Conference Paper

Land Subsidence monitoring 2016 - 2018 analysis using GNSS CORS UDIP and DinSAR in Semarang

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Abstract

Land Subsidence is phenomena likey common and occurred due to natural cause, loading, and geological setting. In the coastal area land subsidence became worse, cause influence by sea-level rise, The impact land subsidence can lead to wider expansion (flooding area called rob), damage or cracking construction/building and large of maintenance cost. Semarang is the capital city in Central Jawa have experienced in land subsidence in several decades. The north of Semarang was reported a higher rate of land subsidence compared with the south. It was believed that the land subsidence areas were affected by young alluvium, ground extraction and a load of the building. To anticipate, land subsidence should be monitored and detected in an early stage. The most effective way of monitoring land subsidence using GPS, DInSAR to evaluate the characteristic of land subsidence. The GPS observation was conducted in 2016 -- 2018 using CORS UDIP as a base station and Sentinel Data was conducted to analyzed the subsidence rate in Semarang. The result showed land subsidence rate in several areas was distributed both spatially and temporally.

Keywords: land subsidence, GPS, InSAR

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1. Introduction

Land subsidence in one of geological problems. Recently land subsidence became a serious issue that must be concern. Land subsidence is caused by consolidation and compression of underground because of either non-human-related or human-related [1]. The impact of subsidence is also one of the major of regional geological disasters that causes serious damage to infrastructure, road and bridge, and environmental settings. There are several methods can be applied using geodetic methods such as Leveling surveys, GPS (Global Positioning System) surveys, InSAR (Interferometric Synthetic Aperture Radar), and microgravity surveys to monitor landsubsidence [2]. There are several cities have been reported by this land subsidence issue. [3]. Semarang was one of those cities.

Land subsidence impacts in Semarang area commonly in urban are large damage and resulting impact is intangible. The damage suck as cracking of building, expand of coastal and inland flooding area. Besides that land, subsidence is also worsened living quality and environment. Another impact is maintenance cost became high compared with the normal situation.

Semarang is the capital and largest city of Central Java Province. Semarang was located 6°580S and 110°250E on the northern coast of Java It has about 1.5 to 2 million inhabitants, Semarang coverage area of about 375 km2 [4]. The geological structure of Semarang is underlain by three lithological units: volcanic rocks of the Damar formation located in the South--West, marine sediments in the North, and alluvial deposits, also in the North [5]. Land subsidence is occurring in areas of marine and alluvial sedi ments [6].

The process of land subsidence in several locations since the 1980s until now. The quarterly mature alluvial deposition factor that has not been fully consolidated is suspected to be one of the important factors causing land subsidence in the city of Semarang [7]. The northern part of Semarang consists of very young alluvium with high compressibility. [8]suggest that the Semarang coastline takes place relatively quickly towards the sea, which is about 2 km in 2.5 centuries or around 8 m / year. The geological conditions of the technique illustrate the physical and mechanical properties of the soil which influence the process of subsidence. The physical and mechanical properties of the land determine the magnitude of the natural consolidation that has taken place. Base on the research [6] land subsidence has occurred in the area of alluvium and marine. And it has been observed since 1980 using geodetic techniques such as cone sounding, consolidation test, standard penetration test, ground-level studies [6]; GPS, leveling, DinSAR, Geometric historic [2]

2. Methods and Equipment

2.1. Methods

2.1.1. DinSAR (Differential SAR Interferometry

The concept of InSAR began to be developed in the 1970s. Since then, extensive research has been carried out throughout the world; This is because several satellites have been launched with better technology. Area coverage will only increase with more radar satellite constellations. Differential Interferometry Synthetic Aperture Radar

(DInSAR) is the technique of acquiring two SAR images in pairs at the same spatial position (differential SAR) or slightly different positions (InSAR terrain height) in the same area as multiplying conjugate multiplication. The final result is a model of digital elevation (DEM) or a shift in the surface of the earth.

