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Study of the Impact of the Growth of Settlement Areas on the Decreased Capacity of Shallow Aquifer and Groundwater in Semarang City (2014-2017)

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ABSTRACT. *The growth of urban areas dominated by residential and industrial land cover will encourage the high use of clean water and land loading (compaction due to building loads). The use of water in people's daily lives and industrial activities still relies on nature, namely in the form of groundwater or aquifers. Continuous water collection, especially in big cities in Indonesia, will have a negative impact on the environment which results in changes in the environment itself. Environmental changes due to the impact of taking water that might occur are land subsidence (LS). For this reason, this study will examine the relationship of the impact of the development of residential areas in the city of Semarang on the decline of shallow aquifer capacity (SAC) and LS. Observation of changes in KAD in this study was observed in the type of shallow aquifer using shallow wells (MAT) data. Whereas for observing land subsidence using the PS InSAR method. For the growth of the residential area of Semarang, it will be focused on the land cover of residential areas in the 2014-2017 period. The overlapping method is used to correlate the effect of changes in KAD and PMT in Semarang City. PS InSAR processing results obtained an average value of average land subsidence per year with a range of 0 ± 3.4 cm to 4.5 ± 3.4 cm and the results of processing obtained the largest land subsidence information found in the District of North Semarang, East Semarang, West Semarang, Pedurungan and Genuk. The change in KAD in the amount of 60% to> a decrease of> 80% occurred in Genuk Sub-District, North Semarang, West Semarang, Pedurungan, Gayamsari. Whereas settlements with population levels based on land use classification maps for settlements are in Genuk, West Semarang, Gayamsari, Pedurungan, Tembalang, and Banyumanik Districts.*

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1. Preliminary

1.1 Background

Increasing population continuously happened in the Big City of Indonesia. Increasing population will affect the increasing demand for aspects of supporting the daily needs of large urban residents, namely the need for clean water. Water is one of the main needs that support the daily activities of people who are still dependent on natural resources, namely groundwater. Continuous groundwater extraction from dense residential activities will have an impact on the environment, one of which is land subsidence.

Observation uses remote sensing with RADAR technology to obtainLS values with the PS-InSAR method. Observation of changes in shallow aquifer capacity from survey results on community wells, and settlement classification data from BAPPEDA.

This study examines the impact of residential growth on groundwater availability in shallow aquifers and land subsidence. Hopefully, the results of this research can be used as well as possible.

1.2 Study Literature

1.2.1 Settlement

The settlement comes from the word settle which means permanent resident, residence/area, area and can also be defined as an area (Yunus H.S., 1999). Thus, the word settlement can be defined as an area consisting of a collection of dwellings inhabited by people who live in a place, finally, settlements have other physical elements besides residential buildings such as markets, educational buildings, and government buildings. (Wiraprama, A.R., 2014)

1.2.2 Aquifer

In Zahra, F. S. (2016), the main factor that determines in making criteria for groundwater damage is the balance between the amount of groundwater availability and its utilization. If the amount of utilization is greater than the amount of water availability, there will be damage to the condition and environment of the groundwater.

Aquifer systems have a recharge process that is influenced by natural factors. In USGS school environment it is explained that there is a relationship between MAT and aquifer capacity and its changes. In natural conditions, aquifers are mainly filled with sediment infiltration and, to some extent, through surface water bodies and adjacent aquifers. Aquifer changes according to Figure II.10 explained that the MAT at the top of the aquifer layer can be identified as one of the references of changes in aquifer capacity qualitatively, decreasing or increasing groundwater reserves from the aquifer layer.

1.2.3. Land Subsidence (PMT)

A land subsidence is a process of land subsidence movement based on a particular datum (geodetic reference framework) where there are various causes (Prasetyo, Y., *et al*, 2018).

The causes of land subsidence can occur both locally and regionally, some factors include the following (Whittaker and Reddish, 1989 in Prasetyo, Y. et al. 2018):

1. Natural subsidence is caused by geological processes such as volcanic and tectonic activities, geological cycles, cavities below the surface of the soil and so on.
2. Land subsidence caused by taking liquid material from the soil such as groundwater or petroleum.
3. Ground subsidence caused by heavy loads on top such as building structures so that the layers of soil.

