Application Of Remote Sensing Technology And GIS For Extraction Of Groundwater Potential Zone Parameters In Gesing Watershed, Purworejo

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Abstract. The increase in the number of residents and the long dry season is the cause of the increasing need for clean water in several areas in the Purworejo regency, one of which is the Gesing river basin area. Therefore, information is needed related to the potential of groundwater in the Gesing watershed, Purworejo district. This study has three objectives, namely: assessing the ability of remote sensing imagery (Sentinel 2A and TerraSAR-X) in extracting land parameters that affect groundwater potential, mapping groundwater potential zones using remote sensing data with geographic information systems in the Gesing watershed, and evaluating the results mapping groundwater potential zones to determine the most influential parameters on groundwater availability in the Gesing sub-watershed Purworejo district. The accuracy of the interpretation results is done by using the confusion matrix method. Spatial modeling uses a quantitative approach weighted with weighted parameters. The weight of each physic parameter is obtained from the Analytical Hierarchy Process (AHP) method. The results showed the accuracy of interpretation of lithology and land use respectively by 93% and 87%. The results of the mapping show that there are 4 classifications of groundwater potential in the Gesing sub-watershed, namely less, medium, good, and very good has and accuracy of 87%. The parameter which greatly influences groundwater potential in the Gesing sub-watershed with a weight value of 0.49 is the aquifer characteristic. While the parameter that has the least effect is drainage density which has a weight value of 0.05.

Keywords: Remote Sensing, Geography information system (GIS), Sentinel 2A, Analytical Hierarchy Process (AHP), Groundwater Potential Zone

1. Introduction

Water is a natural resource that is very important to support human life, both used for consumption, household and agricultural needs as well as industrial needs. The source of clean water that is needed is groundwater. Groundwater is water that is found in soil or rocks, which occupies rock crevices [8]. One of the increasing needs for groundwater is caused by the lack of clean water supply caused by climate influences, which is the occurrence of a long dry season which causes scarcity of clean water in various regions in Indonesia, one of which is the Gesing sub-watershed, Purworejo Regency. The need for clean water in various regions in Purworejo district has increased from year to year. According to the Head of Emergency and Logistics Division of BPBD Purworejo, in 2016 drought occurred in 50 villages, in 2018 drought and clean water disasters hit 56 villages in 11 sub-districts in Purworejo Regency, while in 2019 the drought and clean water disasters expanded to 68 One of the
villages in 16 sub-districts in the Purworejo district, one of which is the Kali Gesing sub-district, the Gesing sub-watershed area, Purworejo district.

Groundwater potential can be identified by using approaches or physical parameters that affect groundwater potential in an area. Parameter extraction that affects groundwater potential can be done by utilizing remote sensing data and Geographic Information System (GIS) technology [1]. Utilization of Sentinel 2A and DEM TerraSAR-X images is a new generation of remote sensing imagery that can be said to have not been used too much in research related to potential zones groundwater so it is necessary to do research related to this matter. Sentinel 2A image has a medium spatial resolution of 10 meters that can be used to extract various parameters determining the presence of groundwater. It is expected that in this study the ability of Sentinel 2A and DEM TerraSAR-X imagery to extract various parameters determining groundwater potential. This study also aims to map the groundwater potential zones by using the Analytical Hierarchy Process (AHP) method as a method of weighting each parameter that affects the potential distribution of groundwater. The results of the Analytical Hierarchy Process (AHP) method analysis are expected to evaluate the most influential parameters of groundwater potential in the Gesing watershed, Purworejo Regency.

2. Study and Dataset

2.1. Study Area
The research location for mapping groundwater potential zones is the Gesing sub-watershed which is a sub-watershed of 12 Bogowonto sub-watersheds administratively located in Kaligesing sub-district, Purworejo district, Central Java. Geographically location sub-watershed Gesing Located 39°04’12” – 40°45’56” E and 91°40’57”6.1 - 91°48’86”7.3 S with an area of ± 4500 hectares. The northern Gesing sub-watershed is bordered by the Mongo, Kodil, and Gading sub-watersheds, the east is bordered by the southern Kulonprogo. Regency bordered by the Ngasinan (Purworejo) sub-watershed and the Ngrancah watershed (Kulonprogo) and the west of the Gesing watershed is bordered by the Keduren sub-watershed.

