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RESEARCH PAPER

Spatial distribution and characteristics of wetlands in Dibrugarh district, Assam: a GIS based approach

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Abstract
Wetlands are vital ecosystems that offer numerous benefits, including supporting biodiversity, regulating climate and aiding public health. Covering only about 6% of the earth's surface, they are incredibly productive, providing habitats for various plant and animal species. Despite their importance, wetlands are under threat from human activities such as agriculture, urban expansion and climate change. This study aims to create a detailed inventory of wetlands in the Dibrugarh district of Assam, India, utilizing high-resolution satellite imagery. Dibrugarh, with its diverse landscape comprising floodplains, lakes, swamps and man-made ponds, is shaped significantly by the Brahmaputra River and its tributaries, Burhidihing and Sessa. Using Resourcesat 2A LISS-IV data, which provides detailed multispectral images, the study identified 1,832 wetlands covering 2,249.94 hectares. These include 18 floodplain wetlands, 70 ox-bow lakes, 23 waterlogged areas and 1,721 ponds and tanks. The Brahmaputra River alone contributes to 18 major wetlands, while the Burhidihing and Sessa rivers form numerous ox-bow lakes. The mapping process involved digitizing the wetland boundaries using ArcGIS software, analyzing their spatial distribution, and comparing them with previous inventory. The study found a significant increase in the number of wetlands identified compared to earlier assessment. The detailed comprehensive inventory of wetlands produced in this study are crucial for informed decision-making by government bodies, urban planners and NGOs. Government bodies can use the data for policy formulation and environmental monitoring. Urban planners can ensure sustainable development and land use planning that preserves wetland ecosystems. NGOs can enhance conservation efforts, community engagement, and sustainable livelihood initiatives.

Keywords Wetland mapping · Remote sensing · GIS · Dibrugarh district

Introduction

Wetlands are dynamic and highly productive ecosystems, offering numerous essential goods and services to human society (Mu et al. 2020; Perennou et al. 2018; Roy-Basu et al. 2020; Colvin et al. 2019; Li et al. 2020; Song et al. 2020). These valuable land resources serve a multitude of natural, social and productive purposes, delivering a broad spectrum of ecosystem services. Although wetlands cover merely about 6% of the earth's surface, they rank among the planet's most productive ecosystems (Turner and Jones 1991). They play a pivotal role in areas such as climate regulation, biodiversity, hydrology and public health (Ramsar Convention Bureau 2001). This significance stems in part from their position as transitional zones between purely aquatic and terrestrial environments, providing food and critical habitats for humans and a diverse array of terrestrial and semi-aquatic animals and plant species. The combination of aquatic and terrestrial habitats within wetlands offers various food sources and providing sites for migratory birds. Additionally, wetlands are highly beneficial to humans due to the diverse habitats they support. Globally, wetlands are utilized for recreation, agriculture, education and timber production (Hollis and Acreman 1994). Many researchers frequently assert that 50% of the world’s wetlands have been lost, though this figure is based on limited evidence (Finlayson 2005; Davidson 2007). More recent estimates by the Ramsar Convention Secretariat (2010) indicate that approximately 64% of global wetlands have been repurposed for other land uses since 1900, with particularly high rates of conversion in floodplain areas (Sanchez-Espinosa and Schroder 2019;

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Tesch and Thevs 2020). The loss and degradation of wetlands are undeniable realities, primarily driven by human activities. The most prevalent causes include agricultural encroachment, urban expansion and the draining of wetlands (Lu et al. 2019; Ondiek et al. 2020; Paul and Pal 2020; Shengjie et al. 2017; Saha and Pal 2019a, 2019b). Human activities are not the only threats to wetlands; invasive species and climate change also exert significant pressure on these ecosystems (Ramsar Convention 2018). As wetlands face numerous challenges, the necessity for effective management and monitoring becomes increasingly critical to their conservation and protection.

To effectively manage and conserve wetland resources, understanding their distribution, location, extent and dynamic changes is crucial. However, defining wetlands universally is challenging due to their diversity (Cowardin et al. 1979; Tiner 2009). Wetlands encompass a broad range of aquatic habitats such as marshes, swamps, bogs, fens, peatlands aquatic beds etc. Generally, wetlands serve as transitional zones between aquatic environments and terrestrial upland areas. Thus, defining the boundaries of wetlands along a water gradient is somewhat arbitrary. Definitions of wetlands can vary, with some including open-water habitats like lakes and rivers, while others exclude permanent deepwater bodies and focus on shallower areas. For instance, the U.S. national wetland classification system generally does not consider permanently flooded freshwater areas deeper than 2 m as wetlands, classifying them instead as deepwater habitats (Cowardin et al. 1979). Conversely, the Ramsar Convention's international wetland conservation treaty defines as "*areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres*" (Ramsar Convention Secretariat 2016). In Canada, wetlands are defined as areas where land is saturated with water long enough to support wetland or aquatic processes, indicated by poorly drained soils, hydrophytic vegetation, and various biological activities adapted to wet environments (National Wetlands Working Group 1997). Despite these technical differences in definitions across countries, there are commonalities. The presence of water, whether temporary or permanent, must be sufficient to support specific animal species, plant communities, soil development and the range of functions associated with wetlands (Tiner 2015). According to Wetlands of India Portal, major wetland types are lakes and ponds, ox-bow lakes, floodplain wetlands, marshes, estuaries, swamps and man-made wetlands such as aquaculture ponds, reservoirs, dams, salt pans and barrages (Wetlands of India Portal).

A crucial tool for wetland management and monitoring is the creation of highly detailed and accurate wetland maps (Ramsar Convention on Wetlands 2018). These maps are essential for identifying threats and pressures on wetlands and assessing the effectiveness of conservation policies (Chasmer et al. 2020). The perception of people on wetlands as wastelands and administrative indifference contribute significantly to their conversion into other land use types. Additionally, the lack of comprehensive large-scale wetland inventories exacerbates wetland loss and degradation (Ekumah et al. 2020; Endter-Wada et al. 2020; Mahdianpari et al. 2020; Uniyal et al. 2020; Xu et al. 2019a, 2019b). Geographic Information System (GIS) coupled with remote sensing (RS) technologies have shown significant value in mapping and monitoring wetland resources (Adam et al. 2010; Lang et al. 2015; Lyon et al. 2001; Rebelo et al. 2009). These technologies generate essential data for wetland conservation, restoration and management efforts. Advances in technology have resulted in the availability of remotely sensed imagery with enhanced spatial, temporal and spectral resolution, improving the precision and detail of wetland maps and inventories.

