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To cite this article: Yudo Prasetyo *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **280** 012001

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Study of Correlation of Residential and Industrial Growth Pattern in Semarang City to the Aquifer Capacity Changes in the Year 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), deep aquifer capacity (DAC) and (LS). Observation of changes in SAC in this study was observed in the type of shallow aquifer using shallow wells (SA) data. For the growth of the residential area of Semarang will be focused on the land cover of residential and industrial areas in the 2014-2017 period. The overlapping method is used to correlate the effect of changes in shallow and deep aquifer capacity in Semarang City. The results of this study get the correlation value of changes in shallow aquifer depth and settlement has a very high correlation from 2014 to 2018 with the percentage always above 50%. From 2014 to 2015 the correlation of shallow aquifer with settlements was 73.78%, from 2015 to 2016 86.88%, from 2016 to 2017 53.69% and in 2017 to 2018 61.54%. The level of correlation of changes in the depth of the deep aquifer level with the industrial area has a low correlation with a large correlation coefficient of only 0.02322. For the direction of the growth of residential areas and industries have a positive correlation with the capacity of the deep and shallow aquifers where the direction of growth of the region follows the pattern extending along the main roads in the city of Semarang.

Keywords: Deep Aquifer, Land Subsidence, Semarang City, Shallow Aquifer

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 a big city.

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 aquifer 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. Land cover classification and interpolation data become one of the techniques in this research technique. This study examines the direction of development of an area with data on the use of clean water, in this case using groundwater. The city of Semarang is the area to be studied by the author, with a time span from 2014 to 2018. In this research use correlation method, and GIS to analyze the correlation on the pattern of aquifer capacity change to the decrease of ground level. For processing, the spatial analysis uses a multi-temporal Landsat imagery. Landsat imagery to find out the number of land cover changes in the Semarang area. This study aims to analyze the impact of the residential and industrial area in changes in the shallow and deep aquifer capacity in Semarang City.

2. Materials 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 shown in **Figure 1**.

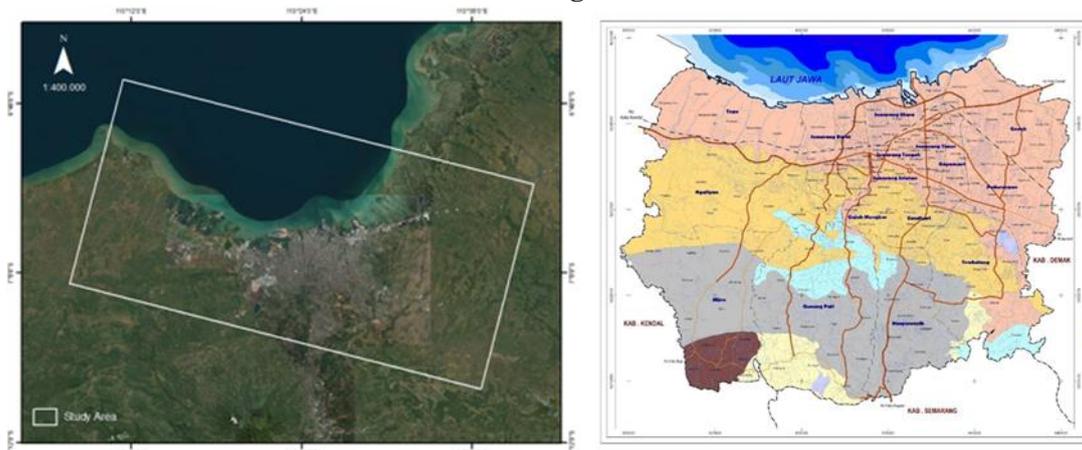


Figure 1. Research Area (Semarang City) [5]

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 [2]. 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. Materials

In this paper using primary and secondary data as follows:

