An assessment of geo-morphology and hydro-biological factors of major wetlands of Bangladesh

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ABSTRACT

The present study investigates the geo-morphological features, hydro-biological profiles and resource characteristics of some selected wetlands in Brahmanbaria district, Bangladesh. Two categories of wetland have been classified on the basis of area such as the small category (40–100 ha), which belongs to 11 wetlands and the large category (100–200 ha) to nine wetlands. The mean depth of all the surveyed wetland does not exceed 3.29 ± 0.83 m. The mean value of organic matter was measured as 7.5 ± 6.34%. The maximum organic matter was recorded at Gagotia beel (24.60%) and the minimum organic matter was recorded at Kajolia beel (2.06%). The mean value of organic carbon was measured as 3.93 ± 3.33%. The highest amount of organic carbon was found at Gagotia beel (12.95%) while the lowest amount of organic carbon was observed at kajolia beel (1.08%). Soil texture indicates the percentage composition of sand, silt and clay in sediment. The average concentration of sand, silt and clay was recorded to be 53.31 ± 15.32, 17.61 ± 9.56 and 29.08 ± 12.87%, respectively. Among the 20 selected wetlands examined, 13 were found to be perennial wetlands where water is available throughout the year. There was significant difference among different wetlands in terms of organic carbon, organic matter, sand, silt and clay ($P < 0.05$) as analyzed by One Way Analysis of Variance (SPSS v.22). The sampling stations were presented as a map created by GIS (ArcMap v.10.1). This qualitative and quantitative assessment will not only provide new information about the geo-morphological and hydro-biological insights into the wetland but also will facilitate the development, management, and conservation of aquatic biodiversity in a significant and worthwhile manner.

Key words | biodiversity, conservation, geo-morphology, GIS and remote sensing, hydro-biological factors, wetland

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INTRODUCTION

Wetlands zones that are water logged, either permanently or seasonally, and therefore comprise exclusive land shelter courses, are some of the absolutely most diverse environments in the world. The crucial element that separate wetlands from other land forms or water bodies is the characteristic vegetation of aquatic plants, adjusted to the unique hydric soil. Although deep water systems are a significant part of the hydrological cycle, where almost 30% of all fresh water is terrestrial ground water, the world's rivers and lake systems contribute only 0.3% (Wang *et al.* 2015). Furthermore, wetlands are also considered the most biologically diverse of all ecosystems, serving as home to a wide range of flora and fauna. They are valuable ecosystems for the reason that the water body harbors biodiversity and provides key services to societies. Wetlands are being gradually destroyed by human or spatial activities; for the time being, ecological restoration is seldom carried out to recover biodiversity and the ecosystem niche (Paula *et al.* 2014). The wetlands in Bangladesh have great ecological, hydro-biological, geomorphological, commercial

and socio-economic importance and play a crucial role in maintaining the ecological balance of ecosystems. Moreover, the wetlands habitat of Bangladesh is under threat due to the increase in population, intensive agriculture, overfishing, siltation, pollution, ill-planned infrastructures, lack of institutional coordination, lack of awareness, etc. As a result, biodiversity is reducing, many species of flora and fauna are threatened, the wetlands-based ecosystem is degenerating, and the living conditions of local people are deteriorating as livelihoods, socioeconomic institutions, and cultural values are affected (Talukder *et al.* 2008). Wetlands also support a significant range of other activities such as extraction of reed, harvesting of edible aquatic vegetation and their products, medicinal herbs, shell, etc. In recent years, long-forgotten historical approaches have been recovered and adapted to new technologies, such as the parallel production of plants or algae, even in multi-trophic systems (Ariel & Jutta 2014). Land transformation in an area, with conversion of much of the original wetland area to agricultural land, has been a steady but gradual process carried out over many decades, and one that has dramatically altered the nature of the physical and biological environment (ADB 2016).

There is broad recognition that the world's natural ecosystems deliver important goods and services to mankind, and whilst the literature includes some contradictory conclusions on the precise nature of 61 regulatory services of ecosystems on the hydrological cycle and wetlands, there is broad agreement on the importance of maintaining sufficient water to these ecosystems to sustain biodiversity and ecosystem integrity (Dadson *et al.* 2013).

Wetlands also exert a considerable influence on the hydrological cycle (Bullock & Acreman 2003), altering flood flows, low flows and groundwater recharge. Some wetlands have isolated hydrological systems, controlled by rainfall and evaporation, such as upland blanket bogs. However, most wetlands are connected hydrologically to other water bodies including rivers, lakes, estuaries, groundwater or the sea. To maintain the goods and services provided by wetlands, there is a need to assess, and where necessary control, these impacts. Assessing and quantifying this impact is important, as it alters the ecological production of ecosystem goods and services that benefit humans (Barbier 2013). Wetlands serve as potential sinks for excess nutrients in agricultural and urban runoff. Brahmanbaria district is one of the most important resource-rich wetland areas of Bangladesh. Geographically it is the transitional zone for flora and fauna in the two river (the Megna and Titas) ecosystems. Although some partial research works have been conducted on the wetlands of Bangladesh (Safiullah 1996), no research has been carried out on the wetlands of the Brahmanbaria district and its surrounding areas in the past. In view of this, it has been deemed essential to prepare an inventory of the selected wetlands in Brahmanbaria District of Bangladesh, examining the hydro-biological and geomorphological characteristics, which might eventually be helpful for fisheries resource management to a greater extent.

