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Mapping and Assessment of Blue Resource by using Remote Sensing Application, Nadia, West Bengal

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Abstract : *Identification and monitoring of blue resources or water resources is an easy-cost-effective task through geospatial ways instead of conventional ways which can achieve sustainable development goals (SDGs). This study focused on blue resource, mainly waterbodies in Nadia District, West Bengal. The aim of this study is to classify waterbodies according to their extent, origin, special characteristics and also assessment of water quality of those waterbodies. Sentinel-2 with special resolution 10 m images have used as datasets and four key indices such as Modified Normalized Difference Water Index (MNDWI), Normalized Difference Chlorophyll Index (NDCI), Normalized Difference Turbidity Index (NDTI), Normalized Suspended Material Index (NSMI) have used to classify and assessment. The outcomes have arrived total 50,520 waterbodies among them 21,066 consists of high clarity or good water quality, 26,555 consists of moderate clarity and 2,899 consists of low water clarity or turbid water. The findings portrait that geospatial techniques are the best way for classification and assessment of water resources and revive the low water clarity or turbid waterbodies with help of nature based solution (NBS) can help us to achieve the Sustainable development in rural and urban areas.*

Key words: *Blue Resource, Geospatial Techniques, Sentinel-2, Monitoring, Nadia*

1. Introduction

The 'Kidneys of Landscape', waterbodies that serves as transitional zone between watersheds and landmasses (Roy and Behera, 2003; Behera et al., 2011). It is one of the most valuable natural resource of the world as they provide a wide range of habitats for various species of animals and plants also serve various natural, economic, social, cultural, recreational features (Mwita et al., 2013; Yang et al., 2021). However, over the last few decades, most of the world's waterbodies have undergone a variety of stress such as hydrologic changes, land use changes, eutrophication, pollutant runoff contamination and fragmentation, due to economic development and human

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disturbance, resulting in heavy impacts on waterbodies' health conditions. Not only that, water hyacinth (Korgaonkar and Gokhale, 2007; Behera et al., 2011) and industrial waste (Reddy, 2007) have become a great threat to aquatic flora and fauna. The status of waterbodies are primarily concerned with maintaining their extent, health and ecological integrity (Fennessy et al., 2004). It also depends on internal and external disturbance of waterbodies, surrounding landscape, their restoration, conservation, mitigation plans and decisions. Thus, waterbodies monitoring, construction, protection, restoration, and management need appropriate assessment methods that have enabled scientists, researchers and practitioners to bring success to their work by requiring standards performance and relative evaluation methods (Mollard et al., 2013). Therefore conservation and management of existing waterbodies are very important to prevent further damage of waterbodies. More ever, inventory, assessment and monitoring of waterbodies are very important and necessary.

The use of sensing applications to analyse waterbodies' classification and quality assessment has been adopted since 1970s (Wang et al., 2004; Chen et al., 2007, 2008; Zhengjun et al., 2008; Su, T.-C. , 2017; Karunakaran et al., 2019). In last few decades, the use of remote sensing and geographical information system (RS and GIS) technology to analyse the extent and quality of waterbodies have implemented and developed (Langan et al., 2019). This technology brings about significant improvements and new possibilities for waterbodies' monitoring day by day. Some researchers have designed waterbodies' classification and extent through Remote Sensing technology in India (Gopal & Sah, 1995; Panigrahy, 2017; Sinha et al., 2017), Australia (Pressey & Adam, 1995), China (Yu et al., 2001; Xu, 2006; Haibo et al.,2011), United States of America (Work and Gilmer., 1976; Lathrop and Lillesand 1986; McFeeters, 1996; Gao, 1996) etc.

