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Floodplain Wetlands in the Upper Brahmaputra Valley, Assam, India

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ABSTRACT

Floodplain wetlands are very important for ecological and socio-economic services and, in Assam large number of people living in-and-around wetlands, often depends on the wetland ecosystem services for their livelihoods. To understand the ecological condition of floodplain wetlands, in the Upper Brahmaputra valley, Assam, assessment was carried out during the pre-monsoon and post-monsoon from October 2016 to May 2017 in six important wetlands. The paper highlights integrated approach to study the landscape status of the catchment area; physico-chemical characteristics of the water and soil. Over the time period of 2016-17, water and soil samples were collected and analysed from six- selected wetlands; and for the image based analysis of these wetlands have been carried out using Landsat-8 image 2016. The study revealed that, in spite of decreasing size, the Fuklai beel is in better condition among all of the wetlands based on the landscape assessment and the Water Quality Index (WQI) value with 66.6% vegetative coverand 57.3 respectively.

1. Introduction

Since time immemorial all over the world, rivers, lakes,seas and oceans and plants and animals associated with them are important to every culture on earth and form an explicit or implicit part of the religious and cultural heritage of almost all human cultures [1, 2]. Wetlands are estimated to occupy nearly 6.4% of the earth's surface, 30% of which is made up of bogs, 26% fens, 20% swamps, about 15% flood plains, etc. [3]. Wetlands constitute some of the richest and vulnerable ecosystems in the world. They are important for environmental, social -cultural and aesthetic services. Because wetlands are one of the most productive ecosystems, comparable to tropical evergreen forests in the biosphere and play a significant role in the ecological sustainability of a region. They are considered to have unique ecological features which provide numerous products and services to humanity [4]. Ecosystem goods and services provided by the wetlands include: water for irrigation, domestic needs, fisheries; non-timber forest products; water supply; and recreation. Major services include: carbon sequestration, flood control, groundwater recharge, nutrient removal, toxic retention and biodiversity maintenance [5]. Their rich physical and biological resources are exploited for food, water, medicinal plants, fuel wood, materials for buildings and handicrafts [6, 7, 8, and 9]. Since 1900, over half of the world's wetland has been disappeared [10]. According to United Nations Millennium Ecosystem Assessment [11],environmental degradation is more prominent within wetland systems than any other ecosystem on Earth.

India has extensive floodplain wetlands, defined as low-lying areas bordering large rivers which are seasonally inundated by the floodwater from the main river channel [12]. In India, the state Assam has the maximum number and water area under floodplain wetlands mainly associated with the rivers Brahmaputra and Barak. These extensive freshwater wetlands are locally known as *Beels, Jalah, Pitani etc.* According to National Wetland Atlas (2010) [14] report of India, these water bodies occupied an area of 764372 ha that is around 9.74 percent of the geographical area of Assam. In Northeast India, wetlands have rarely been evaluated and understood from the angle of the degree of dependence of people on wetland except that of fishes [13]. However, wetlands are an important source of food security and livelihoods in rural areas of Assam in particulars and developing countries in general, but increasing population growth with increasing human activities in-and-around the wetlands as well as natural phenomena in the Brahmaputra floodplain is degrading the resource attributes and diminishing household incomes and livelihood options. In Assam, traditionally, fishing and fisheries have been important part of lifestyle, particularly millions of rural people who still depend on fisheries and other aquatic resources for food and livelihoods. But continuous anthropogenic developmental works and natural processes have led to degradation of some important wetlands, which could also impact on the wetland dependent community. Thus, the changes in the wetlands catchment area may influence significantly the soils, water, plants and animals of a particular wetland.