2.2. Data Set
The data used in the study are TerraSAR-X imagery and Sentinel 2A imagery. Sentinel 2A imagery was launched in June 2015 by ESA (European Space Agency), this image is an image that includes the launch of 6 satellites by Copernicus. Sentinel 2A imagery have almost the same function as Landsat imagery used for thematic-based mapping related to spatial planning, ecosystems, and changes in the appearance of the earth. Sentinel 2A images have a 5-day temporal resolution which will record the same location every 5 days. Sentinel product level 2A is level 1C where the resulting image has been corrected geometrically and radiometrically (surface reflectance). Sentinel 2A imagery has 13 spectral channels consisting of visible, NIR, and SWIR channels. The following is a list of channels owned by Sentinel 2A imagery. Sentinel 2A data used in this study is the June 2019 recording image. The band used is a visible band with 432 composites (true color) which functions to identify visually objects for
3. Methodology

3.1. Parameter
Parameters used in the Landform physical parameters containing Lithology, Landform, land use, drainage density, soil texture, slope, and aquifer characteristics. Such parameters are extracted from Sentinel data and estimated TerraSAR-X imagery. TerraSAR-X imagery is used for obtaining parameter data that is Lithology, Landform, Drainage Density, and Slope. Lithology map and Landform were obtained from the visual interpretation TerraSAR imagery that will processed by using the interpretation key [9]. Drainage density obtained from processing using the streamline hydrology tools in arcGIS. Drainage density is obtained from the ratio between the length of the river and the area of Watershed. Slope obtained from slope tools in arcGIS.

Soil texture parameters obtained from the results of the field test by using the land unit map of 30 sample points. Soils samples are taken in the field then tasted for texture to determine the texture of the soil in the study area.

Map of land use obtained from the supervised Maximum Likelihood with Envi software. Aquifer characteristics were obtained from geo electricity measurement data taken by Dharmawan and Purnama in 2018 [2] in some rock formations in Purworejo district.

Each parameter map is classified and given a score in accordance with the effect of the potential of the land. The more big the effect of parameters is more score value. The score a parameter is obtained from the opinions of expert and related research.

3.2. Analytical Hierarchy Process (AHP)
Analytical Hierarchy Process (AHP) method is a method developed by Thomas L. Saaty [7] in the 70s that is used for making a decision by considering various perceptions, preferences, experience and intuition. In this study Analytical Hierarchy Process (AHP) is used to obtain the weight of the parameters. Based on the weight obtained can be seen the influence of each parameter on the availability of groundwater in study area.

According to [6] Analytical Hierarchy Process (AHP) weighting process consists of several stages, such as:

1. Arrange the Hierarchy Structure (determine the focus, criteria and sub criteria of each goal)
2. Compile the Comparison Matrix (pairwise comparison assessments of more than one expert opinion)
3. Calculating Weight Weights (Normalizing Weight)
4. Priority Weight Value (he weight of each parameter that will be used for decision making)
5. Test the Consistency of Hierarchy (Consistency assessment is carried out to determine whether the comparative evaluation criteria are consistent or not).

3.3. Overlay
Overlay is carried out on all physical parameters of the land that affect the groundwater potential. Groundwater potential assessment is carried out after all variables are given weighting and weighting, the determinant of groundwater potential zones is based on the total number of variables which is the sum and multiplication of weighting factors with each variable in accordance with the equation of the quantitative approach weighted in the equation 1 [4].

\[ P_k = (V1 \times B1) + (V2 \times B2) + \cdots + (Vn \times Bn) \]  \hspace{1cm} (1)

Explanation:
Pk = Total Weighth
V1 = Variable/ parameter 1
V2 = Variable/ parameter 2
Vn = Variable to n  
B1 = variable weights 1  
B2 = variable weights 2  
Bn = variable weights n  

4. Result and Discussion

4.1. Physical Parameters Of The Land  
4.1.1. Lithology

Based on Figure 2, there are 4 large formations in the study area, namely Andesite formation, Jonggarangan formation, Kebobutak formation and Alluvium formation. The Jonggarangan Formation is located in the middle and upstream part of the watershed while the Kebobutak Formation is a formation that dominates the upstream to the middle of the watershed. The Andesite Formation is a formation that dominates the upper reaches of the watershed. But besides that there is also an Alluvial layer that is found in the downstream part of the watershed. That is because the downstream part of the watershed is a part that has a slope which is low enough so that this part of the material is deposited from the rivers at the top. The two dominant formations are the Kebobutak formation with an area of 20.8 km². The Andesite Formation has an area of 12.5 km² in the study area. Jonggarangan Formation covering an area of 7.47 km², alluvial area of 7.4 km² and Dasit covering an area of 0.6 km². The map has an accuracy value of 93%.

