# Detecting Land Cover Changes Using Multi-Temporal Radar Imagery: A Case Study of Taiwan's Western Coastal Region

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**Abstract:** *Satellite remote sensing data have been widely used to identify surface coverage; however, traditional optical images are limited in monitoring long-term surface changes due to cloud cover and atmospheric moisture interference. In contrast, Synthetic Aperture Radar (SAR) is less affected by atmospheric conditions and sunshine, and is more sensitive to surface texture changes, which can complement optical satellite imagery by providing long-term and stable observation of surface changes. Therefore, in this study, the C-band Sentinel-1 GRD images from 2016 to 2024 and the X-band TerraSAR-X data from 2021 to 2025 were collected in the western coastal area of Taiwan to observe the temporal changes of features and water bodies. The study is divided into two parts: land and coastal areas. Firstly, all the images are using SNAP software for a standardized preprocessing workflow, and then the land section involves stacking multi-temporal data and composing false-colour images using selected polarization bands from specific periods to observe changes in urban infrastructure and agricultural activities. For the coastal area, three to five low-tide images are selected every year based on the tide level data, and the average backscatter intensity values are calculated. These annual averages are assigned to different channels of pseudo-color images. The results reveal erosion and sedimentation hotspots along the west coastline of Taiwan. By integrating multi-temporal radar data, this study provides a foundational basis for future applications such as land classification, change detection, and spatial planning.*

**Keywords:** *Synthetic Aperture Radar (SAR), Sentinel-1, TerraSAR-X, Change Detection*

## 1. Introduction

Monitoring dynamic changes in land cover is crucial for understanding environmental shifts, assessing the impacts of human activities, and ensuring sustainable development in coastal and inland regions. In Taiwan, the western coastal areas are ecologically and economically vital, yet highly vulnerable to both human and natural pressures. Coastal erosion, tidal fluctuations, aquaculture expansion, urban development, and large-scale industrial projects have reshaped coastlines and altered urban landscapes over the past decades. Reliable monitoring of these changes is therefore vital not only for environmental conservation but also for informing land-use planning and disaster risk management.

Traditionally, optical satellite imagery (such as Sentinel-2) has been widely used for land cover and coastal studies due to its intuitive spectral information. However, in Taiwan's humid subtropical climate, cloud cover, haze, and atmospheric humidity often limit its effectiveness. In contrast, Synthetic Aperture Radar (SAR), as an active remote sensing system, operates independently of lighting conditions, enabling imaging even at night. Its signals penetrate clouds and remain unaffected by atmospheric water vapor, facilitating all-weather operation. This capability makes SAR an ideal complement to optical imagery. SAR synthesizes a virtual antenna larger than the physical radar antenna by leveraging the motion of the radar system. As satellites traverse fixed orbits, they rapidly transmit microwaves (e.g., X-band, C-band, L-band) and receive ground-reflected echoes. Processing these continuous, overlapping echo signals enhances image resolution and sensitivity to surface roughness, making SAR ideal for detecting subtle changes in terrestrial and coastal environments. Therefore, this study aims to develop and evaluate a multi-temporal synthetic aperture radar method for detecting land cover changes along Taiwan's western coastline. This approach overcomes the limitations of optical monitoring while establishing a robust methodology for long-term environmental observation.

## 2. Methodology

### a. Study Area

The study area encompasses the western coastal region of Taiwan, stretching from Taoyuan in the north to Tainan in the south. This region encompasses diverse environments: urban industrial zones, agricultural plains, aquaculture facilities, and ecologically sensitive wetlands. The area presents a complex landscape where intensive human activities coexist with dynamic coastal succession processes.

### b. Data Used

The research material consists of Sentinel-1 satellite imagery, C-band with a 12-day revisit period. This provides reliable data for assessing temporal variations of land cover and coastal features across Taiwan's western region. Sentinel-1 data used are Level-1 Ground Range Detected images (GRD) with approximately 10m spatial resolution and dual polarization (VV and VH). The dataset spans from January 11, 2016, to December 30, 2024, totaling 533 images covering both northern and southern Taiwan's coastal regions. Additionally, TerraSAR-X data from February 13, 2021, to March 20, 2025, were incorporated to provide enhanced spatial detail with 3m resolution in StripMap mode and 33-day revisit intervals, contributing 48 images for focused coastal analysis.

c. Processing and Analysis

SAR image processing was conducted using ESA's SNAP software and MATLAB for analysis and visualization. The standardized pre-processing workflow included Apply-Orbit-File, radiometric calibration to sigma-nought backscatter coefficients, speckle filtering using the Lee filter, terrain correction with SRTM 3-second DEM, linear to decibel conversion, and subset extraction to focus on study areas.

