ECWS-9
2025
Conference

The 9th International Electronic Conference on Water Sciences

11–14 November 2025 | Online

A Scalable Automated Framework for Multi-Year Landsat Surface Reflectance Mosaicking and Spectral Index Derivation Using Google Earth Engine for Environmental Monitoring

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INTRODUCTION & AIM

Monitoring environmental changes across extensive and dynamic landscapes requires flexible, automated, and scalable remote sensing frameworks capable of consistent, reproducible analysis over multi-decadal timescales. Google Earth Engine (GEE) offers a powerful cloud-based platform with access to decades of Landsat satellite observations and sophisticated processing tools, enabling researchers to efficiently extract meaningful ecological information from vast datasets.

This study introduces an adaptable and automated GEE framework tailored for the multi-year processing of Landsat images, which dynamically selects the appropriate sensors according to the acquisition date, differentiating between Landsat TM (pre-2012) and OLI (post-2012) collections. The workflow efficiently generates seamless, cloud-minimized mosaics targeting key phenological periods (e.g., dry season February 15), and performs rigorous atmospheric correction to ensure temporal consistency across scenes. Using metadata-rich filenames for traceability, the framework calculates a suite of spectral indices, including NDVI, MNDWI, SAVI, MSAVI, and NDWI, offering the flexibility to extend analyses to various vegetation and hydrological health metrics.

Each output pixel corresponds to a 30m × 30m ground area, providing fine-scale spatial resolution necessary to detect subtle changes in mangrove forest structure and water dynamics. The application of this framework to the Sundarbans region in Bangladesh (Khulna, Satkhira, Bagerhat) demonstrated robust and consistent NDVI trends corresponding to known environmental impacts, such as the severe canopy loss during Cyclone Sidr (2007) and subsequent recovery phases. This indicates both the dataset's quality and the efficacy of the analytical approach in capturing complex ecological responses to climatic and anthropogenic stressors.

Beyond this case study, the code's universal design readily adapts to different regions, timeframes, or satellite data, serving as a foundation for comprehensive environmental monitoring. It facilitates the rapid and high-quality generation of various indices suited for tracking vegetation health, water presence, land degradation, or ecosystem disturbances with minimal additional coding. As new satellite missions continue to expand observation capacities, this framework promises longevity and adaptability for remote sensing in climate impact assessment, land management, and conservation planning.

