Determination of The Water Catchment Area in Semarang City Using a Combination of Object Based Image Analysis (OBIA) Classification, InSAR and Geographic Information System (GIS) Methods Based On a High-Resolution SPOT 6 Image and Radar Imagery

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Abstract. Semarang is the biggest city in central Java-Indonesia which has a rapid and massive infrastructure development nowadays. In order to control water resources and flood, the local goverment has been built east and west flood canal in Kaligarang and West Semarang River. One of main problem in Semarang city is the lack of fresh water in dry season because ground water is not rechargeable well. Rechargeable groundwater ability depends on underground water recharge rate and catchment area condition. The objective of the study is to determine condition and classification of water catchment area in Semarang city. The catchment area conditions will be determine by five parameters as follows soil type, land use, slope, ground water potential and rainfall intensity. In this study, we use three methods approach to solve the problem which is segmentation classification to acquire land use classification from high resolution imagery using nearest neighborhood algorithm, Interferometric Synthetic Aperture Radar (SAR) to derive DTM from SAR Imagery and multi criteria weighting and spatial analysis using GIS method. There are three types optical image (ALOS PRISM, SPOT-6 and ALOS PALSAR) to calculate water catchment area condition in Semarang city. For final result, this research will divide the water catchment into six criteria as follows good, naturally normal, early critical, a little bit critical, critical and very critical condition. The result shows that water catchment area condition is in an early critical condition around 2607,523 Ha (33,17 %), naturally normal condition around 1507,674 Ha (19,18 %), a little bit critical condition around 1452,931 Ha (18,48 %), good with 1157,04 Ha (14,72 %), critical with 1058,639 Ha (13,47 %) and very critical with 75,0387 Ha (0,95 %). The distribution of water catchment area conditions in West and East Flood Canal have an irreguler pattern. In northern area of watershed consists of begin to critical, naturally normal and good condition. Meanwhile in southern area of watershed consists of a little bit critical, critical and very critical condition.

Keywords : Flood; GIS; InSAR; Segmentation Classification; Water Catchment Area.

1. Introduction

Water is an essential requirement for human survival. The overall amount of water on Earth at least 1.3 million km3 and is considered inexhaustible and can last up to millions of years in the future [14].

Apart from that, the presence of water is determined by the carrying capacity of nature is less to meet human needs. This is due to population growth continues to increase, while the amount of water tend to

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be dynamic so as to increase the consumption of water will cause the water to become rarely. Lack of water affects all aspects, such as environmental, social, economic and politic.With the facts that occurred as above required a move to reduce the impact of risk on a less optimal watershed management. One problem solving that can be used is to determine the appropriate water catchment areas and to know distribution pattern. Methods of remote sensing and geographic information systems can be used as an approach step to determine the water catchment areas Ana distribution patterns. In remote sensing image processing performed by unsupervised classification methods and Object Based Image Analysis (OBIA) to obtain land cover maps of watershed areas (DAS) and extraction of DTM (Digital Terrain Model) of the image to get a digital elevation model and lop map in the watershed areas. While in data processing-based geographic information system using the overlay method and the weighting of the input data to determine the determination of water catchment areas and the spreading pattern.

2. Study area, data and methods

2.1. Description of the study area

Research area lied in the city of Semarang-Central Java Province with the geographical location between 6 ° 50 '- 7 ° 10' south latitude and 109 ° 35 '- 110 ° 50 east longitude with an area of 373.70 km^2 with a boundary to the north is the Java Sea, south boundary is Semarang regency, east boundary is Demak, and west boundary is Kendal.

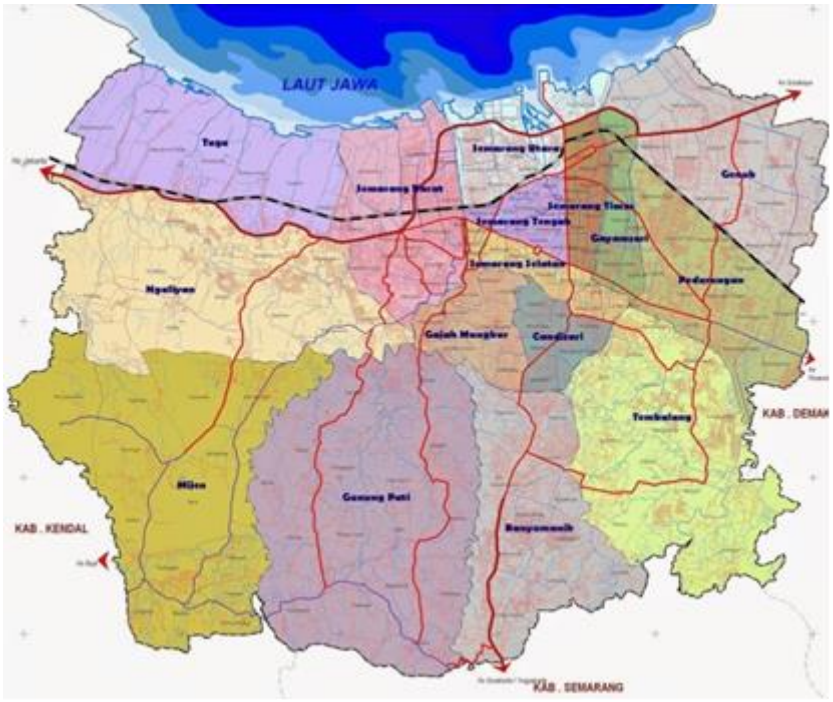

Figure 2.1. Research Area [4]

