Land Subsidence Monitoring of Jakarta by using SBAS DInSAR Technique with Sentinel-1A SAR data

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Abstract. Jakarta is known as one of the fastest sinking cities in the world. Land subsidence in Jakarta is not a new phenomenon and its monitoring was begun since the 1980s. Several monitoring methods have been conducted for many years (i.e. level survey, gravity method, GPS, and DInSAR) and it is found that the subsidence is ongoing. The subsidence leads severe damages to the infrastructures and increase of flood vulnerability. Understanding the subsidence distribution and the rate is very important. Therefore, subsidence monitoring should be continued. In this study, the subsidence monitoring has been conducted by using the SBAS DInSAR method with Sentinel-1A SAR data acquired during 2014-2019. The present condition of subsidence is presented in this paper, and the subsidence map is updated. It is found that the subsidence tendency varies from place to place and the largest subsidence occurs in the parts of north and northeast of Jakarta. It also found that subsidence is increasing in several areas.

1 Introduction

As Indonesian capital city, Jakarta is the largest and most important city in Indonesia. Being both government and business center, Jakarta is growing rapidly. Jakarta and its satellite cities are home of about 30 million people becomes the biggest megapolitan in Southeast Asia. This big population is exceeding Jakarta's carrying capacity. As the results many problems have occurring, especially regarding to the environment [1]. One environmental issue that need to address is land subsidence. Subsidence in Jakarta is not a new phenomenon. Jakarta is one of the fastest sinking cities in the world and it has been studied by many researches for long years. This subsidence impacts bring the tremendous socio-economic lost and lowering the quality of life of affected societies.

In order to make an effective policy to mitigate the subsidence, the information of subsidence spatial distribution and its characteristic are very important. Some method has been applied for mapping the land subsidence in Jakarta such as GPS, etc [2]-[4]. And it is concluded that the subsidence in Jakarta is mainly derived by excessive groundwater

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extraction over the alluvial area. Most severe subsidence was detected occurring in north of Penjaringan Distric area. A mitigation plan such as promoting the residents to make biopories has been conducted aiming to stop the subsidence. However, the subsidence shows no signs of stopping. The floods event due to tidal or known locally as “rob” are also increasingly hitting the north part of Jakarta coast. An adaptation action such as establishing protection wall has been conducted. This action is temporally able to prevent the “robs”, however by time it will less effective due to the wall is sinking because of subsidence. Land subsidence is estimated responsible for 88% of increased flood by 2050 [5].

An updated of subsidence information is very important in order to evaluate the effects of the mitigation plans. However, the terrestrial surveying such as levelling and GPS campaign is costly and time consuming. Because of that, years of GPS campaign by third author’s groups is being halted. In addition, GPS and levelling measurement will give the subsidence information limited only for the observation points. Thus, to overcome those problems, subsidence monitoring by using SAR satellite along with DInSAR method will take very important role [6],[7]. This study aims to know the present subsidence condition of Jakarta. A time-series analysis of Sentinel-1A SAR data by means of SBAS DInSAR [8] is conducted. The monitoring results of subsidence from 2014 to 2019 will be presented.

2 Study Area and geological setting

Jakarta or officially called Special Capital Region of Jakarta is located in the north part of java island 6°12′S 106°49′E. The Jakarta area is extending for 661.5 squares kilometers and divided by five administrative regions. Fig. 1 left hand side shows the satellite photo of Jakarta and several GPS measurements point that was conducted by [3]. Jakarta is lowland are which is geologically Jakarta lies on the three geological units namely: Alluvial (Qa), Beach ridge deposit (Qbr), and Alluvial fan (Qav) (see Fig. 1). Alluvial is compose of clay, silt, sand, gravel, pebble and boulder. Beach ridge deposit mainly found in the north parts composed by coarse sand, well sorted with mollusk shells. Alluvial fan is bedded fine tuff, sandy tuff, interbedded with conglomeratic tuff [9]. Jakarta or was named Batavia is known for flood prone area since the Dutch colonial era.

