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Detection of Water body using Multispectral Imagery for a Geospatial Area

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Abstract*— *Water body detection is a process in environmental monitoring, resource management, and for disaster management applications. The previous work report highlights the increasing importance of precise water body detection in the scenario of climate change, for effective global water dynamics for making this technology vital for sustainable development and environmental conservation. This work presents the use of spectral features of multispectral imagery, for identifying and mapping various aquatic objects with increased accuracy. This work computes different water indices, such as the Normalized Difference Water Index (NDWI), Modified NDWI (MNDWI), and Water Ratio Index (WRI), to detect water body efficiently. Analysis of experimental results show that WRI provides the highest accuracy in delineating water bodies, followed by MNDWI and NDWI.

Index Terms*— *Spectral features, NDWI, MNDWI, WRI.

I. INTRODUCTION

Water body detection, the process of identifying and mapping water bodies from various types of imagery, is an important task in environmental monitoring, water resource management, and disaster management. By multispectral and hyperspectral imagery through remote sensing and image analysis and interpretation technologies the accurate delineation of water resources such as rivers, lakes, reservoirs, wetlands, and coastal areas. The ability to monitor these water resources in real-time is essential for maintaining ecosystem health through water resources management, and mitigation methods can be deployed to reduce the impacts of natural disasters like floods and droughts. As climate change continues to alter global water dynamics, the importance of precise water body detection becomes increasingly paramount for sustainable development and environmental conservation.

II. RECENT WORK

The detection and delineation of water bodies using remote sensing imagery and related technologies have seen significant advancements in recent years. Various studies have developed and customized algorithms and methods to improve the accuracy and efficiency of water resources analysis [1]. This [1] study focused on developing an algorithm that detects and delineates surface water bodies in airborne hyperspectral data automatically, achieving a detection probability generally above 90% across diverse landscapes and sensor types. Peng Qin et. al developed a U-Net framework for small waterbody extraction from remotely sensed hyperspectral images [2]. In this work [2] an improved U-Net framework was employed to enhance the accuracy of extraction of small water bodies from Zhuhai-1 hyperspectral satellite images, achieving nearly 90% accuracy, surpassing traditional methods like SVM and NDWI. Drone-based multispectral imaging has also been utilized to investigate gravelly debris flows and geomorphic characteristics, with high TWI and NDWI values identifying zones susceptible to landslides and sediment deposition [3].

Hyperspectral remote sensing was also applied to monitor the water quality of inland water bodies in Mumbai, using spectral signatures to assess pollution levels [4]. This study found high pollution in the Mithi and Ulhas rivers. Sentinel-2 imagery has been widely used for water body detection, with the Normalized Water Index (NWI) [4], that outperforming the traditional NDWI, providing better separation of water bodies from non-water areas. Based on the analysis of the spectral characteristics of the Sentinel-2 satellite, Wei Jiang [5] designed a water index using the vegetation-sensitive red-edge band (Band 5) and shortwave infrared band (Band 11). The SWI (Sensitive Water Index) proposed in the work [5] enhanced this process further, with Otsu's method for determining the optimal threshold. High-resolution Sentinel-2 images combined with DEM data improved river width detection accuracy for small rivers in the Upper Yellow River, supporting hydrological models [6]

The NDWI has been extensively utilized for the delineation of open water features, enhancing water body detection and suppressing non-water features. This index was further modified in studies [7], using Sentinel-2 imagery, where pan-sharpening algorithms enhanced spatial resolution, making the Modified Normalized Difference Water Index (MNDWI) more effective than NDWI in highlighting water bodies and suppressing built-up features. Landsat multispectral data has also been a focus, with various classification schemes tested to identify and map water bodies accurately. An automated mapping approach using a perceptron model demonstrated effective water pixel

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classification based on reflectance values, emphasizing the importance of appropriate threshold and size parameters [8]. Jinhui Lan proposed an inequality-constrained semi-automatic water body detection algorithm (ICSA) based on the refined spectral description of features provided by GF-5 hyperspectral datasets [8]. Some remote sensing methodologies for identifying the quality of water are likely to be useful for the quality assessment of water resources as their dynamic nature makes the quality detection process difficult [4].

