Chapter – I

INTRODUCTION

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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.

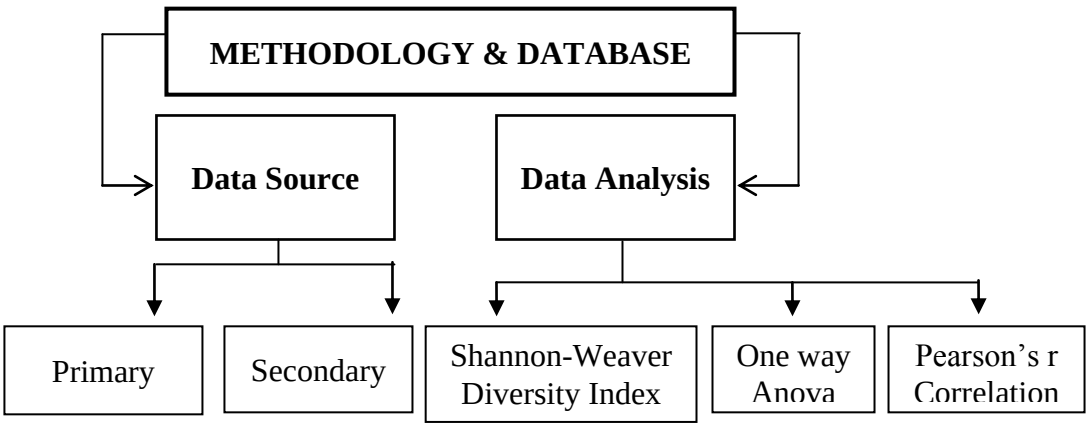
1.6 Hypotheses:

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 ($\bar{X}$), 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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