Table 1. Research Data

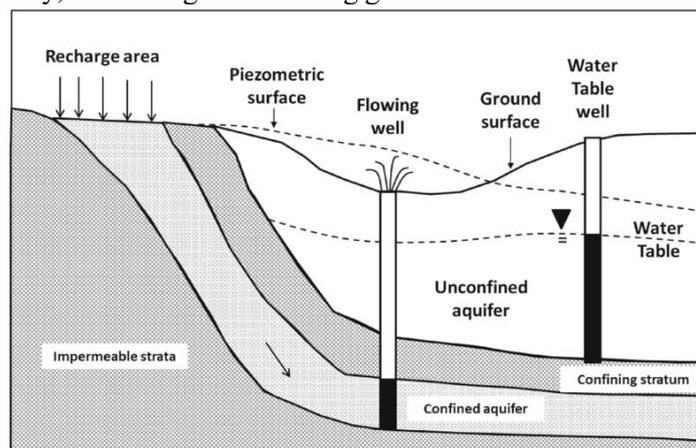
NO	Data	Data Source	Type Of Data
1	Landsat Satellite Imagery of Semarang City	Download data on https://glovis.usgs.gov/	2014-2018
2	Aquifer Data of Semarang City	Dinas ESDM Office of Semarang City	2014-2018
3	Residential Population Data of Semarang City	BPS Office of Semarang City	2014-2018
4	Administrative Vector Data of Semarang City	Bappeda of Semarang City and BIG	2011
5	Aquifer and Geology Map of Semarang, Demak and Ungaran Area	Dinas ESDM Office of Semarang City	2018

2.3. Methods

2.3.1. Definition of Aquifer Zone

In past research [6], 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 2** 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.

**Figure 2.** Vertical Layout of Unconfined and Confined Aquifers [3]

2.3.2. City Growth Pattern.

The development and growth of the city is essentially a product of population dynamics caused by, among others, population growth, activity development, and socio-cultural changes. Variations in the three things in each part of the city will cause the phenomenon of development to differ from one part of the city to the whole which will form a distinctive city structure. Empirical studies of urban geography, especially the city structure have been expressed by several experts, both geographers, and non-geographers. The types of growth patterns of a city are as follows: Concentric, Linear, and Step/jump [5] can be seen in **Figure 3**.

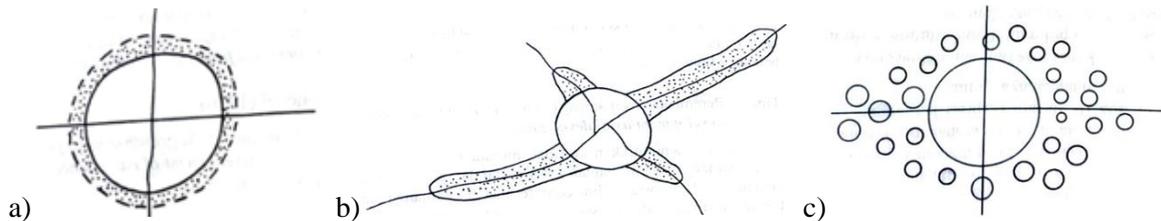


Figure 3. a) Concentric b) Linear c) Step/Jump Pattern

2.3.3. Correlation Concept

The last research [4] revealed that correlation is an analytical technique included in one of the associations/measures measurement techniques. Among the many association measurement techniques, there are two correlation techniques that are very popular until now, namely the Pearson Product Moment Correlation and Spearman Rank Correlation. Correlation is useful for measuring the strength of the relationship between two variables (sometimes more than two variables) with certain scales, for example, Pearson data must be interval or ratio scale; Spearman uses an ordinal scale. The weak strength of the relationship is measured using a range of 0 to 1. Correlation has the possibility of testing a two-way hypothesis (two-tailed).

Correlation is unidirectional if the value of the correlation coefficient is positive, on the contrary, if the coefficient is negative, the correlation is called unidirectional. The definition of the correlation coefficient is a measurement of statistical covariation or association between two variables. If the correlation coefficient is found not equal to zero (0), then there is a relationship between the two variables. If the correlation coefficient is found to be +1, then the relationship is called a perfect correlation or perfect linear relationship with a positive slope. Conversely, if the correlation coefficient is found to be -1, then the relationship is called perfect correlation or a perfect linear relationship with a negative slope.

