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Research Article

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Analysing Water Quality and Aquatic Vegetation Dynamics in a Proposed Bird Sanctuary: A Case Study of Satajaan Beel, North Lakhimpur, Assam

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ABSTRACT
Water quality assessment is crucial for understanding the environmental status of wetlands, which are among the most significant ecosystems on the planet. Satajaan Beel, a small yet vital wetland located in the Lakhimpur district of Assam on the floodplains of the Ranganadi River, serves as the focus of this study. This research evaluates various water quality parameters from samples collected at ten stations within the study area. The Water Quality Index (WQI) was determined using the weighted arithmetic method. The results revealed WQI values indicating very poor water quality for most samples: Sample 1 (77.93), Sample 2 (92.60), Sample 5 (75.47), Sample 6 (78.27), and Sample 8 (98.275). Samples 3 (117.38), 4 (113.47), 7 (131.79), and 10 (119.23) were deemed unsuitable for use without proper treatment, while Sample 9 (46.02) was the only one indicating good water quality. Additionally, the study assessed the biodiversity status of the area. The Normalized Difference Vegetation Index (NDVI) calculation revealed a significant degradation of aquatic vegetation, with a calculated degradation rate of 2.84 acres or 7.84%. A survey conducted from 2018 to 2019 recorded 262 species of vascular plants within this wetland. The study also identified 42 species of fish belonging to 19 families, highlighting the ecological diversity and the need for conservation efforts in Satajaan Beel.

Keywords: Wetland, Water Quality Index, NDVI

Introduction

Wetlands are among the most significant ecosystems on Earth due to the tremendous number of ecosystem services they provide. They play a crucial role not only as aquatic habitats but also in maintaining natural cycles and supporting a wide range of biodiversity. Wetlands contribute to groundwater recharging, water purification, and replenishment. These water-regulating services have earned wetlands the moniker "kidneys of the ecosystem," akin to how forests are referred to as the "lungs of the Earth." Beyond these services, wetlands are highly productive areas for aquatic flora and fauna, as well as for wetland agriculture. They are essential habitats for various water birds and key stopovers for migratory birds [1]. Wetlands have also been termed "biological supermarkets" due to their extensive food chains and rich biodiversity [2]. Birds rely on wetlands for drinking water, feeding, resting, shelter, and as sources of materials, particularly during breeding seasons.

Despite their importance as highly productive ecosystems, wetlands are also incredibly vulnerable habitats. They face significant threats from various anthropogenic factors, including climate change, population growth, and urbanization. Over the years, approximately 35% of the world's wetlands have been lost from 1970 to 2015, and this loss rate has been accelerating annually since 2000 [3]. This trend highlights the urgent need for conservation efforts and sustainable management practices to protect these critical ecosystems and the valuable services they provide to both wildlife and humanity.

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The remaining wetlands are under threat from pollution, unsustainable use, and invasive species, among other factors. India has reported the largest number of wetlands in South Asia, covering approximately 4.6% of its total geographical area, according to a report by Wetlands International South Asia. Globally, about 50% of the world's wetlands have been lost since 1900, with approximately one-third of the natural wetlands in the Indian subcontinent decreasing over the past forty years, as reported by Wetlands International South Asia (WISA) in 2021. Encroachment and high human interference have significantly impacted India's wetlands, with Mumbai losing the most (71%), followed by Ahmedabad (57%), and Bangalore (56%) according to Chatterjee [4]. The Ministry of Environment, Forest and Climate Change (MoEFCC) reported that 42 of India's top 100 wetlands are threatened due to these factors.

In 1992-1993, the Indian Space Research Organisation conducted the first digital mapping of wetlands in India, revealing an extent of approximately 8.26 million hectares. Satellite data analysis identified 3,513 wetlands in Assam alone, covering approximately 1,012 square kilometers [5]. The Northeast region of India hosts three Ramsar wetlands and numerous smaller wetlands, all facing ecological threats and degradation. For instance, Rudrasager or Twijilikma Lake in Tripura, spanning 2.40 square kilometers, is experiencing issues such as siltation and declining water levels. These changes directly and indirectly affect the ecosystem and the surrounding agricultural activities. Rudrasager received its Ramsar designation on November 8, 2005 [6].

The quality of water resources in wetlands is a critical concern and fundamental necessity for all living organisms. Maintaining good water quality is a positive environmental indicator as wetlands provide vast quantities of renewable fresh water, supporting socio-economic development in surrounding areas for human welfare. Water quality serves as a crucial parameter for assessing environmental degradation within wetlands and beyond. Water is indispensable for all living organisms, and any changes in its quality can threaten their survival, affecting drinking, bathing, habitat, and other essential needs. Assessing water quality involves studying both physical and chemical characteristics. Due to increasing population and human negligence, water quality is deteriorating progressively. Therefore, it is essential to rigorously test water before using it for drinking, domestic, agricultural, or industrial purposes. Water quality testing typically includes examining physical parameters such as turbidity and color, and chemical parameters like pH, Electrical Conductivity (E.C), Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Total Hardness, Calcium Hardness, among others. High levels of certain elements beyond permissible limits (e.g., temperature, TDS, other chemicals) can harm aquatic organisms inhabiting the water body. Therefore, ensuring water quality within acceptable parameters is crucial for the health and sustainability of both aquatic life and ecosystems.