For land analysis, multi-temporal images are stacked after alignment and assigned to RGB channels representing different time periods. This enables identification of surface changes through color variations—unchanged areas exhibit neutral color tones, while temporal changes show distinct color differences. Coastal analysis requires the TideModel_MOI18Tide_Tool to select images captured under consistent low tide conditions. Due to varying data availability across different coastal regions, images were selected based on tidal levels below the Mean Sea Surface, depending on regional conditions and image availability. Selected low-tide images from each year were co-registered and averaged to create annual composites that minimize tidal variability while fully capturing coastal changes. Change detection was performed through visual interpretation of RGB composites for land areas and pixel-wise backscatter difference analysis for coastal erosion and deposition pattern identification.

## 3. Results/Findings

Multi-temporal SAR analysis successfully detected diverse land cover changes across Taiwan's western coastal region. In agricultural areas, RGB composites revealed distinct seasonal patterns in Yunlin coastal plains, where pink/purple areas indicated crop rotation cycles with strong February and August signals corresponding to harvest and planting periods, while yellow-green areas showed peak spring growth phases typical of rice cultivation. Black grid blocks in coastal areas demonstrated consistently low backscatter values, indicating stable water-covered aquaculture facilities such as fish ponds and oyster farms.

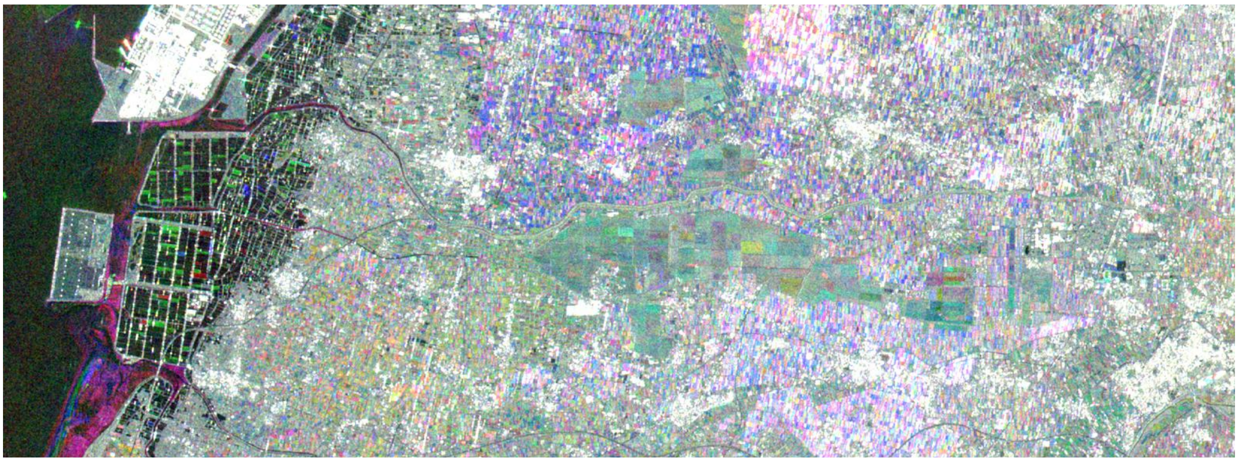

Figure 1 Seasonal crop rotation and aquaculture patterns in Yunlin coastal plains

Urban development monitoring demonstrated clear infrastructure changes in the Taoyuan Aerotropolis project. TerraSAR-X RGB composites (2021-2023-2025) showed yellow areas indicating new development between 2021-2023, including the Northwest Maintenance Area, Satellite Concourse, and New Freight Station, which remained stable through 2025. Mixed colors in the lower portion revealed ongoing Terminal 3 construction activities that continued throughout the study period.

