



Integrating Multi-Sensor Earth Observation Data for Coastal Change Indicators and Sea-Level Rise Scenarios: A Case Study from Northern Egypt

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Introduction

Coastal zones along northern Egypt are increasingly threatened by the combined effects of sea-level rise, land subsidence, and rapid urban expansion, leading to accelerated shoreline retreat and environmental degradation [1,2,3]. Despite their vulnerability, there remains a lack of integrated, long-term assessments that combine multi-sensor satellite data with field observations to effectively monitor and predict coastal changes. Therefore, our goal to develop reliable indicators and future scenarios needed for sustainable coastal management and adaptation planning.

Study Area

The study area is the northern coast of Egypt along the Mediterranean Sea, a low-lying region highly vulnerable to shoreline change, sea-level rise, and human activities.

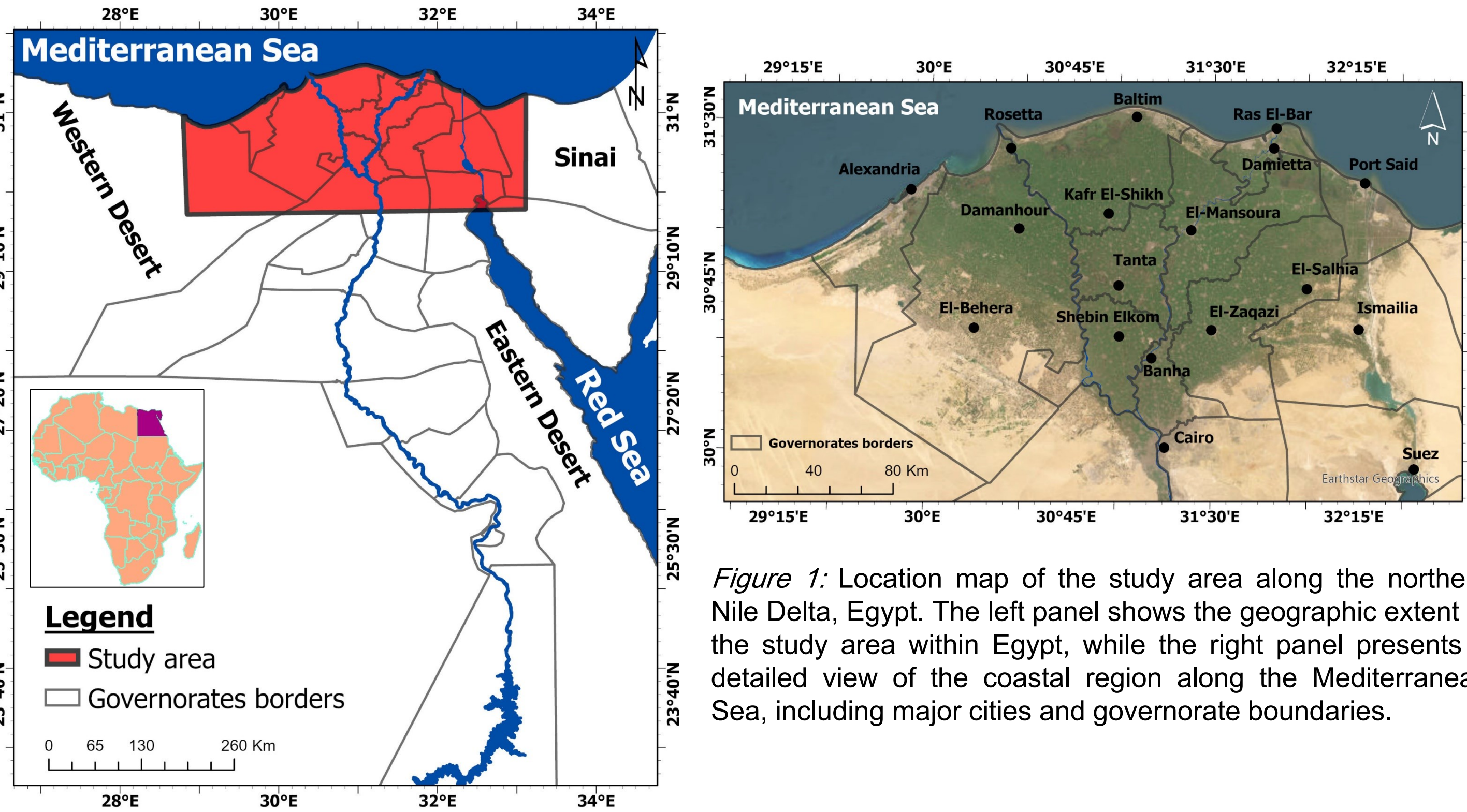


Figure 1: Location map of the study area along the northern Nile Delta, Egypt. The left panel shows the geographic extent of the study area within Egypt, while the right panel presents a detailed view of the coastal region along the Mediterranean Sea, including major cities and governorate boundaries.