1.1 Spatial distribution of wetlands in upper Brahmaputra valley

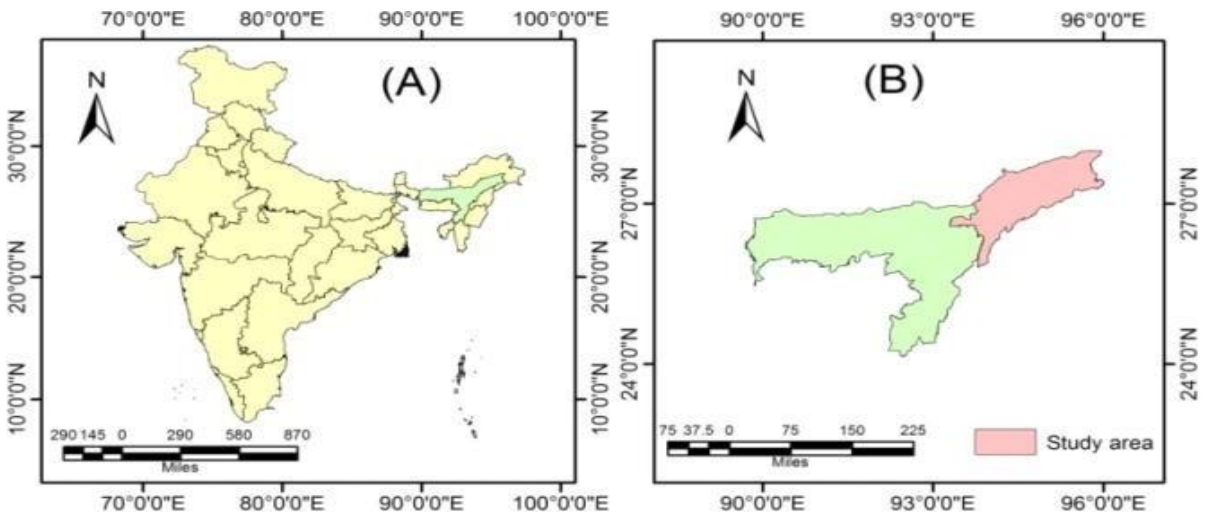
Sl. No.	District	Lake/pond	Ox-bow lake/cut off meander	Riverine wetland	Waterlogged (Natural)	River/ Stream	Tank/pond	Waterlogged (Man-made)	Sub-total	Wetlands <2.25 ha)	Total
		(ha)	(ha	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
1	Dhemaji	776	592	932	1365	29293	23	173	33154	314	33468
2	Dibrugarh	590	1295	146	656	69149	45	45	71926	535	72461
3	Sivasagar	1042	529	113	1330	8698	310	30	12052	530	12582
4	Jorhat	2322	698	417	1124	40977	18	60	45616	363	45979
5	Golaghat	2253	1099	-	1522	38593	3	-	43470	165	43636
6	Lakhimpur	652	1038	134	524	24397	41	63	26849	458	27307
7	Tinsukia	347	1399	1151	1685	35672	63	31	40148	478	40626
Total		**7982**	**6650**	**2893**	**8206**	**246779**	**503**	**402**	**273215**	**2843**	**276059**

Source: National Wetland Atlas: Assam (2010)

Above Table-1 shows that surface water body is spread over an area of 273215 hectares which is occupied 12.58 % of the total geographical area in the upper Brahmaputra valley. Natural surface water body of river/stream occupied the largest area with 246779 ha (90.59 %) of the total surface water area. Another major wetland type is oxbow lake/cut off, which has occupied an area of 6650 hectares (2.5 %). Oxbow lake/cutoff wetland types are important geomorphologic features of the Brahmaputra river and its tributary and these features are created either by the shifting of the river / stream channel or abandonment of the channels.

2. Study Area

The present study was undertaken in the upper reaches of the Brahmaputra River valley in Assam that is one of the provinces located in north-eastern part of India, which is extends between 93o29/ E to 96o02/ E and 25o81/N to 27o97/N and the valley has a total area of 22,957 sq. km. The study area is an important part of Brahmaputra basin that is spread over the countries of Tibet (China), Bhutan, India and Bangladesh has a total area of 5, 80,000 sq. km. In India, it's extend over an area of 1, 94,413 sq.km which is nearly 5.9% of the total geographical area of the country. The upper reach of the Brahmaputra Valley in Assam comprises the districts of Dhemaji, Lakhimpur, Golaghat, Jorhat, Sivasagar, Dibrugarh, and Tinsukia. The prime geographical characters that form the topographical feature of the study area is Brahmaputra River become a braided river after entering Assam, with its extensive unbroken fertile plain, few hillocks. The Brahmaputra valley in Assamisapproximately80to100kmwideandalmost1000km long. A land with high rainfall and fertile plain, upper Brahmaputra valley is endowed with lush greenery, mighty river Brahmaputra, whose tributaries and oxbow lakes provide the region with unique hydro-geomorphic and aesthetic environment. The climate of the study area is sub-tropical and the average annual rainfall over the Brahmaputra valley in upper Assam is around 2300 mm. The characteristics of the wetlands have been presented in the Table2.