2.2. Research Data

In this study used several research data more clearly be seen in the Table 2.1.

Table 2.1.Research Data

No.	Data	Data Source	Year
1	ALOS PALSAR Image	LAPAN	2014
2	SPOT 6 Image	LAPAN	2012

3	GPS Survey and Observation Data	Field Surveying	2016
4	Land Use Map	SPOT Image OBIA Classification	2012
5	Slope and topographic Map	DTM extraction (ALOS PALSAR)	2014
6	Soil Type Map	BPDAS Pemali Jratun	2016
7	Underground Water Potential Data	Dinas ESDM	2016
8	Rainfall Intensity Data	Dinas PSDA	2016

2.3. Object Based Image Analysis (OBIA) Classification

Understanding of object-oriented classification technique which is essentially classify images based segments of the object segmentation into classes of land cover in accordance with the characteristics of the object [17].

More specific definition of the object based classification (Object-based Classification) or any other name Object Based Image Analysis (OBIA) [12] is the process of determining the object into a classroom where every object is regarded as an individual unit. By comparing objects with one another makes it possible to combine groups of similar objects into classes of concern for users. These classes form a region on the image after image classification that can be identified by color or symbol as seen in Fig 2.2.

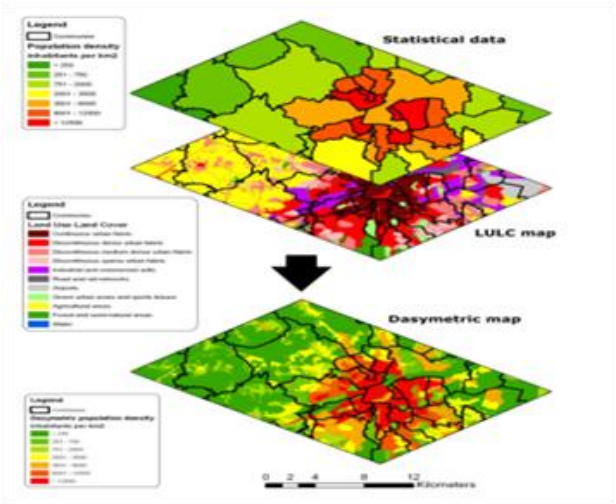

Figure 2.2. Object Based Image Analysis (OBIA) Classification [22]

Image segmentation is an initial step in image classification with object-based method. Image segmentation is used to classify the pixels that have the same structure, with the aim of making each individual structure into regions or individual regions [15]. Segmentation methods are generally categorized into two groups: technical edge-based and region-based. Multiresolution segmentation [3] is one of the region based segmentation algorithm most formidable that has been implemented in commercial software eCognition. In the software eCognition, segmentation is a semi-automated process in which the user can specify certain parameters that affect the size and shape of the segments generated imagery [10] as seen in Fig 2.3.

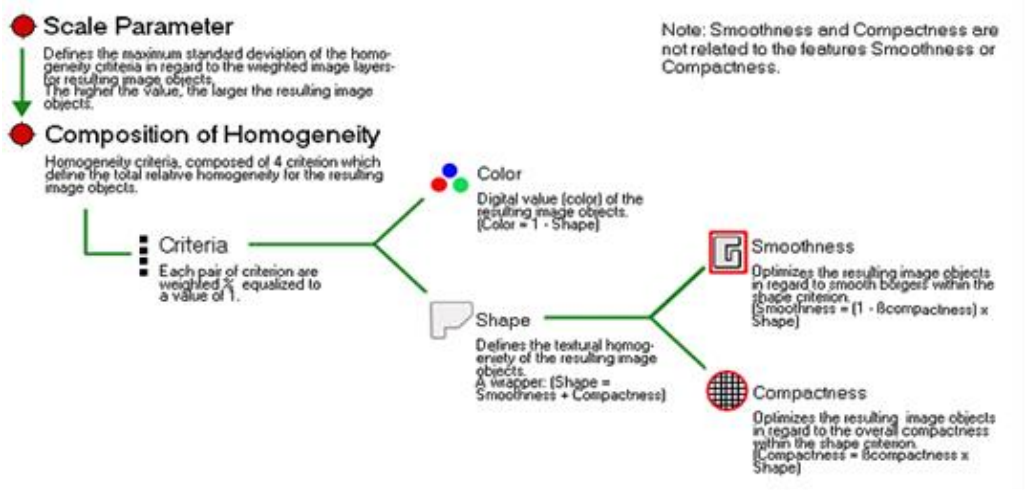

Figure 2.3. Segmentation Parameter Flowchart [6]

2.4. Water Catchment Area Modelling

Value weighting parameter based on the absorption of water in the Ministry of Forestry Regulation Republic of Indonesia No. 32 of 2009 on Procedures for Planning of Forest and Land Rehabilitation Engineering Watershed (RTkRLH-DAS).

