



ISCMRDET 2026

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## International Symposium on Sustainable **Critical Mineral Resource** Development for **Energy Transition**



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**Development for Energy Transition**  
**(ISCMRDET 2026)**

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# Shoreline change assessment on Phu Quoc Island using Satellite Remote Sensing and the Digital Shoreline Analysis System (DSAS)

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## ABSTRACT

Phu Quoc Island, the largest island of Vietnam, is located in the Gulf of Thailand and covers an area of approximately 589 km<sup>2</sup>. The island holds significant strategic importance in terms of economic development, tourism, and national defense, while also supporting diverse and high-value ecosystems, including primary forests, coral reefs, and seagrass beds. In recent years, Phu Quoc has undergone rapid expansion in tourism and infrastructure; however, this growth has been accompanied by increasing challenges such as coastal erosion, environmental degradation, and pressures from accelerated urbanization.

Using high-resolution Landsat imagery spanning the period 1989–2025, this study assesses shoreline dynamics on Phu Quoc Island. Shorelines were extracted using the Normalized Difference Vegetation Index (NDVI), and the Digital Shoreline Analysis System (DSAS) was employed to compute key indicators, including Net Shoreline Movement (NSM) and End Point Rate (EPR). The results indicate that both erosion and accretion processes are occurring simultaneously along the island's coastline, with spatial variability in magnitude. Erosion is more pronounced along the western coast, whereas accretion is more dominant along the eastern coast. Quantitatively, NSM values range from –233.95 m to 375.51 m, with an average of –12.15 m, indicating an overall erosional trend. Similarly, EPR values vary from –6.5 m/year to 10.43 m/year, with a mean rate of –0.34 m/year, further confirming the general tendency toward shoreline retreat.

Overall, the observed shoreline changes on Phu Quoc Island reflect the combined influences of natural processes and human activities. These findings highlight the urgent need for integrated coastal zone management strategies, stricter control of tourism development, and enhanced protection of coastal ecosystems to ensure the island's sustainable development in the future.

**Keywords:** *Phu Quoc Island, erosion and accretion, Landsat, shoreline change*

## 1. Introduction

Phu Quoc Island, the largest island in Vietnam, is located in the Gulf of Thailand (Figure1) and plays a significant role in the country's socio-economic and environmental systems. The island is characterized by diverse ecosystems, including tropical forests, coral reefs, and seagrass beds, which contribute to its high ecological value and biodiversity. In recent decades, Phu Quoc has experienced rapid economic growth, particularly driven by tourism development and infrastructure expansion. While these developments have enhanced regional economic performance, they have also imposed increasing pressure on coastal environments.

Coastal zones are inherently dynamic and are influenced by a combination of natural processes, such as wave action, tidal regimes, and sea-level fluctuations, as well as anthropogenic activities, including land reclamation, coastal construction, and resource

exploitation. These interacting factors have led to significant shoreline changes in many coastal regions worldwide. On Phu Quoc Island, the impacts of these processes are increasingly evident, with noticeable patterns of erosion and accretion along different sections of the coastline. Such changes pose risks to coastal ecosystems, infrastructure, and long-term sustainable development.

Accurate and systematic monitoring of shoreline dynamics is therefore essential for coastal management and planning. Remote sensing techniques, particularly multi-temporal satellite imagery, have proven effective in detecting and quantifying shoreline changes over extended periods. Among these, Landsat imagery provides a valuable long-term dataset for analyzing coastal evolution. In addition, geospatial analytical tools such as the Digital Shoreline Analysis System (DSAS) enable the calculation of quantitative indicators, including Net Shoreline Movement (NSM), which are widely used to assess shoreline change trends (Appeaning Addo, 2008; Himmelstoss, 2018; Maiti, 2018).