Chakrabarty & Sarma conducted a study on drinking water quality in Kamrup district, Assam, focusing on physical and chemical parameters such as Temperature, pH, Electrical Conductivity, Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Turbidity, Dissolved Oxygen (DO), Total Hardness (TH), Calcium Hardness (CH), Magnesium Hardness (MH), Chloride (Cl), Sulphate (SO4), Sodium (Na), and Potassium (K) [7]. Their statistical analysis revealed patterns in parameter distribution and localization of data, highlighting significant impacts from intensive land use for agriculture, construction, waste dumping, and industrial activities on regional drinking water quality. Kumarasamy et al. investigated the hydrochemistry of the Tamiraparani River using multivariate cluster analysis (CA) and principal component analysis (PCA) across 20 sampling stations [8]. Their study identified seasonal and spatial variations influencing parameters such as Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl, H_4SiO_4, SO_4^{2-}, NO^{2-}, and PO43-. They concluded that natural weathering processes predominantly influenced water quality variations more than anthropogenic activities. Patel et al. linked wetland degradation to climate change using Resourcesat-1 AWIFS data from 2004-05 to analyze wetland types, distribution changes, and impacts in India [9]. Chopra et al. utilized remote sensing techniques to map wetlands in Punjab, focusing on monitoring, management, conservation, and seasonal variations in land use, land cover, vegetation status, and water turbidity using satellite data [10]. Monitoring water quality parameters, Water Quality Index (WQI), and wetland ecosystems through remote sensing and GIS play crucial roles in mitigating wetland degradation rates and facilitating effective ecosystem management and conservation efforts. These approaches are essential for addressing environmental challenges and ensuring sustainable water resource management for current and future generations.

Description of the Study Area

Location

The district of Lakhimpur, situated on the northern bank of the Brahmaputra River, is one of the most flood-prone districts in Assam. It borders Arunachal Pradesh to the north, Dhemaji District to the east, the Subansiri River, the northern branch of the Brahmaputra, and Majuli Island to the south, and Sonitpur district to the west. The district spans from approximately 26°49' to 27°37' N latitude and 93°42' to 94°38' E longitude, covering an area of about 2,277 square kilometers. Lakhimpur serves as a gateway to several cities in neighboring states, including Itanagar, the capital of Arunachal Pradesh.The present study focuses on Satajaan Wetland, also known as a bird sanctuary, located in the North Lakhimpur subdivision of Lakhimpur District, Assam. This wetland, situated between 27°12'23.7" to 27°12'40.00" N latitude and 94°03'08.5" to 94°03'08.8" E longitude, lies in the floodplain of the Ranganadi River at an altitude of 101 meters above mean sea level. Satajaan Wetland is known for hosting migratory birds of both national and international significance. It is under severe threat and is adjacent to the Pahumara-Kimin state highway and National Highway 15, approximately 350 kilometers from Guwahati, Assam [11,12].

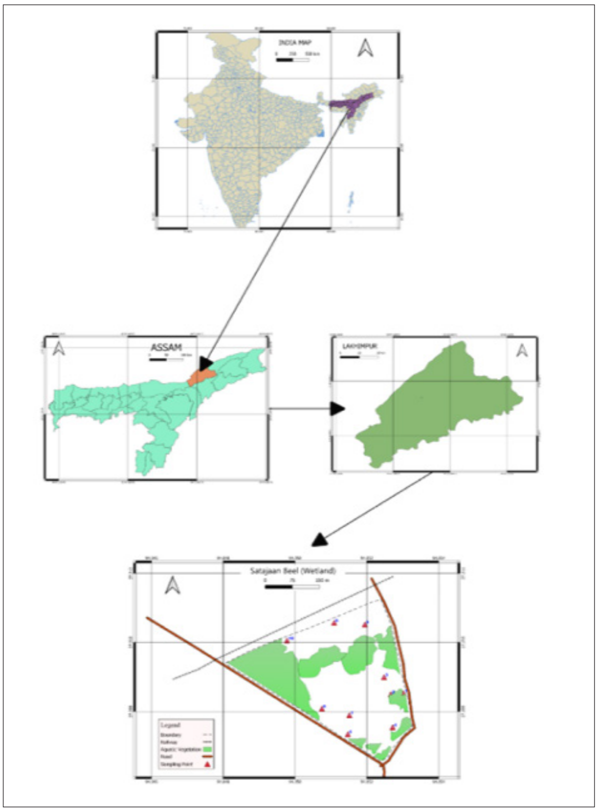

Figure 1: Map of Study area

Climate

The annual rainfall of Lakhimpur district averages around 300 cm, with maximum and minimum temperatures typically reaching up to 31°C and 7°C, respectively. These climatic conditions, characterized by significant rainfall and seasonal temperature variations, play a crucial role in shaping the ecological dynamics of the Satajaan Wetland. The wetland experiences a tropical monsoon climate, similar to the broader district, with four distinct seasons: winter, pre-monsoon, monsoon, and retreating monsoon. Each season brings specific weather patterns that influence the wetland's ecosystem and its biodiversity throughout the year.

Demography

Lakhimpur district in Assam is located on the northern bank of the Brahmaputra River and is known for its diverse cultural and ethnic composition. The majority of the population is Assamese, but the district is also home to various ethnic groups such as the Mishing tribe, Bodo tribe, Deori, Tiwa, and others. Despite their cultural diversity, these communities coexist harmoniously, sharing strong cultural and traditional bonds. The Satajaan Wetland, also known as a bird sanctuary, is surrounded by three small villages inhabited by the Mishing Tribe. The Mishing Tribe relies heavily on Satajaan Wetland for their livelihood and survival. They gather essential resources like firewood, wild edible plants, and medicinal plants from the wetland to meet their daily needs. This dependence underscores the critical role that Satajaan Wetland plays in supporting local communities, not just ecologically but also socio-economically, by providing direct benefits that sustain their traditional way of life.

