CHAPTER - I

INTRODUCTION

1. Experts' proposal for Dipal Beel as Ramsar site:

In a report 'India's Wetlands 2016: Encroached and Polluted' *compiled by Bhim Singh Rawat (we4earth@gmail.com*) and published by SANDRP (South Asia Network on Dams, Rivers and People) says about Diplai Beel that the experts from Assam have recommended to declare the Diplai Beel and the Laoti Beel in the Bodoland Territorial Council area as the second and third Ramsar site of Assam. Signifying their importance, they revealed Diplai Beel as an important breeding ground of the fish-fauna, local and residential water bird species, besides having a rich biodiversity as it has connection with the Brahmaputra River.

A news heading as 'Diplai and Laoti Beels potential Ramsar sites' is published in 'The Assam Tribune' Guwahati, Friday, December 02, 2016 where Prof. P. Saikia of GU, Department of Zoology, who is also State Coordinator of the Asian Waterfowl Census (AWC) said that Diplai Beel fulfills all the nine criteria required to be declared as a Ramsar wetland site, while the Laoti Beel fulfills eight criteria out of the nine in this regard after doing one year long field survey.

2. Definition of a wetland:

Less than 50 years ago the term 'wetland' was virtually unknown to science. Its first use can be traced back to early 1950s when the United States Fish and Wildlife Service prepared an inventory on wetlands in that country for their value as wildlife and waterfowl habitats (Martin *et al.,* 1953).

The term 'wetland' served as an umbrella to bring together a wide spectrum of habitats known by hundreds of local names in different parts of the world which shared between them two major characteristics: they had an abundance of water for at least some time during the year and hence supported a large diversity of waterfowl besides other wildlife. Marshes, swamps, bogs, fens, mangroves and shallow water bodies that had been variously used, abused and despised, became 'liquid assets' (IWRB, 1979) or 'waterlogged wealth' (Maltby, 1986). Wetlands are often described as "Kidneys of the landscape" (Mitch and Gosselink, 1986).

In USA the State of Washington as well as most other states and local governments have accepted the regulatory definition developed by the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency. This definition ascertains that wetlands are those areas that have inundate surface or ground water with a frequency sufficient to support plants and animals that depends on saturated or seasonally saturated soil conditions for the growth and reproduction (Cowardin *et. al*. 1979). The National Research Council of U.S.A in 1992 simply identifies wetlands as transitional areas between terrestrial and open water system, whereas in 1995 the NRC defines them as "an ecosystem that depend on constant or recurrent, shallow inundation or saturation at or near the surface of the substrate (NRC, 1995)."

Other wetland scientists ecologically define a wetland as an ecosystem that "arises when inundation by water produces soils dominated by aerobic processes and forces the biota, particularly rooted plants, to exhibit adaptation to tolerate flooding (Keddy, 2000). According to most widespread definition, wetlands are defined as: "lands transitional between terrestrial and aquatic eco-systems where the water table is usually at or near the surface or the land is covered by shallow water."

Wetlands are defined as areas of land that are either temporarily or permanently covered by water and exhibit enormous diversity according to their genesis, geographical location, water regime and chemistry. Some define as wetlands are areas of land that are either temporarily or permanently covered by water. This means that a wetland is neither truly aquatic nor terrestrial; it is possible that wetlands can be both at the same time depending on seasonal variability. Thus, wetlands exhibit enormous diversity according to their genesis, geographical location, water regime and chemistry, dominant plants and soil or sediment characteristics. Because of their transitional nature, the boundaries of wetlands are often difficult to define.

Fresh Water Act (Article-24) of New York State defines wetlands as lands and submersed lands commonly known as swamps, sloughs, bogs and flats which support wetland vegetation. Wetland vegetation is categorized into wetland trees, wetland shrubs and wet meadow vegetation that depend on permanent or seasonal flooding or sufficient waterlogged soils to give them a competitive advantage over other vegetations such as emergent, rooted floating leaved, free floating, submersed and bog mat plants (Browne *et al*,1995)

Again US Fish and Wildlife service define wetlands as transitional between territorial and aquatic systems where the water table is usually at or near the surface, or land is covered by shallow water. Wetlands are intermediate between purely well drained territorial ecosystem and fresh water ecosystems.

According to Ramsar Convention (Article 1.1), a wetland is defined as: *"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".*

3. History of wetlands:

There has been an unprecedented spurt of interest in wetlands study among researchers, engineers, managers, conservationists, sociologists, economists, biologists, various NGOs and above all the governments. This is reflected in a steep rise in the number of publications, symposia, conferences and participants and the countries joining the Ramsar Convention. In INTECOL's first International Conference on Wetlands, held in New Delhi in 1980, where participated only 100 participants from 13 countries. There were 905 participants from 56 countries participated in the 4^{th} INTECOL's Conference in 1992 held in Columbus, Ohio, U.S.A. and again over 2050 participants from 72 countries in its 6th Conference and in the Wetland Millennium Event,Quebec, Canada, 2000. The number of contracting parties to the Ramsar Convention has grown rapidly from 28 at its first Conference (COP1) in 1980 and only 54 in 1990 at COP4 to 133 in 2002 at COP8. Correspondingly the number of Ramsar sites and area have been grown from 212 (<9 million ha) in 1980 and 489 (30 million ha) in 1990 to 1229 (105.91 million ha) in 2002. (http://www.ramsar.org).

Wetlands had been investigated for several decades and there existed a large number of publications in research journals, until the late 1970s, rarely was a book devoted wholly to wetlands, except for a couple of proceedings of national and international symposia **(**Greeson *et al.,* 1979). The first introductory text on wetlands was published in 1983 and was soon followed by a comprehensive textbook by (Mitsch & Gosselink 1986). During the 1980s and early 1990s there appeared only about 40 books including the proceedings of international conferences (Williams, 1990; Mitsch *et al.,* 1994). These publications included major state-of- the-art reviews of our knowledge on all kinds of wetlands, their distribution, ecology, functions, values, management and conservation (Gopal *et al.,* 1982; Gore, 1983 a,b; Patten *et al.*, 1990, 1993; Whigham *et al.,* 1993**;** NRC, 1995).