Dataset & Methodology

This study combines multi-sensor satellite data (Landsat-5, and Sentinel-2) with field observations to assess coastal changes along northern Egypt. Spectral indices and supervised classification were used to generate LULC maps and identify key surface features. Shoreline changes (1985–2025) were analyzed using DSAS metrics (EPR, LRR, WLR, SCE, NSM), and future positions were predicted for 2035 and 2045. The approach supports evaluating the impacts of sea-level rise and human activities on coastal dynamics.

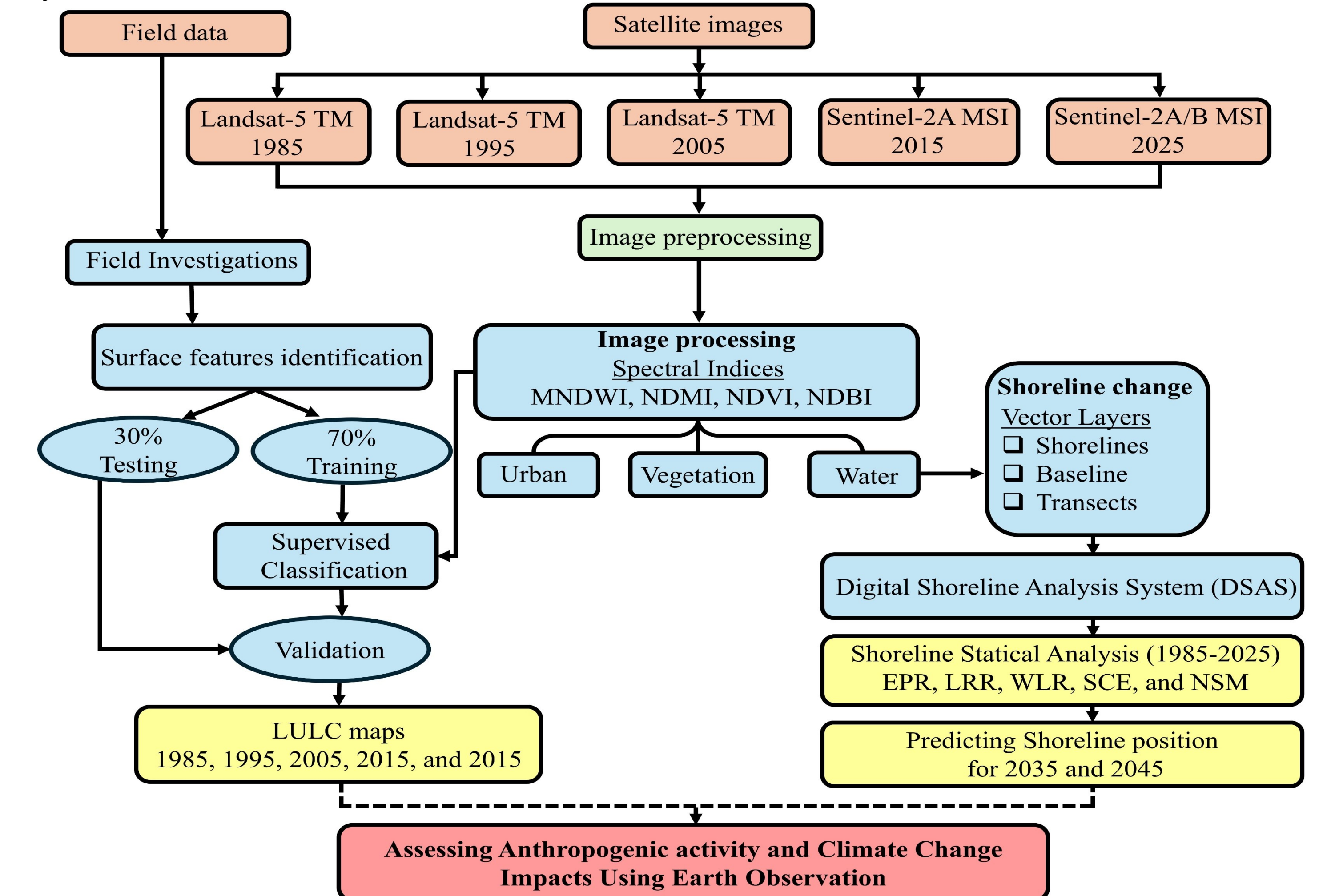


Figure 2: Methodological workflow integrating satellite data and field observations for LULC mapping, shoreline change analysis (1985–2025), and future prediction (2035–2045).

Results & Discussion

The LULC maps (1985–2025) show clear land cover changes in the northern Nile Delta. Vegetation slightly increased, while water areas remained relatively stable. In contrast, urban areas expanded rapidly, especially after 2005, with an increase exceeding 300%. This highlights strong human pressure and growing environmental stress in the region.

