MONITORING OF LAND SUBSIDENCE IN THE NEW JAKARTA SUBWAY, INDONESIA

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ABSTRACT

Several major cities in Indonesia have experienced land subsidence due to groundwater extraction, such as Jakarta. As the capital city of Indonesia, reasonably rapid population growth cannot be avoided. Consequently, the problem of congestion and groundwater withdrawn for daily needs has increased, which triggered land subsidence. So, by providing the first subway expected to be able to solve the congestion problem in Jakarta. However, the land subsidence threat has to consider an important matter.

The deformation can be investigated by monitoring the land subsidence utilizing ALOS PALSAR-2 and using Persistent Scatterer Interferometry Synthetic Aperture Radar (PSInSAR). The result showed that the area of interest has a mostly stable condition with approximate subsidence velocity is – 1 mm/year to 2 mm/year.

1. INTRODUCTION

The North-South corridor of the rapid mass transit Jakarta is divided into three major phases: phase 1, which includes seven elevated stations, and six underground stations were officially operated in 2019. The future of tunneling work is phase 2A and Phase 2B, which would be having 11.8 kilometers in length and planned for the public in 2027 (MRT Jakarta, 2020). This project aims to unravel the congestion problem in the capital city of Indonesia.

Meanwhile, the tunnel construction potentially increases the land subsidence in Jakarta. Previous research revealed that Jakarta has experienced by land subsidence vary from 2 cm to 26 cm in the coastal area. Land subsidence itself can be interpreted as a vertical motion of the lowering ground caused by groundwater or oil or gas extraction load of construction and natural compaction of alluvial soil and tectonic activity. Impacts of surface displacement to the environment can be revealed by cracking buildings and infrastructure, seawater intrusion, wider flood area, the sinking of the coastal area, and social-economic impact. (Abidin *et al*.,2011; Ng *et al*.,2012; Koudogbo *et al*., 2012; Caussard *et al*., 2013; Hutabarat *et al*., 2017; Widodo et al., 2019; Chaussard *et al*., 2013; USGS, 2020). The tunnel construction dewatering system may be less damaged compared to groundwater withdrawn. However, It has a hazardous potential for land subsidence. Surface subsidence can be measured using leveling, GPS data, or InSAR methods (Bayuaji *et al.*, 2010; Abidin *et al.*, 2007; 2008; 2011; 2015). Besides, deformation on the subway has been analyzed by utilizing remote sensing technology in the Shanghai subway, the Burata railway tunnel in Spain, and Madrid city (Perrisin *et al.*, 2012; Fernandez *et al.*, 2013; Sillerico *et al.*, 2015).

The massive advantage of remote sensing technology measures a large area at once and relatively cheaper compare to the conventional method. However, the result of displacement measurement is from satellite direction. Persistent Scatterer InSAR is an advanced DInSAR proposed by Ferreti in 2011 was used to investigate the subsidence pattern. This method identifies strong backscatter with a high coherent target (Ferreti et al., 2001; Perrisin et al., 2012). Therefore, the purpose of this paper is to investigate the land subsidence in phase 2 tunnel construction using ALOS PALSAR-2 from 2016 to 2019 before the tunnel is constructed.

2. METHODOLOGY

Differential synthetic aperture radar interferometry (DInSAR) is a method to calculate the different phases of SAR data, which is useful for measuring the displacement accurately by using at least two pairs of SAR data taken from line-of-sight (LOS) direction (Ferreti et al. 2007). A general equation for calculating the total phase difference ($\Delta\varphi$) is shown below:

$$\Delta\varphi = \varphi_{disp} + \varphi_{topo} + \varphi_{atm} + \varphi_{orb} + \varphi_{scatt} + \varphi_{noise}$$

where φ_{disp} is the surface movement, φ_{topo} is the topography component as a result of terrain elevation. φ_{atm} is the atmospheric effects. φ_{noise} and φ_{scatt} denote the scattering behavior and the phase noise, respectively. Persistent Scatterer Interferometry Synthetic Aperture Radar is a developed method of DInSAR that uses multi images. This method is suitable for dense permanent human-made structures because PSInSAR corresponds to stable objects that give a dominant scatter back to the sensor.

In this research, land subsidence measurement was using 13 images from ALOS PALSAR-2 by Japan Aerospace Exploration Agency (https://www.eorc.jaxa.jp) from 2016 to 2019 with HH polarization. To performance, the PSInSAR analysis, the SARPROZ tool in MatLab was used. Once a master image had set, the slave images would be resampled for each image concerning the master image.

Geologically, Jakarta's lithology is dominated by an alluvial, alluvial fan, and flood plain deposit with high compressibility (compressibility index: 0.36 – 1.16), very soft or soft consistency, and low bearing capacity (Ministry of Energy and Mineral Resources). The study area is the future work of tunnel construction phase 2 of the MRT Jakarta project. In this paper, the interest area has a distance of 500 meters from the trajectory with an estimated environmental impact.