There has been a spate of publications at both national and international levels. Mitsch & Gosselink (2000) list more than 50 books that appeared between 1992 and 2000. After that books on wetlands within a year for review in *Hydrobiologia-I* is prepared. At present a venture to analyze the developments in understanding wetland ecosystem and their functions, in the application of scientific knowledge for utilization and enhancement of wetland resources, and in promotion of policies for their conservation and management is reflected. The situation in developing countries to highlight the vast gap in wetland science, application and policy between developed nations and the Third World is realized.

The *Convention on Wetlands* an intergovernmental treaty was adopted on 2nd February 1971 in an Iranian city of Ramsar, on the southern shore of the Caspian Sea. Now-a-days the name of the convention is written as "Convention on Wetlands (Ramsar, Iran, 1971)". It is known popularly as the "Ramsar Convention". Ramsar is the first of the modern global intergovernmental treaty on the conservation and sustainable use of natural resources. The official name of the treaty is '*The Convention on Wetlands of International Importance especially as Waterfowl Habitat.'* It reflects the original emphasis upon the conservation and wise use of wetlands. Latter the Convention has broadened its scope of implementation to cover all aspects of wetland conservation and recognizing wetlands as ecosystems that are vital for biodiversity conservation and for the well-being of human communities. The convention comes into force in 1975 and now up to January 2017, has more than 163 member states from all parts of the world. The central Ramsar message is the sustainable use of all wetlands. Presently experts have designated a list of more than 2,060 wetlands for special protection as "Ramsar Sites", covering 197 million hectares (1.97 million square kms), larger than the surface area of France, Germany, Spain, Italy, and Switzerland combined.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) serves as Depositary *(The Depositary receives, reviews, and accepts the instruments of accession of each country member of the treaty, keeps the official text of the Convention in six official languages, and provides legal interpretations of the text when required. The Depositary does not have a role in the administration and/or implementation of the treaty.)* for the Convention, but the Ramsar Convention is not part of the United Nations and UNESCO system of environment conventions and agreements. The Convention is responsible only to its Conference of the Contracting Parties (COP), and its day-to-day administration has been entrusted to a secretariat under the authority of a Standing Committee elected by the COP. The Ramsar Secretariat is hosted under contract by IUCN–International Union for Conservation of Nature in Gland of Switzerland.

Today the Ramsar Convention adopts following points to conserve the wetlands

i. to designate wetlands for the List of Wetlands of International Importance.

ii. to formulate and implement planning so as to promote conservation of listed sites.

iii. to advise the Secretariat for any change in the ecological character of listed sites.

iv. to compensate for any loss of wetland resources if a listed wetland is deleted or restricted.

v. to use Ramsar criteria for identifying wetlands of international importance.

vi. to use the Ramsar datasheet and classification system for describing listed sites.

vii. to consider appropriate management measures after designation and where appropriate to use the Montreux Record and Ramsar Advisory Mission mechanisms.

vii. to formulate and implement planning so as to promote the wise use of wetlands.

viii. to adopt and apply the *Guidelines for implementation of the wise use concept*, notably as regards elaboration and implementation of national wetland policies, and the *Additional Guidance on wise use*.

ix. to make environmental impact assessments before transformations of wetlands.

x. to establish nature reserves on wetlands and provide adequately for their wardening.

xi. to increase waterfowl populations through management of appropriate wetlands.

xii. to make national wetland inventories which will identify major sites for wetland biodiversity.

xiii. to train personnel competent in wetland research, management and wardening.

The Parties in 1999 and refined in 2002 is “the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world.

4. Origin of Wetland:

Origin of floodplain wetlands is due to the lithololgy, geological structure, tectonic status and seasonal variation in river discharge and flow characteristics; largely determine the formation of the floodplain wetlands. The beels of the country owe their origin either to the often changing course of rivers in the potamonic stretches or low tectonic adjustment.

5. Wetland Ecology:

5.i. Trophic state of a wetland

Trophic state describes the overall productivity (amount of plants or algae) of a wetland, which has implications for the biological, chemical and physical conditions of the wetland. The trophic state of a wetland is directly tied to the overall algal productivity in the wetland and ranges from very unproductive to highly productive. Factors that increase algal productivity also increase the trophic state of the wetland. Phosphorus is also considered a direct measure of a wetland trophic state. Transparency is the most widely measured characteristic to determine trophic state of a wetland. Trophic state can also be measured with a Secchi disk because most turbidity in wetlands is caused by suspended algae. Secchi disk depth is a measure of wetland trophic state. Trophic State Index (TSI) is based on chlorophyll, phosphorus and Secchi disk depth. Four terms are commonly used to describe wetland trophic state.

5.ii. Oligotrophic:

The wetlands are unproductive with low nutrients (phosphorus <15 μg/L) and low algal productivity (chlorophyll < 3 μ/L). Transparency is greater than 13 feet. Oligotrophic wetlands with few nutrients and little plant production have small pyramids.

5.iii. Mesotrophic:

Here the wetlands are moderately productive, with intermediate levels of chlorophyll, nutrients, and water clarity. It supports abundant populations of rooted aquatic plants.

5.iv. Eutrophic:

The wetlands are highly productive, with high levels of phosphorus and chlorophyll. Water clarity is low and generally ranges from 3 to 8 feet as measured by the Secchi disk method. Eutrophic wetlands with much higher nutrient concentrations, more total plant growth (algae and rooted plants plants) and more fish have larger pyramids.

5.v. Hypereutrophic:

These wetlands have very high phosphorus and chlorophyll levels and water clarity is usually less than 3 feet.

Table no.1

Trophic state of wetland

Trophic State	Chlorophyll concn.(µg/L)	Total phosphorous concn.	Water clarity (Secchi Disk, in ft)	Trophic State Index	Description
Oligotrophic wetland	< 3	<15	>13	<30	Very low productivity. Clear water. Well oxygenated few plants and animals.
Mesotrophic wetland	3-7	15-25	8-13	40-50	Low to medium productivity. Moderately clear water. Abundant plant growth.
Eutrophic wetland	7-40	25-100	3-8	50-60	Medium to high productivity. Fair water clarity. Dense plant growth.
Hypereutrophic wetland	>40	>100	<3	>70	Very high productivity. Poor water clarity. Limited submersed plant growth. Algae dominate.