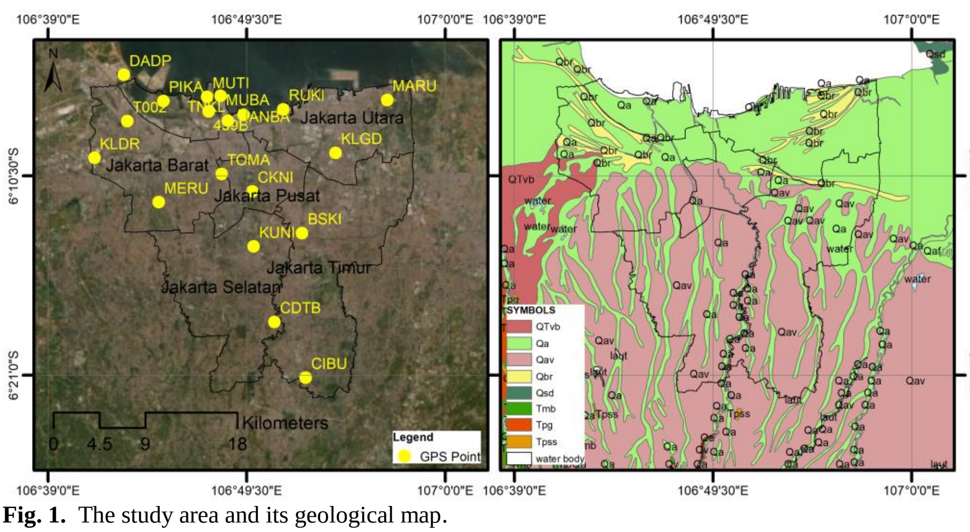

Fig. 1. The study area and its geological map.

3 Method, Data collection, and data processing

This study uses the SAR data to conduct time-series subsidence mapping. A SBAS DInSAR method that was proposed by [8] is employed. Fourty-two scenes of Sentinel-1A SAR data is collected. The Sentinel data was recorded from 12 October 2014 to 24 June 2019 from ascending right-looking observation at the orbit path number 98. All Sentinel-1A SAR data is provided by European Space Agency (ESA) and downloaded from Alaska Satellite Facility (ASF). A digital elevation model ALOS-GDEM 30 m is used to remove the topography phase component from the interferograms. The DEM data is provided by Japan Aerospace Exploration Agency (JAXA). Both data of SAR and DEM can be obtained at no charge.

Fig. 2 shows baseline table of SBAS DInSAR. The geometrical baseline was set at 2% of critical baseline, and the temporal baseline is set 60 days. Critical baseline means the maximum allowable perpendicular baseline value of a pair of SAR data to generate an interferogram. Accordingly, 126 interferograms were generated and analyzed. To suppress the noises, interferogram multi-looking process is conducted. Azimuth looks (number of lines in azimuth direction) and range looks (number of pixels in range direction) is set at 4 and 16 respectively. Goldstein filter is used to enhance the quality of interferograms [10]. To unwrap the interferograms a minimum cost flow (MCF) method is utilized [11]. Displacements maps with 60 m spatial resolution is produced. And in the final stage the pixels which have temporal coherence less than 0.2 is removed. All SBAS DInSAR procedure is done using ENVI SARscape 5.5 software.

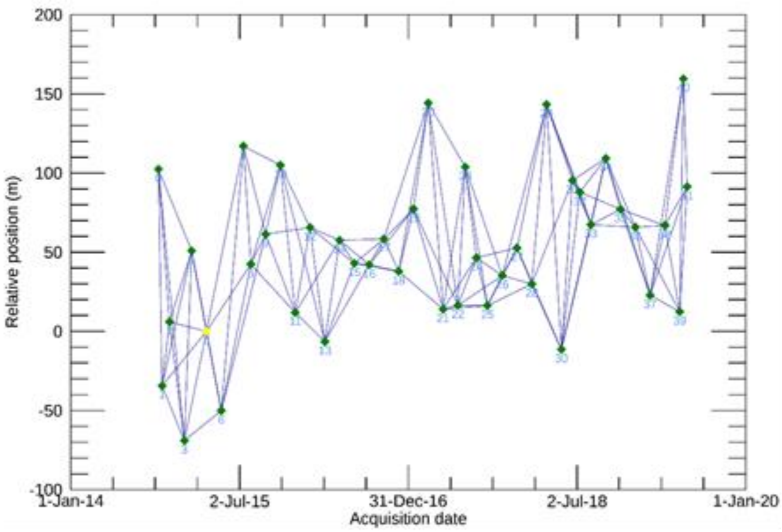

Fig. 2. SBAS baseline table.