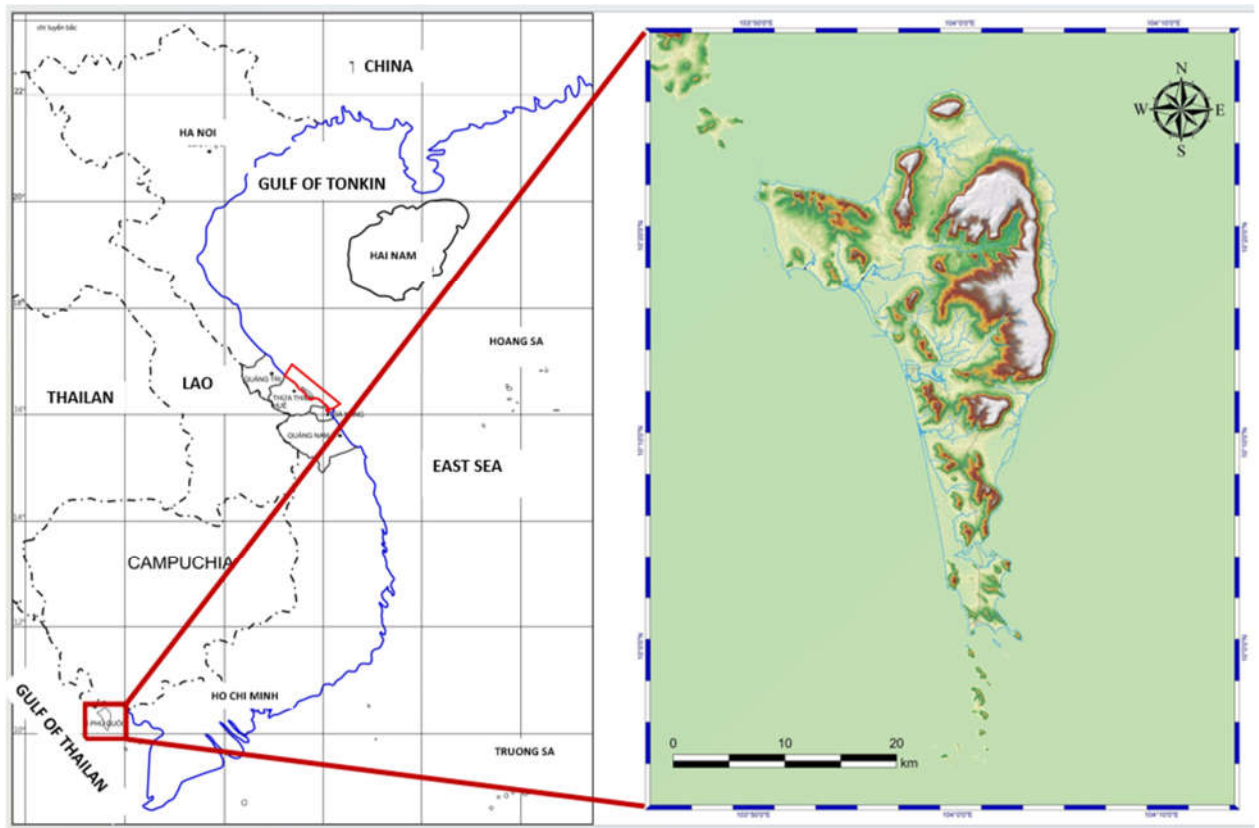


*Figure 1. Location of Phu Quoc Island (google earth)*

Despite the growing importance of Phu Quoc Island as a major economic and ecological zone, comprehensive assessments of its long-term shoreline dynamics remain limited. This study aims to evaluate shoreline changes on Phu Quoc Island over the period 1989–2025 using high-resolution Landsat imagery. By integrating the Normalized Difference Vegetation Index (NDVI) for shoreline extraction with DSAS-based analysis, this research provides insights into spatial patterns of erosion and accretion and contributes to a better understanding of the driving mechanisms behind coastal change. The findings are expected to support the development of effective coastal management strategies for sustainable development on the island.

## **2. Materials and Methods**

### **2.1. Materials**

Landsat program, a joint initiative of the United States Geological Survey and the National Aeronautics and Space Administration, has provided continuous Earth observation

data since 1972. In this study, Landsat imagery covering Phu Quoc Island for the period 1989–2025 was utilized to analyze morphological changes in the region. The dataset includes images from Landsat-5 TM and Landsat-8 OLI/TIRS sensors, with a spatial resolution of 30 m, which were freely accessed from the USGS EarthExplorer platform.

Tidal data were obtained using the WXTide32 software, downloaded from its official website. The Duong Dong river mouth station was selected as the reference site for tidal measurements.