Natural Vegetation and Biodiversity

The forested areas of Lakhimpur district are primarily characterized by tropical rainforests, which provide habitats for a variety of wildlife. Among the notable wild animals found in the district are elephants, leopards, wild dogs, monkeys, and langur monkeys [13]. According to the India State of Forest Report, 2019, the district has a total forest area of 306.57 sq km, including very dense forest covering 29.00 sq km, moderately dense forest covering 85.88 sq km, and open forest covering 191.69 sq km.

Wetlands, often referred to as the "Liver of the Landscape," play crucial roles in regulating various ecological functions and serve as vital habitats for diverse flora and fauna. Satajaan Wetland, densely vegetated with immersed, free-floating, and root-floating plants, supports a rich biodiversity. Numerous surveys conducted by conservationist groups such as the Asian Water Bird Census of India, Bird Conservation Network, and Bombay Natural History Society have recorded significant wildlife diversity in Satajaan Wetland. This includes three types of endangered turtles, 34 species of resident birds, 13 species of migratory birds, and 35 species of fish. Satajaan Wetland serves as a breeding site for Whistling Teal, White Breasted Water Hen, and Bronze Winged Jacana. It also acts as a nesting site for the Indian Purple Moorhen and Coots, while also attracting endangered migratory birds like the White-eyed Pochard from the Pacific Siberia [14]. These diverse habitats and species highlight the ecological importance of Satajaan Wetland as a crucial area for conservation and biodiversity preservation.

Materials and Methods

The samples were collected from 10 sampling points within Satajaan Wetland of Lakhimpur district during the pre-monsoon period in March 2022, using a random sampling method. Water samples were collected from specific depths as required for the study. During the sampling process, a field sheet was maintained to record field parameters, collection date and time, and the coordinates of each sampling location in the study area. Parameters such as pH, temperature, electrical conductivity (EC), salinity, and total dissolved solids (TDS) were measured immediately after sample collection in the field. Further laboratory analysis was conducted for parameters such as calcium, magnesium, sodium, potassium, hardness, phosphate, and sulfate. These laboratory tests provided more detailed insights into the chemical composition of the water samples collected from Satajaan Wetland, supporting a comprehensive assessment of water quality in the area.

Results and Discussion

Water Quality Status

Water Quality Assessment

Table 2 presents descriptive statistics for various water quality parameters collected from Satajaan Wetland. The pH values ranged from 3.26 to 10.56, with an average concentration of 5.2, indicating acidic water conditions. Total dissolved solids (TDS) in the wetland ranged from 114 to 282 mg/L. According to WHO guidelines, the highest desirable limit for TDS is 500 mg/L, while the maximum permissible limit is 1500 mg/L [15]. These findings provide insights into the chemical composition of water in Satajaan Wetland, highlighting areas where water quality standards may be monitored and managed to ensure ecological health and human usability.

Table 1: Methods adopted for analysis of different water quality parameters

Variables	Unit	Methods
Temperature	^{O}C	Digital Thermometer
pH	pH unit	Electrometric
Electric Conductivity	µS	Electrometric
Total dissolved solid	mg/L	Electrometric
Dissolved oxygen	mg/L	Winkler method
Total Hardness	mg/L	EDTA method
Alkalinity	mg/L	Titration Method
Calcium	mg/L	EDTA method
Magnesium	mg/L	EDTA method
Sodium	mg/L	Flame photometer
Potassium	mg/L	Flame Photometer
Chloride	mg/L	Titrimetric
Sulphate	mg/L	Spectrophotometric
Phosphate	mg/L	Spectrophotometric
Nitrate	mg/L	Spectrophotometric

Table 2: Statistical analysis of different water parameter variation in the study area

Parameters	Minimum	Maximum	Mean	Std. Deviation
pH	3.26	10.56	5.2000	2.00481
Temperature	30.60	31.70	31.0600	.39497
TDS	114.00	282.00	176.800	58.38150
Conductivity	101.00	470.00	250.600	98.99854
Salinity	.11	.27	.1600	.04546
Alkalinity	10.00	25.00	14.0000	4.59468
CO2	.02	.02	.0218	.00063
DO	16.11	84.56	34.4295	19.06442
Chloride	11.36	17.04	13.2060	1.77737
Hardness	12.00	36.00	26.4000	7.58947
Calcium	3.21	6.41	4.3286	1.08208
Magnesium	7.19	32.79	22.0714	7.49705
Sulphate	62.65	168.90	105.407	36.65091
Phosphate	-.01	5.64	1.7244	1.70649
Nitrate	17.66	32.11	27.8484	4.55657
Sodium	.00	1.53	.5540	.45191
Potassium	.94	4.10	1.7780	.95708

The total dissolved solids (TDS) values of the samples collected from the study area are within the WHO desirable limit of 500 mg/L. The minimum electrical conductivity (EC) was found to be 101 µS/cm, with a maximum of 470 µS/cm and an average of 250.6 µS/cm. According to WHO standards, the maximum permissible limits for EC are 1000 µS/cm, while BIS sets it at 3000 µS/cm. Dissolved oxygen (DO) levels in the study area ranged from 16.10 mg/L to 40.23 mg/L, averaging 28.38 mg/L. Total hardness (TH) varied from 12 mg/L to 36 mg/L, with an average of 26.4 mg/L. The desirable and maximum permissible limits for TH are 200 mg/L and 600 mg/L, respectively [16]. These findings suggest that the water quality parameters measured in Satajaan Wetland are generally within acceptable limits according to international and national standards, indicating favorable conditions for aquatic life and potential human use.