3. Results and Discussion

3.1. Urban Development Growth Pattern Analysis

The pattern of urban development analyzed is the 3 growth pattern of the city [5]. Analysis of the pattern of development of Semarang City is done by visual interpretation of image classification data. The pattern of the development of the city of Semarang seen from the building and industry classification results.

Semarang city is included in a linear pattern. This is because the development of Semarang City which is seen from the aspect of settlement and industry does not spread evenly. The results of the image classification show the development of the settlement and industry of Semarang City following the transportation path, this is in accordance with the elongated pattern theory proposed [5]. The growth of the city pattern elongated (linear pattern) experienced the fastest growth along the route of the transportation route. The area along the main transportation route is the most severe pressure from development. the description for the longitudinal pattern can be seen in Figure II-17 while for the pattern of the development of Semarang City in **Figure 4** and **Table 2**.

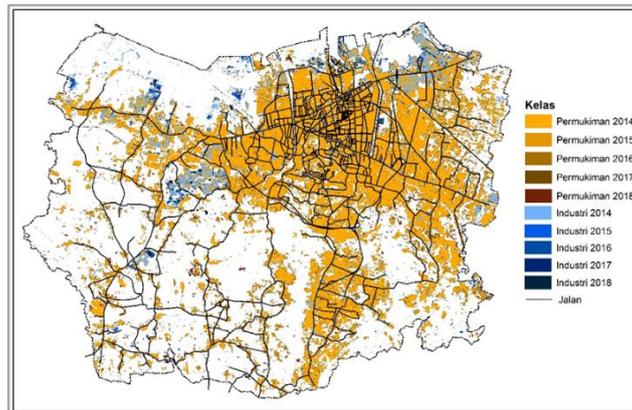


Figure 4. Development Pattern of Semarang City

Table 2. Changes in Land Cover Area.

CLASS	AREA (Ha)				
	2014	2015	2016	2017	2018
Residential	9.700,270	9.937,789	11.976,895	11.955,674	12.087,924
Industry	915,456	1.325,781	1.523,117	935,900	1.487,093
Non Residential, Non Industry	28.470,149	27.822,306	25.585,864	26.194,303	25.510,859

The table shows the area of Landsat images classification results from 2014 to 2018. For residential areas always increase in terms of area, while industrial areas experience an increase and decrease pattern.

3.2. Shallow Aquifer Capacity and Settlement Areas Correlation Analysis

Estimates of changes in the shallow aquifer in Semarang City are carried out by using observations of digging wells in Semarang City. Available observation data are 2016 and 2018 so that for large changes in shallow aquifer depth is the same. This is because changes in depth are sought by the interval system of available data.

For the classification requirements, changes in shallow aquifer capacity indicate large areas that experience shallow aquifer subsidence. If the shallow aquifer level is lower than 25%, the difference between the highest and the lowest decreases is the lower classification. Likewise for moderate, high and very high classifications. The most common aquifer subsidence is in the low classification with an area of 33,487,235 Ha or about 85.68% of the total where more details can be seen in **Figure 5 (A)**.