![Figure 2. Lithology](image)

4.1.2. Landform

Based on the results of the interpretation in Figure 3 the upstream section has a denudational hills terrain eroded strongly to medium and a synclinal structural hill. The landform has a steep slope and is composed of resistant rocks resulting from different erosion and weathering processes. Denudational Landforms that have been eroded tend to have land cover in the form of vegetation which is quite rare so that falling rainwater causes the water to flow into the surface flow. Has an area of 4.9 km².

The Landform contained in the middle is structural mountainous blocks and structural synclinal hills with limestone sandstone, conglomerate and tuff rocks which have a sufficient level of compactness of rocks. The area of the structural mountains and the synclinal hills in the middle of the watershed is 18.8 km².
4.1.3. Soil Texture

Based on the results of the mapping in Figure 4 the upstream part of the watershed has clay soil to sandy clay. Soil with the texture of sandy loam is a combination of soil that is good enough to pass up to save water that enters the soil. Sand texture is a soil texture with a high level of porosity so it has a fairly large level of infiltration. In the upstream part of the texture of clay, sandy loam, sandy loam, and dusty clay each have an area of 9.27 km$^2$, 2.49 km$^2$ and 17.1 km$^2$.

In the middle of the watershed has a texture of sandy loam, gritty gritty, sandy loam, each of which has an area of 3.5 km$^2$ and 7.5 km$^2$. In the middle there is also the same sandy clay loam material as the material in the upstream which has the ability to store low water. In the downstream part of the watershed is the area where river materials are deposited. The material is sandy loam with an area of 8.9 km$^2$. Sandy clay has the ability to pass and store water better so that it has very good groundwater potential in the downstream.

4.1.4. Slope

The slope of the Gesing sub-watershed slope classification in figure 5. Can be identified that in the upper watershed the steep slope reaches 58-100% with an area of 12.5 km$^2$. In the middle part of the watershed, the slope is choppy to undulating with a slope ranging from 42-57% with an area of 12.1 km$^2$. In the downstream watershed area is dominated by the slope of the slope to flat with a slope ranging from 0-28% with an area of 11.9 km$^2$. 

![Figure 3. Landform](image)

![Figure 4. Soil Texture](image)
4.1.5. Drainage Density
Gesing sub-watershed drainage density from the upstream, middle and downstream ranges between 4-10 km² because most of the constituent rocks in the Gesing sub-watershed are resistant rocks which tend to have drainage density which tend to be tightly closed. The results of the classification of flow density in each sub-watershed section can be seen in Figure 6.

4.1.6. Land Use
Based on the results of calcifications in Figure 6, Gesing sub-watershed there are seven types of land use. Among them are high density forests, medium density forests, low density forests, shrubs, rice fields, settlements, and open land. High to medium density land use calcifications which cover almost 90% of the land in the area. So that the possibility of surface runoff is small so that the water will tend to be infiltrated compared to surface runoff. High to medium density forest cover is found in the upstream to middle of the watershed. That is because in this area is a conservation area. High and medium density forests have an area of 16.6 km² and 6.9 km², respectively.

In addition there is also land use in the form of medium density forest. Settlement areas that have little vegetation have very little infiltration. The medium density forest cover class has an area of around 6.5 km² in the watershed area which is spread from the upstream to the middle of the watershed.

The downstream part of the watershed is dominated by land cover in the form of open land, paddy fields, settlements each have an area of 1.5 km², 2.06 km² and 1.7 km². That is because in this area the slope ranges from sloping to flat so it is possible to be made into rice fields and the
construction of larger settlements. Land use in the form of settlements covered by buildings that are very resistant so that it makes it difficult for water to enter the ground. Besides that the use of land in the form of water-saturated field causes water to enter the soil is also less than other land uses. Based on confusion matrix processing, land use maps have an accuracy rate of 87%.

