Identification of groundwater potential zones in the Southern Mountains, Yogyakarta Special Region

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Abstract. Southern Mountains, Yogyakarta Special Region is a zone that extends from the south-eastern part of Yogyakarta Special Region to the east along the southern coast of East Java. From the hydrogeological map, it is known that the area is an area of scarce groundwater. This study aims to determine the potential for groundwater in these areas. The identification of groundwater potential is carried out using the Groundwater Potentiality Index (GPI) method by referring to 5 determining parameters: lineaments, lithology, drainage, topography, and rainfall. Lineament, drainage, and topography data were obtained from the Indonesia Geospatial Portal and the Digital Elevation Model (DEM) belonging to the Indonesian Geospatial Information Agency. The lithological data is obtained from data from the Geological Survey Centre, Geological Agency, Ministry of Energy, and Mineral Resources in the form of Geological Maps of Remote Sensing Image Interpretation Results. Rainfall data were obtained from reports from the Serayu Opak River Basin Office and the Public Works, Housing, and Energy Department of Mineral Resources Yogyakarta Special Region. The evaluation of parameters reveals that even in the scarce groundwater zones, estimation of area with possible of groundwater can be classified into five classes of groundwater potential index, namely: very low (<56.25), low (56.25-90), medium (90-123.75), high (123.75-157.5), and very high (> 157.5). In the next step of research the validation may be conducted on a high and very high GPI value whether their are really is associated with the presence of springs and wells. If it is correlated, future exploration of groundwater in this area will be focused and successful.

1. Introduction

Based on the hydrogeological map of Yogyakarta [1], Southern Mountains, Yogyakarta Special Region which includes the subdistricts of Dlingo, Imogiri, Piyungan, and Pleret (Bantul Regency), as well as Patuk, Gedangsari, Nglipar, and Ngawen (Gunungkidul District) are the area where groundwater is scarce and often reported drought every year. These condition occur relate to the lithology, of the Southern Mountains, Yogyakarta Special Region, which is dominated by sandstone, breccia, and tuff, with characterized to have very low permeability.

The purpose of this study is to determine the groundwater potential zone in this scarce groundwater area by using the GPI method. The GPI method used was adopted from Ettazarini (2007) which focuses on fractured aquifers or groundwater systems that are dominantly developed through fractures. Parameters used in this method include fracture/lineament, lithology, drainage, slope, and rainfall. The use of the GPI method has proven good results in researches located on the south-eastern of Bouregreg
and the Central Moroccan coastal basin, which are dominated by Paleozoic outcrops [2]. Application of this method by using GIS in Indonesia has been also reported by [3]. GIS application to delineate groundwater potential has also widely used such work from [4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14].

2. Research Area
The research area was located in the Southern Mountains region, Daerah Istimewa Yogyakarta, Indonesia. Administratively, the research area consisted of 8 sub-districts in 2 districts. The research area was limited to the rare groundwater zone. The research covered an area of 258.47 km² located at 110° 22'-110° 44' East Longitude and 7° 46'-7° 58' South Latitude. Geologically, the research area located in the Kebobutak formation, Nglipar formation, Nglanggran formation, and Semilir formation [15].

3. Methods
This study used the value of the Groundwater Potentiality Index (GPI) to determine the groundwater potential zone according to [2], see Table 1. This method used five parameters in determining GPI, namely, lineaments, lithology, topography, drainage, and rainfall.

The occurrence and presence of groundwater are believed to be influenced and highly dependent on those GPI factors. To get a thematic map that meet to the GPI criteria, a method is planned as Figure 2 below.
Table 1 Summarized charter adopted for the ground water potentiality index calculation [2]

| Parameters | Description and notation |
|------------|--------------------------|
| Fracturing | 8-10: interconnected major faults, kilometer long faults, shear zone |
|            | 4-7: local faults, frequent fracture plans interconnected and neared plans |
|            | 2-3: frequent diaclases, crack sand schistosity plans |
|            | 1: non fractured rock |
| Lithology  | 8-10: porous and fractured sandstone, fractured conglomerate, vacuolar basalts and dolerites |
|            | 7: alternation of fractured sandstone and micro-conglomerate |
|            | 6: fractured micro-conglomerate, basalt |
|            | 5: fractured sandy schist, fractured sandstone, fractured limestone |
|            | 4: compact sandstone, compact micro-conglomerate, fractured schistose sandstone, pelite and sandstone alternation, alternation of fractured schist and sandstone, fractured siltstone |
|            | 2-3: feebly fractured schist, weathered schist, schist and quartzite alternation, quartzite |
|            | 1: compact schist, compact granite, compact quartzite |
| Drainage   | 9-10: permanent waterway of order up to 6; |
|            | 8: waterway order (6); 7: waterway order (5); |
|            | 6: waterway order (4); 5: waterway order (3); |
|            | 1-4: uphill area, isolated ravine, temporary waterways, waterway order <3 |
| Topography | 10: slope <3; 9: slope 3-6; 8: slope 6-9; 7: slope 9-12; 6: slope 12-24; 5: slope |
| (slope%)   | 24-30; 4: slope 30-45; 3: slope 45-54; 2: slope 54-65; 1: slope >65 |
| Rainfall   | 10: >900; 9: 800-900; 8: 700-800; |
| (mm/year)  | 6-7: 500-700; 4-5: 300-500; |
|            | 3: 200-300; 2: 100-200; 1: <100 |

