India Space Academy

Department of Space Education

Summer Training Programme on Remote Sensing and GIS – 2025

Project title: Mapping Surface Water Bodies using the Normalized Difference Water Index (NDWI) from Satellite Imagery

Project Code: P1

Prepared By:

Satwik Shreshth

MCA 2nd year student

Sikkim University

Date of Submission: 16-Aug-2025

Table of Contents

Content ***Page No.***

Title: Mapping Surface Water Bodies using the Normalized Difference Water Index (NDWI) from Satellite Imagery

Objective:

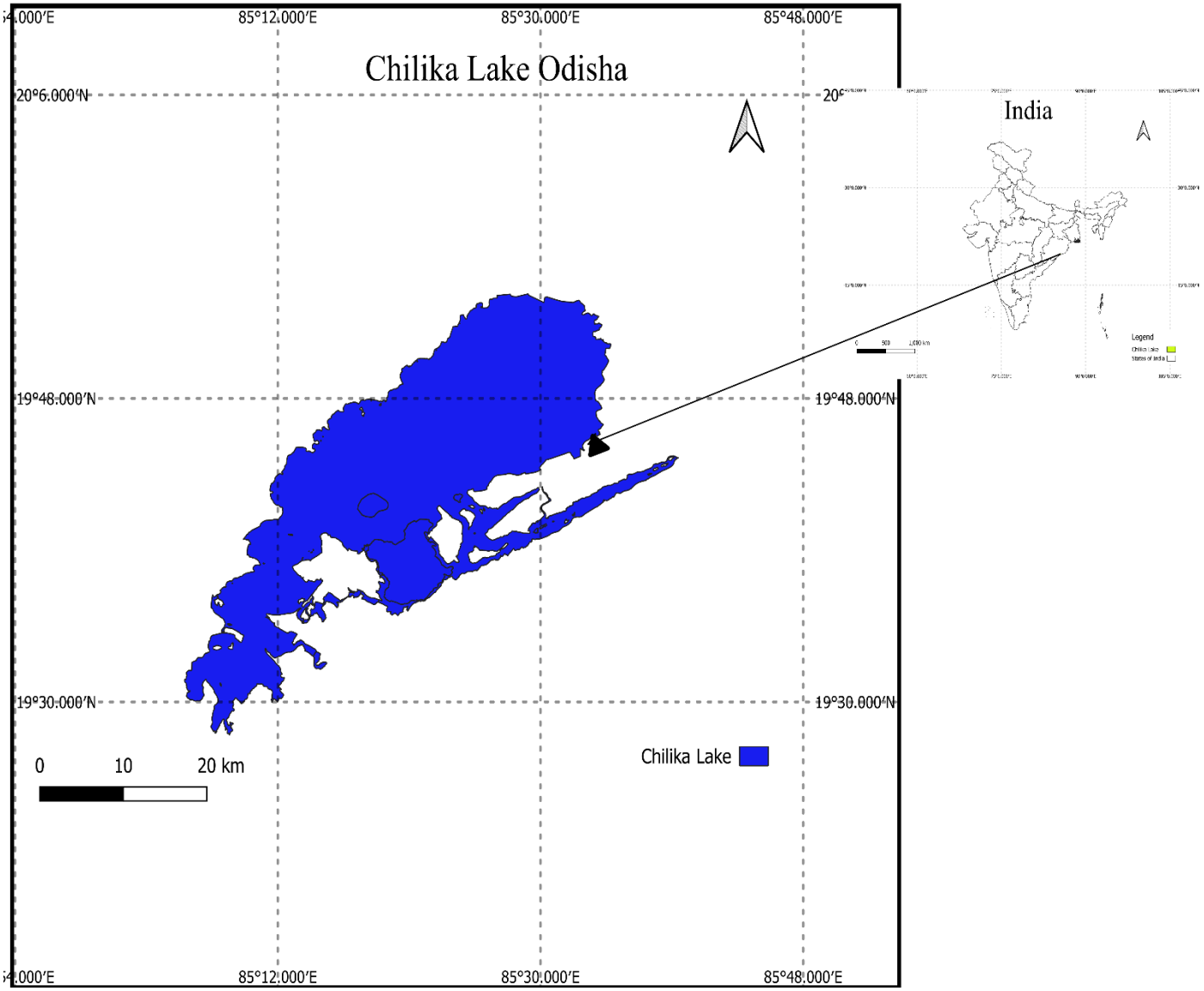
The objective of this project is to map and quantify surface water bodies in the Chilka Lake region of Odisha using the Normalized Difference Water Index (NDWI) technique. By leveraging satellite remote sensing data and cloud-based geospatial analysis through Google Earth Engine (GEE), this study aims to generate NDWI rasters, classify water and non-water areas, extract vectorized water bodies, and calculate their spatial extent (area) with high accuracy and temporal relevance.

Study Area:

- **Name:** Chilka Lake (also spelled Chilika), Asia's largest brackish water lagoon.
- **Location:**
  - **Districts Covered:** Khordha, Puri, and Ganjam
  - **State:** Odisha
  - **Country:** India
- **Geographical Coordinates of Central Point:**
  - **Latitude:** 19.7540° N
  - **Longitude:** 85.4698° E
- **Extent (Approximate Bounding Box):**
  - **North:** 19.93° N
  - **South:** 19.40° N
  - **East:** 85.80° E
  - **West:** 85.13° E
- **Significance:**
  - Recognized as a **Ramsar Wetland Site of International Importance**
  - Critical ecological zone supporting **fisheries**, **migratory birds**, and **Irrawaddy dolphins**
- **AOI Definition:**
  - The Area of Interest (AOI) boundary was extracted and defined using **OpenStreetMap data** via the **QuickOSM plugin** in **QGIS**.