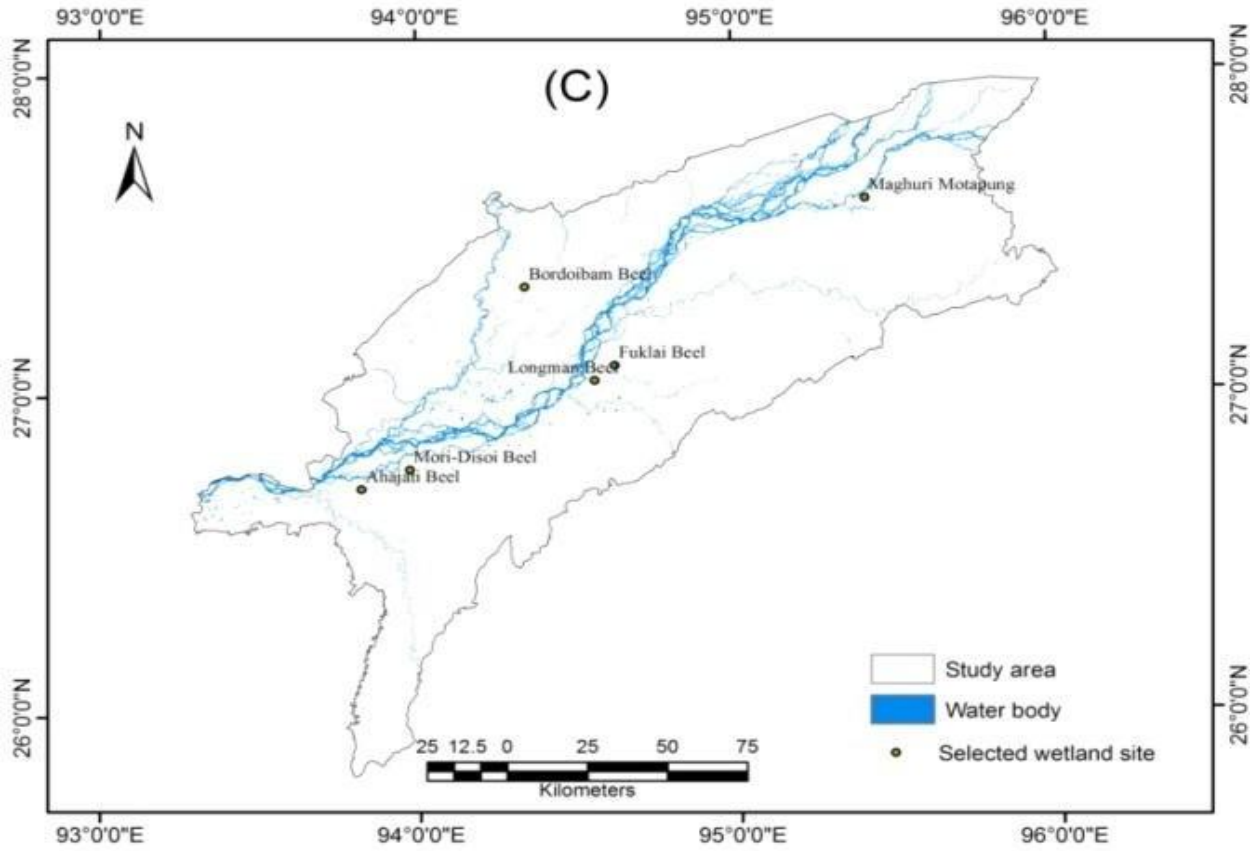


Fig.1: Geographical location of the study area and sampling sites: (A) India, (B) Assam and (C) Upper Brahmaputra valley

Table 2: Description of selected wetlands in the upper Brahmaputra River Valley, Assam (India)

