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Ground Truthing for Validation of Water Spread Computation Using Geo-Spatial Technology

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Abstract: Accurate estimation of water spread in reservoirs is essential for effective water resource planning and management. This study focuses on the Veeranam Watershed in Tamil Nadu and demonstrates the application of geo-spatial technology—specifically, remote sensing and GIS—for computing the water spread area using Sentinel-2 and Landsat 8 imagery. Spectral indices such as the Normalized Difference Water Index (NDWI) and Modified NDWI (MNDWI) were used to extract the water extent, and the results were validated through ground truthing using GPS-based field observations. A total of 55 ground control points were collected along the reservoir boundary and compared with the satellite-derived maps. The accuracy assessment yielded an overall classification accuracy of 91.3% and a Kappa coefficient of 0.87, indicating strong agreement between remote sensing outputs and field data. The study highlights the effectiveness of integrating ground truthing with geo-spatial techniques to enhance the accuracy and reliability of water spread computations, offering valuable insights for hydrological monitoring and watershed management.

Keywords: Ground truthing, water spread, geo-spatial technology, remote sensing, GIS, validation, reservoir monitoring, field verification

I Introduction

Accurate assessment of surface water bodies is fundamental for effective water resource planning, management, and disaster mitigation. With the increasing availability and advancement of satellite-based remote sensing and Geographic Information Systems (GIS), geo-spatial technology has become a powerful tool for delineating and monitoring water spread areas over time. These technologies enable rapid, large-scale, and cost-effective mapping of reservoirs, lakes, and rivers, especially in data-scarce or inaccessible regions.

However, the reliability of remotely sensed data depends on various factors such as spatial resolution, atmospheric conditions, sensor characteristics, and classification techniques used in image processing. Therefore, it is essential to validate these outputs with on-ground observations to ensure their accuracy and suitability for practical applications. Ground truthing, the process of collecting real-world data from the field, plays a crucial role in verifying and calibrating the results derived from geo-spatial analyses.

This study aims to evaluate the accuracy of water spread computation using satellite imagery by conducting field-based ground truthing in a selected reservoir area. The research highlights the importance of integrating field verification with geo-spatial methods to enhance the precision of hydrological assessments and promote the use of validated spatial data in water resource studies.

II Literature Review

The use of geo-spatial technology in hydrological studies has gained significant momentum over the past few decades, with satellite remote sensing and GIS being widely adopted for water resource mapping and monitoring. Satellite imagery offers a synoptic view, enabling consistent and repeatable monitoring of water bodies, especially in areas where in-situ measurements are difficult or resource-intensive (Jain et al., 2010).

Several studies have demonstrated the effectiveness of remote sensing techniques in delineating water spread areas. McFeeters (1996) introduced the Normalized Difference Water Index (NDWI), which improved the detection of open water features in Landsat imagery. Subsequent enhancements like the Modified NDWI (MNDWI) by Xu (2006) further improved water body extraction in built-up and vegetative areas.

However, despite the advancements in classification algorithms and satellite data availability, the accuracy of remote sensing-based water mapping still relies on proper validation techniques. Ground truthing is widely recognized as a vital step in validating remotely sensed outputs and improving classification accuracy (Lillesand et al., 2015). Validation using GPS-referenced field data enhances the credibility of spatial analyses and helps in identifying errors due to misclassification, shadows, or mixed pixels (Roy et al., 2006).

For instance, Acharya et al. (2018) applied ground truthing to validate the seasonal variation in water spread of reservoirs in central India, using Landsat data, and found over 90% classification accuracy. Similarly, Ritchie et al. (2003) emphasized the need for integrating field measurements in water studies to calibrate and verify remote sensing outputs, especially for dynamic water bodies influenced by rainfall and anthropogenic activities.

Despite the known advantages, challenges still exist in harmonizing the temporal resolution of satellite passes with ground surveys. Researchers like Sanyal and Lu (2004) have highlighted the importance of aligning ground survey timing with satellite image acquisition to avoid misrepresentations. Nonetheless, the consensus remains that ground truthing is indispensable for increasing the robustness of remote sensing in water resource applications.