MATERIALS AND METHODS

The present study was accomplished in Brahmanbaria district, which is situated between $90°07'00''E$ and $23°57'10''N$. A global positioning system has been used for the space segment in the wetlands of the District. An interactive map function is being developed to communicate the wetland program's goals, progress, and demonstration, and provide interactive use and visualization of the wetland and summary water quality, and for the public on the status of the wetlands (Marla 2017) (Figure 1).

Primary and secondary sources were considered during the data collection. Primary data were collected through scheduled interviews (Table 1) with local people by the researcher himself. For this, a total of 90 persons were interviewed, and in total data from 75 households were collected by the researcher himself to determine the wetland value of seven Upazilas (Sub-districts) of Brahmanbaria district. The secondary information was collected from the fisheries office of the respective Upazilas. In the present study, univariate as well as multivariate techniques were adopted for analyzing seasonal data. All the aforementioned multivariate methods were performed using the PRIMER V.6 Multivariate Statistical Software (Clarke & Gorley 2006; Molla *et al.* 2015). A similarity matrix was used to produce a hierarchical agglomerative dendrogram for a graphical representation of community relationships using pooled seasonal data sets. The diversity of the aquatic plant community was measured by calculation of the number of species (S) and the total number of individuals (N). All the recorded species/taxons were considered for estimating species diversity following the methods previously described by Morris *et al.*, 2014 in their respective works on biodiversity.

Among multivariate methods, hierarchical agglomerative clustering (CLUSTER) analysis, using the group average linkage technique, was applied for the classification of wetlands into groups of similar structure. Different primary and secondary data sources were used for this research (Table 1). The required data were collected from
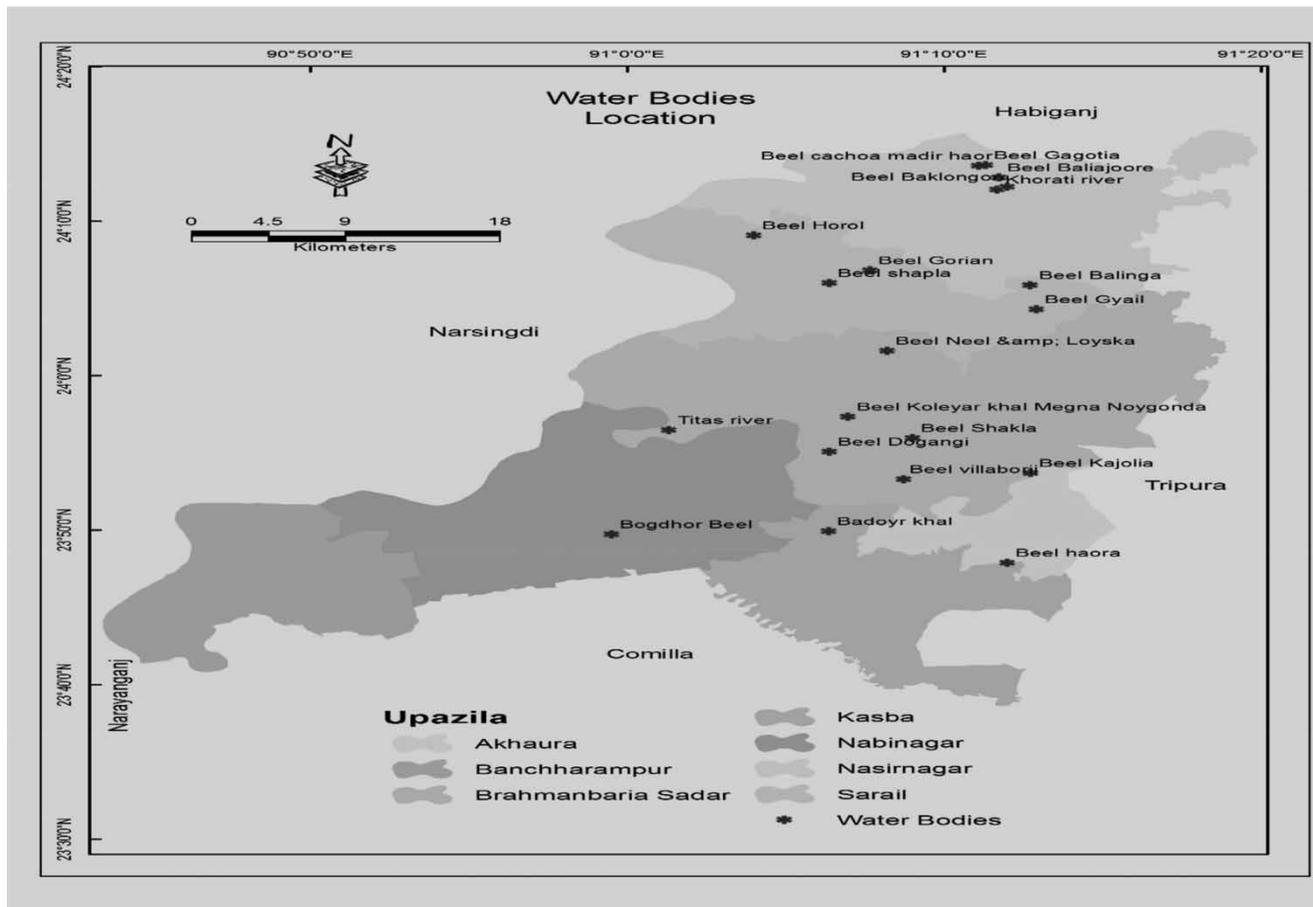
Figure 1 │ GPS survey of major wetlands of the Brahmanbaria districts.

these water bodies to fulfil the research purpose. GPS and other necessary equipment such as a boat, DO bottles, poly-bags etc. were used to identify the location of the studied water bodies and the water properties.