Sl. No.	Wetland name	Wetland Characteristics
1	Maghuri-Motapung Beel	A special characteristic of the beel is the river Dibru, an important tributary of the Brahmaputra River, flows through it.
2	Fuklai Beel	Thelandcoverpatternoftheadjacentareaofthewetlandischaracterizedbyforested,and agricultural land
3	Longman Beel	Thiswetlandischaracterizedbyperennialtypeandfedbytheoverflowofthestreamsandrainwater.Landcoverofthebeelispredominantlyagriculturalpractices,especiallypaddy cultivation.
4	BordoibamBeel	The present day Bordoibambeel is a part of Bordoiam Bird Sanctuary and Subanshiri river whichhadshifteditscourseinthe1950afterdevastatingmegaearthquakeandthiswetland formed.
5	Mora-Disoi	ThiswetlandisformedafterthecutofffromtheDisoiriver.Themajorconcernofthiswetland is effluent from urbanareas.
6	AhazatiBeel	Human encroachment is the major ecological concern of this wetland, especially the alteration for the agricultural practices.

The present study focused on the ecological scenarios of floodplain wetlands and threats to its ecosystem. Six floodplain wetlands i.e. Fuklai, Ahajati, Maghuri, Bordoibam, Longman, Mora-Disoi were selected for sampling. These wetlands were selected for this study because of their significances in ecological, socio-economic values and threats it is currently facing.

3. Material and Methods

3.1. Remote Sensing BasedAnalysis:

$$MNDWI = \frac{(Green-MIR)}{(Green+MIR)}$$

The general approach is to overlay the combined the MNDWI map and Land use/land cover classification maps, center a 1 km buffer area on each sample wetland, and calculate the percentage of forest cover and non-forested cover.

3.2. Landscapeassessments

In this study, Landsat imagery downloaded from USGS Earth Explorer were used to generate and analyses the landscape status of wetlands. Six categories of land use/land cover classes were generated. The classified LULC maps for the buffer area of six-selected wetlands were of year 2016. These LULC classes are mainly categorized as River/Streams, wetland, vegetation, plantation, barren land, and agriculture and built-up. In the landscape assessment, to determine the status of the wetlands GIS based regional level land use, land cover classification had been conducted and 1-km buffers were

created for each selected wetlands. On the basis of percentage of forest cover area available in the buffer area of each wetland have been classified. The achieved overall accuracy was 80.62% and overall Kappa statistics were 0.7246. Based on the percentage of forest cover and non-forested land cover present in the buffer area of the wetlands the condition wetlands are classified in three categories as follows:

Range	Status
0-25	Largely modified and extremely vulnerable to its ecology
25-75	Moderately modified and vulnerable to its ecology
75<	Modified and vulnerable to its ecology

3.3. Physico-chemical Characteristics Data andAnalysis:

Six wetlands of the study area were selected for the water quality analysis.

Water sampling: Water samples were collected from the edge and the core of the wetlands. The samples were collected and analyzed as per standard methods of APHA [16].Parameters used for analyzed the physico-chemical characteristics of water broadly divided into: (1) *Physical parameter:* Temperature, conductivity, Total Dissolved solids (TDS), Turbidity; (2) *Chemical parameters:* pH, Total Hardness, Dissolved Oxygen(D.O),Calcium(Ca),Iron(Fe),Chlorine(Cl).The measurements of water quality index (WQI) has been calculated by using the standards of drinking water quality recommended by the World Health Organization (WHO)[17] and the Bureau of Indian Standards [18]. Following formula has been used to calculate the water quality index for all the wetlands:

$$Qn = \left(\frac{Ci}{Si}\right) X100$$

Where, *Qi* is the quality rating nth water parameter.

Ci is the concentration of the each chemical parameter in the each sampling in mg/l

Si is the standard permissible value of the n^{th} parameter. W = 1/Si Where is the unit weight for the n^{th} parameters

The final WQI results have been calculated using following equation by aggregating the quality rating and the unit weight of the nthparameter.

$$WQI = \sum QnWn / \sum Wn$$

The Water quality index (WQI) level and status of water quality as suggested by Chatterjee and Raziuddin [20] has been presented in Table 3.

Table 3: Criteria for WQI level and status of water quality

Water quality index level	Water quality Status
0-25	Excellent water quality
26-50	Good Water quality
51-75	Poor Water quality
76-100	Very poor water quality
>100	Unsuitable for drinking

The drinking water standards recommended agencies and unit weight for water quality parameters have been presented in following Table4.