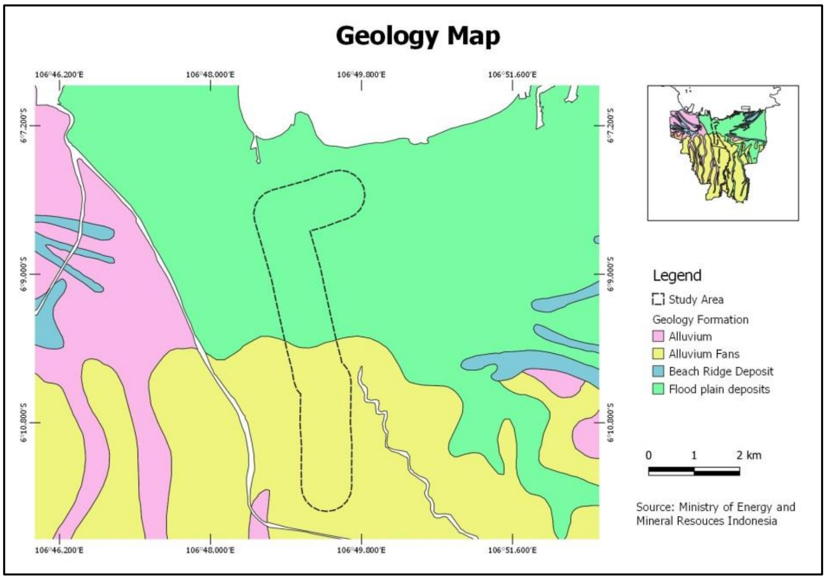

Figure 1 Geology map

3. RESULTS AND DISCUSSION

The result in **Figure 2** showed the ability of PSInSAR processed in SARPROZ to estimate the deformation historically and detect the subsidence location specifically. It represents in Google Earth along with the 3D building.

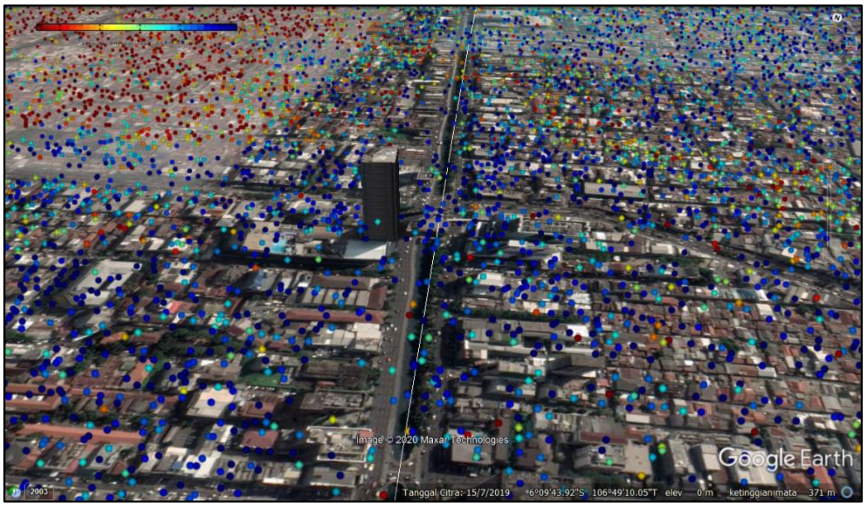

Figure 2 Representation of PSs in Jakarta in Google Earth along with the 3D buildings

As a result of PSInSAR analysis, **Figure 3** showed the velocity of deformation in line of sight (LOS) direction along the subway trajectory. The PS points have been interpolated to represent subsidence on the color scale. Each color contains the value of subsidence velocity, as shown below.