6. Wetland Water:

Water is the most precious gift of God to all organisms living in the world. So water must be discussed here. Wetland has basically three parts such as soil, aquatic organisms and the unavoidable part, water. Life on earth is not possible without water. Although majority of our planet water is covered 70% of the earth surface area, only a very small proportion is associated with the continental areas on which human beings are primarily confined. The freshwater associated with continents, about over 99%, is in the form of ground water or ice which is difficult to use. Water is covered by 70% of the earth surface. In terms of total volume of water around 97% of the world's water is in sea and saline. This means that less than 3% of the water volume in the world is fresh water. However, not all of this is readily available for use and less than 1% of it is used for drinking. The availability of fresh water to mankind is only just 0.3 to 0.5% of the total water available on the earth and therefore its careful use is very important. In today's scenario of unplanned urbanization, rapid industrialization and indiscriminate use of artificial chemicals is a cause of heavy and varied pollution in aquatic environments which lead to deterioration of water quality and depletion of aquatic flora and fauna. Without the knowledge of water chemistry, it is difficult to understand the biological phenomenon fully, because the chemistry of water reveals much about metabolism of the ecosystem and explains the general hydro biological interrelationships.

The most prevalent water quality problem is eutrophication, a result of high-nutrient loads (mainly phosphorus and nitrogen), which substantially impairs beneficial uses of water. Lakes and reservoirs are particularly susceptible to the negative impacts of eutrophication because of their complex dynamics, relatively longer water residence times and their role as an integrating sink for pollutants from their drainage basins. Nitrogen concentrations exceeding 5 milligrams per liter of water often indicate pollution. Declining water quality has become a global issue today. Major alterations to the hydrological cycle is taking place due to human populations grow, industrial and agricultural activities expand and climate change. Water quality is determined by comparing the physical and chemical characteristics of a water sample with water quality guidelines or standards. By the atmospheric processes of evapotranspiration and the deposition of dust and salt by wind, and the natural leaching of organic matter and nutrients from soil, by hydrological factors that lead to runoff and by biological processes within the aquatic environment water can be disturbed. The freshwater environments include streams and lakes, as well as wetlands such as peat lands or bogs, marshes and swamps. Aquatic features such as lakes and wetlands depend upon climatic conditions, geological events or biological actions to develop and maintain bodies of water. Human interactions with water often involve fresh streams, rivers, marshes, lakes and shallow ground waters. It is true for all organisms that our very existence depends on this water; we need an abundance of fresh water to live. Freshwater ecology emphasizes mainly the study of relationship between organisms and the freshwater environment. Study of all aspects that is physical, chemical, geological and biological of freshwater is termed as limnology**;** Wetzel (1983) defined limnology as "study of the functional relationship of fresh water biotic environmental factors." Freshwater habitats are two general types: standing or lentic water such as pond, lake, bog, beels etc. and running or lotic water such as river, stream, spring etc.

Water is by far the most general universal solvent for living beings as well as for other substances. No other liquid dissolves so many common substances. All chemical reactions occur in the solution form. Physico-chemical parameters are highly important factors with regard to the occurrence and abundance of organic species in water. Good quality of water is essential for living organisms. The quality of water can be estimated by examine its physical and chemical characteristics as well as by plankton growing in it. The influence of limnological parameters as one of the functional environmental factors for species occurrence has received great attention (Moyle 1945, Hutchinson 1975, Catling *et al*.1986).The increasing population of human influences in recent years in and around aquatic systems and their catchment areas and have contributed to a large extent to decline of water quality and decreasing of water bodies leading to their accelerated eutrophication**.** Discharge of metropolitan, agriculture and industrial wastes have accelerated the quantum of various chemicals which enter the receiving water, which noticeably change their physico-chemical characteristics.

Changes in the water quality affect the biotic community of the aquatic ecosystem which finally reduces the primary productivity. Limnological studies provide a basic understanding of water nature and generally help to monitor the aquatic environment. These include the observations of diurnal, monthly and seasonal variations in both the biotic and abiotic components of the freshwater ecosystems and finding out the possible relationship among them. Physico-chemical parameters are highly important with regard to the occurrence and abundance of species in water.

Temperature, turbidity, dissolved oxygen (DO), BOD, biogenic salts, chiefly nitrates, phosphates; pH, electrical conductivity, phosphorous, nitrogen etc play a vital role in water. Many studies have correlated the distribution of different aquatic macrophytes with water chemistry in lakes (Moyle 1945, Hutchinson 1975, Catling *et al*.1986).and running waters **(**Whitton 1979, Schneider and Meizer 2003). Several limnological parameters were found to be responsible for the distribution pattern of hydrophytes such as pH (Palmer *et al* 1992), alkalinity (Vestergaard & Sand- Jensen, 2000), conductivity (M*ä*kel*ä et al.* 2004) and nutrients (Heegard *et al*. 2001).

Studies on fresh water bodies like ponds, lakes, rivers and streams have gained greatly importance in recent years. The first use of the term 'Plankton' is attributed to the German marine biologist Victor Hensen, who in the latter half of the 19 th century began a series of expeditions to investigate the distribution, abundance and composition of microscopic organisms in the sea, According to Hensen's terminology, plankton (singular-plankter) included all organic particles that float freely and involuntarily in the open water, free of shores and bottom. Plankton is an important component of fresh water food web. Plankton communities are highly sensitive to environmental changes. As a result, changes in their density and species diversity can give important indications of environmental changes. The planktonic study is a very useful means for the measurement of water quality in any type of water body and also contributes to considerate of the basic nature and general economy of the lake. Some of the important factors that influence the wetland ecosystem are depth, nature of catchment area or river basin, precipitation and duration of connection to river etc. The main morph metric features that influence the productivity of wetland ecosystem are shoreline area, depth and slope. The wetland ecosystem is extraordinarily complex with wide temporal and spatial variations of many key parameters. Some of the important factors that influence the wetland ecosystem are depth, nature of catchment area or river basin, precipitation and duration of connection to river etc. Ecosystem processes in a wetland is determined by the hydrodynamics of wetlands. Water flow plays a vital role in nutrient dynamics and aquatic productivity through transport of nutrients to the organisms and removal of waste. Temperature affects all life processes including growth rate, lifecycle and overall productivity of the entire system, is a key physical variable.