DInSAR is often used to monitor changes (deformation) of an area to the accuracy of cm order. Such an order of accuracy, obtained from the method of processing InSAR data in a differentiable manner. This method uses several pairs of interferograms as well as to detect surface changes in topography with very high accuracy. DinSAR basic concept illustrated in Figure 1

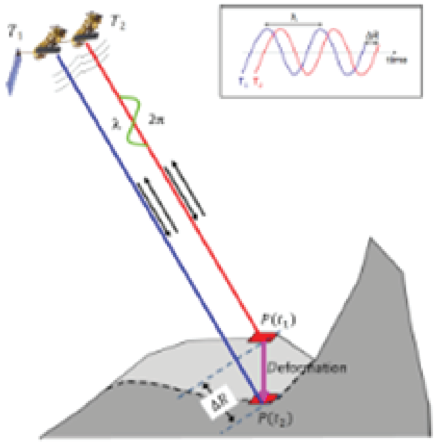

Figure 1: DInSAR basic concept [9].

The most Studies deformation using SAR were defined on spatial analysis of movement with an average rate of displacement. Recently the improvement in techniques processing data and the possibility in analysis nonlinear ground motion, so it could to take advantage of the capability of DinSAR techniques in describing the evolution of natural processes [10]

The principle of interferometry is to measure different phases between SAR images acquired at different times. The phase being a measurement of distance would represent the change in height of the object reflecting signal [11]. The phase being affected by different error sources [12]. Phases comparison without any corrections of error would be to an inaccurate result. Even though a different method has to be developed to be more accurate. Application of SAR interferometry is considered an error source such as; Impact of the atmospheric change, the impact of multipath, the impact of topography [13]

The final result of DinSAR processing is obtained from the calculation which represents location where the height changes during time observation. The result depends on the characteristic of the ground, whereas an object in amplitude close to zero will not be captured. When the large data set over an urban area, the center of the dataset will represent a lower amount of vegetation. The capture location at the subsided area will be conducted to calculate subsidence and subsidence rate, where the larger amount of captured location in the center.

2.1.2. GNSS (Global Navigation Satellite System)

The term GNSS such as GLONASS, GPS, Galileo among others (Hofman-Wellenhof, 2008). High accuracy is needed in measurement for land subsidence or deformation in construction. One of the solutions is using the different types of measurement which is more or less accurate.

The principle of measurement of land subsidence using GPS surveys is shown in Figure 2. Using this method several monuments will be installed on the ground which covers the land subsidence at the prone area. Measurement will depend on certain references (stable). The precise coordinates of monuments ware determined using GPS surveys, Using the result of surveys GPS the characteristic and rate of land subsidence can be derived. GPS monitoring concept was shown in Figure 2.

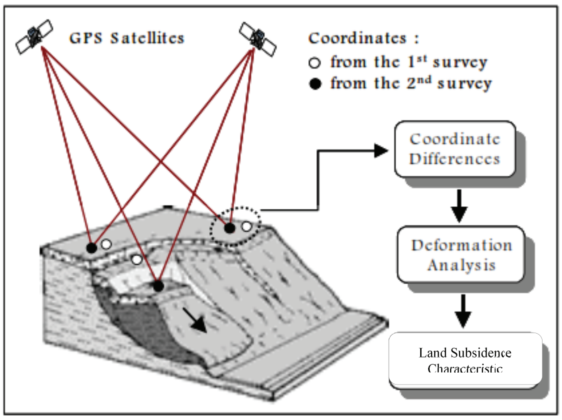

Figure 2: Principle of GPs Survey Method for land subsidence Monitoring [2].

2.1.3. Data Collection

The advance Differential SAR Interferometry (DInSAR) techniques were conducted to evaluate land subsidence time series investigation. The research focuses on the Semarang area, which affected land subsidence. The Data in this research was conducted 15 ascending Sentinel-1A TOPS SAR images (C-band) acquired from 2015 to 2018 covering Semarang. The parameter of Sentinel 1-A was represented in table 1.

Table 1: Specific parameter of Sentinel-1A.

Master / Slave	Acquisition	Track	Orbit	Baseline Perpen-dicular (m)	Baseline Tempo-ral (m)	Modeled Coherence	Height Ambiguity	Delta fDC (Hz)
Master	27 March 2015	76	5223	0,00	0,00	1,00	∞	0,00
Slave	16 Dec 2015	76	9073	3,61	-264,00	0,75	-4317,94	6,49
Master	9 Jan 2016	76	9423	0,00	0,00	1,00	∞	0,00
Slave	10 Des 2016	76	14323	8,37	336,00	0,68	-1861,46	6,97
Master	21 Dec 2017	127	19799	0.00	0,00	0,00	∞	0,00
Slave	13 Apr 2017	127	16124	-34,17	252,00	0,75	456,27	-1,64
Master	5 Oct 2018	127	23999	0.00	0,00	1.00	∞	0,00
Slave	2 Jan 2018	127	19974	-9	276	0.75	1729,16	-0.22

GPS survey was conducted in the campaign survey. To have coordinate differences with high precision in mm level, the survey should have to use dual-frequency geodetic type GPS receivers. The baseline for observation point was adjusted which baseline length is less than 10 km, the observation period of about 6 hours are enough to gain the precision level of several mm. Displacement characteristics can be used to analyze the geometric characteristic of land subsidence phenomena in the area. Three periods of GPS surveys have been conducted from 2016 to 2018 using base station GNSS CORS UDIP (see Table 1), and the configuration of observed GPS network is shown in Figure 3.