METHOD

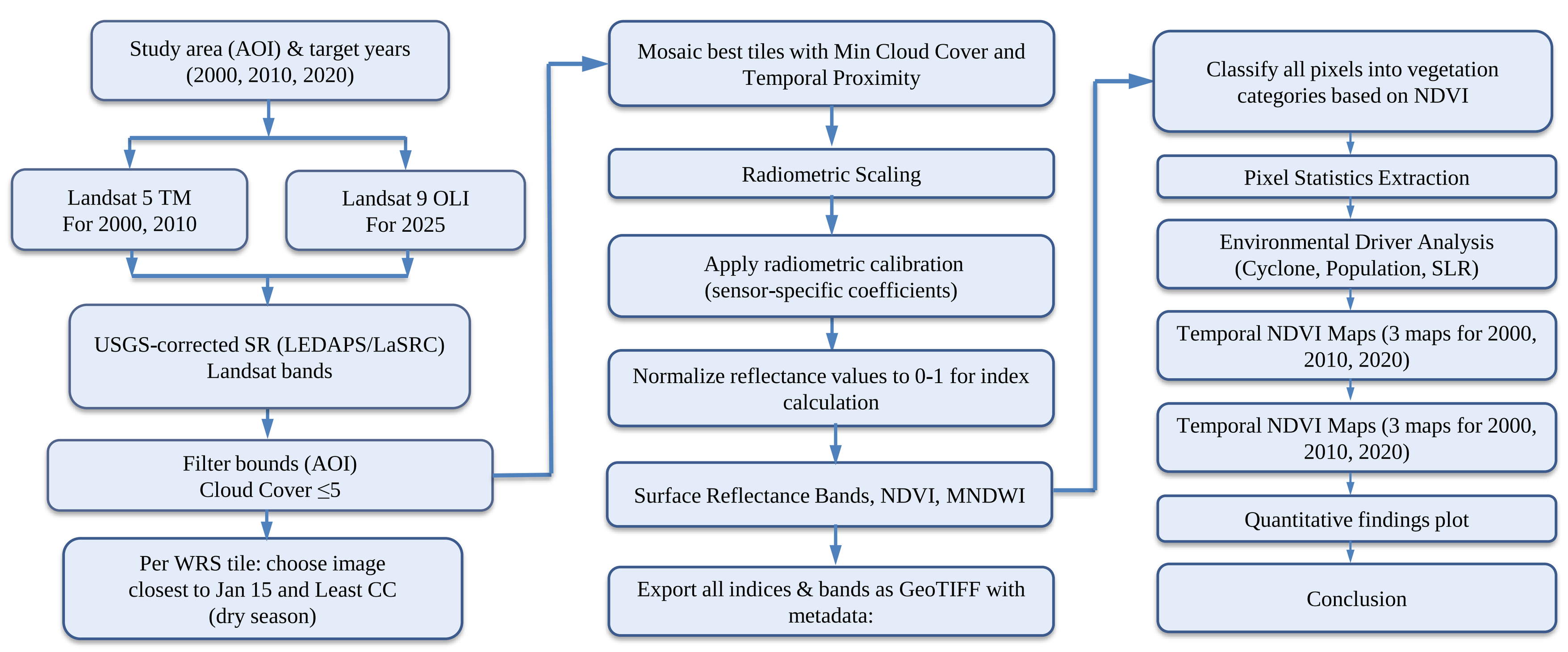

Figure 1. Methodological flowchart.

STUDY AREA

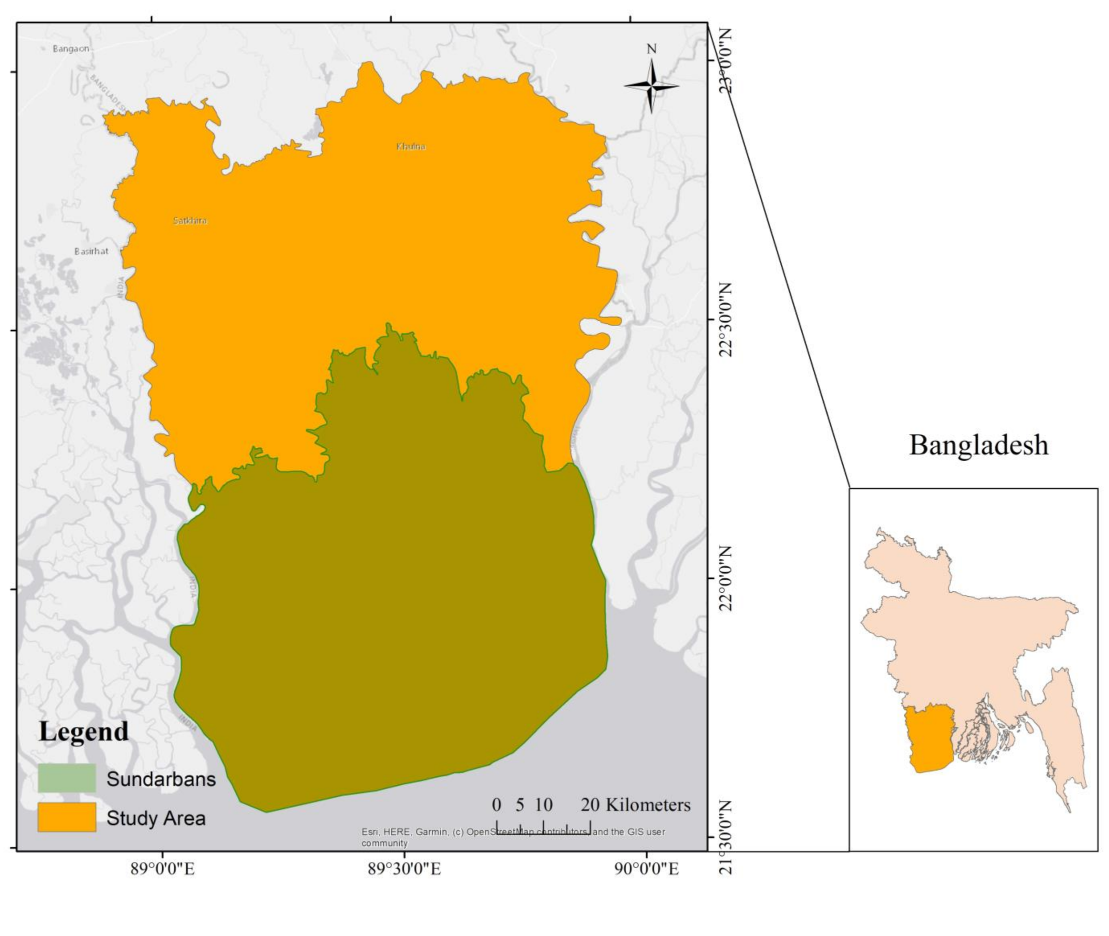

Figure 2. Study area.