7. Wetland Classification in the world:

7. i. Wetlands are classified by different environmentalists in different times. One of the first widely used classifications systems, devised by Cowardin *et al*, (1979) is

i. marine (coastal wetlands including coastal lagoons, rocky shores and coral reefs);
ii. estuarine (including deltas, tidal marshes, and mangrove swamps);
iii. lacustrine (wetlands associated with lakes);
iv. riverine (wetlands along rivers and streams); and
v. palustrine (meaning "marshy" – marshes, swamps and bogs).

Along with intertidal marine and estuarine ecosystems, fresh water wetlands are also classified as 'pulse-stabilized' fluctuating water level ecosystems (Odum, 1983).

7. ii. There are three types of wetlands according to Odum's classification.

i. Riverine wetlands – it includes area located at the vicinity of rivers, on flood plains or low-lying depressions near rivers. Run-off, seepage, flooding from the river is the cause of creation of this type of wetlands.
ii. Lacustrine wetlands- it includes lakes or ponds associated wetlands. Runoff water that overflows from the parent body may create these wetlands.
iii. Palustrine wetlands- it includes marsh lands, bogs, fens, temporary ponds etc. they originate from the filled up ponds, lakes basins or even in old and extinct river beds.

7. iii. The National Wetlands Atlas, 2010 classified the wetlands into following types:

1. Inland wetlands.

a) Natural: 1. Lakes,
2. Ox-bow lakes- cut-off meanders,
3. High altitude wetlands,
4. Riverine wetlands,
5. Water logged and 6. River-stream

b) Man-made: 1. Reservoirs/barrages, 2. Tanks/ponds,
3. Waterlogged and 4. Salt pans

***2. Coastal Wetlands*:**

a) Natural: i. Lagoons, ii. Creeks, iii. Sand/ Beach,

iv. Intertidal mud flats, v. Salt marsh,

vi. Mangroves and vii. Coral Reef

b) Man-made: i. Salt pants, ii. Aquaculture ponds

The Ramsar Convention has adopted a Ramsar Classification of Wetland Type which includes 42 types, grouped into three categories:

1. Marine and Coastal Wetlands,
2. Inland Wetlands, and
3. Human-made Wetlands.

8. Benefits of Wetlands:

Wetlands are one of the most productive ecosystems and play crucial role in hydrological cycle. Utility wise, wetlands directly and indirectly support millions of people in providing services such as storm and flood control, clean water supply, food, fiber and raw materials, scenic beauty, educational and recreational benefits. The Millennium Ecosystem Assessment estimates conservatively that wetlands cover 7% of the earth's surface and deliver 45% of the world's natural productivity and ecosystem services. However, the very existence of these unique resources is under threat due to developmental activities, and population pressure and ecosystem services of which the benefits are estimated at $20 trillion a year (Source: www.MAweb.org). The Millennium Assessment (MA) uses the following typology to wetlands has great significance for more than one reason; most notably because they charge categorize ecosystem services. Wetlands offer several substantive benefits. Some of the most obvious advantages are listed here.

It gives life support systems, winter resorts for a variety of birds for shelter and feeding, suitable habitats for fish and other flora and fauna, effective in flood control, waste water treatment, reducing sediment loads and recharging of aquifers, valuable for their educational and scientific interest (especially their high diversity or species richness), recreational benefits (swimming, diving, and tourism), wetland act as aquifers, conserve moisture, act as pollution filters, and are habitat for biodiversity. They help in water storage and purification, flood control, ground water replenishment, are nurseries for freshwater and marine fish, provide shoreline stabilization and protection against nutrient and sediment retention, harbor and support biological diversity, effects of climate change and pollution and are resources for recreation and tourism, transport and other services. Wetlands conservation has to be taken up as a crusade at district, state, national, regional, and global levels for the welfare of present and future generations. Wetlands exhibit enormous diversity according to their genesis, geographical location, water regime and chemistry, dominant plants and soil or sediment characteristics. Due to their transitional nature, the boundaries of wetlands are often difficult to define. Wetlands share a few attributes common to all forms. Of these, hydrological structure (the dynamics of water supply, throughput, storage and loss) is most fundamental to the nature of a Wetland system.

Regional wetlands are integral parts of larger landscapes; each wetland thus is ecologically unique. Wetlands perform numerous valuable functions such as recycle nutrients, purify water, attenuate floods, maintain stream flow, recharge ground water, and also serve in providing drinking water, fish, fodder, fuel, wildlife habitat, control rate of runoff in urban area, buffer shorelines against erosion and recreation to the society.

Wetland plays a significant role in regional ecosystem, such as the regulation of climate, cleansing of environment and balancing of regional water. Eutrophication can lead to deoxygenation. The extent of the world's wetlands is generally thought to be from 7 to 9 million sq km, or about 4 to 6 percent of the land surface of the Earth (Mitsch and Gosselink 2000). In India the total area under wetlands was estimated to be 11.69 Mha (Patel *et al*. 2009). This accounts for 3.66 per cent of geographic area of the country. Wetlands act as important repositories of aquatic biodiversity (Prasad *et al*. 2002). It has also been estimated that 20 % of the known range of biodiversity in India is supported by freshwater wetlands (Deepa and Ramachandra 1999).

Hydrologic conditions can directly modify or change chemical and physical properties such as nutrient availability, degree of substrate anoxia, soil salinity, sediment properties and pH. These modifications of the physiochemical environment, in turn, have a direct impact on the biotic response in the wetland (Gosselink & Turner, 1978). When hydrologic conditions in wetlands change even slightly, the biota may respond with massive changes in species composition and richness and in ecosystem productivity. Traditional limnological methods of assessment of water quality are time consuming and uneconomical, but using remote-sensing data assessment of water quality and productivity in surface impoundment is both cost effective and fast.

Wetlands are amongst the most productive ecosystems on the Earth (Ghermandi et al., 2008), and provide many important services to human society (P. ten Brink et al., 2012). However, they are also ecologically sensitive and adaptive systems (Turner et al., 2000). Wetlands exhibit enormous diversity according to their genesis, geographical location, water regime and chemistry, dominant species, and soil and sediment characteristics (Space Applications Centre, 2011). Globally, the areal extent of wetland ecosystems ranges from 917 million hectares (m ha) (Lehner and Döll, 2004) to more than 1275 m ha (Finlayson and Spiers, 1999) with an estimated economic value of about US$15 trillion a year (MEA, 2005)

9. Threat to wetlands:

The interaction of man with wetlands during the last few decades has been of concern largely due to the rapid population growth accompanied by intensified industrial, commercial and residential development further leading to pollution of wetlands by domestic, industrial sewage and agricultural run-offs as fertilizers, insecticides and feedlot wastes. The fact that wetland values are overlooked has resulted in threat to the source of these benefits.