Table 2: GPS Survey in Semarang Periode 2016 sd 2018.

Survey	Observation Period	Observed GPS Stations
1	30 April -- 4 Augt 2016	Isla, Pmas, K370, Bm05, Ay15, Prpp, Rmpa, Bm01, Smg3, Smg2, Bm11, Mp69, Smpn, 1124, Bm16, Sfcp, 1125, Bm30, Dri1, Johr, Sp05, N259, Wg17, K371, Ctrm, Smk3, Kop8, Bm03, Kit1, Bmpu, Trml, Bmkai
2	29 April -- 30 July 2017	Isla, Pmas, K370, Bm05, Ay15, Prpp, Rmpa, Bm01, Smg3, Smg2, Bm11, Mp69, Smpn, 1124, Bm16, Sfcp, 1125, Bm30, Dri1, Johr, Sp05, N259, Wg17, K371, Ctrm, Smk3, Kop8, Bm03, Kit1, Bmpu, Trml, Bmkai
3	21 April -- 1 July 2018	Isla, Pmas, K370, Bm05, Ay15, Prpp, Rmpa, Bm01, Smg3, Smg2, Bm11, Mp69, Smpn, 1124, Bm16, Sfcp, 1125, Bm30, Dri1, Johr, Ttg447, N259, Wg17, K371, Smk3, Kop8, Bm03, Kit1, Bmpu, Trml, Bmkai, B061, Bugn

GPS survey in the period of 2016 there are several observation points but not all can be continued at the processing stage because of the conditions and obstruction in the field. In the 2017 period GPS survey, there were several damaged and GPS station was already buried by road maintenance so it could no be observed any more such as SP05, CTRM, and missing observation GPS Survey in SMK3, KOP8, BM03, BMPU KIT1, BMKAI. In the third year period (2018) there are several points that are not measured such as at points BM05, MP69, BM16, SFCP and BM30 due to obstruction factors and the addition of new survey points B061 and BUGN. The observed point should be has a good sky view and less affected by multipath. CORS UDIP used to be a reference station for GPS survey and located at the stable area, besides it has a good view of. Data were conducted with 30-second interval and elevation mask 15 degrees. Distribution of GPS network can be seen in Figure 3

GPS processing results shown that PMAS indicates two slightly distinct value 16,47 cm, 13,00 cm, 0,59 cm year between 2015 -- 2016; 2016-2017 and 2017-2018. In Periode 2016-2018 totally different subsidence rate became 0.59, respectively. The subsidences also occurred at another GPS site like SMG3 and 112 has a fluctuating subsidence value indicating the temporal variation of subsidence. GPS data processing was used gamit 10.7 with 9 IGS (International GNSS Service) such as, BAKO, CNMR, COCO,DARW, IISC, KAT1, SOLO, PIMO, XMIS and UDIP

