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Analysis and Monitoring of Land Subsidence Phenomena in Tambak Lorok, Semarang City Using the In-sar Method

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Abstract. Rapid urbanization and infrastructure expansion in Semarang, particularly in the northern coastal areas, have led to significant land subsidence. Tambak Lorok, located in Tanjung Mas Sub-district, is among the affected areas, with key contributing factors including soft young alluvial soils, excessive groundwater extraction, infrastructure loads, coastal sediment dynamics, and tidal fluctuations. To understand the patterns and rates of land subsidence, this study employs the *Interferometric Synthetic Aperture Radar* (InSAR) method using the *Sentinel Application Platform* (SNAP).
The methodology involves the analysis of Sentinel-1A satellite imagery (2020–2024), *Digital Elevation Model* (DEM) mapping, and examination of changes in watershed (DAS) areas. Additional data were gathered through local community interviews and analysis of Google Maps and DEM data from 2018–2024. Long-term InSAR monitoring reveals that certain areas in North Semarang's coastal zone are subsidining at rates between -0.16 to -0.23 meters per year. Data validation was conducted through triangulation to ensure result accuracy.
These findings highlight the need for more effective mitigation strategies, such as stricter groundwater management, adaptive infrastructure upgrades, and spatial planning that considers subsidence risks. Furthermore, remote sensing technology should be complemented with ground-based monitoring to ensure more accurate and data-driven mitigation strategies. The outcomes of this research are expected to serve as a basis for disaster mitigation and sustainable coastal spatial planning.

Keywords: *Land Subsidence, InSAR, Sentinel-1A, SNAP, Digital Elevation Model, Watershed (DAS), Tambak Lorok, Semarang City.*

INTRODUCTION

Land subsidence refers to the sinking of the Earth's surface due to factors such as soil consolidation and groundwater extraction. This phenomenon has garnered global concern as it contributes to tidal flooding, as observed in Tambak Lorok, Semarang. The area contains soft alluvial soil that accelerates subsidence by over 10 cm per year, exacerbated by tidal effects and watershed changes.
Subsidence in Tambak Lorok creates basins that disrupt water flow and elevate flood risks. Other contributing factors include land-use changes and infrastructure development. To monitor this phenomenon, InSAR techniques utilizing Sentinel-1A satellite data (2019–2024) were applied. This radar-based analysis provides an accurate depiction of subsidence patterns, which can guide mitigation and spatial planning efforts.

EXPERIMENTAL

Study Area

The study site is Tambak Lorok in Tanjung Mas Sub-district, located in northern Semarang. The region's geomorphology is significantly influenced by human activities, including groundwater extraction, infrastructure development, and coastal economic activities. As a result, tidal flooding is frequent in this area.

FIGURE 1. Research location review area, Tambak Lorok Semarang City

Geological Conditions

Semarang's geology varies widely. Northern areas like Tambak Lorok are dominated by alluvial soils formed from silt, sand, and gravel deposits caused by tidal and river flows. Soil types include heavy clay grumusol (Tugu), light-textured regosol (Genuk), and gray alluvial soils (Pedurungan). In hilly areas (Ngaliyan, Tembalang, Banyumanik, Gunung Pati), brown and reddish-brown latosols dominate, while dark brown Mediterranean soils are common in the rain-heavy southern areas. Semarang's topography comprises a northern lowland (ideal for housing and flat agriculture), a central urban area, and southern hills.

Interview Assessment

To investigate subsidence, field evaluations and community interviews were conducted. Visual inspections assessed damage to buildings and infrastructure, while interviews provided local perspectives on the phenomenon. Findings revealed structural cracks, road deformations, and drainage issues, along with socioeconomic impacts such as financial burdens and maintenance difficulties.