Despite benefits, wetlands are the first target of human interference and are among the most threatened of all natural resources. Around 50% of the earth's wetland area is estimated to already have disappeared over the last hundred years through conversion to industrial, agricultural and residential developments. Threats to wetland ecosystems comprise the increasing of biotic and abiotic pressures and perils. Biotic uncontrolled siltation and weed infestation, uncontrolled discharge of waste water, industrial effluents, surface run-off, etc. resulting in proliferation of aquatic weeds, which adversely affect the flora and fauna. Tree felling for fuel wood and wood products causes soil loss affecting rainfall pattern, loss of various aquatic species due to water-level fluctuation. Habitat destruction leading to loss of fish and decrease in number of migratory birds.. Encroachment results in shrinkage of area. Anthropogenic pressures resulting in habitat destruction and loss of biodiversity is uncontrolled resulting in succession changes. Hydrological intervention results in loss of aquifers.

10. Aquatic biodiversity in wetlands:

The total numbers of aquatic plant species exceeds 1200 hundred and a partial list of animals for aquatic and wetland system is given by Gopal,1995. Aquatic biodiversity is dependent on hydrologic regime; geological conditions and efforts are being made to conserve the biodiversity found in the wetlands, streams, and rivers. The goal of this irreplaceable biodiversity is to minimize its loss through sustainable management and conservation practices. The first step in conservation of biodiversity is to assess the diversity of natural resources present and identify those, which are important and most irreplaceable (Groombridge & Jenkin, 1998). Awareness of the unique nature of biodiversity, the plethora of factors contributing to decline in habitat quality and species population s has been growing in the past decade. From the ecological point of view, the diversity of species presents in the wetlands us an indication of the relative importance of the aquatic biodiversity issue as a whole. At present wetland loss is a threat to ecological balance.

11. Role of aquatic macrophytes and Phytoremediation:

Aquatic plants are adapted to living in or on aquatic environments. The high density of water makes aquatic organisms more buoyant, so aquatic plants invest less resources in support of tissues than terrestrial plants. Submerged plants lack the structural and protective structures produced by terrestrial plants. They are not restricted to one particular area. They constitute the primary producers of aquatic ecosystems. They convert incident radiant energy of the sun to chemical energy in the presence of nutrients like phosphorous, nitrogen, iron, manganese, molybdenum and zinc. The productivity of any water body is determined by the amount of plankton it contains as they are the major primary and secondary producers (Davies *et al.,* 2009). Townsend *et al,.* (2000) and Conde *et al,.* (2007) reported that plankton communities serve as bases for food chain. The distributions, abundance, species diversity, species composition of the phytoplankton are used to assess the biological integrity of the water body (Townsend *et al.,* 2000). Phytoplankton also reflects the nutrient status of the ecosystem. They do not have control over their movements thus they cannot escape pollution in the environment. The distribution, abundance and diversity reflect the physico-chemical conditions of aquatic ecosystem in general and its nutrient statue in particular, (Anene, 2003). Phytoplankton includes several groups of algae (e.g., green algae, golden brown algae, euglenophytes, dinoflagelates and diatoms) and one group of photosynthetic bacteria (Cyanobacteria). Planktonic algae may be either benthic (attached to a substrate) or planktonic (floating in the water column).

Phytoplanktons are of great importance in biomonitoring of pollution (Davies *et al.,* 2009). Phytoplankton also reflects the nutrient status of the water environment. Barnes (1980) reported that pollution affects the distribution, standing crop and chlorophyll concentration of phytoplankton.

The phytoremediation of metals is a cost-effective, efficient, environment and eco-friendly ‘green’ technology based on the use of metal accumulating plants to remove toxic metals, including radionuclides as well as organic pollutants from contaminated soils and water (Raskin *et al.,* 1997; Ali *et al.,* 2013). Phytoremediation is also called as botanical bioremediation (Chaney *et al.,* 1997). Green Plants are used to decontaminate soils, water and air. Phytoremediation is an emerging technology that is applied to separate both organic and inorganic pollutants present in the soil, water or air (Salt *et al.,* 1998). Phytoremediation is considered as a new and highly promising technology for the reclamation of polluted sites and cheaper than physicochemical approaches (Garbisu and Alkorta, 2001; McGrath *et al.,* 2001; Raskin *et al.,* 1997). The ability to accumulate heavy metals varies species to species and among cultivars within species, as different mechanisms of ion uptake is operative in each species, based on their genetic, morphological, physiological and anatomical characteristics. Plants play a vital role in metal removal through absorption, cation exchange, filtration, and chemical changes through the root. Numerous plant species have been identified and tested for their traits in the uptake and accumulation of different heavy metals.

The most important factor affecting the rate of metal removal in phytoremediation is plant selection to be used as accumulator. Lasat (2000) has described some considerations for the selection of remediating plants. The plant biomass, the metal removal rate depends on the plant biomass harvested and metal concentration in harvested biomass. The most common and important heavy metals as contaminant in the environment are As, Sr, Cs, U, Cd, Cr, Cu, Hg, Pb and Zn (Raskin *et al.,* 1997; Lasat, M. M., 2000). Some of these metals are micronutrients necessary for plant growth and development, such as Zn, Cu, Mn, Ni, and Co, while others have unknown biological function, such as Cd, Pb, and Hg (Gaur *et al.,* 2004).

12. Wetlands in India:

In India wetlands account for 4.7% of the total geographical area of the country(Bassi, 2014). India's freshwater resources comprise the single most important class of natural endowments enabling its economy and its human settlement patterns. The fresh water resources comprise the river systems, groundwater and wetlands. Each of these has a unique role, and characteristic linkages to other environmental entities. Wetlands, natural and manmade, freshwater or brackish, provide numerous ecological services. They provide habitat to aquatic flora and fauna, as well as numerous species of birds, including migratory species'- A holistic view of wetlands is necessary which looks at each identified wetlands in terms of its causal linkages with other natural entities, human needs, and its own attributes. (*National Environment Policy, 2006)*

Wetlands, variously estimated to be occupying 1-5 % of geographical area of India, support about a 5th of the known biodiversity. Like any other place in the world, there is a looming threat to the aquatic biodiversity of the Indian wetlands as they are often under a regime of unsustainable human pressures. Sustainable management of these assets is highly relevant.