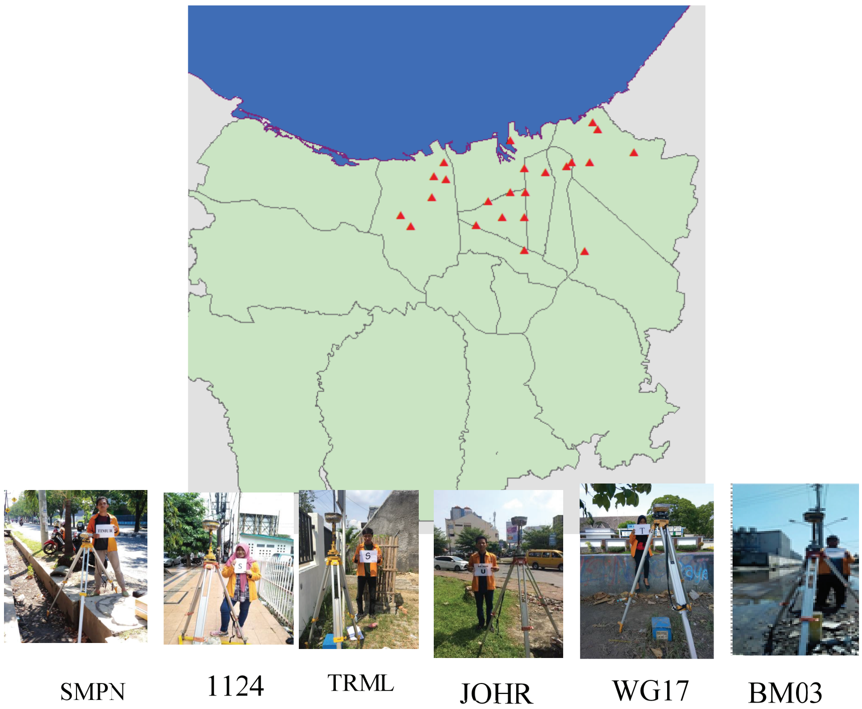

Figure 3: GPS Land subsidence monitoring GPS network 2018.

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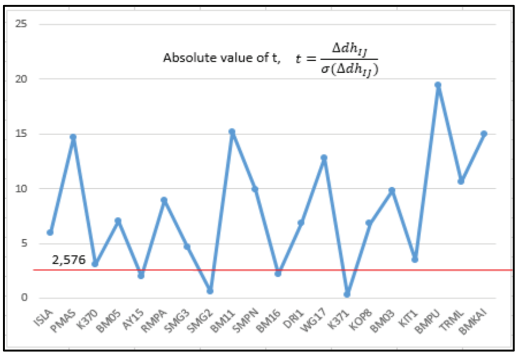
3. Results

This study presents the results of land subsidence for land subsidence monitoring project in Semarang City based on GPS and InSAR data. Results of numerical data analysis clearly revealed the existence of land subsidence in this study.



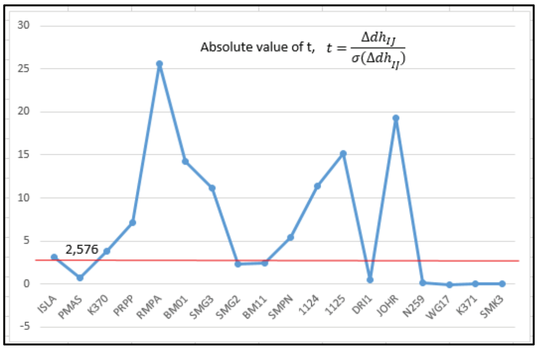


Figure 4: Summary of congruency test of GPS derived land subsidende in 2017 and 2018.

The GPS-derived ellipsoidal height changes and their rates that have passed the statistical testing are shown in figure 5. It could be statistically concluded that with 99

Three years period of GPS observation shown that land subsidence rate is time-dependent. Observation of GPS time series implies a slow down in the annual rate from stating 2016 with small amplitude. Results from GPS Data in 2016 show that land subsidence in Semarang has spatial variations, ranging from 3,4 to 13.7 cm/year with the mean of 11,4 cm/year (see Table 1). While in 2017 and 2018 respectively rate of land subsidence ranging from 0.3 cm/year to 18,3 with the mean 6.5cm/yr , and form 19,1 to 0,1 with the mean 9.1 cm/year. The land subsidence maps in 2016 until 2018 will be shown in figure 6

Subsidence rate from the DInSAR was predicted at the same location via multiple interferograms which collected from 2016 to 2018. The result based on the analysis of Sentinel-1 images, velocity maps along the line of sight direction for both tracks using DInSAR techniques has been created. The velocity of land subsidence values ranging from 1 to 19 cm and locally even higher. To handle the lack of information in the area with vegetation is should confirm because it could impact in low coherence influence final result of DInSAR.