According to the classification of total hardness by USGS the all samples collected from the study area are soft in nature. The chloride of the study area is being fluctuated from minimum 11.36mg/L to 17.04mg/L with an average value of 12.78mg/L. Calcium is one of the major constituents of the total hardness of any water samples, as hardness is mainly governed by calcium and magnesium. By analyzing the water samples of the study area it has been found that the concentration of Ca varied from minimum 3.20mg/L to 6.41mg/L with an average value of 4.32mg/L. The experimental result of magnesium is presented in the Table 2. The analysis of the samples collected from the study area showed that the concentration of Mg has fluctuated from 66.84mg/L to 67.04mg/L having an average value of 66.86 mg/L. The observed value of sulfate of the study area ranges from 62.65mg/L to 168.902mg/L with an average value of 105.4976mg/L. From the present investigation it has been observed that the sulfate content of the study area within the standard value set by WHO and BIS (250mg/L & 200mg/L to 400mg/L respectively), which means the water is safe in terms of sulfate content contaminations. The present investigation of the water samples of the satajaan wetlands shows that the phosphate is fluctuated from minimum 0.01mg/L to maximum 5.636mg/L.

The present investigations indicated that the average phosphate concentration in the study area is approximately 1.72 mg/L. The relatively low phosphate levels observed in the samples collected from the study area may be attributed to adsorption by soil and uptake by plants [15].

Nitrate concentrations in the study area ranged from 17.662 mg/L to 32.11 mg/L, averaging 27.8 mg/L. These values are below the permissible limit set by WHO (45 mg/L). Elevated nitrate concentrations can lead to excessive algal blooms in water bodies. The main sources of nitrogen in water bodies include fertilizers, animal waste, and decomposing vegetation. Sodium levels in the study area ranged from 0 mg/L to 1.53 mg/L. Table 2 reveals that potassium concentrations varied between 0.94 mg/L and 4.1 mg/L, with an average of 1.778 mg/L. These findings provide insights into the mineral composition of the Satajaan Wetland, highlighting variations in essential nutrients crucial for aquatic and plant life. Correlation coefficient matrix of the different physical and chemical parameters of the samples collected from the study area has been derived in the Table 3. From the Table 3, It has been observed that conductivity of the water samples has a positive significant correlation with the pH and Alkalinity, while pH has a positive correlation with conductivity, salinity, alkalinity and potassium ion. Same way alkalinity of the water samples shows a significant positive correlation with the Potassium and Hardness has a positive correlation with the Magnesium.

Table 3: Physicochemical water quality parameters at different sampling site

Sample	Temperature	pH	TDS	Conductivity	Salinity	Alkalinity	Fe2O3	DO	Chloride	Hardness	Calcium	Magnesium	Sulphate	Phosphate	Nitrate	Sodium	Potassium
S1	31.6	5.1	150	159	0.17	15	0.022	34.16	12.78	30	3.20	16.79	125.86	3.87	25.70	1.64	2.6
S2	30.9	4.97	134	199	0.11	15	0.022	32.21	11.36	12	4.80	7.19	84.49	1.86	30.90	0.25	1.25
S3	31.2	3.9	146	307	0.17	10	0.022	36.24	12.78	28	6.41	21.58	81.70	2.69	28.79	0.81	1.42
S4	30.6	4.5	212	101	0.11	10	0.022	40.26	12.78	36	4.80	31.19	105.38	1.28	25.66	0	0.94
S5	30.6	4.48	123	247	0.13	15	0.022	28.17	12.78	28	4.80	23.19	51.98	1.07	26.55	0.28	1.04
S6	31.4	5.13	158	207	0.17	15	0.022	22.14	12.78	24	3.20	20.79	185.93	1.55	31.59	1.53	2.04
S7	31.7	10.56	157	417	0.27	25	0.022	22.14	11.36	28	4.80	23.19	80.60	-0.01	30.97	0.33	4.1
S8	30.9	4.23	282	282	0.15	10	0.022	32.21	12.78	20	3.20	16.79	62.65	0.22	17.66	0.22	1.19
S9	30.9	5.67	270	273	0.15	15	0.022	16.10	15.62	36	3.20	32.79	80.60	5.63	32.11	0.54	1.95
S10	30.8	3.26	156	264	0.17	10	0.022	32.214	12.04	32	4.80	27.19	165.60	1.05	30.51	0.96	1.75

Table 4: Correlation matrix of the physico-chemical parameters

	pH	Temperature	TDS	Conductivity	Salinity	Alkalinity	CO2	DO	Chloride	Hardness	Calcium	Magnesium	Sulphate	Phosphate	Nitrate	Sodium	Potassium
pH	1																
Temperature	0.611	1															
TDS	-0.059	-0.220	1														
Conductivity	.664*	0.429	0.004	1													
Salinity	.759*	.780**	-0.090	0.818**	1												
Alkalinity	.943**	0.168	-0.266	0.595	0.692*	1											
CO2	0.340	0.231	0.125	-0.048	-0.077	0.306	1										
DO	-0.215	0.304	-0.203	-0.461	-0.090	-0.176	0.041	1									
Chloride	-0.443	-0.355	0.314	-0.080	-0.098	-0.425	-.758*	-0.134	1								
Hardness	0.021	-0.291	0.350	0.043	0.103	-0.115	-0.259	-0.313	0.571	1							
Calcium	-0.052	-0.175	-0.518	0.234	0.036	-0.107	-0.156	-0.134	-0.145	0.156	1						
Magnesium	0.029	-0.269	0.429	0.040	0.099	-0.101	-0.240	-0.297	0.599	.990**	0.014	1					
Sulphate	-0.280	0.129	-0.358	-0.357	0.018	-0.145	-0.577	0.169	0.413	0.084	-0.179	0.111	1				
Phosphate	-0.160	0.052	0.293	-0.223	-0.197	-0.129	0.139	0.091	0.385	0.226	-0.234	0.263	-0.037	1			
Nitrate	0.305	0.279	-0.461	0.257	0.295	0.451	-0.206	-0.348	0.202	0.148	0.190	0.122	0.369	0385	1		
Sodium	-0.180	0.411	-0.226	0.023	0.259	-0.059	-0.316	-0.058	0.337	0.001	-0.167	0.025	.741*	0.206	0.497	1	
Potassium	.832**	.862**	-0.220	0.625	.924**	.816*	0.010	0.113	-0.235	-0.060	-0.090	-0.048	0.105	-0.160	0.344	0.192	1