- The shapefile was created from this OSM data and used to precisely delineate Chilka Lake.
- This shapefile was subsequently imported into **Google Earth Engine (GEE)** to serve as the spatial boundary for all further analysis and visualizations.

➢ **A map showing the Area of Interest (AOI), created in QGIS, is included below to provide spatial context for the selected study area.**



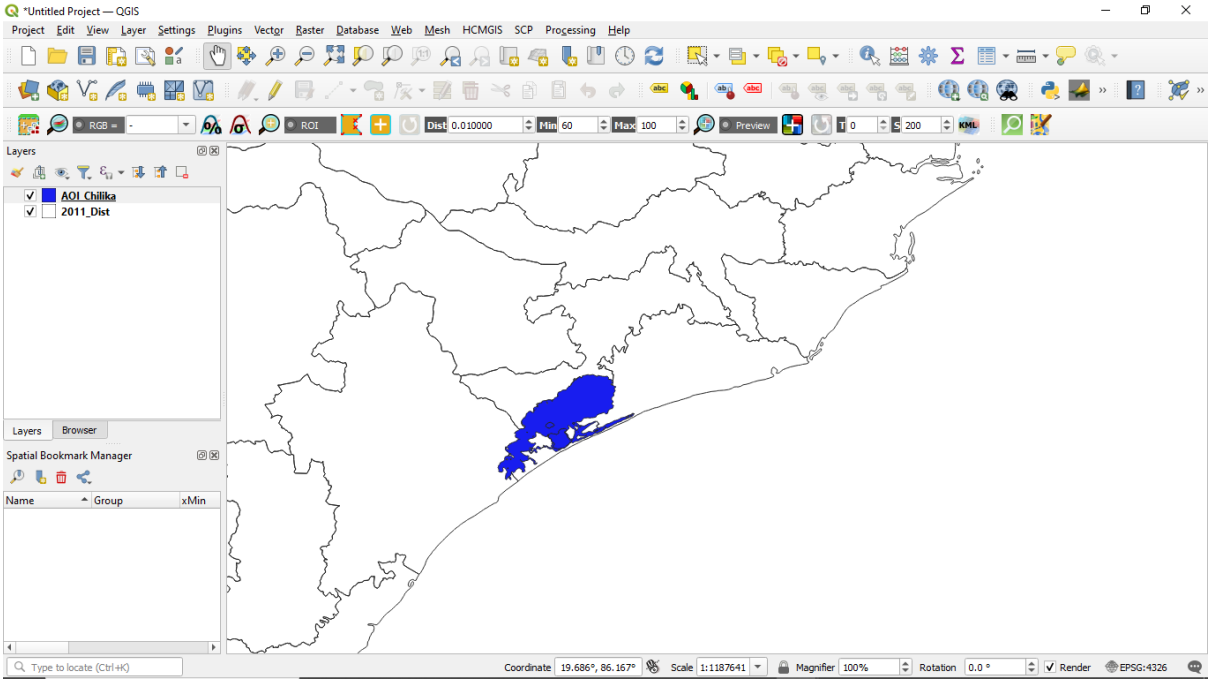
Data Used:

- **Satellite Imagery:**
  - **Dataset:** Sentinel-2 Surface Reflectance Harmonized
  - **GEE Collection ID:** `COPERNICUS/S2_SR_HARMONIZED`
  - **Source:** https://developers.google.com/earth-engine/datasets/catalog/COPERNICUS_S2_SR_HARMONIZED
  - **Temporal Range:** 1st January 2023 to 31st December 2023
  - **Cloud Cover Filter Applied:** Less than 10% for high-quality cloud-free composite
  - **Bands Used:**
    - **B2 (Blue)**
    - **B3 (Green)**
    - **B4 (Red)**
    - **B8 (Near Infrared - NIR)**
  - **Spatial Resolution:**
    - 10 meters (native resolution)
  - **Processing Resolution in GEE:**
    - 30 meters (for vectorization and statistics export)
- **AOI Vector Shapefile:**
  - **Source:** OpenStreetMap (OSM)
  - **Extraction Method:** Created using **QuickOSM plugin** in **QGIS**
  - **Description:** The shapefile outlines the boundary of **Chilka Lake** by querying the OpenStreetMap database directly from QGIS.
  - **Usage:** Imported into **Google Earth Engine** to define the Area of Interest (AOI) for all operations including clipping, NDWI masking, and vector generation.

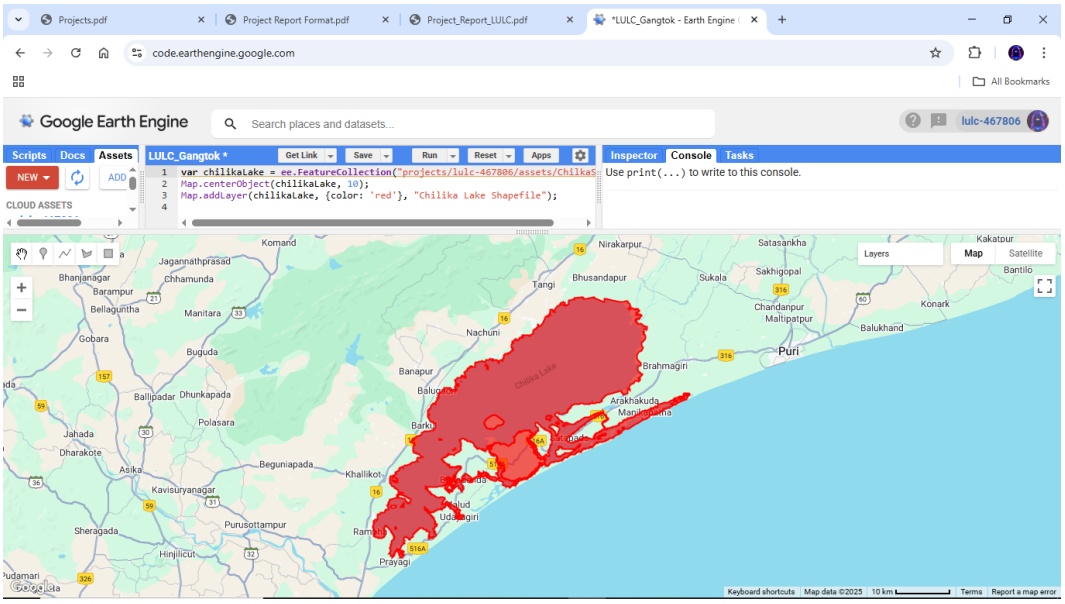
Methodology:

The NDWI-based water body mapping of Chilka Lake, Odisha was carried out using Google Earth Engine (GEE) and QGIS. The methodological framework involves several key steps:

1. **Defining the Study Area (AOI):**
   The Area of Interest (AOI) was defined using a polygon shapefile for Chilka Lake. This shapefile was created in **QGIS** using the **QuickOSM** plugin. The plugin was configured to download OpenStreetMap (OSM) data related to the water body feature with the key-value pair `natural=water`. The resulting vector layer was saved as a shapefile and used as the AOI in the GEE script.



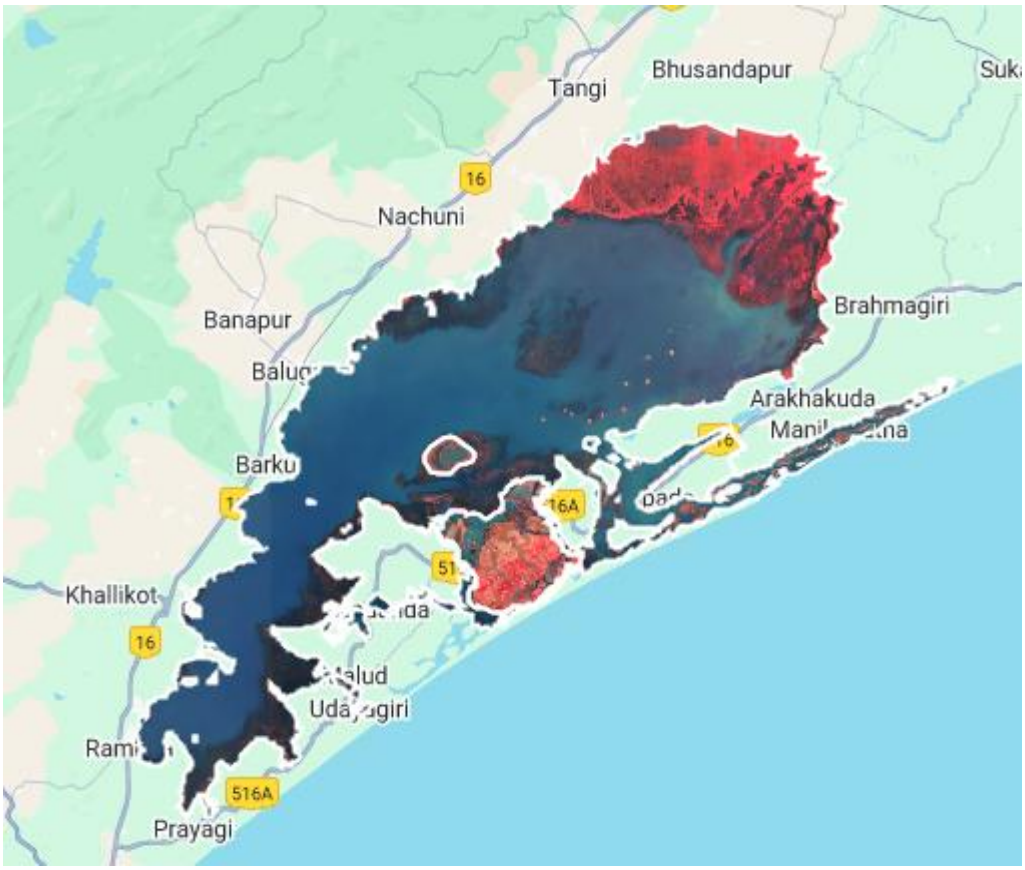
Screenshot 1: Chilka Lake boundary extracted using QuickOSM in QGIS, showing the designated Area of Interest (AOI).



Screenshot 2: Chilka Lake Area of Interest (AOI) visualized in Google Earth Engine, using the QGIS-created shapefile for precise lake boundary mapping**.**

2. **Satellite Data Collection:**
   Sentinel-2 Surface Reflectance imagery (S2_SR) was used for water body detection. The data was filtered over the date range from **January 1, 2023, to December 31,**

2023, and cloud cover was minimized using the QA60 cloud mask band. The imagery was clipped to the AOI for focused analysis.



Screenshot 3: Sentinel-2 false color composite (NIR–Red–Green) highlighting land-water contrast and vegetation over Chilka Lake for the year 2023.