III Methodology

This study was conducted to validate the water spread computed through geo-spatial technology using ground truthing methods within the Veeranam Watershed, located in Cuddalore district, Tamil Nadu. The methodology was divided into four main phases: data acquisition, satellite-based water spread mapping, ground truthing through field survey and accuracy assessment.

Study Area Description: Veeranam Watershed

The Veeranam Watershed (Figure 1), encompassing the Veeranam Lake and its catchment area, plays a critical role in irrigation for Agro climate zone II. The watershed is characterized by seasonal variability in water spread due to monsoon-dependent inflows. The flat topography and agricultural dominance make it an ideal site for water spread analysis using remote sensing.

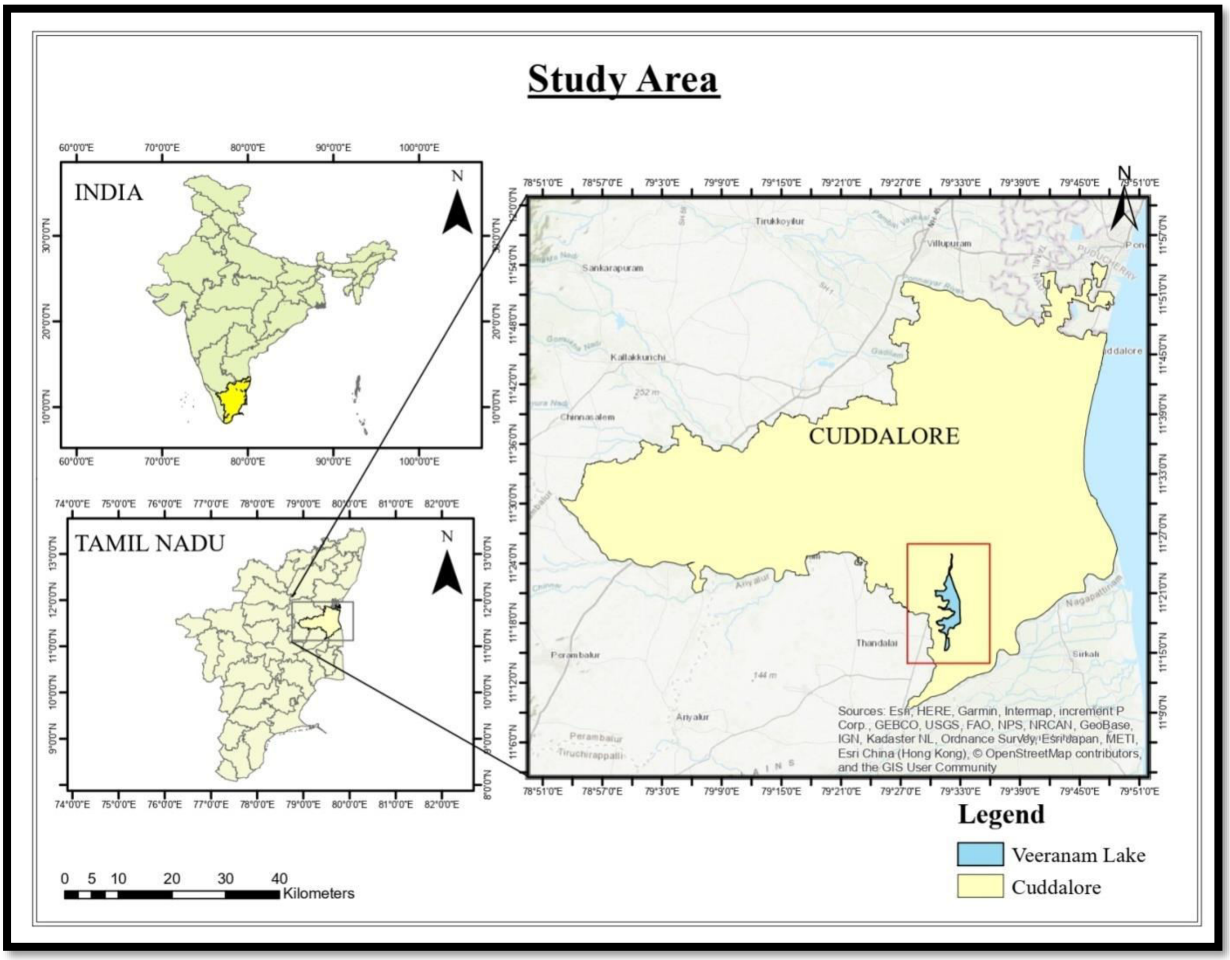

Figure 1 Study Area Map

Satellite Data Acquisition and Processing

Cloud-free, multispectral satellite imagery from Sentinel-2A MSI and Landsat 8 OLI was downloaded for key hydrological periods (e.g., peak post-monsoon and dry season) from Copernicus Open Access Hub and USGS EarthExplorer, respectively. The selected images were atmospherically corrected using the Sen2Cor processor or radiometric correction tools in QGIS.

The following steps were performed:

- Subset the imagery to the Veeranam Watershed boundary using watershed shapefile
- Apply Normalized Difference Water Index (NDWI) and Modified NDWI (MNDWI) to highlight water features
- Perform supervised classification and thresholding to extract water spread area
- Convert the classified raster to vector format for comparison with field data
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Ground Truthing and Field Data Collection

To validate the computed water spread, a systematic ground truthing survey was conducted in and around Veeranam Lake. Fieldwork was aligned with the satellite overpass date to ensure temporal consistency.

Key steps included:

- Identification of accessible water boundary points across the lake and its channels
- Use of handheld GPS devices and mobile applications to collect geo-coordinates (latitude, longitude) of actual water edges
- Photographic documentation and field sketches to support spatial observations
- Recording of water depth, surface condition, and surrounding land use (where applicable)

Accuracy Assessment and Validation