2 Results and disscussion

2.1 Time-series subsidence maps

As the results of SBAS DInSAR, a set of time series subsidence map is generated. Fig. 3a-f shows the subsidence yearly maps of Jakarta in the observation periods from October 2014 to June 2019. In that figure it is found some areas experiencing the largest subsidence which is presented by red color. No remarkable subsidence area is presented in green color. White color is for the area with no SBAS results such as vegetated area and water surface. Fig. 4 shows the comparison of the subsidence map generated by current study with the map that was generated by [6] in the previous study. The previous study was conducting the subsidence mapping by using ALOS-PALSAR data from 31 January 2007 to 26 September 2010 and utilizing PSI methods [6]. From this comparison it is found that some areas in the North Jakarta such as north part of Penjaringan District (Area A) and part of Kosambi District (Area B), showing the large subsidence in both studies results. The new subsidence seems increasing in the Area D which is including the parts of Kalideres, Cengkareng, Cipondoh, Karang Tengah, and Kembangan Districts. More attention is needed for this area to prevent more severe subsidence occurs. However, in other areas it's found the subsidence seems to stable such as in the Area C which includes the parts of Cengkareng and Kalideres Districts.

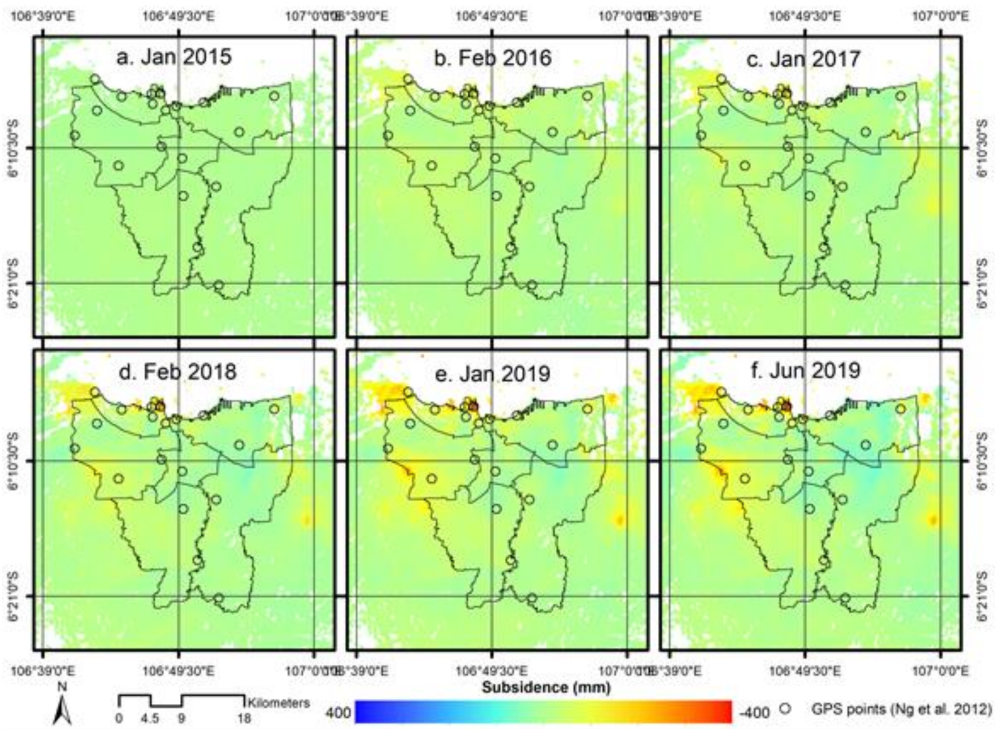

Fig. 3. Time-series of subsidence maps in Jakarta, the initial date is October 2014.