## 2.2. Methods

### a. The Digital Shoreline Analysis System (DSAS)

Assessing coastal spatial dynamics requires the integration of both historical shoreline evolution and morphodynamic processes. The Digital Shoreline Analysis System (DSAS), an extension of ArcGIS (version 10.1), provides a robust framework for quantifying shoreline change rates based on multi-temporal shoreline datasets. It is widely recognized as one of the most effective and commonly applied tools for shoreline change analysis worldwide. DSAS enables automated generation of measurement transects, computation of change rates, and statistical evaluation of shoreline variability. In addition, it incorporates a shoreline forecasting module capable of projecting future shoreline positions (e.g., 10- and 20-year horizons) along with associated uncertainty estimates (Thieler et al., 2009).

The DSAS operational workflow consists of seven main steps: (1) attribute automation, which assigns required and optional fields to shoreline and baseline feature classes within a geodatabase; (2) configuration of default parameters, including baseline, shoreline inputs, metadata, and output settings; (3) transect generation, where transects are cast based on predefined parameters; (4) transect editing, allowing refinement of baseline geometry and individual transects; (5) calculation of shoreline change statistics; (6) data visualization, including adjustment of change-rate symbology and clipping to the shoreline change envelope (VCE); and (7) shoreline forecasting, which integrates observed and modeled shoreline positions to predict future trends with quantified uncertainty.

In this study, DSAS was applied to generate transects perpendicular to the shoreline at user-defined intervals in order to quantify coastal morphological changes over the period 1989–2020. Shoreline change statistics were calculated based on the intersection points between transects and shoreline positions relative to a baseline. Among these metrics, Net Shoreline Movement (NSM) represents the total distance (rather than a rate) between the oldest and most recent shoreline along each transect, reflecting the overall magnitude of shoreline change.

$$NSM = SL_0 - SL_1$$

Where NSM represents the net shoreline movement (m);  $SL_0$  denotes the distance between the baseline and the shoreline (m) at the earlier observation date along a given transect; and  $SL_1$  corresponds to the distance between the baseline and the shoreline (m) at the most recent observation date at the same transect location.

### b. Field surveys

Field surveys were conducted as a primary method for collecting in situ data within the study area. The surveys were carried out on Phu Quoc Island in 2025. The survey area covered the coastal zone surrounding the entire island. The main objective was to assess patterns of coastal erosion and accretion, with particular emphasis on areas experiencing significant shoreline retreat (Figure 2).

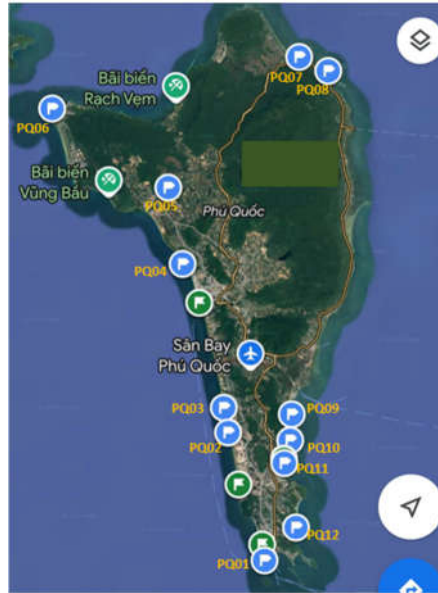


*Figure 2. Field Trip in Phu Quoc Island (2025) (the survey locations are indicated by flag markers)*

### 3. Results and discussion

The shorelines extracted for the period 1989–2025 were imported and integrated into ArcGIS 10.1. The Digital Shoreline Analysis System (DSAS) applies a baseline-based measurement approach to calculate shoreline change statistics from a temporal series of shoreline positions. The baseline serves as the reference from which all transects are generated by the DSAS extension. In this study, the baseline was established approximately 3 km offshore, running parallel to the general orientation of the coastline. Transects, each 3 km in length, were generated perpendicular to the baseline at regular intervals of 30 m using DSAS. In total, 1,485 transects were produced along the baseline.