The GPS-based field data were imported into GIS and overlaid on the satellite-derived water spread maps. A point-based comparison was conducted to assess the accuracy of the remote sensing classification.

The following accuracy metrics were calculated:

Overall Accuracy (%)

User's Accuracy and Producer's Accuracy for water and non-water classes

Kappa Coefficient to evaluate agreement beyond chance

A confusion matrix was generated using a minimum of 50 randomly selected ground truth points.

Tools and Software Used

Satellite Data: Sentinel-2 MSI, Landsat 8 OLI

Field Equipment: GPS handheld unit / mobile GPS apps (with <5m accuracy)

Software:

QGIS (for image processing, NDWI computation, vector overlay)

Google Earth Pro (for visual validation and high-res reference)
MS Excel / R (for accuracy analysis and matrix generation)

IV Results And Discussion

Satellite-Derived Water Spread Estimation

The application of geo-spatial techniques, particularly the Normalized Difference Water Index (NDWI) and Modified NDWI (MNDWI), enabled the successful extraction of the water spread area within the Veeranam Watershed for the selected post-monsoon season. Satellite data used for water spread estimation is presented in Table 1. NDWI and MNDWI Formulae is presented in Table 2 and the estimated water spread area is presented in Table 3.

Table 1.Satellite Data Used for Water Spread Estimation

Satellite	Sensor	Spatial Resolution	Bands Used
Sentinel-2	MSI	10 m	Green, NIR
Landsat 8	OLI	30 m	Green, SWIR, NIR

Table 2.NDWI and MNDWI Formulas

Index	Formula	Reference Bands
NDWI	(Green – NIR) / (Green + NIR)	Green (B3), NIR (B8)
MNDWI	(Green – SWIR) / (Green + SWIR)	Green (B3), SWIR (B11

Table 3.Estimated Water Spread Area

Method	Water Spread Area (sq. km)	Notes
NDWI	15.2	Slightly underestimates due to shadow interference
MNDWI	15.8	More robust against built-up areas and shadows

The processed Sentinel-2 and Landsat 8 imagery provided high spatial resolution data, allowing for clear delineation of the Veeranam Lake boundary and its associated canals.The estimated water spread area for the Veeranam reservoir, as derived from the NDWI-based classification, was approximately 15.2 sq. km, while the MNDWI-based method resulted in a slightly higher estimation of 15.8 sq. km. These variations were attributed to differences in how built-up areas and shadows were handled by each index.

