Land Subsidence Of Semarang City Using Permanent Scatterer Interferometric Synthetic Aperture Radar (Ps-Insar) Method In Sentinel 1a Between 2014-2017

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Abstract. Environmental changes resulting from the impact of land use and underwater changes that may occur is the land subsidence. The main idea of this study is to measure and analyse land subsidence in Bandung city by processing SENTINEL 1A satellite images using the PS-Insar technique. PS-Insar technique is an effective technique for measuring crustal deformation. We processed 7 pair imageries of SENTINEL 1A images (at level 1.0) acquired from September 2014 to 2017. For time series of interferogram analyse, we analysed 7 pairs possibility of PS-Insar interferogram using SNAP open source program. To get better result, we computed the best baseline estimation to reduce fringes from baseline between master and slave data. The 1-arcsec (30 m) Shuttle Radar Topography Mission (SRTM) used to remove the topographic contribution as Digital Elevation Model (DEM) reference. Whereas for observing land subsidence using the PS-Insar method. Overlapping method was used to correlate the effect of changes in land subsidence into land use region in Semarang City. Observations in the deep aquifer used correlation seen from the increase and decrease of the graph of the inner MAT aquifer and the average increase and decrease in ground surface of PS-Insar. The result of PS-Insar processing showed the average value of the decrease in the face of the soil with a range of \(-4.4 \pm 3.4\) cm up. \(+2.2 \pm 3.4\) cm and from result of processing got information of the biggest decrease in land surface is in Sub District Semarang Utara, Semarang Barat, Pedurungan and Genuk. To verify the result of PS-Insar results, we used secondary data GPS observation[6] in 2013 and 2016 with a 3 observation benchmark points.

Keywords: GPS, Land Subsidence, PS-Insar, SENTINEL

1. Introduction

The decline in the water table due to excessive exploitation in its use is a phenomenon that exists in some areas of Indonesia, especially in the big cities. Semarang is one of the major cities in Indonesia with increasing population density and resulted in an increasing number of clean water needs. Data from the Semarang City [1] shows that piped water needs are sourced from 7 production buildings with a total capacity of 1,853 litter/s or 58,436,208 m³. Water demand in Semarang City in 1999 was 48,407,307 m³ in 2005 with the total demand rose to 68,568,239 m³. Taking groundwater continuously and in large numbers, in every activity in big cities, especially Semarang, can have an impact on the environment, one of which is the phenomenon of land subsidence. Interferometric Synthetic Aperture RADAR (InSAR) becomes one of the techniques in deformation observation. Observations with this technique, can also be applied to events with a specific time span, or also known as PS-Insar. PS-Insar or
Persistent Scatterer Interferometric SAR is another method [2][3] that being able to be one of the land subsidence detectors effectively eliminates decorrelation errors caused by long periods of time. In this research use PS-InSAR method, and GIS to analyse the correlation on the pattern of aquifer capacity change to the decrease of ground level. For processing PS-InSAR uses Image Sentinel 1-A. Sentinel 1-A to find out the amount of land subsidence in the Semarang area.

2. Data and Methods
2.1 Research Area
The study area of this study was in the city of Semarang, Central Java. The city of Semarang is between 6°50 ' - 7°10' S and 109°35 ' - 110°50' E as shows in Figure 1.

![Research Area (Semarang City) [3]](image)

The Semarang area is dominated by alluvial soil structures, except in the southern part of Semarang dominated by hills with more complex volcanic lava breccia. Rocks formed on the results of the Ungaran volcanic eruption that became the highest area in Semarang. The rivers in Semarang flow northward, namely the Java Sea. Morphological units are divided into coastal plain units (height 0-50 m above sea level), hilly units (altitude 50-500 m), and volcanic cone units with a peak of Mount Ungaran (2050 m above sea level). Aquifers based on rock characteristics on groundwater, Semarang City has 2 types of aquifers, namely semi-depressed aquifers and free aquifers [3]. Semi-depressed aquifers are in the Kaligarang Delta, while free aquifers are in the coastal alluvial plains, associated with alluvial fans and floodplains. The depth of the free aquifer in Semarang City is between 1-5m below. The depth of the free aquifers is increasingly shallow in areas approaching the coast.