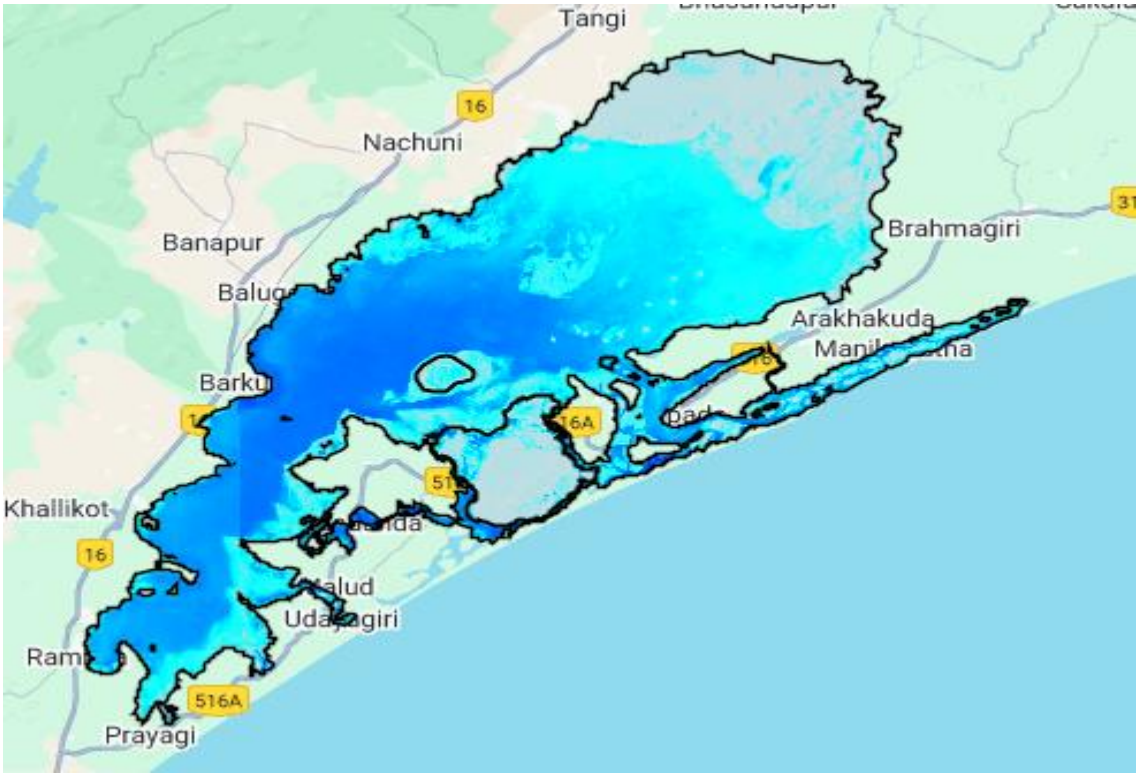
3. **NDWI Calculation:**
   The **Normalized Difference Water Index (NDWI)** was computed using the **Green (B3)** and **Near-Infrared (NIR, B8)** bands of Sentinel-2.

   The formula used is:

$$\text{NDWI} = \frac{\text{Green} - \text{NIR}}{\text{Green} + \text{NIR}}$$

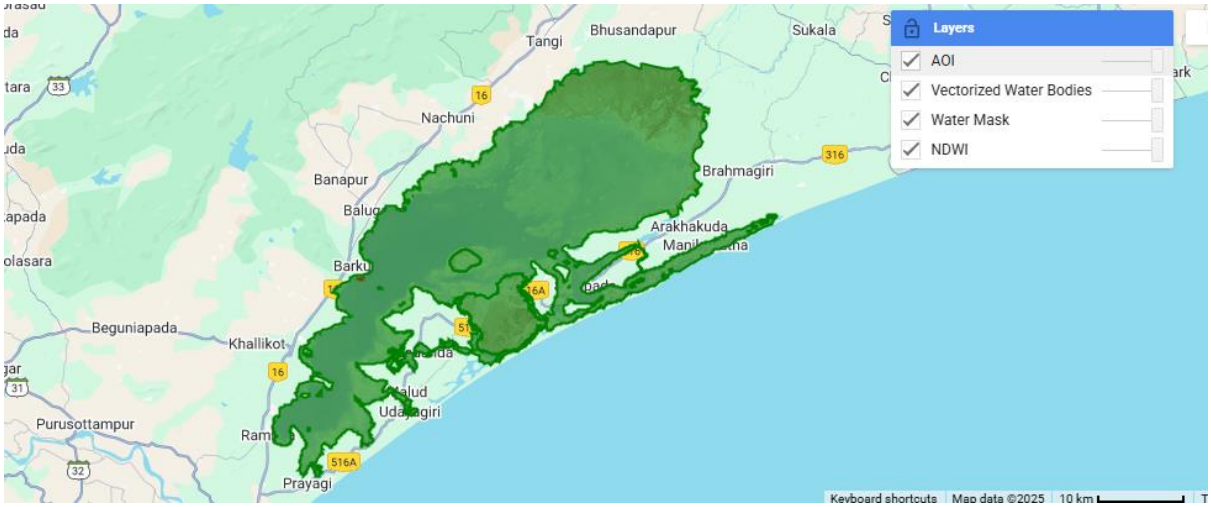
   This index enhances water features while suppressing vegetation and built-up areas.

4. **Thresholding and Water Classification:**
   A threshold value of **0.3** was applied to the NDWI layer. Pixels with NDWI values greater than 0.3 were classified as water, and others as non-water. This binary classification resulted in a raster map highlighting water bodies in white and non-water regions in black.



Screenshot 4: NDWI map showing water bodies in shades of cyan to blue and non-water areas in light gray, derived from Sentinel-2 imagery (2023) over Chilka Lake.