![Land Use Map](image1)

**Figure 7. Land Use**

4.1.7. Aquifer Characteristics

Based on the analysis of geo electric measurements based on the weighted average method in all resistivity prediction columns by Dharmawan [2] andesite formations have porosity of 38%, porosity of 0.8% and aquifer thickness of 6 meters. This formation has the lowest aquifer characteristics for groundwater potential. The porosity and permeability values are analyzed based on the material content contained in this layer. The Andesite formation at the study site has an area of 12.5 km².

Kebobutak formation has aquifer characteristics including porosity of 40%, permeability of 4 m/day and aquifer thickness of 18.5 meters. Based on the analysis results, this formation is a formation that has very good aquifer characteristics for groundwater potential with an area of 21.3 km².

Alluvial formation has aquifer characteristics including 43% porosity, permeability 0.58 m / day and aquifer thickness of 22 meters. the alluvial layer in the Gesing sub-watershed contains more clay material which has a low permeability. So this formation has medium aquifer characteristics for groundwater potential with an area of 7.4 km².

The Jonggarangan Formation is characterized by an aquifer between 33% porosity, permeability of 2.21 m/day and aquifer thickness of 15 meters. Jonggarangan formation has a groundwater potential with an area of 7.5 m². Maps of permeability, porosity and aquifer thickness are respectively in Figure 8, Figure 9 and Figure 10.

![Permeability Map](image2)

**Figure 8. Permeability**
4.2. Parameter Weights
Based on Figure 11. It can be seen that the most influential parameter to groundwater potential is the aquifer characteristics with a weight of 0.29 while the parameter with the lowest weight is the drainage density parameter which is 0.05. The weight is obtained from the opinion of experts in the field of groundwater and then carried out calculations by the Analytical Hierarchy Process (AHP) method.

4.3. Groundwater Potential Zone Gesing sub-Watershed, Purworejo Regency
Groundwater potential classification uses regular interval method which produces 4 groundwater potential classifications which are bad, medium, good and very good. The range of values formed from the results of the analysis is starting from the lowest value of 2.97 and the highest value of 5.56. The higher total value indicates the higher groundwater potential in the study area. Conversely the lower the total value of the total groundwater potential in the area is lower. The results of the
classification of the total value of the effect of groundwater potential on groundwater potential in the Gesing Sub-watershed.

Based on Figure 12 Overall groundwater potential which is classified as very good and good is found in the downstream and slightly upstream of the watershed. Groundwater potential classes are in the middle of the sub-watershed in the middle of the sub-watershed. While potential classes are less in the upstream part of the watershed. Good and very good groundwater potential classes are found in alluvial formations and Kebobutak formations, it is proven based on the results of 2018 geo electric data by Dharmawan [2] in this formation does have good aquifer potential compared to other formations.

Another physical parameter that affects is that this region is located on a flat to medium slope so that the level of infiltration is also large [5]. The slope of the slope is flat to medium so the level of infiltration is also large. In the middle of the watershed is calcified into the potential groundwater. The formation that dominates in the middle of the sub-watershed is the Kebobutak formation. In this formation, based on geo electric data, it actually has good aquifer potential, but in this case the physical parameters used are not only aquifer characteristics but other physical parameters such as the slope which is quite influential on the process of water entering the ground.

At the upstream part of the watershed sub classified into levels of potential groundwater is less, medium to very good. Upstream there are 3 formations consisting of andesite formations, Jonggarangan formations and kebobutak formations. Groundwater potential is less in andesite formations. Where is the characteristic of the aquifer in this formation has a lack of aquifer levels caused by the presence of andesite breccia rock layers and the steep slope that dominates, causing the aquifer thickness is very low [3]. The groundwater potential of the Kebobutak Formation found in the upper watershed is different from the middle kebobutak formation. In the upstream part of the Kebobutak formation it has a high groundwater potential because it is due in the upstream part of the Kebobutak formation to have a medium to flat slope so that the possibility of infiltrated water is higher than the middle part.

![Figure 12. Ground Water Potential Zone](image)

4.4 Validation Analysis
Validation analysis is done by comparing research data with existing conventional data. The existing conventional data consists of interview data with the community related to the depth of the well, adjustment of groundwater basin data and geo electric measurement data.