*Correlation significant at the 0.05 level (2- tailed) **Correlation significant at the 0.01 level (2-tailed)

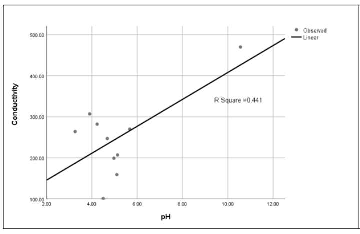

Figure 2(a): EC vs pH

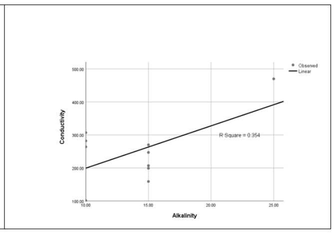

Figure 2(b): EC vs Alkalinity

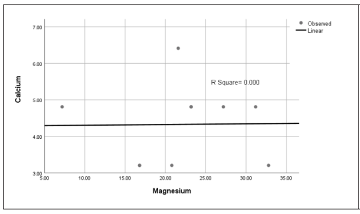

Figure 2(c): Calcium vs Magnesium

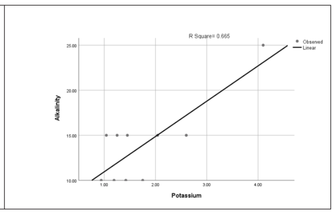

Figure 2(d): Alkalinity vs Potassium

Figure 2: Correlation graph of some significant parameters

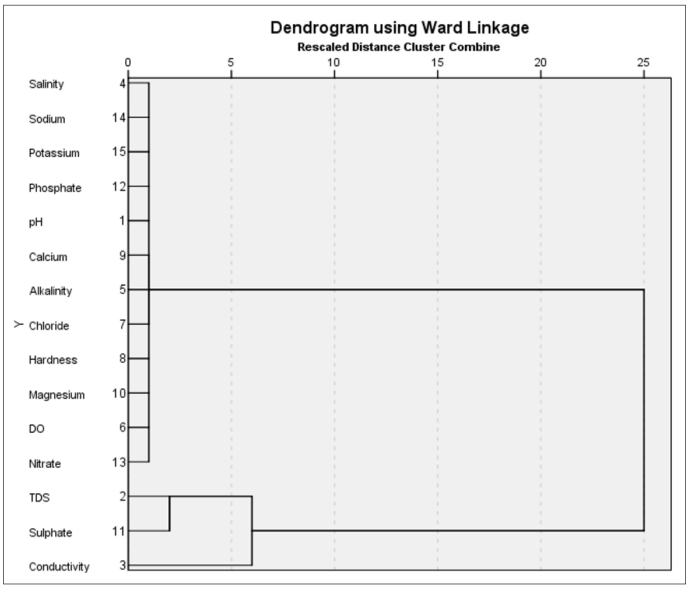

Figure 3: Dendrogram graphic of Cluster Analysis

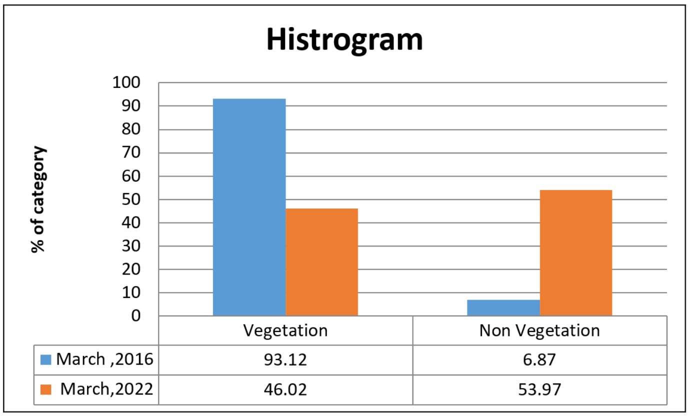

Figure 4: Histogram of parcentage of NDVI classification

From the correlation table, it is evident that several significant correlations exist among various water quality parameters in the study area. Strong correlations include Electrical Conductivity (EC) with pH (R^2=0.441) (Figure 5.14(a)), EC with Alkalinity (R^2=0.354) (Figure 5.14(b)), Alkalinity with Potassium (R^2=0.665) (Figure 5.14(d)), Potassium with Salinity (R^2=0.855) (Figure 5.14(e)), and Alkalinity with Salinity (R^2=0.478) (Figure 5.14(f)). Notably, pH shows no significant correlation with SO_4, NO_3, and PO_4, suggesting minimal influence of anthropogenic activities on pH levels in the study area.