The parameters include soil type, land use, slope and rainfall. Value weighting parameter water infiltration and water infiltration conditions classification criteria can be seen in Table 2.1-II.2.

Table 2.2. Water Catchment Value **Weighting**

No.	Parameter	Value Weighting
1	Soil Type	5
2	Land Use	4
3	Slope	3
4	Underground Water Potential	2
5	Rainfall Potential	1

Table 2.3. Water Cactchment Condition Criteria

No.	Total Score	Condition Criteria
1	>50	Good
2	44-50	Naturally Normal
3	38-44	Start Critical
4	33-38	Rather Critical
5	27-33	Critical
6	<27	Very Critical

For the implementation of the model of the catchment is done in accordance with the flow chart of research. In general, this study is divided into three main methods, namely the formation process map INSAR slope method, the model building process within the catchment using methods OBIA and GIS and field validation process. For field validation process is done by taking a sample of 40 points that represent each land cover classes.

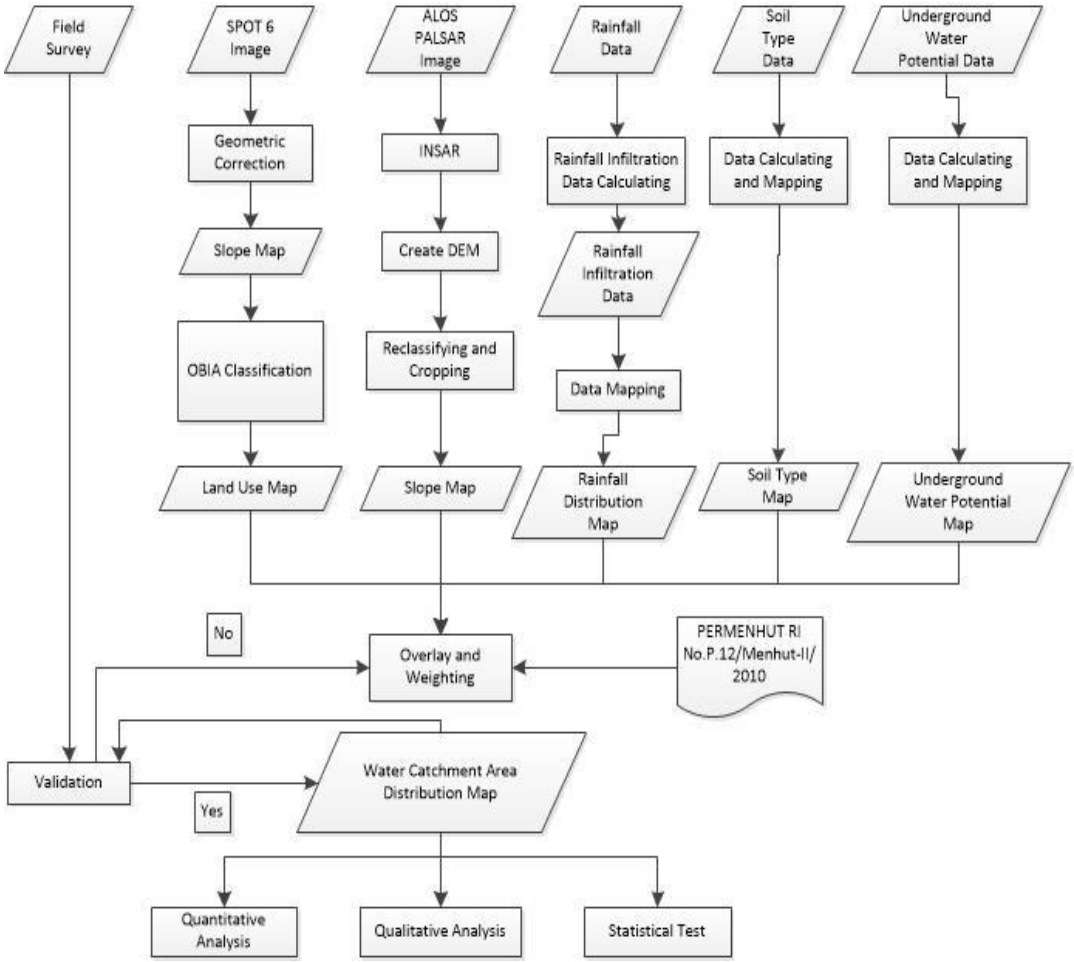

Figure 2.2. Research Methodology Flowchart

3. Results

3.1. Results and Land Use Classification Based OBIA Method

The results of the SPOT image segmentation using a multiresolution segmentation method produces an 1223 object segments for level 3, 5486 object segments for level 2, and 43170 object segments for level 1.