Table 4: Drinking water standards recommending Agencies and unit weight

Sl. No	Parameters	Standards	Recommending agency, Bureau of Indian Standards (1992)	Unit Weight for the nth parameter (Wn)
1	pH	6.5-8.5	BIS	0.1176
2	EC dsm-1	300	BIS	0.0033
3	Dissolved oxygen (mg/l)	5	BIS	0.2000
4	Hardness (mg/l)	300	BIS	0.0033
5	Total alkalinity (mg/l)	250	BIS	0.0040
6	Ca(mg/l)	75	BIS	0.0133
7	TDS (mg/l)	500	BIS	0.0020
8	Fe (mg/l)	0.3	BIS	3.3333
9	Cl (mg/l)	250	BIS	0.0040

Soil Sampling: Soil samples were collected from the bottom of the wetland and vicinity of the wetland boundary. The soil chemistry was analyzed as per the procedure described by United state department of Agriculture [19]. These are the parameters used for examining the soil characteristics: Soil pH, Organic Carbon, EC, Nitrogen, and Iron.

4. Results and Discussion

4.1. Landscape Assessments of the SelectedWetlands

4.1.1. Changing trends of the selected wetlandarea:

Floodplain ecosystem and wetland ecosystem within floodplains are one of the most dynamic systems on earth. The nature of morphological characteristics of floodplain wetlands is greatly influenced by fluvial actions of the feeder Rivers. Because while discussing fluvial-geomorphic characteristics of the wetlands of any particular area no single parameter will be regarded as important as the rivers or the drainage system which plays central role in any kinds of floodplain studies [21]. Apart from this anthropogenic activity plays important role in the modification of wetland characteristics through agricultural expansion, built-up, construction of fisheries etc. Following Table 5 summarizes the temporal changes of surveyed wetland from 2000 to2016.

Table 5: Temporal changes of wetland area between 2000 and 2016 (negative percentage shows decrease in size)

Name of the wetland	Area-2000 (in hectare)	Area-2008 (inHectare)	Area-2016 (in Hectare)	Net changes in %		
				From 2000 to 2008	From 2008 to 2016	Total Changes (2000-2016)
BordoibamBeel	271.26	254.93	193.11	-6.02	-24.24	-28.80
Fuklai beel	499.74	445.31	232.53	-10.89	-47.78	-53.46
Maghuri-Motapung	775.99	655.50	642.88	-15.52	-1.92	-17.15
Longman beel	158.64	185.92	84.91	17.19	-54.32	-46.47
Ahajatibeel	160.43	168.30	113.14	4.90	-34.38	-29.47
Mora-Disoi	82.16	79.69	12.85	-3.006	-83.87	-84.35

TheresultpresentedintheaboveTable5showsthatsizeof all six-selected wetlands are decreasing with the passes of time. In terms of current spreading area of wetland, the Maghuri-Motapungbeel is the largest among all six-selected wetlands and Mora-Disoi has the smallest area. The largest decrease of wetlandareaof84.35%wasdetectedintheMora-Disoiwhich was formed by the abandonment of a stream. From the image based analysis and field based observation, it has been observed that the main reason behind the degradation of the wetlands are sedimentation from the Feeder River actions, alteration of wetlands into croplands, aquaculture ponds etc.