In further, Remote Sensing technology has often been used as cost effective tools for monitoring and rapid effective assessment of rivers, reservoirs, wetlands and fisheries habitats in large areas. BIS (2012), ICMR, WHO, Ministry of Environment and Forests, CPCB, Water Environment Partnership in Asia (WEPA) have recommended almost 29 components for water quality analysis, among P^H, Temperature, BOD, COD, DO, Conductivity, TDS, TSS, Turbidity, Chlorophyll, Fecal Coliform, Nitrate - N etc. are more significant for water quality assessment. Among them, remote sensing applications were first implemented to estimate suspended sediment in surface waterbodies (Ritchie et al., 1974; Ritchie et al., 1976). Only a few of the above parameters can be monitored by Remote Sensing data, chlorophyll-a (Chl-a) (Chen et al., 2008; Wong et al., 2008; Zhengjun et al., 2008; Tebbs et al., 2013; Bonansea et al., 2015; Dona ˜ et al., 2015; Harvey et al., 2015; Kiefer et al., 2015; Su and Chou, 2015; Dörnhöfer and Oppelt, 2016; Dlamini et al., 2016), turbidity (Doxaran et al., 2002; Chen et al., 2007; Wong et al., 2008; Petus et al., 2010; de la Mare et al., 2012; Caballero et al., 2014), and total suspended solids or sediments (TSS) (Chen et al.,2007). But, other chemical parameters of water quality such as BOD, COD, DO, Total Nitrogen (TN), Total Phosphorus (TP), Ammonia nitrogen (NH3-N) etc. cannot be directly measured by remote sensing data (Zhang et al., 2021).

Here, satellite images, Landsat (Cox et al., 1998; Kloiber et al., 2002a,b; Brezonik et al., 2005; Sriwongsitanon et al., 2011; Zhao et al., 2011; Tebbs et al., 2013), MODIS (Hu et al., 2004; Miller and McKee, 2004; Chen et al., 2007; Petus et al., 2010; Dlamini et al., 2016), SPOT (Ouillon et al., 1997; Doxaran et al., 2002), ENVISAT (Harvey et al., 2015; Kiefer et al., 2015) or Sentinel-2 (Su, T.-C., 2017; Xu et al., 2018; Caballero et al., 2022; Zhang et al., 2021) have mostly used to monitor water quality because the high spatial resolutions of 30m or 10m above the images remain unsuitable for mapping small waterbodies (Su and Chou.,2015; Su T.-C., 2017; Zhang et al., 2021). Therefore, the present paper has attempted to identify and analyse the quality of waterbodies in Nadia district through geospatial application.