Fig 3.1 shows the segments are objects on SPOT imagery at level 1 is used for classification the image of the object based on the city of Semarang. Land use in the area of Semarang City neighborhood dominated by vegetation such as forests, parks and estates with an area of 17718.587 ha (45.47%), undeveloped land area as residential and industrial area of 14229.481 ha (36.52%), burden land area of 5128.4187 ha (13.16%) and water bodies such as rivers and reservoirs covering an area of 1888.5926 ha (4.85%). It can see in Fig 3.2.

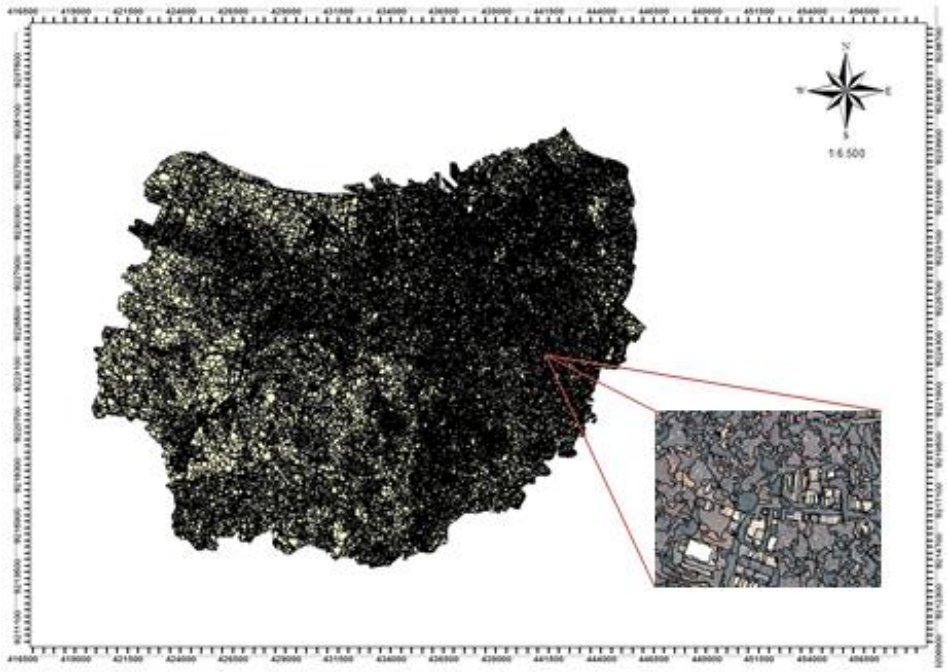

Figure 3.1. SPOT 6 Multiresolution OBIA Segmentation

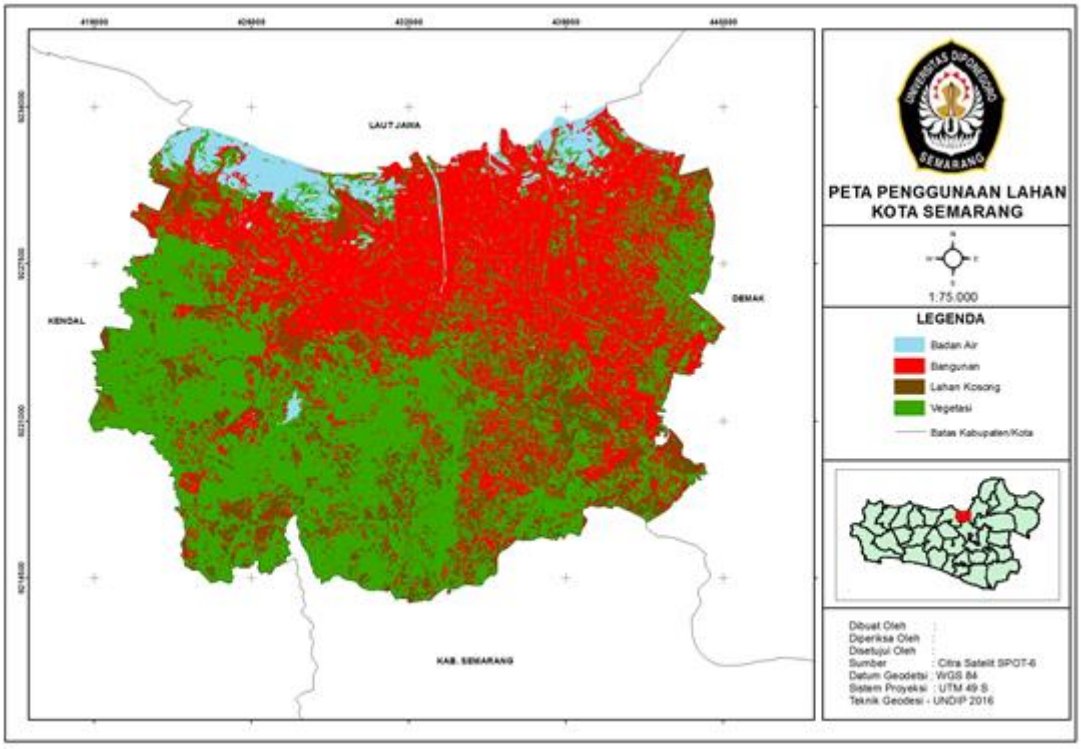

Figure 3.2. Land Use Classification Using OBIA Method in Semarang City

3.2. Soil Type Results and Analysis

Semarang city has largely alluvial soil types covering 13,992.54 ha (35.91%), alluvial soils are young soils derived from precipitation.

