

Mapping conflict-related changes in Gaza using advanced change detection methods and Sentinel-2 data

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Abstract

This study investigates the potential of Sentinel-2 multispectral imagery for conflict-related change detection in densely urbanised environments, using Gaza City as a case study. An unsupervised Iteratively Reweighted Multivariate Alteration Detection (IR-MAD) approach is evaluated through two parallel workflows: binary change detection and multi-class change-type classification. Pre-conflict (27 September 2023) and mid-conflict (26 November 2023) Sentinel-2 Level-2A scenes were processed within Google Earth Engine (GEE). Binary change detection was restricted to built-up areas derived from the Dynamic World product and thresholded using a chi-square test following the IR-MAD statistical framework. Validation against PlanetScope imagery and UNOSAT damage assessments yielded an overall accuracy of 80.8%. In the second workflow, IR-MAD change metrics were integrated with spectral bands and vegetation indices and classified using an XGBoost model, achieving 88.0% overall accuracy. The results demonstrate that IR-MAD provides a robust training-data-free indicator of conflict-related change, while supervised learning substantially improves thematic interpretability. The proposed workflow is fully reproducible using open satellite data and supports rapid, objective damage assessment in conflict-affected regions.

Keywords: conflict-related change detection, IR-MAD, Sentinel-2, XGBoost, Google Earth Engine

Introduction

Earth observation (EO) has become a key tool for monitoring environmental change caused by natural hazards and human activities, including armed conflicts (Marx, 2016; Mueller et al., 2021). In conflict zones, ground-based damage assessment is often constrained by security and accessibility issues, increasing the importance of satellite-based approaches for humanitarian response and accountability reporting (Aimaiti et al., 2022). While very high-resolution imagery and deep learning methods have demonstrated high accuracy, they often depend on costly data and extensive training samples, limiting their transferability and operational scalability (Mueller et al., 2021; Nabiee et al., 2022).

This study addresses the need for an objective and transferable change detection framework based solely on freely available multispectral data. The objective is to evaluate IR-MAD (Nielsen, 2005) as a training-data-free method for detecting conflict-related change and to assess whether integrating IR-MAD outputs with supervised classification improves the discrimination of change types in a complex urban environment. Gaza City was selected as a representative test case due to the intensity of conflict-related damage and the availability of independent reference data (UNOSAT, 2023).

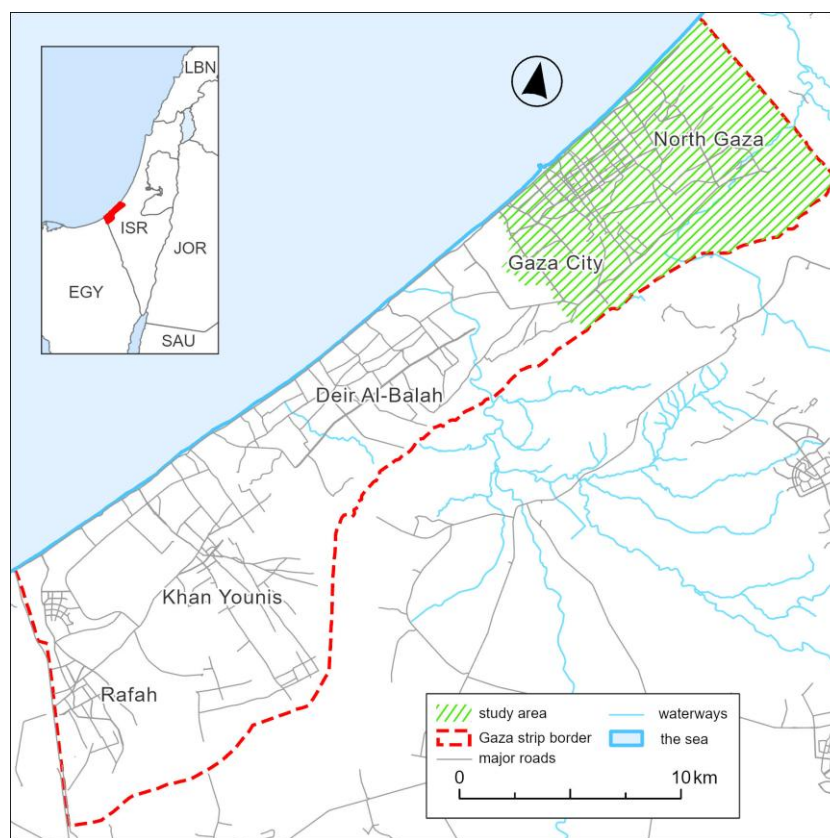
Data and Method

The area of interest comprises Gaza City and surrounding urban districts in the northern Gaza Strip. The total area of interest in our study is roughly 110 km² including the northern part of

the territory (it is shown hatched in Figure 1). Sentinel-2 Level-2A multispectral imagery acquired on 27 September 2023 and 26 November 2023 was used for change detection. Reference data consisted of PlanetScope imagery and UNOSAT damage assessments. Data processing and IR-MAD computation followed the canonical correlation-based approach described by Nielsen (2005) and were implemented in GEE using the Python API.

Binary change detection was performed by thresholding the IR-MAD test statistic using a chi-square distribution, similar to statistical approaches applied in previous conflict-mapping studies (Ballinger, 2023). For change-type classification, IR-MAD features were combined with spectral bands and vegetation indices and classified using the XGBoost algorithm (Chen and Guestrin, 2016), which has proven effective in remote sensing classification tasks (Li et al., 2025).

Figure 1: Location of Gaza Strip and Study Area (Data sources: OpenStreetMap contributors, Natural Earth).



Results

Binary IR-MAD change detection achieved an overall accuracy of 80.8%, comparable to other unsupervised statistical methods applied in conflict environments (e.g. Marx, 2016; Ballinger, 2023). The integrated IR-MAD-XGBoost workflow improved overall accuracy to 88.0% and enabled reliable separation of built-up surface alteration, vegetation decrease, vegetation increase, bare ground alteration, and stable land-cover classes. Vegetation-related changes showed particularly high classification performance (Tab. 1), consistent with findings from multispectral change detection studies (Yin et al., 2025). Comparison with UNOSAT damage assessments confirmed strong spatial correspondence between detected built-up changes and independently reported destroyed buildings.

Table 1: Per-class accuracy and error rates (%).

Class name	PA_%	UA_%	F1
Stable Urban	84.1	93.5	0.885
Stable Vegetation	99.2	100	0.996
Stable Bare Ground	79.1	92.6	0.854
Built-up surface alteration	73	86.1	0.79
Vegetation decrease	100	75.5	0.86
Vegetation increase	100	89.1	0.942
Bare Ground Alteration	90.6	83.2	0.867

Conclusion

The results demonstrate that IR-MAD is a viable training-data-free approach for conflict-related binary change detection using Sentinel-2 imagery, performing on par with other established statistical methods. When combined with XGBoost classification, IR-MAD-derived features outperform simple bi-temporal difference indices in change-type attribution, provided that post-event spectral context is included. The proposed workflow offers a reproducible and scalable solution for rapid damage assessment in conflict-affected regions using openly available EO data.

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