2. Study Area

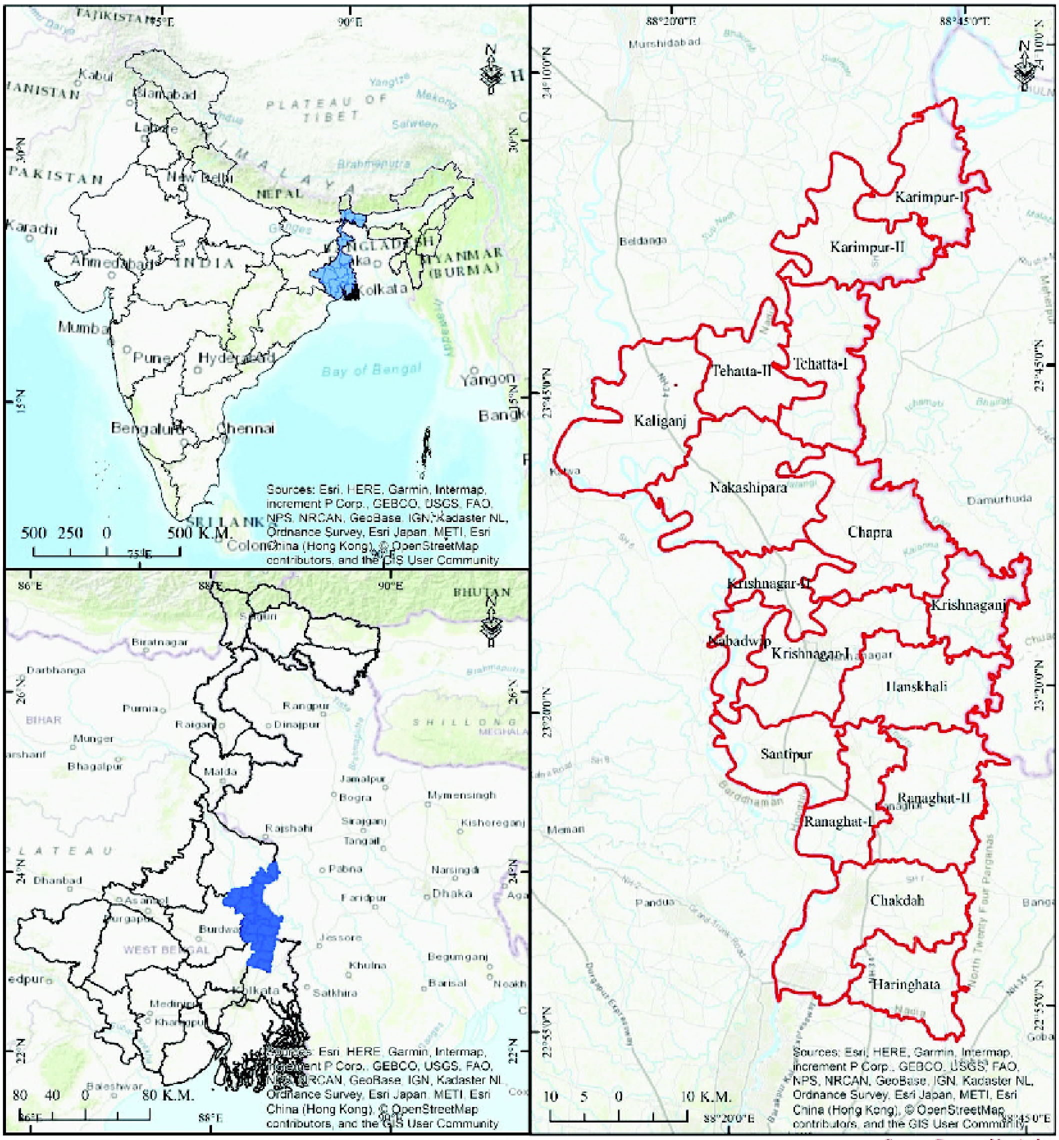
The gangetic delta has mainly subdivided into three divisions such as moribund, mature and active delta (Bagchi, 1944). Only two districts, Murshidabad and Nadia have fallen there. The present paper has chosen as a study area Nadia district which has extended from 22°51′ 57″ N to 24°12′ 48″ N and 88°07′ 28″ E to 88°48′ 27″ E. This district obtained a gentle slope with south- east gradient in general. It has interspersed with lots of jhils, marshes and old river's bed (Majumdar, 1978). The origin of these geomorphic features has been obtained from oscillation of the river Bhagirathi-Hooghly, Bhairab, Jalangi, Mathabhanga-Churni-Ichamati. The maximum-minimum temperature and presently annual normal rainfall of this district are 33°C, 26°C and about 1427mm according to Annual flood report, 2023 published by irrigation and waterways directorate, Govt. Of West Bengal (Figure 1). The main objective of the selection as a study area, Nadia District, is about 7.18% or 281.80 Sq. Km of the total geographical area (3927 Sq. Km.) of this district covered by the wetland area (NWIA Report, 2015) and the residents of this area have chosen fishing as their second livelihood after agriculture. The changing rate of percentage in multidimensionally poor population is lower in Nadia district (11.07% in NFHS-4, 2015-16); 8.20% in NFHS-5, 2019-21) than Murshidabad district (27.23% in NFHS-4, 2015-16); 16.55% (NFHS-5, 2019-21) according to the national multidimensional poverty index (this index based on health and nutrition, education, and standard of living) which was published by Niti Aayog in 2023.

3. Materials and Methods

3.1 *Method for waterbodies Extraction and processing from Sentinel -2 Images*

3.1.1 Selection of Sentinel -2 images and pre- processing

There are two images containing distinctive images, so a single image can't give the total geographical area of this district. Add up two tiles image of 09.01.2022 dated. Chosen image download from Copernicus Open Access Hub (https://scihub.copernicus.eu/). Detailed information about these images is (45QXG and 45QXF dated 09.01.2022). Cloud coverage less than 10% is majorly selected for this work to minimise the sessional error effects. To get a delineated area, the mosicking process is executed by using ArcGIS-10.2.2 software (ESRI).