Traditional wetland mapping through visual interpretation of aerial photographs can also be expensive and labor-intensive (LaRocque et al. 2020). For extensive areas, such as a district, satellite images from Earth observation satellites are a viable alternative to aerial photographs. Modern satellite imagery offers multi-temporal data at a lower cost, covering large areas with appropriate spatial and temporal resolution, which enables frequent updates of wetland cover maps (Bwangoy et al. 2010; Amani et al. 2017). Despite the challenges, these advanced technologies facilitate the effective monitoring of wetlands. Field-based methods, although precise, are impractical for large-scale mapping due to their time and cost demands. Instead, satellite imagery provides an efficient and cost-effective solution for large-scale and fine-resolution wetland mapping, enabling researchers to capture dynamic changes and update maps regularly. This approach is particularly important for capturing the ecological significance of smaller floodplain wetlands, ensuring comprehensive and accurate wetland management and conservation efforts.

There are few global and national wetland inventories available, most of which offer only coarse spatial resolution. Finer resolution inventories are almost non-existent, particularly in developing countries like India (Ramsar Convention Secretariat 2010 and 2016). In India, the most recent and comprehensive wetland inventory is the National Wetland Atlas, prepared by SAC in 2011. This atlas identified and mapped a total of 201,503 wetlands across the entire country on a 1:50,000 scale (National Wetland Inventory and Assessment (2011). Additionally, the only detailed wetland map of Assam, which includes various wetland classes, was created by ARSAC and ISRO in 2010 using IRS LISS 3 satellite imagery with a spatial resolution of 23.5 m (National Wetland Atlas Assam 2010). However, there is a need for studies with even finer resolution due to the ecological importance of numerous smaller floodplain wetlands. Field-based mapping is a recognized and effective method, but it is both time-consuming and costly. Furthermore, a one-time field survey is insufficient for managing wetlands, which are highly dynamic environments. Therefore, researchers often rely on historical satellite images for wetland mapping and time series monitoring over large areas (Mao et al. 2020; Martins et al. 2020; Perennou et al. 2018; Weise et al. 2020).

Assam is richly endowed with wetlands, known locally as *beels*, making the region highly diverse and ecologically dynamic. The lakes in the Brahmaputra and Barak valleys predominantly occupy the floodplains, having originated from these rivers. However, many of the lakes across the Himalayan belt are experiencing ecological stress (Vass et al. 1997). Assam's diverse wetland ecosystems highlight the intricate relationship between biodiversity and human well-being, acting as natural buffers against floods by absorbing excess water during the monsoon seasons and mitigating the impacts of extreme weather events. Notably, Dibrugarh ranks first in terms of the percentage of geographic area covered by wetlands within the district (National Wetland Atlas Assam 2010). Despite this, no studies have been conducted using high-resolution images to analyse these wetlands. The only study, conducted by Lahon et al. (2023), on Merbil with a 30 m spatial resolution. Therefore, this study aims to understand the spatial distribution and characteristics of wetlands in the Dibrugarh district, Assam.

Materials and methods

Description of the study area

Dibrugarh district is located between 27° 05′ 29.09" N and 27° 42′ 20.58" N latitude and 94° 34′ 39.33" E to 95° 29′ 29.35" E longitude, encompassing an area of 3381 km^2 as shown in the Fig. 1. This administrative division comprises six revenue circles such as Dibrugarh East, Dibrugarh West, Chabua, Tengakhat, Naharkatia, Tingkhong, and Moran. The district is bordered by Dhemaji district to the north, Lakhimpur district in the west, Arunachal Pradesh and Charaideo to the south, Tinsukia to the east, and Sivasagar district to the south-west. Dibrugarh features a varied physiography that includes floodplains, *beels*, swamps and occasional hills. The Brahmaputra River marks the northern boundary of Dibrugarh, where it becomes particularly wide (up to 10 km) and braided compared to other parts of the river. Other rivers

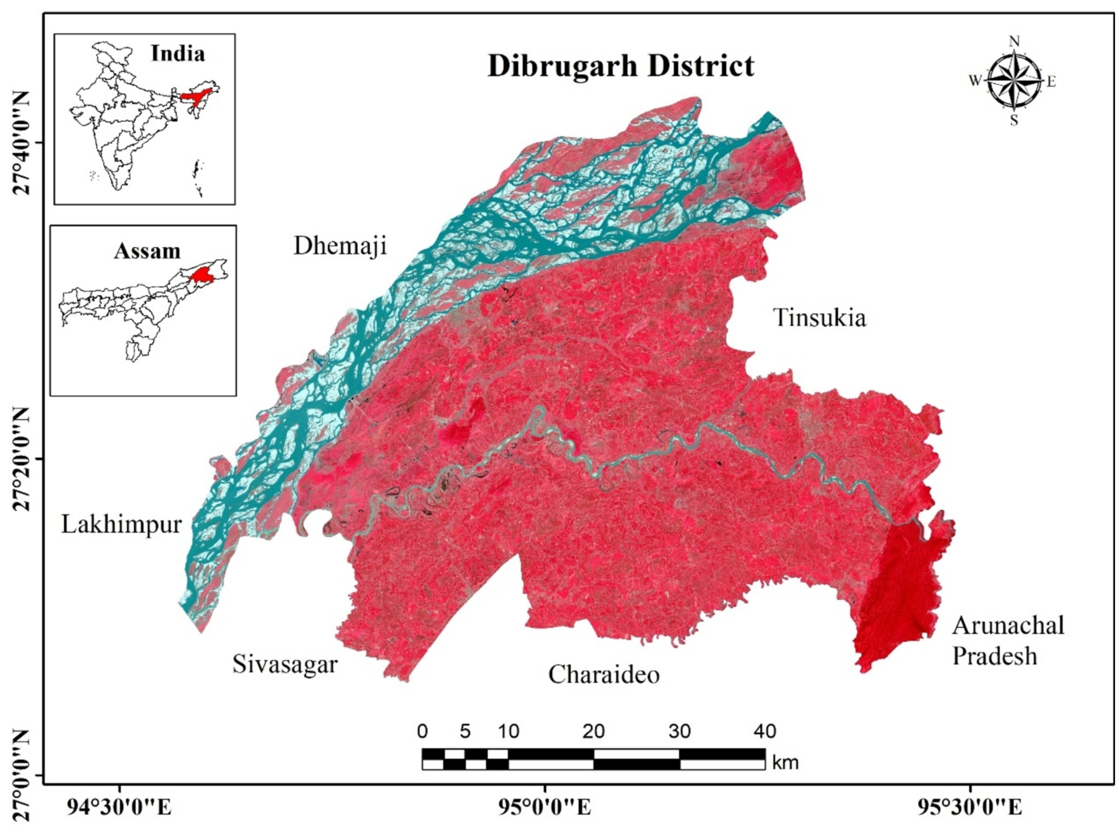

Fig. 1 Map of the study area

include are Burhidihing, Sessa, Dibru, Disang and Lekhijan. The wetland types of the district are floodplain wetlands, ox-bow lakes, man-made ponds and tanks and waterlogged areas. The district experiences a humid subtropical climate, characterized by extremely wet summers and relatively dry winters. The average annual rainfall is approximately 2781 mm (Shah and Shah 2024). Temperature in the region ranges from 9 °C to 32 °C, with the lowest temperatures typically occurring in January and the highest in the month of August (Gogoi et al. 2012). The average elevation is 108 m above mean sea level (MSL). The soil composition mainly consists of sandy to clayey loam types (CHWB 2013), supporting diverse agricultural practices and natural vegetation. The varied physiography and climate conditions contribute to the district's unique ecological and environmental characteristics, making it an important area for ecological studies and conservation efforts.