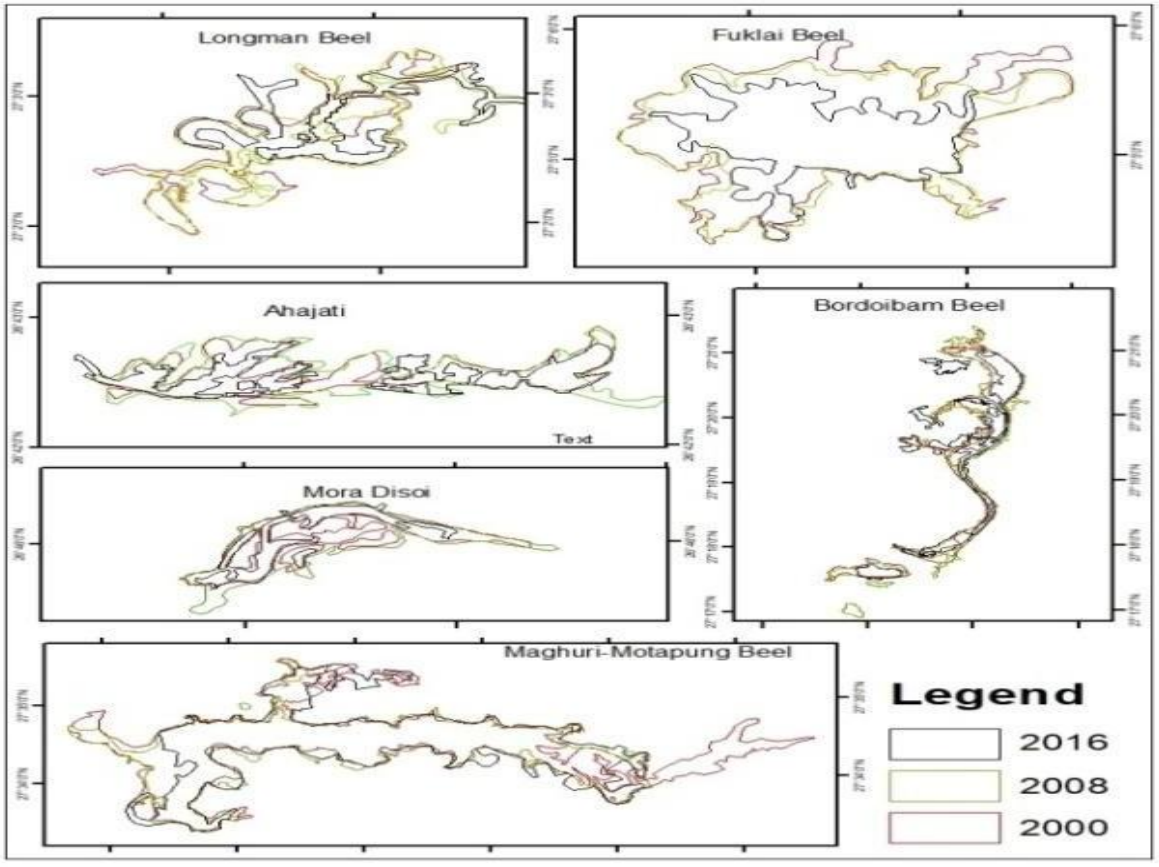


Fig.2: Map of wetland area changes from 2000 to 2008 and 2017

4.1.2 Land use status of the catchment area of wetlands in 1 km buffer: The image based analysis of the multi-temporal a real cover of the wetlands reveal that significant changes in the size of wetlands have taken place from 2000 to 2016. The current landscape pattern of the wetland buffer areas were extracted based on the land use classification images of the year2016.Thepercentageofculturallanduse(e.g.,agricultural and developed urban/ suburban patches) within surrounding landscape of

wetland provides an indirect estimate of connectivity among natural ecological systems [22]. The classification statistics of overall landscape pattern for all wetlands are summarized in the Table6.

Table 6: Status of land covers characteristics of wetlands in 1 km buffer

Category	MaghuriBeel (in hectare)	MoraDisoi (inhectare)	Ahajati (in hectare)	Longman Beel (in hectare)	FuklaiBeel (inhectare)	BordoibamBeel (in hectare)
River/Stream	31.32	1.62	-	4.14	45.9	-
Wetland	23.4	36.54	20.07	33.12	9.72	24.21
Barren land	66.42	46.35	55.8	142.74	59.31	164.52
Vegetation	285.57	17.64	84.51	33.12	825.93	464.4
Plantation	2184.93	-	-	-	-	300.87
Agriculture	165.69	102.15	652.23	1137.15	298.98	1472.94

Agriculture is the dominant land cover type in all the wetlands except in Fuklai beel buffer area which is covered by 66.6% natural vegetation. In two important wetlands, i.e. BordoibamBeel and Maghuri-Motapung beel where tea plantation is the one of the major land use type. The results in the following Table 7 shows the present status of all the wetlands based on its natural vegetation cover which is considered to be a reference condition for healthy condition.