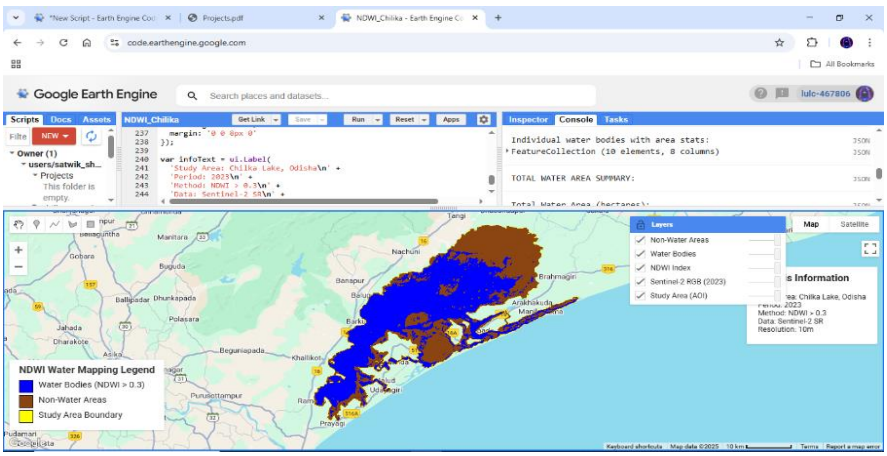
5. **Vectorization of Water Bodies:**
   The classified water mask was converted into vector polygons using the reduceToVectors() function in GEE. A spatial filter was applied to ignore small artifacts and preserve meaningful water body features.



Screenshot 5: Vectorized representation of surface water bodies extracted from Sentinel-2 NDWI, overlaid on the region of interest using polygon features**.**

6. **Water Body Area Statistics:**
   For each water body polygon, the area was computed in square meters, hectares, and square kilometers. These attributes were added to the FeatureCollection using GEE's geometry().area() function. The resulting statistics were exported as a **CSV file** for further use.
7. **Visualization and Map Export:**
   The NDWI raster, water body polygons, and the AOI boundary were overlaid on the GEE Map panel. Symbology included:
   - AOI boundary (Yellow)
   - Water bodies (Blue)
   - Non-Water Area (Red)

Screenshot 6: Visualization of NDWI raster, water body polygons, and Area of Interest**.**



Export of Results:
The following outputs were exported from GEE:

- **NDWI Raster Image** as GeoTIFF
- **Vector water body layer** as shapefile
- **Water area statistics** as CSV file
- **Map Screenshot** for visualization

Results:

- Water body mapping was carried out using Sentinel-2 SR Harmonized imagery, which offers a spatial resolution of 10 meters.
- The Area of Interest (AOI) was defined over **Chilka Lake**, located in **Odisha, India**.
- The **Normalized Difference Water Index (NDWI)** was employed for classification, with a threshold value set at **0.3** to effectively delineate water features.
- The analysis was performed for the **entire year 2023**, utilizing a total of **66 Sentinel-2 images** to ensure consistent temporal coverage.
- Through the NDWI-based classification process, a total of **3,264 individual water bodies** were detected within the AOI.
- The **total surface water area** detected was:
  - **55,530.41 hectares**, or
  - **555.30 square kilometers**
- As the number of extracted water bodies was substantial, it was not feasible to present all individual results within this section.
- Therefore, the **top 50 water bodies**, ranked by surface area, were selected to provide a more focused representation of the results.
- A **bar chart** displaying these top 50 water bodies has been included in the following section to facilitate better visual interpretation of size variations.
- Additionally, a **CSV file containing detailed area statistics** for all detected water bodies has been exported for further reference and analysis.
- All the results, including maps, charts, and detailed analyses, have been provided in the subsequent sections to support better interpretation and understanding.