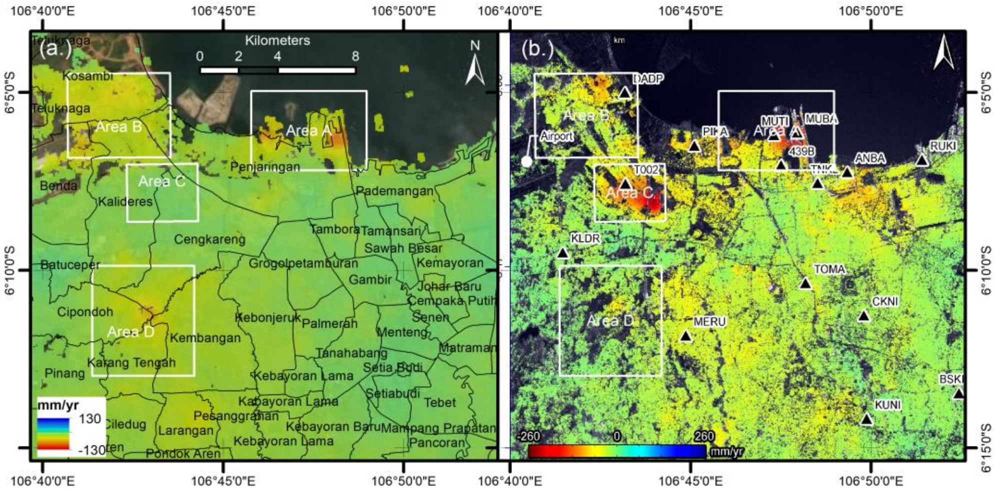

Fig. 4 (a.) Spatial distribution of subsidence results of SBAS DInSAR by Sentinel-1A SAR data compared with **(b.)** the spatial subsidence obtained from the study using ALOS-PALSAR data [6], all GPS points are presented by solid black triangles

2.2 Transition of subsidence

To know the current subsidence behaviour, the transition of subsidence at the former GPS measurement points are extracted. The GPS point location in presented by triangles as shown in Fig. 4b. The subsidence transition of all extracted points is shown in Fig. 5. The results by previous study by [6] and the results of SBAS-DInSAR is presented in this figure. In this result, except for the CIBU point which has no remarkable subsidence, all other points show the linear subsidence. It is found the largest subsidence up to 400 mm is measured at the MUBA point. The subsidence from 50 mm to 100 mm is found at the points DADP, PIKA, ANBA, MUTI, MARU, and MERU. From Fig. 5, the subsidence rate founded by current study is smaller than one which was found from former study for all measurements points in the area C [6].

The quantitative validation of SBAS DInSAR results is desired by using on-sight method, i.e. GPS, surveys, etc. However, the evidence of subsidence can be seen in daily live of affected community, according to BBC news published in 13 August 2018 [12]. The mitigation plans and adaptation plan against the subsidence need to be evaluated and reconsidered.