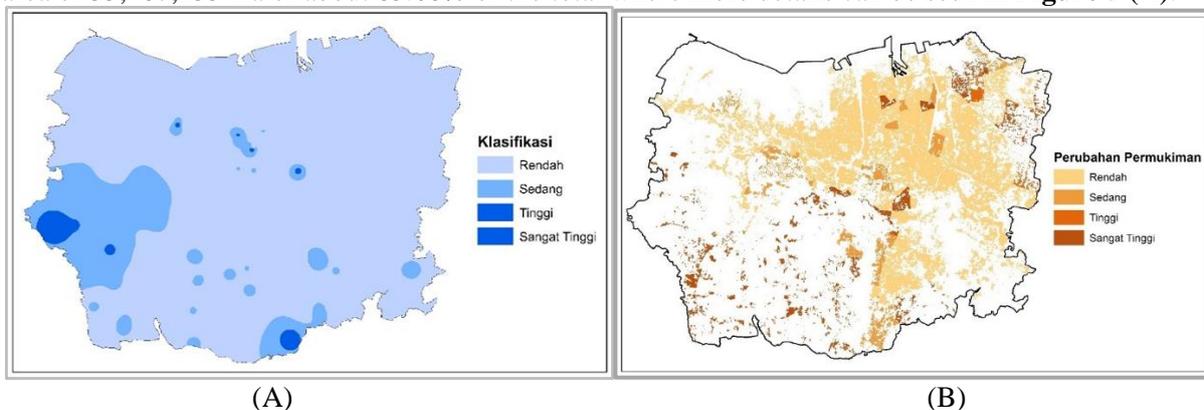


Figure 5. A) Classification of Shallow Aquifer Capacity (SAC) Changes in 2014-2018 B). Classification of Settlement Density from 2014 to 2018

In addition to shallow groundwater subsidence, changes in settlement density are also classified into four classes, namely changes in low, medium, high and very high as shown in **Figure 5 (B)**. It can be seen from **Figure 6** that most of the shallow aquifer depth changes are highly correlated with settlement density.

