

OPTIMISING SENTINEL-1 BACKSCATTER THRESHOLDS FOR SURFACE WATER MAPPING IN SMALL IRRIGATION TANKS: A GOOGLE EARTH ENGINE WEB APPLICATION FOR TANK WATER MANAGEMENT

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Abstract

Small irrigation tanks are essential structures for water management in the dry zone of Sri Lanka, yet consistent time-series observations of their surface-water extent remain scarce. This study develops and assesses optimised Sentinel-1 backscatter thresholds for surface-water mapping, implemented on the Google Earth Engine platform and demonstrating its application at Eru Wewa in the Malwathu Oya River Basin. The model was calibrated using reference points collected on 30 March 2021 by testing VV, VH, and VV–VH threshold combinations and selecting the combination with the highest overall accuracy and Kappa coefficient. The optimal thresholds were negative 17 dB for VV, negative 35 dB for VH, and 14 dB for the VV minus VH difference. The calibrated model achieved an overall accuracy of 95% and a Kappa coefficient of 0.894. Independent reference points from 3 December 2021 and 22 August 2025 gave overall accuracies of 90% and 90% with Kappa coefficients of 0.807 and 0.800, respectively. The estimated water-surface areas were validated on three dates, with a consistent underestimation of between 6% and 15%. The water-surface-area time series from 1 January 2020 to 30 November 2024 was analysed alongside seasonal rainfall to assess the temporal response of the reservoir. The workflow was further developed into a user-friendly web application that generates water-extent time series and converts them into storage based on the area-capacity curve, following the depth-area-storage capacity relationships for village tanks lacking surveyed bathymetric data. The application demonstrates practical reservoir monitoring at Eru Wewa, while broader applicability requires multi-site validation.

Keywords: Dry zone reservoirs, Radiometric thresholding, Remote sensing, Synthetic aperture radar, Village tank cascade systems

1. Introduction

Small irrigation tanks play an important role in water storage and agricultural water management in the dry zone of Sri Lanka [1]. However, temporal variations in their surface water extent are not routinely observed. Satellite remote sensing provides an effective means of monitoring reservoir surface-water dynamics over time [2], including relatively small water bodies [3]. Optical indices such as the Normalised Difference Water Index are widely used for this purpose, but their reliance on cloud-free acquisitions limits observation frequency during the monsoon periods when tank levels change most rapidly, whereas Sentinel-1 synthetic aperture radar acquires data independently of cloud cover and illumination. Therefore, this study aims to optimise Sentinel-1 backscatter thresholds for accurately mapping surface water in small irrigation tanks, using Eru Wewa in the Malwathu Oya River Basin as a case study.

2. Methodology

Sentinel-1 synthetic aperture radar (SAR) imagery was processed in Google Earth Engine, which enables large-scale geospatial analysis and time-series processing [4]. VV and VH backscatter were filtered and used together with the VV minus VH backscatter difference. Multiple threshold combinations were evaluated using reference samples from 30 March 2021. The selected thresholds were independently validated using reference samples from 3 December 2021 and 22 August 2025. Water-surface areas were subsequently compared with Google Earth reference delineations, and a time series from January 2020 to November 2024 was analysed together with daily rainfall. The calibrated workflow was implemented as a Google Earth Engine web application. The user selects a tank boundary and date range, and the application applies the optimised thresholds to every Sentinel-1 acquisition in that period, returning a water-surface-area time series as a chart and classified maps. Mapped areas are interpolated on the tank's area–capacity curve proposed by Imbulana (2022), to give a paired storage time series without any local processing.

3. Results and Discussion

Sentinel-1 is a C-band SAR mission developed by the European Space Agency (ESA) under the Copernicus Programme. It provides all-weather, day-and-night imagery with approximately 10 m spatial resolution and a nominal revisit time of 6–12 days. The optimal thresholds were negative 17 dB for VV, negative 35 dB for VH, and 14 dB for the VV minus VH difference. The model achieved an overall accuracy of 95% and a Kappa coefficient of 0.894, while independent validations achieved 90% and 90% accuracy, confirming reliable Sentinel-1 water classification. The spatial classification results are shown in Figure 1.