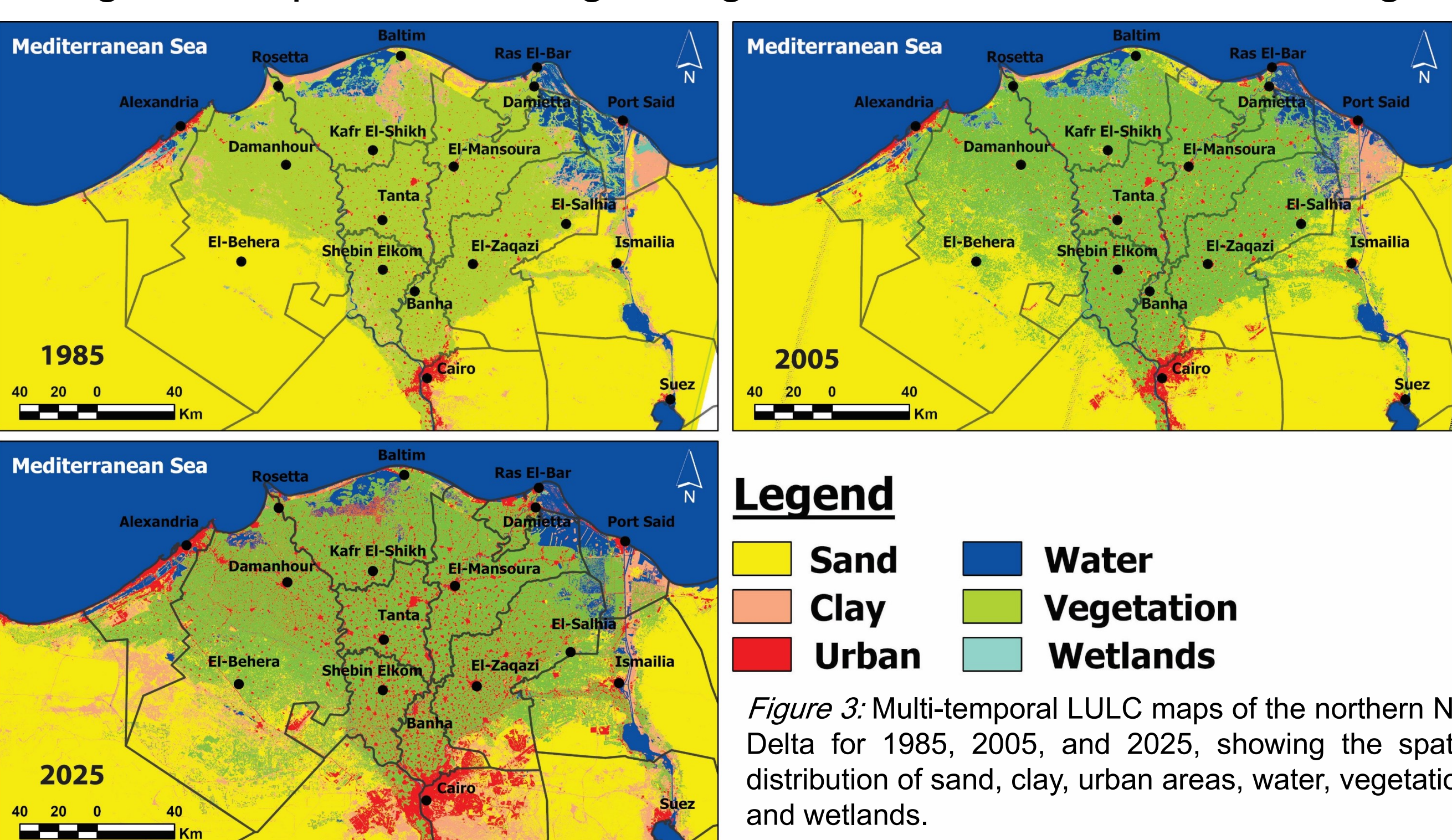


Figure 3: Multi-temporal LULC maps of the northern Nile Delta for 1985, 2005, and 2025, showing the spatial distribution of sand, clay, urban areas, water, vegetation, and wetlands.

The shoreline analysis (1985–2025) reveals significant spatial variability along the northern Egyptian coast. Several regions, particularly around the Nile Delta promontories (Rosetta, Damietta, and Port Said), show pronounced erosion, while other regions exhibit accretion trends. The End point Rate (EPR) results indicate erosion rates reaching up to ~36 m/year in some sections, contrasted with localized accretion exceeding 40 m/year. Predicted shoreline positions for 2035 and 2045 suggest continued retreat in vulnerable regions, highlighting increasing coastal risk driven by both natural processes and human activities.