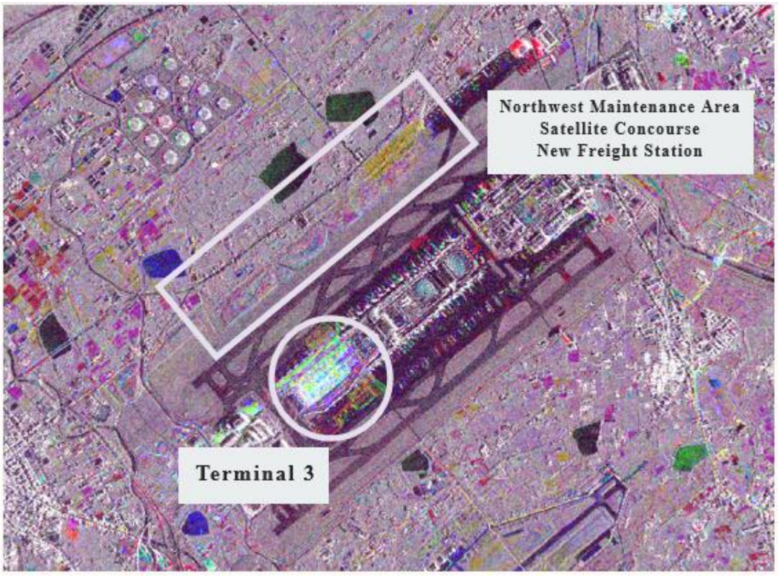


Figure 2 Urban development in Taoyuan Aerotropolis project

Coastal change detection effectively identified erosion and deposition patterns through low-tide SAR imagery analysis. The Zengwen Estuary wetland showed significant dynamics, where RGB composites revealed blue areas indicating recent sediment deposition and red areas representing erosion of previously existing formations. Pixel-wise backscatter difference analysis between annual averages provided quantitative assessment of shoreline changes, with areas showing increased backscatter suggesting sediment accumulation and decreased values indicating erosion processes.

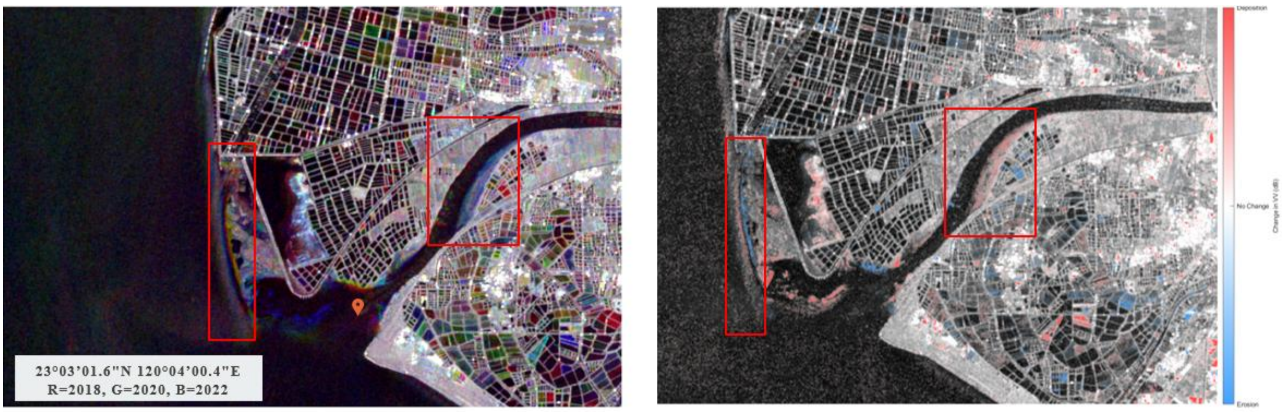


Figure 3 Coastal erosion and deposition patterns at Zengwen Estuary wetland

## 4. Conclusion

This study confirms that multi-temporal synthetic aperture radar imagery can effectively monitor comprehensive land cover and coastal changes in western Taiwan. The developed methodology utilizes C-band Sentinel-1 data from 2016 to 2024 and X-band TerraSAR-X data from 2021 to 2025, successfully overcoming the limitations of optical remote sensing in cloudy subtropical environments. RGB compositing techniques clearly reveal temporal changes, exposing distinct patterns in crop rotation cycles, urban infrastructure development, and coastal dynamics.

This approach proves particularly valuable for monitoring large-scale development projects like the Taoyuan Aerotropolis, where multi-temporal analysis enables clear identification of construction phases. For coastal environments, integrating low-tide SAR imagery with tidal models allows continuous observation of shoreline changes, successfully identifying erosion and sedimentation patterns in ecologically sensitive wetlands such as the Zengwen Estuary.

SAR technology's all-weather monitoring capability effectively addresses surveillance needs under Taiwan's cloudy climate, providing indispensable long-term observational data for environmental management and regional planning. This methodology establishes a foundation for continuous environmental monitoring. By integrating multi-temporal radar data, this research serves as a basis for subsequent land classification, change detection, and spatial planning applications.

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