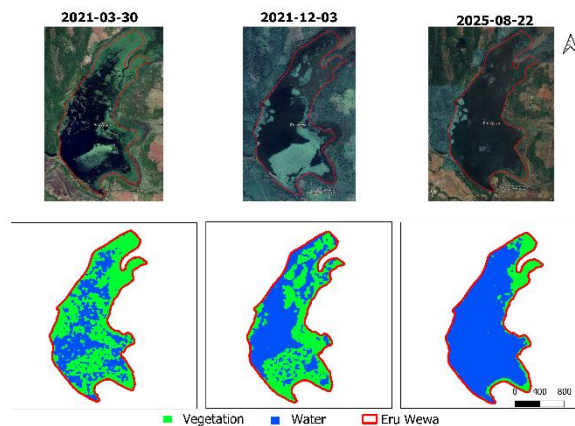


Figure 1: Sentinel-1 water and aquatic vegetation for calibration (30 March 2021) and validation (3 December 2021 and 22 August 2025).

Sentinel-1 underestimated the reference water areas by 6% to 15% (Table 1), potentially due to shoreline vegetation, shallow water, and mixed-pixel effects [3].

Table 1: Comparison of reference and Sentinel-1-derived water-surface areas.

Date	Google Earth reference area (ha)	Sentinel-1 classified area (ha)	Difference (ha)	Relative difference (%)
30 Mar 2021	94.56	83.25	11.31	12
03 Dec 2021	130.75	111.15	19.60	15
22 Aug 2025	195.00	182.66	12.34	6

The 2020 to 2024 time series (Figure 2) showed substantial seasonal variations in water-surface extent that generally corresponded with seasonal rainfall variability.

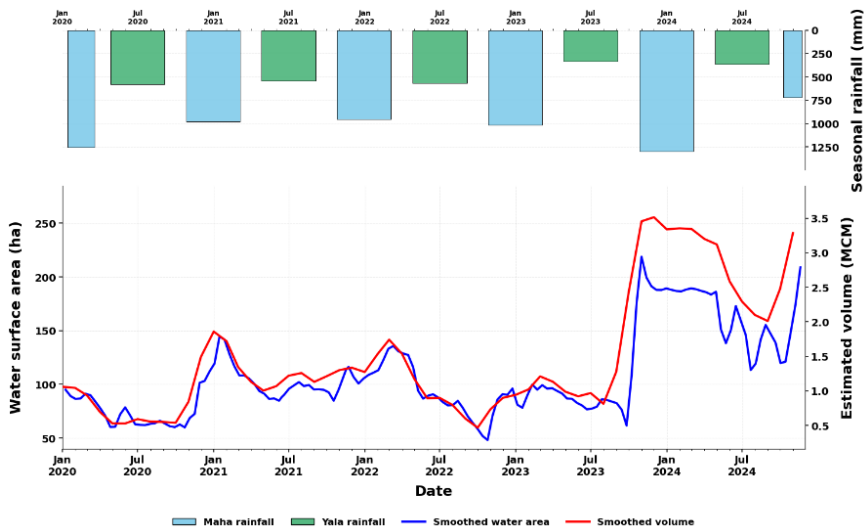


Figure 2: Seasonal rainfall, water-surface area, and estimated reservoir volume variation in Eru Wewa, 2020 to 2024.

4. Conclusion

The study demonstrates that an optimised Sentinel-1 threshold approach can provide consistent multi-temporal estimates of water-surface extent in a small irrigation reservoir. Independent validation confirmed good classification performance, although a systematic underestimation of surface-water area was observed. The temporal variation of rainfall, water-surface area, and estimated storage exhibited similar seasonal patterns. The workflow was implemented as a Google Earth Engine application for generating water-area and storage time series. Further validation using concurrent field observations is recommended.