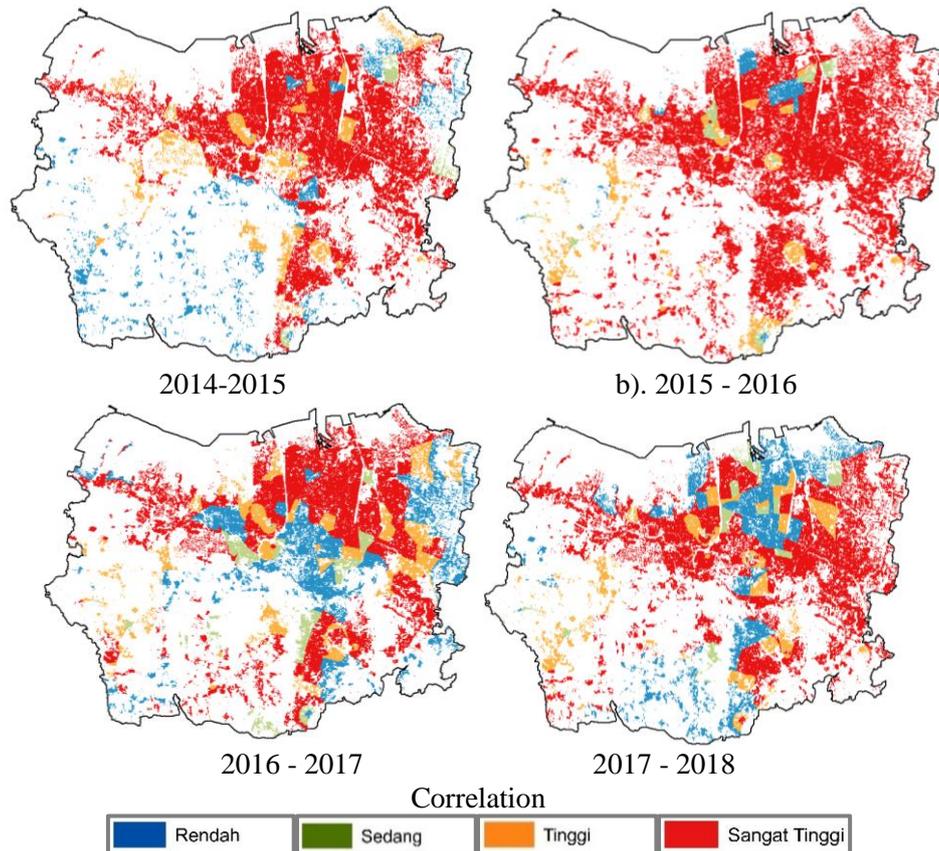


Figure 6. Correlation of Changes in SAC Depth with Settlement Density

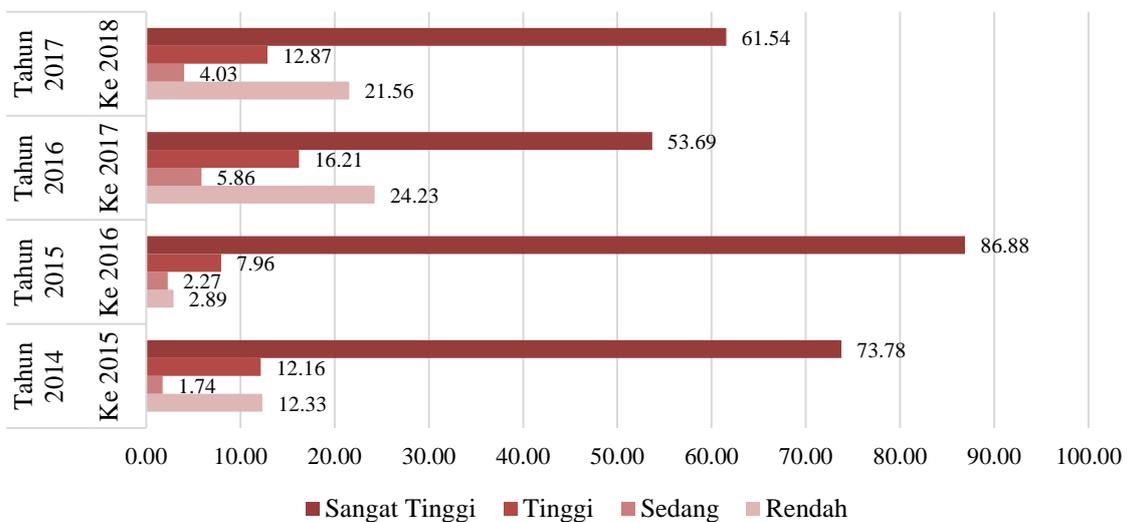


Figure 7. Percentage of Correlation Rate

Percentage of correlation level of shallow groundwater depth decrease with Semarang City settlement density can be seen in brief in the diagram in **Figure 7**. From the picture, it can be seen that the level of correlation is very high always with a very high percentage in the five years of research, namely 2014 to 2018.

3.3. Deep Aquifer Capacity and Settlement Areas Correlation Analysis

Groundwater level processing in Semarang City uses data of monitoring wells spread over seven points can be seen in **Figure 8**. These points are located in the Semarang Demak (groundwater basin/CAT), so the interpolation is done only on the Semarang Demak CAT boundary.

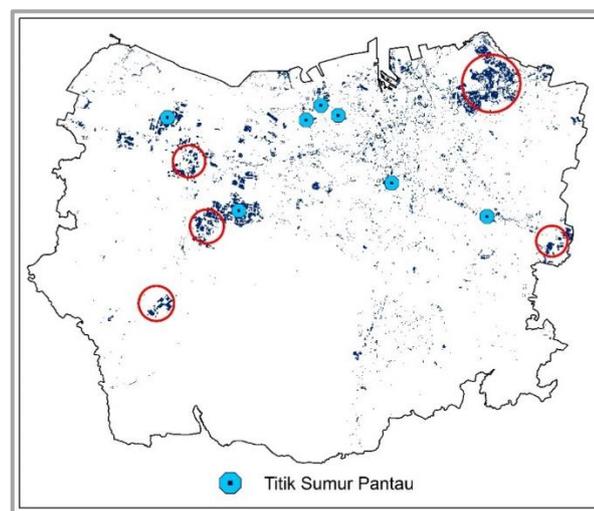


Figure 8. Monitoring Well Points Position

The results of deep aquifer interpolation can be seen in Figure 3. Figure 3 is the result of interpolation for 2014, where the highest groundwater value is -4.249 m and the lowest is -35.166 m. The direction of distribution in this study uses the Standard Deviational Ellipse method for the results of interpolation of the depth of deep groundwater and industrial areas, as seen in Figure 3. Ellipse of elongated groundwater shows a decrease in deep aquifer level that extends to the southeast while the industrial ellipse is more evenly distributed and the direction of growth is inclined towards the east.