It is generally fertile because it contains minerals. Spreading in river valleys and coastal plains that are sensitive to erosion. The next city in the domination of land with an area of 10,880.63 ha mediteran (27.92%), and latosol land with an area of 9647.076 ha (24.75%). Mediteran soil has the same physiographic soil physiographic latosol is to indicate that the volcanic landscape is influenced by volcanic activity. The second composition of this land has undergone further weathering of rocks composed of volcanic breccia, lavas, tuffs which also affect how quickly the water infiltration rate. The las type is an area of land regosol 2619.186 ha (6.72%) and grumusol land with an area of 1825.647 ha (4.68%).

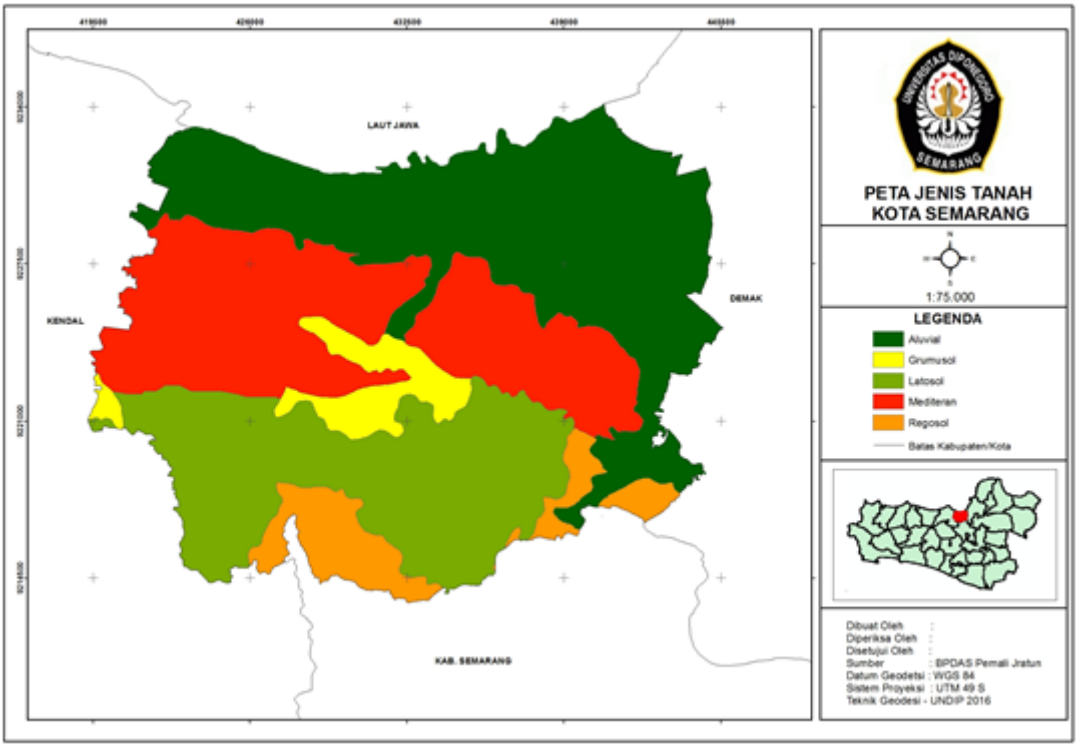

Figure 3.3. Soil Type Map in Semarang City

3.3. Slope Results and Analysis

Topographical conditions in Semarang mostly flat with an area of 28,296.38 ha (72.62%) of the total area of 38,965.079 ha.