Source: Prepared by Author

Figure 1: Study Area Nadia District

3.1.2 Method of Waterbodies extraction from images and mapping

Modified Normalized Difference Water Index (MNDWI) of Xu (2006) is utilised here for water bodies extraction and mapping. Green and SWIR bands have used hare.

Modified Normalized Difference Water Index (MNDWI)

$$= \frac{(\text{Band 3 GREEN}) - (\text{Band 11 SWIR})}{(\text{Band 3 GREEN}) + (\text{Band 11 SWIR})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Using this index, the satellite image has been processed. The DN value range of this processed image will be -1 to +1 and 0 is the threshold value where the positive values indicate water and the negative values indicate other terrestrial units. So, the new classified image shows two land use features such as water and non-water bodies. Finally, the area of waterbodies has been identified and it has also segregated according to their CD block boundaries. The water bodies which are located among two or more CD block boundaries are included in this block where centroids of waterbodies are located. Afterthat a multi-level classification scheme has adopted from Ramsar definition of wetlands and report of National wetland inventory and assessment (NWIA). Waterbodies are classified into three levels-

Level-I shows the extent of the water bodies such as Inland or Coastal.

Level-II shows the basis of origin such as Natural or Man- made and

Level-III shows the special characteristics of water bodies such as Lake, Ox-bow Lake, River, Pond, Riverine wetland, Waterlogged and Others.

3.1.3 Method for Surface Water Clarity based on multiple indices

To assess the overall health conditions of waterbodies, geographical information technology has given us a new opportunity. To determine waterbodies health conditions, three indices have been taken together. They are-

Normalized Difference chlorophyll Index (NDCI)

$$= \frac{(\text{Band 5 Vegetation Red Edge}) - (\text{Band 4 Red})}{(\text{Band 5 Vegetation Red Edge}) + (\text{Band 4 Red})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Normalized Difference Turbidity Index (NDTI) Index

$$= \frac{(\text{Band 4 Red}) - (\text{Band 3 Green})}{(\text{Band 4 Red}) + (\text{Band 3 Green})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Normalized *Suspended Meterial* Index (NSMI)

$$= \frac{(\text{Band 4 RED}) + (\text{Band 3 GREEN}) - (\text{Band 2 BLUE})}{(\text{Band 4 RED}) + (\text{Band 3 GREEN}) + (\text{Band 2 BLUE})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

With the help of above bands, chlorophyll, turbidity and total suspended solids have measured separately of every waterbodies. The range of the all indices values varies from -1 to +1. This is a notable issue that higher values (which are closer to +1) of NDTI, NDCI and NSMI are representative of turbid water and the lower values (which are closer to -1) indicate the clear water of water bodies (Chen et al., 2007; NWIA, 2010; Somvanshi et al., 2011; Mishra & Mishra, 2012; Alka et al., 2014; Beck et al., 2016; Arisanty & Nur Saputra, 2017; Xu et al., 2018; Nguyen et al., 2020) Afterthat a common class had been used here to examine that the indices values are comparatively high or low of a waterbody (Figure 2). The common classes are-

Mean (μ) -Standard Deviation (1σ) = Low

Mean (μ) +Standard Deviation (1σ) = Moderate

Value of more than Moderate range = High

Finally, to determine the health conditions, the value of the same weightage of all components has been integrated like human development index (HDI) and made a new index that is known as Surface water clarity index (SWCI). It has also been segregated according to their CD block boundaries and mapping them. The formula is as below-

$$SWCI = (I^{NDCI} \cdot I^{NDTI} \cdot I^{NSMI})^{1/3}$$

3.1.4 Method of validation

The ground control points of major waterbodies have been taken from the field for validating the current wetland map using Global Positioning System (GPS) and some reference sites have been demarcated through high resolution Google earth images and also validated through the high resolution Annual map of Earth's land surface (https://livingatlas.arcgis.com/landcover). Road network data were collected from Open Street Map (OSM) (https://www.openstreetmap.org). To examine the health conditions of waterbodies water and soil tests have also been done in the laboratory.