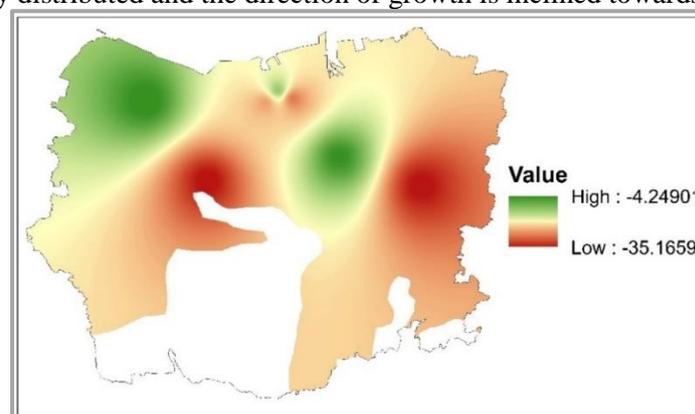


Figure 9. Deep Aquifer Interpolation Data

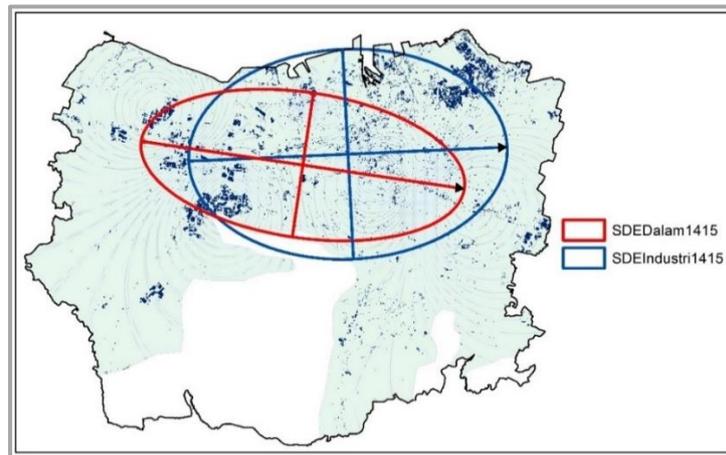


Figure 10. Standard Deviational Ellipse Direction of Deep Aquifer and Industrial Area Correlation

The correlation coefficient of the direction of rotation of SDE groundwater with industry is 0.023. The correlation value shows that both variables have a very weak positive correlation.

4. Conclusion

Based on the research that has been done, it can be concluded as follows:

1. The development of Semarang City follows a linear pattern. The pattern of development is seen from the growth of residential and industrial areas. The longitudinal pattern follows the transportation path and experiences the fastest growth along the transportation route.
2. The shallow groundwater depth has the lowest decrease of -0,011 m and the highest is -3,675 m. Changes in groundwater from 2014 to 2018 each year are the same because the data processed in this study are only from two years of observation. Deep groundwater depth is obtained from seven observation stations with the lowest aquifer level of -37.054 m and the highest -1.618 m.
3. The results of the correlation of changes in shallow aquifer capacity and settlement have a very high correlation from 2014 to 2018 with the percentage always above 50%. From 2014 to 2015 the correlation of shallow aquifer with settlements was 73.78%, from 2015 to 2016 86.88%, from 2016 to 2017 53.69% and in 2017 to 2018 61.54%. The level of correlation between changes in the depth of the groundwater level with the industrial area has a low correlation with the magnitude of the correlation coefficient of 0.023.

5. Acknowledgments

The authors would like to thank the reviewers for their valuable comments. The authors would also like to thank all of researcher and student at Remote Sensing and Photogrammetry Laboratory, Geodesy Engineering Dept-Diponegoro University for a hard work on data processing and discussion. And also, all staff and researcher in Dinas ESDM, BPS, and BIG for an aquifer and attribute data support in this research.

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