The shoreline dynamics of Phu Quoc Island over the period 1989–2025 were analyzed using Net Shoreline Movement (NSM), End Point Rate (EPR), and erosion–accretion mapping, as illustrated in Figures 3 and 4. The results reveal a highly dynamic coastal system characterized by strong spatial variability in both erosion and accretion processes. Quantitatively, NSM values range from  $-33.95$  m to  $375.51$  m, with an average of  $-12.15$  m, indicating an overall tendency toward shoreline retreat. Similarly, EPR values vary from  $-6.5$  m/year to  $10.43$  m/year, with a mean rate of  $-0.34$  m/year, further confirming the general erosional trend.

Figure 3 shows the spatial distribution of shoreline change based on NSM values. Negative values (displayed in red to orange tones) indicate erosion, while positive values (light to dark blue) represent accretion. The data demonstrate that erosion is particularly intense along the western and southwestern coasts of the island, where shoreline retreat reaches significant magnitudes (Figure 5). In several locations, erosion exceeds tens to hundreds of meters, highlighting the vulnerability of these coastlines to wave action and hydrodynamic forces from the Gulf of Thailand. In contrast, the eastern and southeastern coasts exhibit predominantly positive NSM values, indicating shoreline advancement due to sediment deposition, with some areas showing substantial accretion.

Figure 4 complements this analysis by providing a simplified classification of erosion and accretion zones. The spatial distribution clearly confirms that erosion dominates along the west-facing coastline, while accretion is concentrated along the eastern margin. This consistent pattern suggests the presence of a net longshore sediment transport from west to east. The southern tip of Phu Quoc Island appears as a transitional zone, where alternating segments of erosion and accretion occur over relatively short distances, reflecting a complex interplay of coastal processes, including wave refraction, current interactions, and sediment redistribution.

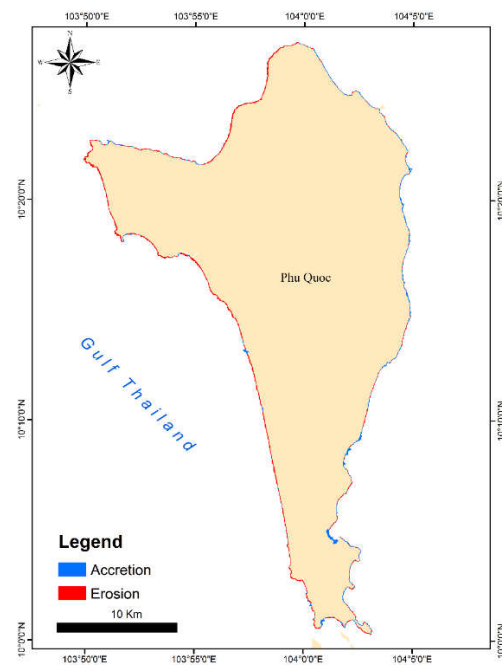
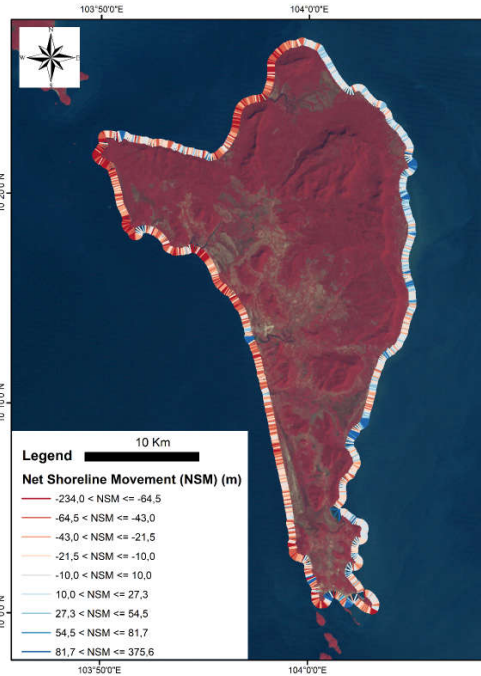


Figure 3. Net shoreline movement (NSM) calculated for the period (1989–2025). Red signifies erosion; blue signifies accretion.

