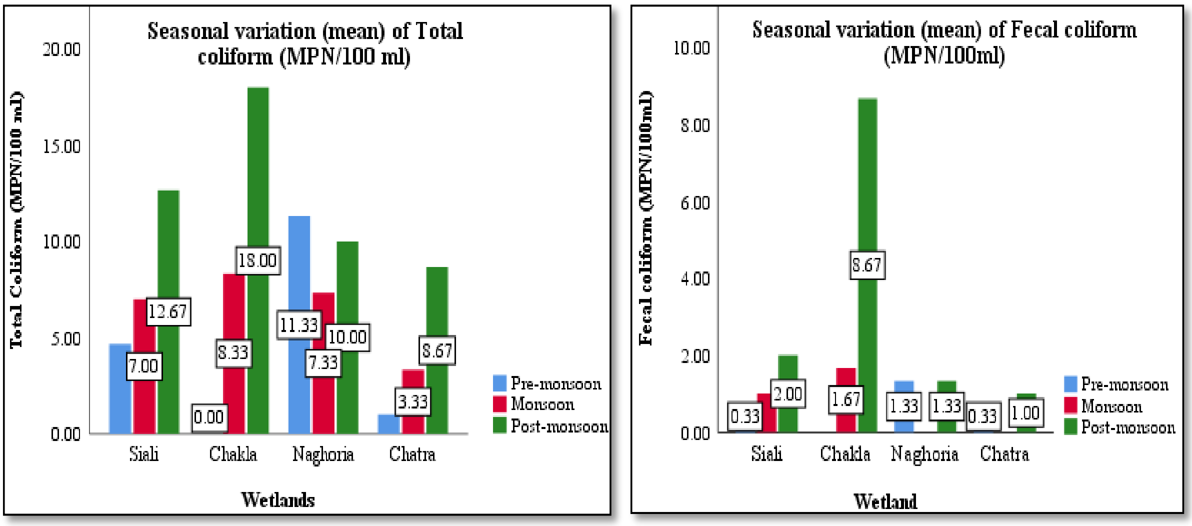


(g)



(h)

Figure 4.2 *Seasonal variations of Chemical water quality parameters between selected wetlands*



(a) **(b)**

Figure 4.3 *Seasonal variations of Bacteriological water quality parameters between selected wetlands*

4.3.3 Naghoria wetland

4.3.3.1 Wetland hydrology:

The hydrology of the Naghoria wetland area is a typical representation of river bed hydrological characteristic. The main support of its drainage is rain water, along with the river water of Kalindri. Sometimes these channels are continuous or partially dissected, somewhere existing as waterlogged channels and somewhere it is captured by inhabitants for the agricultural and settlement purposes. Therefore this wetland is uniquely characterized by the continuous wet and dry courses. The water level is recorded lowest (< 2 meter) during pre-monsoon, from March to end of May, which indicates the dry phase of summer. Water level is at its maximum (> 3 meter) during monsoon, from the end of June to October, as the surface run-off from the vast catchment area enters into the channel by Kalindri River and Nurpur connection via Nurpur barrage from Ganga River *(Map 4.6)*. On the basis of field study and information, taken from Phulbaria and Uttar Lakshipur Gram Panchayat, it is observed that this cut-off channel experiences fluctuation in the water spread area especially during pre-monsoon and monsoon months. Naghoria wetland is almost perennial by nature and apart from its huge surface area; the hydrology of the Naghoria is partially dependent on the ground water regime. Direction of the ground water flow is almost same as the general slope and water table seems to be very close (< 3 m). The excess water drains through Kalindri to Mahananda River. The field study reveals that, Naghoria wetland is capable to store 0.5

meter water as extra amount during the monsoon months (July to September), which is amounted to volume 6,772,784 m^3 of water. Being a cut-off of River Kalindri, Nagoria wetland is potential to store excess water from wetland catchment in order to reduce down the flood peak as well as recharge the ground water. Moreover, the dynamic water storage of this perennial cut-off is recorded 1.2 meter during the study, in which 0.9 meter gets evaporated *(Pal, 2017)*. Out of the remaining portion (0.3 meter) of dynamic wetland water storage, major portion (approximately 60 %) gets infiltrated and acts as ground water reservoir for further usage especially during pre-monsoon.

4.3.3.2 Physico-chemical and bacteriological parameters:

4.3.3.2.1 Physical parameters:

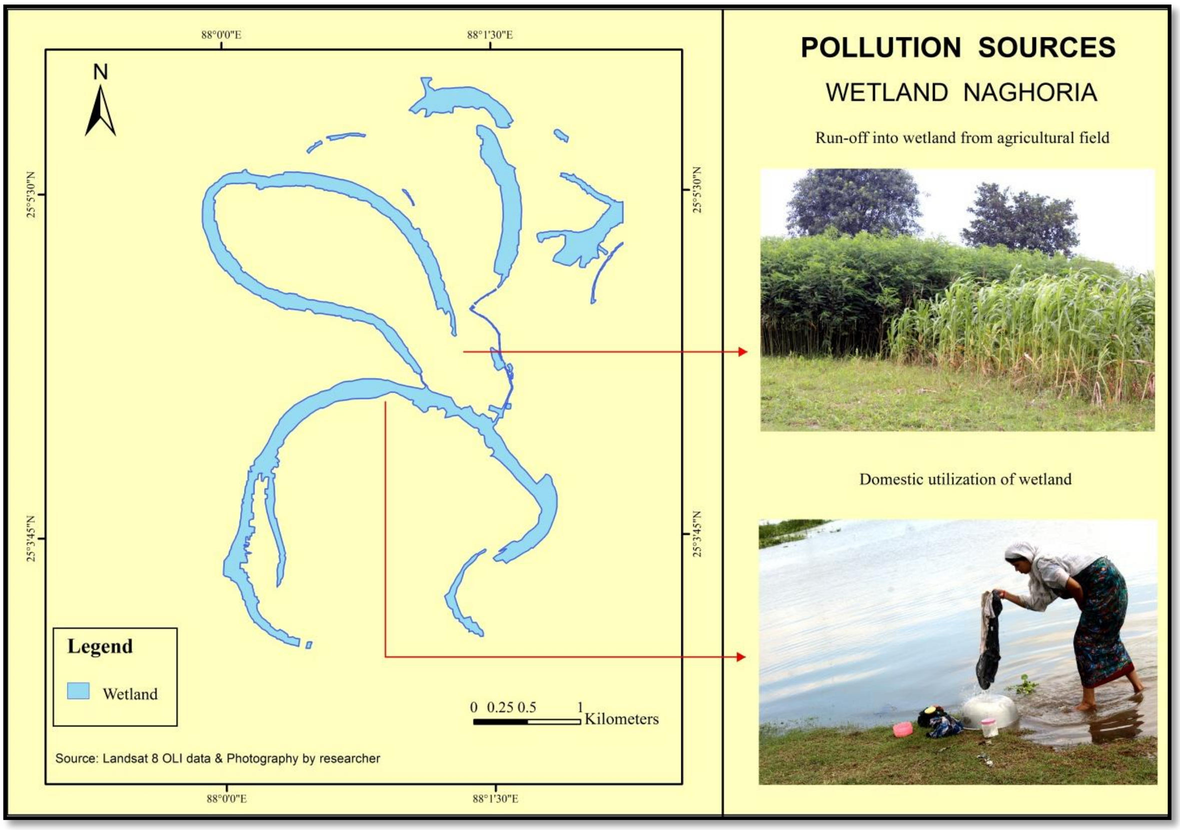
Naghoria wetland records ***water temperature*** between 24.4°C ($\bar{X}$=24.57; σ=0.21) to 32.7°C ($\bar{X}$=32.23; σ=0.40) during the entire study period. Maximum water temperature is recorded in pre-monsoon (32.70°C), followed by monsoon (27.47°C) and minimum during post-monsoon (24.40°C) *(Figure 4.1a)*.

Naghoria wetland records moderate to high ***turbidity*** ranges from 1.72 N.T.U. ($\bar{X}$=2.24; σ=0.46) to 5.75 N.T.U. ($\bar{X}$=5.26; σ=0.43) throughout the study period. The obtained turbidity is high during monsoon (5.75 N.T.U.) and found above the permissible limit in Naghoria wetland, whereas, lowest turbidity is recorded in pre-monsoon (1.7N.T.U.) *(Table 4.4) (Figure 4.1 a and b)*.

4.3.3.2.2 Chemical parameters:

The water ***pH*** ranges from 6.89 ($\bar{X}$=7.06; σ=0.15) to 7.78 ($\bar{X}$=7.65, σ=0.11) throughout the study period. The pre-monsoon (7.78) indicates the water to be slightly alkaline, which substantiates the growth of algae in this wetland. The record depicts a gradual decline of pH during monsoon (7.51) and post-monsoon (6.89) period, which influence the luxuriant growth of emergent macrophytes *(Table 4.4) (Figure 4.2 a) (Map 4.5)*.

The value of ***conductivity*** is recorded to be fluctuating as well as ranges from 77.6 µ.s. ($\bar{X}$=97.27; σ=26.65) to 264 µ.s. ($\bar{X}$=218.7; σ=39.63) throughout the study period. Naghoria wetland shows a marked seasonal change in conductivity, with maximum record during pre-monsoon (264.20µ.s.) which decline successively during monsoon (135.80µ.s.) and post-monsoon (77.60µ.s.) season *(Table 4.4) (Figure 4.2c)*.



Map 4.5: *Agricultural and domestic sewage inflow into Naghoria wetland*

Total dissolved solid displays a significant range of variation across all the seasons from 38.5 ppm ($\bar{X}$=47.3; σ=13.38) to 104.1 ppm. ($\bar{X}$=99.77; σ=4.04). Comparatively higher dissolved solids in Naghoria wetland during pre-monsoon (104.10ppm) is attributed to the presence of high concentration of major cations and anions in wetland water *(Map 4.5)*. Monsoon (76.30ppm) and post-monsoon (38.50ppm) record drastic drop of dissolved solid within wetland *(Table 4.4) (Figure 4.2b).*

Table 4.4 Statistical result on physic-chemical and bacteriological parameters of Naghoria wetland

Parameters	Pre-monsoon			Monsoon			Post-monsoon		
	Mean		Std. Deviation	Mean		Std. Deviation	Mean		Std. Deviation
	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic
Water temperature	32.23	0.23	0.40	27.47	0.27	0.46	24.57	0.12	0.21
pH	7.65	0.065	0.11	7.51	0.00	0.00	7.06	0.09	0.15
Conductivity	218.70	22.88	39.63	135.80	21.73	37.64	97.27	15.39	26.65
Total dissolved solid	99.77	2.33	4.04	76.97	0.67	1.15	47.30	7.73	13.38
Turbidity	2.24	0.27	0.46	5.26	0.25	0.43	3.74	0.12	0.22
Total hardness	187.33	4.67	8.08	117.00	10.50	18.19	71.67	7.96	13.79
Dissolved oxygen	7.03	0.03	0.06	8.37	0.09	0.15	9.20	0.10	0.17
Chloride	0.00	0.00	0.00	0.00	0.00	0.00	24.59	2.33	4.04
Iron	0.05	.007	.012	0.14	0.017	0.029	0.48	0.12	0.21
Fluoride	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arsenic	0.06	0.01	0.01	0.00	0.00	0.00	0.02	0.003	0.004
Total coliform	11.33	0.67	1.15	7.33	0.33	0.58	10.00	1.00	1.74
Fecal coliform	1.33	0.33	0.58	0.00	0.00	0.00	1.33	0.67	1.15

Source: *1. Water sample collected from field study*

2. Water sample tested by P.H.E. Department, under Malda Polytechnic, Govt. of West Bengal.

The ***dissolved oxygen*** in Naghoria wetland records an average concentration, ranging between 7 mg/L ($\bar{X}$=7.03; σ=0.06) to 9.3 mg/L ($\bar{X}$=9.20; σ=0.17). Maximum dissolved oxygen concentration is recorded during post-monsoon (9.30mg/l), whereas relatively lower concentration is recorded in pre-monsoon (7.00mg/L) *(Table 4.4) (Figure 4.2d)*, which may be caused due to the abundance of floating vegetation and pit formation in this cut-off meander.

Total hardness records significant fluctuations ranging between 56 mg/L ($\bar{X}$=71.67; σ=13.79) to 196 mg/L ($\bar{X}$=187.33; σ=8.08) throughout the study period. Its peak value is recorded during pre-monsoon (196mg/L), followed by monsoon (117mg/L) and post-monsoon (56mg/L) season *(Table 4.4) (Figure 4.2e)*. So the hardness status of Naghoria wetland is in the mid-way between hard and soft water and can be termed as normal water and therefore is suitable for the macrophytes and fish cultivation.

In Naghoria wetland ***chloride*** content is recorded very less with a little trace during post-monsoon amounting 26.92 mg/L ($\bar{X}$=24.59, σ=4.04) *(Figure 4.2f).*

Iron and ***arsenic*** components are recorded insignificant throughout the year, ranging from 0.04 mg/L ($\bar{X}$=0.05; σ=0.01) to 0.6 mg/L ($\bar{X}$=0.48; σ=0.21) and 0 to 0.07 mg/L ($\bar{X}$=0.06; σ=0.01) respectively in this water body. ***Fluoride*** content is also below the detectable limit throughout the year. ***Manganese*** and ***nitrates*** are recorded below the detectable limit. The nitrate content in the ground and surface water is normally low, but can reach at high levels due to agricultural run-off and contamination of human and animal waste into this water body *(Map 4.5)*.

4.3.3.2.3 Bacteriological parameters:

The bacteriological analysis of wetland water reveals the profound presence of both the total and fecal coliform round the year in this cut-off. ***Total coliform*** ranges from 7 MPN ($\bar{X}$=7.33; σ=0.58) to 12 MPN ($\bar{X}$=11.33; σ=1.15) per 100 ml water with maximum concentration during pre-monsoon season (12MPN/100ml).

Fecal coliform records only 2 MPN per 100 ml water. The result shows gradual decline in both the coliform counts during the monsoon and post-monsoon seasons *(Table 4.4) (Figure 4.3 a&b)*. The fecal coliform contamination is comparatively less, which would otherwise pose threat to the fishing and other purposes in this wetland ecosystem. The high prevalence of coliform within wetland water suggests a chronic problem and potential health risk especially to those populations, who use this water resource for different purposes.

4.3.4 Chatra wetland

4.3.4.1 Wetland hydrology:

The main support of the drainage of Chatra wetland is surface runoff, along with the consistent supply of municipal sewage flow. This peri-urban wetland is also rain fed and receives substantial amount of water round the year. The extent of water in this wetland fluctuates throughout the entire study time, and records significantly high during monsoon and post- monsoon season. The water level is recorded 2 to 3 meter in several pockets of this wetland, whereas maximum water depth is recorded > 3.0 meter during monsoon, followed by post-monsoon season *(Map 4.6)*. This wetland is particularly valuable in flood regulation as it holds 2.8 meter of excess water during monsoon period as per the field study, which is amounted to volume 9,620,318 m^3 and releases the flood water gradually in a desynchronized manner as well as moderates the peak discharge. The process of water retention and detention act as a very effective tool to regularize the ground water level. In the present study, the dynamic water storage of Chatra wetland is recorded 1.7 meter, including 0.9 meter of water to get evaporated *(Pal, 2017)*. Out of the remaining portion (0.8 meter), approximately 60 % of dynamic wetland water storage gets infiltrated as ground water reservoir and enable high water table by discharging gradually the water during lean period (pre-monsoon season).

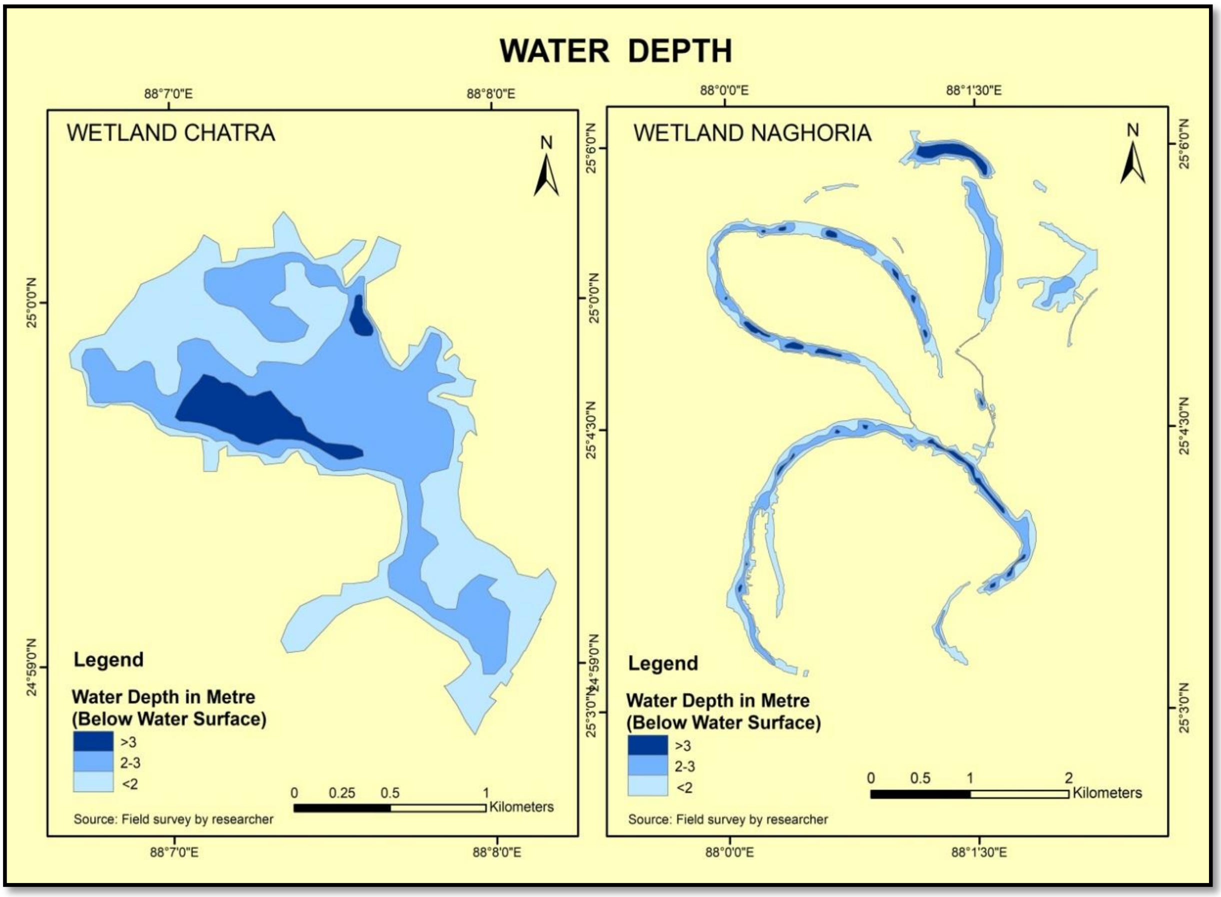
4.3.4.2 Physico-chemical and bacteriological parameters:

4.3.4.2.1 Physical parameters:

In the present study, ***water temperature*** is recorded between 25°C ($\bar{X}$=24.83; σ=0.29) to 32.9°C ($\bar{X}$=32.47; σ=0.45) throughout the study period. Maximum temperature is recorded in pre-monsoon (32.90°C), followed by monsoon (28.83°C) and post-monsoon (24.50°C) *(Table 4.5) (Figure 4.1 a)*. Being shallow water body, Chatra wetland is euphotic throughout and is a region of active photosynthesis process, as it contains a considerable population of the phytoplankton.

Chatra wetland records fluctuating ***turbidity*** ranges from 2.26 N.T.U. (X=3.22; σ=0.94) to 7.67 N.T.U. (X=7.38; σ=0.43) throughout the study. Monsoon (7.67N.T.U.) shows maximum record of turbidity, which exceeds the permissible limit (BIS & APHA). Post-monsoon (4.83N.T.U.) and pre-monsoon (2.26N.T.U.) successively record sharp decline in water turbidity *(Figure 4.1b)*. High turbidity in this peri-urban wetland is caused due to large accumulation of sewage water along with the organic pollutants from the adjacent English

Bazar Municipality *(Map 4.7)*. The increasing trend in turbidity by organic pollutants results into eutrophication.



Map 4.6: *Water depth of wetland Naghoria and Chatra in meter (below water surface)*

4.3.4.2.2 Chemical parameters:

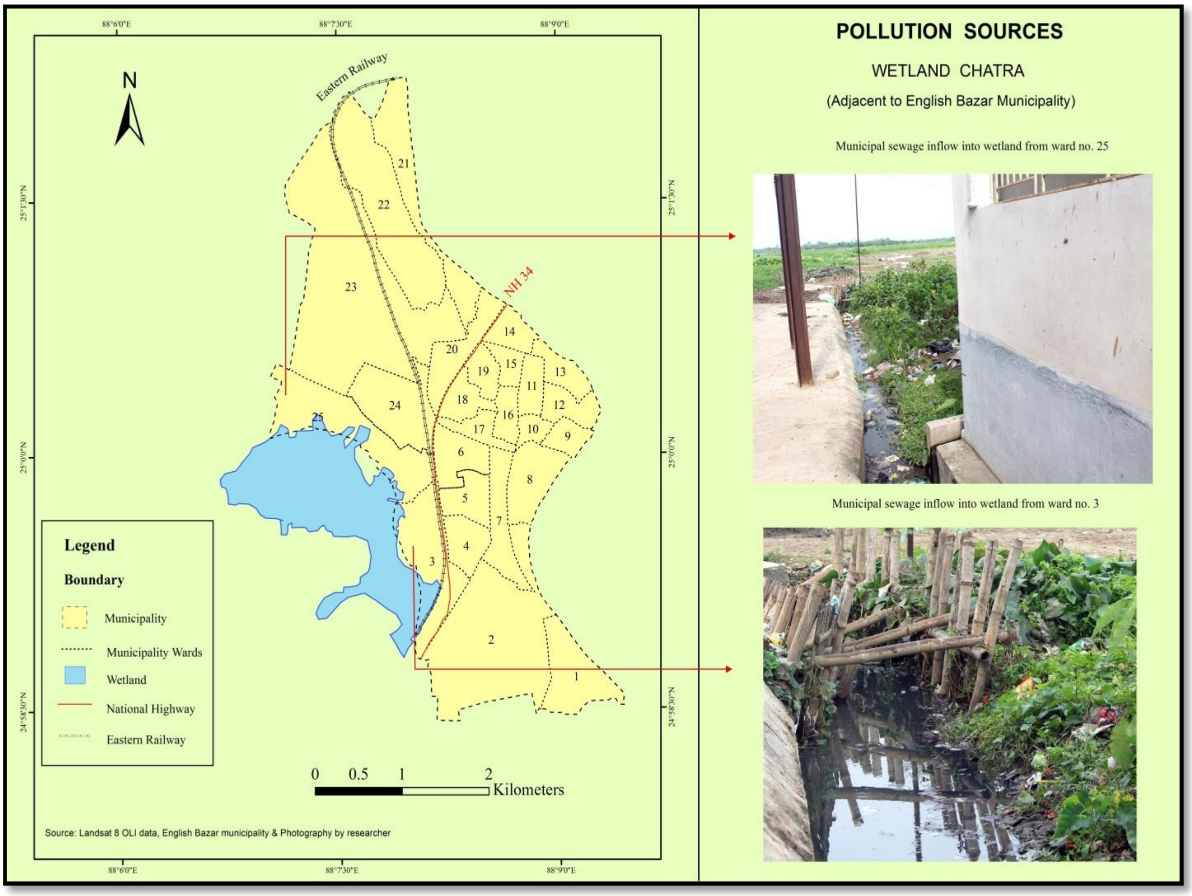
Wetland water ***pH*** ranges from 7.13 ($\bar{X}$=7.17; σ=0.06) to 8.67 ($\bar{X}$=8.24; σ=0.45) throughout the study period. The highest value of pH during pre-monsoon (8.67) reveals that the wetland water is normal to alkaline, associated with the high photosynthetic activity, which eventually substantiates excessive algal growth in wetland water. The recorded pH gradually declines during the monsoon (7.60) and post-monsoon (7.13) *(Table 4.5) (Figure 4.2 a)*, which is attributed to decomposition of carbonaceous materials, entering into the water body from surrounding agricultural field (north-west, west, south-west).

Conductivity in Chatra wetland is recorded highly fluctuating, which ranges between 330 µ.s. ($\bar{X}$=335.33; σ=4.73) to 593 µ.s. ($\bar{X}$=579.33; σ=13.05) *(Table 4.5) (Figure 4.2c)*. Pre-monsoon (593µ.s.) records maximum value of conductivity, which may be caused due to large ionic concentration, pollution status especially from domestic and municipal effluents and sewage and other organic matters from the peripheral localities into this water body. Monsoon (413.67µ.s.) followed by post-monsoon (330µ.s.) record sharp drop of conductivity in this peri-urban wetland *(Map 4.7)*.

Total dissolved solids also records a fluctuating concentration between 169 ppm (X=180.33; σ=14.01) to 298 ppm (X=293.33; σ=4.16) during the entire study period in Chatra wetland. Maximum dissolved solid is recorded during pre-monsoon (298ppm), followed by monsoon (248ppm) and minimum during post-monsoon (169ppm) *(Table 4.5) (Figure 4.2b)*. Primary sources of TDS into receiving wetland are agricultural runoff, domestic sewage, leaching of soil contamination and point source water pollution discharge in the form of municipal sewage from the adjacent municipal wards *(Map 4.7)*. Consequently, high concentration of dissolved solids increases the nutrient status of water body and ultimately results into immense potential of eutrophication. High level of TDS determines disturbances in the ecological balance and suffocation in the aquatic fauna.

The ***dissolved oxygen*** is found within 7.2 mg/L (X=7.50; σ=0.26) to 9.7 mg/L (X=9.63; σ=0.12) throughout the study period, with maximum concentration during post-monsoon (9.70mg/L) *(Table 4.5) (Figure 4.2d)*. The disposal of domestic and municipal sewage as well as other oxygen demanding waste reduces the dissolved oxygen concentration in the receiving peri-urban wetland, which is profoundly observed during pre-monsoon (7.20mg/L) period. Oxygen content of the bottom layer is compared to the surface, which indicates the eutrophic nature of the wetland ecosystem *(Chatrath, 1992)*.

In the present study, ***total hardness*** is recorded between 169 mg/L (X=180; σ=14.18) to 264 mg/L (X=252.67; σ=10.26). The peak value of hardness is recorded during pre-monsoon (264.00mg/L) period, which may be resulted from the sewage outflow from adjacent town into this peri-urban water body *(Table 4.5) (Figure 4.2e)*.



Map 4.7: *Municipal sewage inflow into Chatra wetland from adjacent wards*

Chloride concentration in Chatra wetland is more or less same across all the seasons, which records 53 mg/L (X=54; σ=1.74) to 56.34 mg/L (X=56.34; σ=0) during the entire study period. The relatively high concentration of chloride is recorded during pre-monsoon (56.34mg/L), which may be an index of pollution of animal origin and there is a direct correlation between chloride concentration and pollution levels *(Table 4.5) (Figure 4.2f)*.

The ***iron*** content in the wetland water ranges from 0.07 mg/L (X=0.01; σ=0.08) to 0.39 mg/L (X=0.27; σ=0.12) with maximum record during post-monsoon (0.39mg/L) whereas, minimum during pre-monsoon (0.07mg/L). The ***fluoride*** content is recorded negligible, with a little trace during post-monsoon (0.32 mg/L). ***Nitrate, arsenic, manganese*** contents are considerably low and found below detectable limit across all seasons in Chatra wetland.

Table 4.5 Statistical result on physic-chemical and bacteriological parameters of Chatra wetland

Parameters	Pre-monsoon			Monsoon			Post-monsoon		
	Mean		Std. Deviation	Mean		Std. Deviation	Mean		Std. Deviation
	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic	Statistic	Std. Error	Statistic
Water temperature	32.47	0.26	0.45	28.83	0.17	0.29	24.83	0.17	0.29
pH	8.24	0.26	0.45	7.60	0.18	0.318	7.17	0.03	0.06
Conductivity	579.33	7.54	13.05	413.67	3.22	5.58	335.33	2.73	4.73
Total dissolved solid	293.33	2.40	4.16	248.00	1.53	2.65	180.33	8.09	14.01
Turbidity	3.22	0.54	0.94	7.38	0.25	0.43	5.40	0.29	0.50
Total hardness	252.67	5.93	10.26	202.00	6.00	10.39	180.00	8.19	14.18
Dissolved oxygen	7.50	0.15	0.26	8.93	0.03	0.058	9.63	0.067	0.12
Chloride	56.34	0.00	0.00	54.00	1.00	1.74	56.11	0.00	0.00
Iron	0.08	0.007	0.012	0.17	0.04	0.07	0.27	0.07	0.12
Fluoride	0.00	0.00	0.00	0.04	0.043	0.08	0.32	0.00	0.00
Arsenic	.0027	0.003	0.005	0.00	0.00	0.00	0.00	0.00	0.00
Total coliform	1.00	0.58	1.00	3.33	0.88	1.53	8.67	0.67	1.15
Fecal coliform	0.00	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.73

Source: *1. Water sample collected from field study*

2. Water sample tested by P.H.E. Department, under Malda Polytechnic, Govt. of West Bengal.

4.3.4.2.3. Bacteriological parameters:

In the context of bacteriological analysis, the laboratory test shows that the total and fecal coliform, are less in quantity in comparison with other three wetlands under case study. Average ***total coliform*** count ranges between 0 to 10 MPN (X=8.67; σ=1.15) per 100 ml water with highest record during post-monsoon (10MPN/100ml), whereas minimum during pre-monsoon (2MPN/100ml) period *(Table 4.5) (Figure 4.3a)*.

Fecal coliform is recorded insignificant (3MPN/100ml) throughout the entire water sample collection period *(Table 4.5) (Figure 4.3 b)*.

As per the field observation, Chatra wetland, being peri-urban, receives direct sewage inflow through 9 sewerages under ward no. 3 and 13 sewerages under ward no. 25, connected with several networks of sub-drains along the south-west boundary of adjacent English Bazar municipality. Few number of municipal sewerages from ward no. 23 and 24 along north-west boundary got outfall into this lowland. The water sample test *(Appendix-8)* covering three seasons (pre-monsoon, monsoon and post-monsoon) in consecutive 3 years (2015-18) record most of the water quality parameters to be restricted within permissible range, except water pH, conductivity, dissolved solid and water hardness, as proposed by BIS (2012) and APHA (2017), which is attributed to the filtering effect of Chatra wetland, acting as a *'kidney of landscape'*. The wetland and associated macrophytes (especially the water hyacinth) and microorganisms slow down the surface water flow, as well as allow the suspended particles (sediments and nutrients) to drop down to ground level and maintain the water quality round the year. This peri-urban wetland of Malda district is proved to be potential to treat regular inflow of waste water through several inlets from the adjacent localities.

4.4 Analysis of variance (ANOVA) of wetland water quality parameters:

The physical, chemical and bacteriological parameters of collected water sample from the selected wetlands have been interpreted. The study reveals that the wetlands record an identical trend of selected physico-chemical and bacteriological characteristics of wetland water with a distinct seasonal variation throughout the entire study period, which represent the ecological status of wetlands in Malda district. The variation of different physical, chemical and bacteriological parameters between the wetlands and the seasons has been computed by one way Anova, which is displayed from table 4.6 (a & b) to 4.18 (a & b).

4.4.1. Physical parameters:

4.4.1.1. Water temperature:

In the present study, the physical parameter of water temperature is recorded maximum during pre-monsoon, followed by monsoon and post-monsoon. The maximum water temperature is attributed to intense solar radiation, long day time exposure, high atmospheric temperature and low water level. This work is in accordance with early workers *(Akhtar et al., 2018)* in water bodies of Varanasi; *(Dattatreya et al., 2018)* in South-east coast, India; *(Alam et al., 2015)* in the Beels of Bangladesh.

Table 4.6 (a) Output of Water temperature between wetlands by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	9.036	3	3.012	.276	.842
Within Groups	349.047	32	10.908		
Total	358.082	35			

(I) Wetlands	(J) Wetlands	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Siali	Chakla	.88889	1.55690	.940	-3.3293	5.1071
	Naghoria	.11111	1.55690	1.000	-4.1071	4.3293
	Chatra	-.51111	1.55690	.988	-4.7293	3.7071
Chakla	Siali	-.88889	1.55690	.940	-5.1071	3.3293
	Naghoria	-.77778	1.55690	.959	-4.9960	3.4404
	Chatra	-1.40000	1.55690	.805	-5.6182	2.8182
Naghoria	Siali	-.11111	1.55690	1.000	-4.3293	4.1071
	Chakla	.77778	1.55690	.959	-3.4404	4.9960
	Chatra	-.62222	1.55690	.978	-4.8404	3.5960
Chatra	Siali	.51111	1.55690	.988	-3.7071	4.7293
	Chakla	1.40000	1.55690	.805	-2.8182	5.6182
	Naghoria	.62222	1.55690	.978	-3.5960	4.8404

Statistical analysis shows no significant variation of water temperature between the wetlands ($F=0.28$) where, p value > α value (significance level at 0.05 in two-tailed test) at 95% confidence level. The wetlands, under more or less uniform physiography record an identical trend in water temperature, corresponding with atmospheric temperature. Statistical analysis shows significant ($p<0.05$) variation of water temperature between the seasons ($F=343.73$) where, p value < α value. Table 4.6 (a) & (b) are self-explanatory.

Table 4.6 (b) Output of Water temperatures between seasons by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	341.681	2	170.840	343.729	.000
Within Groups	16.402	33	.497		
Total	358.082	35			

(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre-monsoon	Monsoon	4.00000*	.28781	.000	3.2938	4.7062
	Post-monsoon	7.54167*	.28781	.000	6.8354	8.2479
Monsoon	Pre-monsoon	-4.00000*	.28781	.000	-4.7062	-3.2938
	Post-monsoon	3.54167*	.28781	.000	2.8354	4.2479
Post-monsoon	Pre-monsoon	-7.54167*	.28781	.000	-8.2479	-6.8354
	Monsoon	-3.54167*	.28781	.000	-4.2479	-2.8354

**. The mean difference is significant at the 0.05 level.*

4.4.1.2. Turbidity:

In the present study, high accumulations of sewage water in conjunction with organic load have resulted into high turbidity during monsoon and successively record sharp decline during post-monsoon and pre-monsoon. Low turbidity may be recorded due to trapping of turbidity particles by the underwater hydrophytes in the wetlands *(Vankar et al., 2018)*. This study is in accordance with early workers in the wetlands of Jorhat, Assam *(Lodh et al., 2014)* and Central Gujarat *(Vankar et al., 2018)*.

Table 4.7 (a) Output of Turbidity between wetland by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	30.847	3	10.282	5.396	.004
Within Groups	60.975	32	1.905		
Total	91.821	35			

(I) Wetlands	(J) Wetlands	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Siali	Chakla	-2.07556*	.65072	.016	-3.8386	-.3125
	Naghoria	-.34889	.65072	.950	-2.1119	1.4141
	Chatra	-1.93778*	.65072	.027	-3.7008	-.1747
Chakla	Siali	2.07556*	.65072	.016	.3125	3.8386
	Naghoria	1.72667	.65072	.057	-.0364	3.4897
	Chatra	.13778	.65072	.997	-1.6253	1.9008
Naghoria	Siali	.34889	.65072	.950	-1.4141	2.1119
	Chakla	-1.72667	.65072	.057	-3.4897	.0364
	Chatra	-1.58889	.65072	.089	-3.3519	.1741
Chatra	Siali	1.93778*	.65072	.027	.1747	3.7008
	Chakla	-.13778	.65072	.997	-1.9008	1.6253
	Naghoria	1.58889	.65072	.089	-.1741	3.3519

**. The mean difference is significant at the 0.05 level.*

Statistical analysis shows significant ($p<0.05$) variation in water turbidity between wetlands ($F=5.40$) where, the p value < α value (significance level at 0.05 in two-tailed test) at 95% confidence level. Siali wetland makes significant variation with Chakla and Chatra wetland. It may be caused that, Chatra wetland, being a peri-urban water body, receives large accumulation of sewage water along with the organic pollutants from the adjacent wards under English Bazar municipality. ANOVA also shows significant ($p<0.05$) variation between the surveyed seasons ($F=20.82$) as, the p value < α value *(Table 4.7 (a) & (b))*.

Table 4.7 (b) Output of Turbidity between seasons by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	51.220	2	25.610	20.815	.000
Within Groups	40.601	33	1.230		
Total	91.821	35			

(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Pre-monsoon	Monsoon	-2.92083*	.45283	.000	-4.0320	-1.8097
	Post-monsoon	-1.52417*	.45283	.005	-2.6353	-.4130
Monsoon	Pre-monsoon	2.92083*	.45283	.000	1.8097	4.0320
	Post-monsoon	1.39667*	.45283	.011	.2855	2.5078
Post-monsoon	Pre-monsoon	1.52417*	.45283	.005	.4130	2.6353
	Monsoon	-1.39667*	.45283	.011	-2.5078	-.2855

**. The mean difference is significant at the 0.05 level.*

4.4.2 Chemical parameters:

4.4.2.1 Water pH:

Water pH as a chemical water quality parameter is recorded maximum during pre-monsoon, followed by monsoon and post-monsoon in the wetlands. The pre-monsoon peak may be attributed to active photosynthesis and high decomposition activities. The lower level of pH during monsoon and post-monsoon may be attributed to addition of surface run-off into wetland water and decomposition of organic matter. This study in Malda district is found similar with early observers in the wetlands of Jorhat, Assam *(Abujam et al., 2012)*; in Sagar wetland, Madhya Pradesh *(Choudhary & Ahi, 2015);* in Karnataka *(Majagi, 2014);* in water bodies, U.P. *(Maurya & Singh, 2016)*.

Table 4.8 (a) Output of Water pH between wetland by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	.764	3	.255	2.042	.128
Within Groups	3.992	32	.125		
Total	4.757	35			

(I) Wetlands	(J) Wetlands	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Siali	Chakla	.08111	.16651	.961	-.3700	.5322
	Naghoria	-.04444	.16651	.993	-.4956	.4067
	Chatra	-.30778	.16651	.270	-.7589	.1434
Chakla	Siali	-.08111	.16651	.961	-.5322	.3700
	Naghoria	-.12556	.16651	.874	-.5767	.3256
	Chatra	-.38889	.16651	.111	-.8400	.0622
Naghoria	Siali	.04444	.16651	.993	-.4067	.4956
	Chakla	.12556	.16651	.874	-.3256	.5767
	Chatra	-.26333	.16651	.403	-.7145	.1878
Chatra	Siali	.30778	.16651	.270	-.1434	.7589
	Chakla	.38889	.16651	.111	-.0622	.8400
	Naghoria	.26333	.16651	.403	-.1878	.7145

In the present study, the statistical analysis shows no significant ($p>0.05$) variation of water pH between the wetlands ($F=2.04$) where, p value > α (significance level at 0.05 in two-tailed test) at 95% confidence level. All the selected wetlands maintain an identical record of pH. Conversely, analysis of variance shows significant ($p<0.05$) variation of water pH between the seasons ($F=19.78$) where, the p value < α value. *(Table 4.8 (a) & (b)).*

Table 4.8 (b) Output of Water pH between seasons by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	2.593	2	1.297	19.783	.000
Within Groups	2.163	33	.066		
Total	4.757	35			

(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Pre-monsoon	Monsoon	.27833*	.10452	.031	.0219	.5348
	Post-monsoon	.65500*	.10452	.000	.3985	.9115
Monsoon	Pre-monsoon	-.27833*	.10452	.031	-.5348	-.0219
	Post-monsoon	.37667*	.10452	.003	.1202	.6331
Post-monsoon	Pre-monsoon	-.65500*	.10452	.000	-.9115	-.3985
	Monsoon	-.37667*	.10452	.003	-.6331	-.1202

**. The mean difference is significant at the 0.05 level.*

4.4.2.2 Conductivity:

In the present study, the conductivity is recorded highest during pre-monsoon and relatively lower during post-monsoon seasons in the case studies. High conductivity during pre-monsoon may be caused due to large ionic concentration by addition of domestic sewage into wetlands. Highest concentration of conductivity may also be associated with decreasing fresh water flow and increasing evaporation rate by intense sunlight. Conversely, the lower concentration of conductivity may be caused due to influx of monsoon water into wetlands as well as flushing out of dissolved ion. This observation reveals similarity by the early workers in Kuttanad wetland ecosystem, Kerala *(Sylas, 2010)*; in the urban lakes, Bangalore *(Ramachandra et al., 2014)*; in Rudrasagar wetland, Tripura *(Abir, 2014);* in Surila taal, U.P. *(Maurya & Singh, 2016).*

Table 4.9 (a) Output of Conductivity between wetland by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	646379.499	3	215459.833	54.120	.000
Within Groups	127396.953	32	3981.155		
Total	773776.452	35			

(I) Wetlands	(J) Wetlands	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Siali	Chakla	13.34444	29.74392	.969	-67.2426	93.9315
	Naghoria	-17.65556	29.74392	.933	-98.2426	62.9315
	Chatra	-309.84444*	29.74392	.000	-390.4315	-229.2574
Chakla	Siali	-13.34444	29.74392	.969	-93.9315	67.2426
	Naghoria	-31.00000	29.74392	.726	-111.5870	49.5870
	Chatra	-323.18889*	29.74392	.000	-403.7759	-242.6018
Naghoria	Siali	17.65556	29.74392	.933	-62.9315	98.2426
	Chakla	31.00000	29.74392	.726	-49.5870	111.5870
	Chatra	-292.18889*	29.74392	.000	-372.7759	-211.6018
Chatra	Siali	309.84444*	29.74392	.000	229.2574	390.4315
	Chakla	323.18889*	29.74392	.000	242.6018	403.7759
	Naghoria	292.18889*	29.74392	.000	211.6018	372.7759

**. The mean difference is significant at the 0.05 level.*

ANOVA shows significant ($p<0.05$) variation in water conductivity between the wetlands ($F=54.12$), where the p value < α value (significance level at 0.05 in two-tailed test) at 95% confidence level. Chatra wetland records significant variation with Siali, Chakla and Naghoria wetland. This may be caused that, Chatra wetland receives highly toxic municipal sewage along with agricultural and domestic effluents comparing with other three wetlands, which only receive agricultural and organic waste and it creates a variation between the wetlands. On the contrary, no significant ($p>0.05$) variation is found between the seasons ($F=1.60$) where, the p value > α value. This indicates almost all the seasons identically record the concentration of conductivity within wetlands. Table 4.9 (a) & (b) are self-explanatory.

Table 4.9 (b) Output of Conductivity between seasons by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	68369.817	2	34184.909	1.599	.217
Within Groups	705406.635	33	21375.959		
Total	773776.452	35			

(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Pre-monsoon	Monsoon	71.45000	59.68802	.463	-75.0121	217.9121
	Post-monsoon	104.40833	59.68802	.202	-42.0538	250.8705
Monsoon	Pre-monsoon	-71.45000	59.68802	.463	-217.9121	75.0121
	Post-monsoon	32.95833	59.68802	.846	-113.5038	179.4205
Post-monsoon	Pre-monsoon	-104.40833	59.68802	.202	-250.8705	42.0538
	Monsoon	-32.95833	59.68802	.846	-179.4205	113.5038

4.4.2.3 Total dissolved solid:

In the present study, the total dissolved solid in wetland water records maximum during pre-monsoon due to additional organic and inorganic waste into wetlands from the peripheral locality. Water dissolved solid substantially declines during monsoon and post-monsoon in the wetlands due to influx of monsoon water. The present work is in accordance with the early workers in Bibi Lake, Ahmedabad *(Qureshimatva & Solanki, 2015)*; in Gujarat *(Sonal et al., 2010);* in Chandlodia Lake, Ahmedabad, Gujarat *(Qureshimatva et al., 2015);* in the fresh water pond of Central India *(Yadav et al., 2013)*.

Table 4.10 (a) Output of Dissolved solid between wetland by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	204222.601	3	68074.200	84.890	.000
Within Groups	25661.109	32	801.910		
Total	229883.710	35			

(I) Wetlands	(J) Wetlands	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Siali	Chakla	9.74444	13.34924	.884	-26.4235	45.9124
	Naghoria	-6.45556	13.34924	.962	-42.6235	29.7124
	Chatra	-172.33333*	13.34924	.000	-208.5012	-136.1654

Chakla	Siali	-9.74444	13.34924	.884	-45.9124	26.4235
	Naghoria	-16.20000	13.34924	.623	-52.3679	19.9679
	Chatra	-182.07778*	13.34924	.000	-218.2457	-145.9099
Naghoria	Siali	6.45556	13.34924	.962	-29.7124	42.6235
	Chakla	16.20000	13.34924	.623	-19.9679	52.3679
	Chatra	-165.87778*	13.34924	.000	-202.0457	-129.7099
Chatra	Siali	172.33333*	13.34924	.000	136.1654	208.5012
	Chakla	182.07778*	13.34924	.000	145.9099	218.2457
	Naghoria	165.87778*	13.34924	.000	129.7099	202.0457

**. The mean difference is significant at the 0.05 level.*

Statistical analysis shows significant ($p<0.05$) variation in water dissolved solid between the wetlands ($F=84.89$), where the p value < α (significance level at 0.05 in two-tailed) at 95% confidence level. Between the wetlands, Chatra wetland with Siali, Chakla and Naghoria wetland record significant variation, which may be caused by the following lines: The primary sources of dissolved solid into receiving wetlands of Siali, Chakla and Naghoria are agricultural runoff and domestic sewage. But the peri-urban wetland of Chatra regularly receives the point source discharge in the form of municipal sewage from the adjacent wards, which has made a substantial variation with other three water bodies under case study. No significant variation ($p>0.05$) in the dissolved solid is found between the seasons ($F=1.16$) where, the p value > α value. This result has indicated an identical record of tds throughout the seasons. Table 4.10 (a) & (b) are self-explanatory.

Table 4.10 (b) Output of Dissolved solid between seasons by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	15148.402	2	7574.201	1.164	.325
Within Groups	214735.308	33	6507.131		
Total	229883.710	35			

(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Pre-monsoon	Monsoon	22.25833	32.93208	.779	-58.5502	103.0669
	Post-monsoon	50.14167	32.93208	.294	-30.6669	130.9502
Monsoon	Pre-monsoon	-22.25833	32.93208	.779	-103.0669	58.5502
	Post-monsoon	27.88333	32.93208	.677	-52.9252	108.6919
Post-monsoon	Pre-monsoon	-50.14167	32.93208	.294	-130.9502	30.6669
	Monsoon	-27.88333	32.93208	.677	-108.6919	52.9252

4.4.2.4 Total hardness:

In the present study, total hardness in wetland water is recorded maximum during pre-monsoon due to domestic and municipal sewage inflow, when the water level is low whereas, minimum concentration is recorded during monsoon and post-monsoon due to additional influx of run-off into wetlands. This work is supported by several workers in inland wetlands of Gujarat *(Sonal et al., 2010)*; in the wetlands of Karnataka *(Majagi, 2014)*; in the fresh water lake of central India *(Yadav et al., 2013)*; beels of Bangladesh *(Alam et al., 2015)*; in Chandlodia Lake of Gujarat *(Verma et al., 2012);* in water bodies of Madhya Pradesh *(Choudhary & Ahi, 2015).*

Table 4.11 (a) Output of Total hardness between wetland by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	85433.222	3	28477.741	24.919	.000
Within Groups	36569.778	32	1142.806		
Total	122003.000	35			

(I) Wetlands	(J) Wetlands	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Siali	Chakla	53.556*	15.936	.010	10.38	96.73
	Naghoria	4.000	15.936	.994	-39.18	47.18
	Chatra	-82.222*	15.936	.000	-125.40	-39.05
Chakla	Siali	-53.556*	15.936	.010	-96.73	-10.38
	Naghoria	-49.556*	15.936	.019	-92.73	-6.38
	Chatra	-135.778*	15.936	.000	-178.95	-92.60
Naghoria	Siali	-4.000	15.936	.994	-47.18	39.18
	Chakla	49.556*	15.936	.019	6.38	92.73
	Chatra	-86.222*	15.936	.000	-129.40	-43.05
Chatra	Siali	82.222*	15.936	.000	39.05	125.40
	Chakla	135.778*	15.936	.000	92.60	178.95
	Naghoria	86.222*	15.936	.000	43.05	129.40

**. The mean difference is significant at the 0.05 level.*

Statistical analysis shows significant ($p<0.05$) variation in water hardness between the wetlands ($F=24.92$) where, the p value < α value (significance level at 0.05 in two-tailed test) at 95% confidence level. Between the case studies, Chatra wetland with Siali, Naghoria and Chakla wetland; and Chakla wetland with Siali and Naghoria wetland record significant variations. The regular addition as well as accumulation of sewage from the resident localities and municipalities with presence of high content of calcium and magnesium makes Chatra wetland significantly variable with other water bodies. ANOVA shows marked and significant ($p<0.05$) variation between the seasons ($F=4.75$) of pre-monsoon with post-monsoon where, the p value < α value. *(Table 4.11 (a) & (b))*.

Table 4.11 (b) Output of Total hardness between seasons by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	27273.167	2	13636.583	4.750	.015
Within Groups	94729.833	33	2870.601		
Total	122003.000	35			

(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Pre-monsoon	Monsoon	40.583	21.873	.168	-13.09	94.26
	Post-monsoon	66.917*	21.873	.012	13.24	120.59
Monsoon	Pre-monsoon	-40.583	21.873	.168	-94.26	13.09
	Post-monsoon	26.333	21.873	.459	-27.34	80.01
Post-monsoon	Pre-monsoon	-66.917*	21.873	.012	-120.59	-13.24
	Monsoon	-26.333	21.873	.459	-80.01	27.34

**. The mean difference is significant at the 0.05 level.*

4.4.2.5 Dissolved oxygen:

In the present study, the wetlands record highest concentration of dissolved oxygen during post-monsoon, due to increased solubility of oxygen content because of low atmospheric as well as water temperature *(Maurya & Singh, 2016)*. Lowest concentration of do is observed in pre-monsoon because of increasing water temperature corresponding with atmospheric temperature and high microbial activity, heavy organic load in the form of oxygen demanding waste. This work is in accordance with early workers in East Kolkata Wetland *(Roy et al., 2016)*; in Surila taal, Uttar Pradesh *(Maurya & Singh, 2016)*; in Satajan wetland, Assam *(Hazarika, 2013)*; in wetlands of Mid-westernghat region *(Pramod et al., 2011)*.

Statistical analysis shows significant ($p<0.05$) variation of dissolved oxygen between the wetlands ($F=28.50$) where, the p value < α value (significance level at 0.05 in two tailed test) at 95% confidence level. Significant ($p<0.05$) variation of dissolved oxygen is recorded between Siali and Chakla wetland with Chatra and Naghoria wetland. As the high concentration of do is good for aquatic health of an ecosystem, it is quite unnatural that the wetlands, regularly receive domestic and municipal sewage, record high concentration of do rather than those water bodies receive only agricultural and domestic discharge. But the study consistently records this trend consecutively for three years. Therefore, further research and investigation can be done. However, significant ($p<0.05$) variation is also recorded between the seasons ($F=5.58$) of pre-monsoon and post-monsoon *(Table no. 4.12 (a) & (b))*.

Table 4.12 (a) Output of Dissolved oxygen between wetland by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	83.894	3	27.965	28.501	.000
Within Groups	31.398	32	.981		
Total	115.292	35			

(I) Wetlands	(J) Wetlands	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Siali	Chakla	-.04444	.46695	1.000	-1.3096	1.2207
	Naghoria	-2.81111*	.46695	.000	-4.0762	-1.5460
	Chatra	-3.30000*	.46695	.000	-4.5651	-2.0349
Chakla	Siali	.04444	.46695	1.000	-1.2207	1.3096
	Naghoria	-2.76667*	.46695	.000	-4.0318	-1.5015
	Chatra	-3.25556*	.46695	.000	-4.5207	-1.9904
Naghoria	Siali	2.81111*	.46695	.000	1.5460	4.0762
	Chakla	2.76667*	.46695	.000	1.5015	4.0318
	Chatra	-.48889	.46695	.723	-1.7540	.7762
Chatra	Siali	3.30000*	.46695	.000	2.0349	4.5651
	Chakla	3.25556*	.46695	.000	1.9904	4.5207
	Naghoria	.48889	.46695	.723	-.7762	1.7540

**. The mean difference is significant at the 0.05 level.*

Table 4.12 (b) Output of Dissolved oxygen between seasons by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	29.127	2	14.564	5.578	.008
Within Groups	86.165	33	2.611		
Total	115.292	35			

(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre-monsoon	Monsoon	-1.29167	.65968	.139	-2.9104	.3271
	Post-monsoon	-2.19167*	.65968	.006	-3.8104	-.5729
Monsoon	Pre-monsoon	1.29167	.65968	.139	-.3271	2.9104
	Post-monsoon	-.90000	.65968	.371	-2.5187	.7187
Post-monsoon	Pre-monsoon	2.19167*	.65968	.006	.5729	3.8104
	Monsoon	.90000	.65968	.371	-.7187	2.5187

**. The mean difference is significant at the 0.05 level.*

4.4.2.6 Iron:

In the present study, iron content record maximum concentration during post-monsoon, followed by pre-monsoon and monsoon. This result is found similar by early workers in the wetlands of westernghat regions *(Pramod et al., 2011)*.

Table 4.13 (a) Output of Iron content between wetland by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	1.820	3	.607	12.783	.000
Within Groups	1.519	32	.047		
Total	3.338	35			

(I) Wetlands	(J) Wetlands	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Siali	Chakla	-.35111*	.10269	.009	-.6293	-.0729
	Naghoria	.17333	.10269	.346	-.1049	.4516
	Chatra	.22222	.10269	.155	-.0560	.5005
Chakla	Siali	.35111*	.10269	.009	.0729	.6293
	Naghoria	.52444*	.10269	.000	.2462	.8027
	Chatra	.57333*	.10269	.000	.2951	.8516
Naghoria	Siali	-.17333	.10269	.346	-.4516	.1049
	Chakla	-.52444*	.10269	.000	-.8027	-.2462
	Chatra	.04889	.10269	.964	-.2293	.3271
Chatra	Siali	-.22222	.10269	.155	-.5005	.0560
	Chakla	-.57333*	.10269	.000	-.8516	-.2951
	Naghoria	-.04889	.10269	.964	-.3271	.2293

**. The mean difference is significant at the 0.05 level.*

Statistical analysis shows significant ($p<0.05$) variation of iron content in water between the wetlands ($F=12.78$) where, the p value < α (significance level at 0.05 in two-tailed test) at 95% confidence level. Iron content variation may be caused due to solid waste disposal without treatment into wetlands especially from those, adjacent to municipal boundary. ANOVA shows significant variation between the seasons ($F=4.92$) of post-monsoon with pre-monsoon and monsoon. Table 4.13 (a) & (b) are self-explanatory.

Table 4.13 (b) Output of Iron content between seasons by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	.767	2	.384	4.924	.013
Within Groups	2.571	33	.078		
Total	3.338	35			

(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Pre-monsoon	Monsoon	-.05000	.11395	.900	-.3296	.2296
	Post-monsoon	-.33167*	.11395	.017	-.6113	-.0520
Monsoon	Pre-monsoon	.05000	.11395	.900	-.2296	.3296
	Post-monsoon	-.28167*	.11395	.048	-.5613	-.0020
Post-monsoon	Pre-monsoon	.33167*	.11395	.017	.0520	.6113
	Monsoon	.28167*	.11395	.048	.0020	.5613

**. The mean difference is significant at the 0.05 level.*

4.4.2.7 Chloride:

In the present study, chloride content is recorded highest during post-monsoon and is maintained up to pre-monsoon. The high level of chloride in water may be caused due to high accumulation of organic load through run-off inflow during monsoon. Relatively low level of chloride content in wetland is attributed to maximum evaporation of water during pre-monsoon. This study is in conformity with early workers in Orai pond, U.P. *(Yadav et al., 2013)*; in Pune, Maharashtra *(Yadav & Yadav, 2017)*; in Sagar Lake, M.P. *(Choudhary & Ahi, 2015)*; in Central Gujarat *(Vankar et al., 2018)*.