Based on the nature of the collected data and research objectives, different scientific methods were implied. The spatial distribution of the studied water bodies was found with GPS data. ArcView 3.3 and ArcGIS 9.3 were used for demonstrating the spatial distribution of water bodies on the map. In this work, an inventory of the wetlands of Brahmanbaria district has been prepared in a way that will constitute a basic information system giving a precise account of their location (latitude and longitude, nearest village or town, block/police station). A preliminary survey of the study area was conducted to identify the sampling station. A plot measuring 50×350 m^2 was drawn in different wetlands for collecting sediment and plant samples. For the assessment of sediment quality, surface sediments were collected by using a grab sampler (Wardhani *et al.* 2017). The collected sediment samples were stored in high density

polythene bags and brought to the laboratory for measuring sediment texture, organic carbon and organic matter. Soil texture (% of sand, silt and clay) in the study area was ana-lyzed by the hydrometer method, previously described by Haq & Alam (2005). Soil organic carbon (SOC) was measured by the Walkey and Black wet oxidation method, modified by Haq & Alam (2005). For the estimation of the soil organic matter (SOM) of the study area, a known weight of soil was dried in an oven at 105 °C to a constant weight. Then the oven dried soil was ignited at 500 °C for 6 hours and cooled in desiccators. The loss in dry weight was measured and the organic matter content was expressed as a percentage (Salehi *et al.* 2011) using the following formula:

$$\% \text{ Organic matter} = \frac{ASI \times 100}{AOS}$$

where, ASI = Amount of soil after ignition at 500 °C

AOS = Artificial Organic Soils

Table 1 | General characteristics of wetlands in Brahmanbaria district

Name of the wetlands	Parameters												
	Longitude (E)	Latitude (N)	Average area (hectare)	Average depth (m)	Source of water	Water regime	Flora diversity	Use patterns	Sand (%)	Silt (%)	Clay (%)	Organic matter (%)	Organic carbon (%)
Neel & Loyska (1)	24°01′36″	91°08′ 12″	166.70	2.90	R	NP	6	I, P, J, D	42	6.4	51.5	4.41	2.32
Koleyar (2)	23°57′21″	91°06′58″	63.48	2.29	R	P	5	I, P, D	56	11	33	3.6	1.89
Kajolia (3)	23°53′42″	91°12′44″	89.44	4.15	R	P	5	I, D	43	39.2	18	2.06	1.08
Shakla (4)	23°55′57″	91°09′00″	104.02	2.59	R, Rw	N	7	I, P, J, D	55	14.3	30.7	3.8	2
Dogangi (5)	23°55′05″	91°06′23″	40.87	3.50	R, Rw	NP	5	I, J, D	51	18.3	30.7	7.39	3.89
Shapla (6)	24°06′00″	91°06′23″	119.72	3.81	R, Rw	NP	4	I, P, J	27	18.3	54.7	24.3	12.84
Horol (7)	24°09′05″	91°04′00″	248.48	4.57	R, Rw	NP	7	I, J	32	24	44	9.9	5.21
Gyail (8)	24°04′18″	91°12′55″	108.02	2.74	R, Rw	P	5	I, P, J, D	59	24.3	16.7	7.09	3.73
Balinga (9)	24°05′52″	91°12′43″	46.94	3.20	R, Rw	P	7	I, P, J	61	18	21	7.33	3.85
Gorian (10)	24°06′49″	91°07′40″	40.50	3.96	R, Rw	NP	5	I, J	67	10.28	22.72	5.27	2.7

Name of the wetlands	Parameters												
	Longitude I	Latitude (N)	Average area (acre)	Average depth (m)	Source of water	Water regime	Flora diversity	Use patterns	Sand (%)	Silt (%)	Clay (%)	Organic matter (%)	Organic carbon (%)
Baklongon (11)	24°12′14″	91°12′00″	182.92	3.05	R, Rw	P	5	I, J, D	68	4	28	4.73	2.4
Gagotia (12)	24°13′38″	91°11′18″	48.97	4.41	R, Rw	P	6	I, P, J, D	85	2.27	12.72	24.6	12.95
Baliajoore (13)	24°12′50″	91°11′44″	42.09	2.59	R, Rw	NP	4	I, P, J, D	64	30.72	5.28	7.53	3.96
Khorati (14)	24°12′03″	91°11′40″	43.30	3.96	R	P	4	I, J, D	71	5	24	3.32	1.75
Cachoamadir (15)	24°13′36″	91°11′05″	239.57	3.2	R	P	5	I, P, J, D	42	13	45	3.8	2.01
Villaborii (16)	23°53′18″	91°08′43″	46.94	2.28	R	P	6	I, P, J, D	38	28	34	6.17	3.23
Haora (17)	23°47′53″	91°11′59″	43.71	1.98	R, Rw	P	5	I, P, D	53	22	25	8.71	4.43
Badoyr (18)	23°49′56″	91°06′22″	46.13	3.35	R	P	7	I, P, D	46	24	30	4.32	2.27
Bogdhor (19)	23°49′43″	90°59′30″	41.68	2.43	R	P	6	I, P, J, D	31	17	52	3.51	1.88
Titas (20)	23°56′29″	91°01′19″	105.78	4.6	R	P	4	I, P, J, D	64	11	25	4.79	2.62
Mean			230.96 ± 165.53	3.29 ± 0.83			5.36 ± 1.07		53.31% ± 15.32	17.61 ± 9.56	29.08 ± 12.87	7.5% ± 6.34	3.93% ± 3.33