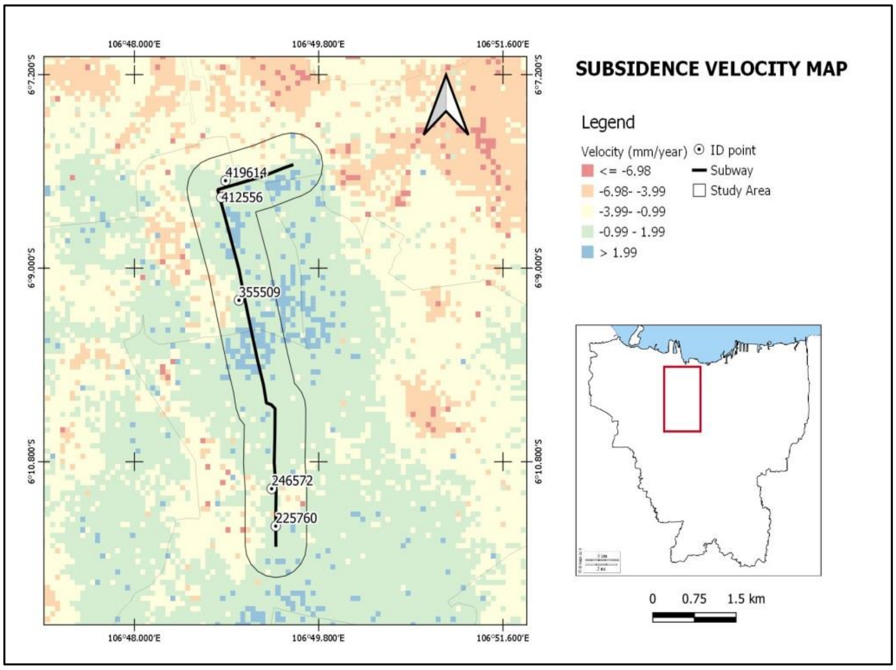

Figure 3 The subsidence velocity map in Phase 2 of the MRT Jakarta project

The subsidence velocity map, the velocity in the study area, showed the small subsidence in the monitoring location with the result that the research area is mostly stable, although some areas experienced by land subsidence.

The PS points were selected as samples for analyzing the deformation in the time-series graph. It can be seen that the displacement is relatively stable except at the id point 355509, which is located in the settlement so that the land subsidence is quite large and the land subsidence continues to decline.

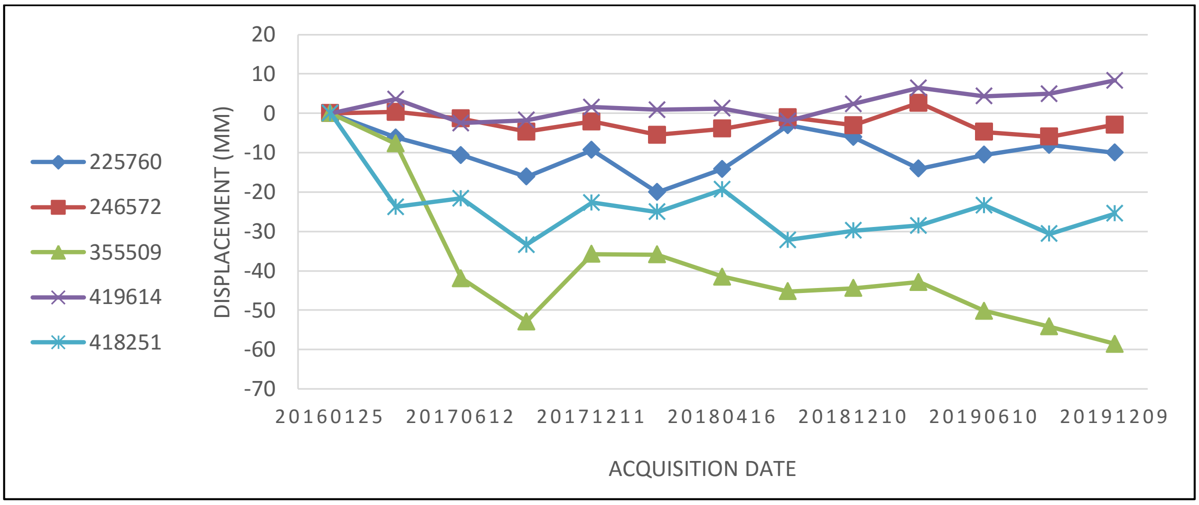

Figure 4 The graph of time-series subsidence

Based on this research, it was found that the phase 2 subway will go through Central Jakarta until North Jakarta and is a continuation of phase 1 tunnel construction. The result analysis of land subsidence using the PSInSAR method showed that the phase 2 subway construction area is mostly stable with the approximate velocity of land subsidence is not greater than -1 mm/year along the trajectory. However, in this research's general interest area, several areas have experienced land subsidence, as is the case at ID point 355509 located in Central Jakarta and its surrounded area and at point 412851 located in North Jakarta. The maximum velocity in the study area is -10 mm/year. If it compared with the results of research in Shanghai, which have lithological similarities with the city of Jakarta, which formed on very soft silt and very soft clay, the research revealed that the maximum displacement velocity was -20 mm/year (Perrisin *et al.*, 2012)

4. CONCLUSION

This paper has indicated the performance of the L-Band SAR dataset in the dense city such as Jakarta and the PSInSAR method to identify the deformation with millimeter accuracy. This research showed that the velocity of the displacement in the phase 2 area has a low value of -1 mm/year to 2 mm/year. It does not represent any danger to buildings' surrounded trajectory. Therefore, the PSInSAR method can calculate the surface motion over time in the same area with a satisfying result. In conclusion, phase 2 of rapid mass transit Jakarta has a stable condition. Besides, this work still needs validation from ground measurement to confirm the result from the line-of-sight measurement.

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