Table 4.14 (a) Output of Chloride content between wetland by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	22154.886	3	7384.962	146.898	.000
Within Groups	1608.726	32	50.273		
Total	23763.611	35			

(I) Wetlands	(J) Wetlands	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Siali	Chakla	41.52000*	3.34241	.000	32.4642	50.5758
	Naghoria	66.35000*	3.34241	.000	57.2942	75.4058
	Chatra	19.06222*	3.34241	.000	10.0064	28.1180
Chakla	Siali	-41.52000*	3.34241	.000	-50.5758	-32.4642
	Naghoria	24.83000*	3.34241	.000	15.7742	33.8858
	Chatra	-22.45778*	3.34241	.000	-31.5136	-13.4020
Naghoria	Siali	-66.35000*	3.34241	.000	-75.4058	-57.2942
	Chakla	-24.83000*	3.34241	.000	-33.8858	-15.7742
	Chatra	-47.28778*	3.34241	.000	-56.3436	-38.2320
Chatra	Siali	-19.06222*	3.34241	.000	-28.1180	-10.0064
	Chakla	22.45778*	3.34241	.000	13.4020	31.5136
	Naghoria	47.28778*	3.34241	.000	38.2320	56.3436

**. The mean difference is significant at the 0.05 level.*

Statistical analysis shows significant ($p<0.05$) variation in chloride content between the wetlands ($F=146.90$) where, the p value < α value (significance level at 0.05 in two-tailed test) at 95% confidence level. The variations between wetlands are attributed to natural contaminants and pollutants by frequent run-off into the wetlands *(Parashar et al., 2008)*. No significant ($p>0.05$) variation is recorded between the seasons ($F=0.57$), where the p value > α value *(Table 4.14(a) & (b))*.

Table 4.14(b) Output of Chloride content between seasons by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	787.231	2	393.616	.565	.574
Within Groups	22976.380	33	696.254		
Total	23763.611	35			

(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Pre-monsoon	Monsoon	-.17250	10.77229	1.000	-26.6055	26.2605
	Post-monsoon	-10.00500	10.77229	.626	-36.4380	16.4280
Monsoon	Pre-monsoon	.17250	10.77229	1.000	-26.2605	26.6055
	Post-monsoon	-9.83250	10.77229	.636	-36.2655	16.6005
Post-monsoon	Pre-monsoon	10.00500	10.77229	.626	-16.4280	36.4380
	Monsoon	9.83250	10.77229	.636	-16.6005	36.2655

4.4.2.8 Fluoride:

In the present study, fluoride content records very negligible throughout the study period. Statistical analysis shows significant ($p<0.05$) variation of fluoride content between the wetlands ($F=14.07$) where, the p value < α value (significance level at 0.05 in two-tailed test) at 95% confidence level. The wetlands, located adjacent to Malda town, record fluoride content below detectable limit. No significant variation of fluoride concentration is recorded between the seasons ($F=2.32$) where, the p value > α value. Table 4.15 (a) & (b) are self-explanatory.

Table 4.15 (a) Output of Fluoride content between wetland by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value.
Between Groups	.294	3	.098	14.071	.000
Within Groups	.223	32	.007		
Total	.516	35			

(I) Wetlands	(J) Wetlands	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Siali	Chakla	.03889	.03932	.757	-.0676	.1454
	Naghoria	.23667*	.03932	.000	.1301	.3432
	Chatra	.11556*	.03932	.029	.0090	.2221

Chakla	Siali	-.03889	.03932	.757	-.1454	.0676
	Naghoria	.19778*	.03932	.000	.0912	.3043
	Chatra	.07667	.03932	.228	-.0299	.1832
Naghoria	Siali	-.23667*	.03932	.000	-.3432	-.1301
	Chakla	-.19778*	.03932	.000	-.3043	-.0912
	Chatra	-.12111*	.03932	.021	-.2276	-.0146
Chatra	Siali	-.11556*	.03932	.029	-.2221	-.0090
	Chakla	-.07667	.03932	.228	-.1832	.0299
	Naghoria	.12111*	.03932	.021	.0146	.2276

**. The mean difference is significant at the 0.05 level.*

Table 4.15 (b) Output of Fluoride content between seasons by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	.064	2	.032	2.321	.114
Within Groups	.453	33	.014		
Total	.516	35			

(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Pre-monsoon	Monsoon	-.01750	.04782	.929	-.1348	.0998
	Post-monsoon	-.09667	.04782	.123	-.2140	.0207
Monsoon	Pre-monsoon	.01750	.04782	.929	-.0998	.1348
	Post-monsoon	-.07917	.04782	.237	-.1965	.0382
Post-monsoon	Pre-monsoon	.09667	.04782	.123	-.0207	.2140
	Monsoon	.07917	.04782	.237	-.0382	.1965

4.4.2.9 Arsenic:

Arsenic content is recorded negligible in all the case studies with small presence during pre-monsoon throughout the entire study period. This work is in accordance with early workers *(Chakraborty et al., 2007)* in the aquifers of English Bazar block, Malda district. Statistical analysis shows significant ($p<0.05$) variation of arsenic content between the wetlands ($F=5.22$) where, the p value < α value (significance level at 0.05 in two-tailed test) at 95% confidence level. The peri-urban wetland, located adjacent to municipal area, record arsenic content below detectable limit throughout the study period, which makes significant variation with other wetlands. Analysis of variance shows significant variation between the seasons ($F=4.62$), especially between pre-monsoon and monsoon *(Table 4.16 (a) & (b))*.

Table 4.16 (a) Output of Arsenic content between wetland by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	.003	3	.001	5.215	.005
Within Groups	.007	32	.000		
Total	.010	35			

(I) Wetlands	(J) Wetlands	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Siali	Chakla	.004333	.006952	.924	-.01450	.02317
	Naghoria	-.017556	.006952	.075	-.03639	.00128
	Chatra	.007667	.006952	.690	-.01117	.02650
Chakla	Siali	-.004333	.006952	.924	-.02317	.01450
	Naghoria	-.021889*	.006952	.018	-.04072	-.00305
	Chatra	.003333	.006952	.963	-.01550	.02217
Naghoria	Siali	.017556	.006952	.075	-.00128	.03639
	Chakla	.021889*	.006952	.018	.00305	.04072
	Chatra	.025222*	.006952	.005	.00639	.04406
Chatra	Siali	-.007667	.006952	.690	-.02650	.01117
	Chakla	-.003333	.006952	.963	-.02217	.01550
	Naghoria	-.025222*	.006952	.005	-.04406	-.00639

**. The mean difference is significant at the 0.05 level.*

Table 4.16 (b) Output of Arsenic content between seasons by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	.002	2	.001	4.618	.017
Within Groups	.008	33	.000		
Total	.010	35			

(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Pre-monsoon	Monsoon	.019417*	.006394	.013	.00373	.03511
	Post-monsoon	.009000	.006394	.349	-.00669	.02469
Monsoon	Pre-monsoon	-.019417*	.006394	.013	-.03511	-.00373
	Post-monsoon	-.010417	.006394	.248	-.02611	.00527
Post-monsoon	Pre-monsoon	-.009000	.006394	.349	-.02469	.00669
	Monsoon	.010417	.006394	.248	-.00527	.02611

**. The mean difference is significant at the 0.05 level.*

4.4.3 Bacteriological parameters:

4.4.3.1 Total coliform:

The total and fecal coliform indicates the bacterial contamination of wetland water in Malda district. In the case studies, maximum total coliform count is recorded during post-monsoon period and is maintained up to pre-monsoon. This result is in accordance with early workers in Kerala *(Jalal & Sanalkumar, 2012)*. The land run-off, full of chemical fertilizers and pesticides from peripheral agricultural field during monsoon and regular influx of domestic sewage throughout all the season are found responsible for relatively high coliform count.

Table 4.17 (a) Output of Total coliform count between wetland by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	144.972	3	48.324	2.099	.120
Within Groups	736.667	32	23.021		
Total	881.639	35			

(I) Wetlands	(J) Wetlands	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Siali	Chakla	-.667	2.262	.991	-6.79	5.46
	Naghoria	-1.444	2.262	.919	-7.57	4.68
	Chatra	3.778	2.262	.356	-2.35	9.91
Chakla	Siali	.667	2.262	.991	-5.46	6.79
	Naghoria	-.778	2.262	.986	-6.91	5.35
	Chatra	4.444	2.262	.222	-1.68	10.57
Naghoria	Siali	1.444	2.262	.919	-4.68	7.57
	Chakla	.778	2.262	.986	-5.35	6.91
	Chatra	5.222	2.262	.117	-.91	11.35
Chatra	Siali	-3.778	2.262	.356	-9.91	2.35
	Chakla	-4.444	2.262	.222	-10.57	1.68
	Naghoria	-5.222	2.262	.117	-11.35	.91

Statistical analysis shows no significant variation of total coliform count between the wetlands (F=2.10) where, the p value > α value (significance level at 0.05 in two-tailed test) at 95% confidence level. The wetlands, which regularly encounter the wetland-catchment interactions through intensive anthropogenic activities, should record a vulnerable coliform count especially after the monsoon run-off. But, in present study, coliform count record is not that much vulnerable as expected. It is a positive indication especially from the ecological perspective of wetland ecosystem and at the same time it reveals an enormous scope for further study. The statistical analysis shows significant ($p<0.05$) variation in coliform count between the seasons (F=14.86), where the p value < α value (significance level at 0.05 in two-tailed test) at 95% confidence level. Table 4.17 (a) & (b) are self-explanatory.

Table 4.17 (b) Output of Total coliform counts between seasons by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	417.722	2	208.861	14.857	.000
Within Groups	463.917	33	14.058		
Total	881.639	35			

(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre-monsoon	Monsoon	-2.250	1.531	.318	-6.01	1.51
	Post-monsoon	-8.083*	1.531	.000	-11.84	-4.33
Monsoon	Pre-monsoon	2.250	1.531	.318	-1.51	6.01
	Post-monsoon	-5.833*	1.531	.002	-9.59	-2.08
Post-monsoon	Pre-monsoon	8.083*	1.531	.000	4.33	11.84
	Monsoon	5.833*	1.531	.002	2.08	9.59

**. The mean difference is significant at the 0.05 level.*

4.4.3.2 Fecal coliform:

Similar with total coliform, the fecal coliform shows maximum count during post-monsoon in the wetland sites. Similar observation is made by early worker in Kuttanad wetland, Kerala *(Sylas, 2010)*. Analysis of variance shows significant ($p<0.05$) variation in fecal coliform count between the wetlands ($F=4.39$), where the p value < α value (significance level at 0.05 in two-tailed test) at 95% confidence level. Chakla wetland records significant variation in fecal coliform count with other case studies, which is attributed to maximum open defecation problem around Chakla wetland as well as polluted water inflow from peripheral settlers. ANOVA shows significant ($p<0.05$) variation in fecal coliform count also between the seasons ($F=6.31$) which, may be caused by increased land run-off during monsoon and post-monsoon, and eventually results into high growth of bacterial population *(Sylas, 2010)*. Furthermore, domestic wastes from the surrounding villages and nearby municipal wards are also responsible for the bacterial contamination in these wetlands *(Irrinki & Irrinki, 2006-07)*. Table 4.18 (a) & (b) are self-explanatory.

Table 4.18 (a) Output of Fecal coliform count between wetland by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	59.222	3	19.741	4.394	.011
Within Groups	143.778	32	4.493		
Total	203.000	35			

(I) Wetlands	(J) Wetlands	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Siali	Chakla	-2.556	.999	.070	-5.26	.15
	Naghoria	.222	.999	.996	-2.49	2.93
	Chatra	.778	.999	.864	-1.93	3.49
Chakla	Siali	2.556	.999	.070	-.15	5.26
	Naghoria	2.778*	.999	.043	.07	5.49
	Chatra	3.333*	.999	.011	.63	6.04
Naghoria	Siali	-.222	.999	.996	-2.93	2.49
	Chakla	-2.778*	.999	.043	-5.49	-.07
	Chatra	.556	.999	.944	-2.15	3.26
Chatra	Siali	-.778	.999	.864	-3.49	1.93
	Chakla	-3.333*	.999	.011	-6.04	-.63
	Naghoria	-.556	.999	.944	-3.26	2.15

**. The mean difference is significant at the 0.05 level.*

Table 4.18 (b) Output of Fecal coliform counts between wetland by Multiple Comparisons Test

	Sum of Squares	df	Mean Square	F	P value
Between Groups	56.167	2	28.083	6.312	.005
Within Groups	146.833	33	4.449		
Total	203.000	35			

(I) Seasons	(J) Seasons	Mean Difference (I-J)	Std. Error	P value	95% Confidence Interval Lower Bound	Upper Bound
Pre-monsoon	Monsoon	-.417	.861	.879	-2.53	1.70
	Post-monsoon	-2.833*	.861	.007	-4.95	-.72
Monsoon	Pre-monsoon	.417	.861	.879	-1.70	2.53
	Post-monsoon	-2.417*	.861	.022	-4.53	-.30
Post-monsoon	Pre-monsoon	2.833*	.861	.007	.72	4.95
	Monsoon	2.417*	.861	.022	.30	4.53

**. The mean difference is significant at the 0.05 level.*

4.5 Correlation matrix of wetland water quality parameters:

The observation on the wetland water quality parameters are analyzed with Pearson's product moment correlation coefficient in order to know the relationship between different parameters and their impact on other water quality parameters, which is displayed in Table 4.19.

In the present study, all the wetlands under case study record similar trend where the ***water temperature*** shows highly significant ($p<0.01$) positive correlation with water pH ($r=0.766$) *(Figure 4.4a)*, total hardness ($r=0.593$) *(Figure 4.4b)* at 0.01 significance level and significant ($p<0.05$) positive correlation with conductivity ($r=0.407$) *(Figure 4.6a)* and dissolved solid ($r=0.371$) *(Figure 4.6b)* at 0.05 significance level. Water temperature shows highly significant ($p<0.05$) negative correlation with iron ($r=-0.513$), total coliform ($r=-0.677$) *(Figure 4.5 a)* and fecal coliform ($r=-0.534$) *(Figure 4.5b)*; and significant negative correlation with dissolved oxygen ($r=-0.396$) *(Figure 4.7 a)*, turbidity *(Figure 4.7b)* and fluoride ($r=-0.355$). Statistical analysis shows that water temperature records non-significant ($p>0.05$) positive correlation with arsenic and negative correlation with chloride within the wetland water.

Wetland water ***pH*** shows highly significant ($p<0.01$) positive correlation with water temperature ($r=0.861$) *(Figure 4.4 a)*, conductivity ($r=0.652$) *(Figure 4.4c)*, dissolved solid ($r=0.619$) *(Figure 4.4d)* and total hardness ($r=0.685$) *(Figure 4.4e)* at 0.01 significance level. Water pH records highly significant ($p<0.05$) negative correlation with iron ($r=-0.576$), fluoride ($r=-0.431$), total coliform ($r=-0.619$) *(Figure 4.5c)* and fecal coliform *(Figure 4.5d).* Water pH records non-significant ($p>0.05$) positive correlation with turbidity, dissolved oxygen, arsenic whereas negative correlation with chloride.

Conductivity of wetland water shows highly significant ($p<0.01$) positive correlation with pH ($r=0.652$), total dissolved solid ($r=0.986$) *(Figure 4.4 f)* and total hardness ($r=0.886$) *(Figure 4.4g)* at 0.01 significance level. Conductivity records highly significant negative correlation with iron ($r=-0.501$) and total coliform ($r=-0.474$). Water conductivity records significant ($p<0.05$) positive correlation with dissolved oxygen ($r=0.413$) *(Figure 4.6 c)* at 0.05 significance level and negative correlation with fecal coliform ($r=-0.342$). Statistical analysis reveals that conductivity has non-significant ($p>0.05$) positive correlation with turbidity and chloride; and negative correlation with arsenic and fluoride.

Table 4.19 Correlation Matrix between water quality parameters of selected wetlands

	WT	pH	Cond	TDS	Turbidity	TH	DO	Iron	Arsenic	Cl	Fluoride	TC	FC
WT	1	.766**	.407*	.371*	-.414*	.593**	-.396*	-.513**	.251	-.087	-.355*	-.677**	-.534**
pH		1	.652**	.619**	-.169	.685**	-.088	-.576**	.015	-.028	-.431**	-.619**	-.519**
Cond			1	.986**	.074	.886**	.413*	-.501**	-.122	.197	-.296	-.474**	-.342*
TDS				1	.159	.871**	.447**	-.508**	-.184	.217	-.290	-.492**	-.351*
Turbidity					1	-.191	.296	.219	-.562**	-.052	.111	.031	.175
TH						1	.286	-.722**	.112	.196	-.278	-.491**	-.513**
DO							1	-.312	.003	-.233	-.374*	.171	-.077
Iron								1	-.187	.103	.419*	.454**	.720**
Arsenic									1	-.406*	-.346*	.382*	.129
Cl										1	.578**	-.119	-.016
Fluoride											1	.138	.183
TC												1	.795**
FC													1

**. Correlation is significant at 0.01 level (2-tailed).

*. Correlation is significant at 0.05 level (2-tailed).

WT=Water temperature, Cond= Conductivity, TDS= Total dissolved solids, TH= Total hardness, DO= Dissolved oxygen, Cl= Chloride, TC= Total coliform, FC= Fecal colifrom.

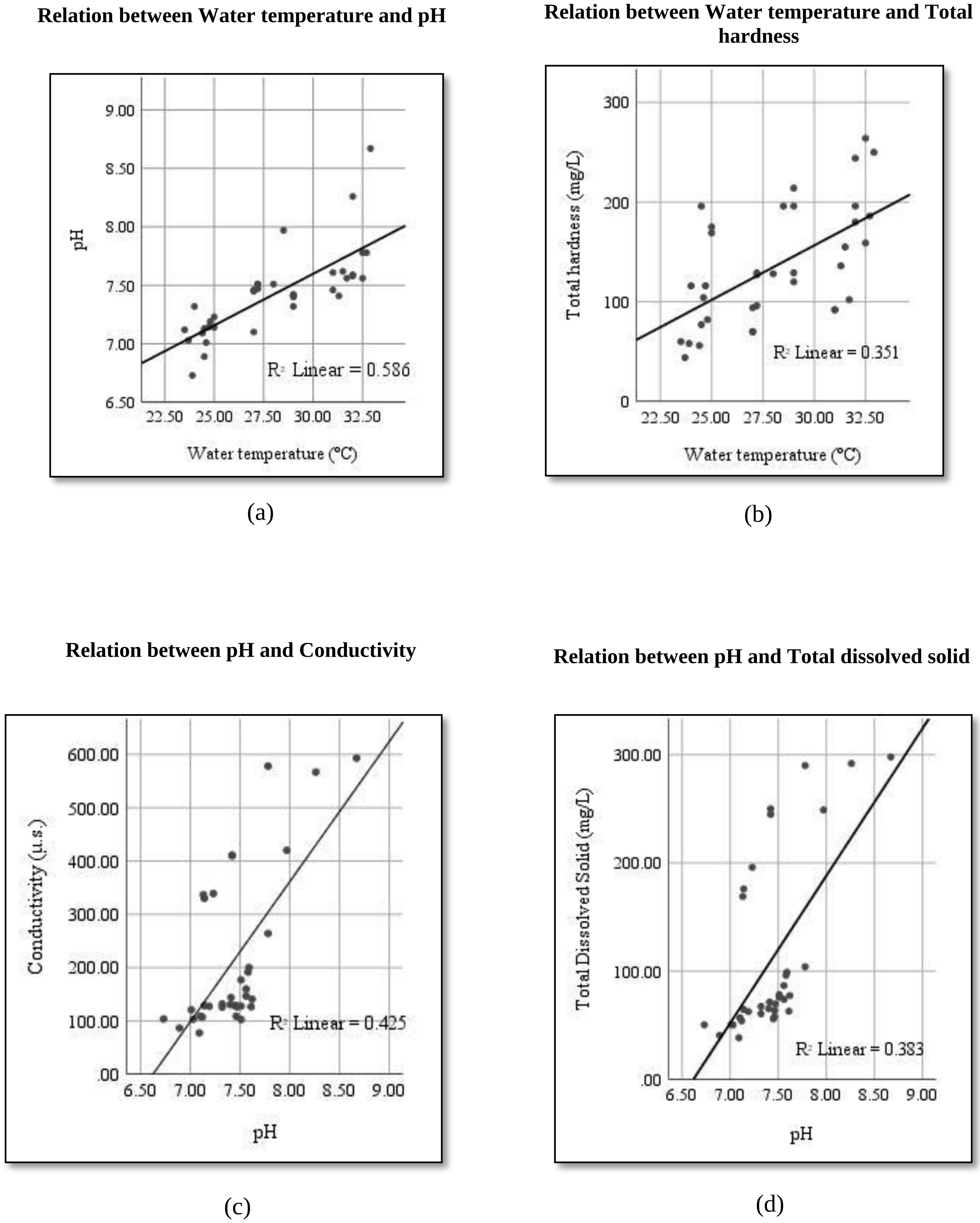
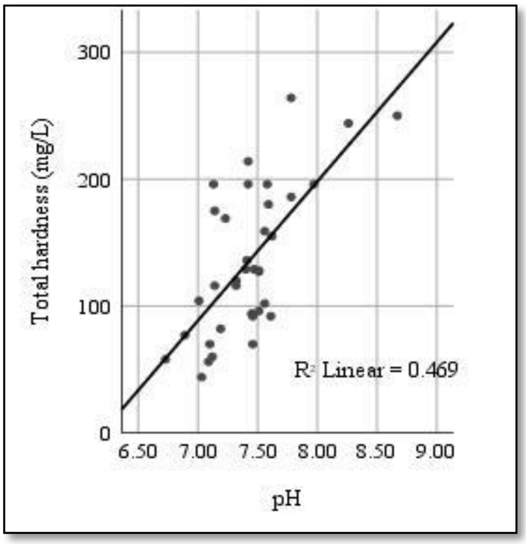


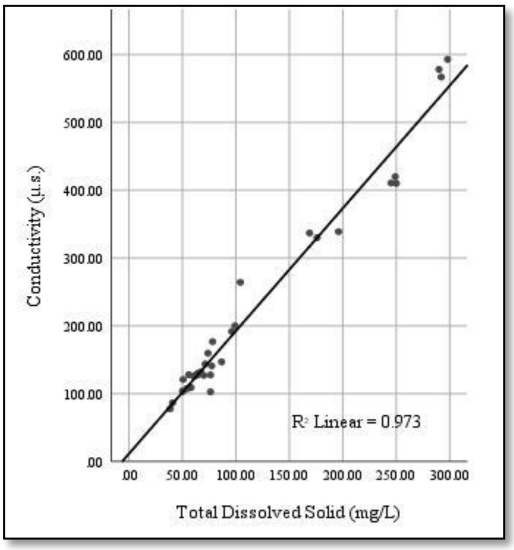
Figure 4.4: *Highly significant (p<0.01) positive correlation between wetland water quality parameters*

Relation between pH and Total hardness



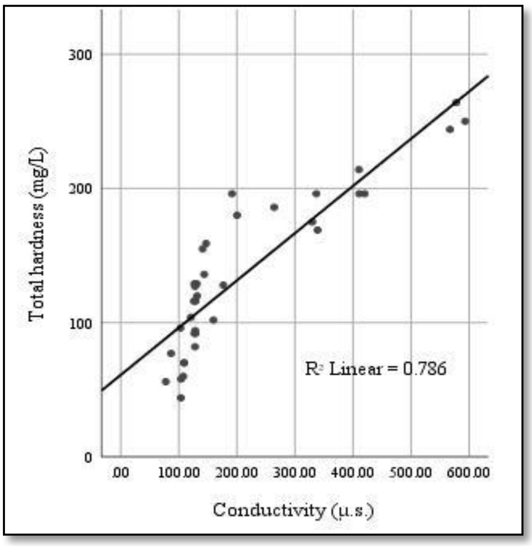
(e)

Relation between Total dissolved solid and Conductivity



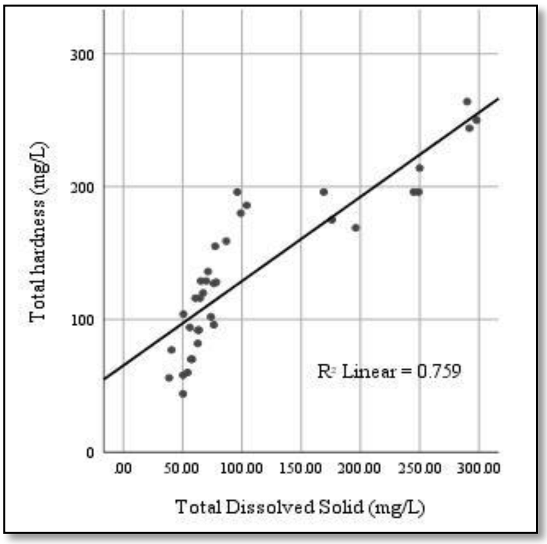
(f)

Relation between Conductivity and Total hardness



(g)

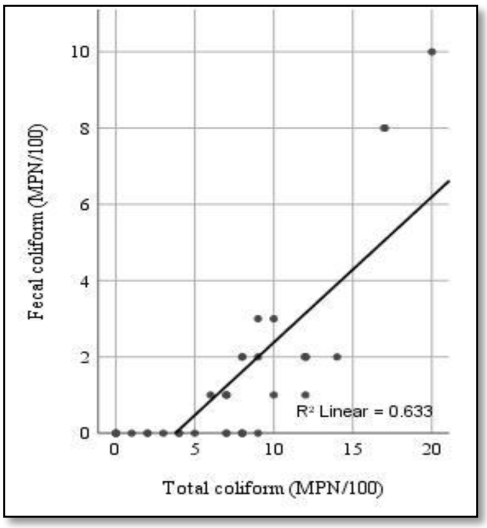
Relation between Total dissolved solid and Total hardness



(h)

Figure 4.4: *Highly significant (p<0.01) positive correlation between wetland water quality parameters*

Relation between Total coliform and Fecal coliform



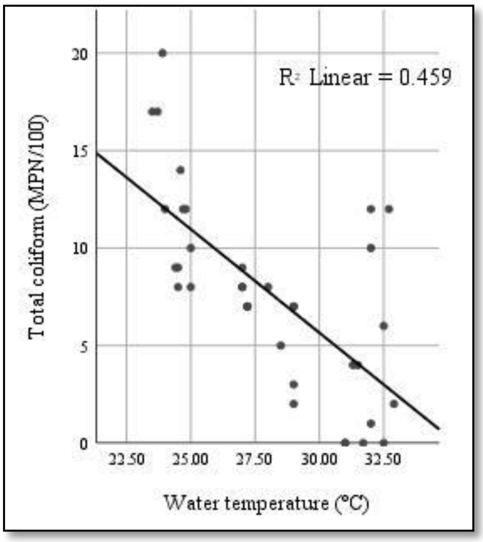
(i)

Figure 4.4: *Highly significant (p<0.01) positive correlation between wetland water quality parameters*

In the present study, ***total dissolved solid*** within wetland water shows highly significant ($p<0.01$) positive correlation with water pH ($r=0.619$), conductivity ($r=0.986$), total hardness ($r=0.886$) *(Figure 4.4 h)* at 0.01 significance level and dissolved oxygen ($r=0.447$). Dissolved solid record highly significant ($p<0.01$) negative correlation with iron ($r=-0.508$) and total coliform ($r=-0.492$); whereas significant ($p<0.05$) negative correlation with fecal coliform ($r=-0.351$). Dissolved solid within wetlands record non-significant ($p>0.05$) positive correlation with turbidity, and chloride and negative correlation with fluoride and arsenic.

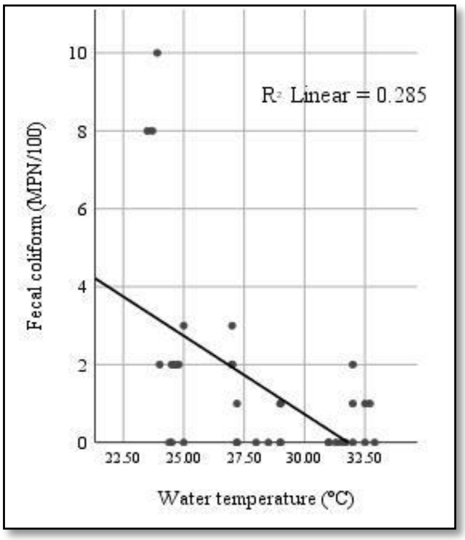
Turbidity shows highly significant ($p<0.01$) negative correlation with arsenic ($r=-0.562$) at 0.01 significance level and significant ($p<0.05$) negative correlation with water temperature ($r=-0.414$) at 0.05 significance level. Turbidity record non-significant ($p>0.05$) positive correlation with water conductivity, dissolved solid, dissolved oxygen, iron, fluoride, total and fecal coliform; and negative correlation with hardness, pH and chloride.

Relation between Water temperature and Total coliform



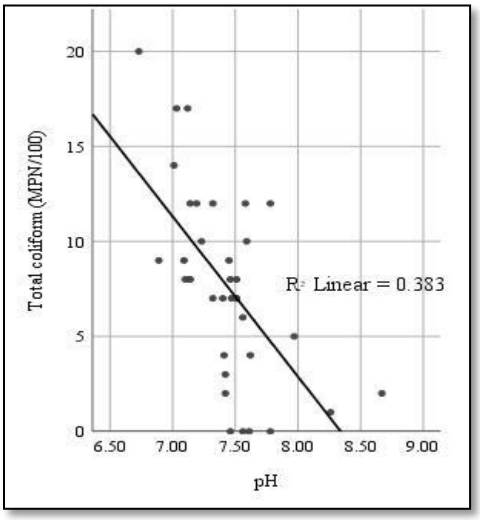
(a)

Relation between Water temperature and Fecal coliform



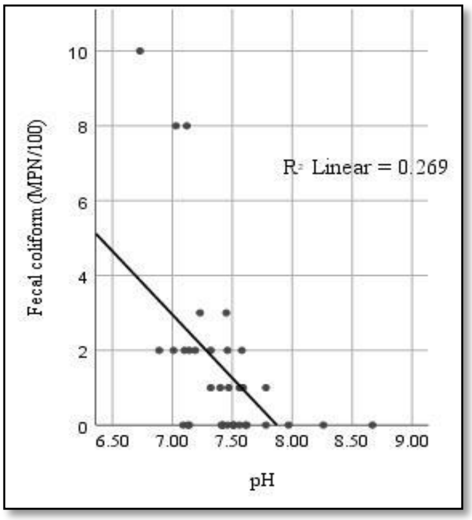
(b)

Relation between pH and Total coliform



(c)

Relation between pH and Fecal coliform



(d)

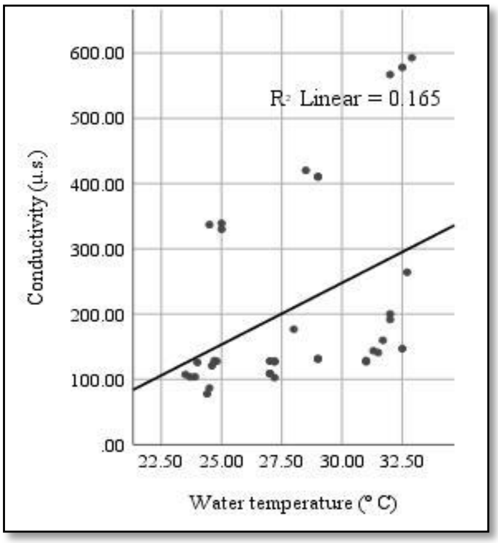
Figure 4.5: *Highly Significant (p<0.01) Negative Correlation between water quality parameters*

Statistical analysis records ***total hardness*** to have highly significant (p<0.01) positive correlation with water temperature (r=0.593), pH (r=0.685), conductivity (r=0.886) and dissolved solid (r=0.881) and negative correlation with iron (r=-0.722), total coliform (r=-0.491) and fecal coliform (r=-0.513) at 0.01 significance level. Total hardness shows non-significant (P>0.05) positive correlation with dissolved oxygen, arsenic, chloride; and negative correlation with turbidity and fluoride.

In the present study, ***dissolved oxygen*** shows highly significant (p<0.01) positive correlation with dissolved solid (r=0.441) at 0.01 significance level. Significant (p<0.05) positive correlation of do with conductivity (r=0.413) and negative correlation with water temperature (r=-0.396) and fluoride (r=-0.374) has been recorded at 0.05 significance level. Dissolved oxygen records non-significant (p>0.05) positive correlation with turbidity, hardness, arsenic and total coliform, whereas negative correlation with iron, chloride and fecal coliform.

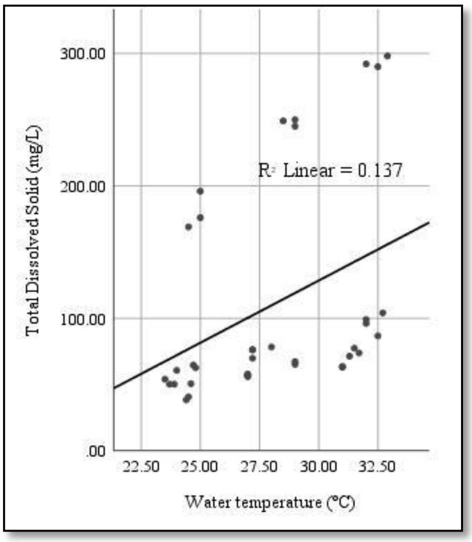
The wetlands record ***iron*** content to have highly significant (p<0.01) positive correlation with total coliform (r=0.454) and fecal coliform (r=0.720); and negative correlation with water temperature (r=-0.513), pH (r=-0.576), conductivity (r=-0.501), dissolved solid (r=-0.508) and hardness (r=-0.722) at 0.01 significance level. Iron content records significant (p<0.05) positive correlation with fluoride (r=0.419) and non-significant (p>0.05) positive correlation with turbidity and chloride; and negative correlation with dissolved oxygen and arsenic.

Relation between Water temperature and Conductivity



(a)

Relation between Water temperature and Dissolved solid

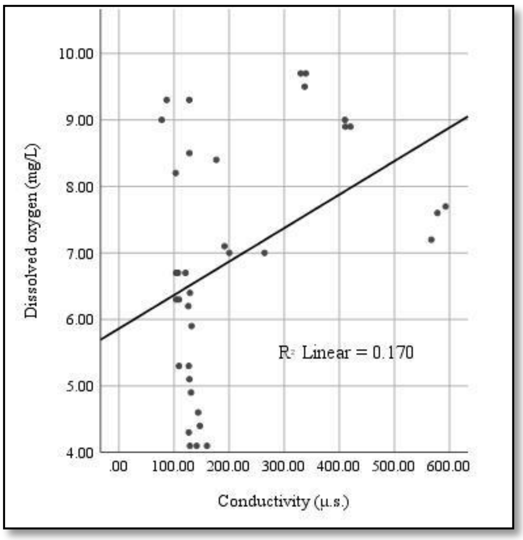


(b)

Figure 4.6: *Significant (p<0.05) Positive Correlation between water quality parameters*

In the present study, ***arsenic*** content records highly significant (p<0.01) negative correlation with turbidity (r=-0.562) at 0.01 significance level. Arsenic records significant (p<0.05) positive correlation with total coliform (r=0.382) and negative correlation with chloride (r=-0.406) and fluoride (r=-0.346) at 0.05 significance level. Arsenic in the wetland water records non-significant (p>0.05) positive correlation with water temperature, pH, hardness and dissolved oxygen; whereas records negative correlation with conductivity, tds and iron.

Relation between Conductivity and Dissolved oxygen



(c)

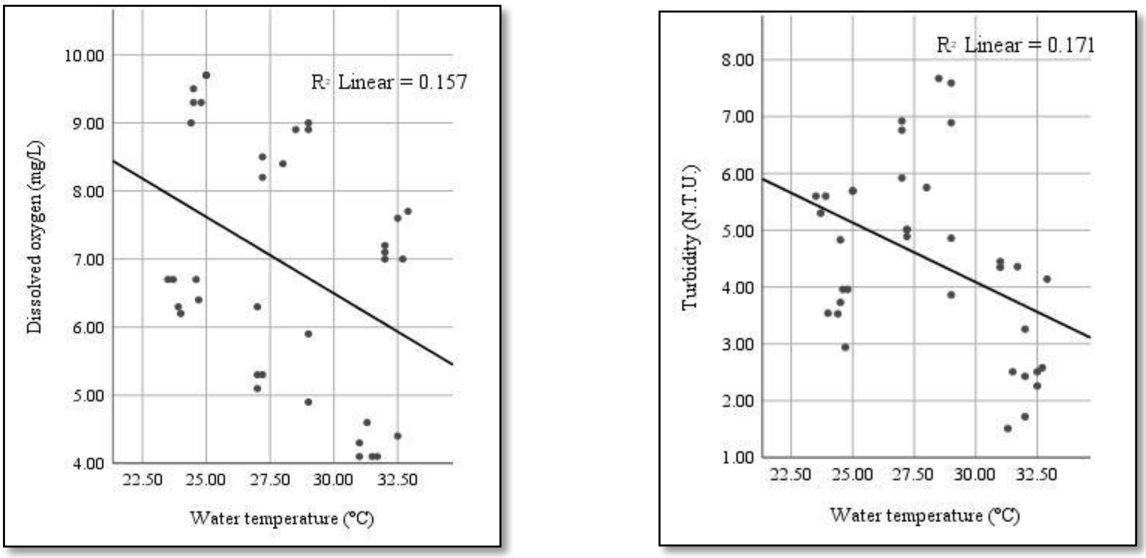
Figure 4.6: *Significant (p<0.05) Positive Correlation between water quality parameters*

Chloride content in wetland water records highly significant (p<0.01) positive correlation with fluoride (r=0.578) and significant (p<0.05) negative correlation with arsenic (r=-0.406). Chloride has non-significant (p>0.05) positive correlation with conductivity, tds, hardness and iron whereas, negative correlation with temperature, pH, turbidity, do, total and fecal coliform.

In the present study, ***fluoride*** content records highly significant (p<0.01) positive correlation with chloride (r=0.578) and negative correlation with pH (r=-0.431). Fluoride records significant (p<0.05) positive correlation with iron (r=0.419) and negative correlation with temperature (r=-0.355), pH (r=-0.431), do (r=-0.374) and arsenic (r=-0.346). Fluoride has non-significant (p>0.05) positive correlation with turbidity, total and fecal coliform, whereas negative correlation with conductivity, tds and total hardness.

Statistical result shows that bacteriological parameters are also correlated with physic-chemical parameters of water quality. ***Total coliform*** shows highly significant (p<0.01) positive correlation with iron (r=0.454) and fecal coliform (r=0.795) (*Fig 4.4 i)* at 0.01 significance level and negative correlation with pH (r=0.731). Total coliform records significant (p<0.05) negative correlation with temperature (r=-0.677), pH (r=-0.619), conductivity (r=-0.474, tds (r=-0.492) and hardness (r=-0.491) at 0.05 significance level. Total coliform count in wetland water shows significant (p<0.05) positive correlation with arsenic (r=0.382) whereas, non-significant (p>0.05) positive correlation with turbidity, dissolved oxygen, fluoride and negative correlation with chloride content.

Relation between Water temperature and Dissolved oxygen **Relation between Water temperature and Turbidity**



(a) (b)

Figure 4.7: *Significant ($p<0.05$) Negative Correlation between water quality parameters*

According to Statistical analysis ***fecal coliform*** shows highly significant ($p<0.01$) positive correlation with iron (r=0.720) and total coliform (r=0.796) and negative correlation with temperature (r=-0.534), pH (r=-0.519) and total hardness (r=-0.513). Fecal coliform shows non-significant ($p>0.05$) positive correlation with turbidity, fluoride and arsenic and negative correlation with dissolved oxygen and chloride of wetland water.

4.6 Conclusion:

In the present study, the physico-chemical as well as bacteriological characteristics of water have been tested and analyzed in case of four wetlands, viz, Siali, Chakla, Naghoria and Chatra, as a representation of entire wetland resource of Malda district . The year round seasonal variation of physico-chemical and bacteriological parameters of these wetlands provide a vivid picture of the ecological status of wetlands under study area. Based on the findings, overall water qualities of the wetlands in Malda district are found within the permissible limit especially for biological species which indicates the prevalence of desirable quality of water. At the same time, wetlands, which are subject to agricultural and municipal sewage inflow from peripheral area, exhibits high concentration of dissolved solid, total hardness, turbidity and conductivity and are found to exceed the desirable limits to some extent. After a detail study on physico-chemical and bacteriological water quality parameters, it reveals that the wetlands within the rural periphery receive land run-off from adjacent agricultural field, whereas the peri-urban water body is contaminated by municipal and domestic effluents discharge into wetland without any discrimination. Therefore, the wetlands encounter several challenges in the form of ever increasing concentration of dissolved solid, conductivity and water hardness especially when the water availability is low during the pre-monsoon period. The high organic components substantially promote the proliferation of pathogenic and bacterial population (coliform bacteria) in wetland water as well as minimize the dissolved oxygen content. So an appropriate conservative measure would be necessary to resolve the existing eutrophication level of these wetlands. The present study urges the need for restoration of the wetland in Malda district in order to ensure the sustainability of a healthy natural ecosystem.

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Chapter – V

UTILIZATION OF WETLANDS

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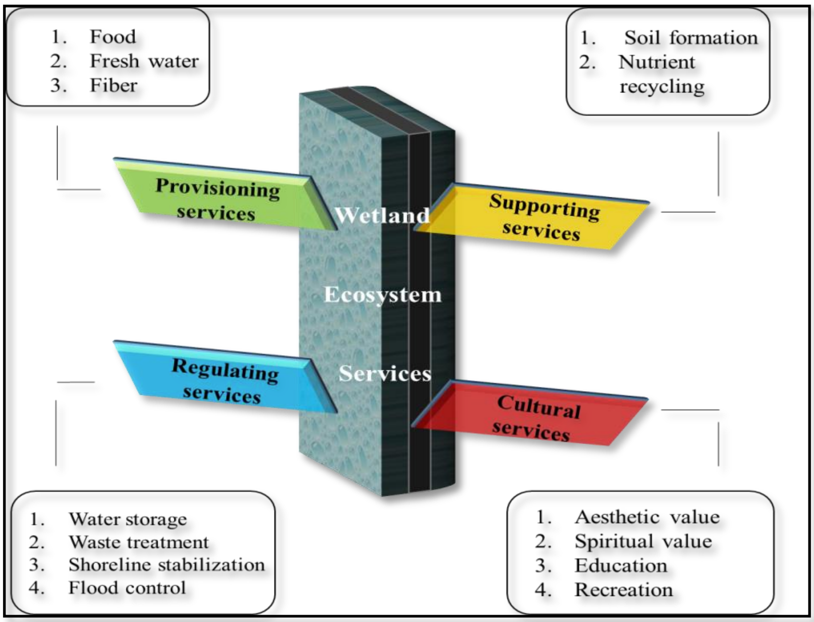
UTILIZATION OF WETLANDS

5.1 Introduction:

The total wetland benefits involve an estimation of many intangible values, which are rather difficult to quantify. These are the values, which form the basis of wetland products and services *(Rao & Datye, 2003)*. Wetlands support an exceptionally large biological diversity as well as provide a wide range of ecosystem services i.e. food, fiber, raw materials and medicines *(Ramachandra & Aithal, 2015)*. Wetland ecosystem depends on constant, recurrent or shallow inundation at or near the surface of the substrate and characterizes the presence of physical, chemical and biological components. Water, modified substrate and distinct biota thus are the essential constituents of these ecosystems *(Ramachandra et al., 2001)*. The wetlands and water bodies with sufficient food and weedy vegetation provide a good habitation for the residents and also supply a valuable number of plant species. The spectacular concentration of different species of animals and plants in the wetlands provide opportunities for tourism as well as recreational activities. In the recent past, non-consumptive benefits of wetlands such as recreation, archaeology, education and science were usually given lower priority in measurement plans than directly consumptive values because of having difficulty to quantify the aesthetic value. But in recent years these values are being given greater attention worldwide *(Das et al. 2000)*. Now-a-days wetlands have been analysed as the *'biological supermarkets'* because of the extensive food webs and rich biodiversity they promote. Wetlands perform numerous functions that are considered to have socio-economic importance and values. The functions and values of wetland ecosystem are determined by human perception, human population pressure and the extent of resources. Human benefits from the wetlands emerge either directly from the use of water plants, animals, soils, food, fibers, raw materials and other components of wetland ecosystem or indirectly from their ecosystem functions including breeding ground for many species, commercially valuable furbearers, water fowls. These benefits are now called as ecosystem services and summarized into *provisioning, regulating, supporting* and *cultural services (Figure 5.1)*. In the present study, the provisioning services of wetlands in the form of providing fresh water, food, fiber, and other biotic components through cultivation, fishing and wetland product collecting activities are discussed, in the perspective of wetlands, under study in Malda district.



Source: *Ramsar Convention, FAO & IWMI, 2014.*

Figure 5.1 *Wetland ecosystem services*

5.2 General study on wetland utilization of Malda district:

Wetlands under study, provides intrinsic values (direct values) to the people, especially those, whose lives and customs are intimately linked with wetland functions. In Malda district, wetlands constitute a special ecosystem nurturing a large variety of flora and fauna and a rich genetic pool, and used as multiple systems. Almost all the wetlands are utilized by the peripheral households directly and indirectly through different occupations like cultivation, fishing, gathering different macrophytes and aquatic fauna. The habitats around and surrounding the wetlands are classified into two categories: (a) *Bed village* and (b) *Belt village*. *Bed villages* are located at the immediate vicinity around the wetlands whose whole lives and customs are intimately linked with the wetland functions. On the other, *Belt villages* are located a bit away, surrounding the wetlands who exploit wetlands especially for major commercial purpose *(Seshavatharam, 1992)*. The wetlands have significant impact on the livelihood of the local people, irrespective of both the village types *(Appendix-9,10)*.

5.2.1 Wetland utilization for cultivation:

The wetland water is used especially for cultivation which is considered a primary driver of economic growth as well as provides critical economic support to the rural households. Further, most of the wetlands experience a good portion of its area coverage to be contributed for cultivation. Some of them have been converted to intensive cultivation, and others are continued to be cultivated in their natural form. Both the kharif crops such as; aman paddy, jute etc. and several rabi crops like wheat, pulses, mustard etc. are cultivated at the wetland edge, especially by the settlers, residing at the periphery. Several varieties of high yielding potential paddy crops are cultivated, in which aman paddy dominates as well as cultivated in the high land of *barind* region. The wetland associated low lands are contributed to a wide range of paddy species such as '*Digha', 'Kalabona', 'Kali Rai', 'Lalbona', 'Laxmi Digha', 'Mughi', 'Metegarol', 'Sada Bona'* of aman varieties, '*Muktahar'* of aush and '*Boali', 'Jagoli'* of boro varieties *(Sarkar & Roy, 2013)*. Apart from the mentioned crops, cash crop like makhana is cultivated in a vast area in the wetlands under *tal* and *diara* physiographic regions. Makhana is suitably cultivated within wetlands, which contains water-logged soil and water table at or near the surface.

5.2.1.1 Wetland utilization for irrigation:

Wetlands are chiefly used as a source of irrigation for the surrounding farm lands. As, it is observed that the canal irrigation in the entire Malda district is non-existing, the alternative source of irrigation is either in the form of extracting ground water or in the form of tapping from the river and wetlands through pump and marshal *(Plate 5.1 & 6.6)*. The farm lands around the rivers mainly use its water for irrigation by paying a certain amount of cost. On the other hand, the level of ground water as is lower in several areas; the cost of irrigating the crop lands is high. As a consequence, the cultivators, around the wetlands always prefer to use small pumps to tap the water from wetlands as a source of irrigation legally or illegally. Pumping of wetland water by shallow bore wells, fitted with pump sets, having a capacity of 2 or 5 Horsepower is also common especially during the pre-monsoon *(Mukherjee, 2008)*. But, for the upland farmers, the cost of pumping water gets relatively higher because of more diesel consumption due to distant location from the wetlands to the cultivated area. Furthermore, it has also been noticed in many cases that the farm lands, adjacent to the wetlands also utilize manual lifting devices for irrigation *(Mukherjee, 2008)*. Thus, the benefits of the farmers around the wetlands is primarily due to the less cost of irrigation and save some money, which can therefore be diverted to the cost of other agricultural inputs.

Plate 5.1: *Wetland water extraction through Marshal*

5.2.2 Wetland utilization for fishing and product gathering:

Along with the support to agricultural production, wetlands facilitate better opportunities for the inhabitants in the form of fishing practice, which has immense socio-economic values, attached to it. The wetlands, located in Malda district provide a nursery habitat for a wide range of fishes including commercial species like Ar, Mrigel, Singi, Koi, Rohu etc. The fishing practice is mainly done by the co-operative societies under Gram Panchayets on lease basis. Moreover, few households, belonging to the bed villages at the wetland periphery, collect several wetland products in the form of both aquatic flora and fauna. They gather macrophytes like kalmi, hingcha, kulekhara as food as well as medicinal ingredient along with local oysters/mollusks, tortoises and other available fishes for their own consumption and income. The combination of these functions and products together makes these wetland ecosystems invaluable to the households throughout the study area.

As per the hypothesis no. 2, wetlands under Malda district is utilized negligible for coir rotting, which has been found during the field study and observation (2016-17).

5.3 Utilization of selected wetlands:

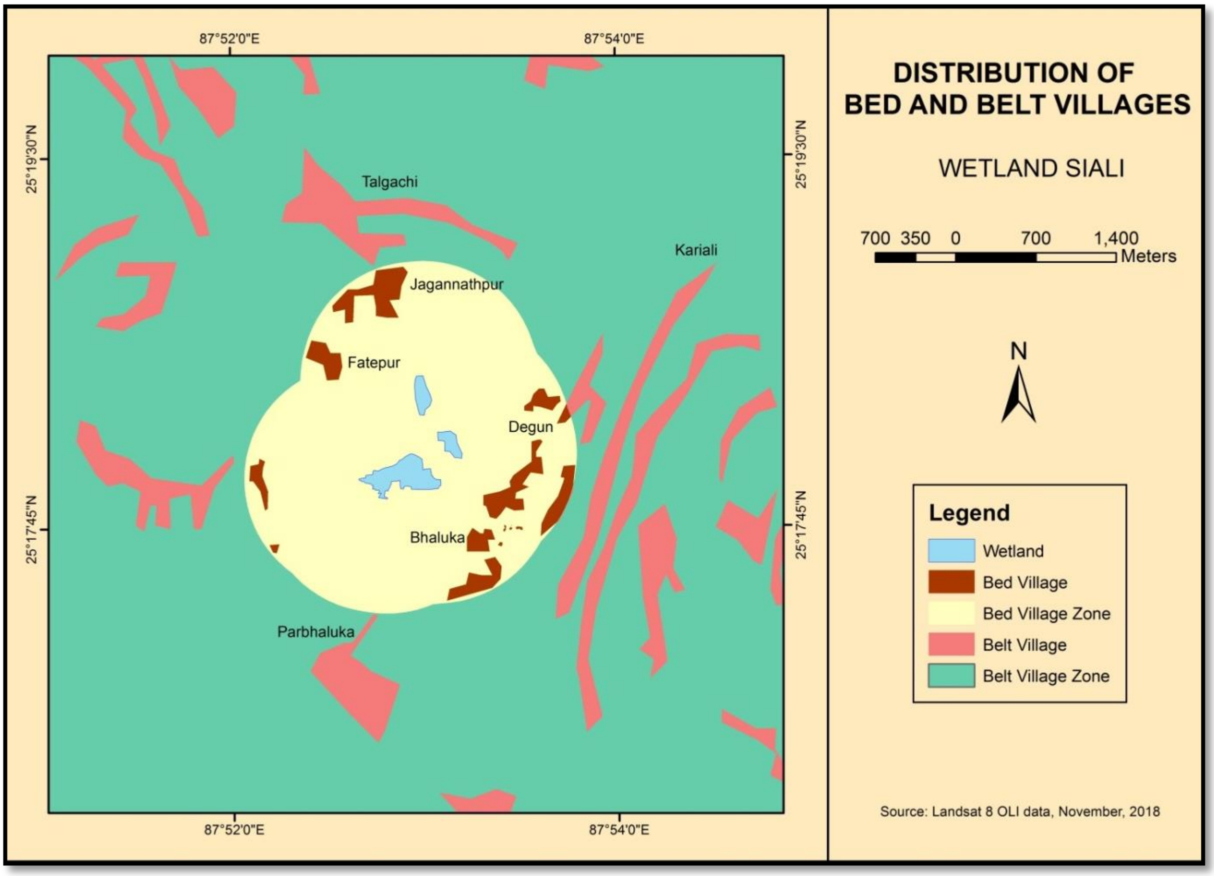
The wetlands under case study (Siali, Chakla, Naghoria and Chatra) are characterized by large number of villages containing households. Being one of the most under developed district of West Bengal, cultivation is the mainstay of the district’s population as well as economy. The district contains certain places where the farmers are well to do with relatively affluent family structure while there are several place where, the rural poor in spite of their hard work, lives in an impoverished state. However, Malda district is characterized by environmental homogeneity but displays a unique feature of cultivation in association with diverse production and productivity of various crops, which vary in different regions.

However, the soil type, climate and association of large quantum of wetlands are compatible for the agricultural crops; consist of rice, pulses, and oil seeds. Along with the crop cultivation, inhabitants depend on wetlands for several other purposes in the form of fish culture, jute retting, hydrophyte and fodder collection. As earlier mentioned, the villages surrounding the wetlands are categorized into bed and belt village. A household survey by random sampling of 5% from bed and belt villages has been conducted in order to determine the utilization of wetland for cultivation, aquaculture, gathering fruits and fiber etc. in the year 2016-17 *(Appendix-9,10)*. Total numbers of households are 1242, have been surveyed from bed and belt villages, surrounding the cast studies. In the present study, it has been observed that all the studied wetlands are chiefly utilized by agricultural activity including cash crops, followed by aquaculture and gathering aquatic products. Further, an economic valuation of these wetland resources is essential in order to put a monetary value to this natural ecosystem.

5.3.1 Siali Wetland

5.3.1.1 Introduction:

Siali wetland provides a wide range of physical benefits to a large section of the local community in the form of food, water and offers a unique habitat for many different species. Since Siali wetland has highly significant economic values, it is very essential to assess the wetland services and functions upon which the people around the wetland rely through their different livelihood activities. This wetland is surrounded by number of villages, wherein seven villages are taken into consideration for conducting household survey, which are placed adjacent to this water body. The villages namely; Jagannathpur, Fatepur, Bhaluka and Degun are considered as bed villages, where the households are entirely dependent on Siali wetland (located at wetland edge up to a distance of 1 km). Whereas, three villages namely Talgachi, Par bhaluka and Kariali have been considered as belt villages, which are relatively less dependent than the bed villagers (located beyond 1 km up to 2 km) *(Map 5.1)*. In the present study, a pre-mentioned household survey (5% of universe) has been conducted in both bed and belt villages, wherein, out of the total 5,665 number of households in bed villages *(District Census Handbook, Census of India, 2011)*, 283 no. of households have been surveyed. Out of total 2,508 no. of households in belt villages *(District Census Handbook, Census of India, 2011)*, 125 households have been surveyed in order to know, the utilization of Siali wetland, by surrounding villagers as well as sustaining their socio-economy *(Table 5.1)* *(Figure 5.2)*. Most of the communities around the wetland comprise of scheduled castes and weaker sections. The major economic benefits that settlers living in the bed and belt villages of Siali wetland, obtain are cultivation, irrigation, jute retting, fisheries and makhana cultivation within wetland.