References

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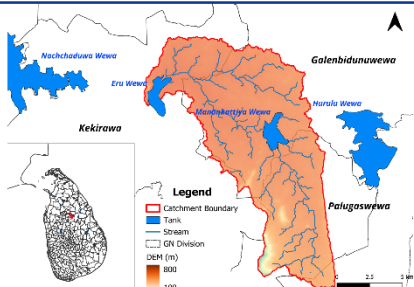
Optimizing Sentinel-1 Backscatter Thresholds for Surface-Water Mapping in Small Irrigation Tanks: A Google Earth Engine Web Application for Water Management

Demonstrated at Eru Wewa — a small dry-zone irrigation tank, Sri Lanka

01 STUDY AREA & CONTEXT

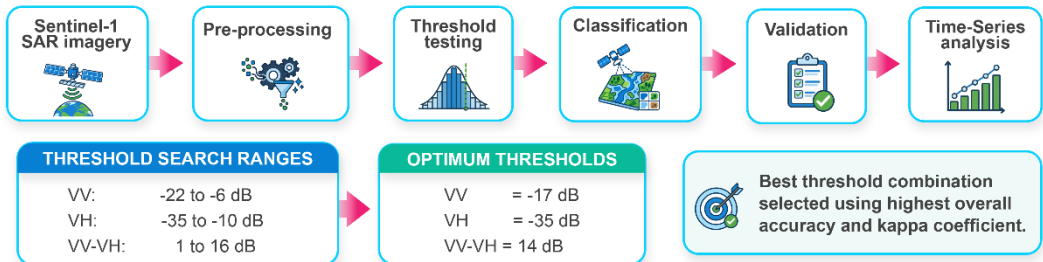


Eru Wewa, Sri Lanka



Small irrigation tank
Dry-Zone water management

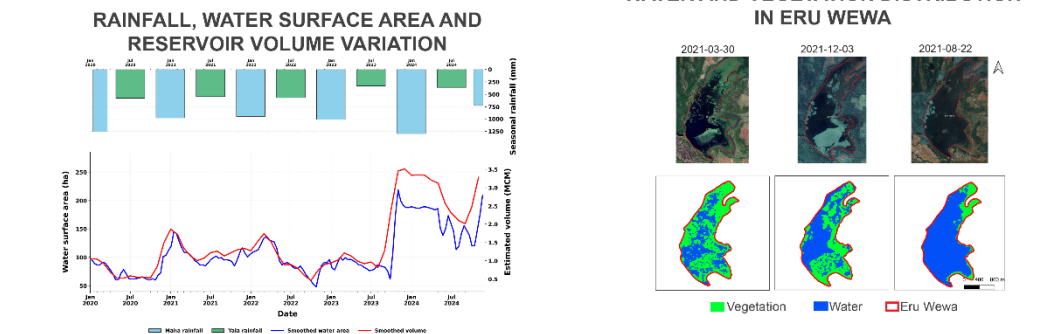
02 METHODOLOGY WORKFLOW



03 VALIDATION & RESULTS

ACCURACY ASSESSMENT			REFERENCE VS CLASSIFIED WATER AREA			
Calibration 30 Mar 2021	Validation 03 Dec 2021	Validation 22 Aug 2025	Date	Google Earth (ha)	Sentinel-1 (ha)	Difference (%)
OA 94.74%	OA 90.48%	OA 90.00%	30 Mar 2021	94.56	83.25	11.96%
Kappa 0.894	Kappa 0.807	Kappa 0.800	03 Dec 2021	130.75	111.15	14.99%
			22 Aug 2025	195.00	182.66	6.33%

04 TEMPORAL RESPONSE (01 Jan 2020 - 30 Nov 2024)



05 KEY OUTCOME



Optimized Sentinel-1 thresholds deliver consistent, cloud-independent estimates of surface-water extent and storage for small irrigation tanks, delivered through a Google Earth Engine web application for day-to-day tank water management.