Data sources

For mapping the wetlands, Resourcesat 2A LISS IV data was downloaded from Bhoonidhi portal (https://bhoonidhi.nrsc.gov.in), which features a high-resolution Linear Imaging Self Scanner (LISS-IV) camera operating in three spectral bands in the Visible and Near Infrared Region (VNIR) with a 5.8-m spatial resolution. The scanner can be steered up to ± 26 degrees across track, providing a 5-day revisit capability (ISRO 2023). LISS IV provides high-resolution multispectral data suitable for detailed land cover mapping. Other ancillary data such as topographic maps, previous land use maps, and existing wetland inventories were collected to support the analysis and validation of results. Table 1 shows the details of satellite data used.

Methodology

Data pre-processing

The downloaded satellite images were georeferenced to a standard coordinate system UTM Zone 46 N, WGS 1984 datum to ensure spatial accuracy and consistency. Radiometric corrections were applied to the satellite images to correct for sensor irregularities and atmospheric effects. A composite image was created by stacking the relevant spectral bands (near infrared, red and green) from the LISS IV sensor using composite bands tools under data management tools in ArcGIS 10.8.2.

Wetland delineation

Polygons were digitized to demarcate the boundaries of wetlands identified from the satellite images in ArcGIS 10.8.2 software. Attributes such as wetland type, area and location were calculated in attribute table for each polygon. The spatial distribution map of wetlands was analysed by overlaying the wetland shapefiles on the district map. Patterns of wetland distribution were examined in relation to their hydrological factors. To enhance visibility, the Dibrugarh district was divided into three segments (a, b, and c) as some wetlands are very small in size. Final wetland distribution maps were produced using ArcGIS 10.8.2. These maps were annotated with relevant details such as scale, north arrow, legend and other cartographic elements. The methodological flow chart is shown in Fig. 2.

Results and discussion

The spatial distribution of wetlands in Dibrugarh district was determined using high-resolution satellite imagery from Resourcesat 2A LISS IV. The results revealed a complex and diverse network of wetlands, including open lakes, ox-bow lakes, waterlogged and man-made wetlands such as ponds and tanks. The Brahmaputra River and its tributaries play a significant role in shaping the wetland landscape of the district, contributing to the formation of numerous oxbow lakes and floodplain wetlands. This distribution is critical as it highlights the connectivity and the ecological interdependence of these wetland systems. The Dibrugarh district of Assam is characterized by a rich network of rivers and wetlands formed by the River Brahmaputra, Burhidihing River and Sessa River. Each of these rivers contributes uniquely to the region's wetland ecosystem, varying in size and type of wetlands they form. The maps (Fig. 3, 4, 5) show the various wetland types identified in the study area namely floodplain wetlands, ox-bow lakes, waterlogged and man-made ponds and tanks. Floodplain wetlands, situated in low-lying regions adjacent to rivers and streams, experience periodic flooding from rising water levels. Oxbow lakes, characterized by their distinctive crescent shape, form when meanders in a

Table 1 Details of dataset used

Date of Acquisition	Satellite	Sensor	Band	Resolution	Path	Row	Source
22/01/2024 15/03/2024 27/03/2024	Resourcesat 2A	LISS IV	B2, B3 & B4	5.8 m	113	052	Bhoonidhi portal, https://bhoonidhi.nrsc.gov.in

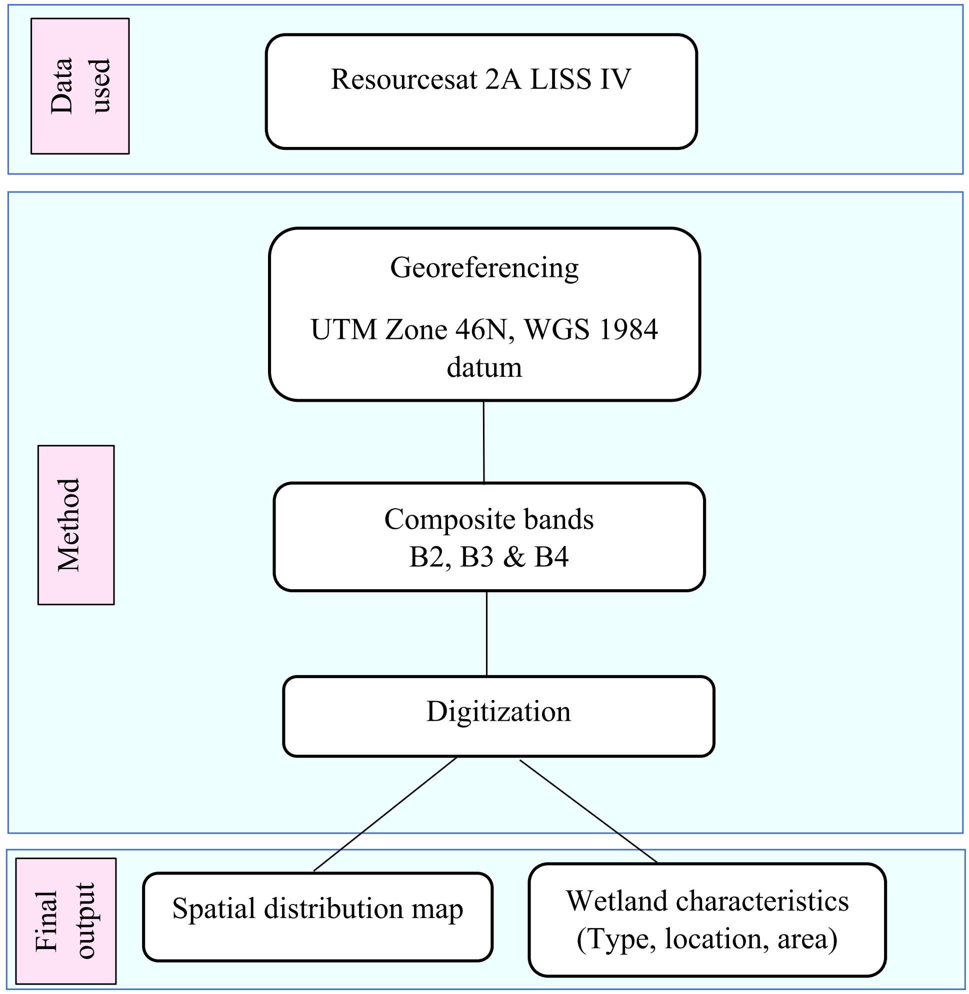

Fig. 2 Methodological flowchart of the study

river are isolated from the main channel due to erosion and sediment accumulation over time. Waterlogged areas denote geographic locations where the soil is excessively saturated with water, leading to visible standing water or saturated soil beneath the surface. Meanwhile, man-made ponds and tanks are artificial water bodies created through human intervention, serving a variety of purposes such as water storage, irrigation, aquaculture, recreation and aesthetic enhancement.