Map 5.1: *Distribution of Bed and Belt Villages around wetland Siali*

5.3.1.2 Wetland utilization for irrigation and cultivation:

Siali wetland has been recognized as valuable land area to facilitate the agricultural exercises for the food and fodder production because of having fertile soil as a result of regular sediment deposits and a reliable supply of water *(Verhoeven & Setter, 2009)*. The majority of the peripheral households are marginal labourers and cultivating different food as well as cash crops, which are considered main source of income for the settlers around wetland.

Table 5.1 Utilization of Siali wetland by households

Village	Village type	Total household	Cultivator (AL+CL household)	Fishing household	Wetland product collecting household	Cultivator+ Fishing household	Other
Jagannathpur	Bed village	283	182	75	4	17	5
Fatepur							
Bhaluka							
Degun							
Talgachi	Belt village	125	45	52	0	5	23
Par Bhaluka							
Kariali							

Source: *Field Survey, 2016-17*

In the present study, above mentioned table reveals that, out of the total number of surveyed households, bed village accounts 182 number households (64.3%) and belt village accounts only 45 households (36%), who are engaged in cultivation, including both the agricultural labourers as well as cultivators. Out of these cultivator households in bed villages, 143 numbers of households (78.57%) utilize the wetland water for irrigating fields and 39 (21.45%) do not utilize this particular water body *(Table 5.2) (Figure 5.3)*.

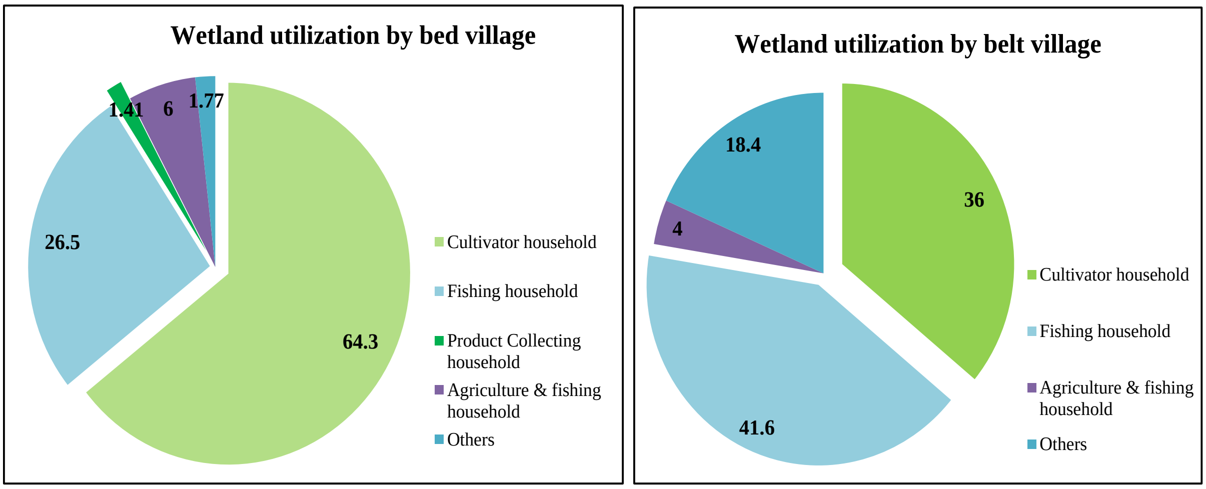


Figure 5.2: *Utilization of Siali wetland by households*

Many of the agricultural households use this wetland water for irrigating their fields as well as for growing varieties of greens in various seasons. The households especially of Degun and Fatehpur (bed villages) are solely dependent on Siali wetland water, either in the form of cultivation in wetland bed or utilizing its water for irrigation. On the contrary, in belt village, out of the total cultivators, only 6 households (13.33%) utilize this wetland, whereas 39 households (86.67%) do not utilize this particular water body for irrigating their agricultural field. The surrounding belt villages practically have less cohesion with this wetland regarding agricultural practices, which is attributed to distant location from Siali wetland.

Table 5.2 Utilization of Siali wetland for irrigation and cultivation

Village type	Cultivator (household)	Wetland utilized	(%)	Wetland un-utilized	(%)
Bed village	182	143	78.57	39	21.43
Belt village	45	6	13.33	39	86.67

Source: *Field survey, 2016-17.*

As per the household survey, out of the total 104.42 ha area under cultivation, irrespective of bed and belt villages, 10.12 ha (9.69%) is irrigated with the help of water from Siali wetland *(Appendix-10)*, in which paddy in 6.88 ha, pulse in 2.43 ha and jute in 0.81 ha are cultivated.

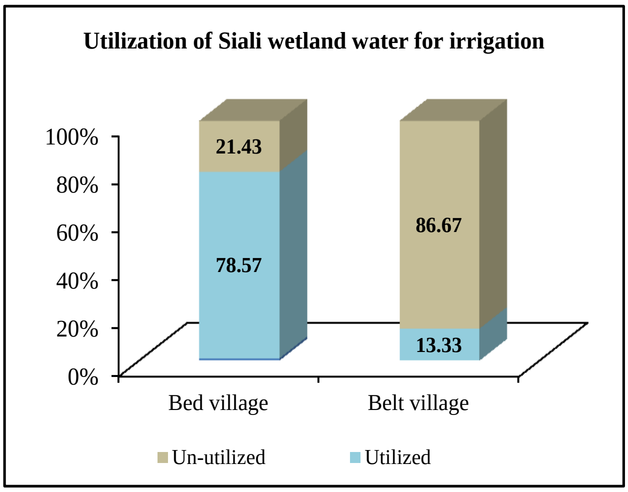


Figure 5.3: *Utilization of Siali wetland water for irrigation*

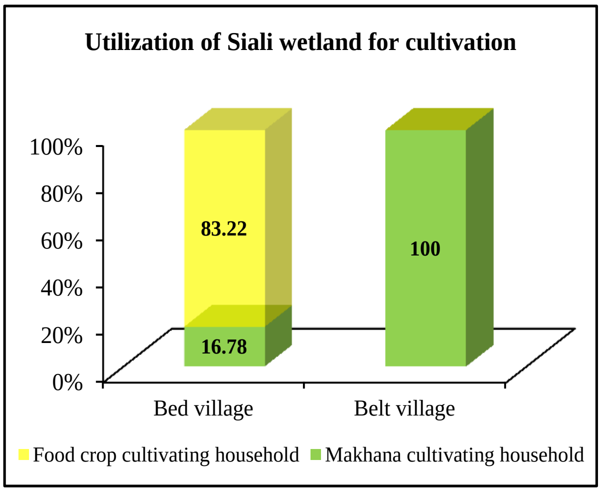


Figure 5.4: *Utilization of Siali wetland for cultivation*

The major crops cultivated, with the help of wetland water are paddy (Aman, Boro), legumes, mustard and pulses (Kalai, Moong) etc. Aman paddy is considered mostly dominant kharif crop, cultivated during June to October and by most of the cultivators and agricultural labourers. Jute is the important commercial crop, cultivated during February to May in the uplands, surrounding this wetland *(Plate 5.2)*. Jute is also cultivated in substantial area under wetland bed at the time of water logging period, as it can withstand the standing water, which is essentially required for jute retting purpose *(Mukherjee, 2008)*. It is noticed at the time of field study that, the wetland edge is occupied with the unique assemblage of aman paddy and jute in their respective growing seasons *(Plate 5.3)*. Boro paddy is another key crop, which is cultivated at the wetland edge during November to February and is mostly remunerative for the cultivators as they could save money in terms of irrigation, fertilizer and labour costs *(Mukherjee, 2008)*. Sometimes, Boro is cultivated in the water spread area of Siali wetland, where the cultivators get the single crop *(Plate 5.7)*. Another major crop, cultivated by the households adjacent to Siali wetland includes Wheat, Corn, and Mustard especially during the time period from October to February. Furthermore, the entire cultivation in these surrounding villages are characterized with a good association of cereals (Motor, Chola, Kalai) as well as several vegetables (Brinjal, Cauliflower, Radish) etc. Another important crop with high economic valuation is Betel leaf on which a good number of households especially of bed villages are dependent. From the field survey, it has been observed that near about 80 % of the cultivators are engaged traditionally from a long period, with betel leaf (dishi/ indigenous) cultivation in combination with other crops *(Plate 5.4)*. These agricultural crops are cultivated with the help of wetland water. Irrigation facility has also been developed with the help of shallow machine at the depth of 45 to 60 feet. Among the mentioned cultivated crops Jute and Betel leaf are considered as important cash crops, which economically sustain the habitants' livelihood. These crops are marketed to Mathurapur, Samsi, Chanchal and Kumedpur markets and local hats.

Plate 5.2: *Jute cultivation during pre-monsoon*

Plate 5.3: *Aman paddy cultivation during monsoon*

Plate 5.4: *Betel leaf cultivation with the help of wetland water*

Plate 5.5: *Researcher during field study*

5.3.1.2.1 Makhana cultivation in wetland:

Along with the food crops, makhana, which is considered an important cash crop with high nutritional value, is cultivated on a mass scale on Siali wetland bed. A significant number of households, irrespective of bed and belt villages, intensively cultivate makhana on lease basis under the fisheries co-operative society. Out of the total wetland dependent cultivators (143 no. households) in bed village, 24 numbers (16.78%) are makhana cultivating household whereas; in belt villages the entire wetland dependent cultivators (6 no. households) are engaged in makhana cultivation *(Table 5.3) (Figure 5.4) (Plate 5.6)*.

Table 5.3 Utilization of Siali wetland for makhana cultivation

Village type	Cultivator (household)	Wetland utilized	Makhana cultivating household	%	Food/Cash crop cultivating household	%
Bed village	182	143	24	16.78	119	83.22
Belt village	45	6	6	100	0	0

Source: *Field survey, 2016-17*

Makhana is cultivated as a seasonal annual crop and dies out after the fruits mature. The seeds are first broadcasted (sowing) in the surface water of wetland during the post-monsoon period (November-December). The germination process of makhana seeds starts in the month of March and the plant comes out above the surface water. After one and half months (30-45 days) from the flowering period, the fruits get fully matured and the ripen seeds start bursting during the month of July-August. The makhana seeds are harvested as well as collected in the last week of July or the first week of August, following three rounds of practices. First round of seeds collection is locally called 'Sharkat', which is associated with maximum collection. Second round is called 'Markat' and the last round, which is of longest duration, is called 'Chharkat' *(Khatun, 2012)*. A large number of households are involved in collecting the seeds from the wetlands through local devices. The collection period starts from 9:00 a.m. and continues day long, up to 4:30 p.m. The labourers, who are involved in collecting the makhana seeds get good wage, which ranges from Rs. 30 per kg to Rs. 50 per kg i.e., Rs. 700/800 to Rs.1000/2000 per day. Initially, the wage is low with the abundance of makhana seeds within wetlands, but it reaches to maximum, while the seeds availability starts diminishing. The traditional involvement of localized settlers has made makhana cultivation pretty much rather than fish cultivation in the last few decades in both the bed and belt villages, surrounding Siali wetland. Moreover, this aquatic crop (makhana) has immense potentiality to provide considerable amount of cushion to counteract the impact of poverty in this district *(Kumari et al., 2014)*.

Plate 5.6: *Makhana cultivation in Siali wetland bed*

Plate 5.7: *Boro paddy cultivation at Siali wetland during post-monsoon*

5.3.1.3 Wetland utilization for fishing:

Aquaculture in the form of fish culture is extensively carried out in Siali wetland, which provides better opportunity for the inhabitants, residing in both bed and belt villages. This wetland facilitates major benefits to the fisheries, with the high consumption of fishes in this district. Out of the total households, bed village contains 75 (26.5%) no. and belt village contains 52 (41.6%) no. of households *(Table 5.1) (Figure 5.2)* to be engaged in fishing practice. The mentioned table clearly depicts that the fishing practice is relatively less in comparison with agricultural activities especially among the inhabitants of bed villages. The entire fishing practice is controlled by the Bhaluka Fisheries Cooperate Society. The cooperative society has leased out different portions of the wetland for three to five years and fishing is done by the private ownership on leasing. Out of the total fishing households, 49 no. of households (65.33%) of bed villages utilize Siali wetland, whereas only 10 (19.23%) households utilize this particular wetland for fishing in the form of fish cultivation and catch *(Table 5.4) (Figure 5.5) (Plate 5.8)*. Being distantly located, majority of the households are inclined for fishing to nearby water bodies rather than this particular wetland. The fishing practice is primarily dominated by Rohu, Ar, Shingi, Mangur, Bata, Mrigel and Catla cultivation. All varieties of carps are produced in this wetland. Different types of fishes (Koi, Mangur, Shingi,) cultivating in this wetland, are considered more profitable as well as utilized for commercial purpose. The fishes, caught from the wetland are sold at random in the markets located at Malda Town. Very little portion of the fish catch are sold in the local market of Fatehpur and Bhaluka hat *(Plate 5.9)*.

Table 5.4 Utilization of Siali wetland for fishing

Village type	Fishing household	Wetland utilized	(%)	Wetland un-utilized	(%)
Bed village	75	49	65.33	26	34.67
Belt village	52	10	19.23	42	80.77

Source: *Field survey, 2016-17*

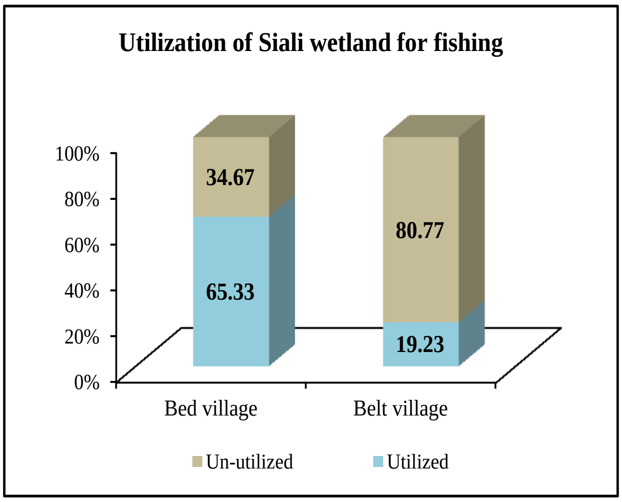


Figure 5.5: *Utilization of Siali wetland for fishing*

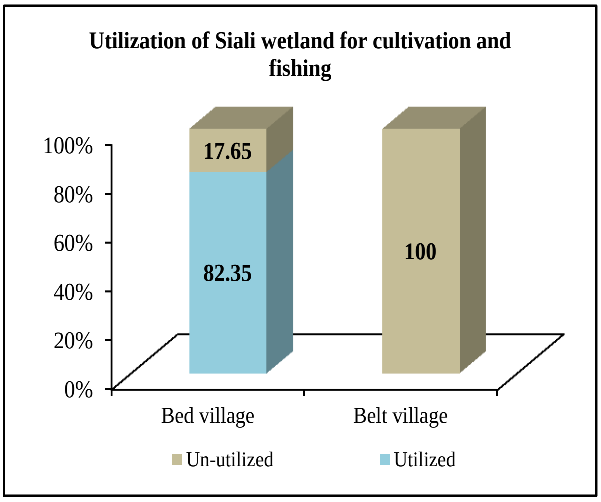


Figure 5.6: *Utilization of Siali wetland for cultivation and fishing together*

Plate 5.8: *Fish catch in Siali wetland*

Plate 5.9: *Fish sold at Fatehpur and Bhaluka market, Malda District*

5.3.1.4 Wetland utilization for cultivation and fishing together:

The field study and household survey reveals that most of the surrounding inhabitants cultivate diverse crops for their subsistence as well as commercial purpose or are engaged in the combination of both cultivation and fishing for their livelihoods. The inhabitants of peripheral villages used to practice cultivation from long back and later have adopted practicing fish culture into that crop land as a form of fish pond *(Irrinki & Irrinki, 2006-07)*.

Table 5.5 Utilization of Siali wetland for cultivation and fishing together

Village type	Cultivator + Fishing household	Wetland utilized	(%)	Wetland un-utilized	(%)
Bed village	17	14	82.35	3	17.65
Belt village	5	0	0	5	100

Source: *Field survey, 2016-17*

Out of the total surveyed households in bed village (283), 17 households (6%) are engaged both in cultivation and fishing *(Table 5.1) (Figure 5.6)*, in which 14 (82.35%) households utilize Siali wetland water both for irrigation or cultivation and for fishing *(Table 5.5.) (Figure 5.6)*. On the other hand, belt villages record only 5 (4%) households, out of total surveyed households (no. 125) to follow cultivation and fishing together but not utilize this particular wetland, which may be attributed to distant location of villages and in between existence of other scattered water bodies. During the field study, it has been observed that makhana cultivation and fishing practice together are found ecologically vulnerable. Before, sowing the makhana seeds, wetland water is completely sterilized through the application of insecticides of Endousulphun group, which is harmful for the fish fauna and found unhygienic for the human health. Moreover, the thorny appearance of makhana creates problem for the fish cultivation. That is why; the households engaged in fishing practice generally cultivate food crops with the help of this wetland, rather than makhana cultivation. But, few numbers of households are found to catch fish species like Koi, Bot koi, Shingi etc., which can tolerate less oxygen above water level and are available in the makhana cultivating wetland field.

5.3.1.5 Wetland utilization for product gathering:

Siali Wetland is considered an important sources of the availability of plentiful grass and livestock feed through grazing throughout the year for the households living in and around the wetlands *(Das et al., 2015)*. The inhabitants of bed villages, surrounding Siali wetland, get the benefit directly from gathering wetland products, as it displays growth of several open water and water edge macrophytes such as Ghima, Kalmi, Hatisur, Hingcha, Kulekhara, Thankuni. These macrophytes constitute an inevitable component of the entire ecosystem, and are used by local habitants directly for the food, fiber and fuel. Some of these macrophytes possess known medicinal properties to the local people e.g. thankuni, kulekhara, hingcha etc. especially of bed villages. Along with macrophytes, this wetland exhibits variety of aquatic organisms (frogs, turtles, mollusks and shellfishes), which provide outputs of commercial value and economic sustenance to the people residing around this water body. The wetland products (aquatic flora and fauna) are collected and sold to the local market in order to supplement the household economy to some extent for the people living in the vicinity of Siali wetland. In comparison, with other occupations, related to wetland, product gathering households contain 4 numbers of households (1.41%) out of total households (283) in the bed villages *(Table 5.1) (Figure 5.2)*. Furthermore, the wetland water is used for domestic work by a small number of households in the form of washing cloths and utensils. The rate of utilization of wetland water for the household purpose has presently been diminishing because number of shallow tube wells has been built up in the village premises. From, interviewing the inhabitants, especially of bed villages, it has been known that the wetland water is presently beyond human use and any other consumption due to drastic water quality deterioration because of polluted and toxic chemical fertilizers from adjacent agricultural field and domestic sewage inflow into this water body.

5.3.1.6 Economic valuation of wetland:

The economic evaluation encompasses the values and importance of diverse functions of wetlands, which are utilized by the stakeholders. These values can therefore be helpful in evaluating developmental projects, policies and frameworks for efficient allocation of wetland resources for their further sustainable development. Further, the purpose of economic valuation is to reveal the true costs of utilizing the wetland as well as environmental resources *(Ramachandra et al. 2005)*. As per the benefits of Siali wetland, in terms of agricultural practice, the majority of households, residing in bed villages along with small number residing in belt villages utilize the wetland water in order to irrigate their agricultural fields of around 10.12 ha as well as minimize the cost of irrigation. As per the household survey, Makhana is cultivated on 1.7 ha of the wetland bed on lease by Bhaluka fishing cooperative society by total 30 no. of households. The gross benefit of surveyed household is recorded Rs. 3,82,500.00 per annum, whereas the total cost in the form of labour cost (Rs. 12,750.00/annum) (for preparing makhana cultivating filed) and lease cost (Rs. 19,125.00/annum) is recorded Rs. 31,875.00. Therefore, the estimated net benefit from makhana cultivation within Siali wetland is recorded Rs. 3,50,625.00 per annum *(Table 5.6)*.

Table 5.6 Economic valuation of Siali wetland

Sources of benefits and cost	Makhana cultivation
Gross benefit (Rs./annum)	3,82,500.00
Area under wetland cultivation (ha)	1.7
lease + labour cost (Rs./annum)	31,875.00
Estimated Net benefit (Rs./annum)	3,50,625.00
Sources of benefits and cost for wetland fishing	Wetland fishing (cultivation+catch)
Total production + Total catch (kg/annum)	8,700
Market price (Rs./kg)	175.00
Total benefit (Rs./annum)	15,22,500.00
Lease (Rs./annum)	75,000.00
Estimated net benefit from wetland fishing (Rs./annum)	14,47,500.00
Sources of benefits and cost for wetland product gathering	Wetland product gathering
Total income (Rs./annum/household)	8,000.00
No. of household gather wetland product	4
Total estimated benefit (Rs./annum) from product gathering	32,000.00
Total estimated benefit from wetland (Rs./annum)	18,30,125.00

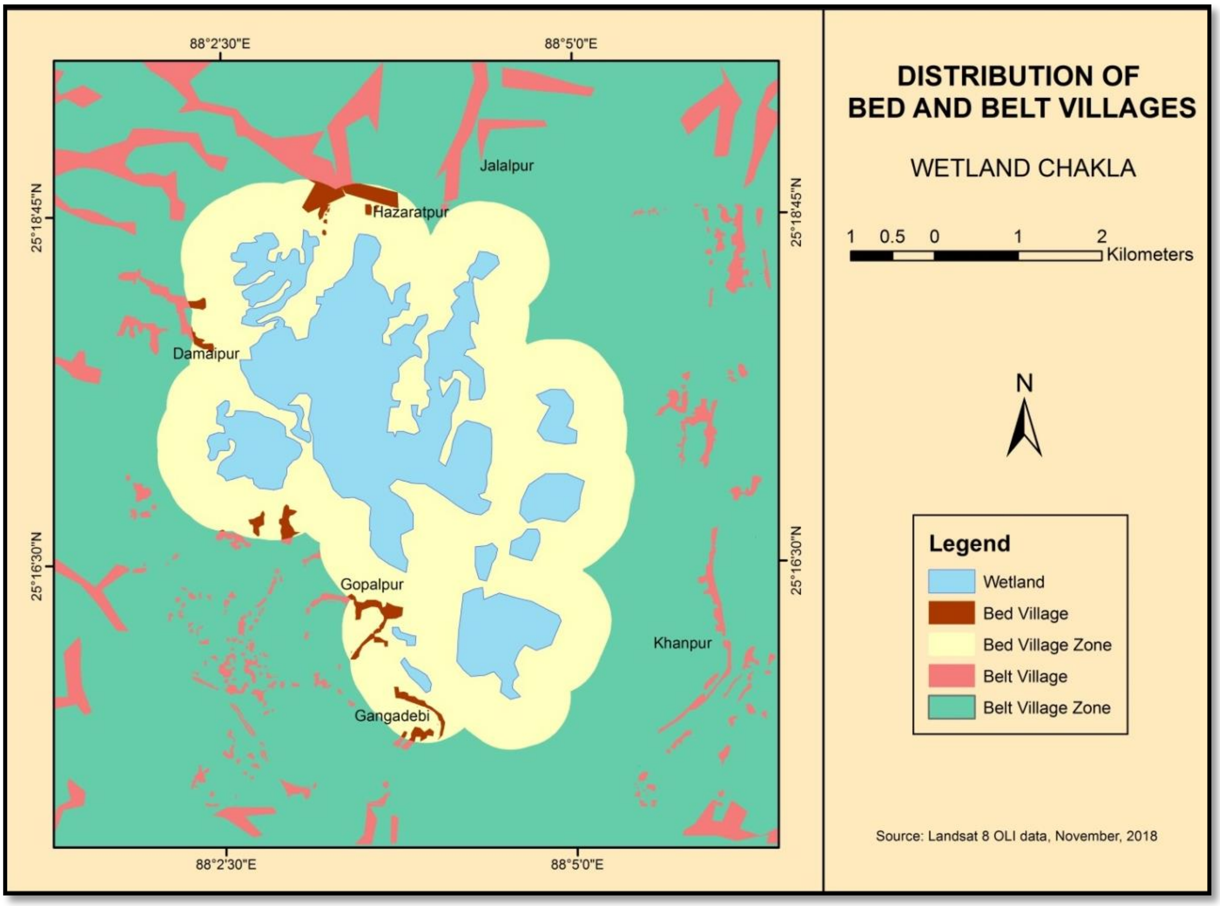
Source: *Field survey, 2016-17*

Apart from makhana cultivation, the beneficiaries (73 households) who are engaged in fish cultivation, irrespective of bed and belt villages get the estimated total benefit of Rs. 15,22,500.00 for the total production including total fish catch of 8,700 kg. per annum (market price Rs. 175.00/kg). The wetland is leased out to the fishermen for Rs. 75,000.00 per annum. Therefore, the net estimated benefit from the wetland fishing including fish catch is recorded Rs. 14,47,500.00 per annum. The households, who gather various wetland products including aquatic flora and fauna, get an estimated benefit of Rs. 32,000.00 per annum. Therefore, the total estimated benefit from Siali wetland in the form of wetland cultivation, wetland fishing as well as wetland product collection is recorded Rs. 18,30,125.00 per annum *(Table 5.6)*.

5.3.2 Chakla Wetland

5.3.2.1 Introduction:

Chakla wetland has immense potentiality as it facilitates cultivation, fishing and gathering several wetland products. The ecological set up in the form of existing landscape, soil and perennial water source in this wetland have made this region more farming oriented. The inhabitants, residing in the peripheral villages are closely associated with this wetland for their diverse economic purposes. The direct eco-functions from Chakla wetland include the usage of wetland water for cultivation as a leading source of irrigation, jute retting as a source of fodder, wetland fisheries for domestic as well as economic sustenance. This vast water body is surrounded by entirely dependent bed villages; namely Gangadebi, Gopalpur, Damaipur, Kaliganj, Shimultala and Hazaratpur, (located at wetland edge up to a distance of 600 meter). On the other, Jalapur and Khanpur are considered as belt villages, relatively less dependent on Chakla wetland (located beyond 600 m up to 1 km) *(Map 5.2)*. Out of total 4,749 no. of households in bed villages *(Census of India, 2011)*, 237 households have been surveyed and out of 2,357 no. of households in belt villages *(Census of India, 2011)*, 117 households have been surveyed by following random sampling of 5% of universe in order to detail survey and analyse the utilization of Chakla wetland by the peripheral settlers.



Map 5.2: *Distribution of Bed and Belt Villages around wetland Chakla*

5.3.2.2 Wetland utilization for irrigation and cultivation:

Chakla wetland is an obvious source of water which is encompassed with extensive agricultural fields. The households, located in the bed village, solely depend on certain irrigation facilities and exploitation of available wetlands and water resources. In bed village, out of the total surveyed households (no. 237), 154 (64.98%) are engaged in cultivation, whereas in belt village, out of total households (no. 117), only 33 (28.2%) households are engaged in cultivation including cultivators and agricultural labourers *(Table 5.7) (Figure 5.7).*

Table 5.7 Utilization of Chakla wetland by households

Village	Village type	Total household	Cultivator (AL+CL household)	Fishing household	Wetland product collecting household	Cultivator+ Fishing household	Other
Gangadevi	Bed village	237	154	35	3	19	26
Gopalpur							
Damaipur							
Kaliganj							
Shimultala							
Hajratpur							
Jalapur	Belt village	117	33	19	0	8	57
Khanpur							

Source: *Primary Census Abstract, Census of India, 2011 & Field study, 2016-17*

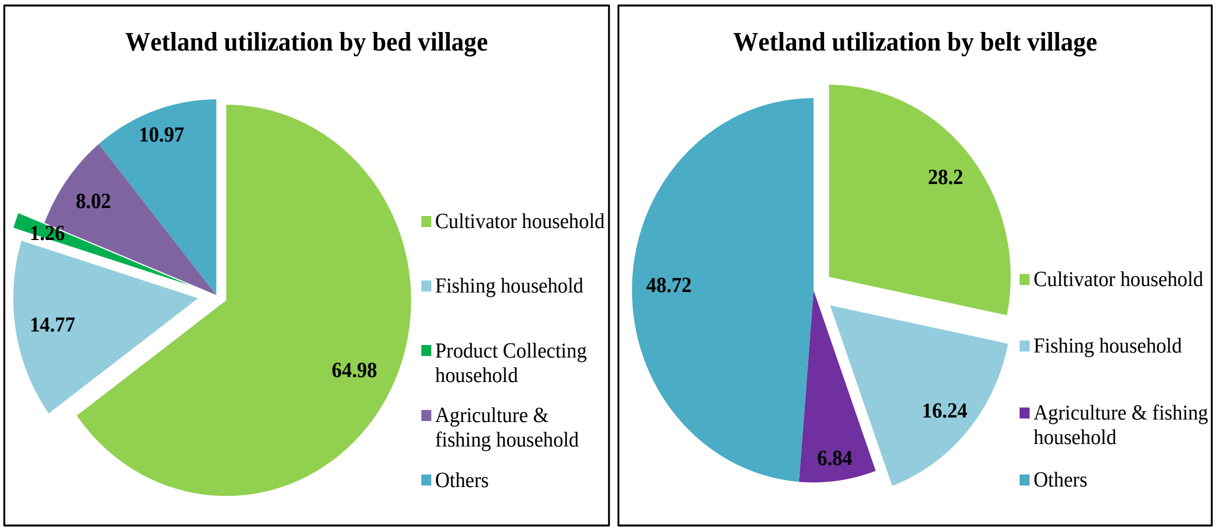


Figure 5.7: *Utilization of Chakla wetland by households*

All the surveyed households in the bed village, who are engaged in cultivation (no. 154), utilize the wetland water (Chakla) for irrigating their farm lands, whereas in the belt village, out of the total cultivators (no. 33), 21 numbers of households (63.64%) utilize Chakla wetland and 12 (36.36%) no. of households do not utilize this particular wetland *(Table 5.8) (Figure 5.8)* which is attributed to distant location from this water body. As per the household survey, out of total 93.5 ha land under cultivation, 10.74 ha (11.49%) is irrigated with the help of Chakla wetland water *(Appendix-10)*, in which paddy in 7.79 ha, pulse in 1.82

ha and jute in 1.13 ha are cultivated. The land holders use the pump set or indigenous system for irrigation. In the present study, the field observation reveals that number of pumps sets (shallow pump) are operated round the year, which are considered the main source of irrigation for vast cultivable fields, surrounding Chakla wetland.

Table 5.8 Utilization of Chakla wetland for irrigation and cultivation

Village type	Cultivator (household)	Wetland utilized	(%)	Wetland un-utilized	(%)
Bed village	154	154	100	0	0
Belt village	33	21	63.64	12	36.36

Source: *Field survey, 2016-17*

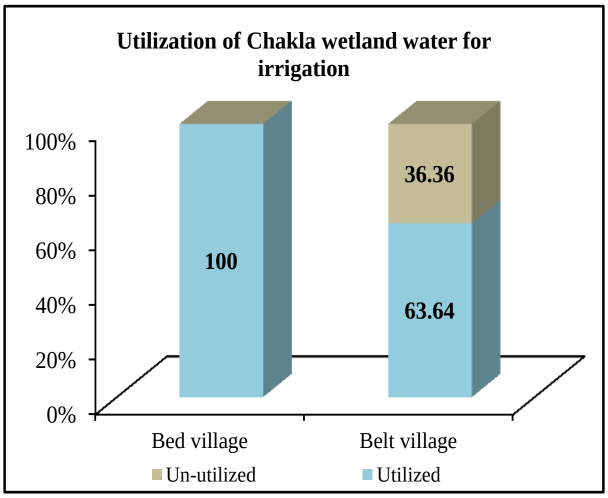


Figure 5.8: *Utilization of Chakla wetland water for irrigation*

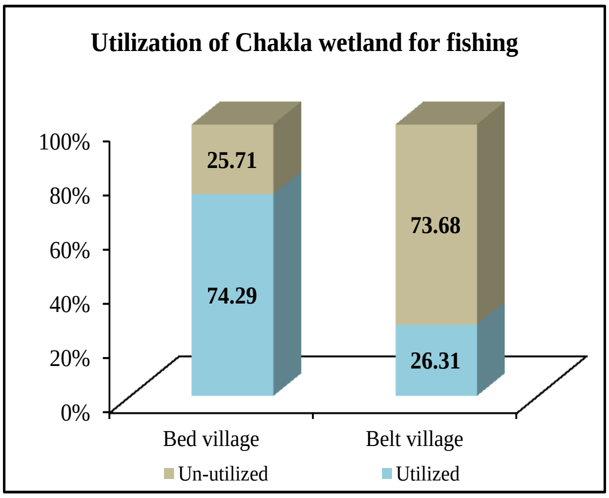


Figure 5.9: *Utilization of Chakla wetland for fishing*

Among the cultivated crops with the help of Chakla wetland water, paddy (Aman, Boro) and jute are the dominant crops in and around wetland bed especially by the bed villagers *(Plate 5.10 & 5.11)*. During the pre-monsoon season, when the wetland bed dries up, cultivation becomes a most common practice by the farmers especially of bed villages. The agricultural labourers and cultivators, residing in bed villages, generally get two crops per year at the immediate vicinity of wetland whereas, the farmers having land in the water spread area, at some distant location from the wetland bed, get single crop *(Mukherjee, 2008)*, because during the monsoon months, some portion of agricultural land in and around this wetland remain completely or partly under the water. Boro paddy, which is considered much remunerative, is cultivated during November to February. A large section of the settlers utilize the wetland water as their main source of irrigation for the boro paddy cultivation and seasonal vegetables. A common variety of paddy named as *'Jaya'* is being frequently cultivated by the households, but not that much commercially worth according to the cultivators. Along with food crops, Jute is the cash crop, which supplements the household economy. During the monsoon period, the field surrounding this wetland gets submerged and except jute, no other crops could withstand the standing water. Beside Paddy and Jute, rabi crops (Wheat, Mustard, Kalai, Potatoes) etc. are well grown crops with the appearance of this water body. Mustard is generally cultivated from October to December, whereas Kalai is cultivated during August to December at the agricultural field, adjacent to wetland. However, several difficulties are experienced by the cultivators in wheat cultivation which may be attributed to lack of proper water outlet and resulting water logging condition in agricultural field especially after the monsoon period. The deficit wheat cultivation is also attributed to persecuting rat dominance in the agricultural field as per interviewing the households. Apart from the mentioned crops, paniphal, one of the traditional water crops, is commercially cultivated as edible fruits in this wetland of Malda district.

Plate 5.10: *Aman paddy cultivation during monsoon*

Plate 5.11: *Jute cultivation during pre-monsoon*

5.3.2.3 Wetland utilization for fishing:

Fishing is a constituent source of food and additional source of income for local villagers and fishermen, who are repeatedly found in and around this wetland. The Chakla wetland is a typical example of middle Ganga wetlands, which was once one of the very momentous water bodies of Malda district for the fish cultivation. Presently Fishing practice has been decreased as well as altered into crop (food and cash crop) cultivation. But still it provides food and shelter to a large number of aquatic fauna and shelters many fresh water fish species. The diversity of fish species is citable, which performs a significant role in the trophic formation of this wetland. Out of the total surveyed household, bed village contains 35 numbers of households (14.77%), whereas belt village holds only 19 (16.24%) households, engaged in fishing practice including fish catch *(Table 5.7) (Figure 5.7) (Plate 5.12)*.

Table 5.9 Utilization of Chakla wetland for fishing

Village type	Fishing household	Wetland utilized	(%)	Wetland un-utilized	(%)
Bed village	35	26	74.29	9	25.71
Belt village	19	5	26.32	14	73.68

Source: *Field survey, 2016-17.*

The table clearly depicts that, in the bed villages a large number of households are engaged in fish cultivation and fish catch in comparison with the belt villages. Out of the total fishing households (35) in bed village, 26 (74.29%) households utilize this vast natural wetland for fish cultivation and catch. Among the fishing households of belt villages (19), only 5 (26.32%) households utilize this particular water body *(Table 5.9) (Figure 5.9)*, due to relatively distant location. Out of the total number of household a small section are fishermen and chiefly dominated by Muslim population. Their main occupation is to catch fishes and to sell it to the middleman, who ultimately takes it to the nearby markets, located at Gazole, Samsi and Malda town. At a time of about 20 years ago, Chakla wetland was a depot as one of the significant sources of variety of fishes, and pisciculture was the major occupation in this region. Presently, regular flood occurrences and the cheap supply of fish from Andhra Pradesh has discouraged the interest of the people, through which so many people, especially the Muslim community have started to shift their cottage from bed villages to different belt villages like, Khanpur, Gobindopur, Jalapur, since last few decades. Catla, Rohu, Boal, Tengra, Mrigel, Mourala, Chanda, Puti are the ample species, which are cultivated in this wetland throughout the year. Silver carp and Grass carp are other variety of fishes cultivated and caught from Chakla wetland. Five cooperative societies are in operation in Chakla wetland namely, Rampur Fishing Cooperative, Ojitpur cooperative, Goalpara cooperative, Boalia cooperative and Dhanga cooperative society. Fishing practice is done on lease basis by these cooperative societies for three to five years. The fishes, caught from the wetland are sold at random in the markets located at Samsi, Alal and Chanchal *(Plate 5.13)*.

Plate 5.12: *Fish catch at Chakla wetland*

Plate 5.13: *Fish sold at Samsi and Alal market*

5.3.2.4 Wetland utilization for cultivation and fishing together:

The settlers, especially from the bed villagers are the direct beneficiaries of Chakla wetland in the form of farming and fishing together. Generally, fish is cultivated after paddy harvest, when the fields are flooded *(Srinivasan, 2010)*. The bed village, adjacent to Chakla wetland, accounts a small number of 19 (8.02%) households to be engaged in crop cultivation and fishing together *(Table 5.7) (Figure 5.7)*, and all the households are dependent on wetland, either in the form of cultivation, or fishing or both, whereas the belt village records 8 (6.84%) households to practice both cultivation and fishing, in which 5 (62.5%) households are dependent on this particular wetland *(Table 5.10) (Figure No. 5.10)*.

Table 5.10 Utilization of Chakla wetland for cultivation and fishing together

Village type	Cultivation + Fishing household	Wetland utilized	(%)	Wetland un-utilized	(%)
Bed village	19	19	100	0	0
Belt village	8	5	62.5	3	37.5

Source: *Field survey, 2016-17*

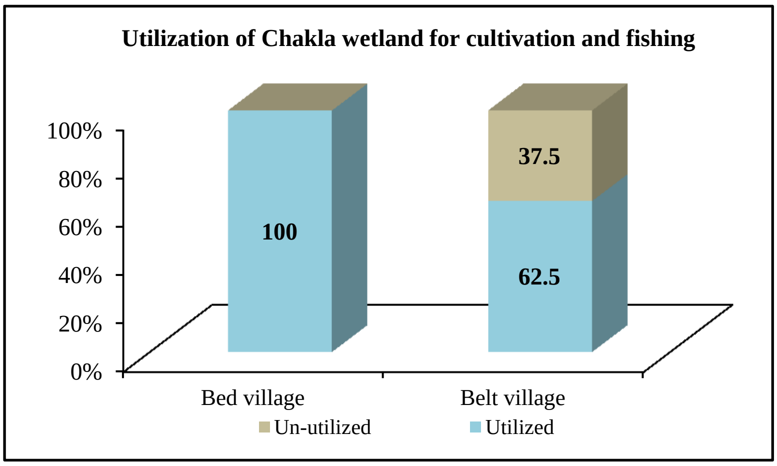


Figure 5.10: *Utilization of Chakla wetland for cultivation and fishing together*

5.3.2.5 Wetland utilization for product gathering:

Chakla wetland exhibits diverse plant composition on which number of people figure on. This wetland flourishes a number of valuable plants and animals, such as plant products**,** fish**,** forage etc. which can be harvested on a sustainable basis to provide an economic return. This wetland acts as the store house of kalmi, hingcha, sushni, thankuni etc. at the water edge, which are gathered by very small number of bed villagers for commercial purpose as well as for sustaining their economy. Out of the total households (no. 237) only 3 (1.26%) households residing in bed villages, at the closest proximity, gather different wetland products *(Table 5.7) (Figure 5.7)*. Macrophytes such as hingcha, kulekhara, and thankuni are used and consumed most efficiently as supplementary vegetables for its medicinal values. These aquatic macrophytes are observed to play substantial role in the local socio-economy i.e., edible plants, medicinal values, feed for livestock, green manure, and thatch cordage. Diversified macrophytes, found in wetland bed and along the wetland edge such as Kalmi Sak, Sushni, Ghima sak, are considered very significant for the day to day human diet and of salubrious consumption. Chakla wetland provides habitat and food to other diverse life forms, which are of major economic consideration. The paddy cultivation at the water edge harbors associated biodiversity i.e. nutritious food in the form of fish, mollusks etc. People belonging to the wetland periphery collect the most conspicuous wetland fauna like shell fishes *(Plate 5.14)*, local mollusks, tortoises and sell in the local market and hat at remunerative price. The market price has made it easier for the sellers to reveal the amount they save in every month through gathering diverse aquatic flora and fauna from this wetland *(Mukherjee, 2008)*. Apart from the mentioned usage, duck keeping is often practiced by the inhabitants, at the periphery of this wetland which is considered one of the sources of duck egg in malda market. Along with the other usage, cattle grazing are allowed on a small scale by the households, especially during the pre-monsoon, at water receding season. A small percentage of households use this wetland water for their daily usage in household works especially for washing purpose. Chakla wetland, being a vast natural water body, facilitates a large community from the adjacent bed and belt villages, belonging to the ailing sections of the society for their livelihood and nutriment.

Plate 5.14: *Shell fishes collected and sold at local market*

Plate 5.15: *Researcher with wetland utilized population*

5.3.2.6 Economic valuation of wetland:

Being a vast natural water body, large number of households are the direct beneficiaries of Chakla wetland for utilizing the wetland water in order to irrigate an area of about 10.74 ha as well as reduce down the cost of irrigation. Moreover, as per the household survey, total 55 no. of households, who are involved in fish cultivation and fish catch within this particular wetland, get an estimated gross benefit of Rs. 15,35,275.00 per annum (total production = 8,773 kg/annum; market price Rs. 175.00/kg). The fish cultivation is practiced on lease by the fishing cooperative society for Rs. 87,000.00 per annum. Therefore, the net estimated benefit from wetland fishing including fish cultivation and fish catch is recorded Rs. 14,48,275.00

per annum *(Table 5.11)*. According to the field survey, the fishing practice in Chakla wetland is found relatively less organized, which could otherwise; promote substantial economic sustenance to the local fishermen. Moreover, a few households especially from the bed villages gather several aquatic products for food, fodder, medicine round the year as well as sell in local market and get an estimated benefit of Rs. 21,600.00 per annum *(Table 5.11)*. Therefore, the estimated total benefit from Chakla wetland is recorded Rs. 14,69,875.00 per annum.

Table 5.11 Economic valuation of Chakla wetland

Sources of benefits and cost	Wetland fishing (cultivation+catch)
Total production + Total catch (kg/annum)	8,773
Market price (Rs./kg)	175.00
Gross benefit (Rs./annum)	15,35,275.00
Lease (Rs./annum)	87,000.00
Estimated net benefit from wetland fishing (Rs./annum)	14,48,275.00
Sources of benefits and cost	Wetland product gathering
Total income (Rs./annum/household)	7,200.00
No. of household gather wetland product	3
Total estimated benefit (Rs./annum) from product gathering	21,600.00
Total estimated benefit from wetland (Rs. /annum)	14,69,875.00

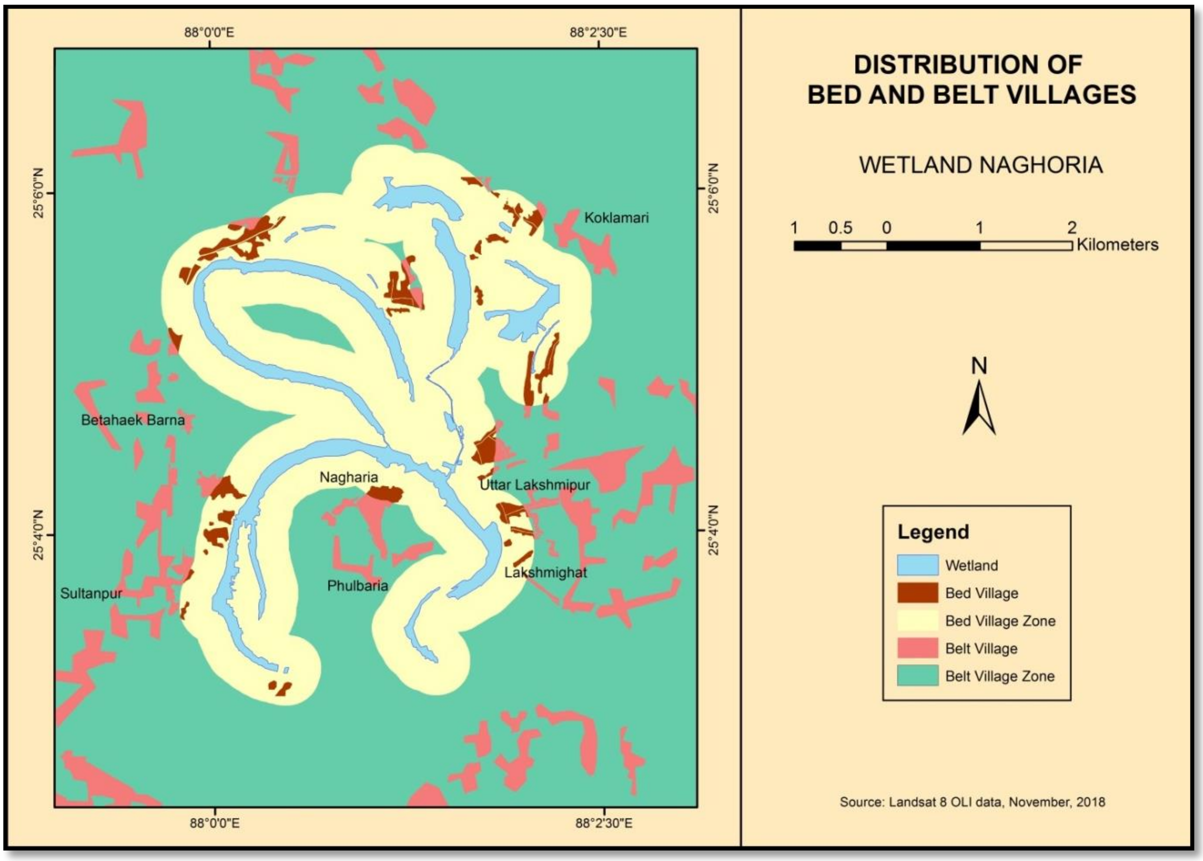
Source: *Field survey, 2016-17*

5.3.3 Naghoria wetland

5.3.3.1 Introduction:

Naghoria wetland, a cut off meander from River Kalindri, in English Bazar block provides an ideal opportunity to highlight its gravity in backing cultivation, especially since many family farming operations, rely on the water, soil, plant and animals found in this wetland to provide food security and ennoble their livelihood. Naghoria wetland is enclosed with three bed villages namely; Nagharia, Lakshmighat and Uttar Lakshmipur, (located at wetland edge up to a distance of 350 meter), whereas, Phulbaria and Koklamari are selected as belt villages (with a distance beyond 350 meter up to 800 meter) *(Map 5.3)*. Out of the total number of 3,309 household *(Census of India, 2011)* in bed villages, 5% of universe i.e. 165

households have been taken randomly and out of total 2,438 no. of households in belt villages, 122 households have been selected as well as surveyed in order to detail analysis on the utilization of Naghoria wetland, especially for the socio-economic livelihood of surrounding settlers. The socio-economic condition of these villages is moderately well. People residing in these villages are engaged mainly in cultivation and fishing, duck rearing, retailing and other economic activities. These characteristics are playing a positive role to the economy and society of the concerned village areas.



Map 5.3: *Distribution of Bed and Belt Villages around wetland Naghoria*

5.3.3.2 Wetland utilization for irrigation and cultivation:

The necessity of cultivation for a flat, productive tract with a ceaseless supply of water from Naghoria wetland, are often a potentially valuable agricultural resource. The agricultural land is mostly double cropped, as the entire land is composed of thick and fertile silt along with the proper irrigation facility of the wetland water. Out of the total surveyed household (no. 165) in bed village at the closest contiguity, 115 households (69.7%) are engaged in cultivation, whereas out of 122 households in belt village, 45 numbers (36.89%)

are engaged in cultivation *(Table 5.12) (Figure 5.11)*. In bed villages, out of the total cultivator households (115), majority of them i.e. 87 (75.65%) households utilize this wetland water in order to provide food security as well as improve their livelihood.

Table 5.12 Utilization of Naghoria wetland by households

Village	Village type	Total household	Cultivator (AL+CL household)	Fishing household	Cultivator+ Fishing household	Duck rearing household	Other
Naghoria Lakshmighat Uttar Lakshmipur	Bed village	165	115	25	8	9	8
Phulbaria Koklamari	Belt village	122	45	11	3	0	63

***Source:** Primary Census Abstract, Census of India, 2011 & Field survey, 2016-17*

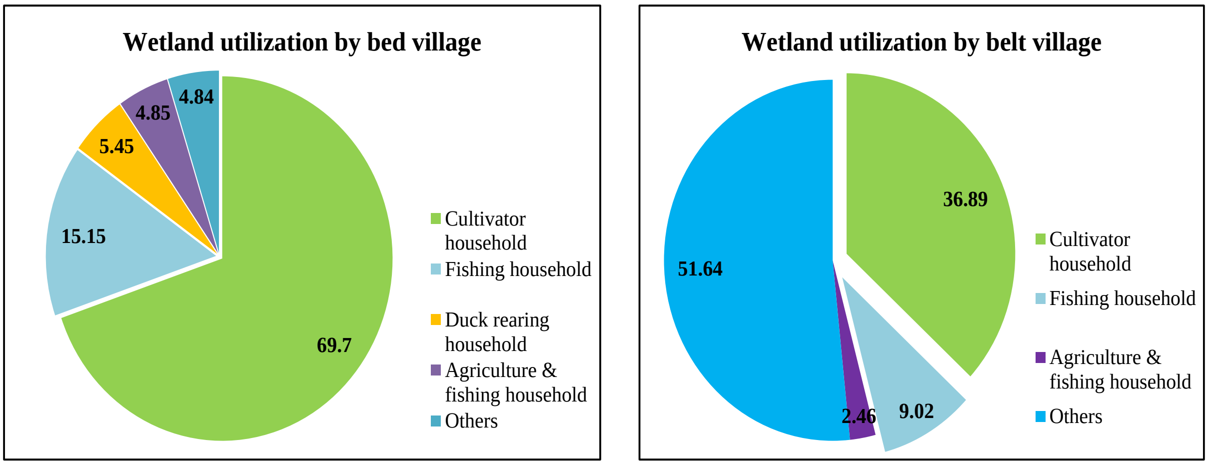


***Figure 5.11:** Utilization of Naghoria wetland by households*

Table 5.13 Utilization of Naghoria wetland for irrigation and cultivation

Village type	Cultivator (household)	Wetland utilized	%	Wetland un-utilized	%
Bed village	115	87	75.65	28	24.35
Belt village	45	0	0	45	100

***Source:** Field survey, 2016-17*

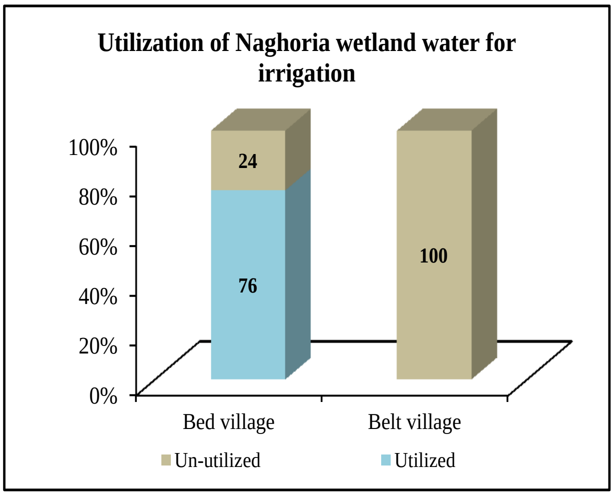


Figure 5.12: *Utilization of Naghoria wetland water for irrigation*

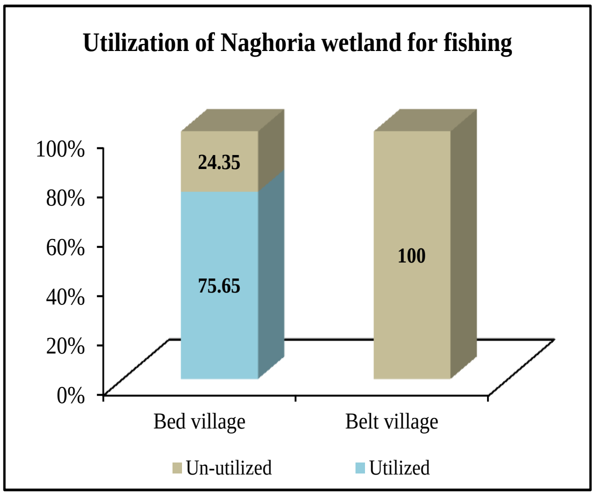


Figure 5.13: *Utilization of Naghoria wetland for fishing*

On the contrary, the cultivator households in the belt village do not utilize this particular wetland for irrigation purpose, which may be caused due to locating far off from the wetland bed *(Table 5.13) (Figure 5.12)*. In the present study, out of the total 65.6 ha area under cultivation, a total of 6.23 ha (9.50%) area, at the closest proximity, is irrigated with the help of Naghoria wetland water *(Appendix-10)*, in which paddy in 3.64 ha, pulse in 1.29 ha, maize in 0.81 ha and jute in 0.49 ha are cultivated. The major crops are paddy (Aush, Aman, and Boro), vegetables, pulses, mustard and mixed crops. Boro paddy is considered a key crop, which starts at the end of November, and is cultivated along the wetland edge of Naghoria. Beside boro; aush and aman paddy are also cultivated at wetland edge with the help of wetland water as zaid and kharif crop respectively. Jute is frequently cultivated cash crop and the availability of water is an additional advantage, which help the people in jute retting, especially those, residing at the close vicinity of this wetland *(Plate 5.16)*. Additional crops are Maize *(Plate 5.18)*, which is cultivated from March to July; Bajra, Kalai and Arhar *(Plate 5.17)* are cultivated during August to November and December. Although, there is fertile and productive cultivable land, most of it has gradually been converted into mango orchards during last few decades, through which per hectare monetary return is excessively high. Simultaneously, the practice of crop cultivation of pulses, vegetables and sometimes aman *(Plate 5.19)* and aush paddy through large land holdings, including mango orchards supplement the household economy of both bed and belt villagers. Commercialization of mango, including their familiarity has encouraged the settlers to shift from sole crop cultivation to the combination of mango orchards and other crops.