The rest is filled by a sloping topography with an area of 6877.422 ha (17.65%), bumpy area of 2811.489 ha (7.21%), rather steep area of 790.243 ha (2.02%) and steep area of 189.546 ha (0.48%). Semarang city northern part has a flat topography. While the central and southern parts in addition to having a flat and hilly topography, as well undulating to steep. Rather steep undulating topography and can be found in the area Candisari, Banyumanik, and Tembalang, while the steep topography are found in Sub Gunungpati and Banyumanik southern part which is a mountainous area. Size slope of each class can be seen in Fig 3.4.

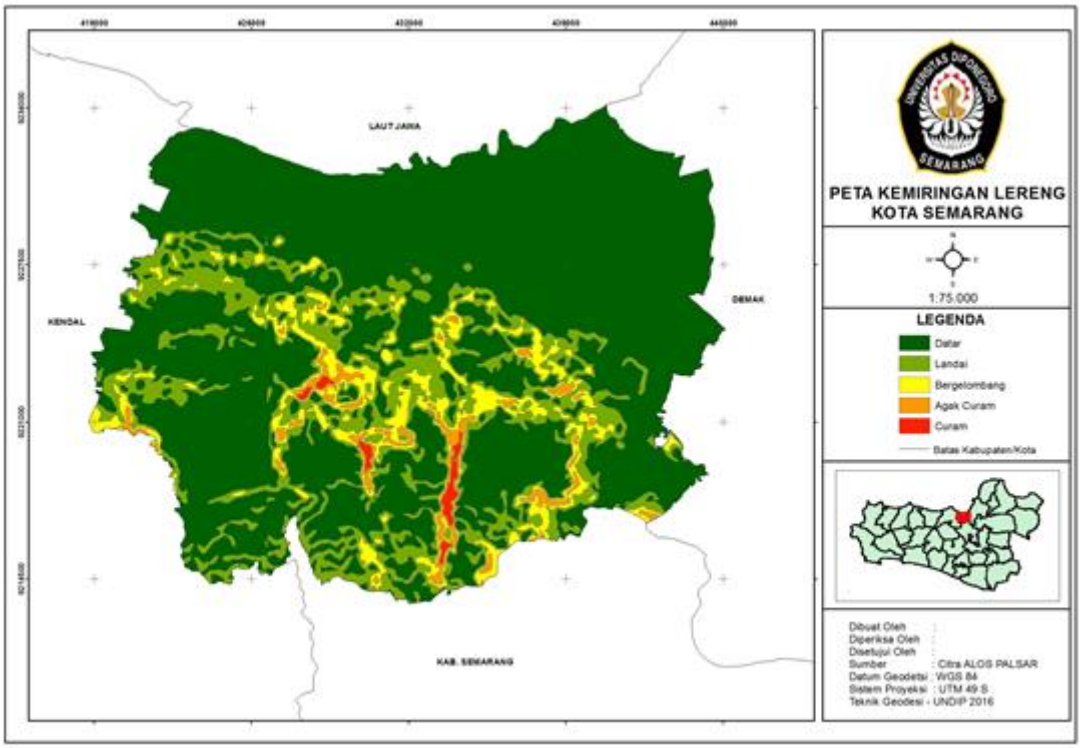

Figure 3.4. Slope Map in Semarang City

3.4. Underground Water Potential Results and Analysis

Whether or not a water catchment area depends on several factors such as soil type, land use, land slope (topography), the potential for ground water and rainfall.

The fifth parameter can not be separated from one another in analyzing a particular area of water infiltration. Based on the fifth parameter calculations results obtained catchment area condition, as shown in Table 3.1 and Figure 3.5, while in each of the districts in the city of Semarang in Table 3.8 and Figure 3.6.

Table 3.1. Water Infiltration Condition Percentage and Area Width

Water Infiltration Status	Width (ha)	Percentage (%)
Good	5633,603	14,46
Naturally Normal	8563,482	21,98
Start Critical	14367,776	36,88
Rather Critical	6852,834	17,59
Critical	3038,975	7,80
Very Critical	499,415	1,28
Total	38956,08	100