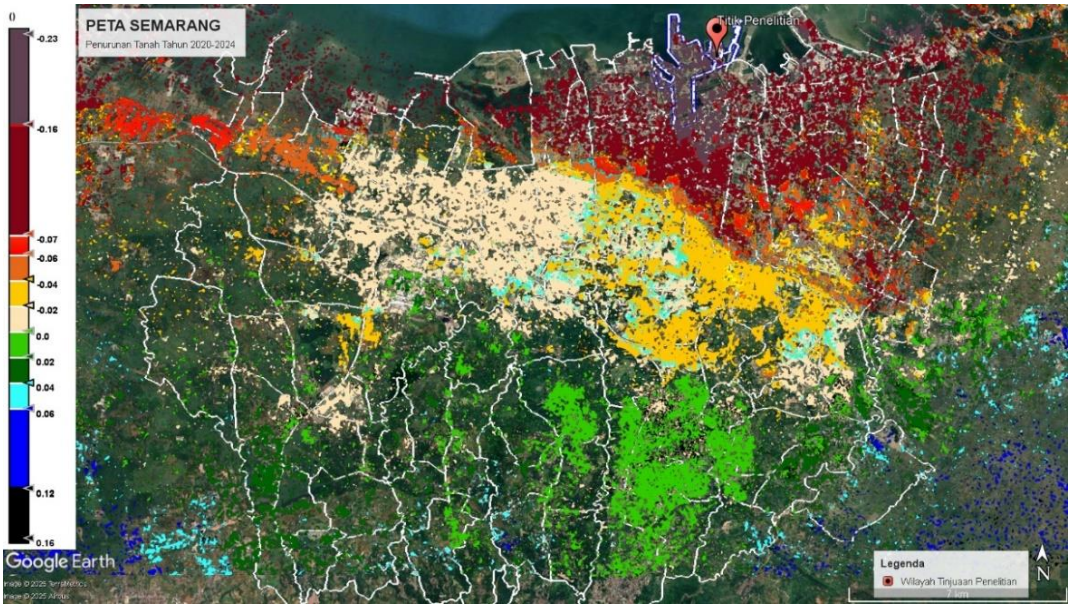
METHOD

Interferometric Synthetic Aperture Radar (*InSAR*) measures Earth surface changes using radar wave phase differences between two or more satellite images, generating interferograms. This technique enables high-precision detection of elevation and land movement, down to millimeter scales. Though limited by inconsistencies, these are mitigated through time-series techniques like PSI-SBAS, SqueeSAR, and radar tomography. The open-source Sentinel Application Platform (SNAP) from the European Space Agency (ESA) was used to process SAR imagery and visualize displacement maps.

RESULT AND DISCUSSION

Subsidence in North Semarang, especially coastal zones, is driven by excessive groundwater use and development, increasing the risk of flooding during high tides and storms. InSAR analysis from 2020–2024 shows subsidence rates in Tambak Lorok ranging from -0.075 to -0.23 m/year. These findings are visualized using color scales to indicate elevation changes.

(a)



(b)

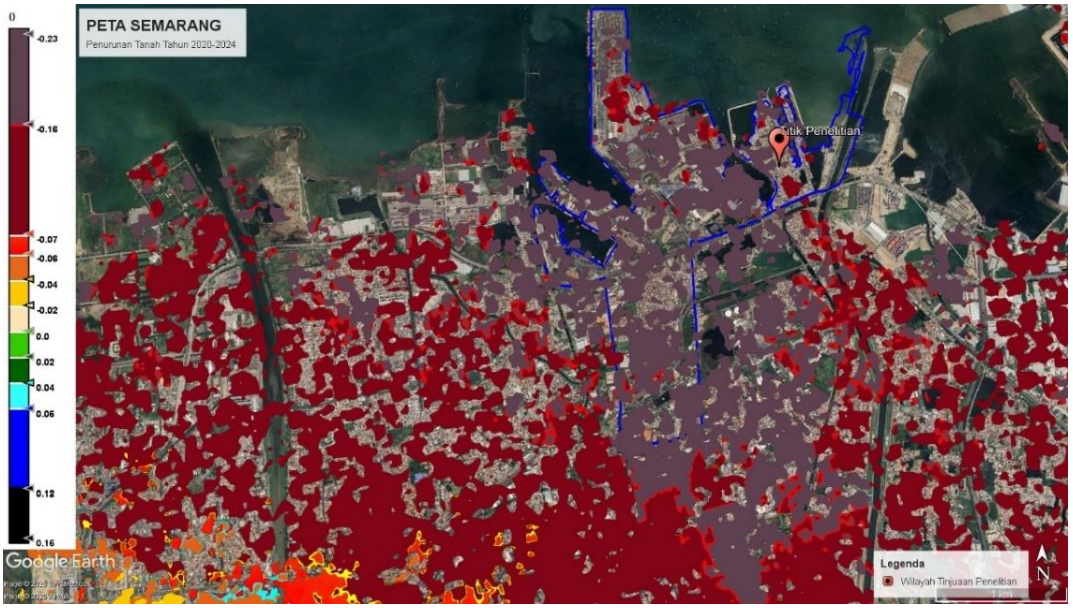


FIGURE 2. (a) & (b) The results of the analysis of the spread of the land subsidence phenomenon in the northern part of Semarang City area for 4 years of observation (2020-2024) in meters

Areas in red (coastal zones) indicate the highest subsidence (-0.23 m/year), primarily in densely urbanized regions influenced by soil compaction, groundwater exploitation, and infrastructure loads. This accelerates risks such as urban flooding, coastal erosion, and infrastructure damage. Subsidence may also alter watershed patterns by redirecting runoff, although causality requires further research. Additional contributing factors include sedimentation, erosion, and human activity. Survey and Sentinel-1A data suggest subsidence rates of 10–13 cm/year, gradually impacting infrastructure and communities.

Figures depict building and infrastructure damage over time. By 2022, house entrances had sunken to ground level, prompting foundation renovations. By 2024, homes had been reconstructed with sturdier structures. Impacts include foundation risks, drainage issues, and aesthetic changes.

CONCLUSION

The analysis indicates that subsidence rates in Tambak Lorok vary by geographic zone, with the highest occurring in the northern coastal area at -0.23 meters over four years. The lowland area shows moderate subsidence, while the southern region remains stable. Residents report floors and roads sinking below water levels, necessitating regular land filling. Tidal flooding has decreased due to seawalls, but rain-induced floods persist. Other impacts include reduced quality of life, financial losses, and psychological stress due to unstable infrastructure.

Disclaimer

This article is intended to provide general insights into civil engineering and is not a substitute for professional advice. The authors and publisher are not liable for any errors, omissions, or consequences arising from the use of this information. Professional consultation is recommended before applying the concepts discussed

Data and Material Availability

This article contains data and materials sourced from reputable references. However, the authors do not guarantee the accuracy, completeness, or timeliness of the presented information. Readers assume responsibility for their use of this data. Further inquiries can be directed to the authors.

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