Plate 5.16: *Aush paddy and Jute cultivation during pre-monsoon*

Plate 5.17: *Arhar cultivation with wetland water during post-monsoon*

Plate 5.18: *Maize cultivation with wetland water*

Plate 5.19: *Aman paddy cultivation during monsoon*

5.3.3.3 Wetland utilization for fishing:

Fishing is an additional source of income for the peripheral settlers and fishermen, who are frequently found in and around Naghoria wetland. In comparison with the agricultural activity, small numbers of households are engaged in fishing practices in Naghoria wetland. Fish is not cultivated in Naghoria wetland because of having no cooperative society. The households, residing in bed village, at a close vicinity to this wetland are engaged only in fish catch, along with crop cultivation throughout the year. Out of the total households in bed village (165), 25 number of households (15.15%) are engaged in fish catch, whereas in belt village (no. 122 households), only 11 (9.02%) no. are found as fish catching households *(Table 5.12) (Figure 5.11) (Plate 5.20)*. In the present study, out of the total fishing households (25) in bed village 19 (76%) households are dependent on Naghoria wetland for fish catching. The mentioned table *(Table 5.14) (Figure 5.13)* reveals a reverse picture in case of belt village, where the total number of fishing households do not utilize this particular water body for fish catch.

Presently, dominant fish species which are usually caught in Naghoria wetland include, Bata, Kalbaush, Catla, Koi, Mangur, Prawn, Rohu, Tangra. As this cut off is well connected with River Kalindri, some of the fishes migrate between wetland and the river and a middling number of riverine fish species have amalgamated here. The commercially important fishes like, Catla, Khera, Kalbaush, Mangur and Prawn are also found as well as caught by the fishermen. The fishermen catch fishes round the year and sell them to Bichitra market, which is considered the main wholesale market of this region and Amriti hat in nearby Malda town.

Table 5.14 Utilization of wetland for fishing

Village type	Fishing household	Wetland utilized	%	Wetland un-utilized	%
Bed village	25	19	76	6	24
Belt village	11	0	0	11	100

Source: *Field survey, 2016-17*

Plate 5.20: *Fish catch at Naghoria wetland*

Plate 5.21: *Duck rearing at Naghoria wetland*

5.3.3.4 Wetland utilization for cultivation and fishing together:

The household survey at field visit reveals that, as fish cultivation is completely absent in Naghoria wetland, the households under bed village use this wetland mainly for crop cultivation (food and cash crop) along with fish catch. The table *(no. 5.15)* depicts that, out of the total surveyed households in the bed village, 8 (4.85%) households are engaged both in crop cultivation and fish catch together *(Figure 5.14)*, in which most of the households (87.5%) are dependent on Naghoria wetland. Whereas, in belt villages only 3 (2.46%) households practice crop cultivation and fish catch together in order to sustain their economy, although they do not utilize this particular water body.

Table 5.15 Utilization of wetland for cultivation and fishing together

Village type	Cultivation + Fishing household	Wetland utilized	%	Wetland un-utilized	%
Bed village	8	7	87.5	1	12.5
Belt village	3	0	0	3	100

Source: Field survey, 2016-17

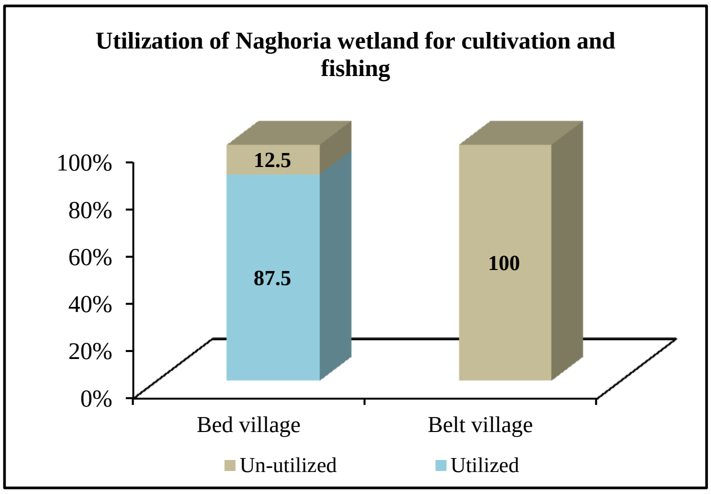


Figure 5.14: *Utilization of Naghoria wetland for cultivation and fishing together*

5.3.3.5 Wetland utilization for duck rearing:

As per the field study, 9 numbers (5.45%) of households are found to be involved in duck rearing within Naghoria wetland *(Table 5.12) (Figure 5.11)*. Duck rearing *(Plate 5.21)* is also considered economically significant as well as one of the important source of duck eggs in nearby Bichitra market and Green park market of Malda town, which is just 12 km away from this wetland, and finally supplement the household economy to some extent for the people living at the vicinity of the wetland. Apart from the mentioned usages, this wetland is negligibly used for cattle grazing especially during the pre-monsoon by bed villagers when this cut-off partially dries off. The wetland bed and its fringe area harbor thick vegetation and support appreciable assemblage of both open water and water edge macrophytes like Kutipana, Paniphal, Water fern, Ghima, Kalmi, Kulekhara, Hatisur etc. These wetland products are not gathered by the villagers presently in an organized manner, which has been known from the field study. Moreover, jute, reeds and many grasses are used for fiber and woody plants are used for the fuel consumption. The households, residing in the bed villages use this wetland water for domestic purpose in washing cloths and utensils.

5.3.3.6 Economic valuation of wetland:

Naghoria wetland, as observed during the field study, provides ample opportunity to the associated households in order to enhance their economic well-being both in terms of cultivation, irrigation and fish catch. Naghoria wetland is considered one of the very few wetlands of the Malda district, which facilitates the irrigation potential to paddy crops (aush, aman and boro) along with other food and cash crop round the year, covering a total area of 6.23 ha, with the help of wetland water.

Table 5.16 Economic valuation of wetland

Sources of benefits and cost	Wetland fishing (fish catch)
Total catch (kg/annum)	3500
Market price (Rs./kg)	250.00
Total benefit (Rs./annum)	8,75,000.00
Lease (Rs./annum)	0
Total benefit from wetland fishing (Rs./annum)	8,75,000.00

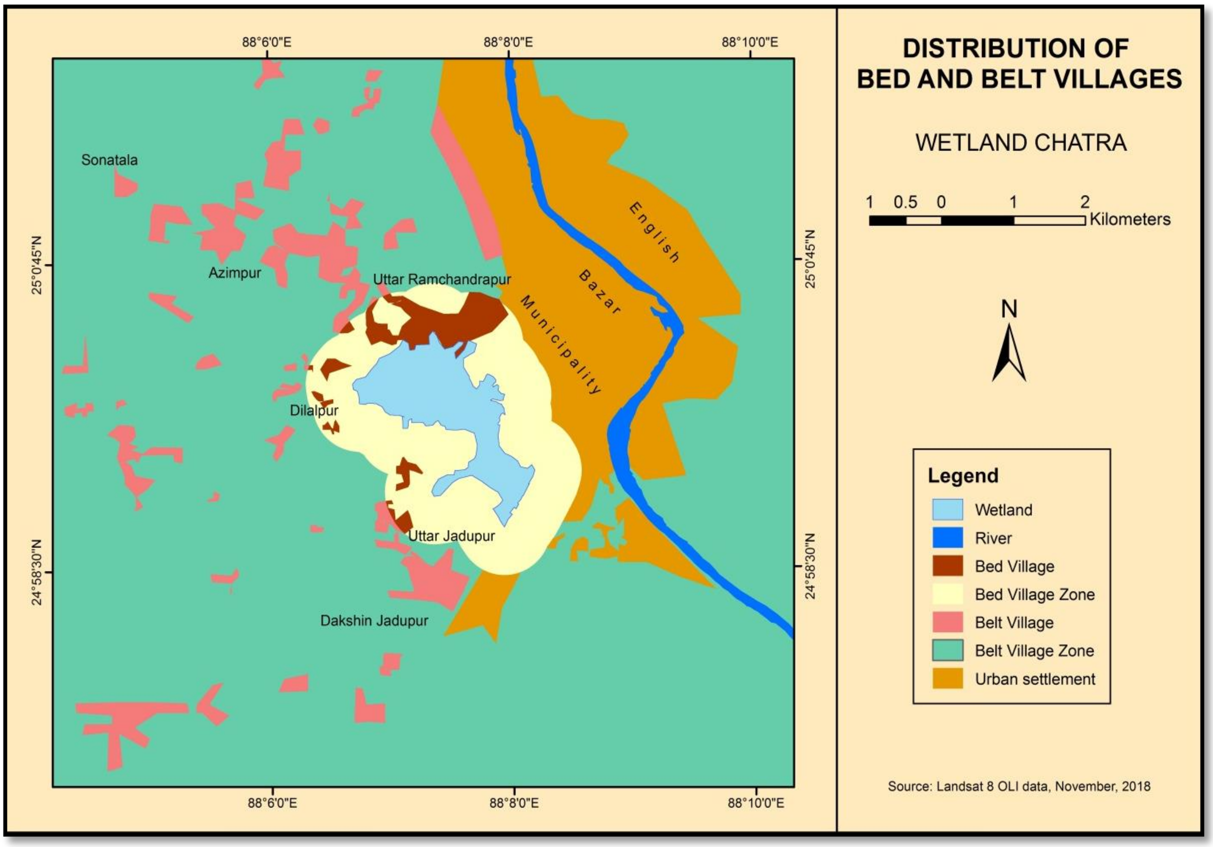
Source: *Field survey, 2016-17*

Apart from the irrigation and cultivation, the field study has recorded a good amount of benefit from the wetland fishing only in the form of fish catch. Although, the fish cultivation is not practiced in Naghoria wetland, the beneficiaries (26 no. of households) catch the available fish fauna, sell it to the local and main market as well as get an estimated total benefit of Rs. 8,75,000.00 per annum (Total catch = 3,500 kg/annum; market price = Rs. 250.00/kg). As, wetland product gathering is not practiced by the local villagers in an organized manner, an estimated total benefit from this cut off meander of River Kalindri is recorded Rs. 8,75,000.00 per annum *(Table 5.16)*.

5.3.4 Chatra wetland

5.3.4.1 Introduction:

Chatra wetland is a significant peri-urban wetland which forms an important component of the entire ecosystem and environment because of having ample biological, ecological, social and economic values. In accordance with other studied water bodies, this wetland is potential to retain substantial water resource to meet the requirement in the peripheral areas. Moreover, Chatra wetland provides a number of valuable plants and animals, such as plant products, fish, forage etc. which can be harvested on a sustainable basis to provide substantial economic return. The wetland has unique location as it is enclosed by villages in the north-west, west and south-west side whereas, the entire eastern portion including north and south-east are surrounded by municipal wards and at a very close proximity. The wetland is generally utilized by village populace in the form of cultivation, fishing, gathering several wetland products and makhana cultivation. The villages namely; Uttar Ramchandrapur, Uttar Jadupur, Dilalpur and Arazi Dilalpur have been considered as bed villages, to be wholly dependent on Chatra wetland (located at wetland edge up to a distance of 650 meter), whereas Sonatala, although an urban area (CT) as per census 2011, has been considered as the only belt village (located 3 km far off this water body) to utilize the wetland water only for commercial cultivation (Makhana), *(Map 5.4)*. Apart from the mentioned belt village, no other belt villages utilize Chatra wetland, as are entirely dependent on tertiary sector of economy and on brick kiln industries. However, out of total 2,672 no. of households in bed villages *(Census of India, 2011)*, 193 households are selected, whereas, in belt villages, out of 2,241 no. of households *(Census of India, 2011)*, 134 households are selected randomly (5% of universe) and surveyed for further detail analysis regarding the utilization of this peri-urban water body. Among the bed villages, Arazi dilalpur does not account any household, as it is entirely under the wetland water coverage.



Map 5.4: *Distribution of Bed and Belt Villages around wetland Chatra*

5.3.4.2 Wetland utilization for irrigation and cultivation:

Chatra wetland is highly productive, and facilitates a wide range of ecosystem services such as food, fiber, fish, timber, housing materials e.g., reeds, medicinal plants, provision of fertile agricultural land, constant water supply by irrigation for the arable usages. The inhabitants, residing in and around this peri-urban water body, depend on wetlands for variety of economic activities such as farming, collection of fish, shellfish, leafy vegetables, grazing, domestic uses, etc. The field study reveals that, the utilization of wetland is considered highest for cultivation in the form of food crop and especially for makhana cultivation on wetland bed. Out of the total surveyed households in bed village (no. 134), 42 (26.12%) households are engaged in cultivation, whereas in belt village (surveyed 59 households) 40 households (25.42%) including cultivators and agricultural labourers are engaged in cultivation *(Table 5.17) (Figure 5.15)*.

Table 5.17 Utilization of Chatra wetland by households

Village	Village type	Total household	Cultivator (AL+CL household)	Fishing household	Wetland product collecting household	Other
Uttar Ramchandrapur Uttar Jadupur Dilalpur	Bed village	134	42	12	9	71
Sonatala (CT)	Belt village	59	40	0	0	19

Source: *Primary Census Abstract, Census of India, 2011 & Field survey, 2016-17*

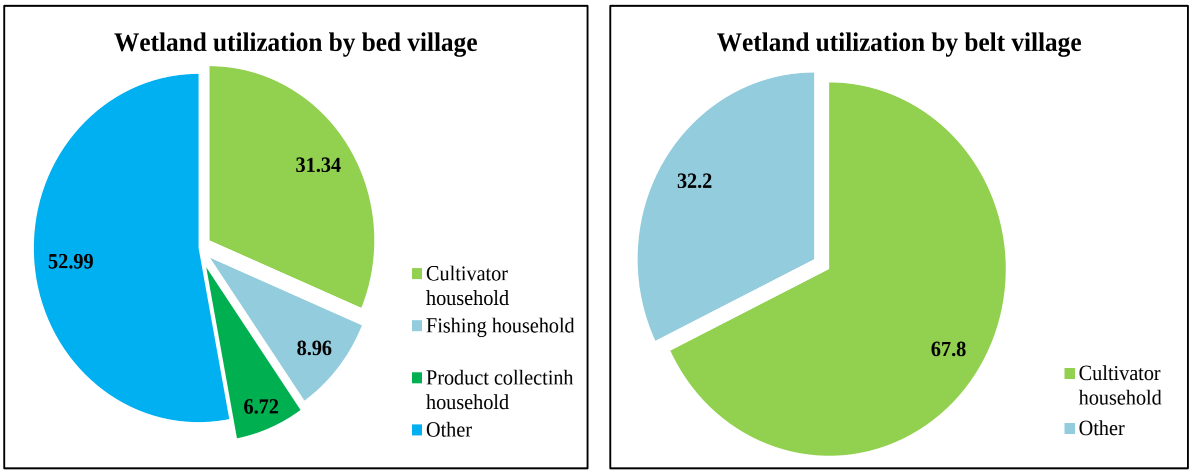


Figure 5.15 *Utilization of Chatra wetland by households*

Chatra wetland acts as an obvious source of water for the agricultural use, which is considered one of the major occupations of the surrounding inhabitants, especially of bed villages. Out of the total cultivated area of 35.26 ha, this wetland acts as water source in order to irrigate a total of 1.82 ha (5.16%) area *(Appendix-10)* for cultivating principal crops namely, aman and boro paddy *(Plate 5.22)*. Paddy fields are kept under wetland water for a major part of the year.

Table 5.18 Utilization of wetland for irrigation and cultivation

Village type	Cultivator (household)	Wetland utilized	%	Wetland un-utilized	%
Bed village	42	27	64.29	15	35.71
Belt village	40	33	82.50	7	17.50

Source: *Field survey, 2016-17*

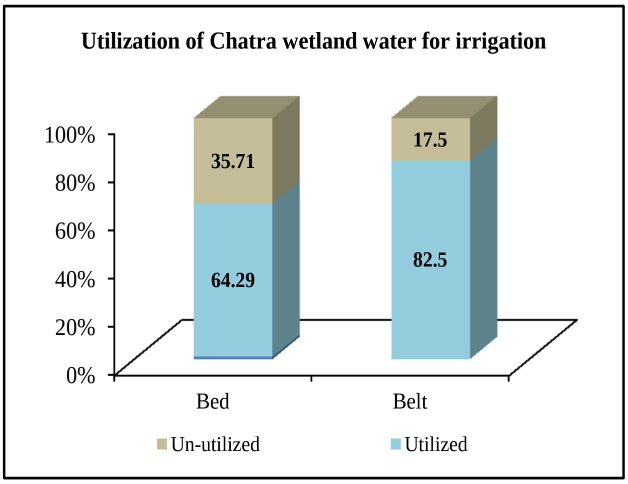


Figure 5.16 *Utilization of Chatra wetland water for irrigation*

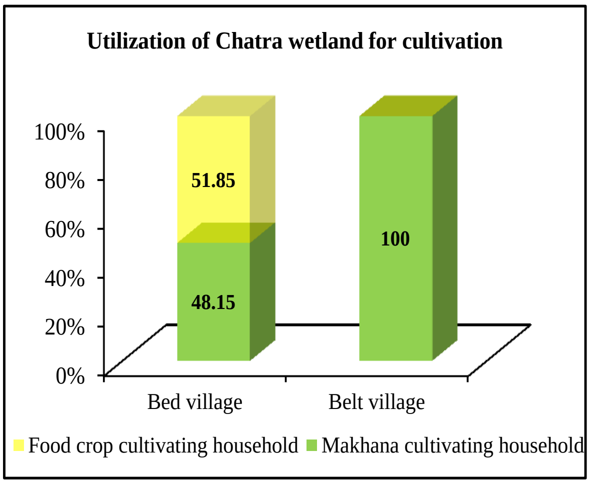


Figure 5.17 *Utilization of Chatra wetland for cultivation*

Out of the total cultivator households (no. 42), 27 (64.29%) households utilize this wetland water whereas, 15 (35.71%) households do not utilize this particular water body for irrigation purpose. In belt village, 33 (82.5%) households directly rely on Chatra wetland for cultivation as well as use the wetland water in order to irrigate their crop lands *(Table 5.18) (Figure 5.16)*. The field study reveals that in belt village, almost all the agricultural households are associated with makhana cultivation over a large area on Chatra wetland bed.

5.3.4.2.1 Makhana cultivation in wetlands:

The greatest benefit that is likely to be achieved is makhana cultivation on Chatra wetland bed. In the early nineties, this geo-plant was observed in Harishchandrapur block. Slowly, it extended out in other blocks especially in English Bazar and got introduced in Chatra wetland from 2003. Among the agricultural household, a significant number are presently engaged in makhana cultivation rather than food crop cultivation. Makhana practice is being dominated in the belt rather than the bed villages. From the frequent observations and household survey, it has conspicuously been noticed that the villagers of Sonatola and Uttar Jadupur are massively engaged in makhana practice rather than fishing, and varied pockets of this wetland is progressively roofed with this hydrophyte at the monsoon months when the water is at its peak. Chatra wetland is leased out zone wise by Uttar Jadupur Gram Panchayat for 3 years to the cultivators for makhana practice within wetland water *(Plate 5.23)*. In the bed villages, out of the total cultivator households (no. 27) to utilize Chatra wetland, 13 households (48.15%) are engaged in makhana cultivation, whereas 14 (51.85%) households cultivate food crops in kharif and rabi seasons. In the belt village, the entire cultivator households are actively inclined to makhana cultivation within this particular water body *(Table 5.19) (Figure 5.17)*. Moreover, most of the people's livelihoods in both the bed and belt villages are solely dependent on makhana cultivation and processing. The present study exhibits that the number of households, engaged in fish catch is relatively less, compared to other case studies, which is attributed to major shifting of fishermen to more profitable crop cultivation in the form of makhana in Chatra wetland bed.

Table 5.19 Utilization of wetland for makhana and food crop cultivation

Village type	Cultivator (household)	Wetland utilized	Makhana cultivating household	%	Food crop cultivating household	%
Bed village	42	27	13	48.15	14	51.85
Belt village	40	33	33	100	0	0

***Source:** Field survey, 2016-17*

***Plate 5.22:** Boro Paddy cultivation at Chatra wetland during post-monsoon*

***Plate 5.23:** Makhana cultivation in wetland bed*

5.3.4.3 Wetland utilization for fishing:

In Chatra wetland, fish is not cultivated due to absence of any fishing cooperative in English Bazar block, but still it promotes immense potential for fishing household in the form of employment generation and several other associated sources of income. Further, it is the place of intense biological activity including the breeding of many species of fishes and aquatic organisms. In the present study, table 5.17 reveals that out of the total household in bed village (no. 134), only 12 (8.96%) households are engaged in fish catching, which are directly dependent on this particular wetland. On contrary, no households of belt village are found to be engaged in fish catch within this particular wetland, as those are entirely devoted to makhana cultivation during last few decades *(Table 5.20) (Figure 5.18) (Plate 5.24)*.

Table 5.20 Utilization of wetland for fishing

Village type	Fishing household	Wetland utilized	%	Wetland un-utilized	%
Bed village	12	12	100	0	0
Belt village	0	0	0	0	0

Source: *Field survey, 2016-17*

The uniqueness of this peri-urban wetland is still characterized by fish faunal diversity, which constitutes the fresh water species such as Chanda, Tangra (big and small), Punti, Mangur, Bacha, Bata etc. A small amount of commercially important fish species like Kalbaush, Bot koi, Khalisa, Mangur etc. are also caught from this wetland. The diverse available fish species, caught by the fishermen are sold to the local hat and market at Malanchapalli, Krishnapalli, Mokdumpur and Bichitra markets of Malda town as well as sustain the livelihood and economy of peripheral settlers *(Plate 5.25)*. According to the field survey, it has clearly been observed that the proportion of households engaged in cultivation and fishing together record negligible. The reason behind is the fishing practice, done in an unorganized manner and only in the form of fish catch in this wetland. Further, majority of the cultivator households irrespective of bed and belt villages are makhana cultivators. And along with makhana cultivation, fishing practice is generally not done because before sowing the seeds, the water needs to be completely sterilized by applying the organochlorine insecticide (Endousulphun group), which poses considerable threat to the oxygen demanding biodiversity and aquatic life. That is why, with the introduction of this aquatic gloating crop, the fishing practice has been hampered as well as restricted in several pockets of this water body. Moreover, the less oxygen demanding fishes (Shingi, Koi, Magur) float freely beneath the makhana covered wetland water. That is why, the households of peripheral villages records a major shifting of wetland based fishing occupation, which has been altered by makhana cultivation during last several years.

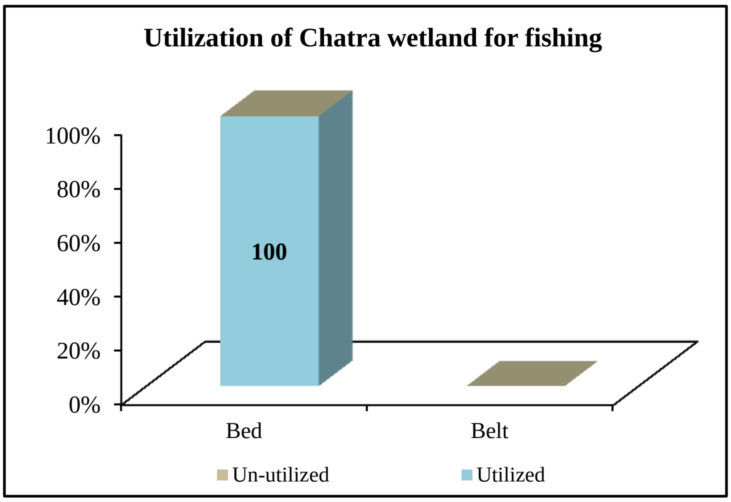


Figure 5.18 *Utilization of Chatra wetland for fishing*

Plate 5.24: *Fish catch at Chatra wetland*

Plate 5.25: *Fish sold at Mokdumpur and Bichitra market*

Plate 5.26: *Teuthowenia pellucida (Gugli) collected and sold at Bichitra market. Malda*

Plate 5.27: *Duck rearing at Chatra wetland*

5.3.4.4 Wetland utilization for product gathering:

Chatra wetland is mostly significant for the survival of diverse flora and fauna. Out of total surveyed households, 9 households (6.42%) *(Table 5.17) (Figure 5.15)* are engaged in gathering several wetland products throughout the year. The macrophytes, collected in the form of open water and water edge vegetation, include ghima, hatisur, hingcha, kalmi and kulekhara which constitute an indispensible component of wetland ecosystems as well as a principal source of food in the food chain of the aquatic animals and fish fauna. Among the available macrophytes the traditional uses of aquatic medicinal plants of thankuni, hingcha, kulekhara etc. are of immense potential. Chatra wetland is roofed with thick coverage of water hyacinth (Kachuripana), which is collected by the peripheral settlers as fodder. This fodder is considered a cheap source of food in order to reduce down the cost of feeding the cattle population, because the fodder available in the local market is quite expensive *(Ramachandra et al., 2005)*. Apart from diverse fish composition, gugli *(Plate 5.26)*, snakes and frogs are common, fed on shellfishes, leeches and other worms, insects etc. which are collected and sold in the local market, as well as supplement the household economy to some extent for the people living in the close proximity of this wetland. Furthermore, duck keeping and rearing is regularly practiced into Chatra wetland by adjacent households *(Plate 5.27)* and the duck eggs are sold to nearby Bichitra and Mokdumpur market. At the same time, this wetland also yields fuel wood for cooking and heating as well as provides food for the entire Malda town and has numerous socio-economic values attached to it.

5.3.4.5 Economic valuation of wetland:

Chatra wetland is considered an important source of economic sustenance especially for those households, who directly and indirectly utilize this water body. The wetland water is utilized substantially in order to irrigate 1.82 ha area, entirely under paddy cultivation. Apart from paddy, no other food crops are significantly found to be cultivated around this water body.

As per the household survey, Makhana is cultivated on 25.2 ha of the wetland bed on lease by Uttar Jadupur Gram Panchayat by a total 46 no. of households. The gross benefit of surveyed household is recorded Rs. 56,70,000.00 per annum, whereas the total cost in the form of labour cost (Rs. 1,89,000.00/annum) (for preparing makhana cultivating filed) and lease cost (Rs. 2,83,500.00/annum) is recorded Rs. 4,72,500. Therefore, the estimated net benefit from makhana cultivation within Chatra wetland is recorded Rs. 51,97,500.00 per annum *(Table 5.21)*. As per the filed survey, apart from makhana cultivation, fish catching is practiced in Chatra wetland by 12 no. of households, which accounts relatively less monetary value with an estimated benefit of Rs. 4,62,500.00 per annum (Total catch = 1850 kg/annum; market price Rs. 250.00/kg). Fish is not cultivated in Chatra wetland, primarily because; no fishing cooperative is in operation. Secondly, this water body is mostly dominated with makhana cultivation, which creates several complications and hindrances to simultaneous fish cultivation. That is why; the fish cultivation has drastically been declined during the last several years, which eventually leads to further economic loss. Moreover, this peri-urban water body holds good proportion of beneficiaries, to gather several aquatic products in the form of macrophytes and aquatic fauna, which accounts an estimated benefit of Rs. 76,500.00 per annum. Therefore, the total estimated benefit by utilizing Chatra wetland by the surveyed households is recorded Rs. 57,36,500.00 per annum *(Table 5.21).*

Table 5.21 Economic valuation of Chatra wetland

Sources of benefits and cost	Makhana cultivation
Gross benefit (Rs./annum)	56,70,000.00
Area under wetland cultivation (ha)	25.2
lease + labour cost (Rs./annum)	4,72,500.00
Estimated Net benefit (Rs./annum)	51,97,500.00
Sources of benefits and cost	Wetland fishing (fish catch)
Total catch (kg/annum)	1,850
Market price (Rs./kg)	250.00
Total benefit (Rs./annum)	4,62,500.00
Lease (Rs./annum)	0
Net estimated benefit from wetland fishing (Rs./annum)	4,62,500.00
Sources of benefits and cost	Wetland product gathering
Total income (Rs./annum/household)	8,500.00
No. of household gather wetland product	9
Total estimated benefit (Rs./annum) from product gathering	76,500.00
Total estimated benefit from wetland (Rs. /annum)	57,36,500.00

Source: *Field survey, 2016-17*

5.4 Wetland potential as alternate economic support:

The present study reveals that, the entire wetland resource of Malda district are of immense potential in order to provide alternate economic support to rural mass through generating gainful self-employment along with displaying a marvelous nutrient dynamics. These wetlands with their abundant biotic assemblage are potential to provide subsistence for a large number of inhabitants in the form of makhana (*Euryale ferox),* Paniphal (*Trapa natans)* and sola (*Aeschynomene aspera)* cultivation during monsoon and post-monsoon along with duck keeping and rearing. There is a scope in revenue generation by practicing makhana in a vast area of the wetlands under *Tal* and *Diara* region, which is associated with numerous economic benefits. Moreover, Makhana cultivation plays substantial role in the local socio-economy in the form of having nutritional value and medicinal importance, whose calorific value compares well with the staple food materials such as wheat, rice, etc. During field study, small distribution of sola, a little branched stout herb has been observed and identified in several wetlands under *Diara* region, which contains significant potentialities in providing nitrogen input in soil in order to enhance the agricultural productivity (especially rice). The green manure with sola is presently recognized as the most efficient way to transform the biologically fixed nitrogen into soil *(Devi, 2013)*. Furthermore, sola is potential in order to provide indigenous handicrafts, which occupy a unique position in India's heritage of handicrafts *(Mandal et al., 2014)*. Moreover, paniphal can commercially be cultivated within wetlands under study as edible fruits which are potential to provide alternate economic return on a sustainable basis to the rural mass of Malda district. Apart from cultivation and fishing, duck rearing within the wetlands, under study contributes to the rural livelihoods as an important part in the agricultural economy. The potentials of duck farming can be tapped to alleviate poverty among the rural communities in and around wetland. Furthermore, the potent duck rearing and farming also provide manure in order to improve the soil fertility of agricultural lands *(Jha & Chakrabarty, 2017)*.

5.5 Conclusion:

The present chapter is focused on the socio-economic valuation and aesthetic importance of wetlands under study. Given their importance for ample water supply and food production, wetlands are considered a principal element for achieving the goals of poverty alleviation in this less developed district of West Bengal. Moreover, the wetlands under study have the potentiality in order to provide alternative economic support to the rural people through generating gainful self-employment. The use of wetlands are dynamic in nature, which vary with space (e.g., across different physiographic zones) as well as time (e.g., across different seasons). The wetland utilization also changes across years depending upon the interest and capability of the stakeholders *(Das et al., 2015)*. In the present study, it is clearly evident that in spite of having potential influence of all the economic activities on wetland's ecology, it seems to be very dangerous for the survival of this ecosystem *(Irrinki & Irrinki, 2006-07)*. The economic and ecological functioning of these wetlands differs considerably, which may be attributed to economic, social as well as political pressure from dominant stakeholders. Wetlands in Malda district have already been affected by ever increasing human induced pressures, engineered by over exploitation of wetland resource, intensive agricultural and aquaculture, which eventually lead to increased loads of pollutants and disinfectants and several conflicting land-use practices. Despite the importance of the range of resources and services which wetland provides, inadvertence over the years and anthropogenic squeezes pose serious menace to the survival of this precious ecosystem. The most important threat arising from man induced willful pressures in the form of indiscriminate and unjust conversion of wetlands for cultivation, human habitation as well as over exploitation of wetland water and associated wetland products and other resources. But even as apathy and ignorance continue to permit conversion of wetlands, people are becoming increasingly aware of the loss of the services, which wetlands once provided free of charge (*Dugan, 1994*). Therefore, the wetlands under study area should immediately be conserved by ensuring their wise use where the sustainability of wetland is of prime importance. Therefore, addressing meaningful strategies, considering the present ecological condition of this aquatic ecosystem, people's participation and the role of non-governmental, educational and governmental organizations is required for the restoration, conservation and sustainable management of entire wetland resources of Malda district.

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Chapter – VI

CONSERVATION OF WETLANDS

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CONSERVATION OF WETLANDS

6.1 Introduction:

Conservation is a socio-economic and ecological paradigm, which is entirely concerned with the sustainable utilization of natural resources – the rate, purpose and efficiency of use *(Tiwari, 2006)*. Conservation is generally acquired through improvement and protection of natural resources including wildlife, water, air, and earth deposits and human resources in a wise manner, securing derivation of their maximum economic as well as social benefits for a long term. Conservation of natural resources is one of the most significant indicators of a country's development. The conceptual basis of conservation initially has emerged as a balanced approach to the management and conservation of natural resources implying a realization of controlled use *(Caldwell, 1990)* and develops a concern against over exploitation of natural resources. Conservation includes the sustainable management of human use of diverse natural resources for current public benefits and sustainable social and economic utilization.

In the present world, various kinds of ongoing developmental process involve progressive transformation of economy and society. As a consequence, environmental degradation has become a frequent occurring phenomenon, which is closely associated with an existing large sized population as well as the application of resource depleting and polluting technology. Environmental degradation not only constitutes a major threat to the economic development, but endangers the very existence on earth's life *(Saha, 2006)*. Wetlands are not exceptions as everywhere, every day, being silently filled up and tend to be one of the most threatened natural ecosystems all over the world. Wetland degradation is chiefly attributed to the increasing human populace, changing land use pattern, over utilization of wetland resources causing negative impressions on wild life, water quality, hydrological cycle and other crucial ecological functions. Since the world convention on environment in 1972 at Stockholm, Sweden, the government and statesmen in different countries became aware of the horrific situation of deteriorating natural ecosystem worldwide, and particularly in the developed countries. Further, the Rio Earth Summit in 1992 drew attention to the crisis resulting with global warming and loss of biodiversity *(Saha, 2006)*. And resultantly, the idea of integration between development and environment considerations has received world-wide attention through the deliberations and resolutions of the United Nations and other international organizations *(Stockholm Declaration, 1972, Bruntland, 1987, IUCN, UNEP & WWF, 1991)*. Therefore, a careful preservation and protection and a planned management of wetlands is awfully important, not even in terms of its intrinsic values and functions but because of numerous economic activities are based on this natural ecosystem.

6.2 Wetland conservation:

In order to preserve and conserve the wetland resource and realizing the importance of this crucial natural ecosystem, several steps have been commenced worldwide from the last few decades. Wetland conservation is aimed at protecting and preserving areas where water exists at or near the Earth's surface, such as swamps, marshes and bogs, which have become a focal issue for conservation due to the ecosystem services it provides. Wetland conservation and proper management aims to conserve the chief ecological services and restore the precious natural resources while fulfilling the socio-economic, and cultural needs of current and future generations. The environmentalists and conservationists have agreed on the view that development is inevitable to achieve a better future, but only when the changes take place in ways that are not wasteful and need not to provide any penalty.

6.2.1 International initiatives:

During the past few decades, numerous efforts have been made to prevent exploitation of wetlands and water bodies. *Ramsar Convention* and *Convention on Biological Diversity (CBD)* are the two land mark initiatives throughout the world towards the conservation of wetlands.

6.2.1.1 Ramsar Convention on Wetlands:

World Wetland Day, which is celebrated each year on 2 February, marks the date of the adoption of convention on wetlands, which was signed in Ramsar, Iran on 2 February, 1971, and came into force on 21 December, 1975. This is most popularly termed as Ramsar Convention, the oldest and first convention and the only global environment covenant/ treaty dealing with a particular natural ecosystem. Presently, this conservation comprises 154 Contracting Parties, and 1,634 wetland sites all over the world, totaling 145.73 million ha, is designated for inclusion in the Ramsar List of Wetlands of International Importance. Since its commencement, the convention has emphasized on the values and the functions of wetlands to be avowed, as well as their importance to the maintenance of biological diversity. Ramsar provides a framework for national action and international co-operation for the conservation and wise use of wetlands and their resources. Further, the convention has broadened its scope to address all the aspects of wetland conservation and reflects the increasing acceptance and recognition of the importance of wetlands as ecosystems which contribute to both the biodiversity conservation and human well-being. In addition, *Montreux record* has been established under this convention by Recommendation 4.8 of the Conference of Contracting Parties, 1990. Montreux record is a register of wetlands under Ramsar list, which encounter immediate challenges from technological development and human interference. As an indication of achievement, in the year of 2015, World Wetlands Day has been celebrated in almost 59 countries. Through the world wetland day (2 February) celebration, Government agencies, non-government organizations and groups of citizens at all levels of the community have taken advantage of the opportunity to undertake actions, which are aimed at raising public awareness of wetland values and benefits in general and the Ramsar Convention in particular *(MoEF & CC, Govt. of India, 1985-86),* which has made a considerable contribution to the conservation and wise use of biological diversity in wetlands. Ramsar convention works in close collaboration with other six International Organization Partners (IOPs) namely; International Union for Conservation of Nature and Natural Resource (IUCN), International Water Management Institute (IWMI), Wetlands International, International Wildfowl & Wetlands Trust (WWT), Birdlife International and World Wildlife Fund (WWF).

6.2.1.1.1 Concept of Wise use and Sustainable management of wetland:

In the present century, holistic planning for the conservation and preservation of wetland ecosystem is gaining momentum. And in this respect, another most indispensable concept, enunciated by Ramsar in association with wetland conservation is *sustainable development*. The concept of sustainable development has been contained in the *Stockholm Declaration* of 1972, which encounter the environmental debate more intensely in the mid 1970's, and has been popularized by the *Bruntland Report*, 1987 and further developed in the document *"Caring for the Earth"* by IUCN, UNEP, WWF, 1991. The concept of sustainable development had its origin to the renewable resource management from early twentieth century and afterwards, it was conceptualized as a fully mobilized approach to the conservation and holistic development by the world conservation strategy, which underlined the interdependence of conservation and sustainable development. Sustainable development has become the buzzword of the present century. It refers to creating a style of economic development, which is sustainable within the context of the planet's ecosystem and human society *(Das et al., 2000)*. Sustainable development requires meeting of the basic needs of present without compromising the ability of future generations in order to meet their own needs and extending to all the opportunity to satisfy their aspirations for a better life *(Bruntland, 1987)*. The emergence of sustainable management is a tool for meeting the people's needs by utilizing the earth capital most judiciously and sustaining the global ecosystems. Water is a fundamental requirement for human life and well-being and wetlands are the cornerstone of sustainable cities, which yield the greatest successive benefits to the present generation, and concurrently fostering its potential to fulfill the needs and aspirations of future generations. Thus proper management of wetland is a means to improve the food production, productivity, as well as alleviating poverty. Being a critical component of sustainable development, sustainable water management is inherently related with the requirement of water resource for developmental purpose but without impairing the future supply. Sustainable water management involves allocating water between competing purposes and users *(Russo et al., 2014)*. Moreover, strategies of wetland use integrate three key principal of sustainability:

1. *Environmentally sustainable,* denotes facilitating a wetland management plan, which does not degrade the wetland and rather regulate and support the foreseeable future.
2. *Economically sustainable* facilitates the utilization of wetlands, which is economically beneficial in a sustainable manner. Further, the scientific knowledge will help in understanding the economic values, which in turn will help in sustainable management and development and
3. *Socially sustainable*, means facilitating the wetland management and strategies within the local community, which is developed by the local people and the stakeholders as well as based on their local knowledge. These approaches have been considered in the wetland discourse in progress the convergence of thinking towards a sustainable wetland management.

In modern times, the concept of *wise use* is at the center of Ramsar philosophy and very closely related with sustainable development. It has been defined first at the *Regina Conference* in 1987. Wise use uncovers the basic concept that, the conservation and sustainable management of wetlands and its resources is absolutely necessary for the benefits and furtherance of human kind, but in a way, compatible with the maintenance of the natural properties of ecosystem. Ramsar convention has made a considerable contribution to the conservation and wise use of wetland biodiversity, which has been defined by the secretariat as "the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development" *(Ramsar Convention Secretariat, 2010)*. Furthermore, wise use of wetlands provides a range of collateral benefits for the local residents, who wholly depend on it for their ultimate survival and livelihood. The essential features of wise use include: a) assessment of wetland resources, b) development of national wetland policy, supported by legislative measures for regulation, c) inventory, d) capacity building, e) conservation of wetland sites and f) research *(Rao & Datye, 2003)*.

6.2.1.2 Convention on Biologial Diversity (CBD):

Ramsar convention responds to the *Convention on Biological Diversity*, which is a multilateral treaty, with the objective to develop the national strategy for the conservation and sustainable use of the entire biological diversity. This biodiversity convention is considered as the first comprehensive global agreement which addresses every aspects relating to biodiversity. The CBD has been enunciated in Rio Earth Summit, Brazil on 5 June, 1992 and entered into force on 29 December, 1993. CBD has universal membership of 193 countries as its parties and India becomes a party to CBD in May 1994. The three main goals of this convention include:

1. Conservation of biological diversity
2. The sustainable use of components of biological diversity and
3. Fair and equitable sharing of benefits arising out of the utilization of genetic resources.

CBD aims to encourage and enable all countries to conserve the biological diversity, to ensure its use, and to reconcile the national interests with maintenance of highest possible levels of global biodiversity *(Murthy et al., 2013)*. The 22 May is celebrated every year as the *International day for Biological Diversity* (IDB). This specific date has been proclaimed by the United Nations, in order to achieve prolong understanding and uplifting awareness towards the contribution of sustainable use of biodiversity, sustainable tourism, and economic development. This legally binding agreement (CBD) has done substantial work on the valuation of biodiversity in general, including wetlands as well as other ecosystems.

6.2.2 National initiatives:

6.2.2.1 National Conservation Strategy:

The Government of India aims to overcome the ever increasing threats to wetlands and maintain the values and functions of wetlands for a long term benefits in accordance with specific strategies, which are set out in the *National Conservation Strategy* by Ministry of Environment and Forest, 1992. The management plan and strategies to be taken for the sustainable use of wetlands are:

1. Protection of the buffer zone near wetlands, to check agricultural encroachment and construction activities, only after thorough analysis of its impact.
2. Effective measures in order to ensure equitable access and responsibility for sustainable use of water resource.
3. Adoption of comprehensive approach for wetland conservation as well as ensure sustainable ecological and economic benefit.
4. Identification, classification and zoning of wetlands for maintaining the water quality as well as enhancing their capability to support various designated uses *(Parikh et al., 2003)*.

6.2.2.2 Ramsar Convention in India:

India is a signatory to Ramsar Convention and has absorbed as a contracting party to this convention in 1981. In last few decades, India has performed an efficient role in conservation and wise use of wetlands. At first, the Chilka lagoon in Orissa and Keoladeo National Park in Rajasthan were designated under the 'Ramsar list' of international importance. On the basis of the country's work in the field of wetland conservation, India has been nominated as a member of standing committee from 1993-1996 and from 1999-2002 *(MoEF, GoI, 2007)*. A total of twenty seven (27) wetlands of India have already been designated as Ramsar sites till date and four (4) are under process of designation. The Sundarban Mangrove in India has been accorded the status of 27th 'Wetland of International Importance' under the Ramsar Convention (Ramsar site no. 2,370) on 30 January, 2019. This site is located within the largest mangrove forest in world, within the delta of the River Ganga and Brahmaputra on the Bay of Bengal in India and Bangladesh as well as listed as an ecological marvel. India has received special acknowledgement at World Park Congress, held at Durban during 2003 for maximum number of sites being entitled in Ramsar list in the year of 2002. During the next triennium, it is proposed to include at least ten sites under the list which will include mosaic of habitats such as high altitude wetlands, corals, mangroves, creeks, and alpine wetlands in the list from India *(MoEF, GoI, 2007)*.

6.2.2.3 Nagoya Protocol under CBD:

India has taken up a unique and innovative biodiversity related activities. The *Nagoya Protocol* on Access and Benefit sharing (ABS) was adopted in 2010 as a supplementary agreement under the aegis of Convention on Biological Diversity (CBD). This protocol translates and gives practical effect to the equity provisions of the Convention on Biological Diversity. It has been signed by India on 11 May 2011 and has entered into force on 12 October 2014. India is successfully following the protocol objectives related with the fair and equitable sharing of benefits arising from the utilization of genetic resources. Moreover, India has hosted the eleventh meeting of the *Conference of Contracting Parties* (COP 11) to the United Nation Convention on Biological Diversity (UNCBD), held from 1-19 October 2012, in Hyderabad. The nation has hosted with an opportunity to fasten, scale-up and strengthen the world wide views on the biological diversity and showcases the leadership on biodiversity in the global arena.

6.2.2.4 National Wetland Conservation and Management Programme:

Acknowledging the importance of protecting the wetlands and water bodies, the Government of India has implemented the *National Wetlands Conservation and Management Programme (NWCMP)* in close collaboration with the concerned State/UT Governments since 1985-86. NWCMP aims at conserving wetlands in the country so as to prevent their further degradation as well as ensuring their wise use for the benefit of local communities and overall conservation of biodiversity *(MoEF, GoI, 2009)*. A total number of 115 wetlands have been identified under this programme till date by the Ministry which requires urgent conservation and management interventions. The identification of selected wetlands comprises several criteria such as location of wetland, topography, area, legal status, intimidations etc. Several steps have been undertaken to arrest further degradation and shrinkage of water bodies due to encroachment, siltation, weed infestation, catchment erosion, surface run-off, which carry pesticides and fertilizers from agricultural fields, and discharge of domestic sewage and effluents. Eventually, this polluted inlets results into deteriorating the water quality, prolific weed growth, decline in biodiversity and other associated problems *(MoEF, GoI, 2007)*. The National Committee on Wetlands, Mangroves and Coral Reefs, 1996 has emphasized the need for formulating national wetland policy in order to stop wetland alteration and degradation, to maintain wetland functions and biodiversity and to establish principles on sustainable resource utilization. In addition, rehabilitation of degraded wetland involving concerned agencies and local community and application of Environmental Impact Assessment on all activities impacting wetlands *(Rao & Datye, 2003)*. In order to promote effective conservation plan to wetlands and lakes, Ministry of Environment & Forests and Climate Change have implemented two separate Centrally Sponsored Scheme (CSS) namely *National Wetland Conservation Programme (NWCP)* and *National Lake Conservation Plan (NLCP)*, which have further been merged in February, 2013 into a newly integrated scheme called the *National Plan for Conservation of Aquatic Eco-systems (NPCA)*. Further, in order to ensure better conservation and management of existing wetlands, MoEF and CC have notified the *Wetlands (Conservation and Management) Rules* in 2010. Later on, the *Draft Wetland Rules* has been brought in 2016, by the ministry as an amendment to the existing rules of 2010.

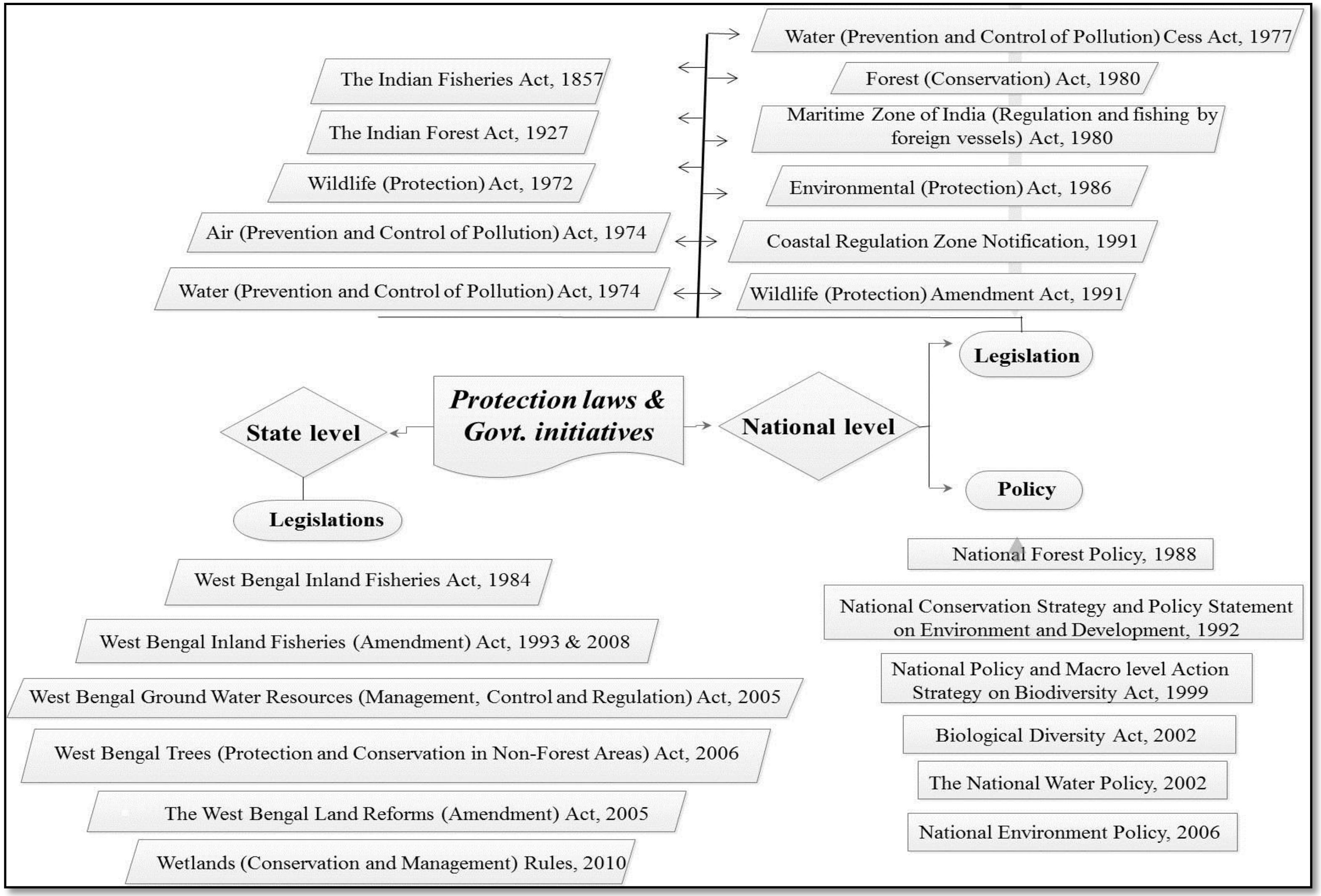
6.2.3 State initiative:

Wetlands in West Bengal are distributed in different geographical regions which range from marine, coastal to inland fresh water wetlands. However, the state is lacking in effective management mechanisms and proper appreciation of their true worth to conserve the wetlands. As a consequence, wetlands are being un-resisted to be downfallen through unsustainable activities, conversion and over exploitation of its resources. West Bengal comprises only two Ramsar sites of international importance namely, East Kolkata Wetland (2002) and Sundarban mangrove (2019). Sundarban (South 24 Parganas) has also been recognized as a *World Heritage Site* by United Nations Educational, Scientific and Cultural Organization (UNESCO) on 7 Dec, 1997 and is considered a biosphere reserve. Kulik Bird Sanctuary (North Dinajpur) is considered as momentous conservation site, which supports 164 bird species of residents and migrants. Further, Ahiron Beel in Murshidabad and the Rasik Beel in Koch Bihar have been designated as the wetlands of national importance under the *National Wetland Conservation Programme* (NWCP). In West Bengal, with the enactment of West Bengal Inland Fisheries Act (1984), the environmental concerns especially regarding wetlands and water bodies has received the acknowledgement as well as become a part of the policy. The state of West Bengal has its own set of laws concerning wetlands, which are given in figure 6.1. In accordance with the Wetland Conservation and Management Rules (2010), under Environment (Protection) Act (1986), the wetlands and water bodies are primarily classified for the purpose of conservation into two classes 1. *Class A* (Forested wetlands) and 2. *Class B* (Non-forested wetlands). Class B is further divided into public and private wetlands, each with another two sub-divisions i.e., natural and man-made *(Dept. of Environment, Govt. of West Bengal, 2012)*. Apart from the mentioned legislations

(Figure 6.1), a policy named, *West Bengal Wetlands and Water Bodies Conservation Policy* has been notified in 2012. The policy has recommended that no wetlands and water bodies can be filled up, degraded, drained, converted or subjected to any kind of activity that is incompatible with the ecological integrity of the wetlands. Like all other states, West Bengal is advised to constitute Wetland Conservation Authority as an institutional framework, with the expertise on wetlands to oversee the effective execution of implemented programmes.

6.2.4 Institutional framework, legislations, policy and plan:

Along with formulating wetland protection act as a legislative vehicle, the effective management of wetlands requires a thorough appraisal of the existing laws, institutions and practices in order to restrict any inconvenience of wetlands, which eventually leads to loss of biodiversity as well as all degeneracy of the natural ecosystem. Some of the government initiatives in the form of protection laws and legal tools (legislations) which have already been passed in the Parliament and are directly and circuitously linked with wetlands are displayed in following *(Figure 6.1)*.

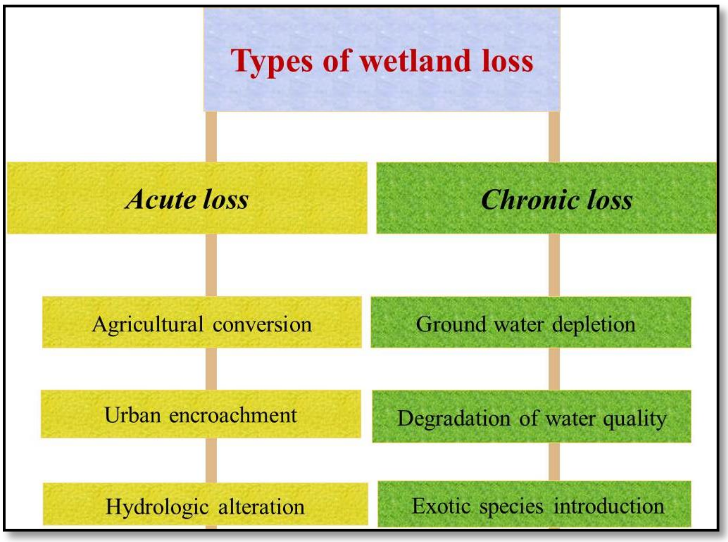


Source: *(Dept. of Environment, Govt. of West Bengal, 2012; Paul & Chanda, 2011; NWCP, 2009; Ramachandra & Ahalya, 2001)*

Figure 6.1 *Institutional framework, legislations, policy and plan*

6.3 Threats to ecological loss of wetlands in Malda:

Malda is significantly occupied by a fairly good portion of area under wetland coverage, which is exceptionally volatile, being particularly vulnerable to the diverse form of environmental changeability. It is well documented that wetlands, located under different physiography, have progressively been lost due to natural as well as anthropogenic activities for several number of years. Presently, a large number of wetlands have been under ongoing threat from environmental degradation in the form of fast expanding human population, land cover change and improper use of wetland resources. Among the threats, to be faced by most of the wetlands are area loss, which can be divided into two broad groups; presented in figure 6.2. The filling up of wet areas with soil and dumping materials constitutes the *acute loss*, whereas the gradual elimination of forest cover with subsequent erosion and sedimentation of the wetlands over many decades is considered as the *chronic loss (Prasad et al., 2002).*



Source: *Prasad et al., 2002*

Figure 6.2: *Types of wetland loss*

In the present study, most of the wetlands have absolutely involved a substantial degeneration of existing wetlands in the form of physical loss in its spatial extent and loss in the wetland functions. Wetland loss may be defined as "the loss of wetland area, due to conversion of wetland to non-wetland areas as a result of human activity" and wetland degradation is "the impairment of wetland functions as a result of human activity" *(Ramachandra et al., 2001).* The major environmental threats to the wetlands and its biodiversity have been observed during study period through diverse forms.