Abbreviations used; for (1) Water regime: P – Perennial, NP = Nonperennial; (2) Source of water: R = River water, RW = Rain water; (3) Use pattern: I = Irrigation, P = Pisciculture, D = Domestic use, J = Jute retting.

A phylogenic table was constructed for listing all the species collected from the study area. The species abundance data for the replicate samples taken in two seasons from three stations set in each wetland were combined before subjecting them to biodiversity analysis.

RESULTS

A total number of 20 wetlands were recorded from the six Upazilas of the Brahmanbaria district throughout the study. The area of the wetlands that were selected for the present study was greater than 100 acres and they were classified into two categories, the small category (40–100 ha) and the large category (100–200 ha). The small category included 11 wetlands, whereas the large category included nine wetlands. Mean depth of most of the water bodies does not exceed 3.29 ± 0.83 m. There is only one wetland, Horol, which is deeper than 4.5 m although a number of eight wetlands did not go above 3 m depth. However, the lowest depth in Haora wetland was 1.98 m. During the observation of data collection, it is clearly seen that a maximum number of 11 wetlands are currently dependent on both river and rain water and only nine wetlands rely on river water. Moreover, it was identified that 13 wetlands out of 20 were full of water for the rest of the year while seven wetlands only had water in the main part of the wetlands (Table 1).

The 20 identified wetlands covered 1869.28 ha, which is about 1% of the total area of the six districts. Characterization of the selected wetlands in Brahmanbaria district was made based on the selected area under four categories. With the application of these characteristics, a cluster diagram was prepared (Figure 2) considering the similarities of their characteristics. From the cluster diagram, it is evident that 10 wetlands, that is, Khorati, Haora, Dogangi, Gorian, Bogdhor, Baliajoore, Badoyrkhal, Gagotia, Balinga, and Villaborii, show the same characteristics. Among the 20 wetlands, only Koleyar sustains a single representative cluster.

Mean depth of most of the wetlands (55%) does not exceed 3.5 m (Figure 3). There are only seven wetlands – Koleyar, Kajolia, Shakla, Horol, Gorian, Gagotia, and Khorati – each of which has a depth ranging from 3.5–4.5 m and only one wetland, Haora, that is shallower than 2 m. Three types of wetland could be recognized: large ponds, large depressions of land and oxbow lakes caused by the change in course of a river. But all of them are flood plain wetlands.

The diversity of macrophytes in Brahmanbaria wetlands is unique, with some number of plant communities in addition to a significantly reduced number of common species. Depth and duration of the water regimes of these several types of wetlands vary and therefore variations occurred among macrophyte plant communities as well (Table 2). Most of these wetlands are rainfed, especially the seasonal ones. On the basis of macrophyte diversity, the wetlands can be classified into three categories, viz., poor, moderate and rich, encompassing seven, five, and three wetlands, respectively. The diversity of wetland macrophytes of Brahmanbaria is represented by nine species. During the rainy season, the largest numbers of macrophytes (more than four) belong to nine wetlands, that is, Neel & Loyska, Kajolia, Shakla, Dogangi, Horol, Gyail, Balinga, Gagotia, Badoyr. However, in the same season, the smallest numbers of macrophytes (not more than four) belong to five wetlands, that is, Shapla, Baklongon, Baliajoore, Haora, and Titas. During the dry season, the largest number of macrophytes (more than six) belong to eight wetlands; that is, Neel & Loyska, Dogangi, Gyail, Gorian, Baliajoore, Haora, Badoyrkhal, Bogdhor whereas the smallest number of macrophytes (not more than four) belong to four wetlands, that is Horol, Khoratiriver, Cachoamadir, and Titas.

Characterization of 20 wetlands in Brahmanbaria district reveal variations among wetland characters under six basic categories. With the application of these characters, a cluster diagram was prepared (Figure 4) considering the similarities of their characteristics. From the cluster digram it is evident that eight wetlands, that is Haora, Cachoa madir, Baklongon, Dogangi, Gyail, Gorian, Kajolia, Koleyar, bear the same characteristics. Another cluster is formed by four wetlands, namely Titas, Baliajoore, Shapla and Khorati, bearing the same characteristics. A further four wetlands, that is Bogdhor, Neel & Loyska, Villaborii, and Gagotia possess similar characters.

Wetland organic carbon and organic matter is shown in Figure 5. The soil remains very high in organic content without two wetlands, Beel Shapla, and Beel Gagotia, having 24.39% and 24.60% respectively.