Validation test was carried out on 30 samples. Based on 30 sample points, there are 4 samples that are not in accordance with the results of the mapping and 26 samples in accordance. The 3 unsuitable samples are found in the medium class sample and the good class there is 1 sample. Based on the adjustment of data processing results and data validation results obtained the level of accuracy of research results calculated using the method of confusion metrix of 87%. A research data can be used if it has a minimum accuracy level of 87% [10]. That is because aspects of the parameters used,
as well as the method of weighting the parameters used. The parameters used only focus on the physical parameters of the land.

The physical factors used are not only the characteristics of the aquifer as the most influential parameter but also other physical factors such as slope, drainage density, land use and soil texture. Accuracy results obtained are also caused by the parameters used do not consider climatological factors such as rainfall which is an input from groundwater. The modeling method also influences the accuracy results. The weight of each parameter is generated from the Analytical Hierarchy Process (AHP) method that utilizes the subjective opinions of each competent expert in the field of groundwater hydrology and also the number of resource persons used is relatively small, namely 3 people, so the opinion of experts should be needed with more numbers so that the results obtained are more accurate with field data.

5. Conclusion

1. Sentinel 2A and TerraSAR-X imagery can be used for extraction of groundwater potential. That is because the resulting parameter map has a good accuracy. The accuracy of the land use map is 87% and the accuracy of the lithology map is 93%. This accuracy can be used for decision making.

2. The mapping results show that there are 4 classifications of groundwater potential in the Gesing sub-watershed, which are less, medium, good, and very good. Good and very good potential classes are found in the downstream part of the watershed and slightly upstream of the sub-watershed. Groundwater potential classes are in the middle and upstream of the sub-watershed are less. Because in the upstream watershed in andesite rock formations. Map has a validation accuracy of 87%. The modelling result have good accuracy and can be used in decision making.

3. Based on the results of the Analytical Hierarchy Process (AHP) method the aquifer characteristics parameter is a parameter that greatly influences groundwater potential in the Gesing sub-watershed with a weight value of 0.49. While the parameter that has the least effect is drainage density which has a weight value of 0.05.

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References

[1]. Daiman, Amit. 2012. “Integrated GIS Modeling for Exploring of Groundwater Potential using Morphometric & Hydrogeomorphological Studies A Case Study of Karawan Watershed, Sagar District, Madhya Pradesh”. Thesis. Remote sensing Application center, Madhya Pradesh Council of Science & Technology, India.

[2]. Dharmawan, Puguh Dan Ig.L. Setyawan Purnama. 2018. Analisis Karakteristik Dan Potensi Akuifer Kecamatan Purworejo Kabupaten Purworejo Dengan Metode Vertical Electrical Sounding (Ves). Jurnal Bumi Indonesia. Vol.7. No. 1. Hal 5-10.

[3]. Kirsch, R., 2006. Groundwater Geophysics, A Tool for Hydrogeology; Second Edition. Berlin: Spriger

[4]. Prahasta, Eddy. 2006. Sistem Informasi Geografis ( Membangun Web Based GIS dengan Mapserver). Bandung: CV. Informatika

[5]. Purnama, Setyawan. 2010. Hidrologi Airtanah. Yogyakarta: Penerbit Kanisius.

[6]. Rahmawati, Ima. 2016. “Monitoring Perubahan Harga Lahan Permusikan Menggunakan Citra Resolusi Tinggi dengan Metode Analytical Hierarchy Process Di Kecamatan Bogor Barat, Kota Bogor Tahun 2007-2014”. Skripsi. Yogyakarta: Universitas Gadjah Mada

[7]. Saaty, T. L. (2008). Decision Making with the Analytic Hierarchy Process . Int. J. Services Sciences, Vol. 1 No. 1, pp. 83-98
[8]. Souissi, Dheka. Mohamed Haythem Msaddek, Lahcen Zouhri, Ismail Chenini, 99 Moufida El May & Mahmoud Dlala. Mapping groundwater recharge potential zones in arid region using GIS and Landsat approaches, southeast Tunisia. 2018. *Hydrological Sciences Journal*, Vol. 63, No. 2, 251–268

[9]. Suharsono, P. 1999. *Identifikasi Bentuklahan dan Interpretasi Citra Untuk Geomorfologi*. Yogyakarta: PUSPICS Faculty of Geography. Universitas Gadjah Mada.

[10]. Sutanto. 2013. *Metode Penelitian Penginderaan Jauh*. Yogyakarta: Penerbit Ombak.