6.3.1 Acute loss

6.3.1.1 Agricultural conversion:

In the present study, the wetlands, located in different blocks are increasingly appalled by ever increasing population growth and resultant agriculture's growing demands for land and water. The wetlands are considered easy prey to encroachment because of poorly defined ownership and because the land underneath is necessary for further developmental activities *(Parikh, 2003)*. The wetlands under study are encircled by agricultural fields, which are considered one of the primary reasons for substantial wetland area loss. The principal threat is the continued expansion of agricultural activities along those wetlands, located at rural periphery *(Table 6.4) (Figure 6.4b)*. This agricultural area expansion leads to unauthorized conversion of wetland into non-wetland purpose as well as progressive direct loss of its spatial extent *(Plate 6.1 & 6.2)*. The trend of reclamation of wetland for the purpose of enhancing agricultural production in order to cope with the growing demand, turn out to be very expensive, both economically as well as ecologically. Although the crop output has definitely been ameliorated district wide, most of the wetlands confront with deadly shrinkage in its areal coverage.

***Plate 6.1:** Siali wetland conversion into agricultural field*

***Plate 6.2:** Chakla wetland conversion into agrcicultural field*

6.3.1.2 Urban encroachment:

Wetland area shrinkage due to urban construction work is considered another vulnerable cause for acute loss. To cope with the thriving population growth *(Table no. 6.1)*, wetlands are becoming the first onslaught whenever land is required for the expansion of numerous developmental activities such as excavation, filling, draining etc. The construction activity is considered major deleterious methods, resulting in the significant loss of spatial spread of those wetlands, located adjacent to urban centres of Malda district. One of the selected peri-urban wetland is Chatra, which is seriously threatened on account of huge scale urban encroachment from north-east, east and south-east, which has been started since 1974 *(Plate 6.5) (Map 6.7 & 6.8)*. In order to accommodate the burgeoning population and ever increasing pressure, this peri-urban wetland has made way to the residential layouts, which eventually has contributed to vigorous urban encroachment *(Plate 6.4) (Figure 6.3)*.

Table 6.1 Population growth scenario in adjacent municipal wards around Chatra wetland

Ward No.	Population			Decadal growth (%)	
	1991	2001	2011	1991-2001	2001-2011
03	6735	9157	13097	35.96	43.03
23	8325	11375	14970	36.63	31.60
24	7116	10230	14838	43.7	45.04
25	-	9454	13491	-	42.70

Source: *Primary Census Abstract, Govt. of India 2001&2011; English Bazar Municipality ward based record of 1996 ;(Chattaraj & Sarkar, 2016)*

The construction of bandh road from NH 34, at the east of existing wetland in 1980-81 has encouraged huge encroachment in the form of three big localities of Malanchapalli, Krishnapalli and Buraburitala, which came up in between 1968 to 1980 *(Table 6.2) (Plate 6.3)*. As a consequence, a large portion of Chatra wetland has been wiped out and is being pirated for the settlement related construction, along with further developmental activities such as schools, markets, and roads etc. Ceaseless urban expansion at the cost of wetland area in Malda district continues to generate a range of negligible impacts on environment, which leave an almost indeterminate legacy.

Table 6.2 Chronology of urban encroachment around Chatra per-urban wetland

Locality	Encroachment started	Nature of encroachment
Malancha Pally (South-east of wetland)	1969-70	Lower middle class and middle class migrants from Bangladesh
Krishnapally (East)	1978-79	Lower middle class and middle class migrants from Bangladesh, service holder and workers of unorganized sectors
Buraburitala (North-east)	1982-83	Lower class immigrants, retrial traders and small traders, land developer and service holder.

Along Malda Govt. Teacher's Training College hostel (East-South)	2000-01	Lower class immigrants and workers of unorganized sectors
South of Noonbahi road (North)	2000-01	Lower class immigrants, middle class retailors, middle class whole sellers
Uttar Ramchandrapur & Uttar Jadupur (North-west & South-west)	2000-01	Agricultural encroachment for wheat cultivation and boro rice
Extension of Malanchapally & Krishnapally (towards north)	2010-11	Mainly lower class people from unorganized sectors and displaced people from Manikchak areas
Extension of Malanchapally & Krishnapally (towards south)	2015-16	Lower class people

Source: *English Bazar Municipality unpublished report, 2004; field study ;(Chattaraj & Sarkar, 2016)*

Plate 6.3: *Urban encroachment at Chatra wetland*

Plate 6.4: *Sold plot at Chatra wetland*

Plate 6.5: *Construction work at Chatra wetland*

Plate 6.12: *Brick kiln industry adjacent to Siali wetland*

6.3.1.3 Hydrological alteration:

Wetlands are very sensorial to any kind of hydrological alteration, which can change and hamper the functions, values as well as the entire appearance of wetlands. Most of the wetlands, under study are envisaged by hydrological alteration of water flowing in or change its level. In the case study of Siali wetland, a sluice gate has been built up at Fatehpur village in order to regulate the direct flow of Fulahar River as well as maintain the maximum flow towards Ganga. As a consequence, the surface flow of Siali wetland (located adjacent to River Fulahar) is not being allowed to be channelized some flow during the lean season (pre-monsoon), when the water level is much low and the surface flow within wetland gets disturbed. Resultantly, the inlet connection of this wetland is not at all functioning since 1999. Siali wetland receives only surface flow, coming from the surrounding low lands during monsoon, which ultimately drifts gradually through the outlet towards River Mahananda. Therefore, this wetland maintain relatively low water level throughout the year and especially during pre-monsoon, when the water availability is low.

In another case study of Naghoria wetland the surface flow of River Kalindri has started receding since 1980, due to the establishment of Nurpur Barrage, which has led this wetland to face devoid of water during the lean season (pre-monsoon). Furthermore, in the lower side of Naghoria, the Kalapahar sluice gate which generally regulates the post monsoon flow, is found non-functioning, and practically this wetland has not been receiving any flow from River Fulahar, is flowing directly to River Ganga in order to maintain an optimum level of water reserve at Farakka barrage throughout the year. Thus erroneous unplanned sluice gate formations conduct an imbalance between the proper inflow and outflow within these wetlands and related long term dearth of water resource. This eventually changes the water level and the volume of surface water flow, especially during lean season *(Chattaraj & Sarkar, 2018)*. As a consequence, the peripheral settlers especially of bed villages (Nagharia, Lakshmighat) encounter immense sufferings from the changing scenario of the traditional socio-economic condition. Further, most of the wetlands, under study experience another change in wetland hydrology in the form of over exploitation of water especially for irrigation and cultivation purpose throughout the year from the peripheral habitat and make differences in water level, goes down *(Plate 6.6 & 6.7).*

Plate 6.6: *Water extraction from Chatra wetland through pump*

Plate 6.7: *Water extraction from Naghoria wetland through Marshal*

6.3.2 Chronic loss

6.3.2.1 Ground water depletion:

Chronic losses include the impairment of wetland functions as a response of human interference. In the present study, the wetlands are considered an exigent part of the hydrological cycle for minimizing the malignance of flood, recharging the ground water as well as maintaining the overall balance of a substantial hydrological, ecological and biological role in the natural functioning of entire district. Several negative externalities in the form of wetland area encroachment and hydrological alterations result into loss of aquifer and resultantly, the ground water reservoir is getting decayed. There is the risk that the ecological characters of wetlands, adjacent to urban localities are being altered to the point where the essential regulating and supporting services *(Figure 5.1)* are lost. These disturbances reduce the benefit that society receives from wetland in controlling the frequent flood occurrence. Presently, the depletion of ground water in wetlands under study is fast and their restoration become very difficult, once these areas are put to mankind use. Furthermore, inestimable pressures on wetland in the form of groundwater extraction, as well as pollution have been documented as extending well beyond the municipal boundaries. Degradation and disappearance of wetlands and water bodies are directly responsible for lowering the ground water table, which is evident from early works in Bangalore city *(Ramachandra & Ahalya, 2001)*.

6.3.2.2 Degradation of water quality:

The deterioration of wetland water quality, through supremely infilling and inflow of polluted urban and agricultural waste water is considered another most visualized problem in the wetlands under study. The wetlands are the primary receptacles for agricultural discharge, full of agro-chemicals, which has brought the crisis of non-point source pollution (pollutants come from widespread area and cannot be traced as a single point source) into forefront. Intensive agricultural activities in association with intensive aquaculture disturb the wetland ecosystem by adding the loads of pollutants such as pesticides, fertilizers, antibiotics, and disinfectants. Out of the selected wetlands, Chakla, Siali and Naghoria are subjected to inflow the ill effects of fertilizers and insecticides, which are used in adjoining agricultural fields as well as aggravate the pollution load *(Plate 6.9)*. A spurt in the volume of agricultural effluents entering the wetland has led to the problem of pollution, and toxic contamination by pesticides and organic compounds. Pollution from agricultural land run-off add materials to surface water and ground water which eventually upset the balance of wetland water chemistry in the form of water pH, conductivity and dissolved oxygen level as well as the biogeochemical cycle of materials in wetland ecosystems. In the present study, wetland siltation is coupled with anthropogenic activity (intensification of agriculture) and results into ever increasing rate of sedimentation, which eventually raise the wetland bed, decline the volume of surface flow, alter the biological composition as well as demote their present status. Moreover, deficiency in proper management of non-point source of pollution like agricultural run-off and unregulated land use management have misled people to consider these wetlands as waste lands that are afflicted by malaria and other vectors thereby, weakening the multiple benefits that they provide. In the context of peri-urban wetland, pollutants such as pesticides, sediments, domestic sewage discharge from different point-sources (also known as ‘the end of pipe pollution’ i.e., pollutants come from a specific source e.g., direct discharge of municipal sewage) and non-point sources (run off from agricultural fields) degrade this wetland functions and affect the entire wetland biodiversity *(Plate 6.8).* To make their situation worse, illegal dumping of solid waste at the close proximity of wetland edge, especially into Chatra wetland contribute to wetland loss and degradation *(Plate 6.10) (Figure 6.3).* Furthermore, rapid expansion of brick kiln industry *(Plate 6.12)*, surrounding the wetlands irrespective of urban and rural periphery, results into polluted water discharge into wetlands under study as well as degrade the water quality.

Plate 6.8: *Point source pollution into Chatra wetland from ward no. 25*

Plate 6.9: *Non-point source pollution into wetlands*

Plate 6.10: *Solid waste dumping at Chatra wetland*

Plate 6.11: *Brick kiln industry adjacent to Chatra wetland*

6.3.2.3 Introducing invasive species and resultant eutrophication:

Water pollution and resultant degradation of wetlands often enhance the accelerated growth of invasive species (one that rapidly spread and replace the native species), which threat wetland ecology and clog the water ways. Moreover, the introduction of invasive species within wetlands often leads to eutrophication (the process of water quality degradation, caused by excessive nutrients), which restricts the exchange of oxygen across the air/water interface within wetlands as well as hampers the process of photosynthesis. Further, extended eutrophication initially lead to algal bloom, which reduces the dissolved oxygen level and subsequently augment the mortality of various benthic organisms. The wetlands under study are encountered prominently by accidental and deliberate arrival of invasive species (*Eichhornia crassipes*, *Pistia stratiotes*) *(Plate 6.13; 6.14 & 6.15)* which eventually decimate the native species, significantly alter the aquatic food webs, and reduce the economic value of productive habitat. The wetlands, located adjacent to urban centers in Malda district, are sustained by inflow, beyond its assimilative capacity, which has further led to eutrophication *(Plate 6.16)* and results into profuse growth and spread of water hyacinth as well as degrade the ecological integrity of wetland ecosystem.

Plate 6.13: *Eichhornia crassipes coverture in Chatra wetland*

Plate 6.14: *Eichhornia crassipes in Naghoria wetland*

Plate 6.15: *Pistia stratiotes in Chatra wetland*

Plate 6.16: *Eutrophication in Chatra wetland*

6.3.2.4 Biodiversity loss:

Wetland resources have been utilized at or beyond their sustainable limits, which cause significant threat to wetland biodiversity and resultant habitat loss. Contextually, the ever increasing demand for enhancing economic growth during last few decades with utter contempt for the long term ecological consequences has led to over exploitation of wetlands of Malda district. Moreover, poor equity of access to the benefits, derived from wetland ecosystem services and native poverty also result in over exploitation of wetland resources out of its economic necessity. In the selected case studies namely; Chakla, Siali and Naghoria wetland, the water quality and quantity deteriorations have contributed to substantial degeneration of biological diversity as well as productivity of wetland ecosystem. Furthermore, Naghoria wetland experiences immense downfall in number of fish fauna, because of over fishing and faulty fishing practices including net fishing, which upset the balance and food web. In Chatra wetland, rapid urbanization swallows the wetland from the east ward side (north-east and south-east), which not only minimizes its spatial extent, but results into direct habitat loss and generates additional pressure on its existing biodiversity *(Figure 6.3)*. The unsustainable planning and subsequent use of water resources in order to support urban population have a significant impact on wetlands and the biodiversity, which support far beyond the peri-urban environment *(McInnes, 2013)*. During field observation and interviewing the local settlers, the detrimental impacts on the arrival of migratory birds along with other animal population have clearly been documented. Acute disturbance in habitat and food in the form of removal of aquatic vegetation and overfishing within wetlands of Malda district are assumed to have caused the disappearance of big migratory colony of Spot bills, Pochards and Pintails in last ten to fifteen years.

In the case study of peri-urban wetland (Chatra wetland), a household survey by random sampling (2% of household) with total number of 173 households, from the adjacent municipal wards (no. 3, 24 and 25) along the north-east, east and south-east boundary has been conducted in 2016-17 in order to know the perception on wetland environment *(Appendix-11) (Figure 6.3)*. The field study, field observation along with the household survey reveals that, Chatra wetland edge and open water experience the problem of solid waste dumping, as proposed by 63 households (36.42%) from the adjacent municipal wards. Moreover, being a peri-urban wetland, it encounters number of threats in which the majorly dominated one is wetland area encroachment as opined by 71 households (41.04%), followed by solid waste dumping with wetland (16.76%), water pollution (9.83%) from both point and non-point pollution sources. A small number of surveyed households (6.36%) have been found conscious regarding declining species diversity, whereas 45 no. of households (26.01%) have expressed their concern regarding this precious natural ecosystem with the respect to all the mentioned wetland degrading parameters *(Figure 6.3) (Appendix 11)*. Furthermore, the household survey reveals that, 42 numbers (24.28%) of households, residing in the contiguous municipal wards feel very serious and think the declining trend of wetland biodiversity, especially the aquatic fauna as vulnerable. The field study also reveals that, the abundance of migratory bird colony during winter months has been recorded relatively less, as compared with other case studies (*Figure 3.15*) in and around Chatra wetland.

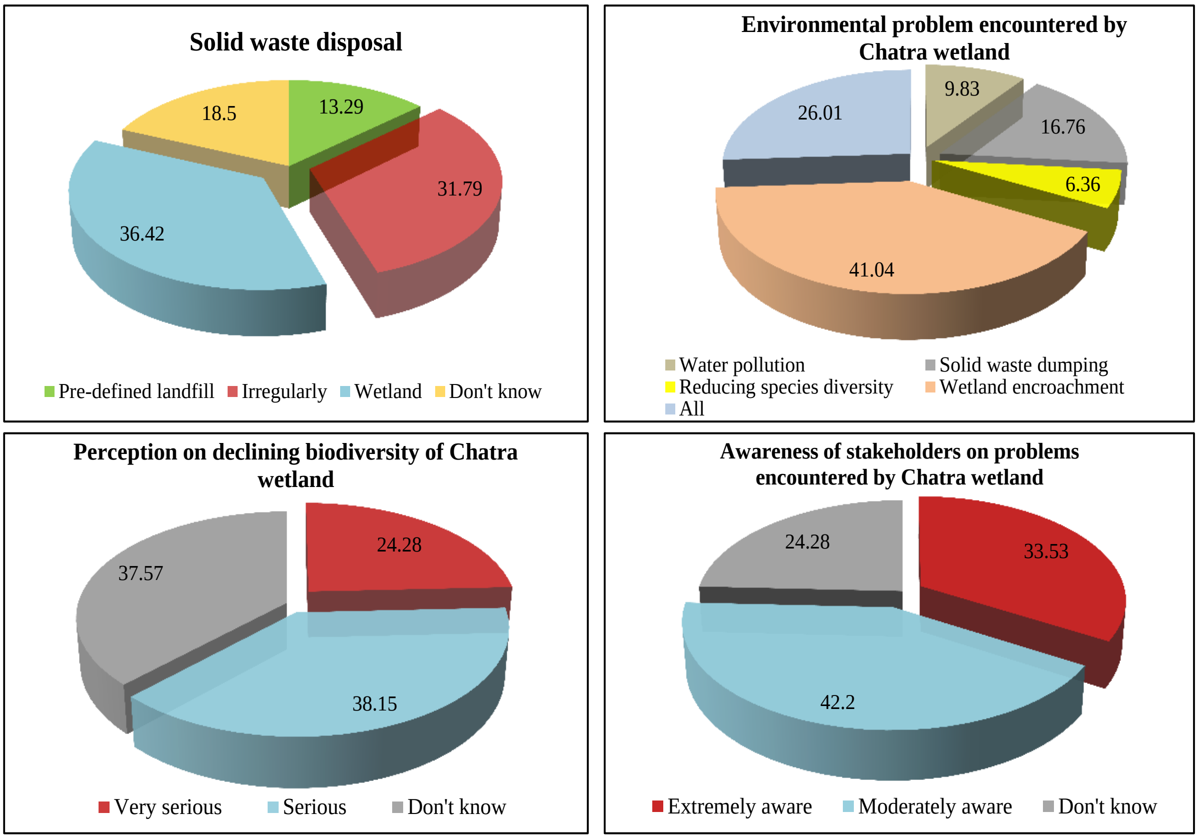


Figure 6.3: *Perception on wetland environment (Chatra) from English bazar municipal ward no. 3, 24 and 25*

The household survey to the adjacent municipal wards has been conducted in order to know, the level of awareness of the settlers as well as the stakeholders regarding these mentioned problems, encountered by Chatra wetland. A total of 58 households (33.53%) are extremely aware and some of those stakeholders have already been engaged with different NGOs and are being the members of Malda Vigyan Mancha and Jalabhumi Suraksha Samiti, whereas, 73 households (42.2%) are moderately aware regarding the problems, frequently encountered by Chatra wetland. The field study also reveals that, a total of 42 households (24.28%) still do not feel and even do not know, that what awareness is and why is it necessary in order to provide a sustainable future *(Appendix 11) (Figure 6.3)*.

The potential for preserving and promoting sustainable livelihood and so alleviating poverty and contributing to national development through wise use, management of wetland ecosystem has not yet been realized *(Friend, 2007)*. The lack of understanding and recognition to wetlands leads to ill-informed decision on wetland management, which eventually contributes to incessant degradation of this natural ecosystem. Instead of having sound governmental commitment and necessary expertise there is unyielding sectoral approach with minimal inter sectorial planning and coordination. Therefore, it is time to plan for raising awareness on the importance of wetlands and for extending strategies of wetland restoration and conservation.

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6.4 Land use land cover (LULC) change around selected wetlands:

In order to assess the level of encroachment of wetland area as well as associated land use land cover changes, the mapping procedure has been done by comparing and analyzing satellite imagery data in the selected wetlands in Malda district.

6.4.1 *Siali wetland:*

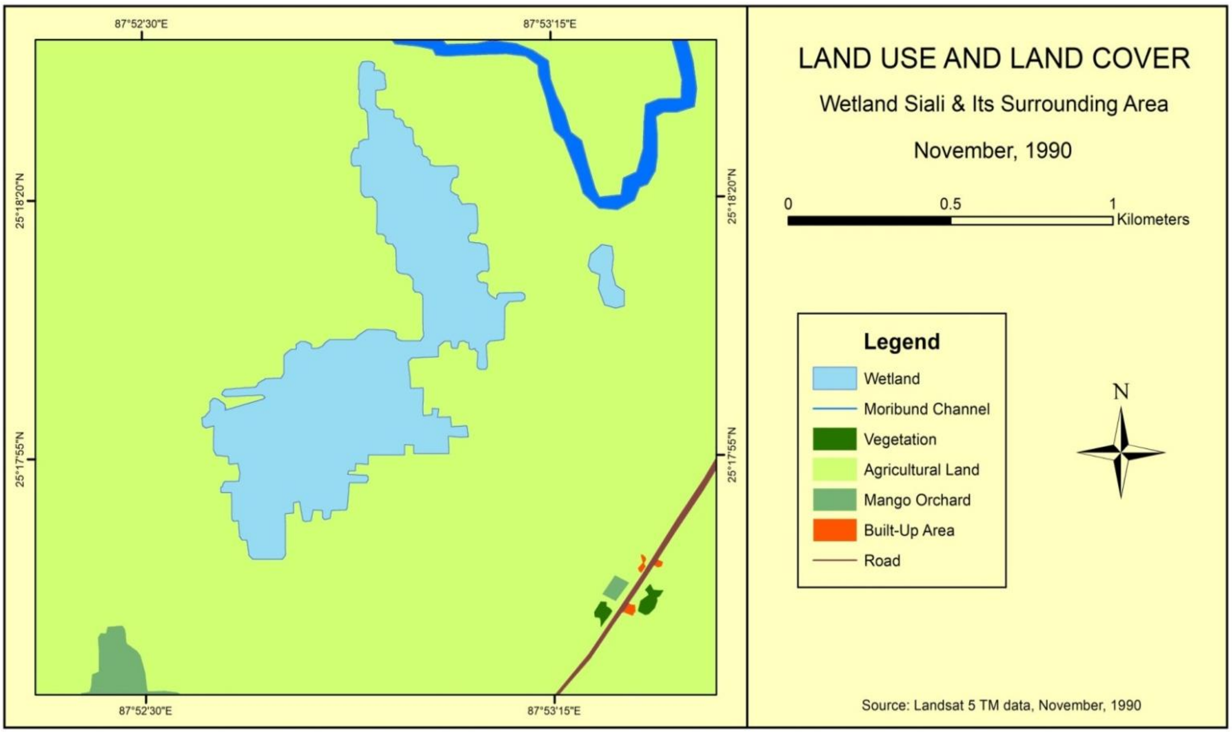
Siali wetland encounters immense challenges from reducing its spatial extent and losing its enormous growth potential for fishing, water fowls as well as the entire socio-economy of the peripheral settlers. As per satellite imagery (TM and OLI), the land use land cover dynamics has conspicuously been identified, where the area extension of wetland has been reduced from 47.49 ha to 18.74 ha with an absolute change of -28.85 ha (-60.63%) during the time frame 1990 to 2018. The commercial utilization of land use, surrounding Siali wetland is chiefly executed especially by mango orchard, which has increased from 3.50 ha to 24.93 ha and brick kiln industry (came into being after 1990) from 0 to 9.02 ha during 1990 to 2018. Moreover, built-up area has been increased negligible, whereas, the agricultural land has been reduced from 355.53 ha to 353.81 ha, as well as converted to mango orchards. Other land use land cover record almost no change around Siali wetland. Table 6.3, figure 6.4a, map 6.1 and 6.2 are self-explanatory.

Table 6.3 Land Use and Land Cover (LULC) change of Siali wetland and its surrounding area in between 1990 and 2018

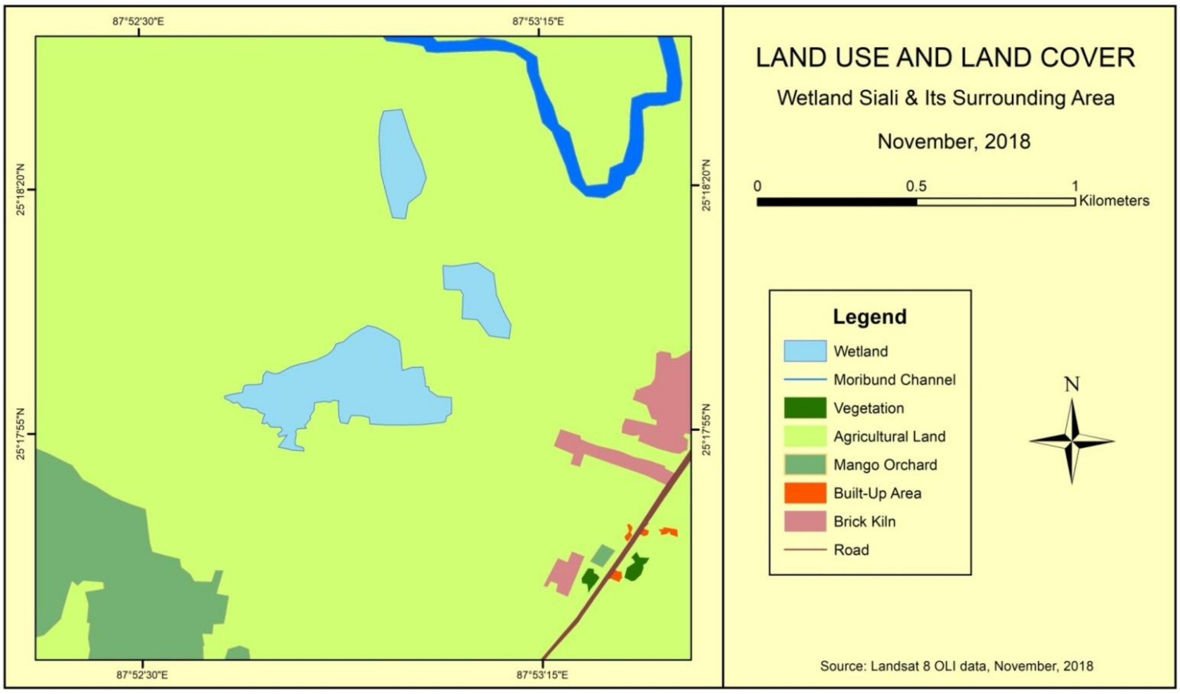
Class Name	Area (ha) 1990	% Area of LULC (1990)	Area (ha) 2018	% Area of LULC (2018)	Absolute change of LULC	% of change of LULC	Status
Agricultural Land	355.53	85.69	353.81	85.28	-1.71	-0.48	Almost No Change

Built-up Area	0.22	0.05	0.35	0.08	0.13	56.46	Increase
Moribund Channel	5.93	1.43	5.94	1.43	0.00	0.01	Almost No Change
Road	1.57	0.38	1.57	0.38	0.00	0.01	Almost No Change
Vegetation	0.55	0.13	0.55	0.13	0.00	-0.02	Almost No Change
Wetland	47.59	11.47	18.74	4.52	-28.85	-60.63	Decrease
Total Area	414.90	100.00	414.90	100.00			

Source: *Landsat 5 TM data (1990), Landsat 8 OLI data (2018), November*



Map 6.1: *Land Use and Land Cover change of Siali wetland and surrounding area in November, 1990*



Map 6.2: *Land Use and Land Cover change of Siali wetland and surrounding area in November, 2018*

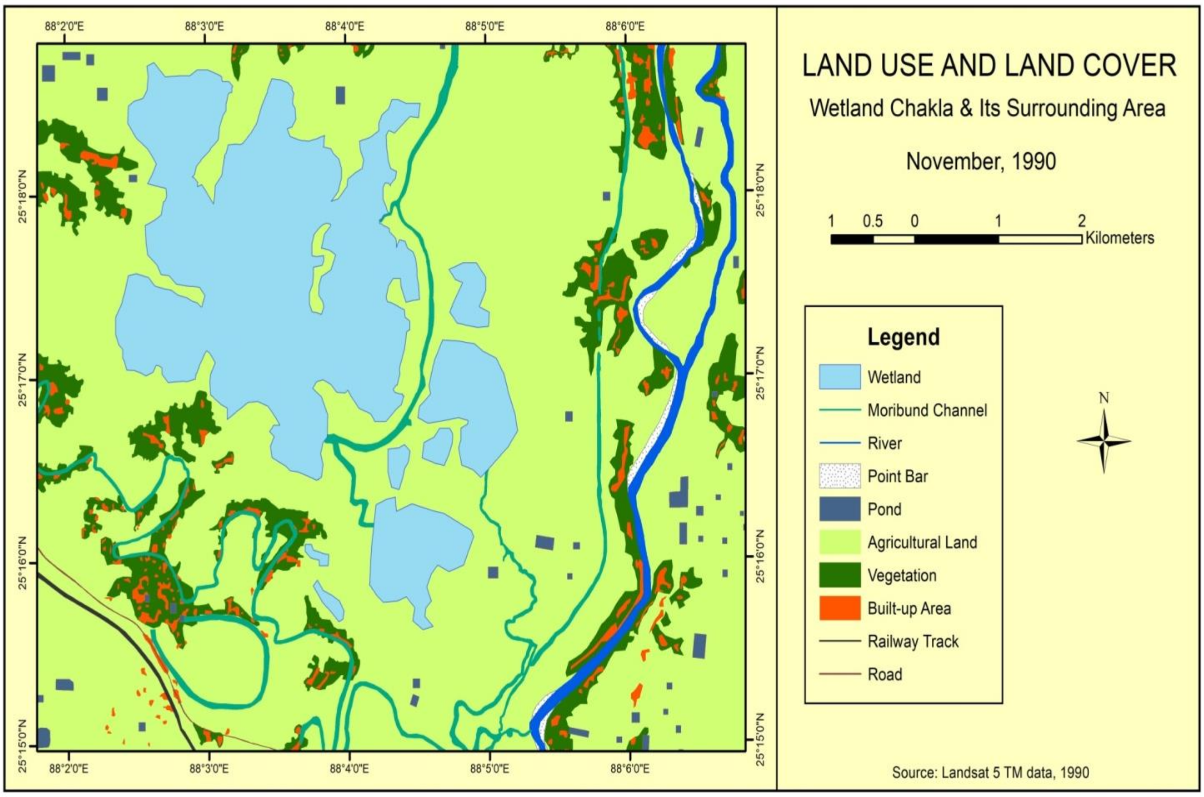
6.4.2 *Chakla wetland:*

The significance of Chakla wetland is restlessly threatened due to ever increasing pressures from unplanned land use activities *(Table 6.4) (Map 6.3 & 6.4)*. An immense livelihood dependency has mounted serious environmental pressures on this ecosystem and has affected them to such an extent that their benefits have declined significantly. The field observation and satellite imagery analysis reveals that the wetland area has been reduced from 1137.13 ha to 842.50 ha with an absolute change of -294.63 ha (-25.91%) during 1990 to 2018. The area under natural vegetation around this vast water body has been decreased by -77.52 ha (-15.62%), which has been converted into agricultural land. As a consequence, the area coverage under agricultural land has been increased from 4123.51 ha to 4411.98 ha, whereas the built-up area has also recorded an increasing trend by 82.59 ha (63.49%) from 1990 to 2018. Table 6.4, figure 6.4b, map 6.3 and 6.4 are self-explanatory.

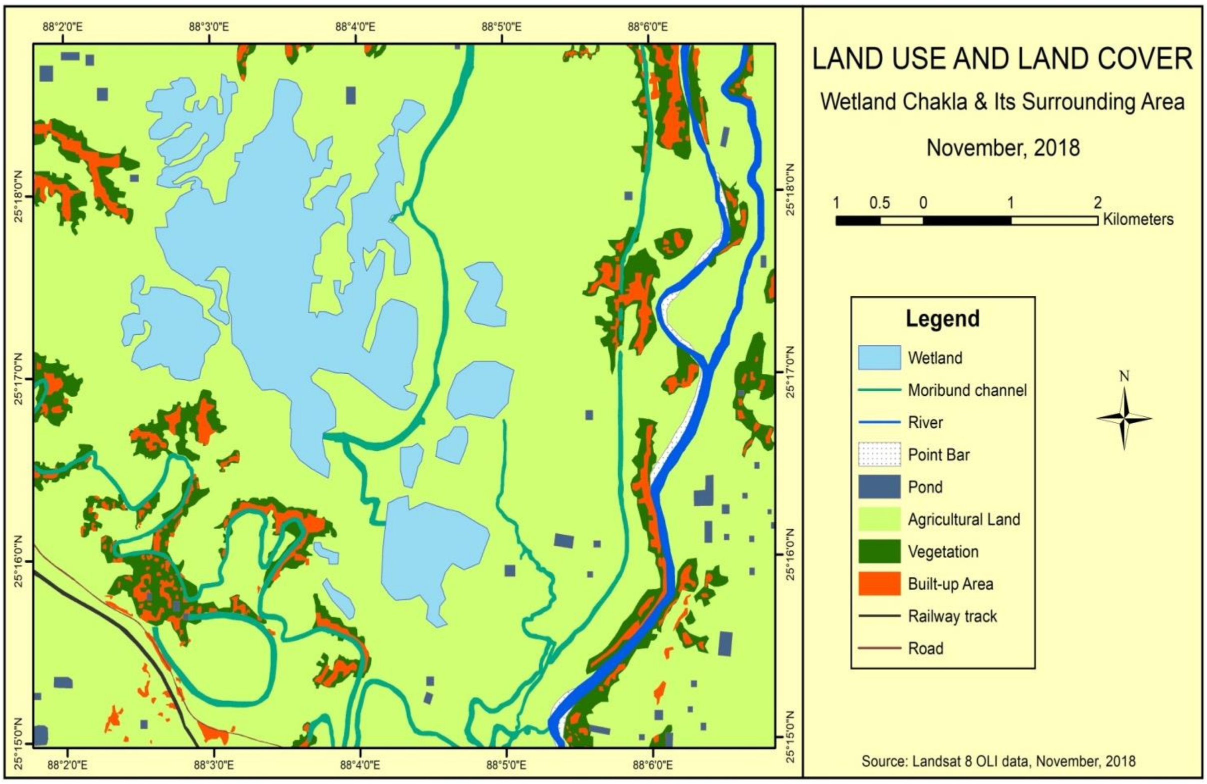
Table 6.4 Land Use and Land Cover (LULC) change of Chakla wetland and its surrounding area in between 1990 and 2018

Class Name	Area (ha) 1990	% Area of LULC (1990)	Area (ha) 2018	% Area of LULC (2018)	Absolute change of LULC	% of change of LULC	Status
Agricultural Land	4123.51	66.86	4411.98	71.54	288.47	7.00	Increase
Built-up Area	130.08	2.11	212.68	3.45	82.59	63.49	Increase
Moribund Channel	115.57	1.87	116.95	1.90	1.38	1.20	Almost No Change
Point Bar	24.07	0.39	24.08	0.39	0.01	0.04	Almost No Change
Pond	48.93	0.79	48.93	0.79	0.00	0.00	Almost No Change
Railway Track	11.60	0.19	11.60	0.19	0.00	0.01	Almost No Change
River	77.12	1.25	76.55	1.24	-0.57	-0.74	Almost No Change
Road	5.00	0.08	5.00	0.08	0.00	0.00	No Change
Vegetation	494.52	8.02	417.27	6.77	-77.25	-15.62	Decrease
Wetland	1137.13	18.44	842.50	13.66	-294.63	-25.91	Decrease
Total Area	6167.53	100.00	6167.53	100			

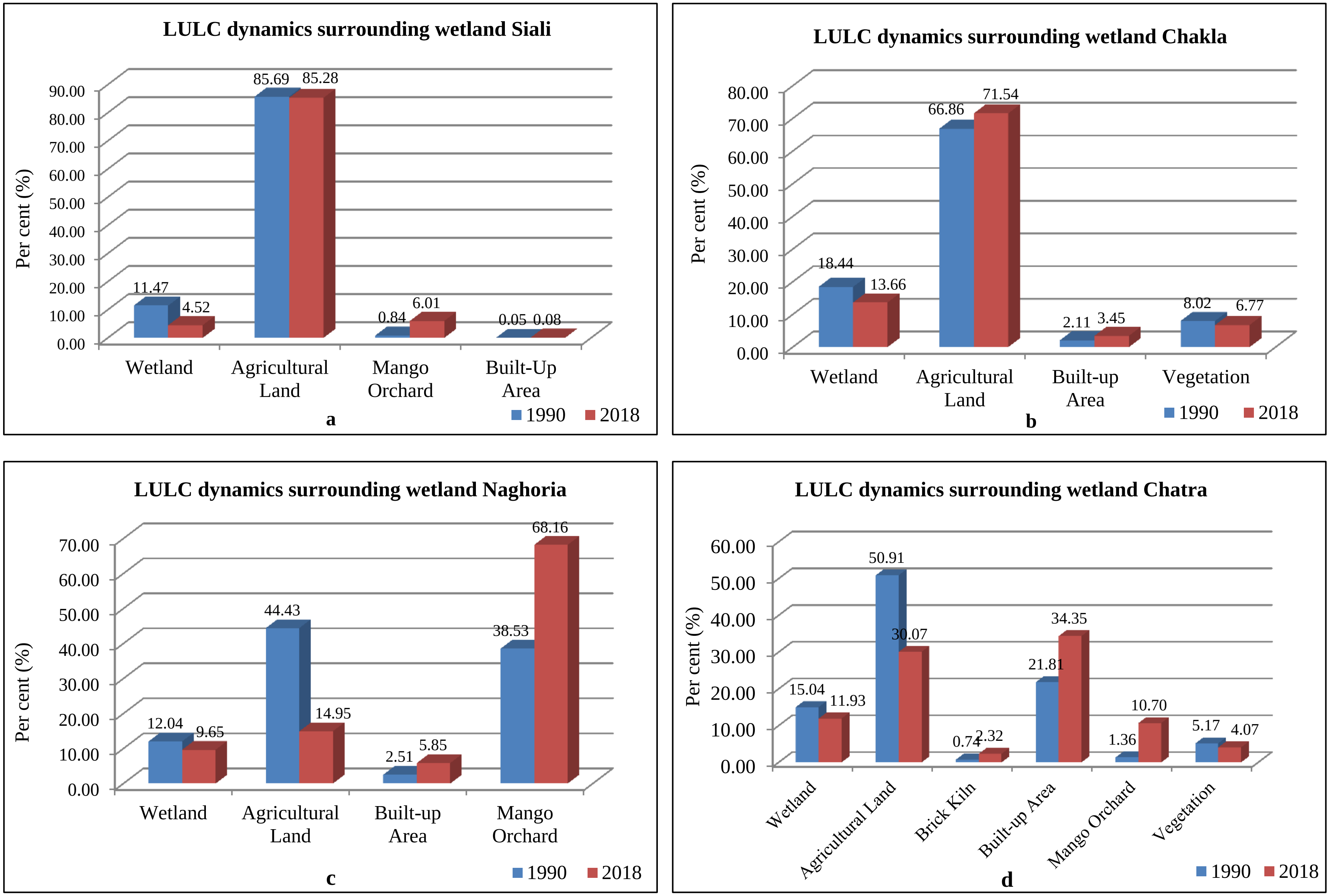
Source: *Landsat 5 TM data (1990), Landsat 8 OLI data (2018), November*



Map 6.3: *Land Use and Land Cover change of Chakla wetland and surrounding area in November, 1990*



Map 6.4: *Land Use and Land Cover change of Chakla wetland and surrounding area in November, 2018*



Source: *Landsat 5 TM data (1990), Landsat 8 OLI data (2018), November*

Figure 6.4: *Land Use Land Cover dynamics surrounding case studies between 1990 and 2018*

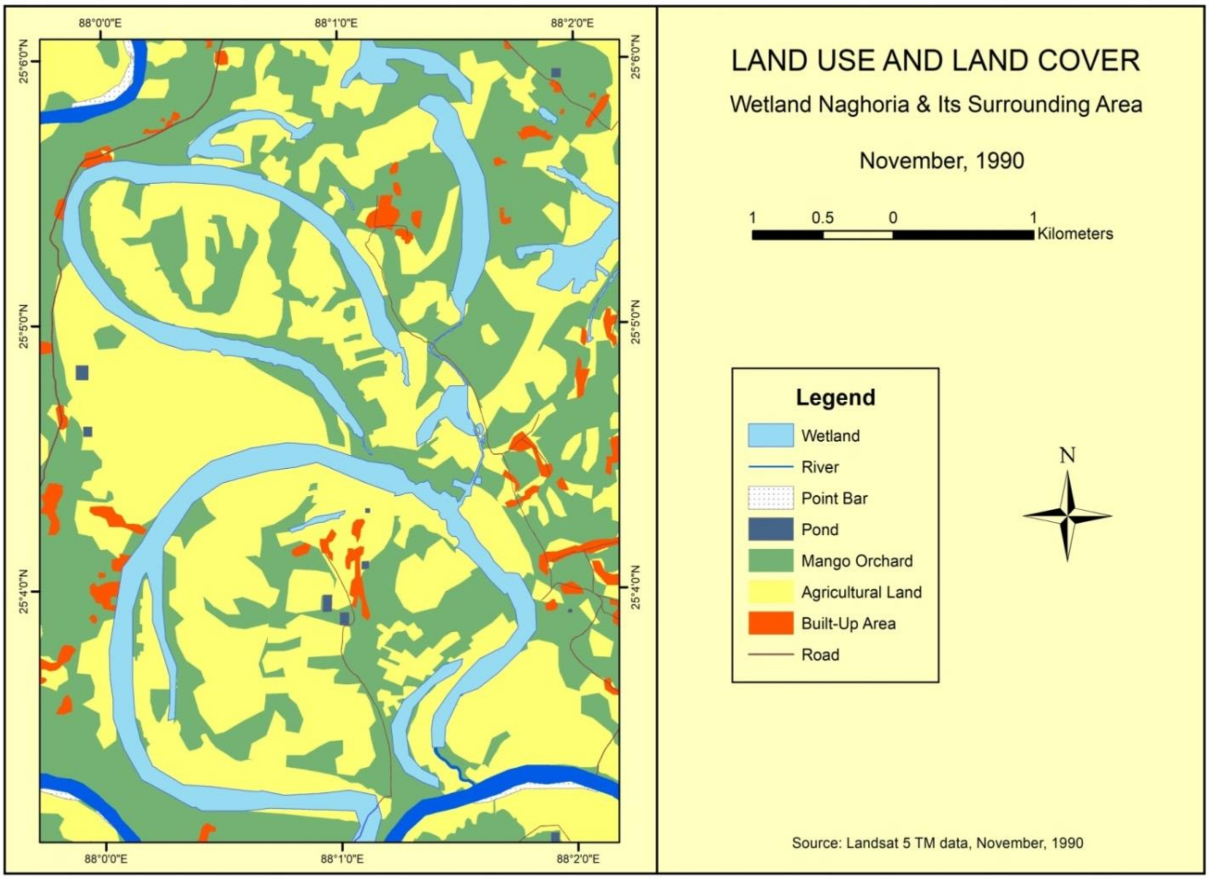
6.4.3 *Naghoria wetland:*

Naghoria wetland encounter immense challenges which results into direct loss and change the way it functions. The wise use of this cut off is lying neglected for long term. As per the field study and satellite imagery observation, the wetland area has been decreased from 284.62 ha to 228.13 ha with -56.49 ha of absolute change (-19.85%) from 1990 to 2018. The land use land cover dynamics has recorded massive change, where the agricultural land has been diminished by -697.09 ha (-66.36%), which has wholly been converted into mango orchards. The commercial utilization of land area adjacent to Naghoria wetland has chiefly been devoted to mango orchards, which increases from 911.07 ha to 1611.65 ha during 1990 to 2018. Moreover, built-up area has also been increased by 78.81 ha during last 30 years. Table 6.5, figure 6.4c, map 6.5 and 6.6 are self-explanatory.

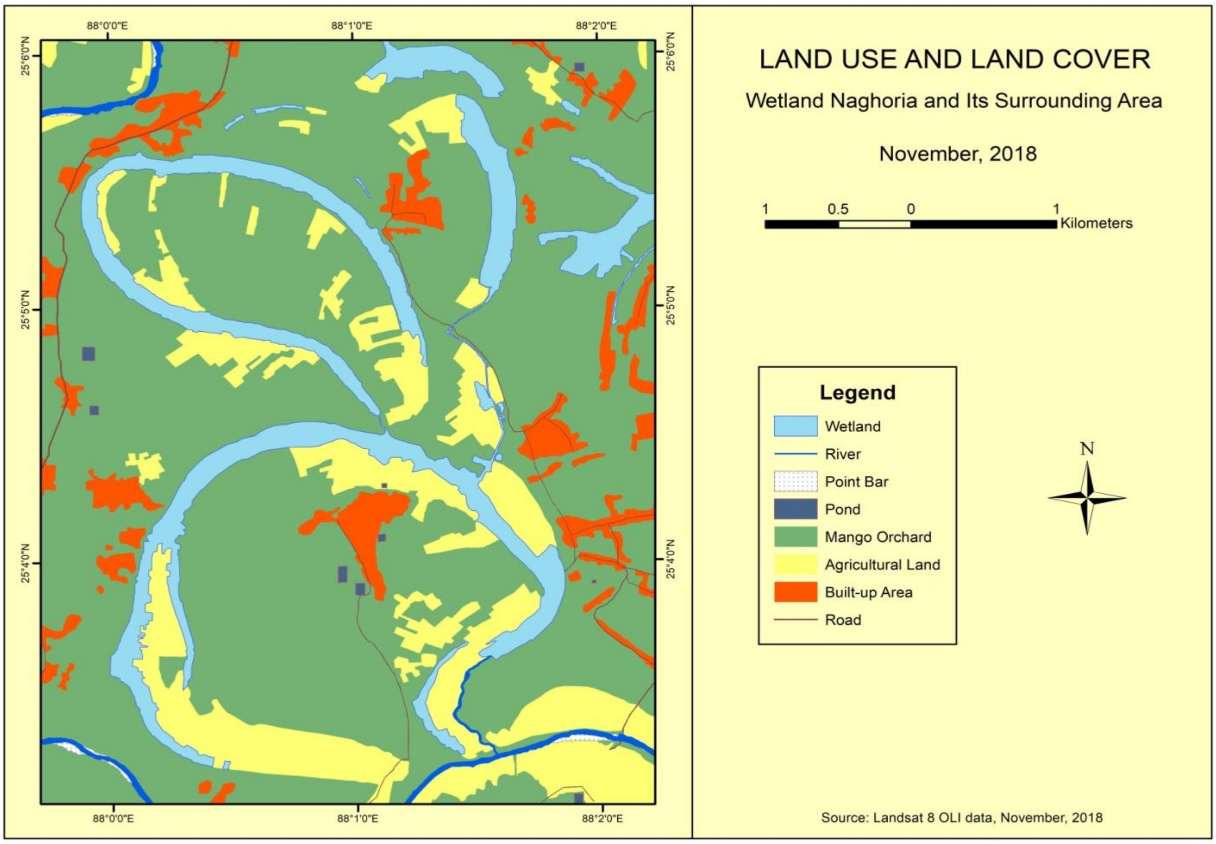
Table 6.5 Land Use and Land Cover (LULC) change of Naghoria wetland and its surrounding area in between 1990 and 2018

Class Name	Area (ha) 1990	% Area of LULC (1990)	Area (ha) 2018	% Area of LULC (2018)	Absolute change of LULC	% of change of LULC	Status
Agricultural Land	1050.52	44.43	353.43	14.95	-697.09	-66.36	Decrease
Built-up Area	59.41	2.51	138.22	5.85	78.81	132.65	Increase
Mango orchard	911.07	38.53	1611.65	68.16	700.58	76.90	Increase
Point bar	8.79	0.37	4.41	0.19	-4.38	-49.83	Decrease
Pond	4.07	0.17	4.07	0.17	0.00	0.04	Almost No Change
River	34.96	1.48	13.48	0.57	-21.48	-61.44	Decrease
Road	10.93	0.46	10.96	0.46	0.06	0.54	Almost No Change
Wetland	284.62	12.04	228.13	9.65	-56.49	-19.85	Decrease
Total Area	2364.38	100.00	2364.35	100.00			

Source: *Landsat 5 TM data (1990), Landsat 8 OLI data (2018), November*



Map 6.5: *Land Use and Land Cover change of Naghoria wetland and surrounding area in November, 1990*



Map 6.6: *Land Use and Land Cover change of Naghoria wetland and surrounding area in November, 2018*

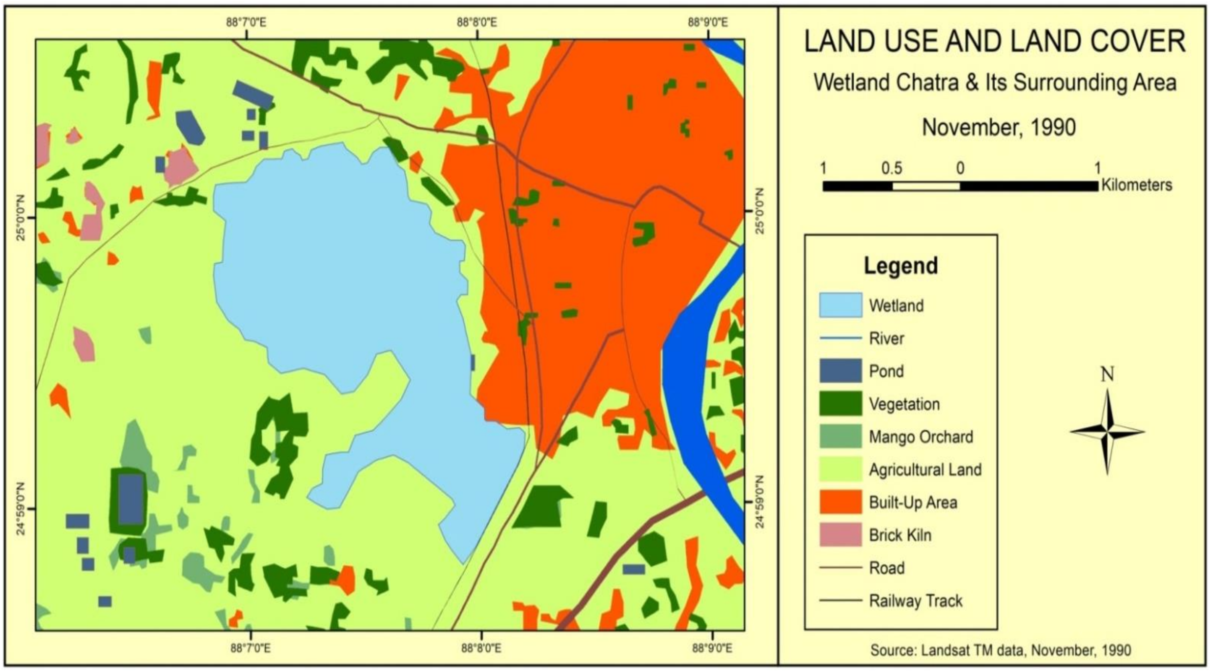
6.4.4 *Chatra wetland:*

Chatra wetland is the only peri-urban water body of Malda district, which is bounded in entire east (including north-east and south-east) by ward no. 3, 24 and 25 under English Bazar Municipality. Being neglected over the years by the municipality and district administration, this unique wetland confronts maximum amount of encroachment from the peripheral area in the form of human habitation and associated economic activities. These anthropogenic disturbances generate serious threats to the very existence of this precious ecosystem *(Map 6.7 & 6.8)*.

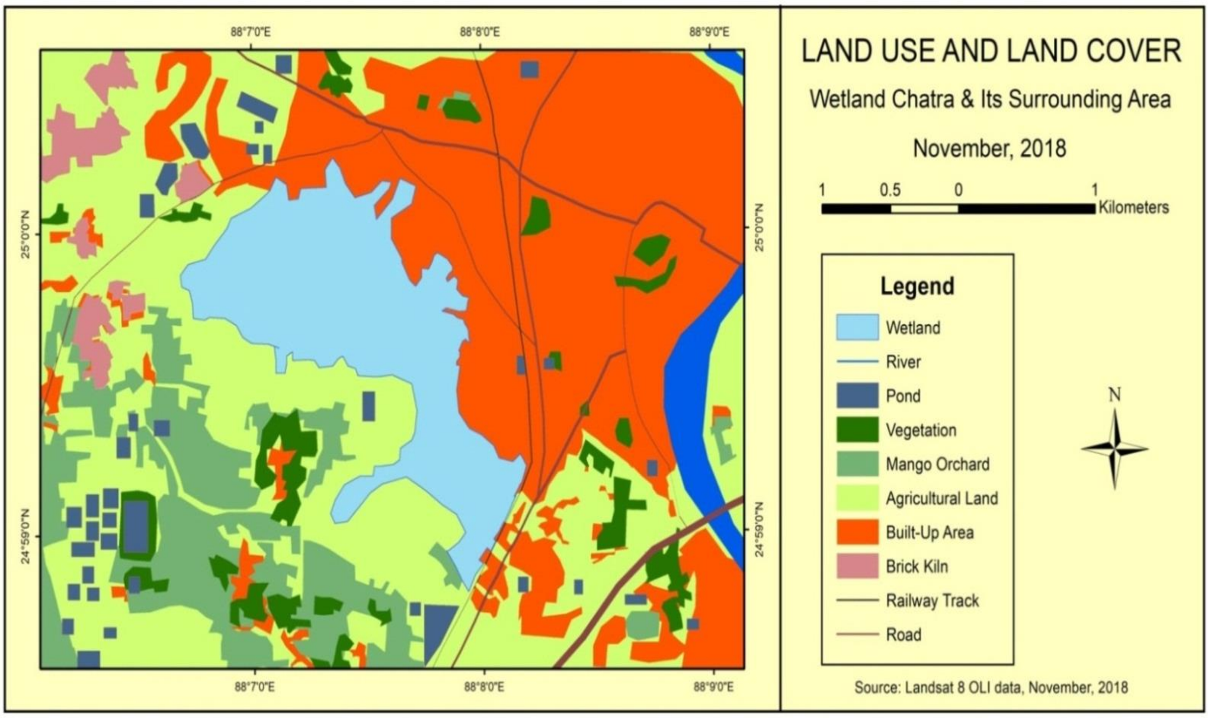
Table 6.6 Land Use and Land Cover (LULC) change of Chatra wetland and its surrounding area in between 1990 and 2018

Class Name	Area (ha) 1990	% Area of LULC (1990)	Area (ha) 2018	% Area of LULC (2018)	Absolute change of LULC	% of change of LULC	Status
Agricultural Land	1001.22	50.91	591.30	30.07	-409.92	-40.94	Decrease
Brick kiln	14.46	0.74	45.60	2.32	31.15	215.43	Increase
Built-up Area	428.95	21.81	675.59	34.35	246.64	57.50	Increase
Mango orchard	26.77	1.36	210.41	10.70	183.64	686.10	Increase
Pond	19.76	1.01	50.93	2.59	31.17	157.68	Increase
Railway Track	3.39	0.17	3.39	0.17	0.00	0.00	Almost No Change
River	42.64	2.17	41.82	2.13	-0.82	-1.93	Almost No Change
Road	31.94	1.62	32.90	1.67	0.96	3.01	Increase
Vegetation	101.72	5.17	80.09	4.07	-21.63	-21.26	Decrease
Wetland	295.73	15.04	234.54	11.93	-61.18	-20.69	Decrease
Total Area	1966.58	100.00	1966.57	100.00			

Source: *Landsat 5 TM data (1990), Landsat 8 OLI data (2018), November*



***Map 6.7:** Land Use and Land Cover change of Chatra wetland and surrounding area in November, 1990*



***Map 6.8:** Land Use and Land Cover change of Chatra wetland and surrounding area in November, 2018*

In the present study, after analyzing the satellite imagery, the wetland area has been recorded to be synchronizing from 295.73 ha to 234.54 ha during the time period 1990 to 2018, with an absolute change of -61.18 ha (-20.69%). The land use land cover dynamics has recorded massive change around Chatra wetland in the form of built-up area, which has increased by 246.64 ha (57.50%) and mango orchard, increased by 183.64 ha (686.10%) during 30 years interval (1990-2018). Furthermore, the land area, surrounding this peri-urban wetland has increasingly been utilized for commercial purpose in the form of brick kiln industry, the area of which has increased by 31.15 ha during mentioned time period. Moreover, the area under natural vegetation has been reduced down by 21.63 ha, which has further been converted to built-up area, being the chief encroacher of Chatra wetland. Table 6.6, figure 6.4d, map 6.7 and 6.8 are self-explanatory.