Table 7: Percentage of vegetation cover present in the buffer area of selected wetlands

Wetland Name	**Percentage of vegetation cover in Buffer area**	**Remarks**
Bordoibam	19.11%	Largely modified and extremely vulnerable to its ecology
Fuklaibeel	66.61%	Moderately natural condition less vulnerable to its ecology
Longman	2.46%	Largely modified and extremely vulnerable to its ecology
Maghuri-Motapung	10.35%	Largely modified and extremely vulnerable to its ecology
Mora-Disoi	8.63%	Largely modified and extremely vulnerable to its ecology
Ahajati	10.39%	Largely modified and extremely vulnerable to its ecology

4.2. Physico-chemical Characteristics ofWetlands

Water Quality: In extensive fertile floodplains created by big rivers, like river Brahmaputra, in which dominant land use type is agricultural often strong, influenced the water quality of wetlands by the surface run-off from the agricultural fields. Apart from these floodplain wetlands, water quality is influenced, to a great extent, by inflow of water from the connecting rivers, local catchment area and by the metabolic processes of plants and animals living within the water body (particularly vegetation). Moreover, the quality of water in floodplain wetlands is influenced by the soil quality (nutrient content) and the atmosphere (i.e. temperature and distribution of atmospheric gases).

Table 8: Spatial and seasonal variation of the physico-chemical parameters in selected wetlands in the Upper Brahmaputra valley, Assam (India)

Sl. No.	Parameters	Maghuri-MotapungBeel		FuklaiBeel		BordoibamBeel		Longman Beel		Mora- Disoi		AhajatiBeel	
		Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M	Pre-M	Post-M
1	pH	6.43	6.8	7	6.4	6.21	7.59	6.7	7.2	6.2	7.1	6.77	6.9
2	EC dsm-1	0.63	0.3	0.89	0.95	0.57	0.33	0.31	0.43	0.23	0.81	0.25	0.27
3	Dissolved Oxygen(mg/l)	5.71	3.58	13.06	10.61	5.1	7.72	5.23	4.19	3.5	7.3	5.71	8.98
4	Hardness(mg/l)	23	67	0	23	137	147	165	171	173	247	128	252
5	Total Alkalinity(mg/l)	65	68	45	63	141	178	78	220	79	185	225	230
6	Ca(mg/l)	10.02	17.9	8.82	87.62	7.25	43	65	85	74	58	17.23	19.24
7	TDS(mg/l)	120	0.2	80	80	91	0.1	263	386	340	380	310	320
8	Fe(mg/l)	0.34	0.4	0.24	0.12	0.23	0.19	0.24	1.05	0.33	0.45	0.15	0.3
9	C l(mg/l)	9.94	19	9.94	21.3	9.98	25	19.2	11.23	173	177	12.78	8.52

Table 9: Mean variation of the physio-chemical parameters of water in selected wetlands

Sl. No		Maghuri- Motapung Beel	FuklaiBeel	BordoibamBeel	Longman Beel	Mora-Disoi	AhajatiBeel
1	pH	6.615	6.7	6.9	6.95	6.685	6.87
2	EC dsm-1	0.465	0.92	0.45	0.37	0.52	0.26
3	Dissolved Oxygen(mg/l)	4.645	11.835	6.41	4.71	5.4	7.345
4	Hardness(mg/l)	45	11.5	142	168	210	190
5	Total Alkalinity(mg/l)	66.5	54	159.5	149	132	227.5
6	Ca(mg/l)	13.96	48.22	25.125	75	66	18.235
7	TDS(mg/l)	60.1	80	45.55	324.5	360	315
8	Fe(mg/l)	0.37	0.18	0.21	0.645	0.39	0.225
9	Cl (mg/l)	14.47	15.62	17.49	15.215	175	10.65

Table 10: Water Quality Index for the six-selected wetlands

Sl. No.	**Wetland Name**	**Total Quality Rating** $(\sum Qn)$	**Total Unit Weight** $(\sum Wn)$	**WQI**
1	Maghuri	370.475	3.6808	119.002
2	Fuklai	305.94	3.6808	57.3
3	Bordoibam	440.2624	3.6068	73.21
4	Longman	677.669	3.6068	202.99
5	Mora-Disoi	669.5533	3.6068	126
6	Ahajati	548.7099	3.6068	78.76