The highest value of clay (54.7%) was found in Beel Shapla, while the lowest (5.28%) was obtained in Beel Baliajoore. The highest proportion of silt was in Beel Kajolia with 39.2% of the silt of the 20 wetlands, followed by Beel Gagotia with 2.27%. The highest value of sand, 85%, was revealed in Gagotia. On the other hand, 27% of sand remained in Beel Shapla (Figure 6).

The maximum number of species (116) was recorded from wetlands during rainy seasons and the minimum number of species (100) was recorded from wetlands during dry seasons. The minimum species richness value
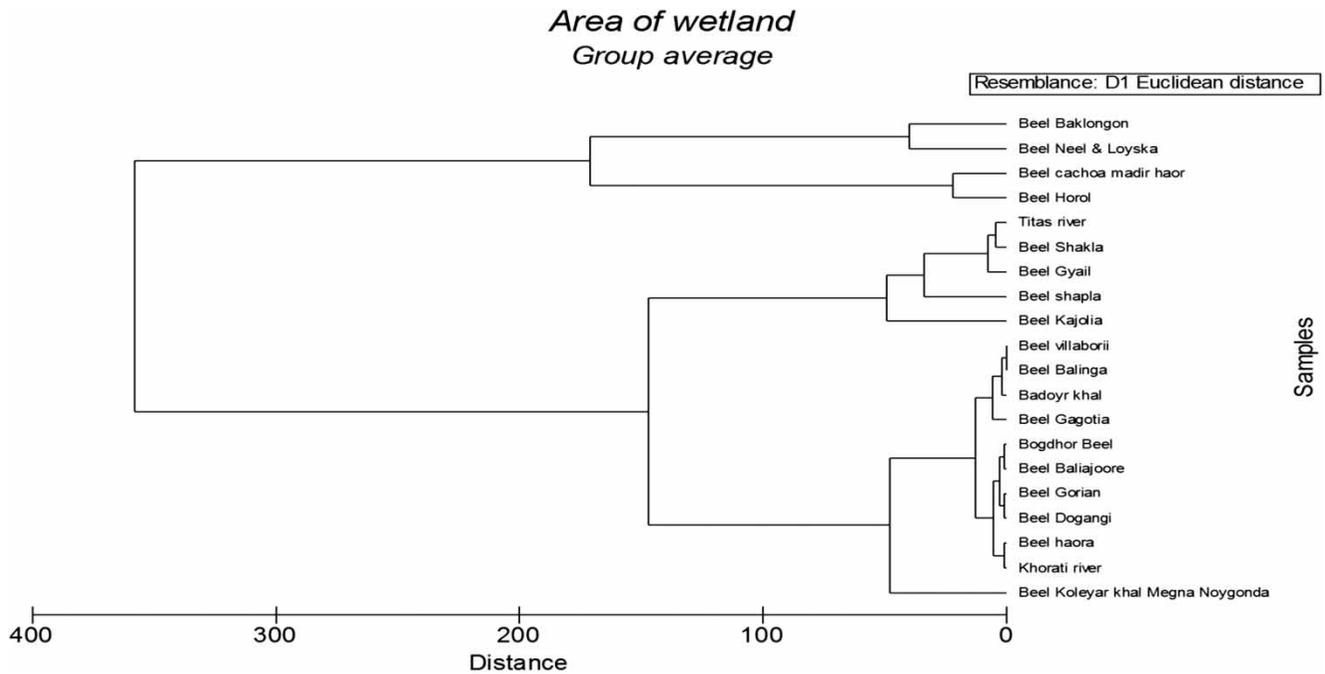
Figure 2 | Dendrogram constructed on the basis of area, showing the percentage of distance among different wetlands of Brahmanbaria district, Bangladesh.

(2.945) recorded from wetlands during rainy seasons and the maximum species richness value (2.957) was recorded from Beel Gagotia during rainy seasons. The minimum Shannon diversity value (0.047) was recorded from wetlands during rainy seasons and the maximum Shannon diversity value (0.063) was recorded from wetlands during dry seasons.

The minimum species evenness value (0.217) was recorded from wetlands during rainy seasons and the maximum Shannon diversity value (0.199) was recorded from wetlands during dry seasons.