6.5 Conservation of wetlands in Malda district:

The conservation and management strategies of wetlands under study keenly look at an integrated research work with precise understanding regarding wetland values and functions as an indispensible tool for constructing a long term conservation strategies. Conservation education is a tool, which can effectively be used for behavioural change by making people aware and by changing their attitudes towards wetlands and environment *(Mahajan, 2003)*.

6.5.1 Conservation strategies and recommendation of selected wetlands:

6.5.1.1 *Siali Wetland:*

In order to avoid further loss and degradation of this natural ecosystem and to maintain the values and functions of wetlands for the long-term benefit, appropriate management and restoration mechanisms need to be implemented. This entails:

1) The operation of already installed sluice gate is to be oriented in such manner to simplify the regular inflow and requisite outflow in order to maintain an adequate surface flow and water volume within wetland throughout the year. Moreover, the inflow and outflow channels, connected with Siali wetland are to be cleared every year with a regular interval especially before the arrival of monsoon (July – September).
2) Patrolling and regular surveillance at wetland site to resist further shrinkage of its spatial extent as well as conversion of wetland into agricultural land.
3) Wetland conservation and management strategy must be comprehensive in terms of addressing the myriad water quality problems, which persist from the non-point source of pollution. Hence, identification of non-point pollution sources (Agricultural runoff, domestic waste) along with the continuous monitoring on the quality of infiltrating water draining into Siali wetland is required.
4) Manual or mechanical de silting and dredging of Siali wetland is immediately to be implemented in order to keep the water volume intact within wetland throughout the year.

5) Makhana cultivation should be succeeded zone wise in this wetland through planned and regulated manner without backpedal the traditional fishing practices as well as keeping the villagers' economy unharmed. Further, frequent monitoring on the use of insecticides before sowing makhana seeds on wetland bed is to be practiced.
6) Over exploitation of wetland resource (over fishing, faulty fishing, and water extraction for irrigation) should strictly be prohibited in order to sustain heterogeneous assemblage of floral and faunal diversity.
7) Promoting awareness regarding the benefits of wetland through wide public awareness campaigns are to be formulated among the stakeholders.
8) Construction of partial embankment to connect Fatepur and adjoining villages surrounding Siali wetland with the main road (Bhaluka road and NH 81) for the purpose of planned eco-tourism development along with the setup of eateries and shops. So that, tourists may be encouraged to come here by cycle-rickshaw or auto-rickshaw from Harishchandrapur (nearest railway station).

6.5.1.2 *Chakla Wetland:*

Adequate management and restoration strategies are need to be redacted in order to rake up and conserve the physical and biological integrity of Chakla wetland. The actions suggested are as follows:

1) Sincere monitoring and productive engineering work are to be implemented in order to keep the surface flow intact within wetland throughout the year by increasing the inflow (through Nuna River in north and Bhoga River in the south) during post-monsoon and checking outflow during monsoon, thus simultaneously recharging the ground water.
2) De siltation and clearance of Mara Mahananda River (flowing south-west of wetland) in regular interval through conventional method in order to regulate the inflow within Chakla wetland complex including Khanpur, Singra and Chakla wetlands.
3) Formulation of stringent legal action against conversion of wetland complex area for non-wetland purposes (agricultural field). Moreover, identifying the non-point source pollution into wetland along with dynamic monitoring is awfully momentous on use of pesticides, land run-off from surrounding agricultural fields within wetland; at least twice a year.

4) Regular monitoring on the physico-chemical components of this wetland water before and after the monsoon season is required for maintaining an orderly scientific pisciculture. So that, it provides a technical support, which aid in formulating comprehensive wetland conservation, restoration and management programme.
5) The existing five fishing cooperative society under Malatipur Gram Panchayat should provide unique opportunity to devise mechanisms in order to promote commercial pisciculture and conserve this wetland complex in a better and coordinated way.
6) Fostering innovative strategy is essential to enhance the fishing activity in an organized way by practicing in already waterlogged agricultural fields for a long time period in a year. It will facilitate in boosting the adjoining rural economy for mass of fishermen.
7) Regulating the diversion and over extraction of water for irrigation and empowering local habitants to establish a participatory, equitable and accountable wetland water use.
8) The awareness and educational programme regarding once existing mega biodiversity in Chakla wetland should be formulated by the scientist and NGOs with the purpose of restoration and conservation of those species (resident and migratory birds, faunal species), which are at the brink of extinction.

6.5.1.3 *Naghoria wetland:*

In order to protect and conserve Naghoria wetland with keeping in view the tremendous potentialities in terms of ecological and economic viabilities and at the same time to maintain its wise use, some actions are suggested as follows:

1) In order to maintain a substantial water table throughout the year within this cut off, the inflow and out flow channels in the form of Nurpur barrage and Kalapahar sluice gate will have to be reoriented. A well-planned arrangement is required in order to increase the recharge potential of this water body as well as to improve the ground water table.
2) Restricting and preventing wetland area conversion to non-wetland purpose (agricultural land and mango orchard) and prohibiting resultant fragmentation in the catchment area. Immediate fencing from eastern (Lakshmighat village) and southern (Naghoria village) part is very urgent in order to arrest further encroachment and

conversion to active agricultural tract. And hoarding with caution notice should be fixed along with clearly drawn demarcation line between wetland area and surrounding agricultural fields.

3) The conservation and management strategies of Naghoria wetland must involve the protection of wetland by checking and regulating the impact of insecticides, fertilizers and effluents, draining into this cut-off from adjacent agricultural tracts. Appropriate and successful long term management of Naghoria wetland require, environmental awareness programme to correct non-point source pollution problem and make a buffer zone at the interface between the water body and adjacent land area, so as to limit anthropogenic activities around this wetland.
4) In association with the previous one, wetland conservation should include the protection of wetland by using water quality standards and safeguarding the biodiversity and productivity. Moreover, strict and continuous monitoring on net fishing and killing of young stocks within wetland and implementing organized fishing practice under the supervision of Uttar Lakshipur and Phulbaria Gram Panchayat is necessary.
5) Aquaculture should be encouraged, adjacent to the bed villages keeping in mind the sustainability and wise use of wetlands. In addition, the possibility of introducing prawn culture in wetland bed should be studied in detail, through which additional gainful employment opportunity can be achieved to the peripheral settlers.
6) Duck rearing within wetland can be served as an alternative economic support for the gainful self-employment. It should be practiced in more coherent and organized manner, avoiding scruffy environment as well.
7) Intense forestation is required, confining the wetland especially between Koklamari and Phulbaria village in order to check intense agricultural activity. Moreover, afforestation enhances aesthetic value of wetlands by increasing arrival of migratory creatures.

6.5.1.4 *Chatra wetland:*

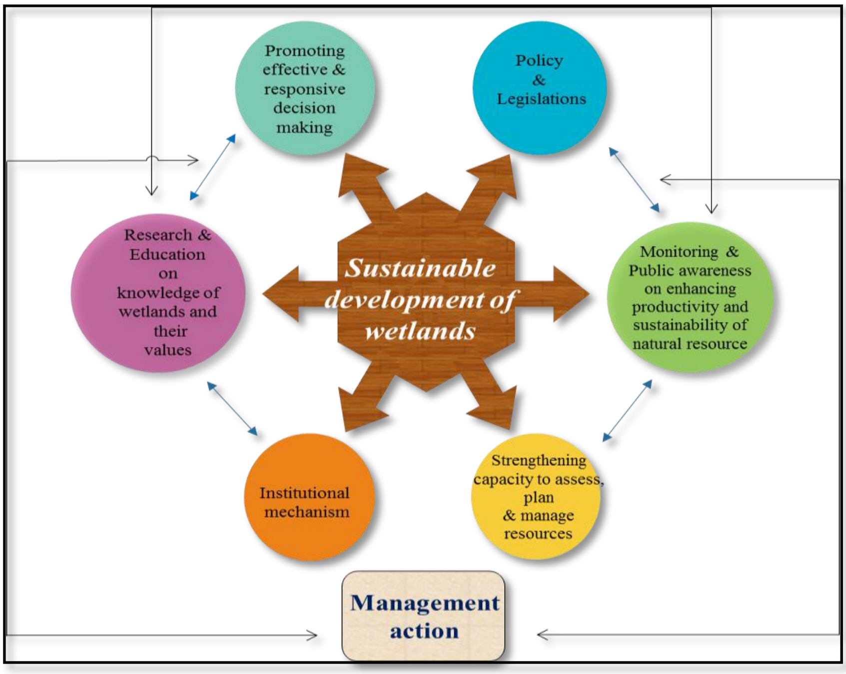
Immediate implementation of regulatory framework is necessary in order to originate a better comprehensive and sustainable conservation and management strategies of Chatra wetland (peri-urban) of Malda district:

1) Strong monitoring and strict measures should immediately be implemented by English Bazar Municipality and local government in order to restrict further alteration of wetlands to other land use categories (built-up area, agriculture and brick kiln).
2) The presently existing area of Chatra wetland will have to clearly be demarcated as well as fenced with the caution notices fixed at the different portions of fencing and must be maintained with successive sound monitoring.
3) Proper identification of point source pollution (municipal sewage) and prohibiting those activities (solid waste dumping, urban construction)) which are unsustainable on the basis of environmental substance. Implementation of integrated solid waste management as per the guidelines of the national Solid Waste Management (SWM) committee is needed *(Roy et al., 2011)*, in order to make the wetland garbage free and to keep them pollution free as well.
4) An appropriate sewage treatment facility is necessary with much emphasis on the re-cycle and re-use of waste water with assurance that does not contaminate the wetland water.
5) Keeping in view the East Kolkata Wetland, the wise use of Chatra wetland can be formulated by utilizing the city sewage for resource recovery practice on scientific basis. Organized waste recycling is to be constructed through basic conservation principal of sewage fed fishing and sewage fed aquaculture. Further, the garbage farms can be utilized for compost production, and applied in cultivation purpose.
6) Identification of non-point pollution sources and intense monitoring is needed for checking the impact of pesticides and fertilizers, and regulating the input, which is draining into this wetland. Conduct regular water quality monitoring, including the collection of surface water, biological samples, laboratory analysis and quality assurance *(Kiran & Ramachandra, 1999)*. Measuring water quality standards can be achieved by integrated efforts from efficient expertise under educational institutions, colleges and university.
7) De silting the wetland in order to enhance the storage capacity to retain and harness rain water in a feasible manner and so as to improve the ground water table by increasing the recharge potential. Moreover, a substantial water table round the year is essential in determining the frequent arrival of bird species.
8) A systematic and well organized areal distinction within wetland should be earmarked for both the makhana and fishing practice to make the pisciculture and its

associated economy uninterrupted. Furthermore, alternate gainful livelihood option can be provided to the surrounding rural community from profitable makhana cultivation via wise use of Chatra wetland.

9) Stringent law should be enforced for the violators against excessive utilization of wetland water and related resources (illegal poaching, trapping and hunting of icthyofauna and avifauna). The judicious utilization of this wetland is largely important for enabling the socio-economic development and simultaneously promotes the social cohesion along with economic stability.
10) Effective afforestation should be implemented at the adjoining areas of wetland (which already have cut down due to construction of railway tract and national highway) to check further encroachment, siltation and agricultural residues from farm chemicals and irrigation water.
11) Lastly, the conservation and management objective of this only peri-urban wetland seeks to harmonize planning at various levels involving concerned stakeholders to achieve the objectives of integrated wetland conservation and sustainable development.

Along with the case studies, the conservation strategies and recommendations for all the wetlands under study in Malda district require the proper implementation of those acts and rules *(Figure 6.1)*, which have yet not been executed, in a decentralized manner initially by the Government Agencies and subsequently by the stakeholders and community participation. So that, there will be stop of conversion of wetland into land for agriculture and other activities, as well as stop of encroachment of built up area to the natural boundary of wetland. Since the state government is the custodians of wetland resource, they must implement *National Wetland Conservation Programme (NWCP)* in order to ensure the wise use of wetlands. The administration is chiefly responsible for sustainable management of wetlands in the form of taking Management Action Plan (MAP) with short term and long term objectives to go in for remedial measures *(MoEF, GoI, 2009)*. Further, the protective and legal tools must directly be interlinked with the wetland conservation programmes in Malda district. It should get prioritized through proper planning and implementation as far as the wetlands under study are concerned *(Figure 6.5)*.



Source: *Acharya & Adak, 2009; Friend, 2007*

Figure 6.5 *Action Plan for Wetland Conservation*

Replacement of ongoing Green Revolution Technology (GRT) is highly essential, which is being widely practiced in the periphery of wetlands. Agricultural intensification with fertilizers, pesticides and other inputs often leads to washing away of soil by water flow and resultant siltation problem within wetlands and water bodies. Therefore, sustainable agriculture is recommended at wetland periphery without causing irreversible alteration to the wetland ecosystem character. As a consequence, siltation rate will also be controlled and wetland water will be pollution free as well.

Regular de siltation of wetlands is required along with use of this nutrient rich sediment in agricultural land which was once a well-known practice in order to make agricultural land more fertile. As a consequence, the water storage capacity and resultant infiltration rate of wetland bed will be increased, which will facilitate the ground water replenishment as well as result in restoration of river and other inland water bodies through the base flow.

Change in makhana cultivation technology especially in applying the toxic insecticides before makhana seed sowing in wetland water, is necessary in order to resist the eutrophication problem and to keep the biodiversity richness intact. Moreover, the Dept. of Fisheries in a close collaboration with Dept. of Agriculture, Govt. of West Bengal should undertake a detailed study in order to determine the possible detrimental effect by the introduction of Makhana practice within wetland. In addition, environmental awareness campaign should frequently be launched for promoting sustainable agriculture and aquaculture along with the establishment of local conservation committee.

The sewage water need to properly be treated before releasing into those wetlands which are connected to urban sewage canal through which waste water is directed to wetlands. So that, there will be no more water pollution, no more eutrophication and wetland biodiversity of native species will be restored.

Restitution of wetlands under study through comprehensive approach needs to be adopted on sound ecological base in order to augment the biotic heritage. In addition, large scale forestation of fruit trees (mango, black berry, sabeda etc.) is required in the contiguity of wetlands with the purpose of nesting and roosting of migratory birds. Moreover, regulating centers are to be set up at wetland periphery in order to keep unremitting records of residents and migrant species and their movement round the year.

Proper efforts must be made to regulate the infestation of aquatic weed (thick mat of *Eichhornia crassiper*, *Pistia stratiotes*) by periodic clearing. Along with manual removal, utilization of available technology for rooting out extensive invasive weeds which can be recycled for energy regeneration through installation of community based biogas plants and compost production.

An appropriate economic valuation of wetland resources is highly essential, which plays an important role of putting a monetary value. Economic valuation catches the attention of decision makers as well as helps in financial resource mobilization and rational decision making *(Rao & Datye, 2003)*.

Formulation and implementation of planned wetland centric eco-tourism through multi-stakeholder partnerships involving public agencies, local communities and the investors for the sake of providing additional alternate income generation to the rural poor and promoting their economic growth.

Being an interface between policy and people, the institutions (rules, procedures, and norms of society) and organizations (government, private sector, and civil society) should encourage and assist the local government, local administration and Gram Panchayat in order to protect and conserve the wetlands of entire district through precise planning and execution.

Public awareness programme using traditional and modern communication media (group meeting, slide show, poster exhibition, workshops, eco-rallies, street theatres etc.) needs to be implemented with high priority, which states to educate the peripheral villagers regarding the substantial values and services provided by wetlands without any cost. All the stakeholder including institutions, government departments, non-governmental organizations

(NGOs), local governments and many others need to be better informed about the rationale, goals and methods of wetland ecosystem restoration. Local inhabitants have to be empowered to establish a participatory, equitable and accountable use of wetland resources in order to control their over exploitation.

6.6 Conclusion:

The human welfare in the form of economic improvement and ecological security of West Bengal depends largely upon the proper functioning of the natural resource systems, wherein wetlands are among the foremost which draw attention *(Dept. of Environment, Govt. of West Bengal, 2012)*. Thus, a paradigm shift in conservation ethic is also a strong need of an hour. This shift is necessary and perhaps mandatory due to the very nature of resource being conserved and 'protected' *(Prasad et al., 2002)*. The mentioned recommendations are essentially applicable to all the wetlands of Malda district which belong to unique individual characteristics. Therefore it is necessary to prepare separate management plans for individual wetlands. It is essential to develop a wetland authority at central government level which would coordinate with the authorities to be set up at the state government level. It would ensure the formulation and implementation of policies and action plans for conservation and wise use of wetlands *(Rao & Datye, 2003)*. Along with mentioned action suggestions; comprehensive laws, policies, regulation standards and guidelines should be adapted with assurance that to be enforced for effective wetland resource management. Moreover, wetland management require adapting multidisciplinary approach with increased coordination between different agencies (state departments concerned with environment, soil, agriculture, hydrology, fishery, forestry, urban planning and development, natural resource management) and policy makers. Effective wetland research is needed according to the regional priorities and initiatives for conservation of wetland biodiversity and their wise use. Preparing inventory and assessment of key macrophytes, icthyofauna and avifaunal species within individual wetland basins and periphery are to be prepared. Furthermore, a network of local administration, municipality, academicians, researchers and NGOs must coordinate grass root level implementation of policies and activities related to wetland conservation. The involvement of stakeholders with proper knowledge would entail the key functions and values of wetlands to gratify the critical resource needs to all the human population and sustainable management of wetlands in Malda district.

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Chapter – VII

CONCLUSION

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CONCLUSION

Malda district is centrally located in West Bengal. Being a flat terrain, the district is crisscrossed with numerous rivers and is made of alluvial formation. The district is endowed with three physiographic regions namely, *Tal* (north and north-west), *Barind* (east) and *Diara* (south and south-west) with small altitudinal variations. The general slope is gentle which is proved by the meandering river courses, flowing from north to south. The district exhibits strong evidences of complex hydrological activities which comprise recurring shifting of river channels, massive bank erosion along with frequent dereliction of rivers. This typical hydro-geomorphic set-up promotes various number and categories of wetlands in the form of natural inland water bodies like seasonal waterlogged areas, cut-off meanders, lakes, marsh etc. The wetlands, referred as lowlands, are covered with shallow and some time temporary or intermittent waters.

Malda district is occupied by freshwater inland water bodies (lakes, marshes and swamps), containing two sub-classes 1. Natural and 2. Man-made. In order to classify different types of wetlands along with estimating their geographical extent (objective no. 2), two classifications have been followed in present study. The first systematic approach regarding wetland mapping and classification has been initiated by Institute of Wetland Management and Ecological Design (IWMED) established by Govt. of West Bengal, Kolkata (2000) with manifold application of remote sensing technologies. They incorporate 562 wetlands (≥ 2.25 ha) with a total area of 294.16 sq. km, out of which, waterlogged seasonal (inland) wetlands are largest in number with an area coverage 209.56 sq. km. The second approach has been conducted by Space Application Centre (SAC) ISRO, Ahmedabad (2010) in collaboration with Institute of Environmental studies and Wetland Management (IESWM), who incorporates a total number of 502 wetlands (≥ 2.25 ha) with an area cover of 20,725 ha. The district is occupied by a considerable number of inland natural wetlands including ox-bow lake formations. Under the man-made classes, tanks occupy a significant number rather than reservoirs and water logged cover. Mapping of the entire wetland resource (objective no. 1) of Malda district has been done in order to monitor their behavior as well as suggest conservation measures for sustainable development of wetland resources. In order to analyse the present status of wetlands of the entire district, a total of four case studies have been selected as representative wetlands for further detail analysis namely, *Siali wetland* under block Harishchandrapur 2, *Chakla wetland* under block Chanchal 2 and Ratua 2 in *tal* physiographic division; *Naghoria* wetland under block Ratua 2 and English Bazar and *Chatra wetland,* under block English Bazar in *Diara* physiographic division *(Appendix-4)*. Selection criteria have been considered for the case studies are; different categories of wetlands (i.e. riverine, waterlogged, ox-bow lakes etc.), degree of human interferences and resultant encroachment of wetland area (depending on location of wetlands at rural and urban periphery) and finally the agro-economic and biological potentials (in order to sustain the socio-economy of peripheral settlers) of wetlands of Malda district. All the wetlands, under study are directly or indirectly linked with the major rivers viz., Ganga, Mahananda, Kalindri, Fulahar along with their tributaries. Out of the case studies, Siali wetland is relatively small sized natural wetland (18.74 ha) with less than 2 to 3.5 m water level throughout the year and appears to be definite irregular shape. The geological composition of the area comprises wide alluvial plain where the gradient is perceptibly gentle. The area is formed by the excessive silting of the Kalindri and Mahananda River of recent origin. The wetland is connected with two inlets, Kankhor and Kali kosi, the tributaries of River Baramasia, which meets with River Kalindri, flowing from north-west to south. Two outlets, through which the excess water drains out, are Kokra Bridge and Elangi canal, connected with this water body, and play significant role in maintaining the hydrology of the entire wetland. Chakla wetland is considered the largest one with 842.50 ha area coverage and 2 to 3.5 m water depth throughout year. The slope is gradual, as is proved by the meandering course of Mara Mahananda (flowing through south-west) and Mahananda River (flowing through east). The entire area of the Chakla wetland complex is covered by typically dark, loosely compacted recent alluvium, with a high water and organic material content. The Nuna and Bhoga River, two tributaries of Mahananda, with southward flow, control the inflow of water during the pre-monsoon season and check the outflow during the monsoon period. The river water from Nuna along with surface discharge is the principal sources of Chakla wetland water. In diara region, extreme bend of River Kalindri has cut-off from main stream and rejected channel forms oxbow lakes. Naghoria wetland is an ox-bow lake with area coverage of 228.13 ha and an average water depth of 2 to 3 m round the year. The general slope of the wetland region is towards east and south-east and is perceptibly gentle. The maximum portion of the region is a part of active flood plain which is formed by immature dark, loosely compacted newer alluvium with higher moisture content. The main support of its drainage is mainly rain water, along with the river water, where surface run-off from the vast catchment area enters into

Naghoria wetland during the monsoon and post monsoon period from Kalindri and through Nurpur barrage from mighty River Ganga. These mentioned three wetlands are characterized with a rural set up, whereas the fourth one namely Chatra wetland is surrounded by both the rural (North-west, west, south-west) and urban (North-east, east, south-east) set up, and located adjacent to English Bazar Municipality, Malda district. Chatra wetland is formed on the flat area and shallow slope, in association with alluvial tract, which is created mainly by the combined actions of erosion and deposition by River Mahananda and River Ganga. This wetland is considered peri-urban with a definite irregular shape. Its area extension is 234.54 ha with less than 2 to more than 3.5 m water level throughout the year. Regular supply of Malda Municipal sewage flow as well as the surface discharge in the form of rain water is the permanent source of water intake of this peri-urban wetland.

The present study analyses the biological diversity of wetlands through field study and interviewing the local people. The diverse species of macrophytes and icthyofauna have been collected as well as identified and avifaunal species are sighted and identified for preparing the inventory as well as estimate the biodiversity potential of these wetlands (objective no. 4). A general survey on the macrophytes, reveals a heterogeneous assemblage of growth forms, namely; emergent, rooted floating leaved, free floating, semi-emergent, submerged rooted, and emergent grass to be present in and around the wetlands under study. A total of 21 species of macrophytes, belonging to 21 genera and 17 families have been collected and identified from present study, which are found in two habitats namely open water and wetland water edge. The dominant families are *Asteraceae*, *Nymphaeaceae* and *Salviniaceae,* represented by 2 species each. The wetlands under case study display a regular growth of macrophytes such as *Centella asiatica, Colcasia esculenta, Enydra fluctuans, Eclipta alba hassk, Heliotropium indicum, Polycarpon prostratum* etc. in wetland water edge. Similarly a large number of aquatic flora such as, *Aeschynomene aspera, Trapa natans, Nelumbo nucifera, Euryale ferox, Nymphaea nouchali* etc. are identified in the vast open water. Moreover, the wetlands act as the store house of known medicinal properties e.g. *Centella asiatica, Hygrophilia auriculata, Enydra fluctuans* etc. which are observed to play substantial role in the local socio-economy of the entire district. Furthermore, the wetland bed harbor a thick assemblage of *Euryale ferox* cultivation, which is full of nutritional value and is considered a commercially viable potential aquatic cash crop. The present study depicts that the wetlands of Malda district are the places of intense biological activity including the breeding of many species of fishes and aquatic organisms. A total number of 24 species, belonging to 21 genera and 14 families of fish fauna have been identified from the case study. The wetlands which have organized fish cultivation through cooperative societies are endowed with rich faunal diversity in association with *Labeo catla, Clarias batrachus, Labeo rohita, Cirrhinus cirrhosis, Arius arius, Cirrhinus cirrhosis, Arius arius, Labeo calbasu, Labeo bata* etc. *Cyprinidae* is found most dominant and diversified family with 11 species. Apart from, diverse species of aquatic flora and icthyofauna, wetlands of Malda district are considered significant natural ecosystem which facilitates diverse ornithological composition. The wetland open water and water edge are characterized by a wide range of feeding and breeding migratory and residential species. A total of 32 bird species, belonging to 27 genera and 17 families are sighted and identified by applying point count method, out of which 23 are residents and 9 are migrant species. The avifaunal family of *Anatidae containing 9 species and Ardeidae with 7 species is considered most dominant*. Various residents namely *Phalacrocorax fuscicollis, Anas paltyrhynchos, Ardea alba, Ardea cinerea, Ardeola grayii, Spilopelia chinensis, Pycnonotus cafer* etc. have commonly been sighted in and around wetlands. Furthermore, large assemblage of migrant bird colonies ranging from Leh, Ladakh and other parts of Himalayas, to Siberia namely; *Anas acuta, Anas clypeata, Anas poecilorhyncha, Aythya nyroca, Aythya fuligula* etc. have been sighted. Migratory birds appear in the wetlands and its periphery during the annual migrations in winter months, from November and stay up to February. The present study has attempted to determine the avifaunal species diversity and species evenness by applying Shannon-Weaver diversity index. Out of the case studies, Naghoria is recorded with maximum species diversity, followed by Chakla, Chatra and Siali wetland. Species evenness index reveals similar picture of highest evenness in Naghoria and relatively lower in Chatra and Siali wetland. The lower species diversity and evenness in peri-urban wetland, compared with other case studies is attributed to increasing water pollution (recorded from water quality testing), wetland area shrinkage and associated problems. The case studies reflect the presence of topographic and biological diversity of all the wetlands in Malda district, which maintain the density and diversity of aquatic floral and faunal species. Being a historical heritage most of architectural structures and ruins in the form of mosques, tombs, and gateways have been formed by the rulers alongside wetlands, in several centuries back. The wetlands with intact biotic diversity (aquatic flora and fauna) in association with historical structures are potential enough in order to promote the eco-tourism activity by constructing proper infrastructure (afforestation, road networks, bird watching tower and other amenities) as well as enhance the aesthetic importance and economic development of the entire district. These evidences along with the inventory of biotic components *(Appendix-5,6,7)* in the wetlands of Malda are sufficient to prove the hypothesis no. 3 i.e., rich biodiversity of wetlands has the potentiality for wildlife vis-à-vis aesthetic and recreational uses i.e., eco-tourism activities. Moreover, the wetlands with heterogeneous biotic assemblage (as proved by field observation and diversity indices) are sufficient to prove hypothesis no. 1 that, wetlands are potential in order to provide biodiversity conservation in Malda district.

Malda district and its environs has been suffering from flood hazard, caused by the River Fulahar, Kalindri, Tangan and Mahananda, overflowing its banks almost annually and cause damage and tremendous stress on the fabric of entire district. The existing wetlands, as interlinked with the major mentioned rivers, are potential in order to protect the district from the fury of occasional flooding. In the present study, the database, which has been generated as the outcome of present research is capable to prove hypothesis no. 1, that the wetlands of Malda district are potential in order to mitigate flood hazard in the adjacent terrestrial ecosystem, by storing large volume of water, ranging from 554,358 m^3 to 42,314,620 m^3 during monsoon period and eventually replenish the ground water. Moreover, the water quality measure is considered an ideal tool for establishing base line data to assess the pollution status within wetlands, which are attributed to various anthropogenic activities and resultant wetland degradation (objective no. 6). In this regard, a general survey on the physical (water temperature, turbidity), chemical (pH, total dissolved solids, conductivity, total hardness, dissolved oxygen, chloride, fluoride, iron content etc.) and bacteriological (total and faecal coliform) water quality parameters have been made. The water samples have been collected from case studies during study period (2015-2018) covering three different seasons (pre-monsoon, monsoon, and post-monsoon) *(Appendix-8)*. Collected water sample are tested in laboratory for further analysis, which reveals the following findings: Water temperature as a physical parameter records an average temperature ranging 27 to 29°C in the wetlands. The average water turbidity is recorded 3 to 6 NTU within the wetlands, with maximum concentration during monsoon, followed by post-monsoon and pre-monsoon. Out of chemical parameters, an average wetland pH is recorded 7.2 to 7.7 with maximum concentration during pre-monsoon. The peri-urban wetland records high pH content which is slightly alkaline and substantiates an excessive algal growth in wetland water. Average conductivity is recorded fluctuating throughout year and ranges from 115µ.s. to 450µ.s. with maximum concentration in wetland, adjacent to urban periphery which may be caused due to large ionic concentration and pollution status especially from point-source pollution. The peri-urban wetland records an average total dissolved solid concentration of 241 ppm, which is attributed to point (municipal sewage) and non-point (agricultural run-off) sources of pollution. Other case studies record an average tds of 55 to 75 ppm. The average total hardness is recorded 75 to 212 mg/L with maximum concentration in peri-urban wetland. The wetlands exhibit high concentration of total hardness, turbidity and conductivity which are found to exceed the desirable limit *(BIS, 2012; APHA, 2017)*. The high content of mentioned chemical parameters is resulted from the agricultural run-off, which is full of toxic chemicals, in association with sewage inflow from the peripheral settlements. The measure of amount of oxygen, available in water for biochemical activity is considered as dissolved oxygen, which is recorded 5 to 9 mg/L with maximum record during post-monsoon. Other chemical components (chloride, fluoride, iron, arsenic etc.) are recorded in low concentration throughout the year. The bacteriological parameters, total and fecal coliform counts are recorded maximum during post-monsoon with an average count 4 to 10 MPN/100 ml and 0 to 4 MPN/100 ml of water respectively. The peri-urban water body receives a large volume of sewer inflow due to favourable slope condition from the adjacent municipality wards (no. 3, 23, 24 and 25) along the north-east and south-west boundary. The water sample test records *(Appendix-8)* that most of the water quality parameters are restricted within permissible range, as recommended by BIS (2012) and APHA (2017), which is attributed to the filtering effect of this peri-urban wetland and the presence of aquatic macrophytes. Some of the chemical parameters (except water pH, dissolved solid, conductivity and water hardness) are recorded a bit higher than the recommended range. Therefore, the present output of water quality test proves the hypothesis no. 1, that the peri-urban wetland is potential to treat waste water inflow from 22 numbers of sewerages, under ward no. 3 and 25 along the south-west boundary of adjacent English Bazar municipality.

Moreover, the variation of different physical, chemical and bacteriological parameters between the wetlands and between the seasons has been computed by one way Anova. The statistical analysis reveals that water parameters record both the significant (p value $< \alpha$ value) and non-significant (p value $> \alpha$ value) results between the wetlands and between the seasons. Water turbidity under physical parameter; conductivity, total dissolved solid, dissolved oxygen, total hardness, iron, chloride, fluoride, arsenic under chemical parameter and faecal coliform under bacteriological parameters have recorded significant variation between the wetlands (case studies) at 0.05 levels in two-tailed test at 95% confidence level. Whereas, the water temperature, turbidity under physical parameters; water pH, hardness, dissolved oxygen, iron, arsenic under chemical parameters; total and faecal coliform under bacteriological parameters record significant variation between the seasons (pre-monsoon, monsoon and post-monsoon) at 0.05 levels in two-tailed test at 95% confidence level.

Furthermore, the observations on the water quality parameters of selected wetlands are further analyzed with the Pearson's product moment correlation coefficient. The correlation coefficient results into highly significant ($p<0.01$) positive correlation between water temperature, pH and water hardness; between pH, total dissolved solid and conductivity; and between total and faecal coliform counts. Highly significant ($p<0.01$) negative correlation is found in water temperature and pH, both with total and faecal coliform. Significant ($p<0.05$) positive correlation is recorded between water temperature, conductivity and tds and negative correlation is found between water temperature and dissolved oxygen. The low content of dissolved oxygen is found during pre-monsoon period, which indicates poor status of aquatic life within wetlands. Therefore, water sample testing and analyzing the water quality parameters of selected wetlands provide a base line data in order to know the ecological status of entire wetland resource of Malda district. The study reveals that, the wetland resource encounter immense challenges from anthropogenic activities either in the form of land run-off from adjacent agricultural field, or is being contaminated by municipal and domestic effluents along with solid waste dumping as well as eventually results into further degradation. Therefore, the hypothesis no. 5 i.e., the current piecemeal and consumption-oriented approaches affecting adversely the wetland resources of malda district, which is proved by water sample test and the different sources of water pollution has also been documented by applying one way Anova test .

The wetlands of Malda district directly and indirectly support large number of population in providing services such as food, fiber and clean water supply. The habitats (villages) surrounding the case studies are classified into two categories *Bed village* (at immediate vicinity of wetland and entirely wetland dependent) and *Belt villages* (a bit far-off and depend on wetlands only for commercial purpose). A household survey (5% of universe) has been conducted randomly from bed and belt villages in order to analyse the utilization of wetlands *(Appendix-9,10)* (objective no. 3). The study reveals that bed villagers are entirely dependent on wetlands through different occupations like irrigation, cultivation, fishing, gathering wetland products (macrophytes and aquatic fauna etc.). However, in the present study, all the case studies experience a good portion of its area coverage along with its ample water resource to be contributed for cultivation, which provides critical economic support to the rural households. Wetland bed along with its edge is utilized for the major crops like paddy (Aush, Aman, Boro), legumes, wheat, mustard and pulses (Kalai, Moong) and mixed vegetables etc. especially by the settlers, residing at the periphery (Bed village). Boro paddy, which is considered much remunerative, is cultivated during November to February in the water spread area, immediately after monsoon. Aush and aman paddy are cultivated at wetland edge with the help of wetland water as zaid and kharif crop respectively. Jute is considered another dominant kharif crop as well as commonly cultivated at the wetland edge. Additional crops such as Corn (March to July) and Bajra (August to November), are cultivated at wetland periphery with the help of wetland water. Siali wetland is characterized with a good association of cereals (Motor, Chola, Kalai) as well as several vegetables (Brinjal, Cauliflower, Radish) etc. along with betel leaf, which is considered an important cash crop of high economic value. These wetlands are also used as a source of irrigation by tapping through indigenous system (shallow pumps or shallow bore wells) for the adjacent farm lands. Therefore, the farmers around the wetlands get initial benefit in the form of less cost of irrigating their farm lands and subsequently, they divert the deposited money in order to buy other agronomical inputs. Along with the support to agricultural production, wetlands facilitate better opportunities for the inhabitants in the form of fishing practice, which has immense socio-economic values, attached to it. The fishing practice is mainly done by the cooperative societies under Gram Panchayats on lease basis in Siali and Chakla wetland. The entire fishing practice is controlled by the Bhaluka Fishing Cooperative Society in Siali wetland (on lease for 3 to 4 years). Fish cultivation is done in Chakla wetland under five cooperative societies (Rampur Fishing Cooperative, Ojitpur cooperative, Goalpara cooperative, Boalia cooperative and Dhanga cooperative society). Diverse varieties of carps are produced in Chakla and Siali wetland along with Rohu, Ar, Shingi, Mangur, Bata, Mrigel and Catla as dominant fish species. Chatra and Naghoria wetland do not have any fishing cooperative and fish cultivation, except fish catch by the local fishermen. Dominant fish species which are usually caught in these wetlands and sold to the local and main market include Bata, Kalbaush, Catla, Koi, Mangur, Prawn, Rohu, Tangra etc. Moreover, a large section of peripheral settlers are dependent for their livelihood on these wetlands both for cultivation and fishing. In the present study, wetlands are utilized for several product gathering in the form of aquatic flora (Kalmi, hingcha, kulekhara) as food which also possess important medicinal ingredients and fauna (oysters/mollusks and gugli). These wetland products are sold at local market, as well as supplement the household economy for the people residing in the vicinity of the wetlands. The aquatic macrophytes are also used by local habitants directly for the food, fiber and fuel. The thick cover of water hyacinth, which is present in all the wetlands, under case study is collected as fodder, which is considered a cheap source for feeding the cattle population. The economic valuation of the case studies have been done, which encompasses the true costs of utilizing the wetland products, utilized by the stakeholders. In the present study, apart from utilizing wetland water as a source of irrigation to cultivate agricultural field, the total benefit from makhana cultivation from the case studies range from Rs. 3,50,625.00 to Rs. 51,97,500.00 per annum. Wetland fishing is found much more remunerative than food crop cultivation and ranges from Rs. 4,62,500.00 to 14,47,500.00 per annum. Wetland product gathering records relatively less profitable (Rs. 21,600.00 to Rs. 76,500.00 per annum) than cultivation and fishing. Therefore, the total estimated benefit, found from the case studies range from Rs. 8,75,000.00 to Rs. 57,36,500.00 per annum. The case studies act as the representative wetlands in order to analyse the dependency on wetland ecosystem, utilization of wetland water and other resources and their economic valuation, which depict a vivid picture of the entire wetland resource utilization in Malda district. Therefore, the sample survey in bed and belt villages is sufficient in order to know the utilization of wetlands by surrounding households as well as to prove the hypothesis no. 2 i.e., wetlands of Malda district are currently utilized for agriculture, aquaculture, and coir rotting, gathering fruits and fiber etc., and also satisfying various socio-economic needs. Although the present study reveals that the coir rotting is practiced negligible in the wetlands of Malda district.

In the present study, the wetlands are found to flourish a number of valuable aquatic cultivation which can be harvested on a sustainable basis in order to provide an alternate economic support to village livelihood (objective no. 5). Wetland cultivation promotes immense potentiality in the form of *Euryale ferox* (makhana) cultivation, which is considered an important cash crop with high nutritional value. The cultivation of *Euryale ferox* has already been introduced as well as expanded on mass scale especially in the wetlands of *Tal* and *Diara* region. A significant number of households, irrespective of bed and belt villages are engaged in makhana cultivation on lease basis under fishing cooperatives and gram panchayats. Being immense potential to provide considerable amount of cushion to counteract the impact of poverty, efforts are being made to spread this distinguished aquatic crop to other wetland areas. Apart from makhana, another important crop with high economic valuation is betel leaf (dishi/ indigenous) on which a good number of households are dependent. The judicious use of wetland water for betel leaf cultivation is considered economically potential enough for sustaining the habitants’ livelihood. Trapa natans, locally called as paniphal, is a traditional aquatic crop and is cultivated in open water. Paniphal can commercially be cultivated as edible fruits in wetlands under study with immense potential to provide alternate economic return on a sustainable basis to the rural mass of Malda district. Apart from wetland cultivation, duck rearing within wetlands is also considered economically significant and an important source of highly demanding duck eggs in market. Moreover, *Aeschynomene aspera* (Sola) is cultivated in small number of wetlands under Malda district, which contains significant potentialities in providing nitrogen input in soil in order to enhance the agricultural productivity and act as green manure. Further, sola cultivation within wetlands is found highly potential as well as remunerative in order to provide indigenous handicrafts and to save the traditional heritage. The present study reveals that, there is ample scope to utilize wetland resources in Malda district (cover a good portion of area under wetland cover) in the form of cultivating commercial crops along with other activities which facilitate the income generation of rural mass, thus prove the hypothesis no. 4 that, wetlands have the potentiality to provide alternative economic support to rural people through generation of gainful self-employment.

In view of the ecological, biological and socio-economic importance of the wetlands, under study, the present work has attempted to analyze a paradigm shift in conservation ethic to this natural ecosystem with special reference on its wise use and sustainable management. The Ramsar Convention (2 February, 1971) and Convention on Biological Diversity (5 June, 1992), two international initiatives have been conceptualized as mobilized approach to the conservation and holistic development of wetland ecosystem. Both the initiatives have made considerable contribution to the wise use of wetland resources, including its biodiversity by the world conservation strategies which underline the interdependence of conservation and sustainable development. A total of twenty seven (27) wetlands of India have already been designated as Ramsar sites of international importance till date. Ministry of environment and Forest, Government of India has conducted strategic and science-based approach, namely National Wetlands Conservation and Management Programmes (1985-86), National Conservation Strategy (1992), with the aim of conserving wetlands in the country so as to prevent their further degradation and ensuring their wise use for the benefit of local communities. Furthermore, a number of protection laws and legislative tools (The Indian Forest Act, 1927; The Indian Fisheries Act, 1857; Wildlife (Protection) Act, 1972; Water (Prevention and Control of Pollution) Act, 1974; Forest (Conservation) Act, 1980; Environmental (Protection) Act, 1986; Wildlife (Protection) Amendment Act, 1991 etc.), policies (National Forest Policy, 1988; National Conservation Strategy and Policy Statement on Environment and Development, 1992; The National Water Policy, 2002; National

Environment Policy, 2006 etc.) *(Figure 6.1)* have been initiated by national and state government in order to restrict any inconvenience of wetlands, which eventually leads to further loss of biodiversity as well as all degeneracy of the natural ecosystem. In spite of being occupied by fairly good number of wetlands, Malda district encounter several vulnerabilities and resultant environmental changeability. In the present study, the satellite imagery (TM and OLI) revel conspicuous land use land cover change surrounding the wetlands between the time periods 1990 to 2018 *(Table 6.3 to 6.6) (Figure 6.4) (Map 6.1 to 6.8)*. All the wetlands record its area alteration to non-wetland commercial purposes especially in the form of mango orchard, agricultural field, brick kiln industry and built-up area. In this regard, a perception study has been made through household survey by random sampling (2% of universe) in the municipal wards (ward no. 3, 24 and 25), which are at the immediate vicinity of the only peri-urban wetland of Malda district (case study- Chatra wetland). The perception study reveals that, the open water and wetland edge encounter rapid area encroachment through continuous expansion of built-up area, solid waste dumping, water quality degradation and biodiversity reduction. Moreover, a small no. of households as well as stakeholders, adjacent to this peri-urban wetland are aware regarding the mentioned problems, whereas a large no. of population in spite of being a part of the ecological problem of wetland, still show a lot of negligence and even do not know the necessity of wetlands, in order to provide a sustainable future *(Appendix-11)*. Therefore, the present study has recommended the outlines of conservation strategies in order to restrict the remarkable changes, already happened to the overall land use conversion and other associated degradation of these wetlands (objective no. 7). Strict measures and continuous monitoring are suggested to be taken immediately by the appropriate authority in order to restrict further wetland alteration (urban encroachment) especially in the peri-urban wetland. Proper legal action is required to check wetland conversion to non-wetland purpose (agricultural land encroachment). Integrated planning is to be taken in order to maintain adequate surface flow within wetlands, throughout the year. Wetland conservation and management strategy must be comprehensive in addressing the degrading water quality which persists from agricultural run-off and sewage inflow. Preparing inventory of aquatic flora and fauna on sound ecological base along with promoting eco-tourism are considered highly essential to augment the aesthetic heritage of wetlands. Moreover, formulating stringent legal actions are required to be taken against the over exploitation of wetland resources. The judicious utilization of this wetland is largely important for enabling the socio-economic development and simultaneously promotes the social cohesion along with economic stability. Public awareness and outreach programmes regarding wetland values and functions are to be decentralized as well as conveyed to the adjoining community. All the stakeholder including institutions, government departments, non-governmental organizations (NGOs), local governments and many others need to stand together and be better informed about the rationale, goals and methods of wetland ecosystem restoration. Furthermore, a network of local administration, municipality, academicians, researchers and NGOs must coordinate grass root level implementation of policies and activities related to wise use of wetlands of Malda district and its conservation for sustainable management. Therefore, already implemented legislations, policies and plans along with conservation strategies and recommendations are sufficient to prove the last hypothesis no. 6, that the economic and environmental functions of wetland can be maintained sustainably if appropriate conservation methods and management technologies are adopted.

The present work concludes with further research scope in strengthening the ability to document, measure and value the linkages between wetland ecosystem and human population in entire Malda district. There is a scope for further research regarding land use land cover change at wetland periphery over the years and increasing metallic pollution within wetland water especially from the accelerated growth of high demanding brick kiln industry. This research can be possible with future satellites, aided with precise and accurate spatial and spectral resolution. However, wetland management as an applied side of wetland science requires a detail understanding of the scientific aspects of wetlands of Malda district. Moreover, this understanding must be balanced with an awareness of legal, institutional and socio-economic realities and incorporating the newly developed space technologies in order to ensure protection of this valuable ecosystem *(Roy & Behera, 2003)*.

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APPENDICES

APPENDICES

APPENDIX - 1

Village wise Depth of Water Level (m bgl) of Blocks of Malda District, 2013-14

Block	Village	Apr 13	Aug 13	Nov 13	Jan 14
Bamangola	Bamangola	8.07	5.35	2.13	4.55
	Bamangola (Swid)	21.98	17.58	15.14	18.28
	Charakdanga	-	-	4.40	4.50
	Makuli	6.12	5.10	2.32	2.85
	Nalagola	-	-	0.79	2.04
	Paikpara	-	-	0.97	4.65
	Pakuya hat	23.70	22.86	20.92	22.81
Chanchal - I	Chanchal (Pz)	10.72	7.96	6.58	6.07
	Ranikamat	3.12	0.61	-0.39	0.89
Chanchal – II	Malatipur	10.18	8.55	6.56	6.63
English Bazar	Battaly	7.26	6.56	5.16	5.80
	Bholanathpur	3.85	2.15	1.14	1.86
	Choto Mohanpara (2)	7.21	5.28	4.59	5.31
	Choto Mohanpara (3)	7.28	6.71	5.05	5.85
	Choto Mohanpara (4)	7.47	6.98	5.26	6.05
	Jadupur	8.49	6.21	5.07	6.52
	Milki	6.24	5.29	4.22	5.08
	Nemasarai				
Gajole	Adina	-	1.61	2.03	3.93
	Agampur	7.82	2.41	1.83	6.13
	Deotala	2.40	0.99	0.96	1.41
	Gazole	3.28	0.67	0.99	1.79
	Masandighi	8.21	2.44	2.65	3.93
	Matol	11.20	8.48	5.23	6.88
	Pandua	2.73	1.52	1.45	4.02
	Ghatsol	11.45	-	1.47	-
	Pandua 1	14.90	2.35	1.21	3.30
	Ghoskol	-	2.37	1.47	2.12
Habibpur	Bulbulchandi				
	Habibpur	7.23	1.35	1.26	3.80
	Jhin Jhin Pukur	-	2.27	1.95	4.50
	Kokabini Tajpur	-	2.37	1.95	4.50
Harishchandrapur - I	Harishchandrapur	6.87	4.99	4.25	4.26
	Kasimpur	6.43	5.79	5.35	4.86
	Tulsihata				
Kalichak - I	Kaliachak	4.54	3.35	2.99	3.32
	Kaliachawk	-	-	2.81	3.36
	Khaschandpur	5.43	4.19	3.67	4.38
	Sujapur	5.77	4.14	3.46	3.85
Kalichak - II	Muthabari	4.20	3.21	2.03	2.86
	Puratan pataldanga	4.74	4.65	3.03	4.33
	Kuriatar				

Kalichak - III	Birnagar	3.86	1.90	2.68	3.27
	Doriapur	-	-	3.72	4.27
	Mahajantala	-	-	3.27	3.77
	16 Mile	6.45	5.59	6.08	6.67
	17 Mile	4.75	3.99	2.60	3.54
Manikchak	Begamganj	5.57	3.26	3.04	-
	Manikchak	6.10	2.04	3.25	4.68
	Mohana (1)	6.84	5.18	-	4.13
	Mohana (2)	5.95	6.90	2.88	4.48
	Mohana (3)	5.04	6.56	2.21	4.52
	Mohana (4)	6.67	7.08	3.31	3.62
Old Malda	Aiho	-	-	2.38	3.96
	Jadupur	-	3.09	2.96	11.61
	Malda (Pz)	9.96	6.14	5.84	7.66
	Malda town	8.37	2.35	5.20	4.34
	Mochia	10.77	8.58	7.23	6.91
Ratua – I	Bhaluka (Pz)	5.90	2.60	4.08	4.97
	Ratua				
	Bhagwanpur	4.89	4.42	4.08	3.93
	Debipur	6.18	3.57	3.69	4.93
	Ratanpur Hat	4.80	1.94	1.11	1.49
	Shamsi	9.02	5.29	4.35	4.80
	Vado	9.37	6.07	5.69	5.85
Ratua - II	Ratua	6.95	3.96	3.76	5.09
	Pirgai	9.53	5.19	5.29	7.49
Harishchandrapur - II	Tulsihata	6.43	5.75	4.71	4.73
	Baroduari				

Source: CGWB, Govt. of India

Village wise Depth of Water Level (m bgl) of Blocks of Malda District, 2014 - 2015

Block	Village	Apr 14	Aug 14	Nov 14	Jan 15
Bamangola	Bamangola	8.24	3.40	5.31	6.1
	Bamangola (Swid)	21.53	3.69	15.73	18.34
	Charakdanga	6.56	1.95	4.28	4.62
	Makuli	5.71	2.77	1.95	4.55
	Nalagola	4.50	2.43	1.42	2.1
	Paikpara	8.95	1.99	1.69	4.95
	Pakuya hat	24.35	7.80	22.15	21.59
Chanchal - I	Chanchal (Pz)	11.59	4.65	6.90	5.83
	Ranikamat	2.05	0.32	-	2.4
Chanchal – II	Malatipur	8.87	8.15	7.67	7.35
English Bazar	Battaly	6.84	2.55	5.24	5.54
	Bholanathpur	3.45	3.16	2.20	2.85
	Choto Mohanpara (2)	6.85	5.40	5.52	6.23
	Choto Mohanpara (3)	6.83	5.40	5.68	6.19
	Choto Mohanpara (4)	7.01	4.05	5.78	6.38
	Jadupur	8.66	3.25	5.44	6.73
	Milki	6.49	3.54	5.09	5.83
	Nemasarai	-	2.55	-	-

Gajole	Adina	7.24	2.20	2.33	4.02
	Agampur	10.07	1.47	2.10	5.87
	Deotala	2.13	2.06	1.26	1.69
	Gazole	20.06	1.30	14.46	18.12
	Masandighi	8.46	2.01	2.45	4.54
	Matol	10.47	1.90	4.54	11.34
	Pandua	7.15	1.95	1.53	9.97
	Ghatsol	-	-	-	-
	Pandua 1	-	-	-	-
	Ghoksol	-	-	-	-
Habibpur	Bulbulchandi	-	-	3.10	-
	Habibpur	7.04	2.27	1.52	3.02
	Jhin Jhin Pukur	6.91	2.92	2.72	4.1
	Kokabini Tajpur	4.03	2.75	2.02	2.69
Harishchandrapur - I	Harishchandrapur	5.84	2.05	4.88	4.41
	Kasimpur	6.10	2.41	5.01	5.02
	Tulsihata	-	2.70	-	-
Kalichak - I	Kaliachak	4.58	2.99	3.69	3.73
	Kaliachawk	3.98	3.18	2.80	3.32
	Khaschandpur	5.15	2.55	3.99	4.28
	Sujapur	5.34	3.05	3.40	4.01
Kalichak - II	Muthabari	3.75	2.90		3.01
	Puratan pataldanga	5.11	3.00	2.91	4.46
	Kuriatar	-	2.40	-	-
Kalichak - III	Birnagar	4.19	2.30	3.10	3.3
	Doriapur	5.71	2.55	-	-
	Mahajantala	6.42	2.15	-	-
	16 Mile	7.85	1.90	-	-
	17 Mile	4.94	2.15	1.80	3.3
Manikchak	Begamganj	5.42	3.75	4.08	5.12
	Manikchak	5.75	-	4.09	DRY
	Mohana (1)	5.76	3.40	3.64	3.52
	Mohana (2)	5.67	3.25	3.62	3.92
	Mohana (3)	5.07	2.10	3.17	4.01
	Mohana (4)	6.66	3.10	4.00	4.86
Old Malda	Aiho	4.96	0.19	2.22	3.06
	Jadupur	15.57	3.16	8.36	12.93
	Malda (Pz)	9.69	7.63	6.82	7.86
	Malda town	7.93	1.84	3.21	4.76
	Mochia	8.61	3.14	6.14	6.62
Ratua – I	Bhaluka (Pz)	6.01	2.62	4.85	5.23
	Ratua	-	2.13	-	-
	Bhagwanpur	5.07	1.92	4.15	4.18
	Debipur	5.97	2.88	4.35	5.23
	Ratanpur Hat	4.19	1.50	1.66	1.95
	Shamsi	8.65	1.53	-	-
	Vado	10.18	1.90	6.90	6.11
Ratua - II	Ratua	7.07	3.66	4.76	5.36
Harishchandrapur - II	Tulsihata	5.83	3.48	5.26	5.67
	Baroduari		2.44	5.24	5.93

Source: CGWB, Govt. of India

Village wise Depth of Water Level (m bgl) of Blocks of Malda District, 2015-16

Block	Village	Apr 15	Aug 15	Nov 15	Jan 16
Bamangola	Bamangola	7.37	4.40	5.35	6.51
	Bamangola (Swid)	22.12	4.85	6.32	20.68
	Charakdanga	5.23	1.84	3.63	4.82
	Makuli	3.47	0.95	3.69	11.84
	Nalagola	3.55	0.43	1.96	3.06
	Paikpara	5.73	0.25	2.56	7.53
	Pakuya hat	24.56	1.60	22.06	23.52
Chanchal - I	Chanchal (Pz)	9.00	6.16	6.61	8.74
	Ranikamat	1.62	0.08	0.78	1.04
Chanchal – II	Malatipur	9.04	7.20	7.56	8.18
English Bazar	Battaly	6.84	4.93	5.56	6.43
	Bholanathpur	3.79	2.23	2.44	1.68
	Choto Mohanpara (2)	6.93	1.49	4.88	6.31
	Choto Mohanpara (3)	6.11	5.21	5.83	3.59
	Choto Mohanpara (4)	7.18	5.60	5.45	5.97
	Jadupur	7.61	3.57	3.79	-
	Milki	6.16	4.64	5.03	5.88
	Nemasarai				
Gajole	Adina	4.37	0.76	2.79	14.44
	Agampur	3.36	0.51	8.12	13.17
	Deotala	2.09	0.91	1.56	2.19
	Gazole	-	0.54	8.37	5.98
	Masandighi	7.17	1.17	2.89	4.36
	Matol	10.25	1.55	6.19	9.42
	Pandua	1.97	1.00	3.86	-
	Ghatsol	-	1.22	7.16	12.92
	Pandua 1	15.57	1.43	4.16	-
	Ghoksol	9.33	0.46	7.19	-
Habibpur	Bulbulchandi	-	1.10	5.22	-
	Habibpur	-	6.85	7.97	10.03
	Jhin Jhin Pukur	6.08	0.28	1.24	3.21
	Kokabini Tajpur	2.85	0.43	5.26	1.98
Harishchandrapur - I	Harishchandrapur	6.48	4.17	4.60	5.92
	Kasimpur	5.86	3.27	3.80	4.03
	Tulsihata	-	4.87	5.66	6.12
Kalichak - I	Kaliachak	4.79	2.21	2.59	3.22
	Kaliachawk	3.78	2.59	3.78	-
	Khaschandpur	5.20	2.03	3.82	3.99
	Sujapur	5.04	2.15	2.42	3.44
Kalichak - II	Muthabari	3.70	0.30	2.30	8.03
	Puratan pataldanga				
	Kuriatar	-	3.65	4.29	4.52
Kalichak - III	Birnagar	3.59	1.21	3.21	3.35
	Doriapur	-	2.73	3.12	4.22
	Mahajantala	-	2.52	3.40	3.62
	16 Mile	-	4.22	4.49	4.75
	17 Mile	-	1.84	2.58	3.52
Manikchak	Begamganj	5.50	2.90	4.13	5.23
	Manikchak				
	Mohana (1)	5.37	6.05	4.31	4.85
	Mohana (2)	6.70	1.91	4.00	5.37
	Mohana (3)	5.00	2.01	3.34	5.7
	Mohana (4)				