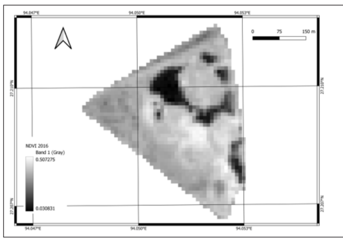

Figure 5(a): March, 2016

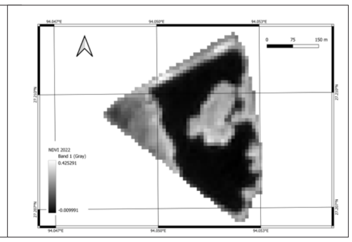

Figure 5(b): March, 2022

Figure 5: NDVI map of study area of 2016 and 2022 in grey scale

Water Quality Index

Among the 16 parameters analyzed during the study area, 14 parameters namely pH, EC, TDS, Chloride, Total Hardness, Calcium, Magnesium, Total Alkalinity, DO, Sodium, Potassium, Sulfate, Nitrate, Free Carbon di oxide were considered for the water quality index study. For the present study WQI was determined using the Weighted Arithmetic Water Quality Index method, which was originally developed by Brown et al. in 1970.

Table 5: Water quality standard recommended by BIS, ICMR and WHO

Parameters	BIS		ICMR		WHO	
	D	P	D	P	D	P
pH	6.5-8.5		7-8.5	6.5-9.2	7-8.5	6.5-9.2
EC	750	3000	-	-	-	-
TDS	500	2000	-	-	500	1500
Chloride	250	1000	-	-	250	-
Total Hardness	300	600	300	600	200	-
Calcium	75	200	75	200	75	200
Magnesium	30	100	50	150	50	150
Total Alkalinity	200	600	-	-	-	-
DO	-	-	-	-	-	-
Sodium	-	-	-	-	50	200
Potassium	-	-	-	-	-	-
Sulfate	200	400	-	-	-	250
Nitrate	45	-	-	-	50	-
Free Carbon di oxide	-	-	-	-	-	-

Water quality index can be calculated using following formula:
$WQI = \Sigma Q_n W_n / \Sigma W_n$

Where Q_n = quality rating scale of the nth parameter, W_n = the unit weight of the nth water quality parameter.

The quality rating scale, Qn for each parameter, is calculated by
$Q_n = 100\ [(V_n - V_i)/(V_a - V_i)$

Where V_n = the estimated concentration of nth parameter analyzed in the water, V_i = the ideal value of this parameter, $V_n = 0$ (except pH = 7.0 and DO = 14.6 mg/l), Vs =standard permissible value for the nth parameter.

Unit weight (Wn) is calculated using the formula:
$W_n = k/V_s$

where k is proportionality constant calculated by
$k = [1/\Sigma 1/V\ s = 1, 2, \dots, n]$

The water quality status (WQS) according to WQI is shown in Table 6.

Table 6: Water Relative weight (Wi) of the parameters used for WQI determination

Prameters (unit)	Standard value (Sn)	Relative weight (Wi)
pH	8.5	0.152246696
EC	3000	0.000431366
TDS	2000	0.000647048
Alkalinity	600	0.002156828
Total Hardness	600	0.002156828
Calcium	200	0.006470485
Magnesium	100	0.012940969
Sodium	200	0.006470485
Potassium	2.7	0.479295154
Sulphate	250	0.005176388
Nitrate	45	0.028757709
Chloride	1000	0.001294097
DO	5	0.258819383
Free CO2	30	0.043136564

The primary purpose of identifying the WQI is to protection of public health but also to protect the natural flora and fauna. This chapter will describe the physical and chemical parameter of water of the study area and comparison with national and international water quality guideline. The water quality index of the different samples collected from the study area shows that though water of the study area is safe in terms of different physical and chemical parameter but the water is not healthy in terms of WQI, indicating that the water of the study area is not suitable and assured for the human health.

Principal Component Analysis (PCA)
Principal Component Analysis (PCA) was conducted on the Table 5.5(a) to analyze the different chemical and physical parameters of the study area samples, identifying factors contributing to dataset variance. Component 1 explains approximately one-third (30.27%) of the total variance, showing strong positive correlations with pH, salinity, potassium, and moderate positive correlations with alkalinity and nitrate. Potassium and salinity have high positive factor loadings (0.97 and 0.13, respectively), while chloride and TDS show high negative loadings (both > -0.29) on the first principal component (PC1). This component indicates associations with high ion concentrations leading to elevated conductivity. Component 2 explains 20.07% of the total variance, demonstrating strong positive correlations with sodium and sulfate, and moderate positive correlations with nitrate and chloride.

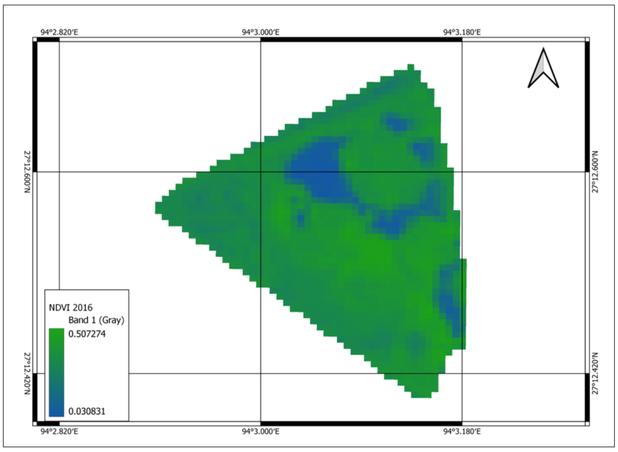

Figure 6: NDVI value bassd map of March, 2016

Different hydrogeochemical processes leading to increased mineralization are influenced by combinations of Na+, Cl−, HCO3−, and SO4− ions. PC 2 exhibits high positive factor loadings for sulfate and sodium (0.89 and 0.01, respectively), and negative loadings for free CO2 and TDS (both > -0.71). This suggests sulfate originates from the dissolution of feldspathoid groups and evaporite sediments, while the negative factor for free CO2 indicates biologically mediated sulfate reduction in metamorphosed carbonate rocks. PC 3 demonstrates the highest positive loading for total hardness and magnesium (0.96 and 0.02, respectively), and negative loadings for free CO2 and temperature (both > -0.38). Accounting for 15.77% of the total variance, Component 3 shows strong positive correlations with magnesium and hardness, and a moderate positive correlation with TDS. This component highlights magnesium ions as significant contributors to total hardness.