The distribution pattern indicates that the wetlands are predominantly concentrated along the floodplains of the Brahmaputra River and its tributaries the Burhidihing river and Sessa river. There are 1721 ponds and tanks followed by ox-bow lakes (72), waterlogged area (23) and floodplain lakes (18) as shown in Table 2. These wetlands are crucial for maintaining biodiversity, supporting agriculture and providing flood control. The presence of man-made wetlands, such as fish ponds and agricultural reservoirs, also underscores the role of wetlands in supporting local livelihoods. The analysis revealed that the wetlands in Dibrugarh vary significantly in size and extent. Larger wetlands are primarily associated with the Brahmaputra River, while smaller wetlands are scattered throughout the district. Table 1 provides a summary of the different wetland classes and their respective areas.

Floodplain wetlands

The River Brahmaputra is a significant water body in Dibrugarh, creating 18 open freshwater lakes as shown in the Fig. 3 and Table 3. These wetlands are the largest in the district compared to those formed by the other two rivers. The largest wetland is the Maijan Wetland, situated in the northern part of the district near Dibrugarh town, covering an area of 158.9 hectares. The smallest wetland in this group has an area of 0.11 hectares. Collectively, the wetlands formed by the Brahmaputra cover a total area of 299.37 hectares.

Ox-bow lakes

The Burhidihing River, a tributary of the Brahmaputra, forms 33 oxbow lakes along its banks. Oxbow lakes are crescent-shaped lakes formed by the meandering of rivers.