Old Malda	Aiho	4.04	0.09	1.35	-
	Jadupur	14.36	2.22	6.72	15.02
	Malda (Pz)	9.44	5.38	7.34	8.69
	Malda town				
	Mochia	7.00	5.77	5.59	6.47
Ratua – I	Bhaluka (Pz)	5.96	2.96	5.13	5.73
	Ratua	-	3.04	5.09	6.13
	Bhagwanpur	-	2.83	4.92	-
	Debipur				
	Ratanpur Hat	4.36	0.97	1.86	3.24
	Shamsi	-	5.21	8.67	9.99
	Vado	9.33	4.86	7.06	8.85
Ratua - II	Ratua	6.69	2.26	5.27	6.24
	Pirgai	8.85	5.97	8.04	8.82
Harishchandrapur - II	Tulsihata	6.03	4.32	4.25	6.15
	Baroduari	6.72	3.73	4.20	4.85

Source: CGWB, Govt. of India

Village wise Depth of Water Level (m bgl) of Blocks of Malda District, 2016-17

Block	Village	Apr 16	Aug 16	Nov 16	Jan 17
Bamangola	Bamangola	13.05	5.67	4.27	6.63
	Bamangola (Swid)	27.79	21.19	18.06	19.45
	Charakdanga	7.45	2.63	3.22	3.48
	Makuli				
	Nalagola	4.44	1.63	2.73	2.48
	Paikpara	10.24	1.08	2.85	5.81
	Pakuya hat	22.90	5.40	23.72	22.79
Chanchal - I	Chanchal (Pz)	6.35	8.21	6.63	7.35
	Ranikamat	6.32	0.32	-	-
Chanchal – II	Malatipur	5.40	8.94	7.92	7.86
English Bazar	Battaly				
	Bholanathpur	3.80	2.37	1.34	1.79
	Choto Mohanpara (2)	7.40	6.76	6.29	6.67
	Choto Mohanpara (3)	7.35	6.57	6.33	6.69
	Choto Mohanpara (4)	6.80	6.65	6.64	6.97
	Jadupur	8.68	3.78	5.53	-
	Milki	6.29	5.47	5.34	5.87
	Nemasarai	-	8.29	8.48	10.15
Gajole	Adina	13.95	4.51	2.29	3.20
	Agampur	15.27	8.87	5.60	5.51
	Deotala	4.56	2.45	1.45	1.79
	Gazole	19.89	-	23.16	20.54
	Masandighi	9.21	1.26	4.14	7.09
	Matol	11.20	5.14	4.53	7.23
	Pandua	6.95	1.09	1.77	2.36
	Ghatsol	-	3.40	-	-
	Pandua 1	14.30	1.39	1.94	2.37
	Ghoksol	-	3.43	3.42	5.38
Habibpur	Bulbulchandi	-	1.02	-	-
	Habibpur	9.72	1.16	1.95	3.85
	Jhin Jhin Pukur	4.97	0.32	1.49	2.74
	Kokabini Tajpur	9.25	0.70	2.12	1.74
Harishchandrapur - I	Harishchandrapur	7.65	4.80	4.27	4.22
	Kasimpur	-	3.37	-	-
	Tulsihata	6.76	5.00	5.61	-

Kalichak - I	Kaliachak	7.69	2.79	3.63	4.00
	Kaliachawk	5.23	1.70	3.51	2.88
	Khaschandpur	5.64	1.95	2.63	4.35
	Sujapur	6.30	2.06	-	-
Kalichak - II	Muthabari	3.65	-	2.57	2.95
	Puratan pataldanga	5.80	-	2.70	3.12
	Kuriatar	9.16	3.53	-	-
Kalichak - III	Birnagar	3.65	1.98	2.88	3.10
	Doriapur	3.72	2.69	2.03	2.48
	Mahajantala	7.35	2.39	-	2.31
	16 Mile	7.90	4.11	-	-
	17 Mile	3.75	1.71	1.30	1.52
Manikchak	Begamganj	7.05	-	3.93	4.75
	Manikchak	5.71	-	-	-
	Mohana (1)	5.20	3.82	4.93	4.86
	Mohana (2)	5.18	2.75	4.89	4.86
	Mohana (3)	6.05	3.87	3.54	4.29
	Mohana (4)	5.70	2.32	4.42	5.22
Old Malda	Aiho	3.57	1.55	2.69	3.26
	Jadupur	2.96	4.75	8.77	13.61
	Malda (Pz)	10.03	6.71	7.09	9.12
	Malda town				
	Mochia	6.74	5.89	5.42	5.76
Ratua – I	Bhaluka (Pz)	6.07	3.56	4.65	5.23
	Ratua	4.87	6.24	4.43	4.97
	Bhagwanpur	4.96	-	4.69	-
	Debipur	2.28	-	3.83	5.02
	Ratanpur Hat	6.75	1.29	1.28	1.98
	Shamsi	6.28	5.18	-	-
	Vado	10.26	7.41	6.03	6.23
Ratua - II	Ratua				
	Pirgai	6.11	7.71	-	-
Harishchandrapur - II	Tulsihata	4.88	4.66	4.78	4.80
	Baroduari	-	3.80	4.17	4.37

Source: CGWB, Govt. of India

APPENDIX – 2

Distribution of different types of wetlands in Malda district

Nature of wetlands present		Different classes of wetlands present	No.	Total wetland area (ha)	Pre-monsoon area (ha)	Post-monsoon area (ha)
INLAND	NATURAL	Ponds/Lakes	22	2760.79	123.74	1409.92
		Cut-off Meanders/Ox-bow Lakes	190	2986.80	484.25	2806.22
		Waterlogged Seasonal	235	20956.49	3828.66	8283.90
		Marsh/Swamp	20	2047.09	2047.09	2047.09
	MAN MADE	Reservoirs	4	34.86	11.54	34.86
		Tanks	90	613.07	349.25	591.74
		Waterlogged	1	17.85	0.00	17.85
		Total	562	29416.95	6844.53	15191.58

Source: Institute of Wetland Management and Ecological Design, 2000

APPENDIX – 3

Distribution of different types of wetlands in Malda district

Sl. No.	Name of wetland (Case study)	Area (Ha)		Absolute change in Area (Ha)	% Change	Average water depth (m)	
		1990	2018			Pre-monsoon	Monsoon & Post-monsoon
1	Siali wetland	47.59	18.74	-28.85	-60.63	1.5	2.75
2	Chakla wetland	1137.13	842.50	-294.63	-25.91	1.75	2.5
3	Naghoria wetland	284.62	228.13	-56.49	-19.85	2.0	2.6
4	Chatra wetland	295.73	234.54	-61.18	-20.69	1.8	3.0

Source: Landsat 5 TM data, November, 1990 & Landsat 8 OLI data, November, 2018; Field study, 2015-18

APPENDIX – 4

Area covers of case studies (Wetland) in 1990 and 2018

Wetland category	No.	Total wetland area (ha)	Post-monsoon area (ha)	Pre-monsoon area (ha)
Inland wetlands - Natural				
Lakes/Ponds	123	4608	3511	1434
Ox-bow Lakes/Cut-off Meanders	31	582	519	360
High altitude wetlands	-	-	-	-
Riverine wetlands	148	1527	1406	929
Waterlogged	48	382	370	166
River/Stream	32	12906	12883	11856
Inland wetlands – Man-made				
Reservoirs/Barrages	-	-	-	-
Tanks/Ponds	105	558	536	467
Waterlogged	15	162	159	83
Salt pans	-	-	-	-
Total	502	20,725	19384	15295

Source: Space Application Centre (ISRO), 2010

APPENDIX – 5

Inventory on Macrophytes in wetlands

Sl. No.	Local / common name	Family	Genus	Species	Scientific name	Habitat	Growth form	IUCN Red list
1.	Kulekhara	Acanthaceae	Hygrophila	auriculata	*Hygrophilia auriculata*	WE	SE	LC
2.	Thankuni	Apiaceae	Centella	asiatica	*Centella asiatica*	WE	E	LC
3.	Kachu	Araceae	Colocasia	esculenta	*Colcasia esculenta*	OW	E	LC
4.	Water lettuce	Araceae	Pistia	stratiotes	*Pistia stratiotes*	OW	FF	LC
5.	Halencha	Asteraceae	Enhydra	fluctuans	*Enydra fluctuans*	WE	E	LC
6.	Kesuri	Asteraceae	Eclipta	alba hassk	*Eclipta alba hassk*	WE	E	LC

7.	Hatisur	Boraginaceae	Heliotropium	indicum	*Heliotropium indicum*	WE	E	LC
8.	Ghima	Caryophyllaceae	Polycarpon	prostratum	*Polycarpon prostratum*	WE	E	LC
9.	Kalmi	Convolvulaceae	Ipomoea	aquatica	*Ipomoea aquatica*	WE	SE	LC
10.	Sola	Fabaceae	Aeschynomena	aspera	*Aeschynomene aspera*	OW	SR	LC
11.	Kureli	Hydrocharitaceae	Hydrilla	verticillata	*Hydrilla verticillata*	OW	SR	LC
12.	Paniphal	Lythraceae	Trapa	natans	*Trapa natans*	OW	RFL	LC
13.	Sushni	Marsileaceae	Marsilea	Quadrifolia	*Marsilea Quadrifolia*	WE	SE	LC
14.	Padma	Nelumbonaceae	Nelumbo	nucifera	*Nelumbo nucifera*	OW	RFL	LC
15.	Makhana	Nymphaeaceae	Euryale	ferox	*Euryale ferox*	OW	RFL	LC
16.	Saluk	Nymphaeceae	Nymphaea	nouchali	*Nymphaea nouchali*	OW	RFL	LC
17.	Jangli dal	Poaceae	Hygroryza	aristata	*Hygroryza aristata*	WE	EG	LC
18.	Kachuripana	Pontederiaceae	Eichhornia	crassipes	*Eichhornia crassipes*	OW	FF	LC
19.	Bara-pana	Potamogetonaceae	Potamogeton	perfoliatus	*Potamogeton perfoliatus*	OW	SR	LC
20.	Kuti-pana	Salviniaceae	Azolla	ceae	*Azolla ceae*	OW	FF	LC
21.	Water fern	Salviniaceae	Salvinia	cucullata	*Salvinia cucullata*	OW	FF	LC

Source: Field study, 2016-17

Habitat: OW = Open Water, WE = Water Edge. Growth form: SE = Semi-emergent, E = Emergent, SR = Submerged rooted, RFL = Rooted Floating leaved, FF = Free floating, ER = Emergent grass.

APPENDIX – 6

Inventory on Icthyofauna in wetland

Sl. No.	Local / common name	Family	Genus	Species	Scientific name	IUCN Red list
1.	Chanda	Ambassidae	Chanda	nama	*Chanda nama*	LC
2.	Ar	Ariidae	Arius	arius	*Arius arius*	LC
3.	Bot Koi	Badidae	Badis	badis	*Badis badis*	LC
4.	Tangra	Bagridae	Mystus	tengara	*Mystus tengara*	LC
5.	Shrimp	Caridea	Caridean	shrimp	*Caridean shrimp*	LC
6.	Mangur	Clariidae	Clarias	batrachus	*Clarias batrachus*	LC
7.	Prawn	Crangonidae	Macrobrachium	rosenbergii	*Macrobrachium rosenbergii*	LC
8.	Bata	Cyprinidae	Labeo	bata	*Labeo bata*	LC
9.	Catla	Cyprinidae	Labeo	catla	*Labeo catla*	LC
10.	Chang	Cyprinidae	Ophicephalus	gachna	*Ophicephalus gachna*	LC
11.	Grass carp	Cyprinidae	Ctenopharyngodon	idella	*Ctenopharyngodon idella*	LC
12.	Kalbaush	Cyprinidae	Labeo	calbasu	*Labeo calbasu*	LC
13.	Koi	Cyprinidae	Cyprinus	carpio	*Cyprinus carpio*	LC
14.	Mourala	Cyprinidae	Amblypharyngodon	mola	*Amblypharyngodon mola*	LC
15.	Mrigel	Cyprinidae	Cirrhinus	cirrhosus	*Cirrhinus cirrhosus*	LC
16.	Rohu	Cyprinidae	Labeo	rohita	*Labeo rohita*	LC
17.	Silver carp	Cyprinidae	Hypophthalmichthys	molitrix	*Hypophthalmichthys molitrix*	LC

18.	Tilputi	Cyprinidae	Pethia	ticto	*Pethia ticto*	LC
19.	Shingi	Heteropneustidae	Heteropneustes	fossils	*Heteropneustes fossils*	LC
20.	Chuno pansal	Mastacembelidae	Mastacembelus	pancalus	*Mastacembelus pancalus*	LC
21.	Lata	Ophiocephalidae	Ophiocephalidae	punctatus	*Ophiocephalidae punctatus*	LC
22.	Khalisha	Osphronemidae	Trichogaster	chuna	*Trichogaster chuna*	LC
23.	Boal	Siluridae	Wallago	attu	*Wallago attu*	LC
24.	Tepa	Tetraodontidae	Tetradon	cutcutia	*Tetradon cutcutia*	LC
25.	Tilapia	Cichlidae	Tilapia	sparrmanii	*Tilapia sparrmanii*	LC
Aquatic fauna						
1.	Gugli	Cranchiidae	Teuthowenia	pellucida	*Teuthowenia pellucida*	LC
2.	Earthworm	Lumbricidae	Lumbricus	terrestris	*Lumbricus terrestris*	LC

Source: Field study, 2016-17

APPENDIX – 7

Inventory on Resident Avifauna in and around wetland

Sl. No.	Local/ common name	Family	Genus	Species	Scientific name	IUCN Red list
1.	Bengal vulture	Accipitridae	Gyps	indicus	*Gyps indicus*	CR
2.	Indian small skylark	Alaudidae	Alauda	gulgula	*Alauda gulgula*	LC
3.	Black capped kingfisher	Alcedinidae	Halcyon	pileata	*Halcyon pileata*	LC
4.	Small blue kingfisher	Alcedinidae	Alcedo	atthis	*Alcedo atthis*	LC
5.	Resident ducks	Anatidae	Anas	paltyrhynchos	*Anas paltyrhynchos*	LC
6.	Whistling teals	Anatidae	Dendrocygna	javanica	*Dendrocygna javanica*	LC
7.	Cattle egret	Ardeidae	Bubulcus	ibis	*Bubulcus ibis*	LC
8.	Great Egret	Ardeidae	Egretta	alba	*Ardea alba*	LC
9.	Grey heron	Ardeidae	Ardea	cinerea	*Ardea cinerea*	LC
10.	Intermediate egret	Ardeidae	Ardea	intermedia	*Ardea intermedia*	LC
11.	Little egret	Ardeidae	Egretta	garzetta	*Egretta garzetta*	LC
12.	Pond heron	Ardeidae	Ardeola	grayii	*Ardeola grayii*	LC
13.	White stork	Ciconiidae	Ciconia	ciconia	*Ciconia ciconia*	LC
14.	Painted stork	Ciconiidae	Mycteria	leucocephala	*Mycteria leucocephala*	NT
15.	Spotted doves	Columbidae	Spilopelia	chinensis	*Spilopelia chinensis*	LC
16.	Koel	Cuculidae	Eudynamys	scolopaceus	*Eudynamys scolopaceus*	LC
17.	Cormorant	Phalacrocoracidae	Phalacrocorax	fuscicollis	*Phalacrocorax fuscicollis*	LC
18.	Little cormorant	Phalacrocoracidae	Microcarbo	niger	*Microcarbo niger*	LC
19.	Yellow crown woodpecker	Picidae	Leiopicus	mahrattensis	*Leiopicus mahrattensis*	LC
20.	Weaver birds	Ploceidae	Ploceus	philippinus	*Ploceus philippinus*	LC
21.	Parakeet	Psittaculidae	Melopsittacus	undulatus	*Melopsittacus undulatus*	LC
22.	Red vented bulbul	Pycnonotidae	Pycnonotus	cafer	*Pycnonotus cafer*	LC
23.	White-cheeked bulbul	Pycnonotidae	Pycnonotus	leocotis	*Pycnonotus leocotis*	LC
24.	Brown fish owl	Strigidae	Bubo	zeylonensis	*Bubo zeylonensis*	LC
25.	Flycatcher	Monarchidae	Terpsiphone	paradisi	*Terpsiphone paradisi*	LC
26.	Falcon	Falconidae	Falco	amurensis	*Falco amurensis*	LC

Source: Field study, 2016-17

Inventory on Migratory Avifauna in and around wetland

Sl. No.	Local / Common name	Family	Genus	Species	Scientific name	IUCN Red list
1.	Grey leg goose	Anatidae	Anser	anser	*Anser anser*	LC
2.	Pintail	Anatidae	Anas	acuta	*Anas acuta*	LC
3.	Red crested Spot bill	Anatidae	Netta	rufina	*Netta rufina*	LC
4.	Shovellor	Anatidae	Spatula	clypeata	*Anas clypeata*	LC
5.	Spot bills	Anatidae	Anas	poecilorhyncha	*Anas poecilorhyncha*	LC
6.	White eyed pochard	Anatidae	Aythya	nyroca	*Aythya nyroca*	NT
7.	Tuffed pochard	Anatidae	Aythya	fuligula	*Aythya fuligula*	LC
8.	Bitterens	Ardeidae	Botaurus	lentiginosus	*Botaurus lentiginosus*	LC
9.	Spotted sandpiper	Scolopacidae	Actitis	macularius	*Actitis macularius*	LC
10.	Grey headed swamphen	Rallidae	Porphyrio	poliocephalus	*Porphyrio poliocephalus*	LC
11.	Marabou stork	Ciconiidae	Leptoptilos	crumenifer	*Leptoptilos crumenifer*	LC

Source: Field study, 2016-17

IUCN Red list: LC = Least concern, NT = Near threatened, VU = Vulnerable, EN = Endangered, CR = Critically endangered, EW = Extinct in the wild, EX = Extinct.

APPENDIX – 8

Record of Physico-chemical and Bacteriological parameters of wetland water (2015-16 to 2017-18)

Wetland	Year	Season	Water Temp.	pH	Con	TDS	Tur	TH	DO	Iron	Ar	Cl	F	TC	FC
Siali	2015-16	Pre-monsoon	31.30	7.41	143.80	71.40	1.51	136	4.60	0.22	0.010	72.05	0.17	4	0
Siali	2015-16	Monsoon	29.00	7.32	131.70	67.30	3.86	120	5.90	0.43	0.000	73.07	0.23	7	1
Siali	2015-16	Post-monsoon	24.70	7.14	128.70	64.70	2.94	116	6.40	0.69	0.015	78.43	0.29	12	2
Chakla	2015-16	Pre-monsoon	31.00	7.61	126.80	63.00	4.45	92	4.30	0.47	0.000	27.58	0.24	0	0
Chakla	2015-16	Monsoon	27.00	7.46	109.00	58.00	6.76	70	6.30	0.50	0.000	27.20	0.20	8	2
Chakla	2015-16	Post-monsoon	23.50	7.12	107.50	54.10	5.60	60	6.70	0.62	0.016	40.24	0.18	17	8
Naghoria	2015-16	Pre-monsoon	32.00	7.58	191.70	96.10	1.72	196	7.10	0.04	0.049	0.00	0.00	12	2
Naghoria	2015-16	Monsoon	27.20	7.51	102.80	76.30	5.01	96	8.20	0.12	0.000	0.00	0.00	7	0
Naghoria	2015-16	Post-monsoon	24.40	7.09	77.60	38.50	3.53	56	9.00	0.24	0.012	26.92	0.00	9	0
Chatra	2015-16	Pre-monsoon	32.50	7.78	578.00	290.00	2.26	264	7.60	0.09	0.008	56.34	0.00	0	0
Chatra	2015-16	Monsoon	29.00	7.42	410.20	250.00	6.89	214	9.00	0.13	0.000	53.00	0.13	2	0
Chatra	2015-16	Post-monsoon	24.50	7.13	337.00	169.00	4.83	196	9.50	0.16	0.000	56.11	0.32	8	0
Siali	2016-17	Pre-monsoon	31.50	7.62	140.90	77.40	2.51	155	4.10	0.15	0.016	72.05	0.18	4	0
Siali	2016-17	Monsoon	29.00	7.40	130.80	65.30	4.86	129	4.90	0.40	0.000	78.07	0.23	7	1
Siali	2016-17	Post-monsoon	24.00	7.32	125.90	60.70	3.54	116	6.20	0.51	0.010	73.43	0.31	12	2
Chakla	2016-17	Pre-monsoon	31.00	7.46	128.80	63.70	4.35	92	4.10	0.82	0.000	27.58	0.22	0	0
Chakla	2016-17	Monsoon	27.00	7.10	109.00	57.00	6.92	70	5.30	0.50	0.000	27.20	0.20	8	2
Chakla	2016-17	Post-monsoon	23.70	7.03	103.50	50.30	5.30	44	6.70	1.20	0.011	40.24	0.16	17	8
Naghoria	2016-17	Pre-monsoon	32.00	7.59	200.20	99.10	2.43	180	7.00	0.06	0.067	0.00	0.00	10	1
Naghoria	2016-17	Monsoon	27.20	7.51	127.80	76.30	5.01	127	8.50	0.12	0.000	0.00	0.00	7	0
Naghoria	2016-17	Post-monsoon	24.50	6.89	86.60	40.70	3.73	77	9.30	0.60	0.020	26.92	0.00	9	2
Chatra	2016-17	Pre-monsoon	32.00	8.26	567.00	292.00	3.26	244	7.20	0.07	0.000	56.34	0.00	1	0
Chatra	2016-17	Monsoon	29.00	7.42	410.70	245.00	7.59	196	8.90	0.13	0.000	53.00	0.00	3	0
Chatra	2016-17	Post-monsoon	25.00	7.14	330.00	176.00	5.69	175	9.70	0.26	0.000	56.11	0.32	8	0

Siali	2017-18	Pre-monsoon	32.50	7.56	146.90	86.70	2.51	159	4.40	0.19	0.016	72.01	0.18	6	1
Siali	2017-18	Monsoon	27.20	7.47	126.80	69.80	4.89	129	5.30	0.45	0.000	73.37	0.23	7	1
Siali	2017-18	Post-monsoon	24.60	7.01	120.90	50.70	3.96	104	6.70	0.53	0.010	78.43	0.31	14	2
Chakla	2017-18	Pre-monsoon	31.70	7.56	159.80	73.90	4.36	102	4.10	0.84	0.000	32.75	0.22	0	0
Chakla	2017-18	Monsoon	27.00	7.45	128.00	56.00	5.92	94	5.10	0.50	0.000	34.20	0.20	9	3
Chakla	2017-18	Post-monsoon	23.90	6.73	103.90	50.30	5.60	58	6.30	1.28	0.011	40.24	0.16	20	10
Naghoria	2017-18	Pre-monsoon	32.70	7.78	264.20	104.10	2.58	186	7.00	0.06	0.067	0.00	0.00	12	1
Naghoria	2017-18	Monsoon	28.00	7.51	176.80	78.30	5.75	128	8.40	0.17	0.000	0.00	0.00	8	0
Naghoria	2017-18	Post-monsoon	24.80	7.19	127.60	62.70	3.96	82	9.30	0.60	0.020	19.92	0.00	12	2
Chatra	2017-18	Pre-monsoon	32.90	8.67	593.00	298.00	4.14	250	7.70	0.09	0.000	56.34	0.00	2	0
Chatra	2017-18	Monsoon	28.50	7.97	420.10	249.00	7.67	196	8.90	0.25	0.000	56.00	0.00	5	0
Chatra	2017-18	Post-monsoon	25.00	7.23	339.00	196.00	5.69	169	9.70	0.39	0.000	56.11	0.32	10	3

Source: Field study and laboratory test

*Water temp. – Water temperature; Con – Conductivity; TDS – Total dissolved solid; Tur – Turbidity; TH – Total hardness; DO – Dissolved oxygen; Ar – Arsenic; Cl – Chloride; F – Fluoride; TC – Total coliform; FC – Fecal coliform.

APPENDIX – 9

QUESTIONNAIRE

1. General observation

Questionnaire no. -
Household no. -

Date of Interview:

1. Name of the wetland -

- **Wetland Hydrology:**

1. Source of water (inflow): a. Rainfall ( ), b. Runoff ( ), c. River ( ), d. Drain ( ), e. Waste water drain ( ).

2. Outflow (if any):

3. Water level / depth: a. Pre-monsoon ____ (m/ft) b. Monsoon and post-monsoon ____ (m/ft).

4. Does this wetland dry out completely? a. Every year ( ), b. Occasionally ( ), c. Rarely ( ).

- **Wetland land use:**

1. Land use: a. Urban ( ), b. Agriculture ( ), c. Forest ( ), d. Mining ( ), e. Grazing ( ), f. Fallow ( ), g. Fishing ( ).

2. Solid waste disposal in wetland: a. Yes ( ) b. No ( )

- **Wetland Biodiversity:**

1. (I) Vegetation around the wetland: a. Present ( ) b. Absent ( )

(II) If present then specify:

a. Trees ________________ Native / Exotic, b. Herbs ____________ Native / Exotic, c. Shrubs _____________ Native / Exotic, d. Creepers ___________ Native / Exotic, e. Weeds ________ Native / Exotic.

(III) Which kind of aquatic vegetation in and around this wetland? a. Submerged ( ), b. Emergent ( ), c. Free floating ( ), d. Submerged rooted ( ), e. Floating leaved ( ), f. Emergent grass ( ).

2. What are the aquatic vegetation, seen in open water and wetland water edge? a. ___, b.___.

3. What are the species of icthyofauna? a. ___, b. ___, c. ___, d. ___, e. ___.

4. Whether any variation comes in species types? Specify _____________________.

5. What are the resident bird species? a. ___, b. ___, c. _____, d. ___, e.___.

6. What are the migratory bird species? a. _____, b. _____, c. _____, d. _____, e. _____.

7. Timing of the arrival of migrants _________________________.

8. Duration of staying around wetland _______________________.

9. Species of small invertebrates: a. Mollusks ( ), b. Insects ( ), c. Spiders ( ).

10. Availability of amphibians, reptiles, small invertebrates_________________.

- **Wetland water quality & Pollution status:**

1. Sources of pollution within wetland: a. Domestic sewage ( ), b. Industrial effluents ( ), c. Agricultural runoff ( ), d. In-wetland activities ( ), e. Cattle wading ( ), f. Others ( ). Specify ____.

2. Pollution level: a. Very high ( ), b. Moderately high ( ), c. Medium ( ), d. Low ( ), e. Negligible ( ).

3. Visual: a. Clean ( ), b. Looks clean but smells ( ), c. Appears polluted ( ).

- **Wetland functions & Values:**

1. Wetland water used for: a. Drinking water supply ( ), b. Irrigation ( ), c. Fisheries ( ), d. Transport ( ), e. Religious activities ( ).

2. Use of biological resources: a. Reeds and grasses for thatch and fodder ( ), b. Plant cultivation for food ( ), c. Fish ( ), d. Prawn ( ).

3. (I) Purpose of collection of biological resources from wetland: a. Self-consumption ( ), b.

Selling purpose ( ).

(II) If it is for selling in which market & how far it is? ____________________________________.

4. Function of wetland: a. Ground water recharge ( ), b. Flood mitigation ( ), c. Tourism (local/national/international) ( ), d. Support biodiversity ( ), e. Socio-cultural ( ), f. Aesthetic ( ).

- **Major problems:**

1. What are the major problems, encountered to this wetland? a. Reduction in area (shrinkage) ( ), b. Reduction in depth (siltation) ( ), c. Encroachment ( ), d. Algal bloom ( ), e. Aquatic weeds ( ), f. Decline/loss in fisheries ( ), g. Eutrophication ( ), h. Toxic pollution ( ).

2. Encroachers: a. Local residents ( ), b. Builders ( ), c. Govt. ( ).

- **Public Awareness:**

1. Are local communities aware of the problems of the wetland? a. Yes ( ) b. No ( ).

2. Are local communities interested in the restoration of the wetland? a. Yeas ( ) b. No ( ).

3. Are there active local conservation groups (NGOs) interested in the wetland? a. Yes ( ) b. No ( ).

- **Restoration activities required:**
  1. How to restore this wetland? a. Improvement of water quality by wetland treatment ( ), b. Diversion and treatment of sewage ( ), c. Catchment treatment to check erosion ( ), d. Others ( ). Specify ____.

2. Household Survey on resources and economic values of wetlands

Questionnaire no. - **Date of Interview:**

Household no. –

- **Background information / General Particulars:**

1. Name of respondent / interviewer:

2. Gender: a. Male ( ) b. Female ( ).

3. Age of the interviewee:

4. Address: a. Village _________, b. Block _______, c. Dist. ______, Ph. No. ___________.

- Interview is administered to the household head ( )
- Interview is administered to a close family member ( )
  - His / her relation to the household head _________________________.

5. Nearest wetland:

6. Distance of house from wetland: ___minutes by walk / ___km.

7. How long have you been living here as household / family? _____ Years.

- **Household characteristics:**

1. What is / are the household member's occupation? a. Farmer / Cultivator ( ), b. Agricultural labourers ( ), c. Fishermen ( ), d. others (non-fish and macrophytic resource collection) ( ).

2. Whether he / she is dependent on wetland or not? a. Yes ( ) b. No ( ).

3. Main source of income: ________.

4. Secondary / alternate income source: ____________.

5. Any income from the wetland related activities: ___________.

- **Wetland cultivation, size of land and cropping preference:**

1. Size of the land: ________ ha.

2. (I) Do you produce for your family consumption? a. Yes ( ) b. No ( ).

(II) How much is the total cultivated area _______ ha?

(III) How much area is cultivated with the help of wetland water ____ha?

3. What are the crops you grow with the help of wetland water? Rank your crops according to order of importance i.e., production)

Sl. No.	a. Food crops	b. Cash crops
1.		
2.		
3.		
4.		

4. (I) Which crops are grown in and around the wetland during pre-monsoon, monsoon and post-monsoon? a. ____, b. ____, c. ____, d. ____, e. ____.

(II) Crops are grown in the wet season: a. ____, b. ____, c. ____, d. ____.

5. (I) Do you cultivate makhana within wetlands a. Yes ( ) b. No ( )?

(II) If yes, than how much area within wetland is under makhana cultivation _____ha?

(III) What is the price of lease for makhana cultivation _________Rs./ha/annum?

(IV) What is the labour cost for makhana cultivating filed _______Rs./ha/annum?

(V) What is the total production of makhana _____Kg/Quintal/ha?

(VI) What is the market price of Makhana _____Rs./Kg/Quintal?

6. Are your farming plot irrigated a. Yes ( ) b. No ( )?

7. What are the pesticides used in the agriculture around wetland? a. ____, b. ____.

8. What are the fertilizers? a. ____, b. ____, c. ____.

9. What is the nearby market & how far it is located? ____________.

10. (I) Does the market of your produce favourable? a. Yes ( ) b. No ( ).

(II) If no, what are the causes? ____.

11. (I) Are the prices enough supportable? a. Yes ( ) b. No ( ).

(II) If no, why? a. Low prices ( ), b. Fluctuating food prices ( ), c. others ( ).

Specify ____.

12. How was the trend in agricultural production around wetland in the last five (5) years? a. Increased ( ), b. Decreased ( ), c. Did not change ( ), d. Fluctuating ( ).

13. If increased then why did the agricultural production increase? a. Quality of seeds got better ( ), b. Usage of chemical fertilizers and pesticides have increased ( ), c. Usage of organic fertilizers have increased ( ), d. Irrigation from the wetland has increased ( ), e. Agricultural machinery has improved ( ), f. others ( ). Specify ____.

14. (I) what has been the price trend of farm produces for last five (5) years? a. Increasing ( ), b. Decreasing ( ), c. Fluctuating ( ).

(II) Why? Specify ____.

15. What is the average benefit from the farming activities in and around wetland? ________.

16. What is the cost of hiring land for cultivation ____________Rs./ha/annum?

What is the total area under wetland cultivation ______________ha?

17. What is the net benefit and total estimated benefit from wetland cultivation __________ Rs. /annum?

18. In your opinion, what the major constraints you are encountered in your agricultural practices? a. ____, b. ____, c. ____.

- **Wetland fishing:**

1. How many types of fish species are cultivated as well as caught by the fishermen in wetland?

Sl. No.	Type of fish	Amount (kg/day)
1.		
2.		
3.		

2. What are the exclusive fish species for commercial purpose? a. _____, b. _____, c. ____.

3. What is the total production including total fish catch ___________kg/annum?

4. What is the market price of fish, cultivated and caught from wetland _________Rs./kg?

5. What is the amount of lease ___________Rs./annum?

6. What is the estimated total benefit from wetland fishing ____________Rs./annum?

7. What is the nearby market & how far is it located? _____________.

8. (I) Does the market of your produces feasible? a. Yes ( ) b. No ( ).

(II) If no, what are the causes? ____.

9. (I) Are the prices supportable? a. Yes ( ) b. No ( ).

(II) If no, why? a. Low price ( ), b. Fluctuating prices ( ), c. others ( ). Specify ________.

10. (I) What has been the price trend of fish produces for last five (5) years? a. Increasing ( ), b. Decreasing ( ), c. Fluctuating ( ).

(II) Why? Specify ____.

11. In your opinion, what are the major constraints do you face in your fishing practice? a. ______, b. _____, c. _____.

- **Wetland product gathering:**

1. What are the products, collected from wetlands by households, residing in bed villages?

Sl. No.	Wetland product		Amount (kg/day)
	Aquatic macrophytes	Aquatic fauna	
1.			
2.			
3.			

2. What is the total estimated benefit from wetland product gathering __________ Rs. /annum?

3. Collection of other wetland resources: a. Firewood ( ), b. Wild medicines ( ), c. Fodder ( ) and other products ( ).

4. What is the nearby market & how far it is located? ____.

5. (I) Is the market of your produces feasible? a. Yes ( ) b. No ( ).

(II) If no, what are the causes? ____.

6. (I) Are the prices supportable? a. Yes ( ) b. No ( ).

(II) If no, why? a. low price ( ), b. Fluctuating prices ( ), c. Others ( ).

Specify ____.

(II) Why? Specify ____.

➢ **Perception on Environment:**

1. How are the solid wastes disposed? a. Disposed to a pre-defined landfill ( ), b. Disposed to a wild disposal area ( ), c. Disposed irregularly, d. Disposed to wetland ( ), e. Others ( ). Specify ____.

2. What is the biggest environmental problem facing by nearby wetland? a. Water pollution ( ), c. Solid waste ( ), d. Endangered species ( ), e. others ( ). Specify ____.

3. What do you think about declining biodiversity / endangered species in wetland area? a. Very serious ( ), b. Serious ( ), c. No problem ( ), d. Don't know ( ).

4. What are the major constraints encountered in the wetland area / peripheral zone? ____.

5. What do you think should be done to solve these problems? ______________________________.

6. Do you think this wetland should be protected? ____.

➢ **Miscellaneous:**

1. (I) Do you have any grievances about the land conversion /acquisition? a. Yes ( ) b. No ( ).

(II) If yes have you communicated with the concerned person?

2. What are the domestic / household functions served by the wetland water? a. Bathing ( ), b. Cooking ( ), c. Washing clothes ( ), d. Washing utensils ( ), e. others ( ). Specify ___________.

3. (I) Do you have any problem with the quality of wetland water? a. Yes ( ) b. No ( ).

(II) If yes, then what are the problems? a. Not clean ( ), b. Difficult to access ( ), c. Low quality (hardness), d. others ( ).

5. What type of waste water system do you have in your house? a. Common sewage system ( ), b. Septic tank disposed regularly by municipality ( ), c. Septic tank disposed regularly by him / herself ( ), d. Discharge directly to a wetland ( ), e. others ( ).

➢ **Suggestions:**

❖ What should be done to improve the wetland resources in a sustainable manner? ____.

❖ Whether the local administration is concerned about the importance of wetland?

____.

❖ Do you think that proper maintenance of wetland will develop proper village economy? ____.

❖ Feel free to share any comments / opinion in the following box regarding this wetland utilization and conservation:

THANKS VERY MUCH FOR YOUR COOPERATION

APPENDIX - 10

Utilization of wetlands by surrounding households

Wetland	Village type	Village	JL. NO.	HOUSEHOLD									
				Total	Surveyed	Cultivator CL+AL	Wetland Utilized	Wetland Un-utilized	Makhana cultivating	Food/cash crop cultivating	Fishing	Wetland Utilized	Wetland Un-utilized
Siali wetland	Bed	Jagannathpur	172	1527	60	45	25	20	0	25	8	2	6
	Bed	Fatepur	173	2127	82	62	59	3	10	49	14	11	3
	Bed	Bhaluka	175	1712	90	37	21	16	14	7	44	29	15
	Bed	Degun	176	289	51	38	38	0	0	38	9	7	2
	Belt	Talgachi	171	1423	54	18	2	16	2	0	19	0	19
	Belt	Parbhaluka	174	41	47	22	4	18	4	0	29	10	19
	Belt	Kariali	177	1044	24	5	0	5	0	0	4	0	4
		Total		**8163**	**408**	**227**	**149**	**78**	**30**	**119**	**127**	**59**	**68**
Chakla wetland	Bed	Gangadebi	112	736	45	33	33	0	0	33	5	5	0
	Bed	Gopalpur	113	195	30	18	18	0	0	18	6	7	0
	Bed	Damaipur	114	1208	47	32	32	0	0	32	8	8	0
	Bed	Kaliganj	115	438	25	18	18	0	0	18	1	0	0
	Bed	Shimultala	118	435	35	22	22	0	0	22	5	2	3
	Bed	Hazaratpur	185	1737	55	31	31	0	0	31	10	4	6
	Belt	Jalalpur	186	1058	55	11	4	7	0	4	6	1	5
	Belt	Khanpur	191	1299	62	22	17	5	0	17	13	4	9
		Total		**7106**	**354**	**187**	**175**	**12**	**0**	**175**	**54**	**31**	**23**
Naghoria wetland	Bed	Nagharia	25	1371	60	43	37	6	0	37	10	8	2
	Bed	Lakshmighat	26	1112	54	39	28	11	0	28	5	4	1
	Bed	Uttar Lakshmipur	41	826	51	33	22	10	0	22	10	7	3
	Belt	Phulbaria	24	1180	75	34	0	34	0	0	9	0	9
	Belt	Koklamari	129	1258	47	11	0	11	0	0	2	0	2
		Total		**5747**	**287**	**160**	**87**	**72**	**0**	**87**	**36**	**19**	**17**
Chatra wetland	Bed	Uttar Ramchandrapur	71	403	47	10	3	6	0	3	7	7	0
	Bed	UttarJadupur	88	1208	52	21	15	4	8	7	2	2	0
	Bed	Dilalpur	87	217	35	11	9	5	5	4	3	3	0
	Belt	Sonatala (CT)	29	2241	59	40	33	7	33	0	0	0	0
		Total		**4069**	**193**	**82**	**60**	**22**	**46**	**14**	**12**	**12**	**0**

Wetland	Village	HOUSEHOLD						AREA (Ha)	
		Product collecting	Cultivator+fising	Wetland Utilized	Wetland Un-utilized	Others	Duck rearing	under cultivation	under wetland irrigation
Siali wetland	Jagannathpur	0		2	1	4	0	15.05	1.84
	Fatepur	0	6	6	0	0	0	23.3	3.45
	Bhaluka	0	8	6	2	1	0	16.6	1.65
	Degun	4	0	0	0	0	0	19.02	2.01
	Talgachi	0	2	0	2	3	0	14.95	0.57
	Parbhaluka	0	3	0	3	5	0	10.9	0.6
	Kariali	0	0	0	0	15	0	4.6	0
	Total	**4**	**22**	**14**	**8**	**28**	**0**	**104.42**	**10.12**
Chakla wetland	Gangadebi	1	5	5	0	1	0	14.9	2.16
	Gopalpur	2	4	4	0	0	0	13.7	2.42
	Damaipur	0	5	5	0	2	0	12.5	3
	Kaliganj	0	0	0	0	6	0	8.6	0.52
	Shimultala	0	4	4	0	4	0	9.4	0.7
	Hazaratpur	0	1	1	0	13	0	11.5	1.34
	Jalalpur	0	3	1	2	35	0	12.2	0.6
	Khanpur	0	5	4	1	22	0	10.7	0
	Total	**3**	**27**	**24**	**3**	**83**	**0**	**93.5**	**10.74**
Naghoria wetland	Nagharia	0	2	2	0	0	5	15.21	3.3
	Lakshmighat	0	2	2	0	5	3	12.79	1.87
	Uttar Lakshmipur	0	4	3	1	3	1	12.12	1.06
	Phulbaria	0	3	0	3	29	0	14.12	0
	Koklamari	0	0	0	0	34	0	11.36	0
	Total	**0**	**11**	**7**	**4**	**71**	**9**	**65.6**	**6.23**
Chatra wetland	Uttar Ramchandrapur	9	0	0	0	21	0	11.25	0.82
	Uttar Jadupur	0	0	0	0	29	0	10	0.61
	Dilalpur	0	0	0	0	21	0	6.01	0.39
	Sonatala (CT)	0	0	0	0	19	0	8	0
	Total	**9**	**0**	**0**	**0**	**90**	**0**	**35.26**	**1.82**

Source: Primary Census Abstract, Census of India, 2011 & Field survey, 2016-17

APPENDIX – 11

Perception on Chatra wetland environment

Ward no.	Surveyed HH	Solid waste disposal				Environmental problem, encountered by wetland					Perception on declining biodiversity			Awareness of stakeholders		
		Pre-defined landfill	Irregularly	Wetland	Don't know	Water pollution	SWD	Reducing species diversity	Wetland encroachment	All	Very serious	Serious	Don't know	Extremely aware	Moderately aware	Don't know
03	56	10	17	21	8	3	11	4	28	10	14	22	20	16	26	14
24	62	9	21	17	15	6	12	3	20	21	17	28	17	27	22	13
25	55	4	17	25	9	8	6	4	23	14	11	16	28	15	25	15
Total	173	23	55	63	32	17	29	11	71	45	42	66	65	58	73	42

Source: Field study, 2016-17

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Assessment of the Ecological Status of Wetlands, Malda District: A Comparative Study

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Abstract : *The present study has been carried out to analyse the ecological status of four selected wetlands along with its existing biodiversity of Malda district, West Bengal. An evaluation on the aquatic health of wetlands, located in different physiography has been made in relation to the physic-chemical as well as bacteriological parameters. The study has revealed that taland diararegion containing wetlands especially the peri-urban wetland (Chatra) consistently record high level of certain water quality parameters throughout the study period. These high trends of certain parameters are attributed to nearby location of agricultural fields and adjacent municipal area.The wetlands under study are drained by agricultural run-off, municipal and domestic sewage, which is full of organic load. As a consequence, the biotic diversity, which is an indication of ecological health, encounters immense challenges from consequent decline. Therefore, the study is intended for restoring the ecologically vulnerable wetlands in Malda district to ensure the sustainability of a healthy ecosystem.*

Keywords : *Wetland, ecological status, aquatic health, physic-chemical, bacteriological parameter, biodiversity, sustainability.*

Introduction

Wetland is used to define the universe of hydrological entities in the form of swamps, marshes, bogs, pits, fens and similar areas, where the water table is at or near the surface. In wetland, water is the primary factor, controlling environment and its biotic life *(NWCP, 2009)*. Wetlands performindispensable ecological services such as, flood control, water storage and purification, floral and faunal habitats as well as socio-economic sustenance to number of people.Generally, the overall functions of wetland are directly related to its ecological status in the form of physical, chemical and biological integrity. Moreover, wetland water quality employs the influences upon the diverse assemblage of biotic com-ponents. Therefore, a thorough assessment of the water quality is essential for the conservation and sustainable management of wetlands.

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Fig. 1. Physiographic divisions of Malda District

Study area

Malda districtin West Bengal represents a mature geomorphic process with strong evidences of complex hydrological activities. The district is characterised by recurring shifting of river channels, bank erosion and dereliction of rivers which facilitate wetland formation here. Malda is divided into three physiographic divisions namely, *Diara* (south & south-west), *Tal* (north & northwest), and *Barind* (east) (Fig. 1). Diara is composed of alluvial formation by frequent flood water of Ganga and Mahananda River. Tal is associated with numerous small sized pools of natural depressions. Being geographically low lying region, both these physiography experience frequent floods as well asprovide a unique fluvio-geomorphic set-up for the formation of natural inland wetlands like cut-off meanders, seasonal waterlogged areas, lakes, and marsh etc. The wetlands namely, Chatra (24^o 58´ 30´´ N to 25°00´ 30´´ N; 88°06´ E to 88^o 08´ E) and Naghoria (25°01´ 30´´ N to 25°05´ 45´´ N; 87° 59´ 45´´ E to 88° 04´ 30´´ E) underdiara region and Siali (25^{o}18´ N to 25^{o}19´ N; 87^{o}53´ E to 87^{o}54´ E) and Chakla (25°16´ 30´´ N to 25^o 18´ 30´´ N; 88° 02´ 20´´ E to 88^o 04´ 30´´ E) undertal region are selected as representative sample (Fig. 2).

Wetlands under study

Chatrawetland is acclaimed as only peri-urban wetland,which is located in the areas adjacent to Malda town *(Chattaraj & Sarkar, 2016)*. The regular supply of sewage flow from the municipality through several points is the major inflow of this water body. The average areal extent is 190.62 ha with a water depth which keeps on varying from 2 meter (pre-monsoon) to 3 meter (monsoon). The extreme bend of the Kalindri River has cut off from the main stream and rejected channel forms an oxbow lake which appears to be Naghoria wetland. The wetland is placed in the extreme end of the north-western part of English Bazar block and 12 km away from the Malda town. The average spatial extent of this wetland is 84.25 haandmaintainsan average depth of 2.0 to 2.7 meter round the year. The surface run off from the vast catchment area enters into this water body by Kalindri River and through Nurpur connection via Nurpur barrage from Ganga River.

Siali wetland is fed by the tributaries of Kankar and Kalikoshi, originating from Kalindri River, through which the inflow of water in this wetland complex is controlled. Kokra Bridge and Alangi canal are the two outlets through which the excess water drains out from this water body. The average areal extent of Siali wetland is very low comparing with other selected samples, which extends up to 11 ha. The average water depth varies from 1.5 to 2 meter (pre-monsoon) to 2.5 to 3 meter (monsoon), when the total area of this wetland gets filled up with the water. The hydrology of Chakla wetland is mainly run-off feeding. The catchment area of Chakla wetland is large and it gets enough rainfall with an ultimate result of flash run off.Nuna and Bhoga rivers, the two tributaries of Mahananda from north and south respectivelycontrol the inflow and outflow of this wetland.Chakla wetland is a vast natural water body, with spatial extent of 577.72 ha andan average depth of 2.5 meters with small fluctuations throughout the year. The present study has been conducted to

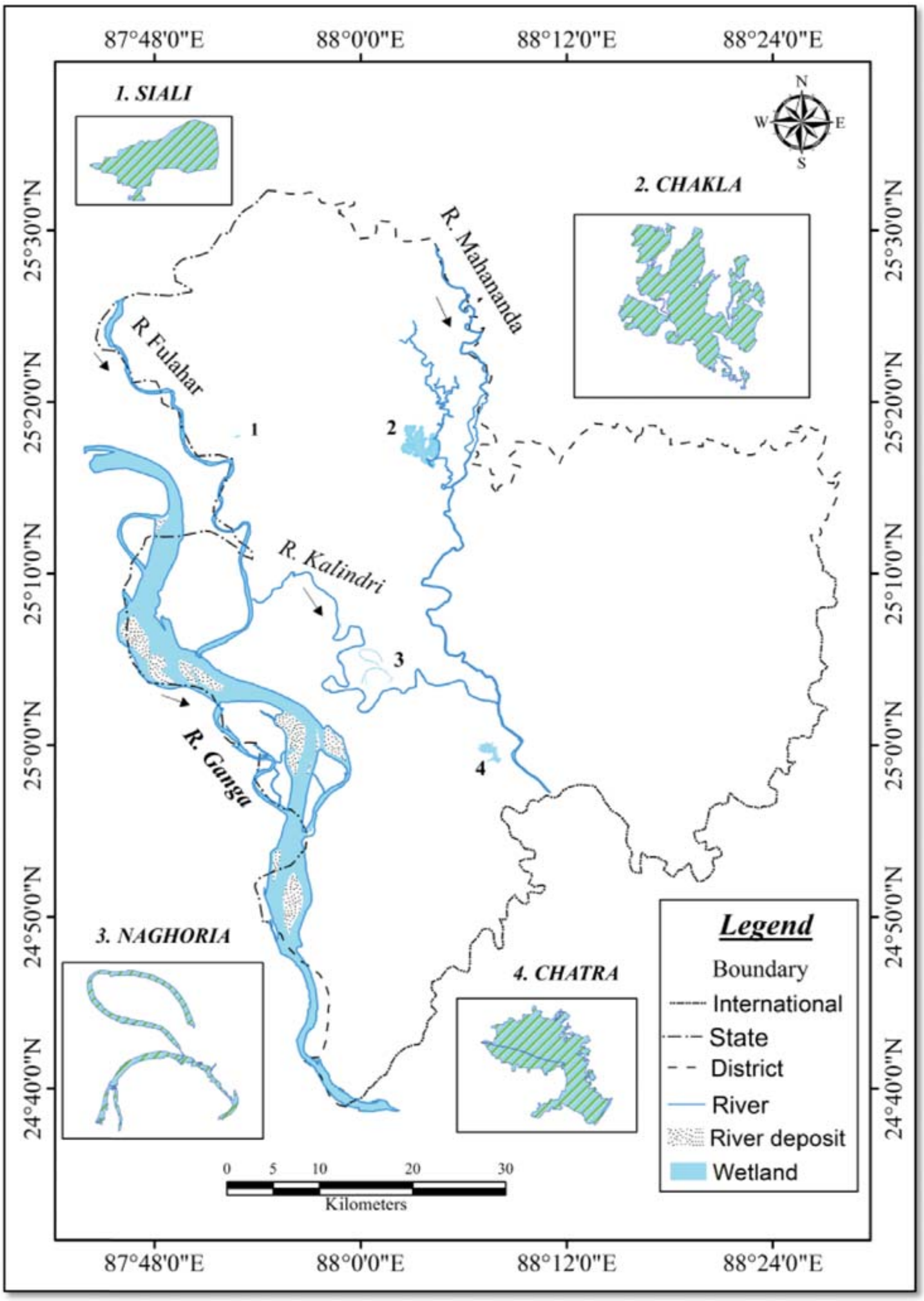

Fig. 2. Distribution of wetlands

determine the water quality of mentioned wetlands. The study has also attempted to analyse a comparative study on the physic-chemical and bacteriological parameters of wetland water in association with existing biotic diversity of Diara and Tal region under Malda district.

Objectives

The present study has been carried out with following objectives:

- To study the seasonal and spatial variation of physic-chemical and bacteriological characteristics of wetland water from two physiographic divisions.
- To determine an interrelationship between the water quality parameters and resultant reaction with the wetland water.
- To assess the status of biotic diversity within wetlands and monitoringits behavior for the development of innovative estimation measures.

Database and Methodology

The entire study on the ecological status of wetlands is based on both the primary and secondary data.The basic areal data have been procured from the Survey of India (SOI) topographical maps (1:63,360 and 1:50,000), Land use/Land Cover maps (1:50,000) and from the satellite images (LISS-III with 23.5 m resolution) of Malda district.The water samples are investigated in detail for various *physical* (water temperature and turbidity), *chemical* (pH, conductivity, total dissolved solid, dissolved oxygen and total hardness) and *bacteriological* (total coliform and fecal coliform) parameters of the wetlands under study*(Table no. 1)*. Wetland water samples are collected for three years (2015-March to 2018-February), covering three different seasons viz. pre-monsoon (March-May), monsoon (June-September) and post-monsoon (October-February). The water samples have been collected in separate disinfected polyethylene cans from a depth of about 1 meter to 1.5 meter from the wetlands and tested with the help of Public Health Engineering Department laboratory, Govt. of West Bengal. For the statistical analysis mean, and Standard Deviation (SD) of water samples have been calculated according to the physiographic divisions *(Table no. 2 & 3)*. The water samples have been analysed by one-way Analysis of Variance (ANOVA) to determine the differences among the group mean individually between wetlands and between the seasons with the help of SPSS, version 25.0 *(Table no. 4 to 12)*. The P value for variation is considered significant if $P<0.05$ (*) and non-significant if $P>0.05$(ns). Furthermore, the correlation between mentioned parameters are analysed byPearson's correlation coefficient (r) in order to determine the relationship between variables along with positive and negative correlations *(Table no. 13)*. The P value for correlation is considered significant if $P<0.05$ (*), highly significant if $P<0.01$ (**) and non-significant if $P>0.05$(ns).

Table 1.Wetland water components, instruments used, unit of measurement and permissible limit

Sl. No.	Water quality parameters	Instrument used	Unit of measurement	Permissible limit (BIS)*
A. Physicalparameters				
1.	Water temperature	Thermometer	°C	
2.	Turbidity	Turbidity Meter	Nephelometric turbidity unit (N.T.U.)	5
B. Chemical Parameters				
1.	pH	pH Meter	-	6.5 – 8.5
2.	Conductivity	Conductivity Meter	µ.s.	400
3.	Total Dissolved Solid (T.D.S.)	Conductivity Meter	Parts per million (ppm)	200
5.	Dissolved Oxygen (D.O.)	DO Meter	mg/L	18
6.	Total Hardness (T.H.)	Titration method	mg/L	600
C. Bacteriological parameters				
1.	Total coliform	MPN – Most probable number	MPN/100 ml	Shall not be detectable in any 100 ml sample
2.	Fecal coliform	MFT – Membrane filter tube	MPN/100 ml	Shall not be detectable in any 100 ml sample

Source: *Bureau of Indian Standards (BIS) May, 2012*

Result and discussion

The study of water quality by analysing physic-chemical and bacteriological parameters is an integral part of the evaluation of the health of any wetland ecosystem *(Sylas, 2010)*.

A. Physical parameters:

1. Water temperature

In the present study, the wetland water record maximum temperature during pre-monsoon, followed by monsoon and post-monsoon period irrespective of both the physiography, which has also been reported from earlier workers in Tripura *(Abir, 2014)*;in Kerala*(Jala & Sanalkumar,2012)*. The wetlands under diara region (Table no. 2) has recorded an average water temperature ranges from 24.43°C to 32.47°C ($\overline{X}$ =28.59; σ = 4.03) whereas, tal region (Table no. 3) containing wetlands have recorded 23.70°C ($\overline{X}$ = 27.31; σ = 3.77) to 31.77°C ($\overline{X}$ = 28.20; σ = 3.67). Maximum temperature (32.47°C) is recorded from Chatra wetland during pre-monsoon and minimum temperature (23.70°C) from Chakla wetland during post-monsoon.