These advancements in remote sensing technologies and methodologies for water body detection, delineation, and analysis contribute significantly to environmental monitoring and management, providing accurate, efficient, and scalable solutions for various landscapes and water quality assessments.

III. METHODOLOGY

Fig 1 shows the flowchart depicting the process of detection of water bodies using extracted indices by using open-source Q-GIS.

The steps are as follows:

1. Load Band Layers in Q-GIS: Necessary bands loading in Q-GIS platform.

2. Calculate Spectral Index using Raster Calculator: The Raster Calculator tool of Q-GIS is used for the computation of e the spectral indexes.

3. Save Spectral Index Feature: Save the computed spectral index as an extracted feature.

4. Analyze the Spectral Index Values: Analyze the values of the spectral index.

5. Select an Appropriate Threshold: Determine the correct threshold for identifying water bodies based on analysis of the spectral index values.

6. Export the Water Body Extracted Area: export the area identified as water bodies.

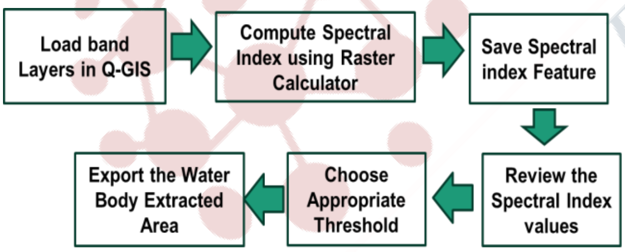

Fig 1. Flow chart for Relevant Band imagery Processing

IV. SPECTRAL INDICES

Spectral indices are computed using pixel values of desired spectral bands, to highlight specific properties or conditions of materials. Indices simplify the analysis due to spectral signature information that depicts specific material properties. Water indices that are used in the detection of water bodies in this work are as stated below.

1. Normalized Difference Water Index (NDWI)

$$NDWI = \frac{(Green - NIR)}{(Green + NIR)}$$

2. Modified NDWI (MNDWI)

$$MNDWI = \frac{(Green - SWIR2)}{(Green + SWIR2)}$$

3. Water Ratio Index (WRI)

$$WRI = \frac{(VRE1 - SWIR2)}{(VRE1 + SWIR2)}$$

V. RESULTS AND ANALYSIS

A. Dataset

The hyperspectral images captured by the Sentinel-2 satellite encompass a swath width of 10-20 km, covering a diverse array of water bodies. This extensive coverage presents challenges in simultaneously extracting various types of water bodies, as differing water qualities exhibit distinct spectral signatures. However, the Sentinel-2 datasets offer a broad spectral range and good spectral resolution, enabling precise characterization of object spectral signature information. Table 1 provides detailed information about the Sentinel-2 satellite bands.

Table 1: Sentinel band Information

Band	Resolution	Central Wavelength	Description
B1	60 m	443 nm	Ultra Blue (Coastal and Aerosol)
B2	10 m	490 nm	Blue
B3	10 m	560 nm	Green
B4	10 m	665 nm	Red
B5	20 m	705 nm	Vegetation Red Edge 1 (VRE1)
B6	20 m	740 nm	Vegetation Red Edge 2 (VRE2)
B7	20 m	783 nm	Vegetation Red Edge 3 (VRE3)
B8	10 m	842 nm	Near Infrared (NIR)
B8a	20 m	865 nm	Vegetation Red Edge 3 (VRE4)
B9	60 m	940 nm	Water Vapor
B10	60 m	1375 nm	Short Wave Infrared (SWIR1)
B11	20 m	1610 nm	Short Wave Infrared (SWIR2)
B12	20 m	2190 nm	Short Wave Infrared (SWIR3)

[Ref: https://browser.dataspace.copernicus.eu/]

In this experiment, we conducted surface water extraction, and analysis using multispectral image datasets obtained by the sentinel-2 satellite for Powai Lake Area. A representative multispectral image is displayed in Fig 2

Fig 2. Study Area: Powai Lake, Mumbai, India

The sentinel-2 satellite dataset consists of 13 different layers as shown below.