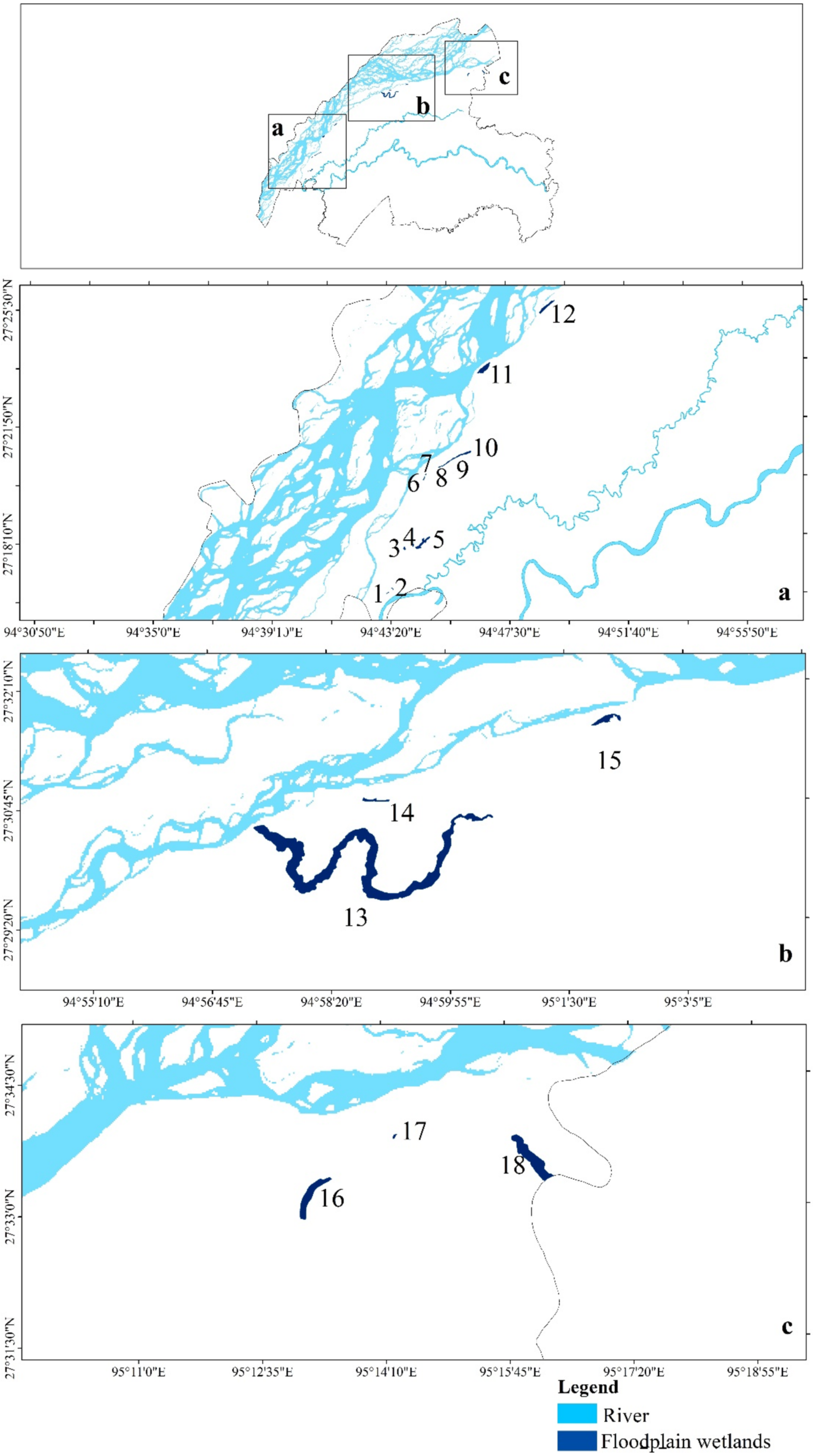

Fig. 3 Distribution of floodplain wetlands of Brahmaputra River

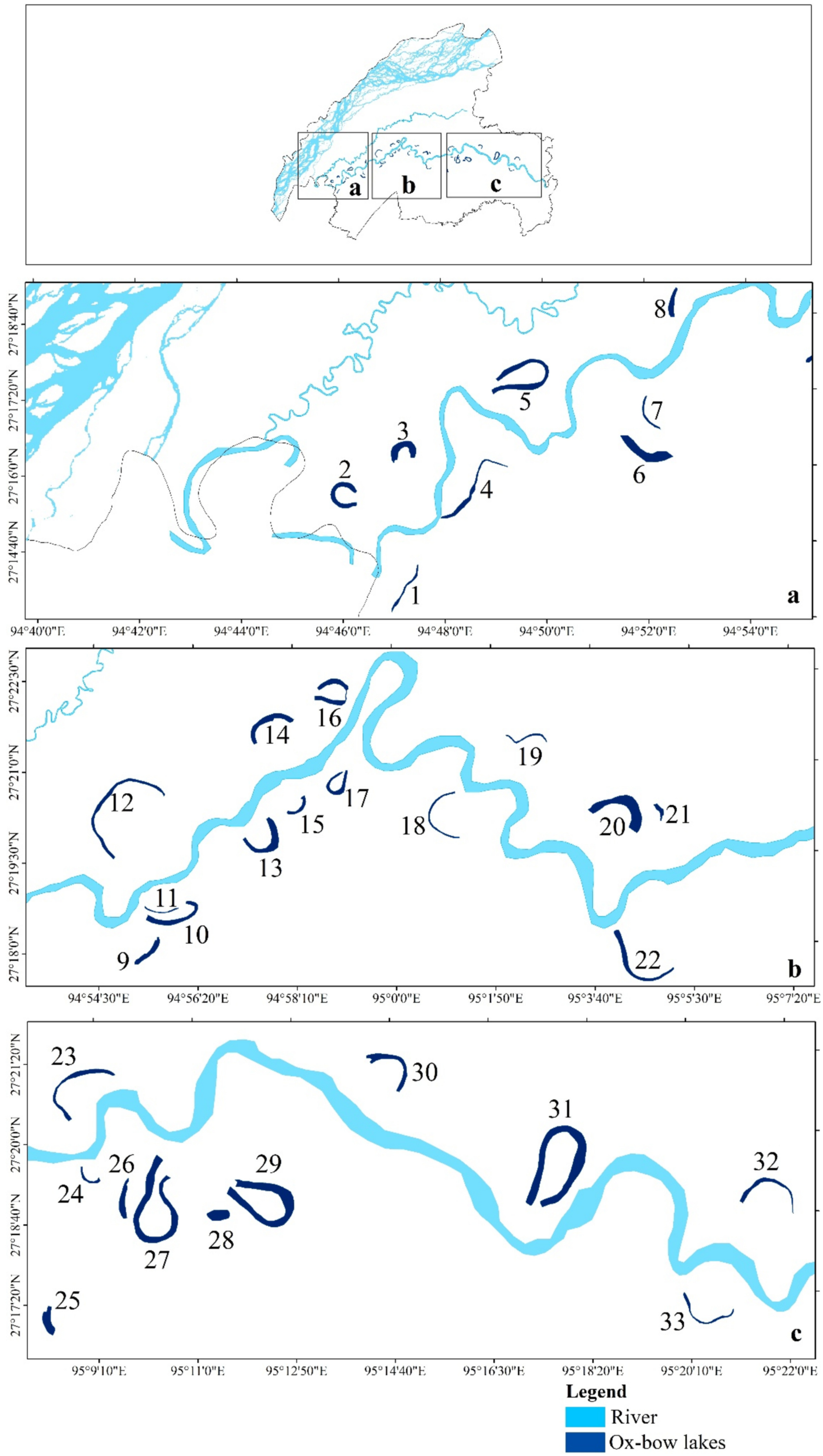

Fig. 4 Distribution of ox-bow lakes of Burhidihing River

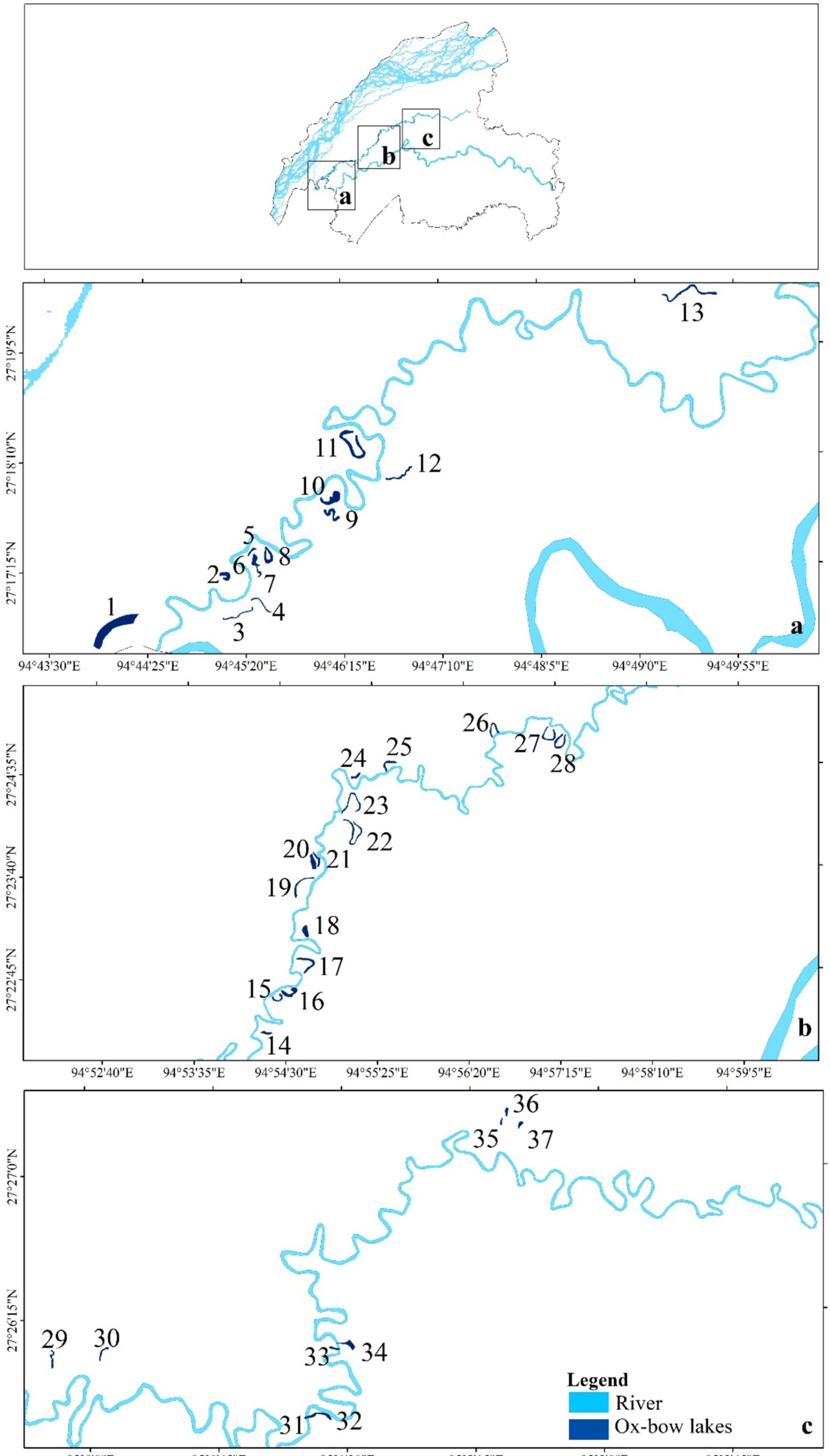

Fig. 5 Distribution of ox-bow lakes of Sessa River

Table 2 Types of wetlands

Sl no	Waterbody	No of wetlands	Area (ha)	Area (%)
1	Floodplain wetlands	18	299.37	13.30
2	Ox-bow lakes	70	1010.79	44.92
3	Ponds and tanks (Man-made)	1721	447.66	19.90
4	Waterlogged area	23	492.12	21.88
Total		1832	2249.94	100.00