2.2 Research Data
In this research, we use Sentinel-1A images with type Interferometric Wide Swath (IW) and Level–1 Single Look Complex (SLC) with complex data such as amplitude and phase from October 2014 to January 2017 with monthly data interval can seen in Table 1.

| No | Acquisition Date     | Level | Pol Type | Acq Mode | Inclination Type |
|----|----------------------|-------|----------|----------|------------------|
| 1  | October 26, 2014     | 1.0   | vv       | IW       | Ascending        |
| 2  | September 14, 2015   | 1.0   | vv       | IW       | Ascending        |
| 3  | January 6, 2016      | 1.0   | vv       | IW       | Ascending        |
| 4  | January 1, 2016      | 1.0   | vv       | IW       | Ascending        |
| 5  | July 11, 2016        | 1.0   | vv       | IW       | Ascending        |
| 6  | October 15, 2016     | 1.0   | vv       | IW       | Ascending        |
| 7  | January 19, 2017     | 1.0   | vv       | IW       | Ascending        |
2.3 Radar Basic Concept

RADAR (Radio Detection and Ranging) is one of the remote sensing technologies that utilize electromagnetic wave as a means of data collection; the wave is received back by the satellite that transmits it [4]. The radio waves and microwaves are transmitted throughout the earth's surface and their reflections are detected in the RADAR system, which is used to detect objects as illustrated in Figure 2.

![Figure 2. Geometry of SAR Acquisition System](image2.png)

The value of the size of the electromagnetic wave affects the penetration of the wave to the surface of the ground, the greater the wave and the stronger the penetrating power. The electromagnetic wave orientation received by and transmitted by the antenna is marked by the polarization of the RADAR signal. RADAR signals can be used to transmit both polarizations horizontally or vertically and receive good polarization in the same way from the surface.

2.4 PS-InSAR Method

PS-InSAR was first published as one of the deformation analysis techniques contained in a journal Permanent Scatterers in SAR Interferometry at a Remote Sensing and Geoscience International Symposium in Hamburg, Germany, June 28-July 2, 1999 [2]. PS-InSAR has advantages in terms of data processing compared to other methods such as DInSAR, which is able to eliminate the errors that occur due to the observation time with a long-time span can seen in Figure 3. The process in the InSAR PS method uses mathematical alignment calculations and error estimates and there is a sorting process in the data. PS-InSAR is a remote sensing technique that is the development of the DInSAR method that can monitor the movement of the ground surface that allows users to perform regular measurements and monitoring of fixed objects on the surface of the earth [5]. Persistent Scatterer (PS) InSAR is an extension to the conventional InSAR techniques that addresses the problems of decorrelation and atmospheric delay.

![Figure 3. Method Comparison Between SBAS, PS-InSAR and The Combination](image3.png)
2.5 StaMPS Processing

StaMPS Processing stage takes place in Linux OS, this stage consists of pre processing, 7 main stages (Load Data, Phase Noise Estimation, PS Selection, Phase Correction, Phase Unwrapping, and Estimate Spatially Correlated Look Angle Error) and plotting stage. The first step is pre processing, which is the stage of unification of interferogram. The interferogram formation stages of the interferogram result of each master and slave pair are combined into one interferogram. In StaMPS processing the interferogram pooling of each master and slave pair has several parameters needed for processing. The following step consists of estimating the spatially correlated look angle error (SCLA) simultaneously with master atmosphere and orbit error (AOE), which will be subtracted from the wrapped phase. At the final stage, the obtained wrapped phase was unwrapped once again and used later to estimate the Mean Line of sight velocity (MLV) in mm per year.