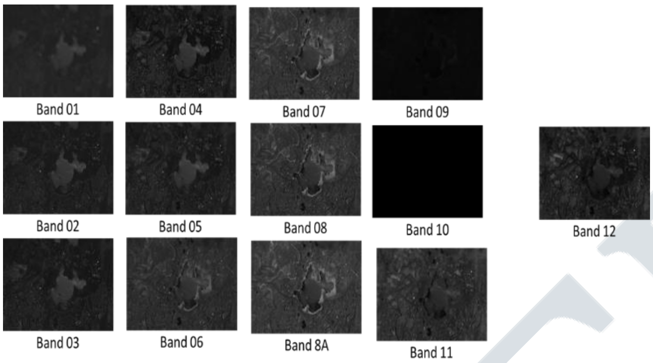

Fig 3. Sentinel-2 Layers of Powai Lake area

For downloading satellite data, we extracted the Powai Lake Map shape file (.KML) from Google Earth and then uploaded it to Copernicus Data Space. The Powai Lake Map shape looks as follows.

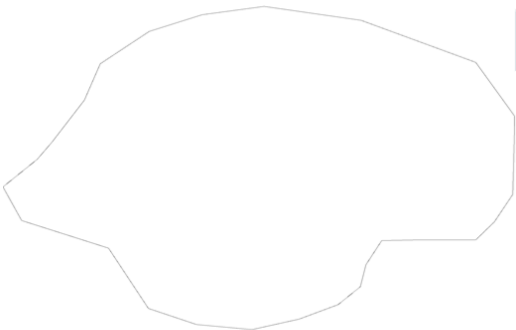

Fig 4. Shape File of Powai Lake

B. Tool Used

The band images given as input to Q-GIS and spectral indices are calculated using the Q-GIS Raster Calculator

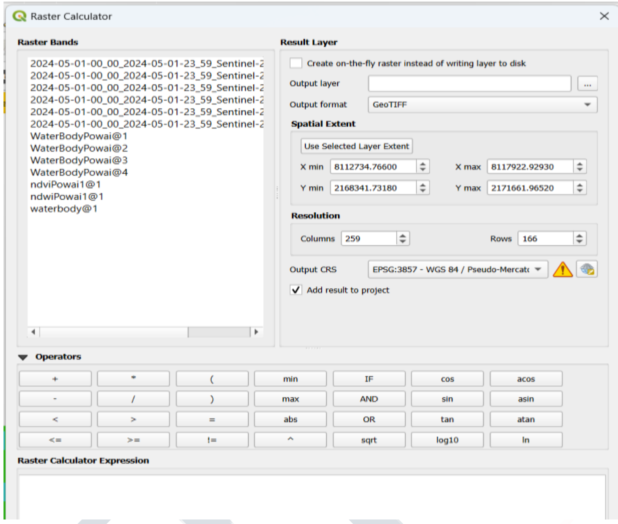

Fig 5. Screenshot of QGIS Raster Calculator

C. Results of NDWI calculations

Fig 6 shows the extracted image with NDWI pixels for the Powai Lake area. It can be seen from Fig 6 that the NDWI values from the water lake are in a specific range and differ from non-watery areas.

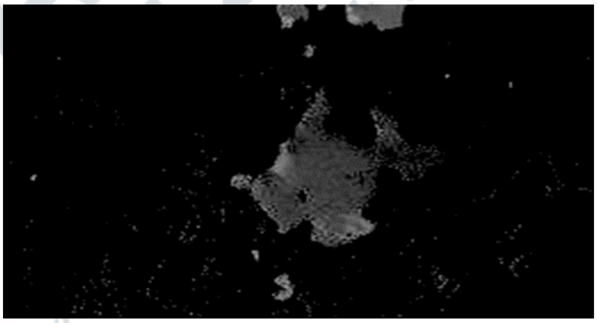

Fig 6(a). Extracted NDWI of Powai Lake

To make the lake area visible we can apply different threshold values. The range of NDWI values is shown below.

