Multi-Method Remote Sensing for Mangrove Detection and Mapping in Panadura Estuary, Sri Lanka

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Mangrove ecosystems are critically important coastal biomes that provide essential ecological services, including carbon sequestration, shoreline protection, nursery habitat, and biodiversity support. Panadura estuary, located in Sri Lanka's Western Province and connected to the Bolgoda Lake, supports significant mangrove stands that are increasingly threatened by urban expansion, aquaculture, and anthropogenic disturbances. This study presents a comprehensive multi-method approach to detect, map, and quantify mangrove cover in Panadura estuary using three complementary methods: (1) satellite-based spectral index analysis incorporating the Combined Red-edge and MIR Index (CRMI), NDVI, NDMI, and NDSI ; (2) Google Earth Engine (GEE)-based classification using multi-temporal Sentinel-2 (10m and 20 m resolution) and Landsat imagery (30 m resolution); (3) visual interpretation and manual digitizing in Google Earth Pro (GEP) using very high resolution (VHR) time-series imagery (1 – 5 m resolution). Accuracy assessment was performed using 130 ground-truth validation points. Among the 21 true mangrove species reported in Sri Lanka, seven species were recorded in the Panadura estuary. The GEE-based classification estimated a total mangrove extent of 22.04 ha, compared with 12.2 ha derived from Google Earth Pro digitization and 31.4 ha estimated using the NDVI-based approach. The NDVI method achieved an overall accuracy of 48.9% (Kappa=0.44), whereas the GEE-based classification produced the highest validation accuracy (94.6%), demonstrating its superior reliability for mangrove mapping. The CRMI index showed superior performance in discriminating mangroves from non-mangrove vegetation and intertidal mudflats, together with NDVI, NDSI, NDWI, and NDMI. The results indicate that the mangroves in the Panadura estuary remained in a generally healthy condition between 2025 and 2026, although a slight decline in vegetation health was observed during the Southwest Monsoon and the Cyclone Ditwa period. The NDVI-based approach likely overestimated mangrove extent because dense terrestrial vegetation adjacent to the estuary exhibited similar spectral responses. Conversely, manual digitization in Google Earth Pro may have underestimated mangrove area due to the exclusion of fragmented or sparsely vegetated patches. Overall, this study highlights the complementary nature of the three approaches and recommends an integrated workflow for future mangrove monitoring in Sri Lanka's coastal wetland systems.

Keywords: *CRMI, Google Earth Engine, Google Earth Pro, Mangrove mapping, Remote sensing*