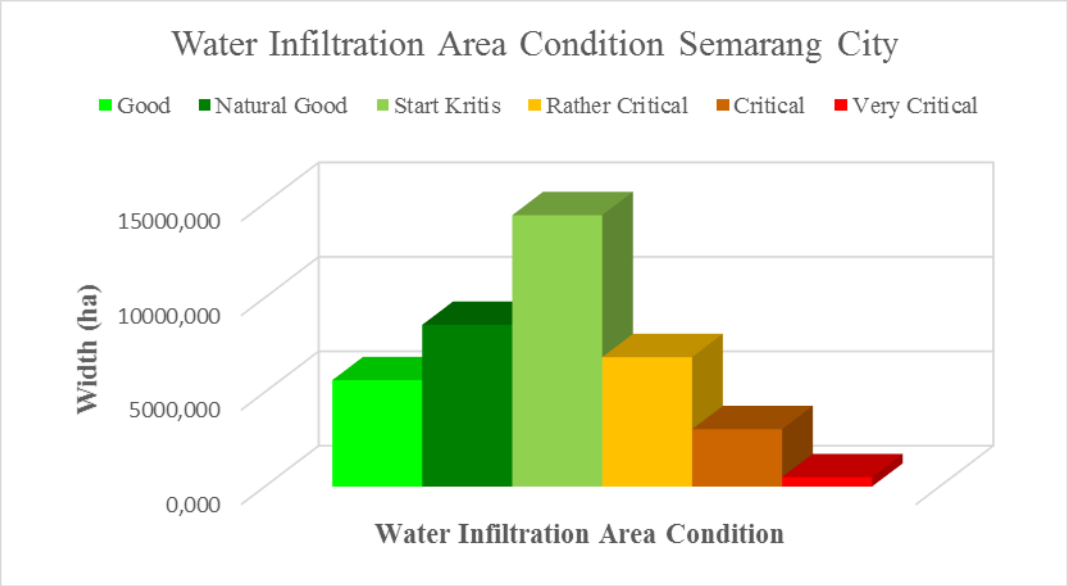

Figure 3.5. Water Infiltration Area Condition in Semarang City

Table 3.2. Sebaran Kondisi Kawasan Resapan Air Kota Semarang

No.	District	Condition (ha)						Total
		Good	Naturally Normal	Start Critical	Rather Critical	Critical	Very Critical	
1	Banyumanik	222,360	1237,971	715,684	719,079	146,312	13,594	3055,001
2	Candisari	0,232	55,090	208,919	175,880	245,479	16,658	702,258
3	Gajahmungkur	2,882	116,239	338,954	252,945	243,052	8,352	962,425
4	Gayamsari	129,157	5,657	456,522	24,623	0,000	0,000	615,959
5	Genuk	920,629	209,319	1316,282	339,716	0,000	0,000	2785,946
6	Gunungpati	1371,391	2234,334	943,256	932,668	426,207	169,091	6076,946
7	Kaliwungu	268,891	2918,874	1768,958	594,648	242,023	89,166	5882,561
8	Ngaliyan	13,212	278,022	1976,121	920,477	1045,902	169,044	4402,778
9	Pedurungan	722,726	163,595	1428,753	3,181	2,128	0,000	2320,383
10	Semarang Barat	230,843	93,318	1201,837	511,552	190,259	0,092	2227,902
11	Semarang Selatan	46,202	52,186	226,259	290,172	4,553	0,000	619,372
12	Semarang Tengah	49,184	3,238	475,189	10,840	0,104	0,000	538,554
13	Semarang Timur	72,377	0,846	463,597	24,190	0,000	0,000	561,010
14	Semarang Utara	85,636	19,665	954,746	160,539	0,000	0,000	1220,586
15	Tembalang	865,574	930,524	1050,743	793,769	313,319	28,985	3982,913
16	Tugu	632,306	244,604	841,957	1098,553	179,636	4,434	3001,490
Total		5633,603	8563,482	14367,776	6852,834	3038,975	499,415	38956,08

Based on the data above, the condition of water catchment area in Semarang mostly in critical condition with extensive start 14367.776 ha (36.88%), a natural normal condition with extensive 8563.482 ha (21.98%), good condition an area of 5633.603 ha (14.46%), the condition rather critical area of 6852.834 ha (17.59%), critical conditions measuring 3038.975 ha (7.8%) and the condition is very critical area of 499.415 ha (1, 28%).