Cluster Analysis (CA)
From the dendrogram analysis, two distinct clusters have been identified. The first cluster includes temperature, free CO2, magnesium, chloride (Cl-), nitrate (NO3-), calcium (Ca+), salinity, pH, alkalinity, potassium (K+), dissolved oxygen (DO), phosphate (PO43-), and potassium (K+). The second cluster consists of total dissolved solids (TDS), sulfate (SO43-), and electrical conductivity (EC). Total dissolved solids (TDS) represent the cumulative concentration of all organic and inorganic substances present in liquid, whether molecular, ionized, or suspended. Elevated TDS levels often indicate increased dissolved substances in water, which can influence its chemical composition and environmental characteristics.

From the dendrogram, it has been observed that TDS, SO43- and conductivity are in the same cluster. TDS is measurement of dissolved combined content of all organic and inorganic substances present in liquid in molecular, ionized or suspended form. High TDS is often caused by sodium, chloride and potassium. Sulphate is also a constituent of TDS and may form salts with sodium, potassium, magnesium and other cations. The major sources of sulpahte are the dissolution of gypsum and anhydrite [17]. Sulpahate is also a major anion in hard water reservoir. Sulphate can be generated naturally as mentioned or may be result of municipal discharge as well as runoff from the fertilized agricultural land present nearby area also may contributes to the sulphate in the water body [17]. The realtion between TDS and EC can be derived as TDS (mg/L) = ke × EC (µS/cm) where ke is a constant of proportionality [18]. From the relationship it can be observed that there is a linear positive relationship between TDS and EC, i.e. increasing of TDS will increase the amount of EC, where sulphate is a major constituent of the TDS in case of water samples collected from the Satajaan wetland.

The cluster including temperature, free CO2, magnesium, chloride (Cl-), nitrate (NO3-), calcium (Ca+), salinity, pH, alkalinity, potassium (K+), dissolved oxygen (DO), phosphate (PO43-), and potassium (K+) demonstrates interrelated characteristics in water quality parameters. The solubility of carbon dioxide (CO2) in pure water varies with temperature and pressure, with lower temperatures reducing its solubility. When CO2 dissolves in water, it forms carbonic acid, increasing water acidity. Magnesium and calcium significantly contribute to water hardness, with magnesium hardness reflecting total hardness changes. Alkalinity and hardness interact through carbonate and bicarbonate ions, common in aquatic systems, influencing overall water quality. Additionally, phosphate can mitigate water hardness by sequestering metal ions, thereby influencing water mineral composition [19,20]. These interactions highlight the interconnectedness of parameters in assessing water quality.

Biodiversity of Satajaan Wetland

Fish Diversity of Satajaan Wetland

Fish being an obligate aquatic fauna, they are very important to evaluate the ecological health of the wetland. The study done by Hazarika revealed that there are as many as 42 species of fish belonging to 19 families [21].

Shannon index (H) is derived from a mathematical formula used in communication area by Shannon in 1948 which is applied to biological system [21]. In the present study of the fish diversity show the Shannon diversity index "H" is 3.066, indicates that the Satajaan wetland is in healthy status.

Pielou index (J) is one of the significant indexes which are applied to biological system, derived from Shannon index by Pielou in 1966 [21]. The value of Pielou index is 0.920, indicating that the fish of Satajaan wetland is almost equally distributed.

Simpson diversity index is an index applied to biological system, which was derived by Simpson in 1949 [21]. According to the table 5 the "D" and "1-D" values are 0.067 and 0.933 respectively of the Satajaan wetland, indicating satisfactory biodiversity of the habitat still now.

Table 7: WQI and status of water quality

Water Quality Index Level	Possible usage
0-25	Drinking, irrigation and industrial
25-50	Drinking, irrigation and industrial
50-75	Irrigation and industrial
75-100	Irrigation
>100	Proper treatment required before use

Table 8: WQI values of the samples collected from the study area

Sample No.	WQI Level	Water Quality Status
Sample no. 1	77.93	Very Poor Water Quality
Sample no. 2	92.60	Very Poor Water Quality
Sample no. 3	117.38	Unsuitable
Sample no. 4	113.47	Unsuitable for drinking
Sample no. 5	75.47	Very Poor Water Quality
Sample no. 6	78.27	Very Poor Water Quality
Sample no. 7	131.79	Unsuitable
Sample no. 8	98.275	Very Poor Water Quality
Sample no. 9	46.02	Good Water Quality
Sample no. 10	119.23	Unsuitable

Table 9: Factor loadings on the principal components for various water quality parameters

Parameters	Component					
	1	2	3	4	5	6
pH	.904	-.309	-.007	.028	.151	.058
Temperature	.834	.178	-.283	-.091	-.289	.171
TDS	-.143	-.294	.416	-.806	.144	-.025
Conductivity	.726	-.086	.096	.072	.503	-.246
Salinity	.943	.147	.126	.001	.059	-.174
Alkalinity	.870	-.162	-.162	.096	.161	.161
CO2	.143	-.718	-.365	-.150	-.076	.401
DO	-.037	.038	-.176	-.016	-.958	-.019
Chloride	-.288	.572	.652	-.201	.128	.028
Hardness	-.001	.011	.962	.055	.100	.090
Calcium	-.068	-.148	.138	.886	.118	-.178
Magnesium	.009	.033	.954	-.072	.085	.117
Sulphate	-.048	.898	.025	.068	-.220	.038
Phosphate	-.136	.050	.255	-.216	-.073	.851
Nitrate	.346	.449	.058	.417	.350	.588
Sodium	.139	.851	-.093	-.074	.067	.260
Potassium	.974	.133	-.030	.019	-.139	-.048
% of variance	30.27	20.07	15.77	11.13	7.92	5.92
Cumulative %	30.27	50.35	66.12	77.25	85.17	91.10

