

# **Urban Expansion Monitoring: Lulu Mall Project, Trivandrum (2017–2024)**

Post Applied: Imagery Analyst

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## 1. Introduction & Objectives

This project analyzes urban sprawl in Trivandrum, specifically monitoring the construction of the Lulu Mall complex and surrounding infrastructure. The analysis spans from **January 2017** (pre-construction) to **January 2024** (post-construction/operational), utilizing a multi-sensor approach with Sentinel-1 (SAR) and Sentinel-2 (Optical) imagery.

## 2. Data Sets Used

*The analysis relied on open-source Earth Observation data ingested via the Microsoft Planetary Computer STAC API:*

- **Sentinel-2 Level-2A (Optical):** Bottom-of-Atmosphere (BOA) reflectance.
  - Resolution: 10m (Visible/NIR bands), 20m (SWIR bands).
  - Selection Criteria: Cloud cover < 10%, dry season acquisition (Jan–May) to minimize phenological variance.
- **Sentinel-1 (SAR):** C-band Synthetic Aperture Radar.
  - Product: Radiometric Terrain Corrected (RTC).
  - Polarization: VV (Vertical-Vertical) and VH (Vertical-Horizontal).
  - Mode: Interferometric Wide (IW).

## 3. Methods & Results

### A. Optical Analysis: NDBI Change Detection

- **Method:** Calculated the Normalized Difference Built-up Index (NDBI) using SWIR (B11) and NIR (B08) bands.
  - $$\text{NDBI} = (\text{SWIR} - \text{NIR}) / (\text{SWIR} + \text{NIR})$$
- **Why this method:** Unlike NDVI (which only detects vegetation loss), NDBI specifically highlights materials with high SWIR reflectance, such as concrete and asphalt.
- **Results:** The difference map (NDBI\_2024 - NDBI\_2017) successfully isolated the newly constructed building surrounding the mall. The mall building footprint was already there.
  - *Pros:* Easy to interpret; distinguishes built-up land from bare soil better than simple RGB.

- *Cons:* Can confuse bare dry soil with concrete if spectral signatures are similar.

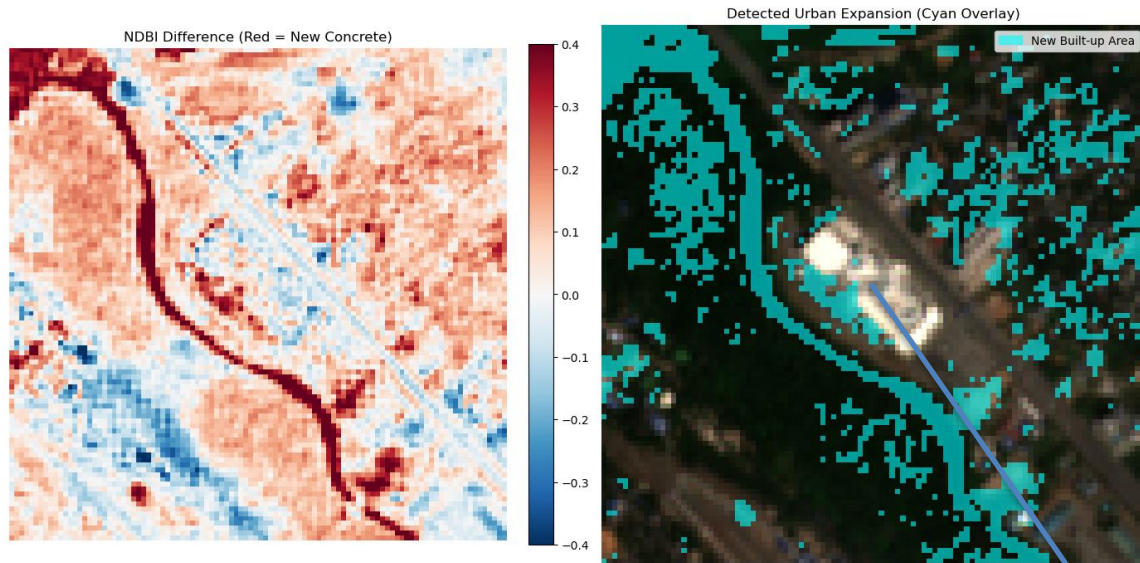
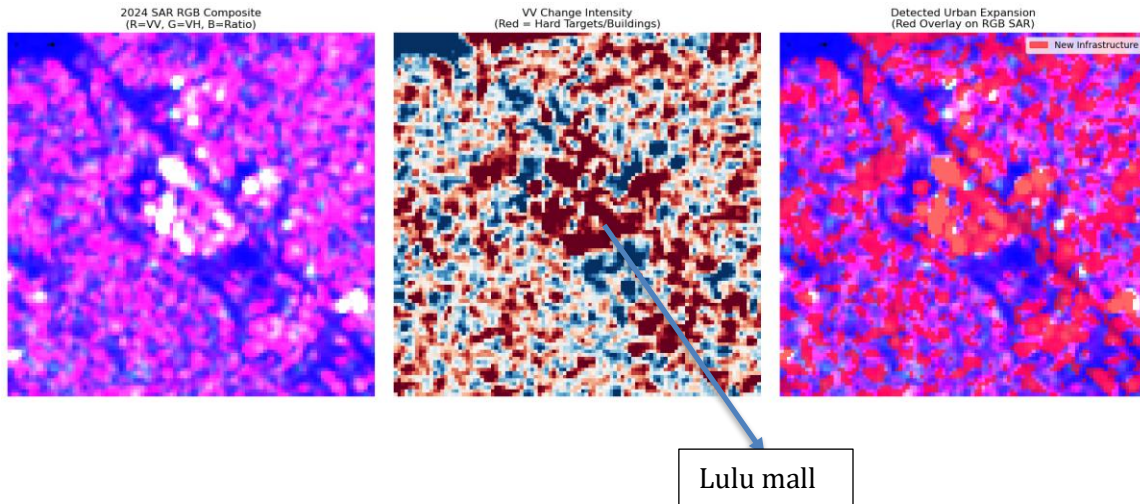