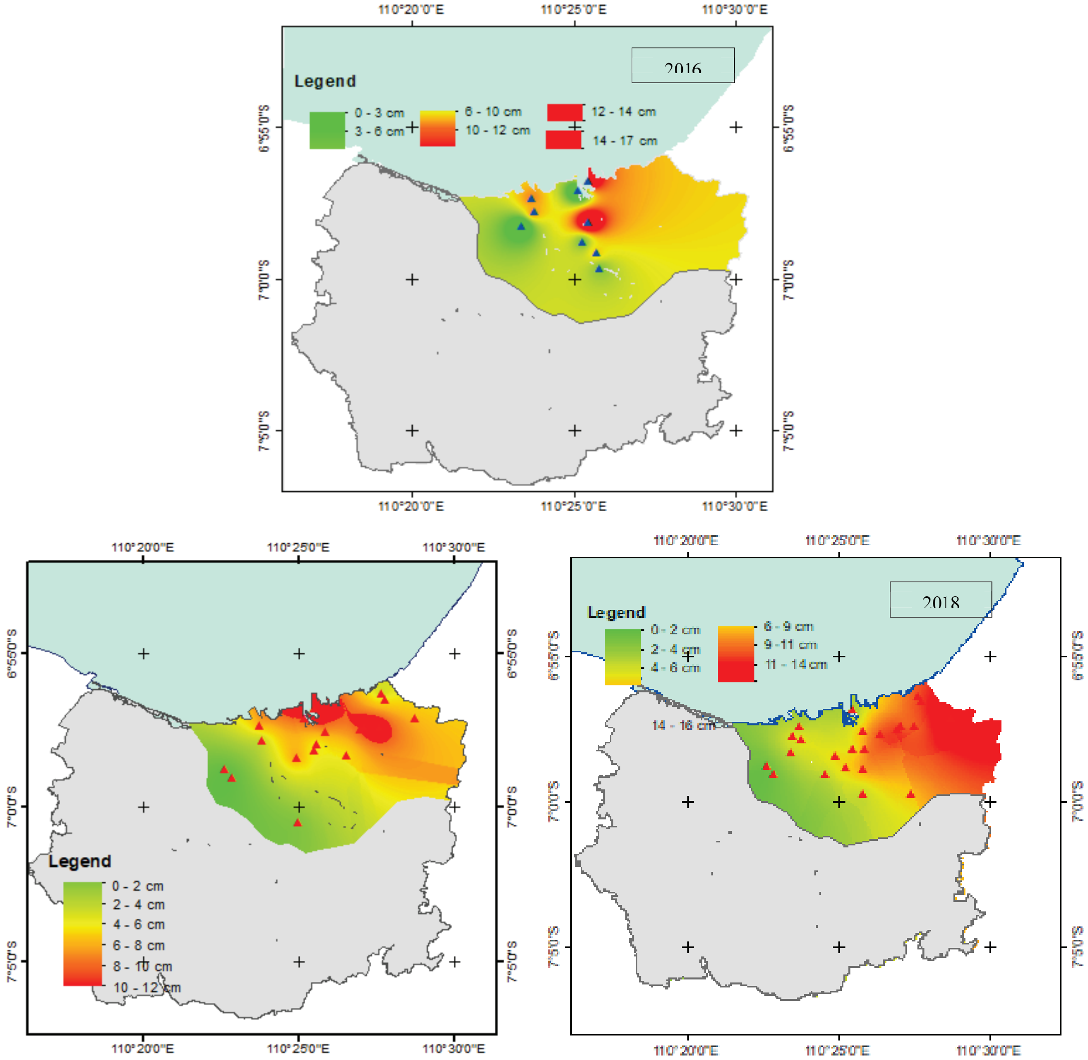


Figure 5: Land Subsidence observation using GNSS technique with CORS UDIP as Base Station.

Figures 7 show changes in elevation land subsidence that occurred from 2016 to 2018. It can be concluded that the value of decline occurs in the northeast with a decreasing value that varies per year. The highest land subsidence occurred in 2015, while for the lower grades in 2016 and 2017 with the highest land subsidence value of 7 cm.

When it compares the amount of DInSAR estimated subsidence rate along with 30 GPS sites, they show subsidence that is quite common with identical deformation level. Spatial analysis proves that the deformation score shows that deformation scores are relatively higher in residential and agricultural areas which consume excess groundwater, loading placed in the basin.