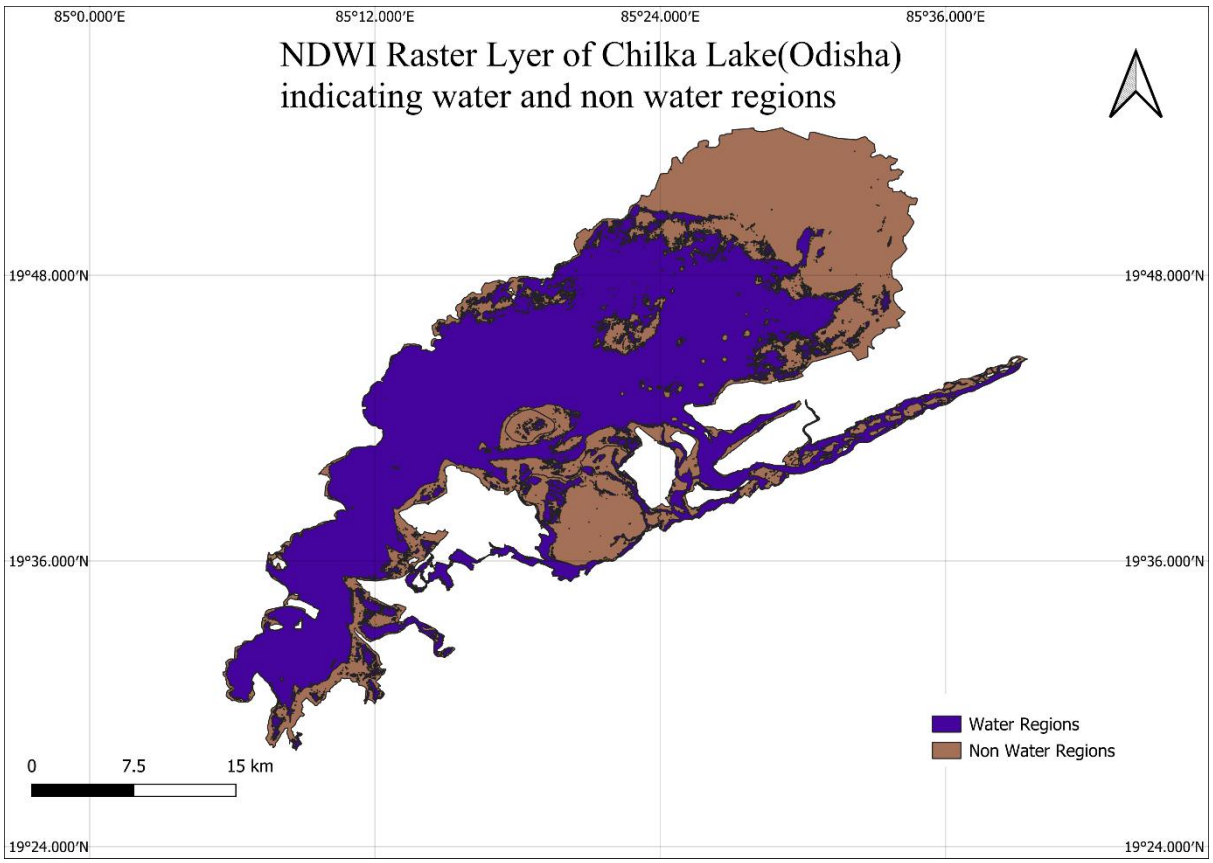


Image 7: NDWI (Normalized Difference Water Index) raster layer displaying water (blue) and non-water (red) regions for Chilka Lake, Odisha.

Image 8: Vector Polygons showing surface water bodies.