Estimated area of wetlands in India (Million ha) Table no.2

Paddy cultivation area	40,90 Million ha
Fish culture area	3.60 Million ha
Area under capture fisheries (blackish and freshwater)	2.90 Million ha
Mangroves area	0.40 Million ha
Estuaries area	3.90 Million ha
Backwater area	3,50 Million ha
Man made impoundments	3.00 Million ha
Rivers including main tributaries	28,000 Km
Canals and irrigation channels	113,000 Km
Total area of a Wetlands (Excluding Rivers)	58,2 Million ha

(Source: Directory of Asian Wetlands, IUCN, 1989)

India is a signatory to the Ramsar Convention for management of wetland, for conserving their biodiversity and wise use extending its scope to a wide variety of habitats, including rivers and lakes, coastal lagoons, mangroves, peat-lands, coral reefs, and numerous human-made wetland, The Ministry of Environment and Forests has identified a number of wetlands for conservation and management under the National Wetland Conservation Programme.

13. Wetland classification in India:

Wetlands are classified into different types based on their origin, vegetation, nutrient status, and thermal characteristics, like

i. Glaciatic Wetlands (e.g.,Tsomoriri in Jammu and Kashmir, Chandertal in Himachal Pradesh),

ii. Tectonic Wetlands (e.g., Nilnag in Jammu and Kashmir, Khajjiar in Himachal Pradesh, and Nainital and Bhimtal in Uttaranchal).

iii. Oxbow Wetlands (e.g., Dal Lake, Wular Lake in Jammu and Kashmir and Loktak Lake in Manipur and some of the wetlands in the river plains of Brahmaputra and Indo-Gangetic region. Deepor Beel in Assam, Kabar in Bihar, Surahtal in Uttar Pradesh),

iv. Lagoons (e.g., Chilika in Orissa)

v. Crater Wetlands (Lonar lake in Maharashtra)

vi. Salt water Wetlands (e.g., Pangong Tso in Jammu and Kashmir and Sambhar in Rajasthan)

vii. Urban Wetlands (e.g., Dal Lake in Jammu and Kashmir, Nainital in Uttaranchal and Bhoj in Madhya Pradesh),

viii. Ponds/Tanks, man-made Wetlands (e.g., Harike in Punjab and Pong Dam in Himachal Pradesh),

ix. Reservoirs (e.g., Idukki, Hirakud dam, Bhakra-Nangal dam),

x. Mangroves (e.g., Bhitarkanika in Orissa),

xi. Coral reefs (e.g., Lakshadweep)

xii. Creeks (Thane Creek in Maharashtra), seagrasses, estuaries, thermal springs are some kinds of wetlands in the country.

14. Wetlands in Assam:

In Assam, floodplain wetlands are known as Beels. The Brahmaputra valley with its in -numerable fresh water lakes (called Beel), ox-bow lakes (era suti), marshy tracts and seasonally flooded plains and hundreds of riverine sandbars and islands is, still, an ideal wetland eco-system which contains specialized wetland animals like water dolphin, dugong and the one-horned rhino and reptiles like the crocodile, the winter monitor lizard and few species of turtles along with different rare water plants These species are either extinct or highly endangered at present.

The GIS studies the layers of wetland boundary, water-spread, aquatic vegetation and turbidity for wetland categorization. They mapped around 5097 wetlands by using 1, 50,000 scales in Assam. The study identified 6081 small wetlands of size less than 2.25 ha. Almost 9.74% of wetlands in Assam is identified by this GIS study team. 84% of the wetland is covered by river or stream. District-wise geographical distribution of wetlands is remarkable in Assam (source*: ENVIS Centre: Assam.).*

Table- 3

Wetland area coverage in five districts of Assam (in descending order):

Name of District	Total Geographical Area (sq km)	Total Wetland Area covered (ha)	Total % of Wetland Area	Total % of District-wise Geographical Area
Sonitpur	5324	83427 ha	10.91	15.67
Dibrugarh	3381	72461 ha	9.48%	21.43
Barpeta	3245	59038	7.72	18.19
Dhubri	2838	56538	7.40	19.92
Darrang	3481	48983	6.41	14.07

(Source: National Wetland Atlas, Ministry of Envt and Forests, Govt of India and ENVIS Centre: Assam)

15. The various types of wetlands found in Assam are as follow:

15.i. Lakes / Ponds/ Beel:

There are 690 lakes and ponds recorded in Assam, These lakes /ponds cover an area of 15494.00 ha (approx) which constitutes 0.20 percent of the total geographical area of the state and 15.30 % of the total area under wetlands. The smallest of them measures 2.50 ha while the largest one has 882.50 ha of areal coverage. Majority of this type of wetlands have water with low turbidity. Assam Remote Sensing Application Centre shows district wise distribution of 3513 numbers of wetlands in Assam.

15.ii. Lakes and Meanders:

A total 861 number of ox-bow lakes/cut-off meanders are observed throughout the state of Assam, covering an area of 15460.60 ha which is 0.20 % of the total geographical area of the state and 15.27 percent of the total area under wetlands. The smallest one is 5.0 ha while the largest one is 582.50 ha found in aerial coverage. Waterlogged areas numbering 1125 are observed which are unevenly distributed covering an area of 23431.50 ha which is 0.30 % of the total geographical area of the state and 23.15 % of the total area under wetlands. The smallest is 2.5 ha and the largest one is 3010.00 ha in aerial coverage. These water-logged areas play a vital role in the economy of Assam due to their presence in the rural areas which contain a good number of aquatic flora and fauna. They have potentiality in supplying of irrigation water to the agricultural fields during dry time.

15.iii. Swamps or Marshy Lands:

The swampy/marshy wetlands in Assam are identical on satellite image as reddish spots which indicate vegetations and dark blue spots signifies the presence in the low lying area. The water, of swampy/marshy area is moderate to highly turbid. 712 numbers of swampy/marshy areas have been identified from satellite data which covers 43433.50 ha indicating 0.55 % of the total geographical area of the state and 42.91 % of the total area under wetlands.