Table 2. Result of wetland water quality parameters (Diara region)

Water quality parameters	Naghoria wetland					Chatra wetland				
	Pre-monsoon	**Monsoon**	**Post-monsoon**	**Mean ($\bar{X}$)**	**SD (σ)**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Mean ($\bar{X}$)**	**SD (σ)**
Water temperature	32.23	27.47	24.57	28.09	3.87	32.47	28.83	24.43	28.58	4.03
Turbidity	2.24	5.01	3.74	3.66	1.39	3.22	7.38	5.40	5.33	2.08
pH	7.65	7.51	7.06	7.41	0.31	8.24	7.60	7.17	7.67	0.54
Conductivity	218.70	135.80	97.27	150.59	62.05	579.33	413.67	335.33	442.78	124.58
Total dissolved solid	99.80	76.97	47.30	74.69	26.32	293.30	248.00	180.33	240.54	56.85
Total hardness	187.33	117.00	71.67	125.33	58.28	252.67	202.00	180.00	211.56	37.27
Dissolved oxygen	7.03	8.37	9.20	8.20	1.09	7.50	8.93	9.63	8.69	1.09
Total coliform	11.33	7.33	10.00	9.55	2.04	1.00	3.33	8.67	4.33	3.93
Fecal coliform	1.33	0.00	1.33	0.89	0.77	0.33	0.00	1.00	0.44	0.51

Table 3. Result of wetland water quality parameters (Tal region)

Water quality parameters	Siali wetland					Chakla wetland				
	Pre-monsoon	**Monsoon**	**Post-monsoon**	**Mean ($\bar{X}$)**	**SD (σ)**	**Pre-monsoon**	**Monsoon**	**Post-monsoon**	**Mean ($\bar{X}$)**	**SD (σ)**
Water temperature	31.77	28.40	24.43	28.20	03.67	31.23	27.00	23.70	27.31	3.77
Turbidity	2.18	4.54	3.48	3.40	1.18	4.39	6.53	5.60	5.51	1.07
pH	7.53	7.40	7.16	7.36	0.19	7.54	7.34	6.96	7.28	0.29
Conductivity	143.87	129.77	125.17	132.94	9.74	138.47	115.33	104.97	119.60	17.15
Total dissolved solid	78.50	67.30	58.70	68.17	9.93	66.90	57.00	51.57	58.49	7.77
Total hardness	150.00	126.00	112.00	129.33	19.22	95.33	78.00	54.00	75.78	20.75
Dissolved oxygen	4.37	5.37	6.43	5.39	1.03	4.17	5.57	6.57	5.44	1.21
Total coliform	4.67	7.00	12.67	8.11	4.11	0.00	8.33	18.00	8.71	9.01
Fecal coliform	0.33	1.00	2.00	1.11	0.84	0.00	1.67	8.67	3.45	4.60

Source: *Field Study by author, 2015-18.* Statistical analysis shows water temperature has no significant ($p>0.05$) variation between wetlands ($F = 0.058$) where the p value > á, which is attributed to identical climatic character throughout the district. ANOVA records significant ($p<0.05$) variation between the seasons ($F=151.61$), where the p value<á *(Table no. 4 (a)&(b))*.

Table 4(a). Output of Water temperature between wetlands by one way Anova

	Sum of Squares	df	Mean Square	F	P value
Between Groups	2.547	3	.849	.058	.981
Within Groups	117.824	8	14.728		
Total	**120.371**	**11**			

Table 4(b). Output of Water temperature between seasons

	Sum of Squares	df	Mean Square	F	P value
Between Groups	116.901	2	58.450	151.606	.000
Within Groups	3.470	9	.386		
Total	**120.371**	**11**			

2. Turbidity:

Diara containing wetlands record an average turbidity ranges from 2.24N.T.U. ($\overline{X}$ =3.66; σ = 1.39) to 7.38N.T.U. ($\overline{X}$ =5.33; σ=2.08)*(Table no. 2)* and tal region records 2.18N.T.U. ($\overline{X}$ =3.40; σ=1.18) to 6.53N.T.U. ($\overline{X}$ =5.51; σ=1.07) throughout the study period *(Table no. 3)*. Maximum turbidity (7.38N.T.U.) is recorded during monsoon period from Chatra wetland, under diara region. The high accumulation of sewage water in conjunction with organic load have resulted high turbidity during the monsoon period in the study area. This study is in accordance with early workers in the wetlands of Jorhat, Assam *(Lodh et al., 2014)*; in Central Gujarat *(Vankar et al., 2018)*. Continuous sedimentation in the wetland water results in high turbidity, which eventually leads to inadequate conditions for many aquatic macrophytes and algae to photosynthesize as well as survive *(Reilly & Paudel, 2010)*.Analysis of variance shows that water turbidity has no significant (p>0.05) variation between the wetlands (F=1.643) where p value>α *(Table no. 5 (a))*, but recordsignificant variation between seasons (F=6.097), wherep value<α *(Table no. 5 (b))*. The significant seasonal variation in water turbidity is attributed to increasing surface run-off during monsoon from adjacent tracts.

Table 5(a). Output of Turbidity between wetlands by One way Anova

	Sum of Squares	df	Mean Square	F	P value
Between Groups	10.846	3	3.615	1.643	.255
Within Groups	17.602	8	2.200		
Total	**28.448**	**11**			

Table 5(b). Output of Turbidity between seasons

	Sum of Squares	df	Mean Square	F	P value
Between Groups	16.368	2	8.184	6.097	.021
Within Groups	12.080	9	1.342		
Total	**28.448**	**11**			

B. Chemical parameters:

1. pH:

In the present study average pHis recorded 7.06 ($\overline{X}$ = 7.41; σ = 0.31) to 8.24 ($\overline{X}$ = 7.67; σ = 0.54) in the wetlands under diara (Table no. 2), which falls within alkaline range. The wetlands under tal tract record an average pH from 6.96 to 7.54 ($\overline{X}$ = 7.28; σ = 0.29) throughout the study period (Table no. 3). The alkaline wetland water under diara tract may be associated with the high photosynthetic activity, which eventually substantiates excessive algal growth in the wetland water. Maximum pH (8.24) is recorded from Chatra wetland site in pre-monsoon and minimum from Chakla wetland (6.96) during post-monsoon. This study is found similar with previous works in the wetlands, Assam *(Abujam et al., 2012)*; in the wetlands, Karnataka *(Majagi, 2014).*The analysis of variance shows that water pH has no significant ($p>0.05$) variation between the wetlands (F = 0.671), where p value >á, but significant ($p<0.05$) variation between the seasons (F = 9.385) where p value < α (Table no. 6 (a)&(b)).

Table 6(a). Output of water pH between wetlands by OnewayAnova

	Sum of Squares	df	Mean Square	F	P value
Between Groups	.255	3	.085	.671	.593
Within Groups	1.014	8	.127		
Total	**1.269**	**11**			

Table 6(b). Output of pH between seasons

	Sum of Squares	df	Mean Square	F	P value
Between Groups	.858	2	.429	9.385	.006
Within Groups	.411	9	.046		
Total	**1.269**	**11**			

2. Conductivity:

The wetlands, located in diara tract record an average conductivity ranges from 97.27µ.s. ($\bar{X}$ =150.59; σ = 62.05) to 579.33µ.s. ($\bar{X}$ = 442.78; σ =124.58) (Table no. 2), which may be caused due to pollution especially from domestic and municipal effluents and other organic matters from the peripheral localities into thesewetlands. On the other hand, tal region records an average conductivity between 104.97µ.s. ($\bar{X}$ =119.60; σ = 17.15) to 143.87µ.s. ($\bar{X}$ = 132.94; σ = 9.74) (Table no. 3), which is relatively lower than diara. Maximum concentration (579.33µ.s.) of conductivity is recorded in Chatra wetland during pre-monsoon and minimum (104.97µ.s.) in Chakla wetland during post-monsoon. Similar observation is made by early workers in water bodies of Kerala *(Sylas, 2010);* Karnataka *(Ramachandra et al., 2014).* Statistical analysis shows significant ($p<0.05$) variation in conductivity between wetlands (F = 14.539) where p value < α, but no significant ($p>0.05$) variation between the seasons (F = 0.442) where p value < α *(Table no. 7(a) & (b)).*

Table 7(a). Output of Conductivity between wetlands by OnewayAnova

	Sum of Squares	df	Mean Square	F	P value
Between Groups	215455.702	3	71818.567	14.539	.001
Within Groups	39517.769	8	4939.721		
Total	**254973.470**	**11**			

Table 7(b). Output of Conductivity between seasons

	Sum of Squares	df	Mean Square	F	P value
Between Groups	22789.634	2	11394.817	.442	.656
Within Groups	232183.837	9	25798.204		
Total	**254973.470**	**11**			

3. Total dissolved solid (T.D.S.):

In the present study, total dissolved solid within the wetlands of diara fluctuates between 47.30ppm ($\bar{X}$ = 74.69; σ = 26.32) to 293.33ppm ($\bar{X}$ =240.54; σ = 56.85)(Table no. 2) whereas, tal region records an average tdsrange from 51.57ppm (=58.49; σ = 7.77) to 78.50ppm ($\bar{X}$ = 68.17; σ = 9.93) (Table no. 03) in wetland water. Diararegion records both the highest (293.30ppm) and lowest (47.30ppm) concentration of dissolved solid from Chatra and Naghoria wetland during pre-monsoon and post-monsoon period respectively. Higher concentration of tds during pre-monsoon period enhances the nutrient status of water body, which ultimately results into eutrophication and disturbs the ecological balance of wetlands. This study is found similar with earlier workers, in the wetlands of Ahmadabad, Gujarat (*Qureshimatva & Solanki, 2015)*. The statistical analysis shows thatdissolved solid has significant ($p<0.05$) variation between wetlands ($F = 22.223$), but no significant ($p>0.05$) variation between the seasons ($F = 0.319$) (Table no. 8(a)&(b)).

Table 8(a). Output of Dissolved solid between wetlands by OnewayAnova

	Sum of Squares	df	Mean Square	F	P value
Between Groups	68072.318	3	22690.773	22.223	.000
Within Groups	8168.417	8	1021.052		
Total	**76240.736**	**11**			

Table 8(b). Output of Dissolved solid between seasons

	Sum of Squares	df	Mean Square	F	P value
Between Groups	5050.469	2	2525.235	.319	.735
Within Groups	71190.266	9	7910.030		
Total	**76240.736**	**11**			

4. Total hardness:

The average water hardness is recorded from71.67mg/L ($\overline{X} = 125.33$; $\sigma = 58.28$) to 252.67mg/L ($\overline{X} = 211.56$; $\sigma = 37.27$) in the wetlands under diara (Table no. 2) and 54.00mg/L ($\overline{X} = 75.78$; $\sigma = 20.75$) to 150.00mg/L ($\overline{X} = 129.33$; $\sigma = 19.22$) under tal division (Table no. 3). Pre-monsoon period consistently records high concentration of hardness with highest (252.67mg/L) value in Chatra wetland, which may be attributed to domestic as well as municipal sewage discharge within wetland. This result is in close conformity with the findings of several workers in wetlands, Karnataka *(Majagi, 2014)* in U.P. *(Yadav et al., 2013)*.Analysis of variance shows water hardness has significant ($p<0.05$) variation between the wetlands ($F = 6.799$), but no significant ($p>0.05$) variation between seasons ($F = 1.339$) where p value>α (Table no. 9(a)&(b)).

Table 9(a). Output of Total hardness between wetlands by One way Anova

	Sum of Squares	df	Mean Square	F	P value
Between Groups	28478.646	3	9492.882	6.799	.014
Within Groups	11170.410	8	1396.301		
Total	**39649.056**	**11**			

Table 9(b). Output of Total hardness between seasons by One way Anova

	Sum of Squares	df	Mean Square	F	P value
Between Groups	9090.609	2	4545.305	1.339	.310
Within Groups	30558.446	9	3395.383		
Total	**39649.056**	**11**			

5. Dissolved oxygen:

In the wetlands under study, average concentration of dissolved oxygen ranges from 7.03mg/L ($\bar{X}$ = 8.20; σ = 1.09) to 9.63mg/L ($\bar{X}$ = 8.69; σ = 1.09) underdiara(Table no. 2), whereas in tal it records 4.17mg/L to 6.57mg/L ($\bar{X}$ = 5.44; σ = 1.21) (Table no. 3) throughout the study period. Recorded values of do ranging from post-monsoon highs to pre-monsoon lows are inversely related to the temperature cycle. Maximum (9.63mg/L) dissolved oxygen is recorded during winter in Chatra wetland. Oxygen content of the surface water is relatively lower during pre-monsoon, which indicates the eutrophic nature of the wetland water. Minimum (4.17mg/L) do is recorded in pre-monsoon period from tal region, containing Chakla wetland. This observation is in accordancewith early workers *(Vankar et al., 2018; Qureshimatva et al., 2015)*. *Trisal (ed. Chatrath, 1992)* pointed out the similar result in the water body of Kashmir. Statistical analysis shows significant ($p<0.05$) variation in do between wetlands (F = 7.604) where p value<α, and no significant ($p<0.05$) variation between seasons (F = 1.559) where p value>α (Table no. 10(a) & (b)).

Table 10(a). Output of Dissolved oxygen between wetlands by OnewayAnova

	Sum of Squares	df	Mean Square	F	P value
Between Groups	27.901	3	9.300	7.604	.010
Within Groups	9.784	8	1.223		
Total	**37.685**	**11**			

Table 10(b). Output of Dissolved oxygen between seasons

	Sum of Squares	df	Mean Square	F	P value
Between Groups	9.696	2	4.848	1.559	.262
Within Groups	27.989	9	3.110		
Total	**37.685**	**11**			

C. Bacteriological parameters:

1. Total coliform:

Total coliform gives the information about coliform bacteria and is considered to be much accurate indication of animal waste within the wetland water. Diara region (Table no. 2) records an average coliform counts range from 1MPN/100ml ($\overline{X}$ =4.33; σ = 3.93) to 11.33MPN/100ml of water ($\overline{X}$ = 9.55; σ = 2.04)whereas, an average coliform count is recorded between 0 to 18MPN/100 ml of water ($\overline{X}$ = 8.71; σ = 9.01) in the wetlands under tal physiography(Table no. 3). In the present study, maximum (18MPN/100ml) coliform count is found in Chakla wetland under tal region during post-monsoon period, which is in conformity with the workerin Kerala*(Jalal &Sanalkumar, 2012)*.Diara region records relatively low concentration and somewhere no concentration of coliform counts within the wetlands. As per the statistical analysis, no significant ($p>0.05$) variation in tc count is recorded between wetlands (F = 0.547) and between seasons (F=0.430) where the p value > α (Table no. 11(a) & (b)).

Table 11(a). Output of Total coliform count between wetlands by One way Anova

	Sum of Squares	df	Mean Square	F	P value
Between Groups	48.298	3	16.099	.547	.664
Within Groups	235.382	8	29.423		
Total	**283.680**	**11**			

Table 11(b). Output of Total coliform count between seasons

	Sum of Squares	df	Mean Square	F	P value
Between Groups	139.327	2	69.663	4.343	.048
Within Groups	144.353	9	16.039		
Total	**283.680**	**11**			

2. Fecal coliform:

The fecal coliform is recorded insignificant throughout the entire study period. Diara region (Table no. 2) records an average counts ranges from 0 to 1.33MPN/100ml water ($\overline{X}$ = 0.89; σ = 0.77) and tal records 0 to 8.67MPN/100ml water ($\overline{X}$ = 3.45; σ = 4.60)(Table no. 3). In diara and tal physiography, post-monsoon period records relatively higher count of fecal coliform than the other two seasons.Statistical analysis shows no significant ($p>0.05$) variation of fecal coliform counts between the wetlands (F = 0.956) as well as between seasons (F = 2.006) where p value > α (Table no. 12(a)&(b)).

Table 12(a). Output of Fecal coliform count between wetlands by OnewayAnova

	Sum of Squares	df	Mean Square	F	P value
Between Groups	16.293	3	5.431	.956	.459
Within Groups	45.430	8	5.679		
Total	**61.724**	**11**			

Table 12(b). Output of Fecal coliform count between seasons

	Sum of Squares	df	Mean Square	F	P value
Between Groups	19.033	2	9.516	2.006	.190
Within Groups	42.691	9	4.743		
Total	**61.724**	**11**			

Correlation matrix of water quality parameters

The observation on the water quality parameters (physical, chemical and bacteriological) of the wetlands under study are analysed with Pearson's r correlation coefficient and presented in table no. 13. Wetland *water temperature* shows highly significant ($p<0.01$) positive correlation with pH ($r=0.861$)and significant ($p<0.05$) positive correlation with hardness ($r=0.586$)and significant ($p<0.05$) negative correlation with total coliform ($r=-0.696$). *Turbidity* shows non-significant ($p>0.05$) positive correlation with conductivity, dissolved solid, dissolved oxygen, total and fecal coliform and negative correlation with temperature, pH, and hardness of wetland water. Wetland*pH* shows highly significant ($p<0.01$) positive correlation with conductivity ($r=0.717$) and total hardness ($r=0.782$) and significant ($p<0.05$) positive correlation with tds ($r=0.680$)and negative correlation with total coliform ($r=-0.731$). Water *Conductivity*shows highly significant ($p<0.01$) positive correlation with tds ($r=0.991$) and hardness ($r=0.896$).

Total dissolved solid shows highly significant ($p<0.01$) positive correlation with total hardness ($r=0.883$)and significant ($p>0.05$) positive correlation with pH ($r=0.680$).*Total hardness*records highly significant ($p<0.01$) positive correlation with pH, conductivity and tds and significant ($p<0.05$) positive correlation with temperature. *Dissolved oxygen* shows non-significant ($p>0.05$) positively correlated with conductivity, dissolved solid, turbidity, water hardness, and total coliform whereas negative correlation take place with temperature, pH and fecal coliform. The bacteriological parameters such as, *Total coliform* shows highly significant ($p<0.01$) positive correlation with fecal coliform ($r=0.796$). Fecal coliform shows non-significant ($p>0.05$) positive correlation with turbidity and negative correlation with temperature, pH, conductivity, hardnessand dissolved oxygen of wetland water.

Table 13. Correlation Matrix between water quality parameters

	WT	pH	Conductivity	TDS	Turbidity	TH	DO	TC	FC
WT	1	0.861**	0.392	0.358	-0.444	0.586*	-0.417	-0.696*	-0.537
pH		1	0.717**	0.680*	-0.271	0.782**	-0.100	-0.731**	-0.560
Conductivity			1	0.991**	0.071	0.896**	0.418	-0.494	-0.317
TDS				1	0.161	0.883**	0.451	-0.509	-0.334
Turbidity					1	-0.196	0.299	0.023	0.168
TH						1	0.296	-0.508	-0.503
DO							1	0.176	-0.057
TC								1	0.796**
FC									1

**. Correlation is significant at 0.01 level (2-tailed); *. Correlation is significant at 0.05 level (2-tailed).

WT= Water Temperature, TDS= Total Dissolved Solid, TH= Total Hardness, DO= Dissolved Oxygen, TC= Total Coliform, FC= Fecal Coliform.

Biotic components

The physic-chemical and bacteriologicalparameters of water have a conspicuous impact on wetland aquatic life.From the biodiversity point of view, the wetlands under both diara and talregion maintain a stable aquatic ecosystem by having floral and faunal diversity. The macrophytesin the form of emergent, floating-leaved and submerged namely; *Heliotrpiumindicum, Enudrafluctuam, Hygrophiliaauriculata, Centallaasiatica, Nelunbonucifera, Nymphaenonhali, Salviniacucullata, Colcasiaescilenta and Euryoleforex* etc.are identifiedinwetland edge and open water. Furthermore, these wetlands act as nursery ground for several inland fresh water fish species namely;*Ariusarius, Labeobata, Catlacatla, Cirrihinusmrigala and Labeorohita,Clariusbatrachus, Labeocalbasu*, etc.Moreover, these wetlands support a large congregation of resident and migratory water fowls. The wetlands and riparian zone are encountered with the common resident species such as, *Ardea alba, Spilopeliachinensis, Terpsiphoneparadisi, Falco amurensis, Eudynamys, Ardeolagrayii , Leiopicusmahrattensis,Alcedoatthis* and migratory species namely; *Anseranser, Anasacuta , Anasclypeata, Anaspoecilorhyncha*etc.The richness and assemblage of biotic components is an accurate indication of an ecological health of a particular wetland *(NWCP, 2009)*. The arrival of migratory bird species is one of the good indicators for studying variety of environmental problems. In the present study, the biotic assemblage in diara is found relatively less than thetal region. Being located adjacent to Malda town, the wetlands under diara are facing major challenges, interfered with the man induced alterations and encroachment in a regular basis *(Chattaraj&Sarkar, 2016)*. The draining of raw sewer and dumping of garbage into these water bodies acceleratethe process of eutrophication and subsequently minimize the content of dissolved oxygen, which has recorded during study period. The water quality parameters of pH, conductivity, dissolved solid, water hardness are recorded maximum in the wetlands ofdiara region, whichencountera drastic decline in the migratory bird population. The wetlands, especially under diara tract are declining its erstwhile varied biotic resources *(Chattaraj&Sarkar, 2016)*.

Conclusion

In the present study, the seasonal variation of physical, chemical and bacteriological water quality parameters from demarcated physiographic divisions throughout the study period display a vivid picture on the ecological health of the wetlands. Based on the findings, the overall wetland water quality is recorded within the permissible limit in tal region (Siali and Chakla) and indicatesthe prevalence of desirable quality of water. The water bodies (Naghoria and Chatra) under diararegion exhibits high concentration of certain parameters, which are found to exceed the desirable limits (BIS).Unlawful human activities like garbage dumping, poisoning and introduction of exotic species within the wetlands are responsible for reiterating the water quality and resulting into diminution and fragmentation of biodiversity*(Chattaraj&Sarkar, 2016)*. The present study urges the need for restoring the ecologically vulnerable wetlands in Maldadistrict to ensure the sustainability of a healthy ecosystem.Therefore, adoptingimmediate actions is need of the hour to regulate further deterioration of these wetlands as well as to restrict them from becoming ecologically inactive water bodies.

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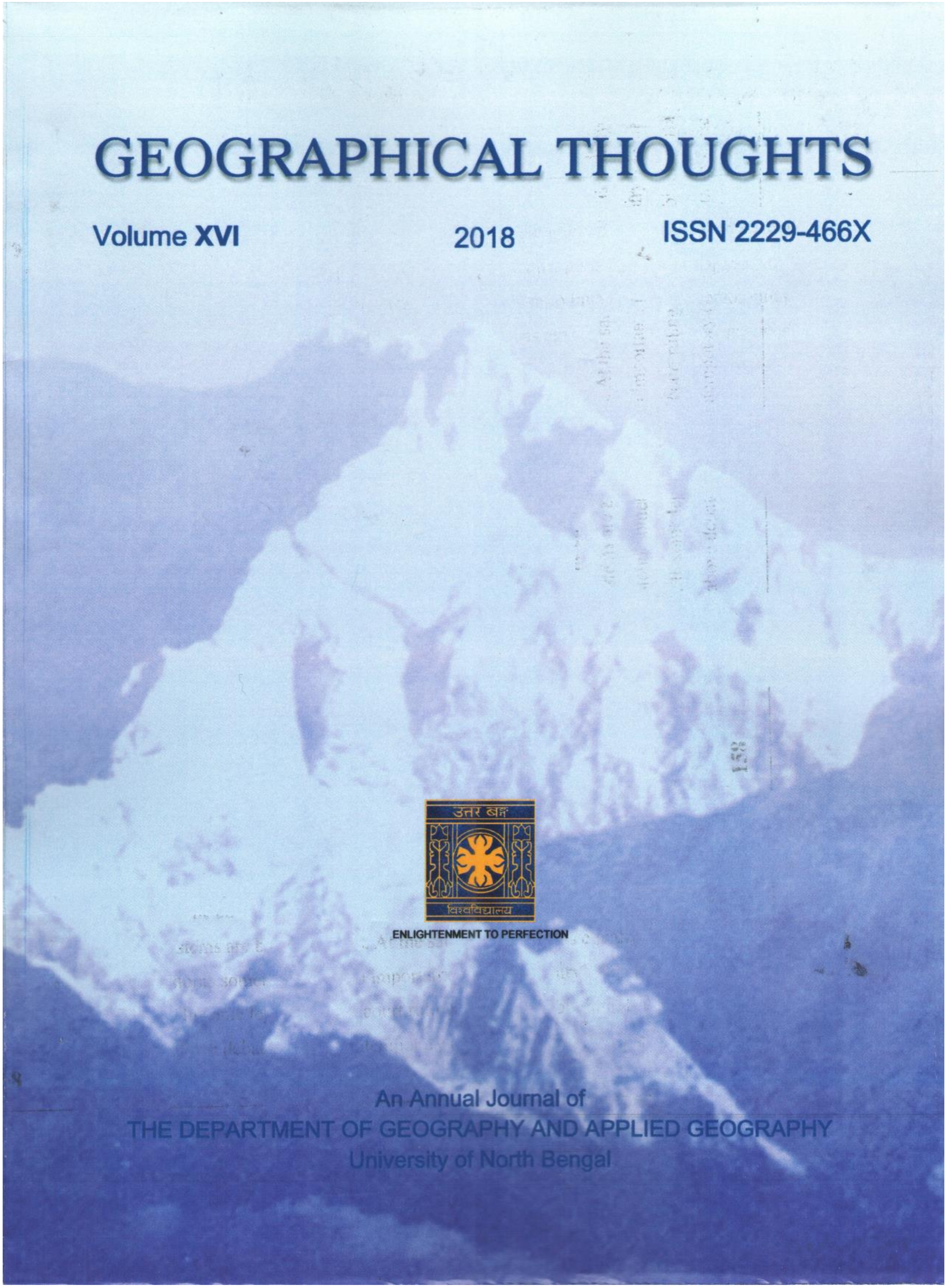

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A STUDY ON THE DIVERSITY OF AQUATIC MACROPHYTES AND ASSOCIATED ECONOMIC POTENTIALS IN THE WETLANDS OF MALDA DISTRICT

Diyali Chattaraj* & Prof. Subir Sarkar**

Abstract

The wetlands exhibit a heterogeneous assemblage of aquatic macropytes, which form of bulk of wetland flora. The present study has been undertaken in two wetlands, of Malda district, West Bengal, in order to identify the diversity and distribution of aquatic macrophytes. Both the case studies are occupied by substantial area cover under aquatic macrophytes, which are further classified on the basis of habitats and growth forms. An inventory of aquatic macrophytes has also been prepared to provide a baseline record of which species are found within the wetlands. Moreover, the economic valuation of these aquatic macrophytes has been done to know how potential these wetland plants are in order to promote the economy of rural mass around the case studies in Malda district. The present work concludes with the necessity of conservation ethics and public awareness, related to the utilization of wetland resources and associated aquatic macrophytes.

Key words: *Aquatic macrophytes, habitats, growth forms, inventory, economic valuation, economic potentials, conservation ethic.*

Introduction

The wetlands have commonly been viewed as the transitional habitats between the terrestrial (land) ecosystem and aquatic (water) ecosystem. The hydrological system of different wetlands greatly vary, which ranges from permanent inundation (shallow water habitat) to periodic soil saturation (seasonal water logged habitat) at or near the soil surface. The wetlands are made up of a mixture of soil and water, which act as a genetic reservoir of certain species of aquatic macrophytes. The aquatic macrophytes have specialized morphological, physiological, or other adaptabilities for living, growing, and reproducing in wet areas of prolonged saturation near the surface *(Tiner, 2012)*. Aquatic macrophytes, often called hydrophytes are considered the key component of wetland ecosystem to play a crucial role in the structure and functioning of aquatic ecosystem.

Study area

Malda district (24°40′20″N to 25°32′08″N latitudes and 87°45′50″E to 88°28′10″E longitudes) in the state of West Bengal, being crisscrossed with the major river systems (River, Mahananda, Kalindri, Tangan, Fulahar) promotes a unique fluvio-geomorphic condition for the formation of wetlands. The district is divided into three well-defined physiographic divisions namely, *Diara* (south&south-west), *Tal* (north&northwest), and *Barind* (east), are well-occupied by > 500 number of wetlands (each with ≥2.25 hectare). In the present study, two wetlands, namely *Siali wetland* (25°18′N to 25°19′N latitudes and 87°53′E to 87°54′E longitudes), located in block Harishandrapur 2 under *Tal* region; and *Chatra wetland* (24° 58′

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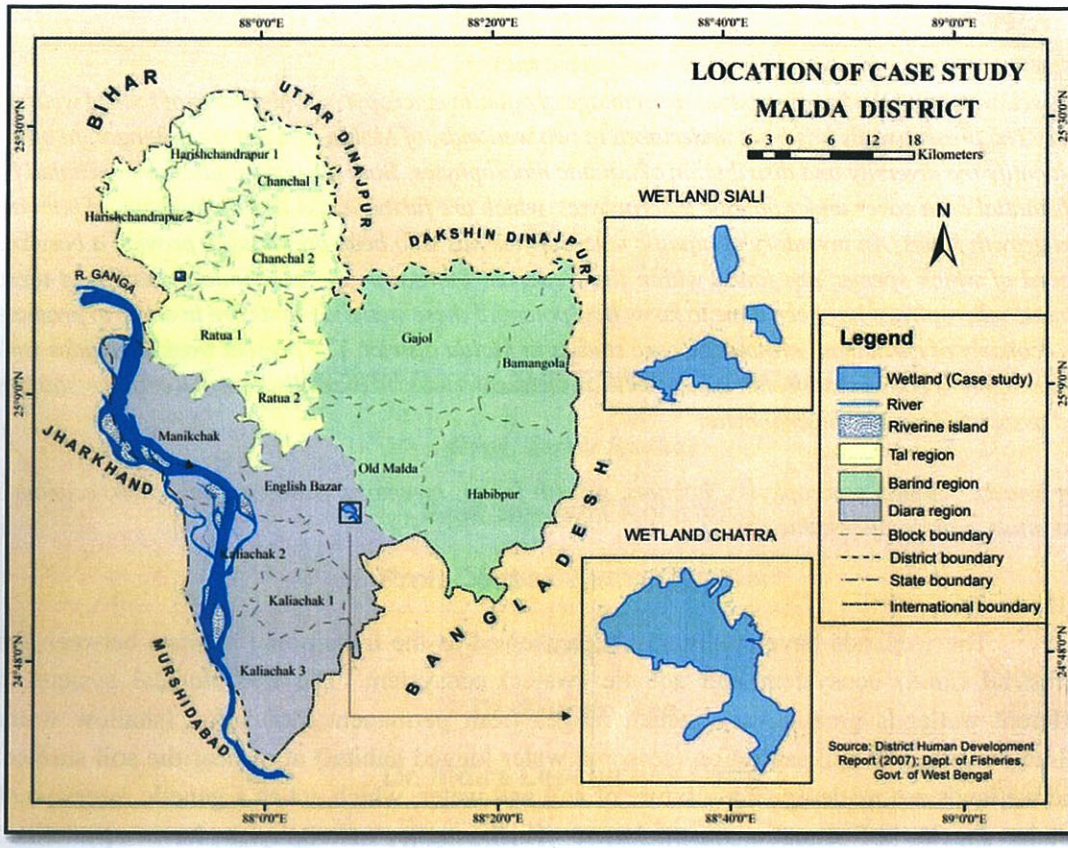
30″N to 25°00′30″N latitudes and 88°06 ′E to 88° 08 ′E longitudes), located in block English Bazar under *Diara* region *(Map 1)*, have been selected as case study, in order to assess the diversity of aquatic macrophytes within the wetlands.



Map 1: Location map of case study, Malda Ditsrict

Objectives

The present study has been carried out with the following objectives:

1. To prepare an inventory of aquatic macrophytes and provide a baseline record of which species are found within the case studies (wetlands).
2. To identify the spatial distribution of aquatic macrophytes within case studies.
3. To analyse the economic potential of aquatic macrophytes, found within case studies.

Database and methodology

The present study on the diversity of macrophytes and their economic potentialities are entirely based on both primary data and secondary sources. In order to fulfil the objective no. 1, to prepare an inventory of aquatic macrophytes, field survey has been conducted for one year from March 2016 to February 2017. The diverse species of aquatic macrophytes have been collected, photographed and taken to laboratories for further identification as well as are kept into record. The aquatic macrophytes, collected from the case studies, have been identified by

"Plant systematics" of Simpson (2010) and "Plant systematics: An Integrated Approach" of Singh (2016). In order to fulfil objective no. 2 i.e., the spatial distribution of macrophytes within wetlands, the satellite image of Landsat 8 OLI data has been consulted for individual case studies with similar time frame (November, 2018). In order to know the utilization of aquatic macrophytes, found within wetlands, a household survey (5% of population) by random sampling has been followed in the villages, which are located at the immediate vicinity, surrounding the case studies. Moreover, a market survey (nearby markets of case studies) has also been conducted in order to know the economic valuation as well as potentials of wetland macrophytes (objective no. 3) to sustain the socio-economy of surrounding villagers.

Inventory and spatial distribution of aquatic macrophytes

The Siali and Chatra both are considered as natural water body. Siali wetland is riverine and is fed by two tributaries namely; Kankhor and Kali kosi, of river Baramasia. The water area extension of Siali wetland is 18.74 ha. The water depth is recorded 1.5 meter during pre-monsoon season, whereas during monsoon and post-monsoon, water level increases to $\geq$ 3.5 meter in several pockets. Chatra wetland is an isolated waterlogged and appears to be a vast wetland with an area extension of 234.54 ha. The water level fluctuates throughout the year with minimum 1.5 meter depth at pre-monsoon, and 3.5 meter during monsoon, which maintains up to post-monsoon season. The wetlands under study act as lush habitat to provide variety of aquatic macrophytes, which have developed a wide range of adaptations in order to endure, survive and utilize the wetland environment. In the present study a total 11 number of species, belonging to 11 genera and 10 families have been collected and identified from Siali wetland *(Acanthaceae-1, Apiaceae-1, Asteraceae-1, Boraginaceae-1, Caryophyllaceae-1, Hydrocharitaceae-1, Nymphaeaceae-1, Pontederiaceae-1, and Salviniaceae-2)*. The other case study Chatra wetland records a total of 11 species, belonging to 11 genera and 9 families during the entire study period (2016-17) *(Acanthaceae-1, Araceae-2, Asteraceae-1, Boraginaceae-1, Caryophyllaceae-1, Fabaceae-2, Nymphaeaceae-1, Pontederiaceae-1 and Potamogetonaceae-1)*. The aquatic macrophytes, found within the case studies are namely; *Hygrophilia auriculata* (Kulekhara), *Centella asiatica* (Thankuni), *Enydra fluctuans* (Hingcha / Halencha) *(Plate 1E)*, *Heliotropium indicum* (Hatisur) *(Plate 1F)*, *Polycarpon prostratum* (Ghima), *Hydrilla verticillata* (Kureli), *Euryale ferox* (Makhana) *(Plate 1D)*, *Hygroryza aristata* (Jangli dal), *Eichhornia crassipes* (Kachuripana) *(Plate 1C)*, *Azolla ceae* (Kutipana), *Salvinia cucullata* (Water fern), *Colcasia esculenta* (Kachu) *(Plate 1A)*, *Pistia stratiotes* (Water lettuce) *(Plate 1B)*, *Aeschynomene aspera* (Sola), *Nymphaea nouchali* (Saluk), *Potamogeton perfoliatus* (Bara-pana) *(Table 1) (Plate 1)*. The perennial plant of *Eichhornia crassipes*, commonly known as water hyacinth grows rapidly into extensive surface mats especially in Chatra wetland during the pre-monsoon (March to May) period. Chatra wetland experiences other aquatic macrophyte i.e., *Pistia stratiotes*, commonly called water lettuce, as an annual plant to be widely expanded throughout the year. Both these water hyacinth and water lettuce are considered invasive species (one that is potential to rapidly spread and replace native species), to be better adapted to higher nutrient levels *(Keddy, 2010)*. The aquatic marcophytes, found within the case studies have been grouped into 6 growth form classes, based on their similarities in structure and function; namely Semi-emergent (SE), submerged rooted (SR), rooted floating leaved (RFL), free floating (FF), emergent (E) and emergent grass (EG). The growth form includes the degree of independence, the plant morphology, leaf traits etc. In Siali wetland, the dominant growth form is found as emergent (36.4%), with 4 no. of species, followed by free floating (27.3%) with 3 species, rooted floating leaved, semi-emergent, submerged rooted and emergent grass (9.1%), each with 1 species *(Figure 1)*. In Chatra wetland, out of total species (11no.), emergent growth form is mostly dominant (36.4%) with 4 species, followed by free floating and rooted floating leaved and submerged rooted (18.2%) each with 2 species, and semi-emergent (9.1%) with 1 species *(Figure 2)*. Moreover, the aquatic macrophytes have also been classified on the basis of habitat. Habitat is considered as the summation of all the biotic (living) and abiotic (non-living) factors that surround and potentially influence the plant organisms with specific characteristics in the form of adequate food, water and space. In the present study, the aquatic macrophytes have been classified into 2 habitats; 1. Open water and 2. Water edge. Siali and Chatra wetland comprise 5 species and 7 species of aquatic macrophytes under open water habitat whereas; 6 species and 4 species under water edge habitat respectively *(Table 1)*.

Table 1 Inventory of aquatic macrophytes within case study

Sl. No.	Local / common name	Family	Genus	Species	Scientific name	Habitat	Growth form	Wetland
1.	Kulekhara	Acanthaceae	Hygrophila	auriculata	*Hygrophilia auriculata*	WE	SE	Siali Chatra
2.	Thankuni	Apiaceae	Centella	asiatica	*Centella asiatica*	WE	E	Siali
3.	Kachu	Araceae	Colocasia	esculenta	*Colcasia esculenta*	OW	E	Chatra
4.	Water lettuce	Araceae	Pistia	stratiotes	*Pistia stratiotes*	OW	FF	Chatra
5.	Hingcha / Halencha	Asteraceae	Enhydra	fluctuans	*Enydra fluctuans*	WE	E	Siali Chatra
6.	Hatisur	Boraginaceae	Heliotropium	indicum	*Heliotropium indicum*	WE	E	Siali Chatra
7.	Ghima	Caryophyllaceae	Polycarpon	prostratum	*Polycarpon prostratum*	WE	E	Siali Chatra
8.	Sola	Fabaceae	Aeschynomena	aspera	*Aeschynomene aspera*	OW	SR	Chatra
9.	Kureli	Hydrocharitaceae	Hydrilla	verticillata	*Hydrilla verticillata*	OW	SR	Siali
10.	Makhana	Nymphaeaceae	Euryale	ferox	*Euryale ferox*	OW	RFL	Siali Chatra
11.	Saluk	Nymphaeceae	Nymphaea	nouchali	*Nymphaea nouchali*	OW	RFL	Chatra
12.	Jangli dal	Poaceae	Hygroryza	aristata	*Hygroryza aristata*	WE	EG	Siali
13.	Kachuripana	Pontederiaceae	Eichhornia	crassipes	*Eichhornia crassipes*	OW	FF	Siali Chatra
14.	Bara-pana	Potamogetonaceae	Potamogeton	perfoliatus	*Potamogeton perfoliatus*	OW	SR	Chatra
15.	Kutipana	Salviniaceae	Azolla	ceae	*Azolla ceae*	OW	FF	Siali
16.	Water fern	Salviniaceae	Salvinia	cucullata	*Salvinia cucullata*	OW	FF	Siali

Source: *Field survey, 2016-17*

In the present study, the spatial distribution of aquatic macrophytes is found in considerable portion within the wetlands. Out of the total water spread area (18.74 ha) in Siali wetland, 3.6 ha (19.18%) area is occupied by aquatic macrophytes *(Map 2)*. The wetland has been fragmented into three parts over time, because of immense agricultural encroachment almost from all the

Plate A: Colcasia esculenta

Plate B: Pistia stratiotes

Plate C: Eichhornia crassipes

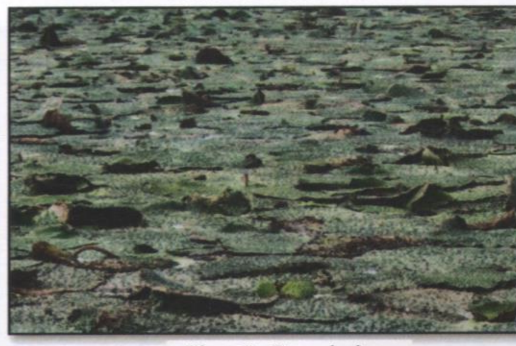


Plate D: Euryale ferox

Plate E: Enydra fluctuans

Plate F: Heliotropium indicum

Plate 1 (A-F): Inventory of Aquatic Macrophytes within case study

sides. The aquatic macrophytes are observed in the north-west, south-west and north-east portion of the main water body. The fragmented parts are occupied by scattered pockets of wetland macrophytes. In Chatra wetland, 82.9 ha (35.4%) area out of total water extension (234.54 ha) has substantially be occupied by aquatic macrophytes *(Map 3)* of diverse growth forms, found in the habitat of open water and water edge. In both the case studies, *Eichhornia crassipes* and *Euryale ferox* are found mostly dominant to cover a substantial portion out of all the mentioned aquatic macrophytes.

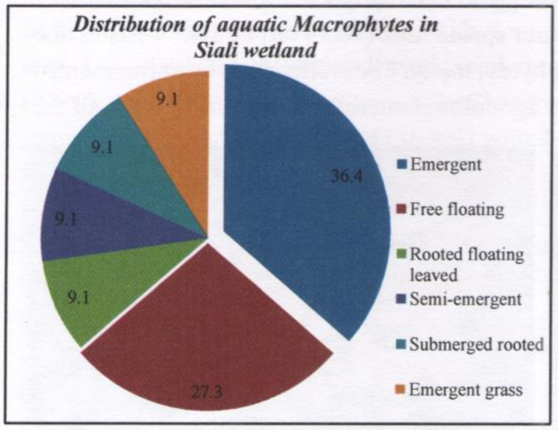


Figure 1: Distribution of aquatic macrophytes in Siali wetland based on growth forms

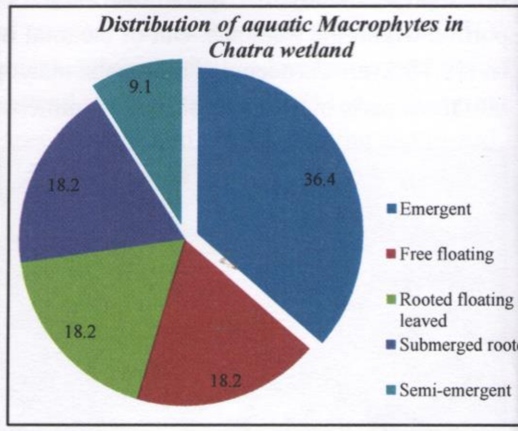
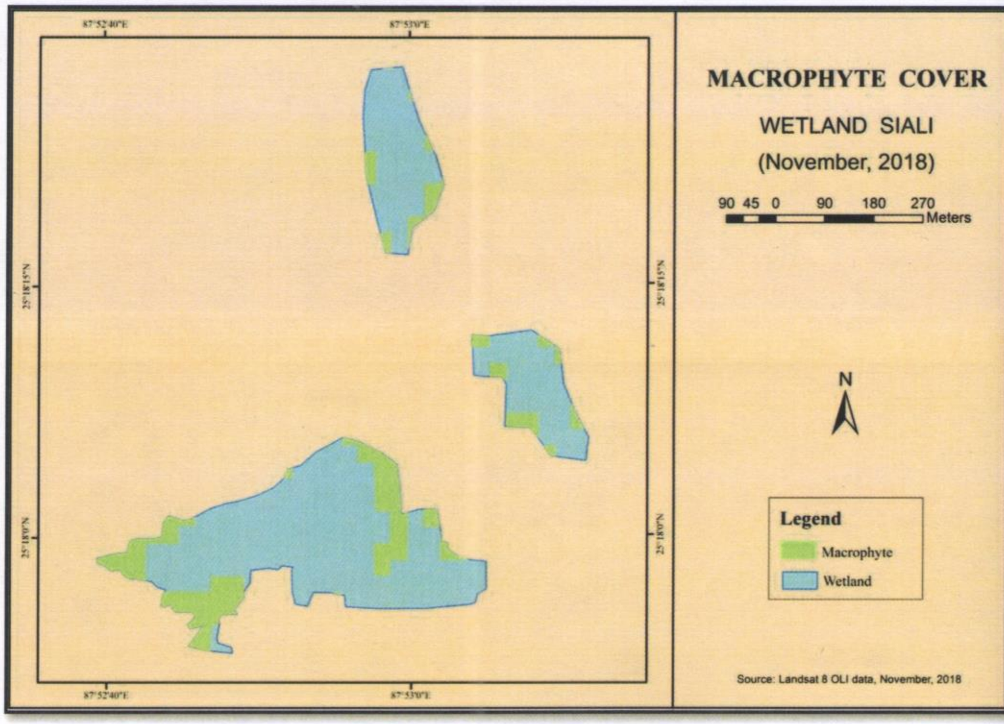


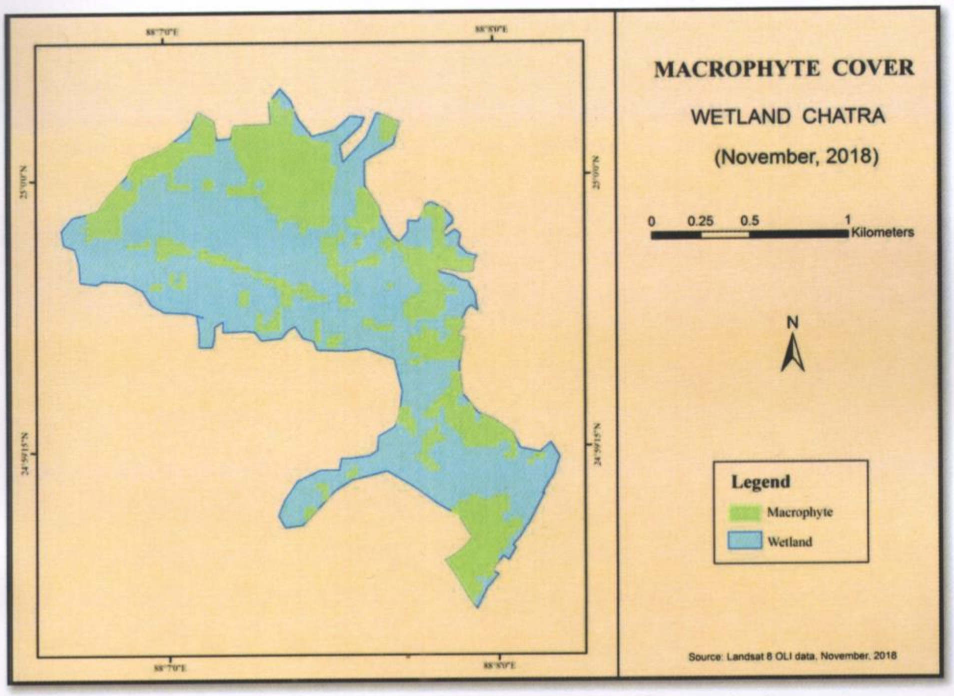
Figure 2: Distribution of aquatic macrophytes in Chatra wetland based on growth forms



Map 2: Distribution of aquatic macrophytes in Siali wetland

Economic potential of aquatic macrophytes:

The wetlands under study experience a large portion of area roofed with makhana especially at the monsoon months when the water is at its peak. Makhana cultivation within the wetlands of Malda district, especially in Siali wetland, located in Harischandrapur 2 block, has been introduced from the north-eastern part (Mithilanchal region) of the neighbouring state of Bihar which accounts approximately over 80 % of India's total makhana production. The mother plant *Euryale ferox* Salisb. (makhana) under the family of Nymphaeaceae is a large water lily which is commonly known as *gorgon nut* or *fox nut*. Morphologically it is a rooted macrophyte with attached rosette of spiny floating leaves. The rounded leaves ranging from 1 to 2 meter is entirely covered with numerous spines on all the surfaces. Makhana has much thicker cluster roots of fleshy and fibrous nature, as long as 40 to 50 cm. This unique aquatic plant is having bright purple-blue flowers, up to 4 to 5 cm long, with white petals in the centre, and long pedicel. It is an absolutely seed propagated plant, which produces 15 to 20 rounded, spongy fruits, having sharp prickles. Each fruits consists of number of seeds (less than 2 cm in diameter), which are finally processed into the edible white and starchy form as makhana *(Plate 3)*. After the initial broadcasting of makhana seeds during the post-monsoon (November-December) season and subsequent germination during pre-monsoon (March) and harvesting process, the ripen seeds start bursting during the month of monsoon (July-August). The seeds are generally harvested as well as collected in the last week of July or first week of August, following several rounds of practices *(Plate 2)*. Being a labour intensive crop, makhana cultivation includes number of processes like harvesting, collection, cleaning, rubbing, storage,



Map 3: Distribution of aquatic macrophytes in Chatra wetland

packing and marketing. The entire process of makhana practice involves large number of labours. Especially, labourers involved in seeds collection, get good wage, which ranges from Rs. 500.00-1000.00 to Rs. 1500.00-2000.00 per day, depending upon the location of floating seeds *(Chattaraj, 2019)*.

In the present study, a household survey has been conducted in the villages, which are located adjacent to the case studies. A total of 7 villages surrounding Siali wetland namely; Jagannathpur, Fatepur, Bhaluka, Degun, Talgachi, Parbhaluka and Kariali have been surveyed.

Out of the total 408 no. of surveyed households, 30 households (7.35%) are found to cultivate makhana on wetland bed. Makhana is cultivated extensively on 1.7 ha of the wetland bed on lease by fishing cooperative society (Bhaluka) by makhana cultivating households. The gross benefit of surveyed household is recorded Rs. 3,82,500.00 per annum. The total cost of makhana cultivation is divided into two types: 1. Labour cost (in order to prepare the makhana cultivating field on wetland bed) = Rs. 12,750.00 per annum and 2. Lease cost = Rs. 19,125.00 per annum. Therefore, the total cost from makhana cultivation on 1.7 ha area is recorded Rs. 31,875.00. Therefore, the estimated net benefit from makhana cultivation on Siali wetland bed is recorded Rs. 3,50,625.00 per annum *(Table 2)*.

Table 2 Economic valuation of Siali wetland

Sources of benefits and cost	Makhana cultivation
Gross benefit (Rs./annum)	3,82,500.00
Area under wetland cultivation (ha)	1.7
lease + labour cost (Rs./annum)	31,875.00
Estimated Net benefit (Rs./annum)	3,50,625.00
Sources of benefits	Wetland product gathering
Total income (Rs./annum/household)	8,000.00
No. of household gather wetland product	4
Total estimated benefit (Rs./annum) from product gathering	32,000.00
Total estimated benefit from wetland	3,82,625.00

***Source:** Field study, 2016-17*

In another case study, a list of 4 villages namely; Uttar Ramchandrapur, Uttar Jadupur, Dilalpur and Sonatala adjacent to Chatra wetland have been surveyed in order to know the status of makhana cultivation by surrounding settlers along with its economic potentials to sustain the socio-economy of the inhabitants. Out of the total 193 no. of surveyed households, 46 households (23.83%) are engaged in makhana cultivation on wetland bed. There is a scope in revenue generation by practicing makhana on Chatra wetland bed. Makhana is cultivated extensively on 25.2 ha area on lease by gram panchayat (Uttar Jadupur) by makhana cultivating households. The gross benefit of surveyed household is recorded Rs. 56,70,000.00 per annum. The total cost of makhana cultivation is in the form of labour cost i.e., Rs. 1,89,000.00 per annum and lease cost i.e., Rs. 2,83,500.00 per annum. Therefore, the total cost from makhana cultivation on 25.2 ha area is recorded Rs. 4,72,500.00. Therefore, the estimated net benefit from makhana cultivation on Chatra wetland bed is recorded Rs. 51,97,500.00 per annum *(Table 3)*.

Table 3 Economic valuation of Chatra wetland

Sources of benefits and cost	Makhana cultivation
Gross benefit (Rs./annum)	56,70,000.00
Area under wetland cultivation (ha)	25.2
lease + labour cost (Rs./annum)	4,72,500.00
Estimated Net benefit (Rs./annum)	51,97,500.00
Sources of benefits and cost	Wetland product gathering
Total income (Rs./annum/household)	8,500.00
No. of household gather wetland product	9
Total estimated benefit (Rs./annum) from product gathering	76,500.00
Total estimated benefit from wetland	52,74,000.00

***Source:** Field study, 2016-17*

Moreover, this aquatic macrophyte plays substantial role in the local socio-economy in the form of having nutritional value and medicinal importance. The calorific values of makhana seeds are highly rich in vitamin, protein and mineral contents (magnesium, potassium and phosphorus) and compares well with staple food materials (wheat, rice, etc.) but low in

Plate 2: Makhana seeds, as raw product

Plate 3: Makhana seeds, as finished product

saturated fats, sodium and cholesterol content. The edible part of the seed contains moisture (12.8%), protein (9.7%), carbohydrates (76.9%), minerals (0.5%) and a very low amount of fat (0.1%) *(Anonymous, 1952)*. Along with having nutritional value, Makhana is popularly used in the medicinal purposes against several human ailments (respiratory, circulatory, digestive, excretory and reproductive systems) *(Chattaraj, 2019)*.

Apart from makhana, the other aquatic macrophytes are gathered by small no. of households in both Siali and Chatra wetland. According to household survey, out of the total no. of households, 4 households (1.41%) around Siali wetland and 9 households (6.72%) around Chatra wetland, residing at the immediate vicinity, gather aquatic macrophytes namely thankuni, hingha/helencha, hatisur, ghima, kulekhara. These macrophytes are used by local inhabitants directly for the food, fiber and fuel. Some of these macrophytes (thankuni, kulekhara) possess known medicinal properties to the local people. The thick mat of water hyacinth within case studies especially during pre-monsoon season is collected by the peripheral settlers as fodder and provides an important source of income as well as reduce down the cost of feeding the cattle population, as the fodder, which is available in the local market is quite expensive. The total no. of households (4) around Siali wetland, after gathering the aquatic macrophytes, sells it to the local or nearby market (Bhaluka market, Bichitra market and local hats, Malda) and get an estimated benefit of Rs. 32,000.00 per annum. Therefore, the total estimated benefit from Siali wetland in the form of makhana cultivation and product gathering is recorded Rs. 3,82,625.00 per annum *(Table 2)*. In Chatra wetland, total product gathering households (9) get an estimated benefit of Rs. 76,500.00 per annum. The total estimated benefit from Chatra wetland, in the form of makhana cultivation and other aquatic product collection is recorded Rs. 52,74,000.00 per annum *(Table 3)*.

The presence of aquatic macrophytes, within wetlands has started gaining importance not only because of the systematic stocktaking of plant diversity, but also because these plants have several implications with functional values of wetlands. The aquatic macrophytes especially, water hyacinth is highly effective absorbent to have the unique filtering effects by removing as well as filtering the nutrients (nitrogen and phosphorus) and toxic wastes, coming from the adjacent land areas. The metabolism of aquatic macrophytes (nutrient uptake, oxygen release by the submerged rooted plants etc.) is considered essential in wastewater treatment and wetland restoration.

Conclusion

The present study reveals that, the case studies are enriched with aquatic macrophytes, which are considered economically potential in order to sustain the local economy. In Malda district, both Siali and Chatra wetlands along with the existing aquatic macrophytes are used as multiple systems and have significant impact on the livelihood of local people. One observation is found during field study that, before makhana seeds sowing, the cultivators use a pesticide of endosulfan group (organochlorine insecticide), which is considered highly toxic to create a noxious effect on the fish fauna and associated wetland biodiversity. Therefore, a changing technology is necessary in makhana cultivation especially in applying the toxic insecticides in wetland water in order to keep the biodiversity richness intact. Moreover, public awareness needs to be implemented, which states to educate the peripheral villagers regarding the proper utilization of wetlands and associated aquatic macrophytes.

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