Land subsidence in the Semarang plain was recorded from 1982 to 1996, ranging from 0.5 to 2.2 m per year. Two main factors that cause land subsidence in the plains of Semarang are groundwater use and additional load due to rock fill. Land subsidence only occurs in lowland areas while in hilly areas there are no signs of land subsidence (land subsidence) caused by these two factors. Soil subsidence prediction in Semarang was calculated using a 1-D consolidation model simulation, the results obtained showed that the land subsidence grew larger to the north-northeast (coast), according to the pattern of groundwater subsidence, the spread of soft clay layer thickness, soil thickness, and the amount of sand layer in the delta plateau deposit. (Marsudi, 2001 in Zahra, F.S. 2017).

1.2.4 PS InSAR

PS InSAR was first published as one of the deformation observation techniques contained in a journal of Permanent Scatterers in SAR Interferometry at an International Symposium on Remote Sensing and Geoscience in Hamburg, Germany, June 28-July 2, 1999. PS InSAR has advantages in data processing compared with other methods such as DInSAR, which is capable of eliminating decorrelation errors that occur due to the observation time with a long time span. The process in the InSAR PS method uses mathematical alignment calculations, and error estimates and there is a sorting process in the data.

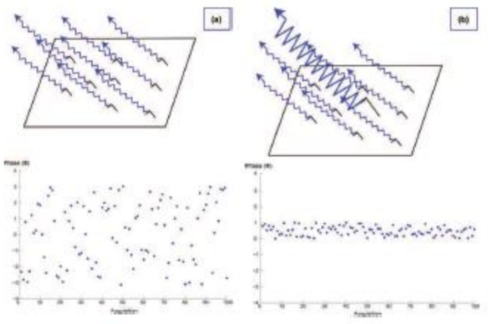

Figure 1.1 Back Scattering Phase in the DInSAR and PS InSAR Methods with 100 of the same Element Iterations (Seyfallah, 2013)

1.2.5 Overlay

The overlay is an essential spatial analysis that combines the two layers/thematics that are entered. In general, technical analysis is divided into raster or vector data formats (Prasetyo, Y., *et al*, 2018)

1. Vector

In this format, some geographic information system software divides it into two groups, namely intersect and union. At intersecting, layer 2 will cut layer 1 and vice versa to produce an output layer that contains the attributes of both the layer 1 attribute table and the layer 2 attribute table. While on the union, the spatial analysis will combine the new layer (the widest spatial dominance) The new layer that is generated (output) will contain attributes that come from the two attribute tables that are entered.

2. Raster

In general, in terms of raster data, the overlay spatial analysis function is realized in the form of the implementation of several arithmetic operators which includes most cases where two digital images are used to produce another digital image (output). Thus in this spatial analysis, the image pixel values will be combined using arithmetic and binary operators to produce new pixel values (composite). On raster/grid, layers maps can be expressed as arithmetic variables that can be imposed by algebraic functions.

2. Data and Methodology

This section explains in detail about the research carried out, including the location of the study, the data used, and the methodology applied.

2.1. Data and Location

2.1.1 Research Data:

The data used in this study are::

1. SLC Image Sentinel 1-A level 1 2014-2017
2. DEM SRTM in the Year 2011
3. Data Survey SAC Semarang City within 2003-2016 shallow aquifer capacity
5. Settlement classification in Semarang City 2014-2017

The equipment used in this study includes hardware and software, as follows:

1. Hardware:
   a. Laptop with the specification AMD-A8, RAM 4 GB, and operation system Windows 64-bit.
   b. Computer 16.04 LTS 64-bit.
   c. Harddisk 1TB
2. Software
   a. SNAP Dekstop.
   b. ArcMap 10.3.1
   c. SNAPHU.
   d. StaMPS
   e. Triangle

2.1.2 Research Location

This study took place in the city of Semarang, Central Java, Indonesia

Figure 2.1 Administration Map of Semarang City (BAPEDA, 2017)

The city of Semarang is between 6º50 '- 7º10' LS and 109º35 '- 110º50' BT with an area of 373.70 km2. The northern boundary is the Java Sea, south of Semarang Regency, the east is Demak Regency, and the west is Kendal Regency.

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 which became the highest area in Semarang. The rivers in Semarang flow northward, namely the Java Sea. Morphological units are divided into coastal plain units (altitude 0-50 m above sea level), hill units (altitude 50-500 m), and volcanic cone units with a peak of Mount Ungaran (2050 m above sea level).