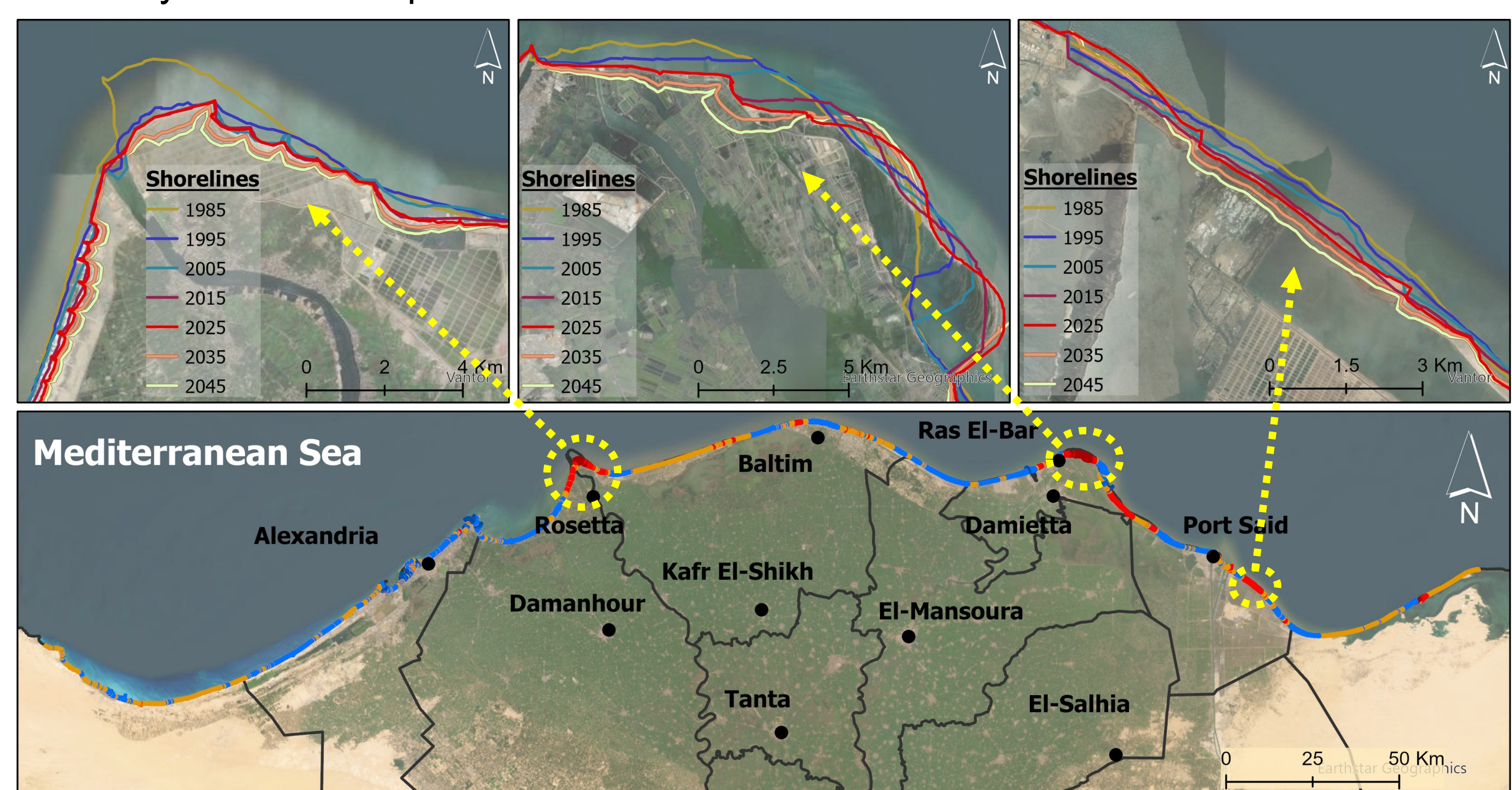


Figure 4: Shoreline change analysis along the northern Nile Delta showing spatial patterns of erosion and accretion based on EPR (m/year), with highlighted hotspots at Rosetta, Damietta, and Port Said, and examples of multi-temporal shoreline positions and future projections.

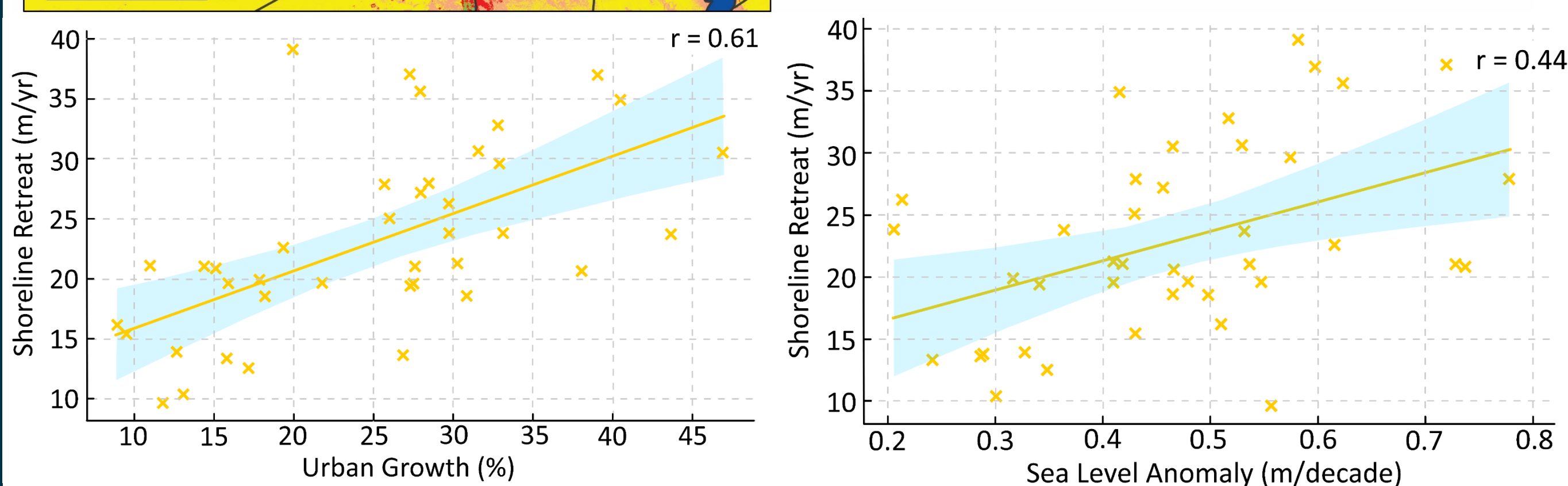


Figure 5: Statistical analysis of shoreline retreat in relation to urban growth and sea level anomaly

Conclusion: The correlation analysis shows a moderate positive relationship between shoreline retreat and urban growth ($r = 0.61$), indicating a strong anthropogenic influence on coastal erosion. In comparison, shoreline retreat also correlates positively with sea-level anomaly ($r = 0.44$), though with a weaker relationship. These results suggest that while both factors contribute to shoreline changes, urban expansion plays a more dominant role in driving coastal retreat in the study area.

References

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