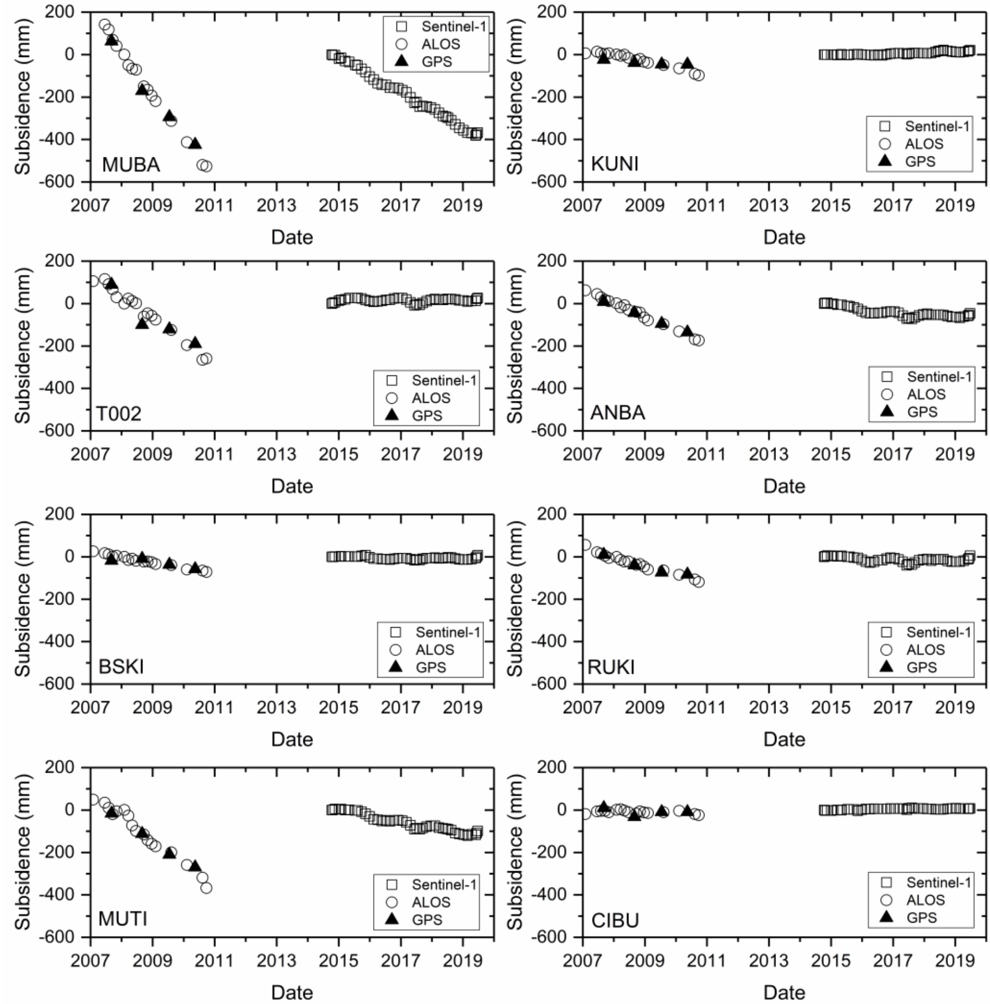

Fig. 5. The transition of subsidence at the GPS measurement points obtained by ALOS-PALSAR, GPS and Sentinel-1A. The ALOS-PALSAR and GPS data are redrawn from [6].

3 Conclusions

Jakarta is facing severe subsidence for decades. Monitoring activities in order to know the present condition of subsidence in Jakarta is very important. A terrestrial surveying by GPS was conducted annually. However, it was costly and time consuming, and the activity is being suspended. SBAS DInSAR method using Sentinel-1A SAR data able to provide information of subsidence over large area of Jakarta for 2014-2019, effectively. By comparing the subsidence behavior in period of 2007-2011 by ALOS-PALSAR, it is found that the area subsidence at north part of Penjaringan and Kosambi Districts do not much change. The subsidence is still on going linearly, despite the magnitude is slower as shown in MUBA GPS point. In other area namely; Cipondoh Indah and Rawa Buaya (area D) the subsidence rate is found increasing. Unfortunately, there is no GPS measurement point is set in that area. Some areas are found being stable such as in the area C (part of Cengkareng and Kalideres Districts). A measurement by GPS method was conducted at this point named T002. Comparing the previous result and the result of this study, it is clearly seen that this area become stable. This study results are important information of current subsidence situation in Jakarta. These up to date results can be used to evaluate the mitigation effort against the subsidence.

All the Sentinel-1A/B SAR data used in this research were kindly provided by the European Space Agency (ESA) and downloadable from the Alaska Satellite Facility (ASF). The ALOS Global Digital Elevation Model (AW30DEM) data were provided by the Japan Aerospace Exploration Agency (JAXA). The administration boundaries data were provided by Open Street Map (OSM). Many thanks are extended to these institutions.

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