Based on Geological Map of Magelang-Semarang Sheet (Tahnden, et al., 1996 in Zahra, F. S., 2016), the stratigraphic structure of Semarang City from the youngest to the oldest is as follows:

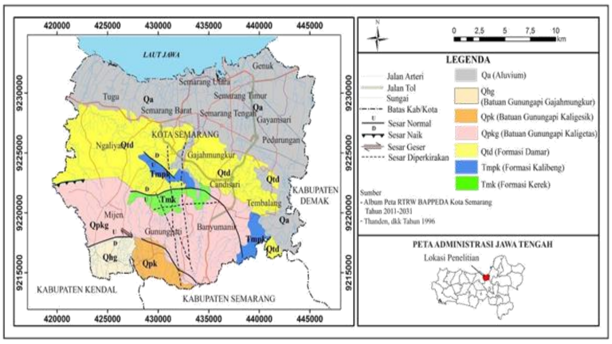

Figure 2.2 Geological Structure of Semarang and Surrounding Areas (Marsudi, 2000 in Zahra, F.S. 2017)

Based on its hydrogeological conditions, the water potential in the city of Semarang originates from the rivers flowing in Semarang, including Garang River, Pengkol River, Kreo River, Banjir Kanal River, Sringin River, Kripik River, Dungadem River and so on. Kali Garang is the main river that flows through the valleys of Mount Ungaran following a fairly swirling turn.

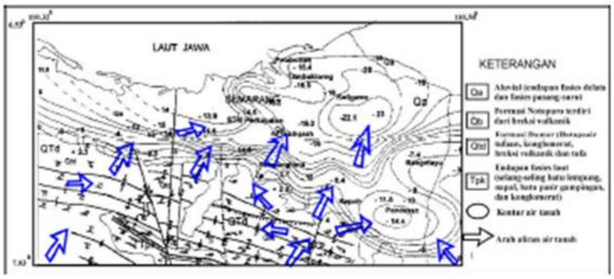

Figure 2.3 Regional Groundwater Flow in Semarang and Surrounding Areas (Marsudi, 2000 in Zahra, F.S. 2017)

2.2. Methodology

The methodology used in this study is the overlapping methodology between the data that has been processed. Clearly stated in the diagram in Figure 2.4.

Data processing in this study aims to obtain three pieces of information, namely SAC data, LS data and settlement data in Semarang City. SAC data processing was obtained from the survey results on shallow aquifers in the community wells in Semarang City in 2003 from the ESDM Department and 2016 which were then interpolated using kriging interpolation so that Firza S Processed Groundwater Change Change Zoning Map was produced, 2016. to identify qualitative changes in KAD.

The processing of LS data is obtained from the results of the 1-A RADAR Sentinel Image as many as 7 images processed by the StaMPS method with the initial process in the form of interferogram formation, phase deletion and StaMPS processing so that the scatterers point identifies deformation. Then the data was selected to identify LS in Semarang City.

Settlement data was obtained from the Semarang City BAPPEDA which showed population density and density throughout the city of Semarang. The data is used as data to analyze the impact of settlement densities in Semarang City with SAC and LS.