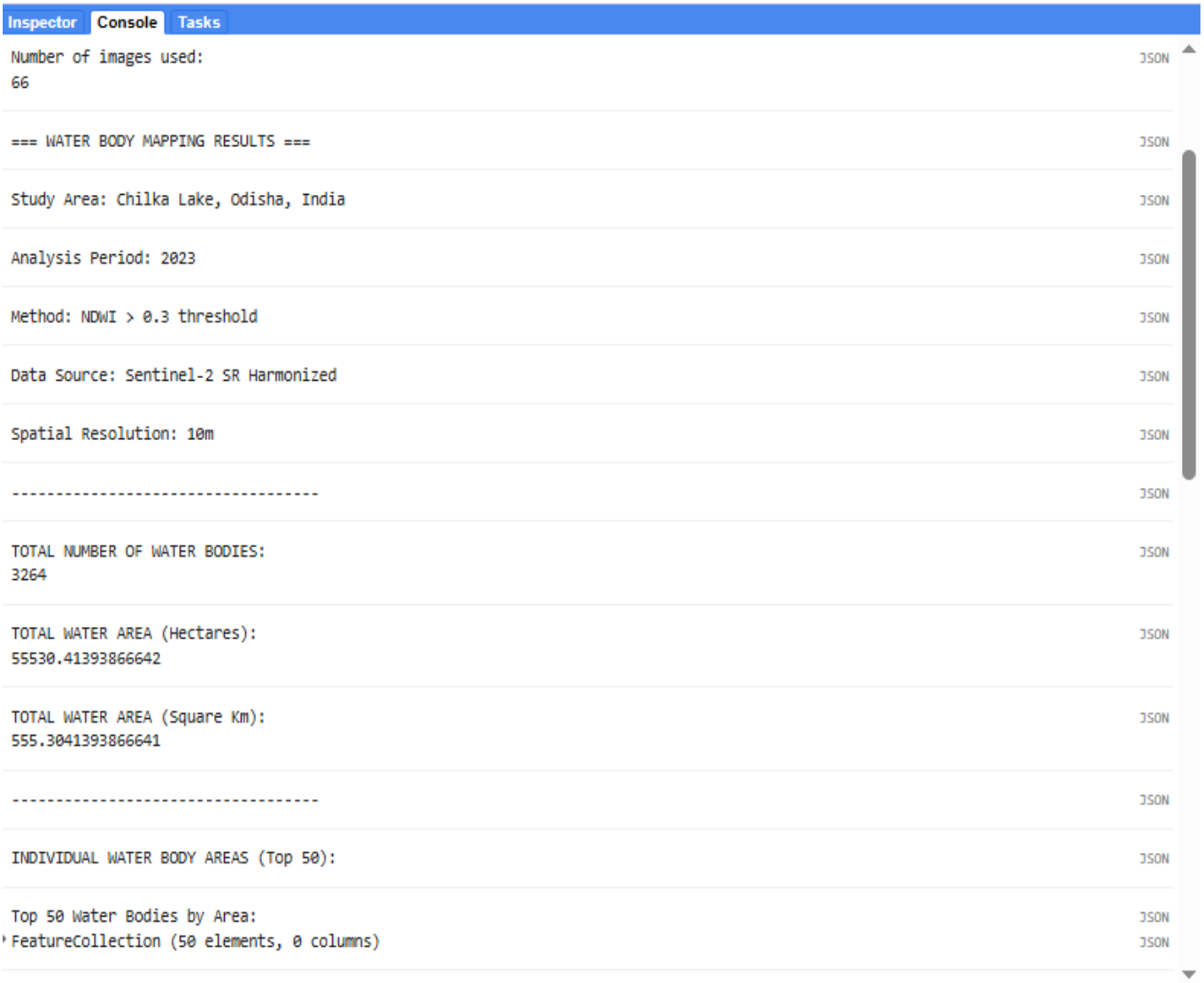


Image 9: Console of GEE showing area statistics of water bodies

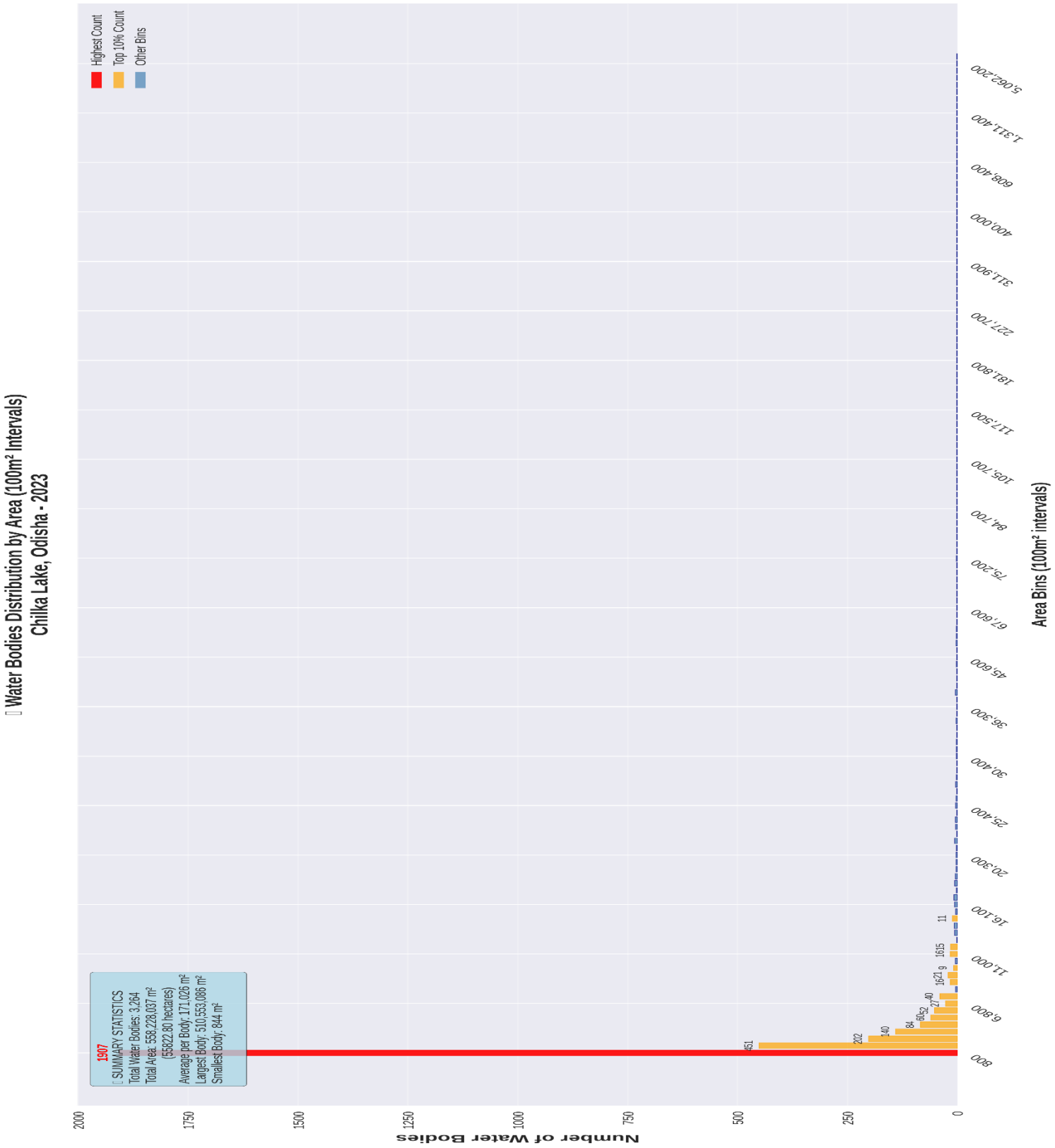


Image 10: Bar chart showing the surface area (hectares) of the largest 50 water bodies identified within the Chilka Lake study region, grouped by 100 m² intervals to illustrate the distribution and comparative sizes of these water bodies.