Table 3 Floodplain wetlands of the Brahmaputra River

Sl no	Location		Area (ha)
	Lat	Long	
1	27° 16′ 27.1910" N 27° 16′ 31.5614" N	94° 43′ 11.1352" E 94° 43′ 15.6922" E	0.27
2	27° 16′ 5.6791" N 27° 16′ 7.1493" N	94° 42′ 21.9554" E 94° 42′ 24.2768" E	0.11
3	27° 15′ 54.6869" N 27° 15′ 57.3809" N	94° 42′ 20.9396" E 94° 42′ 24.7450" E	0.98
4	27° 16′ 35.2474" N 27° 16′ 38.3650" N	94° 43′ 22.0263" E 94° 43′ 25.9526" E	0.34
5	27° 17′ 49.9036" N 27° 17′ 55.6202" N	94° 43′ 47.4576" E 94° 43′ 53.0645" E	1.31
6	27° 17′ 51.9002" N 27° 18′ 14.0936" N	94° 44′ 12.5456" E 94° 44′ 44.2032" E	12.51
7	27° 20′ 24.0990" N 27° 20′ 54.8870" N	94° 45′ 3.9116" E 94° 46′ 13.1449" E	10.31
8	27° 20′ 0.8781" N 27° 20′ 7.9336" N	94° 44′ 31.2860" E 94° 44′ 36.0096" E	0.69
9	27° 20′ 10.3857" N 27° 20′ 12.8661" N	94° 44′ 36.4445" E 94° 44′ 38.0507" E	0.16
10	27° 34′ 2.7431" N 27° 34′ 11.2355" N	95° 17′ 24.9361" E 95° 17′ 31.9835" E	2.54
11	27° 23′ 19.9397" N 27° 23′ 40.3376" N	94° 46′ 29.1618" E 94° 46′ 55.4781" E	17.1
12	27° 25′ 10.7469" N 27°25′ 35.3712" N	94° 48′ 40.7021" E 94° 49′ 13.3026" E	11.83
13	27° 29′ 37.0375" N 27° 30′ 38.1919" N	94° 57′ 19.5428" E 95° 0′ 30.8821" E	158.9
14	27° 30′ 47.4325" N 27° 30′ 50.5649" N	94° 58′ 46.8315" E 94° 59′ 8.5135" E	2.04
15	27° 31′ 39.3057" N 27° 31′ 47.1691" N	95° 1′ 50.8099" E 95° 2′ 14.2571" E	5.36
16	27° 32′ 54.4469" N 27° 33′ 23.3176" N	95° 13′ 5.4210" E 95° 13′ 30.2345" E	14.41
17	27° 33′ 48.9839" N 27° 33′ 52.0603" N	95° 14′ 17.6252" E 95° 14′ 21.0340" E	0.38
18	27°32′ 46.5794" N 27° 33′ 50.3562" N	95° 15′ 48.7213" E 95° 17′ 4.0082" E	60.13

The largest oxbow lake created by the Burhidihing River covers an area of 128.20 hectares. On average, these oxbow lakes have an area of 29.10 hectares. The total wetland area formed by the Burhidihing River amounts to 960.36 hectares, making it a significant contributor to the district's wetland ecosystem as depicted in Table 4 and Fig. 4.

The Sessa River forms 37 oxbow lakes, which are generally smaller compared to those formed by the Burhidihing River. The largest oxbow lake created by the Sessa River has an area of 10.15 hectares. Although specific details about the average size of these lakes are 1.28 hectares, they are smaller in comparison to those formed by the Burhidihing River (Table 5 and Fig. 5). Total area cover by these wetlands are 50.43 ha.

Waterlogged area

A waterlogged area refers to land that is permanently or seasonally saturated with water, creating conditions that support specific types of vegetation and wildlife adapted to wet environments. There are 23 waterlogged areas identified in the districts that covers an area of 492.12 hectares.

Man-made wetlands

Man-made wetlands constitute aquaculture ponds and tanks. Ponds are bodies of stagnant water, varying in size, serving various ecological roles. Tanks are constructed artificial reservoirs primarily intended for the storage and regulation of water, catering to agricultural, residential, and urban needs. There are 1721 ponds and tanks in the district as shown in the Fig. 6. They are distributed all over the district and ranges between 0.03 to 5.72 hectares.

The Brahmaputra River's braided nature leads to the formation of open lakes, while the meandering characteristics of the Burhidihing and Sessa rivers result in the creation of ox-bow lakes as these rivers cut off portions from their main bodies over time. The fluvio-originated wetlands in Dibrugarh district play a significant role in supporting the livelihoods of the local population. According to the 2010