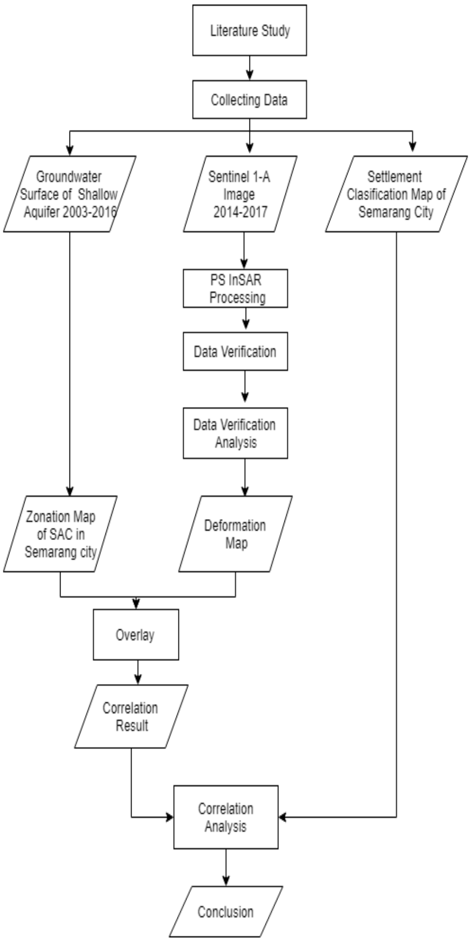

Figure 2.4 Research Workflow

The LS and SAC map results are correlated to then be classified with the overlay method so that the correlation between them can be analyzed. The results of the correlation were then re-analyzed with settlement data from the Settlement Spatial Planning Map of BAPPEDA to see the impact on densely populated areas with regions that were previously classified as LS and SAC.

After that, it was concluded that which areas were densely populated and whether the area had an impact on the reduction in SAC and LS events.

3. Result and Discussion

3.1. Change Zone SAC

Decreased groundwater levels in shallow aquifers in the city of Semarang occur only in all study areas. There are pond areas in parts of northern Semarang, along with a groundwater level with the largest number of a shallow aquifer level decrease reaching more than 80% and the lowest <40%.

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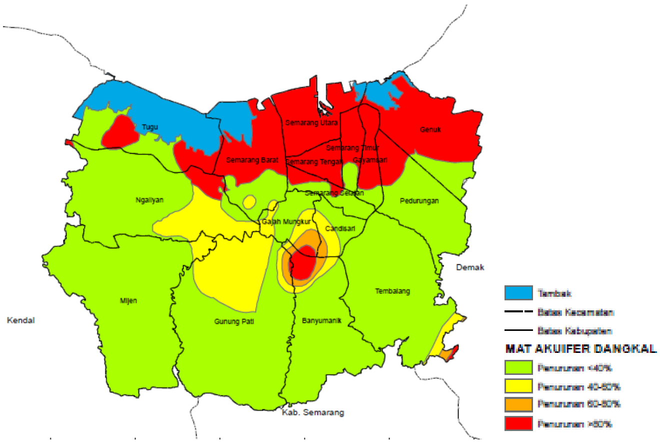

Figure 2.5 Zone Result of SAC Semarang City

Based on the results of the groundwater zoning map in shallow aquifers, the data shown in Table 2.1 is obtained.

Table 2.1 Area of Semarang City SAC Based on MAT Zonation Map of Shallow Aquifer

Number Estimation Decreased of Groundwater-Surface	**Area Decreased (Ha)**
Decreased Groundwater Surface <40%	24,681.71
Decreased Groundwater Surface 40-60%	3,697.17
Decreased Groundwater Surface 60-80%	413.00
Decreased Groundwater Surface >80%	7,842.57

The percent value obtained was obtained from a decrease in the depth of the well in 2003 and in 2016 and an estimated change in depth which was reduced in percent units. Based on the results of the regions that experienced the largest decline in KAD were in Genuk, North Semarang, West Semarang, Gayamsari, Banyumanik and Pedurungan sub-districts.

3.2. LS Results

PS InSAR processing results in the form of a land subsidence, accompanied by a correction of the mean ground subsidence. The results of average ground water reduction based on PS InSAR processing using Sentinel SAR 1A imageries in 2014-2017 is shown in Figure 2.6.

Based on the results of the PS-InSAR processing, the results showed that there was a decrease in soil face with an average land subsidence per year with a range of 0 ± 3.4 cm to 4.5 ± 3.4 cm and from the processing results obtained the largest land subsidence information found in the area of North Semarang District, West Semarang, Pedurungan and Genuk.

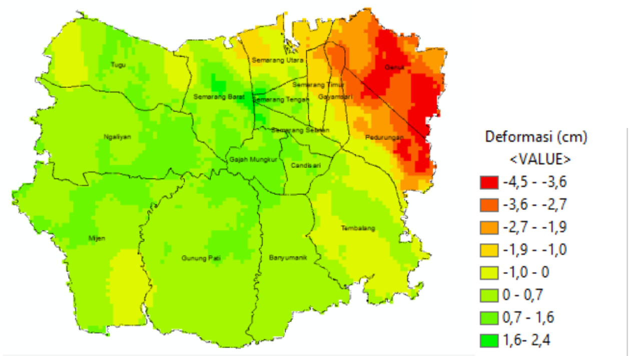

Figure 2.6 Result LS of PS InSAR

Tabel 2.2 Deformation in Each District of Semarang City

NO	Region	Deformation (cm)	
		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