As far as the use patterns of these wetland are concerned, as many as nine wetlands have multifarious
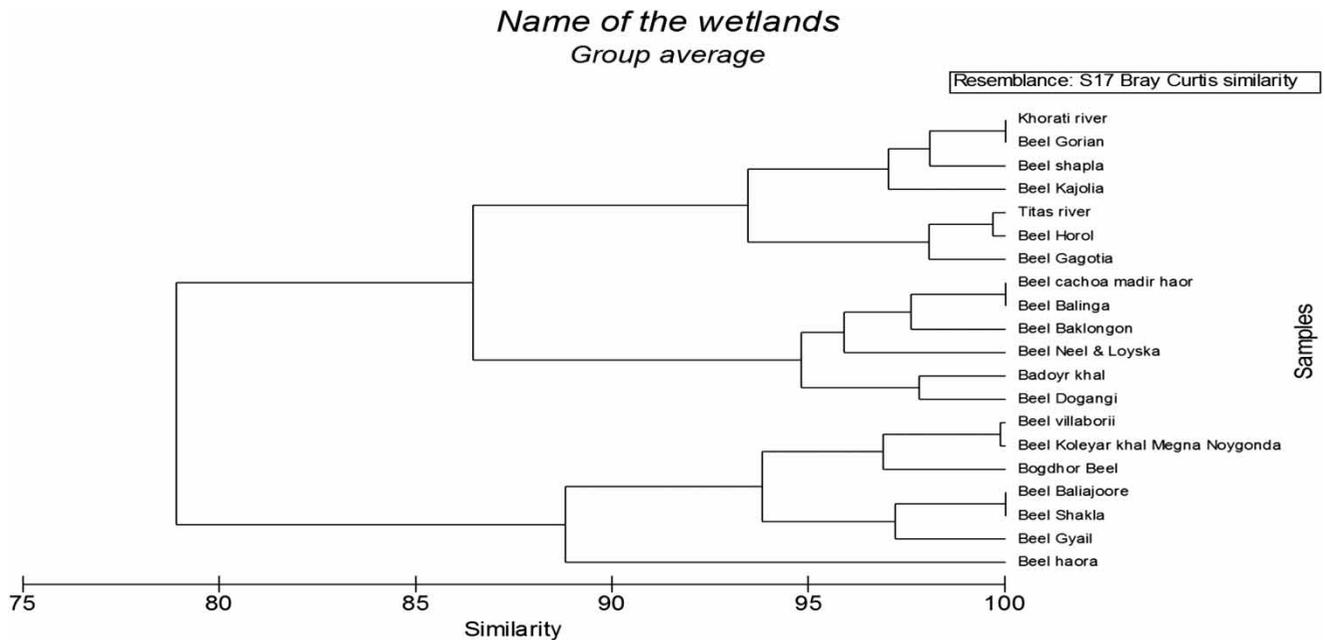

Figure 3 | Dendrogram showing the percentage of similarity among different wetlands of Brahmanbaria district, prepared on the basis of depth.

Table 2 | Diversity indices of macrophyte for different seasons: Species number (S), total number of individuals (N), Margalef's species richness (d), Shannon Wiener diversity index (H') and Pielou's evenness (J')

	S	N	d	H'	J'
Dry season	7	100	0.063	2.957	0.217
Rainy season	9	116	0.047	2.945	0.199

uses, for example, pisciculture, irrigation, jute retting and domestic purposes. As many as 14 wetlands are used for scientific and traditional pisciculture. In addition, 16 wetlands' water among the 20 was used for jute retting. This process is one of the important factors responsible for the quality of jute fiber which drives the export market in the country. Moreover, most of the wetlands water was used for indoor and outdoor domestic purposes such as preparing food, washing clothes and dishes, watering the yard and garden, drinking and even washing the domestic animals. All these wetlands are being used for cultivation, especially fisheries, in the rainy season and paddy during the dry season, it is hardly possible for anyone to differentiate and identify them as wetlands. As such, as many as 11 parameters are used to classify the concerned wetlands. So far as location is concerned, 15 wetlands are located in rural areas and only five are associated with urban life in Brahmanbaria district, and the values are accordingly linked with the cultural status and socio-economic needs of the rural people who use them. Only one, that is the Koleyar khal wetlands, out

of 20 wetlands, is considered as a man-made wetland, which clearly speaks about the dominance of the natural type.

DISCUSSION

The total area covered by the 20 wetlands is 4519.03 ha, which is about 1% of the total geographic area of the district of Brahmanbaria itself. Wetlands have been recorded from the six Upazilas (Akhura, Brahmanbariasadar, Kasba, Nabinagar, Nasirnagar and Sarail) of the Brahmanbaria district in Bangladesh throughout the present study. The wetlands belong to many categories, the smallest ones (40–100 ha) include as many as 11 wetlands and nine wetlands belong to the largest category (100–200 ha). Similarly, Windmeijer & Andriesse (1993) made a brief classification of wetland systems in West Africa, wherein they divided the wetland longitudinally into three parts based on geomorphological and hydrological characteristics. Mwita *et al.* (2012) also estimated wetland sizes ranged between 0.5 and 747.54 ha where wetlands were smaller in size (0.5–35 ha) and densely distributed in the highlands, while flood plains were large (10–747.54 ha) and sparsely distributed. Lyon (2001) followed a similar land-based inventory system for wetland characterization using the geomorphological and hydrobiological approach.