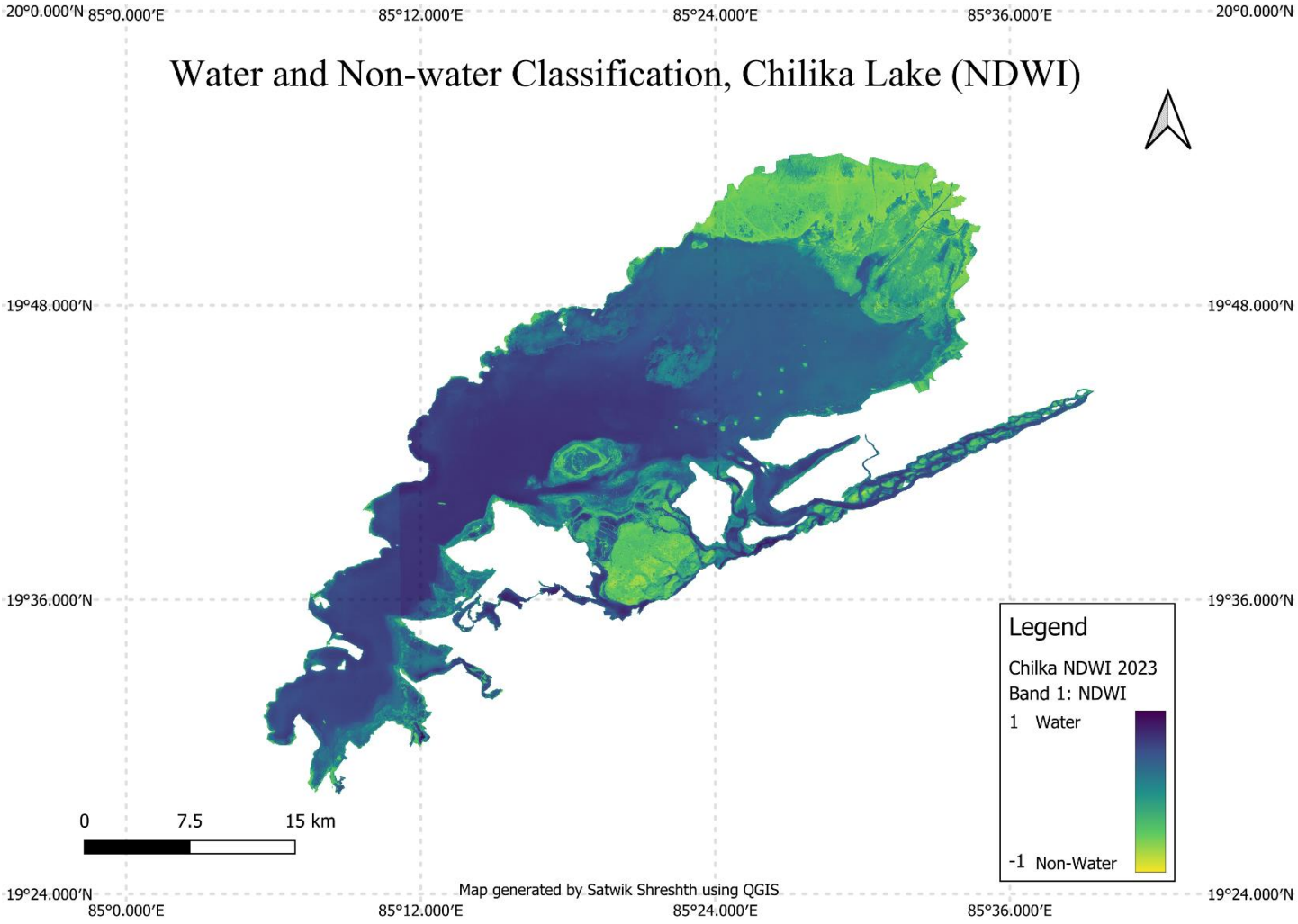


Image 11: Final NDWI Map of Chilka Lake (Odisha)

Conclusion:

The study utilized the Normalized Difference Water Index (NDWI) to extract and analyze surface water bodies within the Chilka Lake region using Sentinel-2 satellite imagery on the Google Earth Engine (GEE) platform. The following key outcomes and methodological aspects were identified and achieved:

Research Achievement

- A comprehensive water body mapping was conducted using NDWI, enabling efficient delineation of surface water features.

- The use of GEE allowed for handling large geospatial datasets in a cloud-based environment, reducing the burden of local processing.
- A successful demonstration of NDWI's ability to detect water features based on green and NIR reflectance difference was achieved.

Technical Implementation

- Sentinel-2 MSI imagery was effectively employed, and NDWI was computed using the green (B3) and near-infrared (B8) bands.
- Water features were extracted through thresholding techniques and vectorized to generate water masks.
- Further analysis was supported using in-built GEE functions and custom scripts for map generation and area calculation.

Data Processing Workflow

- The workflow included image selection, cloud masking, NDWI computation, threshold application, and vector conversion.
- Additional filtering was applied to exclude false positives caused by shadows, urban structures, or cloud-affected pixels.
- Outputs were exported in multiple formats (GeoTIFF, CSV, SHP) for further analysis and reporting.

Regional Context Integration

- The study area focused on the Chilka Lake region in Odisha, which is India's largest coastal lagoon and ecologically sensitive.
- Seasonal and geographic relevance was maintained by selecting appropriate timeframes and regional boundaries using shapefiles.
- The spatial analysis considered administrative limits and hydrological behaviour specific to the Chilka ecosystem.

Output Generation

- The NDWI raster was classified to distinguish water and non-water areas visually.
- Water bodies were vectorized and area statistics (in hectares/sq.km) were computed for each polygon.
- All outputs, including maps, charts, and statistical summaries, were exported and visualized to support result interpretation.

Documentation and Methodological Contributions

- A replicable methodology for surface water detection was documented using open-source tools and data.
- The process demonstrated how cloud-based platforms like GEE can be integrated into environmental mapping workflows.
- The approach provides a baseline for future studies focusing on seasonal water fluctuation and flood mapping.

Research Implications

- The study supports water resource management, ecological conservation, and hydrological modeling efforts.
- Local authorities and environmental agencies may utilize the outputs to track water body changes over time.
- The NDWI technique contributes to broader geospatial applications in wetland **conservation, land use planning, and climate change studies.**

Applications

- The methodology can be extended to monitor other regional lakes, reservoirs, or wetlands.
- Applications in disaster management (e.g., flood monitoring), irrigation planning, and biodiversity protection are feasible.
- Educational institutions and researchers can adapt this workflow for academic purposes and training.

References:

1. Jiang, W., Ma, L., Wang, J., & Li, Y. (2020). A new index for identifying water body from Sentinel-2 satellite remote sensing imagery. *ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences, V-3-2020*, 33–40. https://isprs-annals.copernicus.org/articles/V-3-2020/33/2020/
2. Li, L., Xu, Q., & Wang, Z. (2018). Water body detection from Sentinel-2 data using NDWI and MNDWI. *Remote Sensing, 10*(7), 1177. https://doi.org/10.3390/rs10071177
3. McFeeters, S. K. (1996). The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features. *International Journal of Remote Sensing, 17*(7), 1425–1432. https://doi.org/10.1080/01431169608948714
4. QGIS Development Team. (2025). *QGIS User Guide*. https://docs.qgis.org/latest/en/docs/training_manual/rasters/changing_symbology.html