3.3. Results of Correlation of SAC, LS, and Settlement

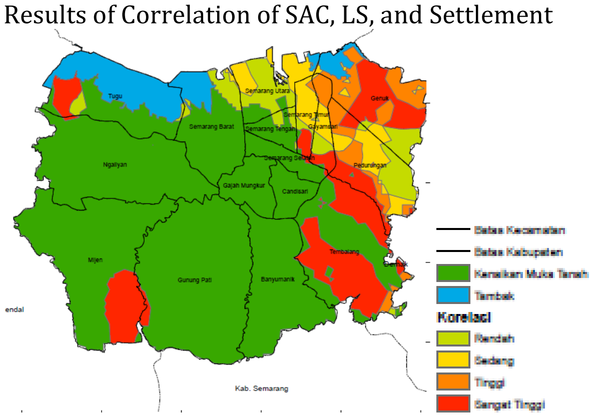

Figure 2.7 Correlation SAC and LS

Based on the results of the correlation there are several sub-districts with very high to moderate correlations, namely Genuk, North Semarang, West Semarang, Pedurungan, Mijen and Gayamsari sub-districts.

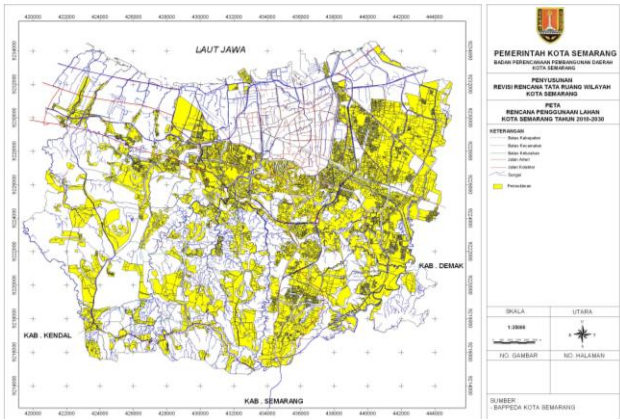

Figure 2.8 Settlements in Semarang City (BAPPEDA, 2017)

Based on the map of settlements in the city of Semarang there are several sub-districts with dense settlements namely Genuk, West Semarang, Gayamsari, Tembalang, and Banyumanik Districts.

Table 2.3 Decreased KAD in several Sub-districts in Semarang City

SAC	Region
Decreased <40%	Ngaliyan, Tembalang, Semarang Selata, Mijen
Decreased 40-60%	Gunung Pati, Banyumanik, Gajah Mungkur
Decreased 60-80%	Candsari, Gajah Mungkur, Banyumanik
Decreased >80%	Genuk, Semarang Utara, Semarang Barat, Pedurungan, Gayamsari

4. Conclusion

PS InSAR processing results obtained an average value of average land subsidence per year with a range of 0 ± 3.4 cm to 4.5 ± 3.4 cm and the results of processing obtained the largest land subsidence information found in the District of North Semarang, East Semarang, West Semarang, Pedurungan and Genuk. Whereas KAD is also in the same sub-district from the range of decreasing MAT in KAD 60 to> from 80%, namely Genuk, North Semarang, West Semarang, Pedurungan, Gayamsari sub-districts. The result of the correlation between shallow aquifer capacity and average annual land subsidence in the city of Semarang is a very high level of correlation, which is a percentage of 47.58% with details of the results of a high correlation of 16.09%, medium correlation level of 16.29% and low of 20.02%. While the level of correlation of deep aquifers to the average land subsidence per year is obtained from the change in deep aquifer capacity has no correlation at all on average annual subsidence in the city of Semarang. Based on the Land Use Map (BAPPEDA, 2017) the regions that have the LS and the largest decrease in KAD are areas with densely populated settlements compared to the areas located in the east of Semarang except for a few areas, namely Banyumanik and Tembalang. Based on the results of this spatial study, the growth of densely populated areas has an impact on the decline in KAD and LS. Because the nature of KAD is easily accessible and widely used by the community at large and based on data from the findings in this study.

5. Conflict of Interest

Penulis menyatakan tidak ada konflik kepentingan dalam artikel ini (*The authors declare no competing interest*).

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