RESULTS & DISCUSSION

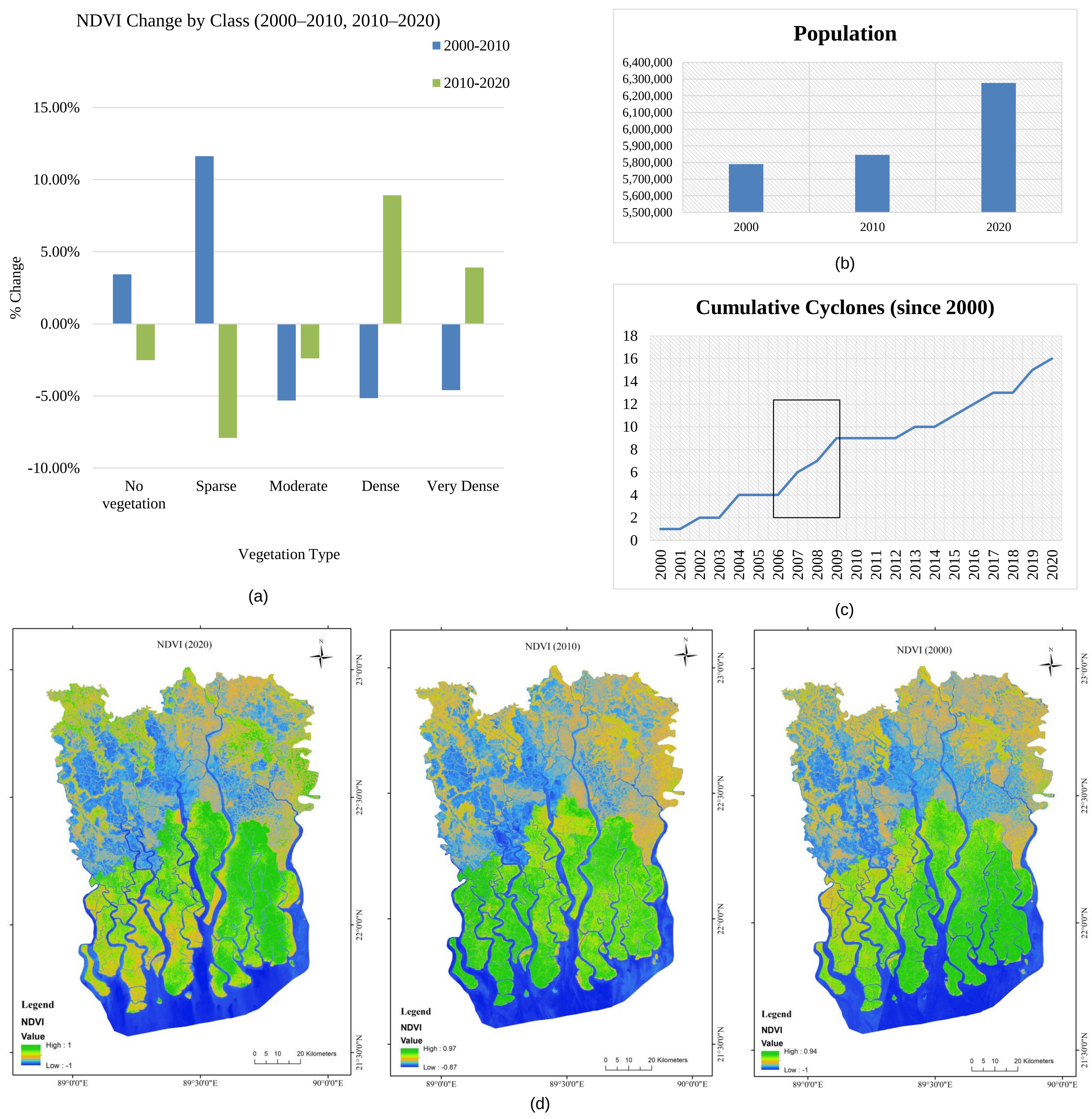

Figure 3. (a) NDVI Change by Class, (b) Population per year, (c) Cumulative cyclone events (interpolated), (d) NDVI of the year 2020, 2010, 2000.

CONCLUSION & FUTURE WORK

This study applied a robust, automated remote sensing workflow to map and analyze the spatio-temporal changes in mangrove forest structure across the Sundarbans region of Khulna, Satkhira, and Bagerhat for the years 2000, 2010, and 2020. Vegetation health and density, classified using NDVI and related indices at 30m resolution, revealed that the region suffered dramatic degradation following major cyclonic events, most notably Cyclone Sidr (2007), with NDVI and dense forest classes declining sharply between 2000 and 2010. Partial but incomplete recovery was observed by 2020, with key shifts in vegetation class structure and persistent loss in moderate-density forest, signifying increased fragmentation and altered ecosystem composition.

Populations in the study region changed minimally, so the observed ecosystem dynamics are best explained by climate drivers, particularly cyclone frequency and intensity. The advanced code framework proved highly effective: by mosaicking images at key phenological dates under ≤5% cloud cover, applying radiometric corrections, and generating indices including NDVI, MNDWI, SAVI, MSAVI, and NDWI, it enabled reliable, repeatable, and granular (30m) analysis critical for climate-vulnerable landscapes.

Future research should expand the temporal resolution of analysis by incorporating annual or seasonal time series of NDVI and MNDWI, allowing for more robust trend and correlation statistics and more precise detection of disturbance/recovery intervals. The flexible code can be adapted as new satellite collections become available, providing a platform for near-real-time monitoring, disaster response, and annual ecosystem "health reporting." Integrating species-specific indices, ground validation (e.g., sediment, salinity, or biomass data), and socioeconomic layers (e.g., migration, livelihoods) will deepen causal understanding and management relevance.

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