4. Results and Discussion

4.1 *Classification and Assessment of waterbodies*

4.1.1 Classification of waterbodies according to their extent and origin

According to Modified Normalized Difference Water Index (MNDWI) value ranges, there has been identified about 50520 waterbodies and also covered by 38564 ha area water resources (Table 1). Among them, 94.19% or 36324 ha (36324 waterbodies) of area has enfolded by natural wetlands, 5.14% or 1983 ha (133 waterbodies) of area has been enveloped by man- made wetlands and 0.67% or 257 ha (21 waterbodies) of area has been covered by others where sometimes water presence had observed (Figure 3). According to Ramsar definition of wetlands and report of

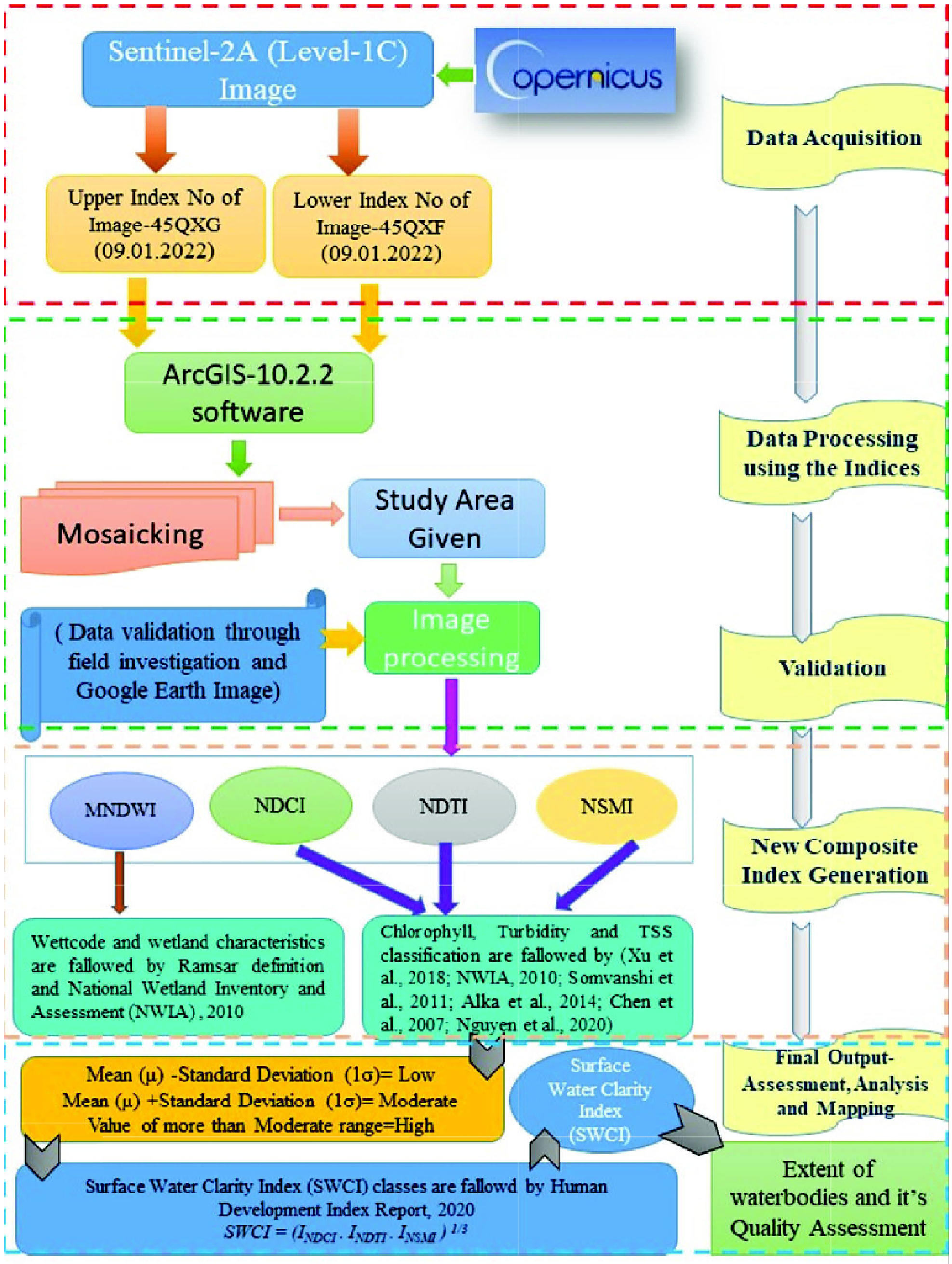


Figure 2: Overall framework of methodology

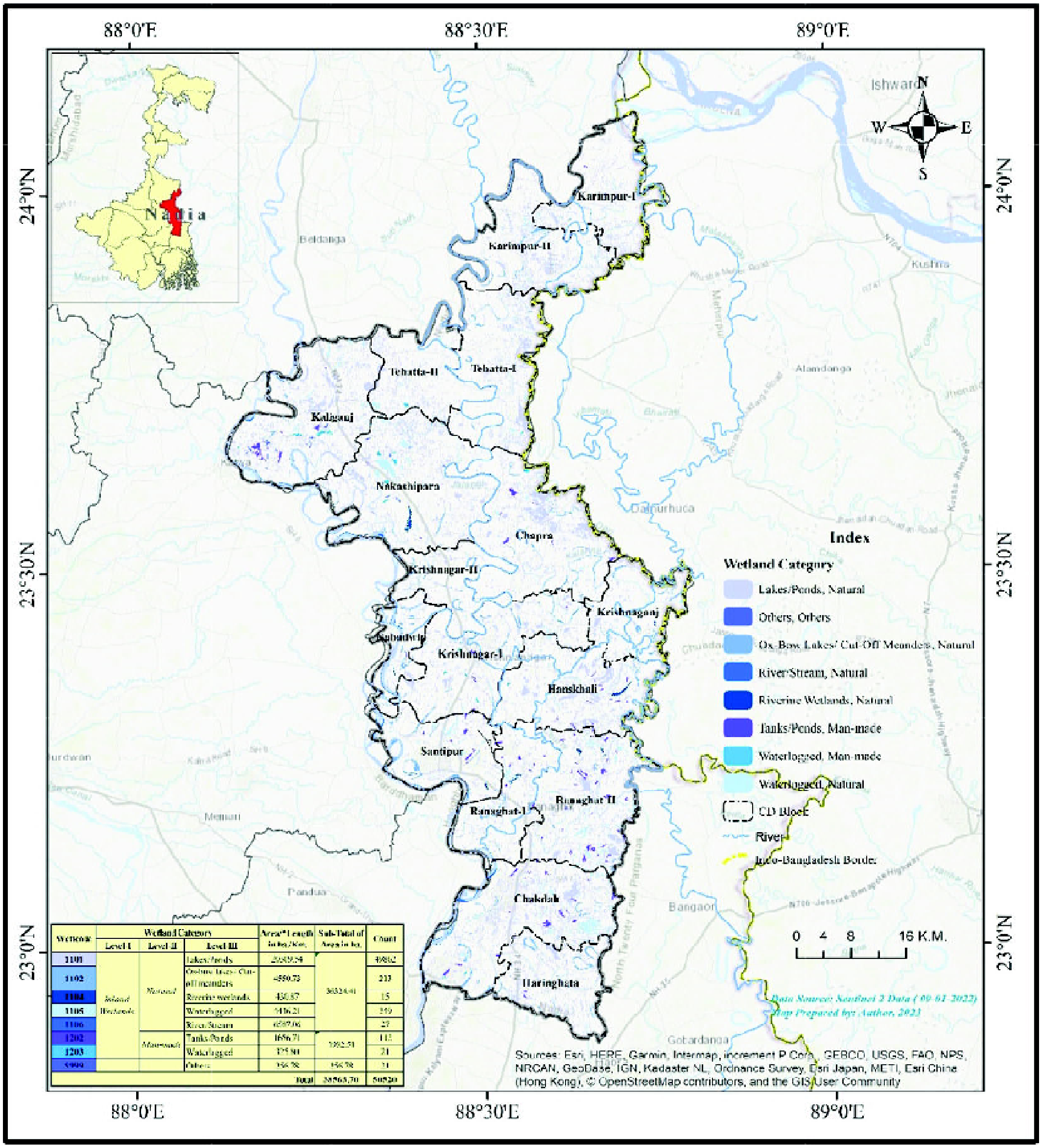


Figure 3: Distribution of waterbodies in Nadia District.