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization., a. Rotation converged in 7 iterations

Table 10: Fish diversity indices of Satajan wetland

Diversity Indices	Index Value
Shannon Diversity Index “H”	3.066
Pielou Evenness Index “J”	0.820
Simpson Diversity Index “D”	0.067
Simpson’s index of diversity “1 - D”	0.933

Table 11: NDVI divided statistics of the wetland of March, 2016

NDVI value based category	NDVI value	% of category	Area of category
Non-Vegetation	0.03-0.15	6.87%	2.37 acre
Vegetation	0.15-0.50	93.12%	32.14 acre

Table 12: NDVI divided statistics of the wetland of March, 2022

NDVI value based category	NDVI value	% of category	Area of category
Non-vegetation	-0.009-0.15	53.97%	18.63 acre
Vegetation	0.15-0.42	46.02%	15.88 acre

Vascular Plants Diversity of Satajaan Wetland

The present study of floristic survey in the Satajaan wetland using secondary data led to record of a total of 262 vascular plant species. It is observed that 262 no. of species of vascular plants have been found in Satajaan wetland. Out which only 7 are Pteridophytes and the remaining 255 are angiosperms that are again represented by 190 species of Magnoliopsida and 65 species of Liliopsida.

Avian Diversity of Satajaan Wetland

The surveys were done on 22 December 2019 from 0600-1400 h and 10 January 2021 from 0700-1200 h to record the diversity of birds visiting the study site in winter. They able to identify total of 71 and 68 bird’s species in the first and second surveys respectively. According to them they able to record total 87 species commutatively from the both surveys. From the surveys it has been observed that about thirty-four were migratory birds, of which eight were specifically waterfowls. In addition to the different species of resident birds found there, some migratory terrestrial birds were also recorded such as Tickell’s Leaf Warbler (Phylloscopus affinis), Pallas’s Grasshopper Warbler (Locustella certhiola), Black-faced Bunting (Emberiza spodocephala), and aquatic birds such as Gadwall (Mareca strepera) & Ferruginous Duck (Aythya nyroca).

Change Detection of Area of Aquatic Vegetation

The NDVI have been widely used to examine the relation between Spectral variability and the changes in vegetation growth. It is also used to determine the production of green vegetation and the vegetation changes.

Normalized Difference Vegetation Index (NDVI) is calcuated to monitoring the temporal chnages associuated to the vegetation change by using the following formula:

NDVI= (NIR-RED)/(NIR+RED) or NDVI = (Band 4- Band 3)/(Band 4+ Band 3).

The value of NDVI varies from -1 to 1, where soil, rocks have broadly had similar NDVI close to ‘0’, whereas near zero and negative values indicates the non-vegetation class such as water, snow, built up areas and barren lands. On the other hand, NDVI values little higher than ‘0’ indicates the vegetation cover, moderate and high value of NDVI indicates the stressed and healthy vegetation respectively. Only active vegetation has higher positive NDVI value typically between 0.1 and 0.6 [22].

From the NDVI calculation it has been observed that the area of the aquatic vegetation in the study area has been degreded drastically. The rate of degradtion of aquatic vegetation in the study area is calculated 2.84 acer or 7.84%.

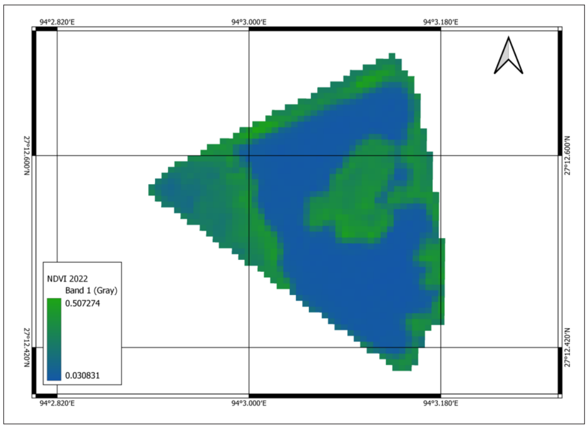

Figure 7: NDVI value bassed map of March, 2022

Conclusion

The present study investigates the water quality of the Satajaan wetland situated in the Lakhimpur district on the floodplain of Ranganadi. It was found that the quality of the wetland is not in good conditions with WQI value of above 50. The all parameters that have been analyzed within the study area revealed that only sample 9 is within the acceptable limits of WQI. The wetland is dominated by Mg and SO4 ions. Principle component analysis of the samples collected from the study area indicates the wreathing of feldspathoid groups. There is also indication of decaying of plants and animal’s matter.

The floristic survey carried out in the Satajan Beel (wetland) in the Lakhimpur district of Assam in NE India led to record of a total of 262 Species of vascular plants. The present study revealed that there are as many as 42 species of fish belonging to 19 families. Among the families Cyprinidae having 13 species followed by Channidae (04 Species), Bagridae and Osphronemidae (3 species each). The surveys were done on 22 December 2019 from 0600-1400 h and 10 January 2021 from 0700-1200 h able to record total 87 species commutatively from the both surveys.

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