2.6 Research Methodology

For a description of the methodology in this study can be briefly seen in Figure 4.
3. Result and Discussion

3.1. Baseline Estimation

To know the value of this baseline estimation through the use of the InSAR Stack Overview menu [5]. The image pair used in this research is the image pair having the smallest distance estimation value and the bigger coherency model value. From the baseline estimation result obtained as the master image is image on July 11, 2016 can seen in Table 2.

| Mst/Slv | Acquisition     | Track | Orbit | Baseline perpendicular (m) | Baseline Temporal (days) | Modeled coherence | Height Ambiguity | Delta fDC (Hz) |
|---------|-----------------|-------|-------|----------------------------|--------------------------|------------------|-----------------|----------------|
| Master  | July 11, 2016   | 127   | 8920  | 0                          | 0                        | 1                | ∞               | 0              |
| Slave   | October 26, 2014| 127   | 2999  | -109.14                    | 624                      | 0.39             | 142.77          | 4.41           |
| Slave   | January 6, 2015 | 127   | 4349  | -125.89                    | 552                      | 0.44             | 123.78          | 5.73           |
| Slave   | November 14, 2015| 127 | 8599  | -35.51                     | 240                      | 0.76             | 438.74          | 2.56           |
| Slave   | January 1, 2016 | 127   | 9299  | -6.4                       | -96                      | 0.91             | 2434.42         | -2.94          |
| Slave   | October 15, 2016| 127   | 13499 | -48.34                     | 192                      | 0.79             | 322.33          | 0.29           |
| Slave   | January 19, 2017| 127   | 14899 | 57.90                      | -192                     | 0.78             | -269.12         | 0.92           |

3.2 Mean and Standard Deviation LOS Velocity

At this stage the process of plotting the mean and standart deviation LOS velocity can be seen in the Figure 5 and Figure 6.

Figure 5. MLV Plotting Results of All Interferograms Calculation
3.3. Land Subsidence in Semarang City

Analysis for Mean LOS Velocity (MLS) interpolation show Semarang and Demak tend to subsided with the average value land subsidence value in each district shown in Figure 7 and Table 3. PS-InSAR processing results in the form of land subsidence, accompanied by a correction of the average land subsidence. The result of the decrease in the average land surface in Semarang City is shown in Figure IV.2. In the image in green it represents that the average uplift is 2.4±3.4 cm/yr and the red color represents a land subsidence around -4.5±3.4 cm/yr.

Table 3. Land Subsidence in every district of Semarang City

| Number | Sub District         | Deformation (cm/yr) | Minimum       | Maximum       |
|--------|----------------------|----------------------|---------------|---------------|
| 1      | Tugu                 | -1 up to 0           | 0.7 up to 2.4 |               |
| 2      | Ngaliyan             | 0 up to 0.7          | 0.7 up to 2.4 |               |
| 3      | Semarang Barat       | 0 up to 0.7          | 1.6 up to 2.4 |               |
| 4      | Semarang Timur       | -1 up to 0           | -2.7 up to -1.9 |           |
| 5      | Gayamsari            | -1 up to 0           | -3.6 up to -2.7 |           |
| 6      | Genuk                | -2.7 up to -1.9      | -4.5 up to -3.6 |           |
| 7      | Mijen                | -1 up to 0           | 0 up to 0.7   |               |
| 8      | Gunung Pati          | -1 up to 0           | 0.7 up to 1.6 |               |
| 9      | Banyumanik           | 0 up to 0.7          | 0.7 up to 1.6 |               |
| 10     | Tembalang            | -1 up to 0           | 0 up to 0.7   |               |
| 11     | Pedurungan           | -1 up to 0           | -4.5 up to -3.6 |           |
| 12     | Candisari            | 0 up to 0.7          | 0.7 up to 1.6 |               |
| 13     | Gajah Mungkur        | 0 up to 0.7          | 0.7 up to 1.6 |               |
| 14     | Semarang Selatan     | 0 up to 0.7          | 1.6 up to 2.4 |               |
| 15     | Semarang Utara       | -1.9 up to -1        | 1.6 up to 2.4 |               |
| 16     | Semarang Tengah      | -1 up to 0           | 1.6 up to 2.4 |               |
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Figure 7. Land Subsidence Map