Figure 2. Flow chart of methods

4. Result and Discussion
Based on the lineament fracture parameters, major fault types were found in the form of shear fault structures in the southwest, northeast, and centre of the research area. Major faults given the notation 8-10 are located in the Dlingo, Imogiri, and Ngawen areas. Notation 4-7 in the form of local faults located
in the Patuk, Gedangsari, Nglipar areas, and in the form of a fault extending from Piyungan to Pleret. Furthermore, the majority of joints/fractures or massive rocks are found in each area as shown in Figure 2. There are 6 lithological groups in the research area, namely: Alluvium, Sambipitu formation, Nglanggran formation, Semilir formation, Kebo formation and Butak formation. Parameter notation in this area is classified in the notation between 2 – 7. The lithology parameter mapping is as shown in Figure 3. Rainfall data in the research area were obtained from data from 2008 to 2019. The highest rainfall was in the Patuk, Gedangsari, and Nglipar areas, ranging from 2000 – 2250 mm/year. Then, it can be seen in Figure 3.

The distribution of rainfall in the research area ranges from 1,250 to 2,250 mm indicating a humid tropic with the entire study area receiving more than 1,000 mm of rainfall annually. Areas with high rainfall have factors that indicate good groundwater potential. The map of each parameters shown in Figure 3(a-e).

Map of groundwater potential zones reveal by overlaying all the GPI factors in GIS. Based on the results of the research, the groundwater potential zone classification is set to low, medium low, medium high, and high. The groundwater potential zone map is presented also in Figure 3f.

Based on the Figure 3, the research revealed that 82.02% (211.98 km²) of the research area showed a zone of low groundwater potential. The zone of low groundwater potential was the largest index in the research area. The low/rare groundwater potential zone is characterized by the absence of a straight line, a slope of more than 20°, the lithology of the Kebobutak formation, the Semilir formation, the Nglanggran formation, and the Sambipitu formation, as well as higher distribution. The rock collection consists of sedimentary rocks such as tuff, claystone, and shale. Moreover, 0.8% (2.07 km²) of the research area is classified as having a zone of high to very high groundwater potential. While the zone of medium-high groundwater potential covers 4.35% (11.24 km²) of the research area. The existence of zones of medium high to high groundwater potential can be related to the presence of interconnected local faults, frequent faults, and long large faults; greywacke, alluvium and quarterly unconsolidated deposits, higher rainfall, gentle slope below 20°, and lower distribution of drainage. Although, the high possible area of groundwater resources can be revealed on this study, one should be bear in mind that an evaluation or validation of this result must be done based on the existing springs and successful existing deep wells. This validation will prove whether this GPI method applicable to be apply on this region or there are some correction shall be made. Nevertheless, this study at least can answer the objective of this research.
Figure 3. Thematic map of (a) Lineament, (b) Lithology (c) Slope, (d) Drainage, (e) Rainfall, and (f) Final GPI Map of the research area

5. Conclusion
On this study, GPI method is used to determine the location groundwater potential in the scarce groundwater region. The study reveals that the groundwater potential in the study area can be classified into four class: low, medium low, medium high, and very high groundwater potential covering 212 km$^2$ (82.02%), 33.16 km$^2$ (12.83%), 11, 24 km$^2$ (4.35%), and 2.07 km$^2$ (0.8%) of the study area, respectively. The zone of high groundwater potential is characterized by the presence of interconnected local faults, frequent faults, and long large faults; greywacke, alluvium and quarter unconsolidated deposits, higher rainfall, gentle slope below 20°. However, evaluation using spring discharge and drilled wells on this area should be conducted to prove the validity of the map. If it is correlated, this study map can serve as a guide for local governments and planners on favorable areas for prospective groundwater exploration.
The author would like to thank profusely to several government agencies in supporting in presenting the data and information needed. The author also would like to express gratitude to Aliakbar Hashaemi and Huda Nur Madani for supporting maps and assisting with GIS processing.