Figure 1: Optical analysis showing new built-up areas (Cyan) overlaid on 2024 True Colour imagery.

## B. SAR Analysis: Dual-Pol Log-Ratio

- **Method:** Applied a Log-Ratio change detection on VV and VH channels.
  - $\text{Log\_Ratio} = \log_{10}(\text{Image}_{2024} / \text{Image}_{2017})$
- **Why this method:** Simple subtraction in SAR is prone to "speckle" noise. The ratio method effectively highlights relative changes in backscatter intensity. VV polarization was weighted heavily to detect "double-bounce" scattering typical of vertical walls and metal structures.
- **Results:** The method identified high-intensity changes corresponding to the mall's main structure. The vertical expansion of buildings was very clear in SAR.
  - *Pros:* Works day/night and through clouds; highly sensitive to man-made geometry (metal/concrete).
  - *Cons:* Susceptible to false alarms from temporary metal objects (vehicles, shipping containers).

Lulu mall



#### 4. Geolocation Accuracy & Coregistration

- **Input Accuracy:** Sentinel-2 absolute geolocation accuracy is within 12.5m ( $2\sigma$ ). Sentinel-1 is highly accurate due to orbital precision.
- **Processing:** All datasets were dynamically reprojected and coregistered to **EPSG:32643 (UTM Zone 43N)** using the 2024 Sentinel-2 pixel grid as the master reference. This ensures sub-pixel alignment between the optical and radar layers.

#### 5. False Positives/Negatives

- **False Positives:**
  - *Optical:* Some riverbanks appeared as "buildup" due to high SWIR reflectance in the dry season.
  - *SAR:* High traffic density or temporary parking lots can mimic permanent structures due to corner reflection from vehicles.
- **False Negatives:**
  - Low-rise residential expansions under heavy tree canopy were missed by Optical (canopy obstruction) but partially captured by SAR.

#### 6. Quality Checks & Edge Cases

- **Edge Case:** The "No-Data" boundaries (0 values) in SAR were handled by clamping inputs to a minimum of 0.001 to prevent logarithmic math errors.
- **Cloud Artifacts:** Although <10% cloud cover filters were used, thin cirrus clouds can slightly skew NDBI values. The SAR analysis provided a robust cross-check in these areas.

## 7. Recommendations

- **Workflow:** Integrate a "Water Mask" (NDWI) to automatically exclude river banks from the buildup detection, reducing false positives.
- **UI Improvement:** For a client-facing tool, add a "confidence slider" that allows the user to adjust the change threshold (currently fixed at 0.15 for Optical and 0.20 for SAR) in real-time.