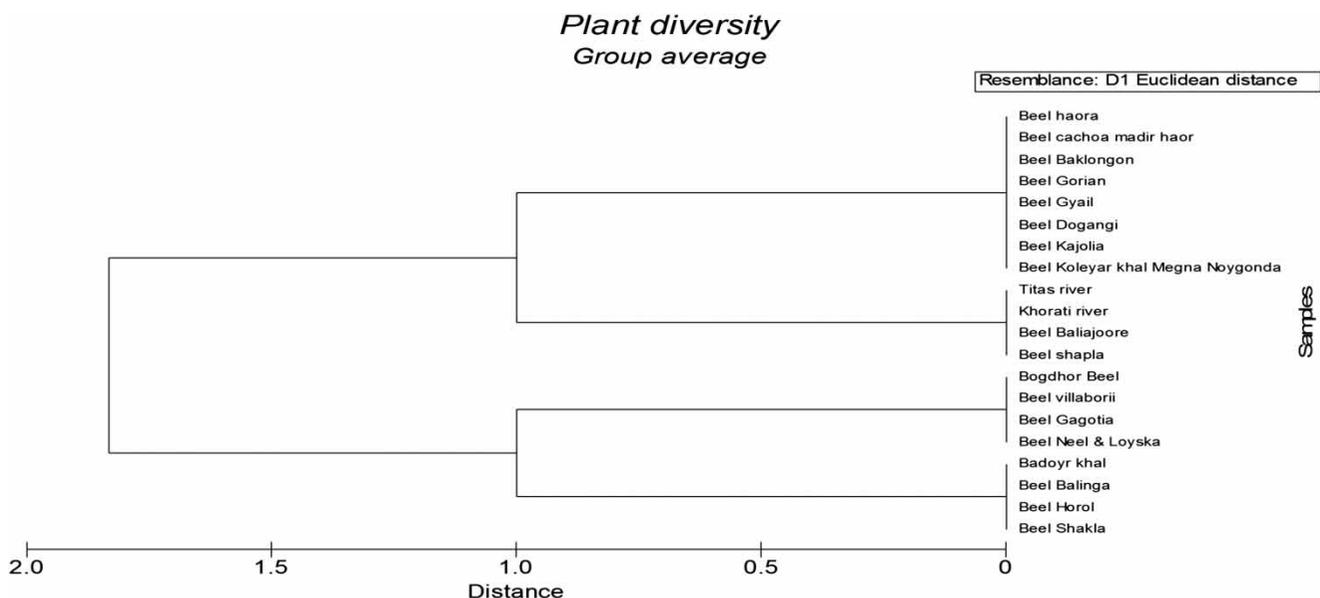The depth of all the surveyed wetlands does not exceed 4.57 m. There are only three wetlands that each range from

Figure 4 | Dendrogram showing the percentage of distance among different wetlands of Brahmanbaria district, prepared on the basis of depth.
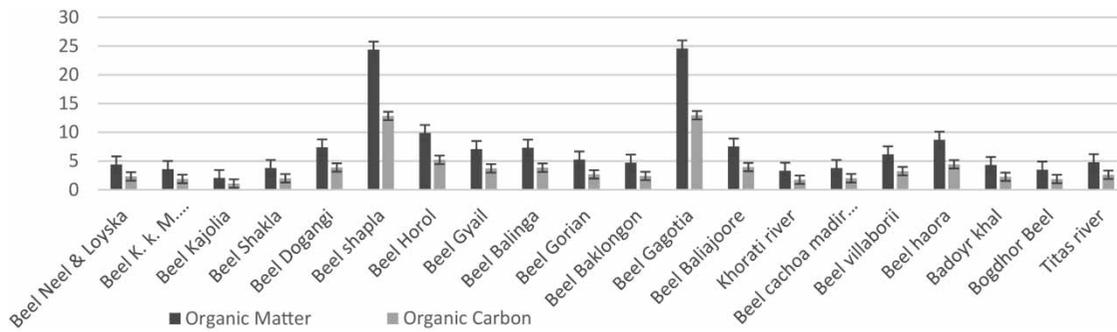
Figure 5 | Percentage of organic matter and organic carbon in different wetlands of Brahmanbaria district.

4.00 to 4.57 m and only one wetland, Beel Horol, which is deeper than 4.5 m. These results are similar as Inventory of wetlands of Nadia district, where the mean depth of most water bodies (80 percent) does not exceed 3.048 m. There are only 15 wetlands that each have depths ranging from 3.048 to 4.56 m. The classification reveals five hydrological parameters of each wetland that are quite likely to help assessment of their ecological values and rationalization of their utilization. Sushma *et al.* (2012), as well as Uddin *et al.* 2012, identified the Haripur Beel as deeper than 4.572 m. In the rainy season, it becomes an enormous lake more than 4.572 deep. Deep flooding suddenly rises to flood level and water currents prevents the cultivation of kharif crops in most of the area. Interestingly, 65% (i.e. 13 out of 20) of the total wetlands studied are perennials (Table 1) herein, ensuring the availability of water throughout the year, which corresponds with Nadia district wetlands with about 45 out of 75 waters in same range. It is worthwhile mentioning that management strategies proposed by Sushma *et al.* (2012) to ensure uninterrupted supply of water and biotic resources and sustainable development work based on them promise a lot of benefits. The same classification of perennial and non-perennial wetlands

is shown in Nielsen (2006), which for Mt. Desert Island, Maine, included hydrologic susceptibility factors for wetlands in Acadia National Park. So far as the use patterns of these wetlands are concerned, as many as nine wetlands have multifarious uses, such as pisciculture, irrigation, jute retting and other purposes. As many as 14 wetlands are used for scientific as well as traditional pisciculture. Sushma *et al.* (2012) identified that in all, as many as 19 out of the 20 wetlands are used in irrigation. On the whole, as many as 72 out of 75 wetlands are used in irrigation (Bala & Mukherjee, 2010), and 29 wetlands have multifarious uses such as pisciculture, irrigation, jute retting and other purposes. Geographic information systems (GIS) in combination with remote sensing data were used to identify 20 wetlands among the six Upazilas of Brahmanbaria district, which will help with the conservation and management of the wetlands. Similarly, Sharma *et al.* 2014, which encompasses water resource assessment, hydrologic modeling, assessment and monitoring of the environmental impacts of water resources projects and water quality mapping and monitoring, identified wetlands by using a GIS system.