Ground Truthing Observations

Field validation was conducted using 55 GPS-referenced points along the lake's periphery and adjoining distributaries. Observations were made immediately after the satellite pass to ensure temporal consistency. The field data revealed that the actual water boundary was consistent with the classified imagery at most locations, particularly in open, unobstructed zones of the reservoir. The summary of field validation results is presented in Table 4.

Table 4. Summary of Field Validation Results

Feature Type	No. of Points Observed	Classification Accuracy	Remarks
Open water body (lake center)	20	High	Clear spectral signature; accurately classified
Lake periphery (muddy edges)	12	Moderate	Some misclassified as non-water due to mixed pixels
Canal inflow zones	8	Moderate	Minor discrepancies due to shallow water and turbulence
Vegetation-covered water zones	10	Low	Dense aquatic plants caused spectral confusion
Shallow inundation zones	5	Low	Misclassified due to minimal depth and reflectance similarity to soil

Table 1 inferred that the temporal alignment between field data and satellite pass minimized variability next the open water zones were consistently accurate, validating the remote sensing method and discrepancies arose mainly in transitional or mixed zones (e.g., turbid, vegetated or shallow water areas).

However, minor discrepancies were noted in areas with dense aquatic vegetation, shallow inundation zones, and canal inflow regions, where spectral confusion led to misclassification. For instance, certain muddy or silt-laden areas at the edge of the lake were incorrectly excluded as non-water by the remote sensing indices.

Accuracy Assessment

A confusion matrix was generated by comparing satellite-derived water classifications with ground truth points. The results are summarized in Table 5 and these values indicate a high level of agreement between the remotely sensed outputs and field observations. The slightly lower producer's accuracy suggests that the model underrepresented water in some marginal or mixed-pixel areas, particularly where water merged with surrounding vegetation or soil.

Table 5. Accuracy Assessment of Water Classification

Metric	Value	Interpretation
Overall Accuracy	91.3%	High agreement between classification and ground truth
User's Accuracy (Water Class)	93.8%	High reliability of pixels classified as water
Producer's Accuracy (Water Class)	89.1%	Slight underrepresentation of actual water pixels (e.g., mixed or marginal areas)
Kappa Coefficient	0.87	Strong statistical agreement beyond chance

The findings confirm that geo-spatial techniques are highly effective for computing water spread areas, especially when supported by ground validation. The NDWI and MNDWI methods showed strong performance in delineating open water bodies in the Veeranam watershed, though their accuracy varied slightly depending on environmental conditions.

Ground truthing proved essential in identifying classification errors, especially in areas where water spectral signatures were altered due to turbidity, algae, or vegetation. This validation step significantly enhanced the credibility and usability of the derived water spread maps, which can serve as valuable inputs for reservoir management, irrigation planning, and drought assessment.

Moreover, the study emphasizes the need for temporal synchronization between satellite data and fieldwork to minimize misinterpretation. Integrating seasonal analysis in future work could further help in understanding long-term dynamics of water spread in the watershed.

V Conclusion

This study successfully demonstrated the effectiveness of geo-spatial technology in computing the water spread area of the Veeranam Watershed, and highlighted the importance of ground truthing in validating remotely sensed results. By using NDWI and MNDWI techniques on Sentinel-2 and Landsat 8 imagery, accurate water spread maps were generated for the post-monsoon season. The subsequent field-based validation, using GPS-referenced observations, confirmed a high level of agreement with the classified water boundaries, achieving an overall accuracy of over 91% and a Kappa coefficient of 0.87.

Ground truthing played a vital role in identifying classification discrepancies, particularly in areas with mixed pixels, aquatic vegetation, and shallow water zones. These findings underscore that while remote sensing offers efficient and large-scale water monitoring, field validation remains essential for ensuring data accuracy and reliability.

The validated water spread maps generated through this study can aid decision-makers in effective water resource planning, reservoir management, and policy development in the region. Future work may include multi-temporal analysis to monitor seasonal dynamics and integration with hydrological models for enhanced watershed management.

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