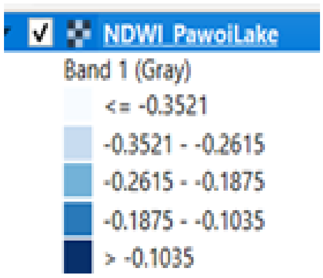

Fig 6(b). Range of NDWI values of Powai Lake

After applying the threshold value -0.1035 the result is promising to extract the watery area of Powai Lake from the given input image. The extracted area after applying the threshold is shown in Fig 7.

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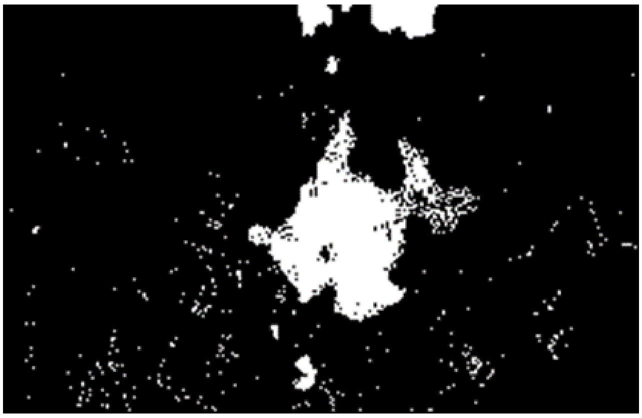

Fig 7. Extracted waterbody after applying Threshold.

D. Results of MNDWI calculations

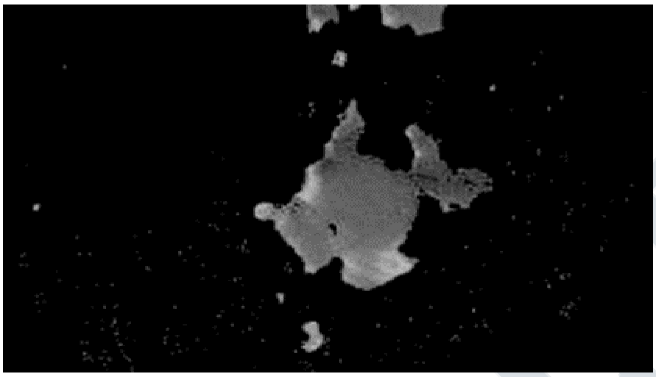

Fig 8(a). Extracted MNDWI of Powai Lake

Fig 8-a shows the MNDWI index layer for the Powai Lake area. Compared to NDWI it's clearer and more precise. The range of values of MNDWI is as below.

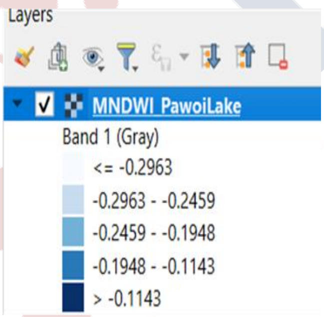

Fig 8(b). Range of MNDWI values of Powai Lake

After empirical analysis, the threshold value derived is -0.1143. The results are as follows in Fig 9.

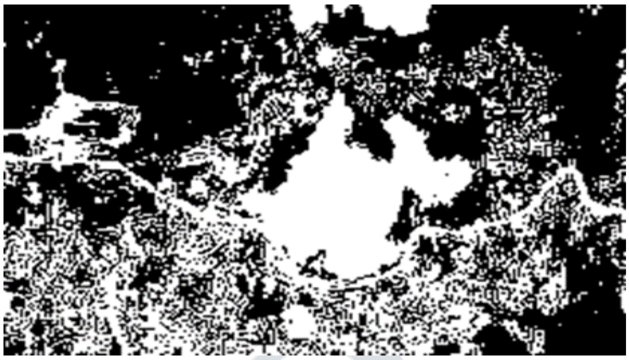

Fig 9. Extracted waterbody after applying Threshold -0.1143

E. Results of WRI calculations

The extracted image using the WRI index is shown in Fig 10-a. It has been shown that the WRI range of values tends to be in the positive range which is also shown.