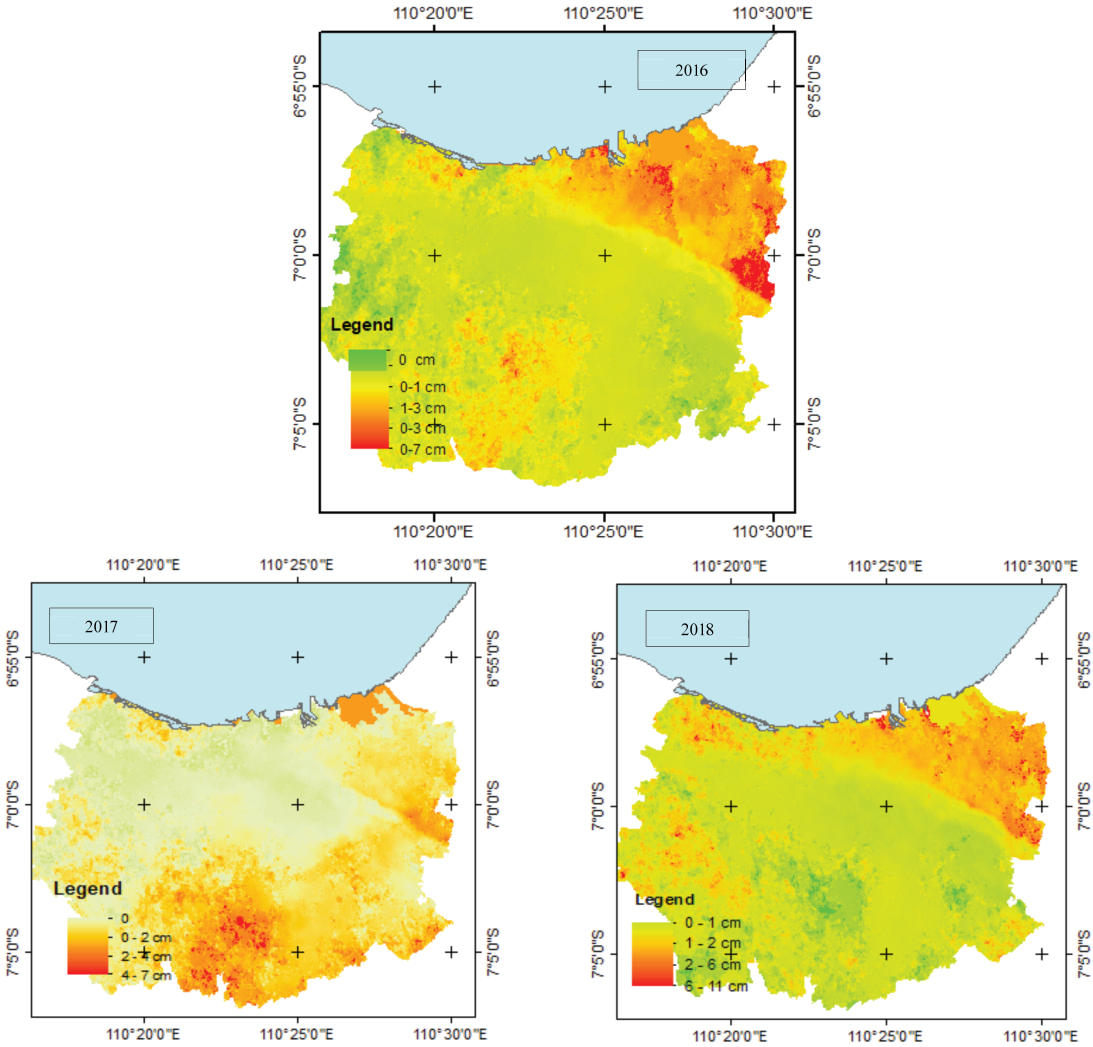


Figure 6: Land Subsidence using DInSAR technique.

4. Discussion

This research will explain about the rate of land subsidence in Semarang coastal area. By using geodetic and DinSar method will show the late of land subsidence. To have analysis relationship correctly it should be conducted much more data spread across multiple GPS Stations which are continuously observed.

The main goal of this research is to serve information about the latest of land subsidence in the coastal area in Semarang demak, and also investigate the possible impact and consequences in the future. Two methods in this research GNSS and DInSAR can be applied for analyzing both the spatial and temporal monitoring in land subsidence. Satellite base imaging and positioning system such as ESA's Sentinel-1and GNSS assure interoperability.

5. Conclusion

By another geoscience such as geotechnical, geological, hydrological and also meteorological data can be combined in the future interpretation of land subsidence phenomenon. This information could be support to prevent the infrastructure such as irrigation, road, drainage. Further study is needed to identify the real characteristic and pattern of land subsidence phenomena in Semarang. GPS and DinSAR measurement should be integrated with other geodetic techniques method as leveling, gravimetric and automatic-water-level

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Conflict of Interest

The authors have no conflict of interest to declare.

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