Figure 4. The accretion - erosion area in Phu Quoc island between the years 1989 and 2025

The observed patterns can be attributed to both natural and anthropogenic factors. Natural drivers include wave climate, monsoonal wind regimes, and coastal currents, which control sediment transport pathways. Stronger wave exposure along the western coast likely enhances erosional processes, whereas the relatively sheltered eastern coast favors sediment deposition. In addition, human activities such as coastal development and land-use changes may locally intensify shoreline instability.

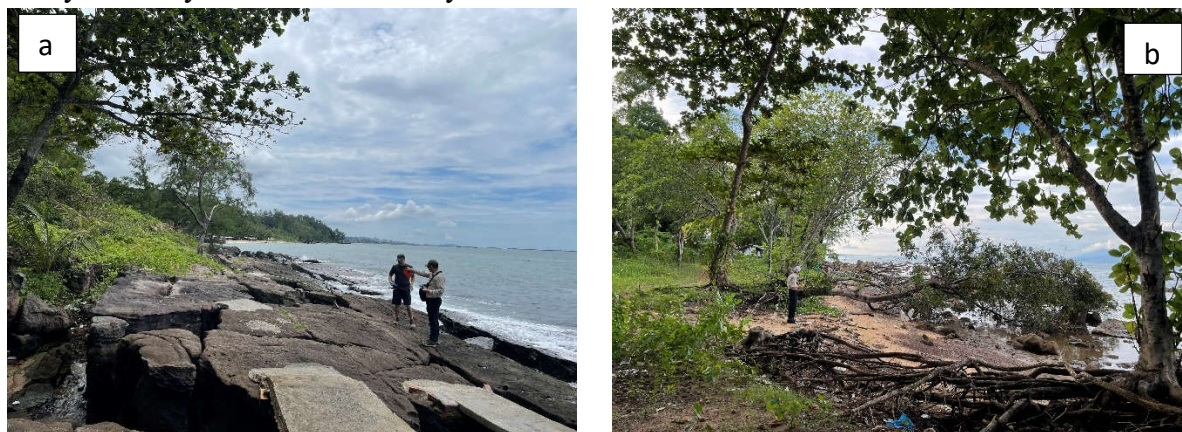


Figure 5. Field photographs at sites PQ4 (a) and PQ7(b)

Overall, the combined interpretation of NSM data and erosion–accretion mapping provides a comprehensive understanding of shoreline evolution on Phu Quoc Island. The clear contrast between erosion-dominated western coasts and accretion-dominated eastern coasts highlights the need for targeted coastal management strategies. Without appropriate mitigation measures, ongoing shoreline changes may pose increasing risks to coastal infrastructure, ecosystems, and sustainable development on the island.

**Interpretation and implications:** The observed spatial pattern suggests that coastal processes are strongly controlled by wave direction, hydrodynamics, and sediment supply (Anthony EJ, 2015; Bao TQ, 2011). The dominance of erosion on the western coast and accretion on the eastern coast indicates a net eastward sediment transport.

These findings are important for:

- Coastal zone management
- Hazard mitigation (especially erosion-prone areas)
- Sustainable development planning on Phu Quoc Island

The combined analysis of NSM and erosion–accretion mapping demonstrates that Phu Quoc Island’s coastline has undergone significant and spatially variable changes between 1989 and 2025, with a clear contrast between erosion-dominated western coasts and accretion-dominated eastern coasts.

#### **4. Conclusion**

This study evaluates shoreline changes on Phu Quoc Island during 1989–2025 using multi-temporal Landsat imagery and the Digital Shoreline Analysis System (DSAS). The results indicate a highly dynamic coastline with significant spatial variability in erosion and accretion processes.

NSM values range from  $-33.95$  m to  $375.51$  m, with a mean of  $-12.15$  m, while EPR values vary between  $-6.5$  m/year and  $10.43$  m/year, averaging  $-0.34$  m/year. These results suggest an overall trend of shoreline retreat despite localized accretion.

A clear spatial pattern is observed, with erosion dominating the western coast and accretion prevailing along the eastern coast, reflecting the influence of wave climate and sediment transport processes.

Overall, the study highlights the increasing vulnerability of Phu Quoc’s coastline and emphasizes the need for effective coastal management strategies to support sustainable development.

#### **Acknowledgements:**

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