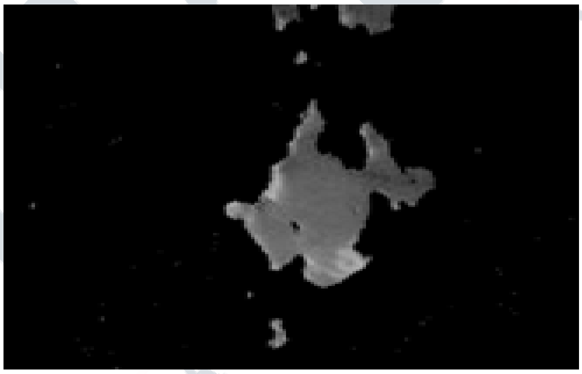

Fig 10(a). Display of Extracted WRI of Powai Lake

The range of WRI values is:

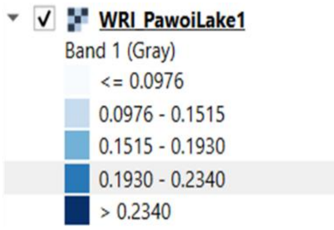

Fig 10(b). Range of WRI values of Powai Lake

The image after applying the threshold is shown in Fig 11:

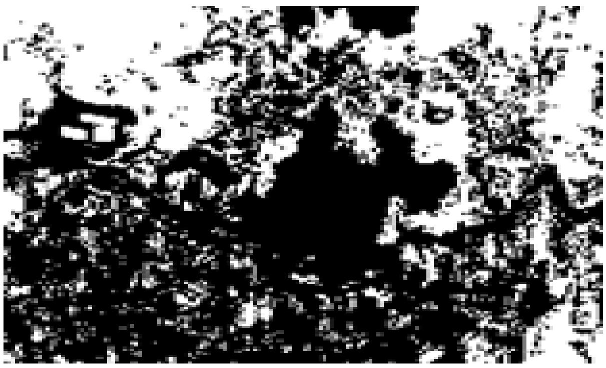

Fig 11. Extracted water body display after applying Threshold value 0.2340 to WRI

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VI. DISCUSSION

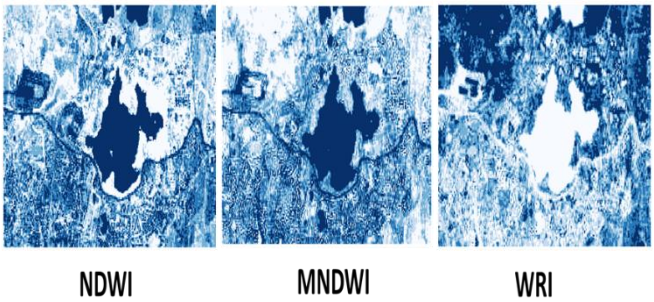

Fig 12. Images after applying thresholding on Spectral Indices f on NDWI, MNDWI, and WRI for the area of Powai Lake

Water bodies are analyzed using spectral Signature, which denotes the unique characteristics of each object. The selected area is analyzed using extracted three spectral indices and Fig 12 shows the results. The WRI index, using a threshold value of -0.0976, effectively distinguishes water bodies as shown in Fig 12 above. Similarly, other indices perform well in identifying rivers, though they may encounter challenges with water hyacinths, shadows, and narrow areas. The spectral index NDWI exhibits the weakest performance, requiring additional modification to accurately separate water bodies from shadows and dense vegetation.

VII. CONCLUSION

In this work, three spectral indices are computed namely NDWI, MNDWI, and WRI. By analyzing the spectral signature information provided by the Sentinel-2 multispectral imagery, very good accuracy can be achieved for identifying and mapping water bodies of different sizes such as rivers, lakes, reservoirs, wetlands, and coastal areas. These three spectral indices are useful in detecting water bodies. The information fusion approach from all three indices may improve the accuracy of water body detection.

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