Table 4 Ox-bow Lakes of Burhidihing River

Sl. No	Location		Area (ha)
	Lat	Long	
1	27° 13′ 31.8264" N 27°14′ 21.1167" N	94° 46′ 57.0319" E 94° 47′ 28.8860" E	9.57
2	27° 15′ 21.7363" N 27° 15′ 49.2995" N	94° 45′ 46.9078" E 94° 46′ 17.7607" E	26.51
3	27° 16′ 8.5293" N 27° 16′ 31.4752" N	94° 46′ 59.0390" E 94° 47′ 28.6549" E	26.87
4	27° 15′ 9.4849" N 27° 16′ 10.8223" N	94° 47′ 56.6552" E 94° 49′ 16.1518" E	23.65
5	27° 17′ 19.6495" N 27° 17′ 56.0253" N	94° 48′ 58.7141" E 94° 50′ 6.1594" E	54.07
6	27° 16′ 5.4341" N 27° 16′ 33.8539" N	94° 51′ 29.5887" E 94° 52′ 31.5349" E	45.89
7	27° 16′ 40.0794" N 27° 17′ 15.3100" N	94° 51′ 56.0999" E 94° 52′ 17.0277" E	6.71
8	27° 18′ 38.2534" N 27° 19′ 9.0253" N	94° 52′ 28.2286" E 94° 52′ 39.5807" E	12.87
9	27° 17′ 48.0127" N 27° 18′ 14.7951" N	94° 55′ 9.8446" E 94° 55′ 38.2007" E	13.92
10	27° 18′ 26.1555" N 27° 18′ 50.1208" N	94° 55′ 23.4524" E 94° 56′ 20.6737" E	24.38
11	27° 18′ 38.5667" N 27° 18′ 45.3692" N	94° 55′ 21.9511" E 94° 55′ 59.1634" E	2.83
12	27° 19′ 32.7264" N 27° 20′ 52.3574" N	94° 54′ 24.4587" E 94° 55′ 46.4550" E	33.59
13	27° 19′ 36.7856" N 27° 20′ 11.8454" N	94° 57′ 12.0443" E 94° 57′ 51.4674" E	31.42
14	27° 21′ 24.5049" N 27° 21′ 54.4841" N	94° 57′ 22.5928" E 94° 58′ 10.4257" E	25.46
15	27° 20′ 14.2448" N 27° 20′ 32.5361" N	94° 58′ 1.2043" E 94° 58′ 22.4701" E	7.59
16	27° 22′ 1.2658" N 27° 22′ 27.9966" N	94° 58′ 34.1697" E 94° 59′ 11.6398" E	25.69
17	27° 20′ 32.9265" N 27° 20′ 57.0033" N	94° 58′ 45.3457" E 94° 59′ 9.1241" E	15.06
18	27° 19′ 48.4831" N 27° 20′ 34.2833" N	95° 0′ 37.9670" E 95° 1′ 12.2977" E	9.91
19	27° 21′ 21.1151" N 27° 21′ 30.6683" N	95° 2′ 5.0503" E 95° 2′ 50.7016" E	5.60
20	27° 19′ 50.4340" N 27° 20′ 27.8697" N	95° 3′ 35.2386" E 95° 4′ 34.6919" E	56.70
21	27° 20′ 1.8325" N 27° 20′ 19.0417" N	95° 4′ 47.9715" E 95° 4′ 58.9010" E	5.35
22	27° 17′ 23.7005" N 27° 18′ 14.6667" N	95° 4′ 1.5089" E 95° 5′ 7.7377" E	29.20
23	27° 20′ 22.8970" N 27° 21′ 14.2464" N	95° 8′ 24.0080" E 95° 9′ 33.5679" E	29.15
24	27° 19′ 20.5203" N 27° 19′ 37.1327" N	95° 8′ 53.3448" E 95° 9′ 14.7116" E	5.64
25	27° 16′ 49.8059" N 27° 17′ 18.7686" N	95° 8′ 7.5272" E 95° 8′ 21.3705" E	18.36
26	27° 18′ 44.7013" N 27° 19′ 24.9956" N	95° 9′ 35.3402" E 95° 9′ 46.1820" E	17.33
27	27° 18′ 20.2217" N 27° 19′ 47.5535" N	95° 9′ 50.6850" E 95° 10′ 40.7527" E	95.16
28	27° 18′ 40.9566" N 27° 18′ 51.6256" N	95° 11′ 12.5010" E 95° 11′ 38.2322" E	18.65
29	27° 18′ 33.6191" N 27° 19′ 21.7019" N	95° 11′ 35.5684" E 95° 12′ 50.3462" E	96.55
30	27° 20′ 46.0748" N 27° 21′ 24.6311" N	95° 14′ 13.5878" E 95° 14′ 58.6407" E	27.10
31	27° 18′ 48.8197" N 27° 20′ 9.4204" N	95° 17′ 8.3245" E 95° 18′ 17.3449" E	128.20
32	27° 18′ 38.2130" N 27° 19′ 13.7740" N	95° 21′ 6.8844" E 95° 22′ 6.0931" E	20.09
33	27° 16′ 49.4479" N 27° 17′ 20.9789" N	95° 20′ 1.9333" E 95° 20′ 57.7154" E	11.25

National Wetland Atlas Assam (National Wetland Atlas, 2010), there were 751 wetlands in the district, covering an area of 3,312 hectares. However, the present study has identified a total of 1,832 wetlands, with a combined area of 2,249.94 hectares. The disparity between these figures can be attributed to the resolution of the satellite imagery used. The National Wetland Atlas Assam utilized imagery with a spatial resolution of 23.8 m, which is too coarse to detect smaller wetlands in the region effectively. In contrast, the current study employed imagery with a 5.8-m spatial resolution, allowing for a more accurate and detailed mapping of the wetlands. This study serves as a preliminary yet vital effort in the inventory mapping of wetlands, offering numerous benefits to government bodies and NGOs. It facilitates informed decision-making, enhances biodiversity conservation, supports sustainable resource management and boost climate change resilience. For urban planners, this detailed mapping aids in sustainable urban development and land use planning, ensuring that development initiatives do not compromise wetland ecosystems. For government agencies, the data supports policy formulation, disaster management and environmental monitoring efforts, leading to better governance and resource allocation. NGOs benefit from this mapping through improved targeting of conservation efforts, community engagement initiatives and sustainable livelihood projects. By providing a comprehensive overview of the wetland distribution and characteristics, this study ensures that all stakeholders can work towards balanced development and ecological preservation. This approach contributes to a sustainable and resilient future