All the physico-chemical and biological character of the water, which influences the growth, production and reproduction of fishes are collectively termed as water quality considered here. To obtain good productivity from a water body, its water should be suitable for the aquatic vegetation and organisms living there. All the sampling sites of the six wetlands are indicated water quality parameter fulfilling standard quality for aquatic life. The physico-chemical parameters of the floodplain wetlands of the upper Brahmaputra valley (Assam, India) had been investigated during the year 2016-17. The recorded temperature of all the wetlands during the field test had been rangingbetween21oCto29oCwhichindicatesthesuitabilityof the surface water temperature for fish. The highest amount of TDS was recorded 360 mg/l in Mora-Disoibeel and lowest amount was in Maghuri-Motapung beel with 60.1 mg/l. The reason behind the high amount of TDS recorded in the Mora Disoibeel is draining waste water from the near by urban center. The EC values of the wetlands are below tolerance limit. The values of EC range from 0.26 us/cm in Ahajatibeel to 0.92 us/cm in Fuklai beel. It has been observed that DO level varies from 11.83 to 4.64 mg/l in the study area. The maximum permissiblelimitofDOis3.0mg/l according to board of Industries. The highest DO was recorded in Fuklai Beel 11.83 mg/l, while the low DO level was recorded in the Maghuri- Motapungbeel. Hardness of water indicates high mineral content. Hard water mineral generally indicate the overall concentration of calcium (Ca2), and magnesium (Mg2), Iron (Fe) and sometimes other dissolved compound such bicarbonates and sulfates. Higher alkalinity is responsible for rising pH in water. All the selected wetlands have above the recommended level of minimum alkalinity. The lowest alkalinity level was recorded in Fuklai beel with 54 mg/l and highest was recorded in Ahajatibeel.

4.2.2 Soil Quality: The soil plays a important role in determining the level of nutrient availability to aquatic flora and fauna. Soil quality is important for wetland productivity because soil can regulate the drainage, flow and storage of water and solutes, which includes nitrogen, phosphorous, pesticides, and other nutrients and compounds dissolved in the water. Soil organic and total nitrogen are important for the wetland ecosystems that greatly influence the productivity of wetland ecosystem. The quality of wetland soil varies from place to place due to its varied physical and bio-chemical composition.

Table 11: Soil quality analysis of the six-selected wetlands

Sl. No.	Parameters	Ahajati	Mora-Disoi	Bordoibam Beel	Fuklai Beel	Longman Beel	Maghuri-MotapungBeel
1	pH	4.6	7.1	5.8	5.5	5.9	6.8
2	Organic Carbon (g/kg)	12.3	7.7	18.3	24.6	29.8	10.5
3	Soil Texture (%)						
Sand		71	87	90	68	59	61
Silt		19	9	7	22	23	34
Clay		8	4	3	10	18	5
4	Available Nitrogen (mg/kg)	179	167	256	320	270	191

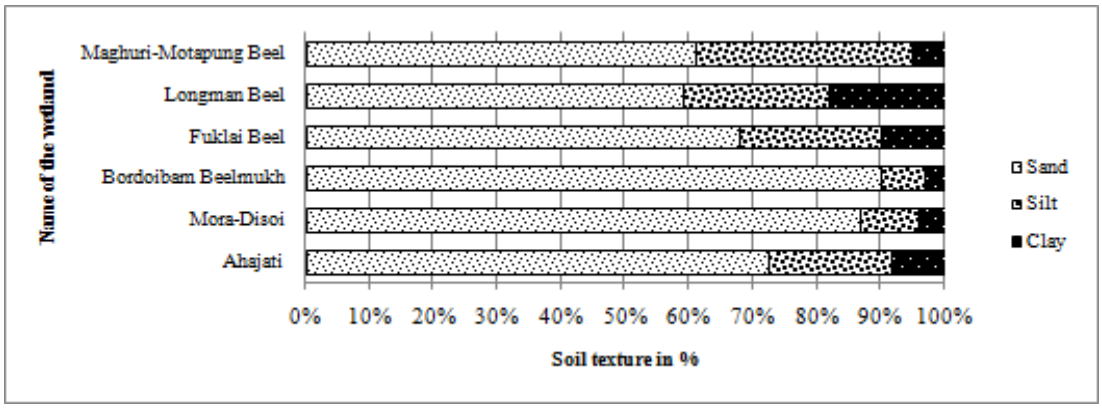


Fig.3. Percentage of different soil texture (includes Sand, Silt and clay) in selected wetlands

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