In the present study, the maximum number of species (116) were recorded during the rainy season while the
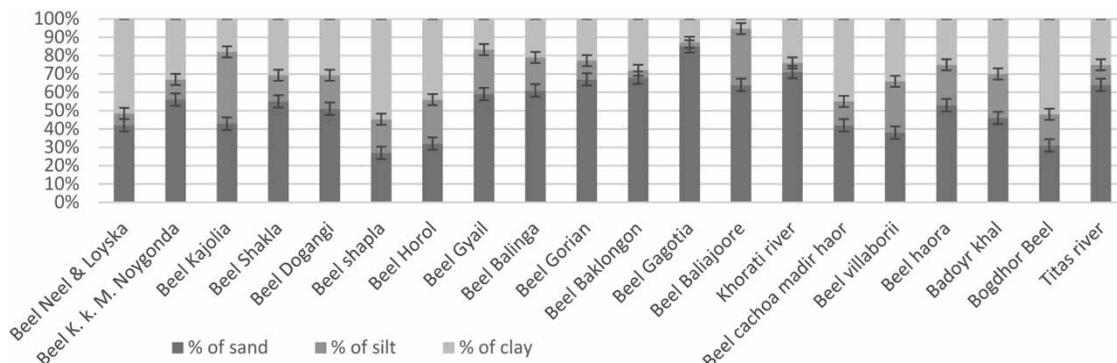

Figure 6 | Percentage of sand, silt and clay in different wetlands of Brahmanbaria district.

minimum number (100) was recorded in the selected wetlands during the dry season. In the rainy season, submerged wetland vegetation grows in fresh water conditions within which some species have underwater flowers, while others have long stems that allow the flowers to reach the surface. During their recent investigations, Western Australia's Department of Environment & Conservation (2012) found that submerged plant species were the main source of food for native fauna, habitat for invertebrates, and also play a significant role in water purification.

Among the 20 wetlands investigated in the present study, the lowest proportion of clay was found in Gagotia Beel while the highest value was obtained in Beel Shapla. However, the highest proportion of silt was found in Beel Kajolia and the lowest was in Baklongon. Moreover, the highest value of sand was observed in Gagotia whereas the value was lowest in Beel Shapla. (Figure 6). Overall, soil textures in the selected sites had high percentages of sand, which is a typical phenomenon of wetlands developed from river sources. Sediment structure that contains mud covers about 40 percent of the continental aquatic environment such as lakes, rivers, estuaries, and deltas containing high proportions of clay sediments (Hillier 1995). Clearly, clay is a critical component of sedimentary environments. In addition, soil sand and clay portions are often considered as soil bulk density in many hydrological models to determine the soil water-holding capacity of surrounding wetlands. Moreover, in many cases the clay percentage helps to increase the rate of SOM (Akihiko & Rota 2017).

Wetland organic carbon and organic matter is shown in Figure 5. The soil was very high in organic matter content, apart from two wetlands having 12.95% and 12.84% respectively. Several cases have demonstrated that it is possible to restore organic matter levels in the soil with activities that raise the procurement and supply of organic matter, such as the use of cover crops and desisting from burning, and that reducing decomposition rates, such as through reduced and zero plow, leads to progress in the organic matter content in the soil (Sampson & Scholes 2000). In our study, we observed that some of the wetlands were situated beside urban area where they became directly or indirectly affected by anthropogenic sources. The effects of human disturbance on SOC storage were presumably caused by the impact of N deposition on SOC, which were negative in the grassland and positive in the shrublands community of wetlands (Chen *et al.* 2018). Thus, the negative effect of N decomposition on SOC may be cause by a reduction in microbial carbon contribution to the stable soil carbon pool, whereas the positive effects may be attributable to the N-induced increase in root biomass (Liang & Balser 2012).

SOC and organic matter influence various species of the wetlands (Groenewald 2010). Generally, SOM is a primary source being derived from litter fall, root turnover, and microbial organisms; it is one of the most telling indicators of wetland maturity and is also accumulated in wetland ecosystem as an important source of nutrient (Bruland & Richardson 2006). Moreover, according to Ahn & Peralta (2012), SOC, being a significant portion of SOM, has also been a useful indicator of soil quality and has been found to be correlated to a great number of specific soil processes that occur in wetlands, such as respiration, denitrification and phosphorus sorption.

CONCLUSION

The scientific consideration for wetland services has dramatically increased over the past decade, but few studies have been conducted on wetland ecosystem services for conservation and management. We used an ecosystem service approach to assess large distributions of habitat and various wetland ecosystems, and explored the resources among the wetlands of Brahmanbaria, Bangladesh. It appears most likely that various interesting and important characteristics are available in the investigated wetlands. These characteristics are valuable and significant in the preparation of an inventory to reflect the present status of the wetlands. All data collected and analyzed during this survey (including all characteristics of important wetlands in each region/district, distribution of rare species of fauna and flora, recommendations including land use and conservation measures, and maps of all levels) were compiled, which will serve as important tool for wetland management and protection. The clustering and branching pattern, which is based respectively on the similarities and dissimilarities of wetlands, is quite likely to help in assessment of ecological values and rationalization of groups or clusters of the utilization of wetlands for sustainable development. It would also be helpful in executing identical strategies for restoration as well as development (as a resource) for each cluster of wetlands.

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