Table 5 Ox-bow lakes of Sessa River

Sl no	Location		Area (ha)
	Lat	Long	
1	27° 16′ 36.4598" N 27°16′ 53.6746" N	94° 43′ 54.6845" E 94° 44′ 20.0210" E	10.15
2	27° 17′ 9.8612" N 27° 17′ 14.0439" N	94° 45′ 5.6147" E 94° 45′ 11.6211" E	1.27
3	27° 16′ 50.2128" N 27° 16′ 56.6175" N	94° 45′ 7.0777" E 94° 45′ 24.0706" E	0.68
4	27° 16′ 53.6625" N 27° 17′ 1.0443" N	94° 45′ 22.7858" E 94° 45′ 34.1009" E	0.55
5	27° 17′ 21.7835" N 27° 17′ 25.8832" N	94° 45′ 21.4826" E 94° 45′ 26.5798" E	0.39
6	27° 17′ 16.7937" N 27° 17′ 22.9894" N	94° 45′ 23.4817" E 94° 45′ 28.0876" E	1.16
7	27° 17′ 11.3138" N 27° 17′ 16.8166" N	94° 45′ 26.1174" E 94° 45′ 29.0310" E	0.39
8	27° 17′ 18.0914" N 27° 17′ 26.6442" N	94° 45′ 30.8402" E 94° 45′ 35.5639" E	1.60
9	27° 17′ 38.8750" N 27° 17′ 45.1000" N	94° 46′ 4.2734" E 94° 46′ 13.1225" E	1.59
10	27° 17′ 46.9804" N 27° 17′ 53.8999" N	94° 46′ 2.4259" E 94° 46′ 13.6645" E	2.88
11	27° 18′ 9.9606" N 27° 18′ 24.0668" N	94° 46′ 13.7619" E 94° 46′ 28.1753" E	4.17
12	27° 17′ 58.9840" N 27° 18′ 5.7432" N	94° 46′ 39.1175" E 94° 46′ 53.9223" E	1.09
13	27° 19′ 25.9109" N 27° 19′ 34.4905" N	94° 49′ 15.0141" E 94° 49′ 45.8351" E	2.54
14	27° 22′ 13.6423" N 27° 22′ 15.4532" N	94° 54′ 15.0694" E 94° 54′ 22.3115" E	0.54
15	27° 22′ 31.4560" N 27° 22′ 35.4262" N	94° 54′ 22.1867" E 94° 54′ 28.5177" E	0.63
16	27° 22′ 33.5335" N 27° 22′ 38.6976" N	94° 54′ 27.9319" E 94° 54′ 37.5192" E	1.72
17	27° 22′ 46.1685" N 27° 22′ 54.5715" N	94° 54′ 37.1278" E 94° 54′ 48.1511" E	1.55
18	27° 23′ 5.3672" N 27° 23′ 11.9291" N	94° 54′ 40.7918" E 94° 54′ 44.8011" E	1.33
19	27° 23′ 26.6909" N 27° 23′ 37.6595" N	94° 54′ 36.6029" E 94° 54′ 48.6550" E	1.15
20	27° 23′ 42.1607" N 27° 23′ 50.2053" N	94° 54′ 46.2435" E 94° 54′ 49.8626" E	1.48
21	27° 23′ 43.0397" N 27° 23′ 51.2666" N	94° 54′ 47.9885" E 94° 54′ 52.2288" E	0.69
22	27° 23′ 54.6865" N 27° 24′ 8.4963" N	94° 55′ 6.5213" E 94° 55′ 17.7996" E	1.88
23	27° 24′ 11.6543" N 27° 24′ 22.6913" N	94° 55′ 5.4812" E 94° 55′ 17.2155" E	1.42
24	27° 24′ 30.0991" N 27° 24′ 33.4132" N	94° 55′ 11.7779" E 94° 55′ 17.3389" E	0.56
25	27° 24′ 33.6777" N 27° 24′ 39.5411" N	94° 55′ 31.1517" E 94° 55′ 39.0057" E	0.92
26	27° 24′ 51.1954" N 27° 24′ 59.00249" N	94° 56′ 35.4187" E 94° 56′ 41.3974" E	0.88
27	27° 24′ 48.9890" N 27° 24′ 56.6507" N	94° 57′ 6.5930" E 94° 57′ 14.8988" E	1.17
28	27° 24′ 44.7029" N 27° 24′ 52.4143" N	94° 57′ 13.8911" E 94° 57′ 20.7999" E	1.39
29	27° 25′ 59.8993" N 27° 26′ 5.4676" N	94° 59′ 46.1949" E 94° 59′ 47.7804" E	0.24
30	27° 26′ 2.0615" N 27° 26′ 6.1927" N	95° 0′ 3.4585" E 95° 0′ 6.8507" E	0.22
31	27° 21′ 14.2757" N 27° 21′ 23.8848" N	94° 52′ 48.4434" E 94° 52′ 53.8434" E	1.04
32	27° 20′ 23.5500" N 27° 20′ 29.9924" N	94° 51′ 49.4125" E 94° 51′ 52.0775" E	0.50
33	27° 26′ 4.2134" N 27° 26′ 5.4520" N	95° 1′ 24.1364" E 95° 1′ 27.8398" E	0.16
34	27° 26′ 4.1026" N 27° 26′ 7.3195" N	95° 1′ 26.6994" E 95° 1′ 33.1430" E	0.48
35	27° 27′ 13.8270" N 27° 27′ 15.9155" N	95° 2′ 25.3077" E 95° 2′ 26.2116" E	0.10
36	27° 27′ 16.5216" N 27° 27′ 19.1602" N	94° 2′ 27.0955" E 94° 2′ 28.1629" E	0.66
37	27° 27′ 12.5888" N 27° 27′ 14.7541" N	95° 2′ 31.4720" E 95° 2′ 33.3285" E	1.25

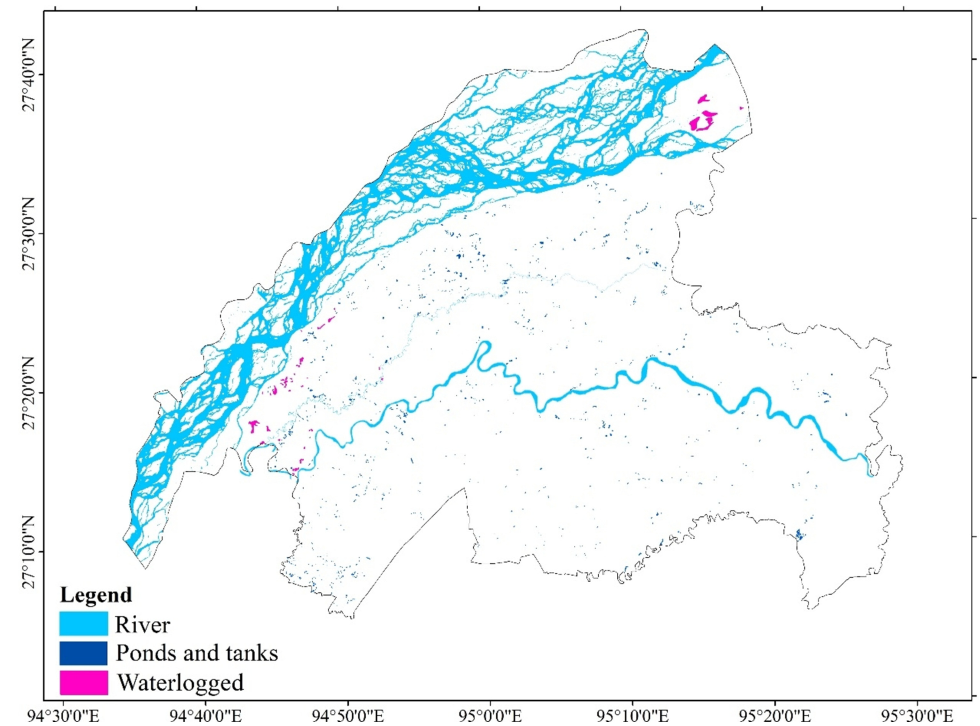

Fig. 6 Distribution of ponds/tanks and waterlogged areas in Dibrugarh District

for the Dibrugarh district, ensuring that its natural resources are managed wisely and effectively for the benefit of current and future generations.

Conclusion

The wetlands of Dibrugarh district in Assam are a dynamic and highly productive ecosystem, playing a crucial role in supporting biodiversity, agriculture, flood control, and local livelihoods. The study highlights the importance of detailed and accurate wetland mapping for effective conservation and sustainable management. This study provides a detailed and comprehensive analysis of the spatial distribution and characteristics of wetlands in Dibrugarh district, Assam, using GIS and remote sensing techniques. Using high-resolution satellite imagery, this study identified 1,834 wetlands covering an area of 2,249.77 hectares, revealing a significant increase in the number of wetlands compared to previous assessments that used coarser resolution imagery. The Brahmaputra River, along with its tributaries the Burhidihing and Sessa rivers, shapes the diverse wetland landscape of Dibrugarh, forming open lakes, oxbow lakes and waterlogged areas. However, it is important to admit that this mapping exercise could have been validated through sufficient ground truthing of the wetlands. The absence of ground truthing may be considered as a limitation of the study. In future, field-based validation may be carried out to enhance the accuracy of the remote sensing and GIS data. The findings of the present study however, provide critical insight into the region's wetlands, highlighting the need for precise wetland inventories to support decision-making and policy formulation. For urban planners, the data facilitates sustainable land use planning, ensuring that wetland ecosystems are preserved amid development projects. NGOs can use this information to enhance targeted conservation efforts, engage communities, and promote sustainable livelihood initiatives.

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Declarations

Conflict of interest The authors declare no conflict of interest.

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