National wetland inventory and assessment (NWIA) classification scheme, there are no such footprints of high altitude wetlands, reservoirs/ Barrages, salt pans (Inland wetlands) and coastal wetlands in this study area.

Table 1: Estimated Area of waterbodies in Nadia District

Sl. No.	Wettcode	Wetland Category	No. of Wetlands	Total Wetland Area (in ha)	% of Wetland Area (in ha)
	1100	Inland Wetlands-Natural	2022	2022	2022
1	1101	Lakes/Ponds	49862	20310	52.66
2	1102	Ox-bow lakes/ Cut-off meanders	213	4551	11.80
3	1103	High altitude wetlands	0	0	0
4	1104	Riverine wetlands	15	431	1.12
5	1105	Waterlogged	249	4446	11.53
6	1106	River/Stream	27	6587	17.08
		Sub-Total Inland Wetlands-Natural	**50366**	**36324**	**94.19**
	1200	Inland Wetlands-Mane-made			
7	1201	Reservoirs/Barrages	0	0	0
8	1202	Tanks/Ponds	112	1657	4.30
9	1203	Waterlogged	21	326	0.84
10	1204	Salt pans	0	0	0
		Sub-Total Inland Wetlands-Man-made	**133**	**1983**	**5.14**
		Sub-Total Inland Wetlands-Natural and Man-made	50499	38307	99.33
11	9999	Others (where sometimes water presence)	21	257	0.67
		Total	**50520**	**38564**	**100**

Note: *High altitude wetlands, Reservoirs/Barrages and Salt pans wetlands category were not observed in this Study Area*

Source: Modified Normalized Water Index (MNDWI) from Sentinel 2 Data, 09-01-2022

4.1.2 Classification of waterbodies according to their special characteristics

Table no 1 reflects that there are numerous waterbodies according to their special characteristics. From natural wetlands, the area has occupied by lakes/ ponds 20309.54 ha (49862 waterbodies); ox-bow lakes/ cut-off meanders 4550.73 ha (213 waterbodies); riverine wetlands 430.87