15.iv. Reservoirs:

Reservoirs are manmade water bodies used for irrigation, flood control, municipal water supplies hydro-electric power generation etc. It covers 2662.5 ha area which represents 0.03 % of the total geographical area of the state and 2.63% remains as wetlands. Water type of these wetlands is of low turbidity. Tanks and Ponds of small sized tanks are made by people in Assam for fish and household works.

16. Wetland flora of Assam:

Assam has more fresh water wetlands than any other states in the North Eastern states of India union. The two major drainage systems of Assam are the mighty Brahmaputra and the Barak, have the flood plains attached with patches of marshy depressions and swamps as well as perennial water bodies of varying shape, size and depth. These are locally named as beel, haor, jalah, doloni, hola pitoni etc. Many ancient Rulers of Assam dug tanks such as Joysagar, Sibasagar, Dighalipukhuri, Jorpukhuri, Hazarapukhuri etc. in Assam. It is found that there are an estimation of 3531 numbers of beels and haors, 18562 numbers of ponds and tanks in Assam. Deepor Beel, near Guwahati is the only Ramsar site in Assam. There are other important wetlands such as chandubi, Rata, Sohola, Taralipathar, Fokolai, Mer.Sunbil, Jamjing, Sagunpara, Motapung, Sarlane, Sareswar, Roumari, Khalihamari,Sapekhati, Dhir etc.

A macrophyte is an aquatic plant that grows in or near water and is emergent, sub mergent, or floating. It grows in marshy land, partly submerged in water so that it re grows from buds, rhizomes, corms etc. below the water surface. In lakes and rivers macrophytes provide cover for fish and acts as substrate for aquatic invertebrates, producing oxygen, and act as food for fish and aquatic life. The macrophyte species of Assam have diverse habits and characters. More than 100 species of aquatic macrophyte have been described by researchers and classified into broad categories such as

i. Free floating hydrophyte- *Azolla pinnata, Eichhornia crassipes, Lemna minor, Pistia sp, Salvinia sp etc.*
ii. Submerged (Suspended) hydrophyte- *Ceratophyllum demersum, Utricularia gibba etc.*
iii. Submerged (Anchored) hydrophyte- *Hydrilla sp, Potomogeton sp,Vallisnaria sp. Nechamandra sp.etc.*
iv. Anchored with free floating leaved Hydrophytes- *Euryale ferox, Nelumbo nucifera, Nymphaea nouchali, Nymphoides sp, Trapa bispinosa etc.*
v. Emergent hydrophytes- *Ipomoea aquatic, Polygonum flaccidum Cyperus sp, Sagittaria trifolia etc*.

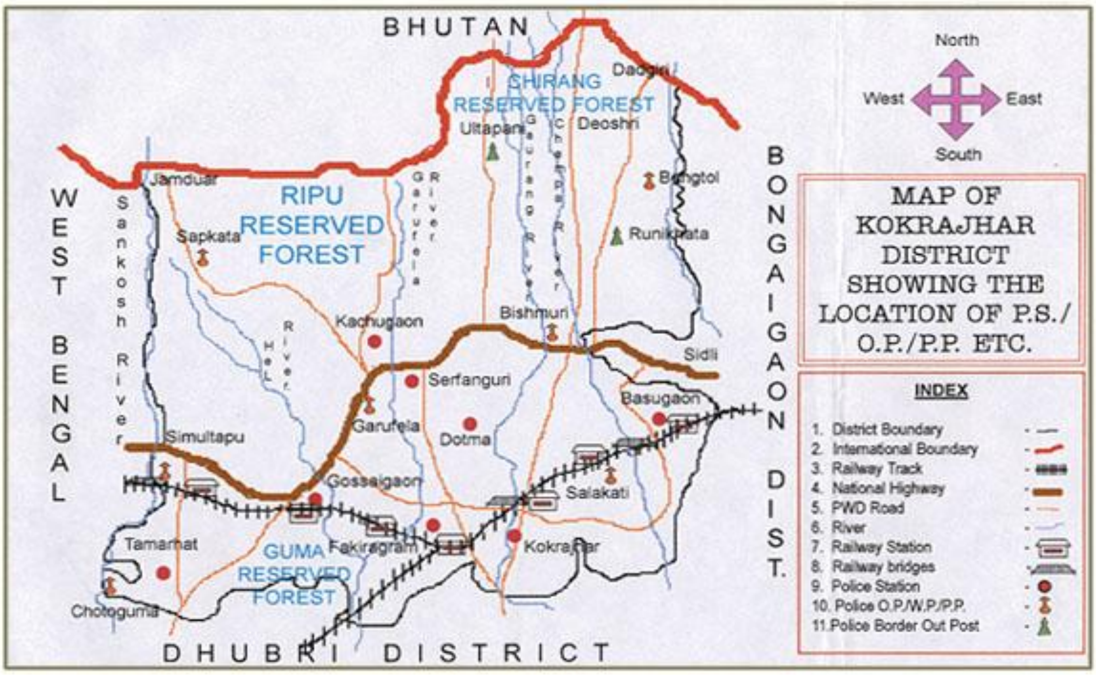
17. Brief profile of Kokrajhar District:

Kokrajhar was originally a part of undivided Goalpara district of Assam. In 1957 new Civil Sub- Division was created after carving out the Northern part of Dhubri Sub-Division and some part of Goalpara Sub-Division. This new sub- division was called Kokrajhar Sub-Division This area was consisted of five tracts of the Eastern Doors such as Bijni, Sidli, Chirang, Ripu and Guma with a total area of 3,129 square kilometres (1,208 sq m). In the 1st July, 1983 this sub- division is upgraded into a district called Kokrajhar District with headquarter at Kokrajhar Town.

Kokrajhar district can be described as the Gateway to the North Eastern region of India. Both road and rail touch this district at Srirampur before they enter into other districts in Assam and to other North-Eastern states. The district has a total area of 3,169.22 sq. Km. It is located on the North bank of the river Brahmaputra. The district lies in between 89.46' E to 90.38' E longitudes and 26.19" N to 26.54" N latitudes. The district is bounded in the North by the Himalayan Kingdom of Bhutan, Dhubri district in the South, Bongaigaon district in the East and West Bengal in the West. Kokrajhar is also the head quarter of Bodoland Autonomous Districts Council (BTAD) created in 2003.