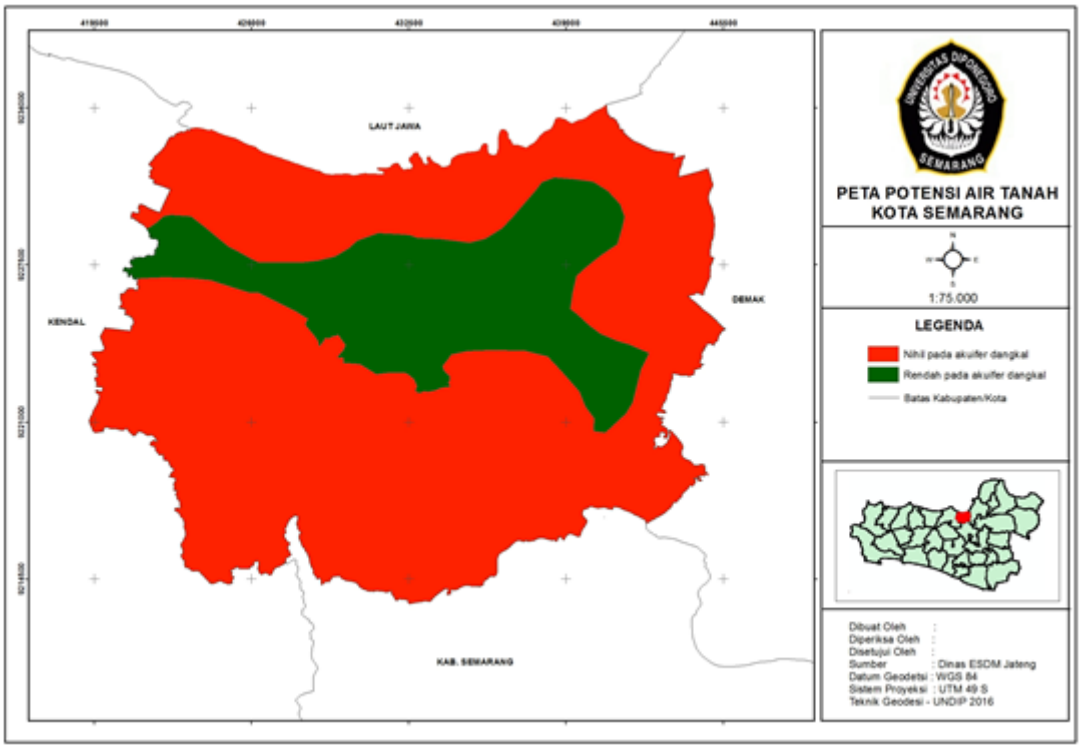

Figure 3.6. Underground Water Potential in Semarang City

4. Discussion and summary

In this study, the condition of water cacthment area in Semarang unfavorable. This is because the vast amount of water absorption good condition and normal to experience only 14197.085 ha (36%) of the total area of Semarang city.

While the condition critical to very critical start reaching 24759 ha (64%). Areas that could potentially be a water catchment area of Semarang is Gunungpati and Kaliwungu subdistrict. Gunungpati District has a good conditions water catchment area around 1371.391 ha and natural normal area of 2234.334 hectares, while the Kaliwungu District has good water catchment area around 268.891 ha and natural normal area of 2918.874 ha. From the total amount of water absorption good and natural normal condition in Semarang, a total of 6793.490 ha (47.9%) were in two districts. Gunungpati area and Kaliwungu have the same soil water potential, which has good quality water to a depth of 1-20 mbpt shallow aquifer. The depth of the groundwater table 1-15 mbpt, transmissivity coefficient of water 5 to 13.5 m^2/ day, the discharge of water from 0.03 to 0.13 liters / sec / m, and the optimum discharge from 0.2 to 1 ltr / sec. Based on this study, the estimated volume of ground water with good water infiltration condition and a value of transmissivity (T) of at least 5 m2 / day covering an area around 5633.603 ha was 102.8 trillion ltr / yr. The value of transmissivity (T) a maximum of 13.5 m^2 / day was 277.5 trillion liters / year. While the condition of water catchment areas with natural normal criteria is a minimum area of 8563.482 ha 156.3 trillion liters/year and a maximum of 421.9 trillion liters/year. The total volume of groundwater minimum and maximum can be seen in Figure 4.1.

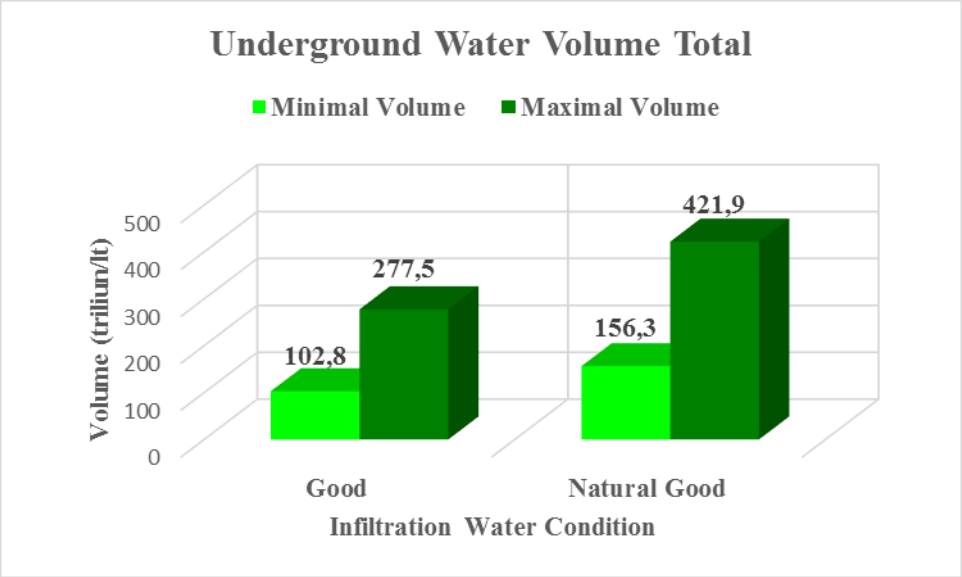

Figure 4.1 Total volume of Groundwater on Water Infiltration Condition Good and Normal Natural

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