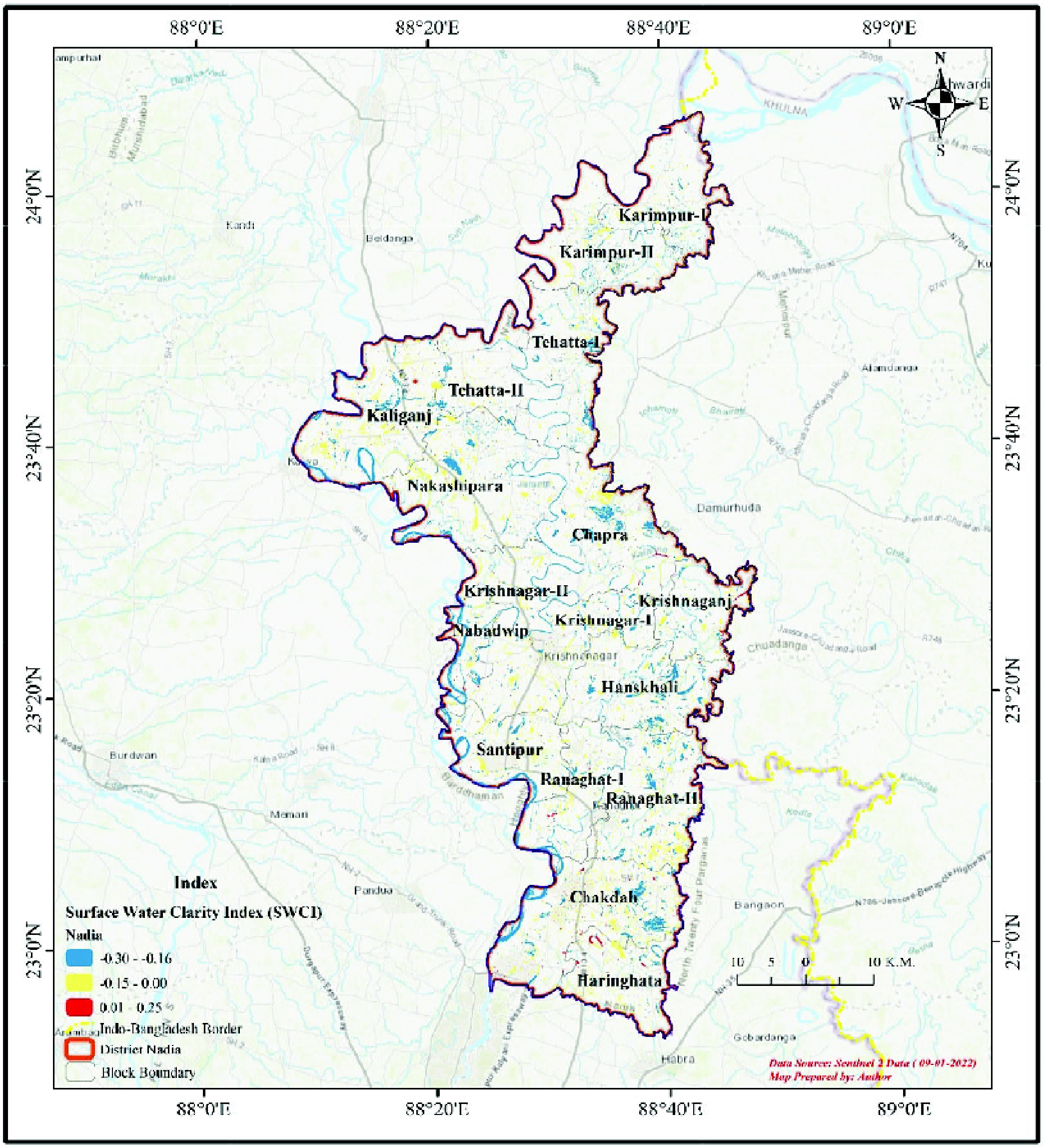


Figure 4: Surface Water Clarity Index (SWCI) in Nadia District

ha (15 waterbodies); waterlogged 4446.21 ha (249 waterbodies); river/ stream 6587.06 ha (27 waterbodies) respectively. On the other hand, man-made wetlands have covered by tanks/ponds 1656.71 ha (112 waterbodies) and waterlogged 325.80 ha (21 waterbodies). Only 256.78 ha area or

21 waterbodies could not be perfectly categorised between natural and man- made wetlands (Figure 3).

4.1.3 Assessment of waterbodies according to their water quality

In previous decades water quality was assessed only through conventional ways but now it can be measured through geospatial techniques. All identified waterbodies have been segregated according to their water clarity (Surface Water Clarity Index or SWCI) to determine their present status of water quality. The maximum- minimum value of SWCI has been observed - 0.31 to +0.25. The ranges -0.31 to -0.16 indicates high water clarity or good water quality; -0.15 to 0.00 indicates moderate water clarity or quality and 0.00 to +0.25 indicates low water clarity or turbid water. From above observation (total waterbodies - 50520), high water clarity has been observed among 21066 waterbodies; moderate water clarity has been found among 26555 waterbodies and low water clarity has been seen among 2899 waterbodies (Figure 4).

5. Conclusions

In conclusion, this study provides a comprehensive classification of waterbodies and an assessment of their current health conditions. Here the use of multi-temporal remote sensing technology is essential for the effective identification and continuous monitoring of these important resources. Furthermore, the restoration of turbid or low-clarity water bodies through nature-based solutions (NBS) gives an opportunity for promising pathways toward achieving long-term sustainability. Emphasizing the integration of advanced technologies and natural approaches will be crucial for ensuring the sustainable management and preservation of water resources in the future.

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