There are two civil sub-divisions in Kokrajhar district. They are Kokrajhar and Gossaigaon. The district has eleven Developmental Blocks such as 1) Kokrajhar (Titaguri), 2) Dotma, 3) Kachugaon, 4) Gossaigaon, 5) Hatidhura, 6) Bilasipara (Part), 7) Chapar-Salkocha (Part), 8) Rupshi (Part), 9) Mahamaya (Part), 10) Golokganj (Part), and 11) Debitola (Part). According to the 2011 census Kokrajhar district has a population of 886,999 with Male: 4, 52,965 and Female: 4, 34,034. The district has a population density of 280 inhabitants per sq km. Its population growth rate over the decade 2001-2011 was 5.19%. Kokrajhar has a sex ratio of 958 females for every 1000 males and the literacy rate of 66.63%. The district is multi ethnic. *(Source; www.india.gov.in)*

Fig no. 1



Map of Kokrajhar District, Assam

There are some major beels other than Diplai Beel in the Kokrajhar district such as Sareswar Beel, Silainalia Beel, Bhelakuba Beel, Dhir beel etc. along with many small beels. Wetlands are distributed more in number in Kokrajhar sub-division thanGossaigaon sub-division.

Demography:

Soil is sandy loam to clay loam in structure and acidic. It is located on the North bank of the river Brahmaputra. Physiography of the district is almost flat alluvial land. The district is demographically dominated by tribal and non-tribal communities namely Bodo, Koch-Rajbangshi, Santhal, Rava, Garo, Yogi, Bangali. Muslims, Nepali, adivashi etc.

Climate:

The climate is sub tropical humid to wet humid during summer and cold with foggy condition during winter. Both South-West and North-East monsoon bring rain to this region.

Physiography:

The rocks found in the district are sedimentary. In the southern most part of the distric,t there are two small hills which are composed of metamorphic rocks.

Drainage:

The district is characterized by almost plain topography with a gentle slope from North to South. The district is endowed with river Brahmaputra and the tributaries Sankosh, Gaurang, Hel, Champamoti, Tipkai etc. which flow down from North to South, from the Bhutan hills to reach the mighty Brahmaputra. Rain water flows down from the hill tracts of Bhutan and along the foothills and reserve forests of the district.

Forest:

Forest is most prominent features of Kokrajhar district. The present area under reserved forests is 1,719sq. km that includes parts of Aie Valley Forest Division of Bongaigaon district and Guma Range of Dhubri Forest Division. There are two forest divisions under Kokrajhar district are Haltugaon and Kachugaon. About 55% of the total geographical area of the district is under reserved forest. Kokrajhar district covers forest area about 1364 sq.km which is 43.04 per cent of the total geographic area of Assam. Dense Forest is 1203 sq. km. and Open Forest is 161sq.km. According to Forest Department's report the present position of Reserved Forest is 1719.43 sq. km. and others 45.17 sq.km respectively. *(State Forest Report, 2001 under Forest Survey of India. Govt.of India).*

18. Wetland Types in Kokrajhar District

Table no. 4

Wetland type - *Inland wetlands*	No. of wetlands	Total wetland area (ha)	% of wetland area (ha)	Open water	
				Post monsoon area in ha	**Pre monsoon area in ha**
Natural Wetlands					
Lakes/Ponds/Beels	37	457	1.84	243	145
Oxbowlakes/Cut off meanders	76	1160	4.67	679	331
Riverine	6	32	0.13	32	6
Waterlogged	57	318	1.28	214	81
River/Stream	105	22681	91.33	22067	22077
Man made Wetlands					
Tanks/ Ponds	1	33	0.13	31	19
Small wetlands <2.25 ha)	152	152	0.61		
Total	**434**	**24833**	**100.00**	**23266**	**22659**

(*Source: Remote Sensing Dept, Govt. of Assam)*

19. Major Fresh water Beels in Kokrajhar District.

Table no. 5

Name of Major Beels in Kokrajhar District	Area in hectare
1. Sareswar beel	478.00
2. Diplai beel	455.75 (3.96 sq. km)
3. Silainalia beel	97.30
4.Bhelakoba beel (22 parts)	< 500.00
5. wetlands (closed/open, 85 parts)	502.00

(*Source: Fishery Dept.,BTAD*)

20. Reasons for choosing this topic of Research:

Fresh water ecosystem provides habitats to plant species, fishes, birds, insects and other animals. Their interactions with physical factors result in a balanced ecosystem with plants providing food and shelter to other organisms that live in and close to the waterof the water body. Macrophytes can be observed by naked eyes and its responds to environmental conditions within a wetland. Macrophytes respond strongly to the environmental conditions within wetland. The tolerance limit of aquatic macrophytes is linked with the chemical and physical qualities of water (Heegaard *et al*, 2001). It is possible to quantify environmental changes by analyzing the plants both chemically and physically. Changes in community composition or the abundance of individual species provide valuable information of how and why an ecosystem might be changing (Scott et al, 2002). Macrophytes are means of indirect monitoring of water qualities. Eutrophication can produce a progressive change in species composition resulting in the eventual loss of species diversity. Eutrophication due to anthropogenic intervention, results in the decline of submerged vegetation and domination of phytoplankton in many lakes (Koner, 2001).

Diplai Beel is a natural freshwater body with rich biodiversity and an echo spot in the Kokrajhar District but in recent times due to direct and indirect anthropogenic activities, its echo environment has been disturbed. Its biodiversity has been affected. It is an overall attempt from this research to ventilate the present status of the Beel to the administrative authority. Time has come to protect its ecology and natural environment along with water qualities, the impacts of eutrophication and human interference before it becomes imbalanced.

20. Period of study: *November, 2014-15 to November, 2016-17*

21. Aim and objectives of the study:

1. To study the seasonal macrophyte Diversity, Density, Abundance and Dominance in the water of Diplai Beel, a natural freshwater body in Kokrajhar District.
2. To study of the seasonal physico-chemical characters of Diplai Beel water and its influence on macrophyte diversity, density, abundance and dominance in the Diplai Beel.
3. To study the phytoremedial status of some macrophytes in the Diplai Beel water.