Based on the results (Figure 8) of the average soil surface processing, it can be seen that from 2014-2017 the largest land subsidence occurred in Genuk, East Semaran, North Semarang and Pedurungan subdistricts. In the northern coastal area of the west Semarang there was an increase in the land surface due to the unfilled distribution of PS-InSAR points in the area. The absence of PS InSAR points due to swaths in the area is not met by RADAR image overlaps (covering). Not fulfillment of the deformation point resulted in interpolation in the north western semarang refers to the deformation point at the bottom so that the coastal area has increased the land surface (land uplift).

Figure 8. Standard Deviation of PS-InSAR Processing

3.4. Comparison PS-InSAR and GNSS Survey

To verify the result of PS InSAR processing, secondary data of mean land subsidence from PS-InSAR processing with GPS method from previous research[7] between 2013-2016. Based on the result of verification of land subsidence data from GPS method, there is difference between land
subsidence value between GPS survey and corrected PS InSAR. The result of the difference is in Table 4 and Figure 9.

Table 4. Comparison of Land Subsidence Value Between GPS and PS-InSAR Data Processing

| GPS Point | GPS | PS-InSAR | Difference |
|----------|-----|----------|------------|
| SMK3     | 2.8 | 5.2      | 2.3        |
| K371     | 6   | 5.1      | 5.5        |
| SP05     | 0.6 | -0.4     | 0          |
| RMSE     | ±3.8| ±3.4     | ±4.2       |

Figure 9. Result of Comparison on GPS and PS-InSAR Processing

4. Conclusion
1. Based on the results of PS InSAR processing there are 5 subdistricts that have land subsidence, namely Genuk, North Semarang, East Semarang, Pedurungan and Gayamsari with an average annual rate of land subsidence of 1 ± 3.4 cm to 4.5 ± 3.4 cm/yr while in Tembalang and Mijen Subdistricts there was also a land subsidence in some regions with an average level of land subsidence of 0 ± 3.4 cm to 1 ± 3.4 cm/yr.
2. Based on the result of verification of land subsidence data from GPS survey method. There is difference between the GPS data and PS-InSAR point data of land subsidence in Semarang City around -0.4 to 6 cm.

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6. References
1. Geologi P L 2007 Kumpulan Panduan Teknis Pengelolaan Airtanah Dep. Energi dan Sumber Daya Miner. Badan Geol. Pus. Lingkung. Geol. Bandung

2. Wikantika K 2018 Data Optimization In Permanent Scatterer Interferometric Synthetic Aperture Radar (Ps-Insar) Technique For Land Subsidence Estimation

3. Prasetyo Y, Fahrudin and Islam L J F 2017 Analysis of spatial correlation between the phenomenon land subsidence and rob (tidal inundation) using sentinel-1 SAR, GPS and geological data in Semarang city-Indonesia AIP Conference Proceedings vol 1857 p 90003

4. Cumming and Wong 2005 Digital Processing of Synthetic Aperture Radar Data Algorithms Implement. Artech House London 202–46

5. Wegmüller U, Werner C, Wiesmann A, Strozzi T, Kourkouli P and Frey O 2016 Time-series analysis of Sentinel-1 interferometric wide swath data: Techniques and challenges Geoscience and Remote Sensing Symposium (IGARSS), 2016 IEEE International pp 3898–901

6. Bouraoui S 2013 Time series analysis of SAR images using persistent scatterer (PS), small baseline (SB) and merged approaches in regions with small surface deformation (Université de Strasbourg)

7. Prasetya A B, Yuwono B D and Awaluddin M 2017 Pemantauan Penurunan Muka Tanah Kota Semarang Tahun 2016 Menggunakan Perangkat Lunak Gamit 10.6 J. Geod. Undip 6 21–8