The integration of remote sensing and geoelectrical resistivity for identifying the distribution of groundwater potential in Palu City

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Abstract. Groundwater distribution is one of the factors that can support the development of a region, including Palu City, which is the Capital of the Central Sulawesi Province. This research was conducted to find out the distribution of the groundwater potential in Palu City. The parameters used in remote sensing data were based on geomorphological factors, fertility, and vegetation density. Geomorphology used DEM data from SRTM imagery, while vegetation fertility used unsupervised classification method, and vegetation density used the NDVI method. The weight test of the three factors was conducted using the AHP method. The parameters of the geoelectrical resistivity used Wenner and Schlumberger configurations. In remote sensing, the weighting results obtained the vegetation fertility of 39, vegetation density of 33, and geomorphology of 16. The Geoelectrical resistivity obtained the resistivity value of rocks of 10 - 69.66 Ωm as a layer of groundwater potential distribution. The high distribution of groundwater potential is generally in the Palu valley, while the moderate distribution is in the eastern hills and a small part in the western hills and the low distribution is in the western hills and eastern part of Palu City.

1. Introduction

Groundwater distribution is one of the factors that can support the development of a region, including Palu City, which is the Capital of the Central Sulawesi Province. The regional development of Palu City is greatly influenced by the potential of ground water. The rapid distribution of population settlements always in line with the consideration of the groundwater potential of the concerned area. The population growth rate along with the acceleration of industrial activity in a region, is always directly proportional to the increase in the need for clean water [1]. One method that is commonly used for finding out the potential of water is remote sensing method [2].

Remote sensing is a method for obtaining data of an object without directly having any contact to the related object [3]. The remote sensing is for measuring the energy radiated from the surface of the
earth. The measurement is used for making a description of the below-the-surface natural landscape [4, 5]. Remote sensing data consists of a collection of pixels that have digital numbers on each pixel forming an image [6].

The presence of groundwater potential can be identified by remote sensing based on the geomorphology, density and fertility of vegetation [7]. The geomorphological review is based on maps that describes the shape of the earth's surface or natural form. The under surface flow of water and the recharging and discharging processes of groundwater are strongly influenced by the geomorphological shape of an area. In order to detect the density and fertility of vegetation through satellite imagery, it is conducted by calculating the vegetation index, namely NDVI (Normalized Difference Vegetation Index) [8]. NDVI value is a value to determine the green pigment level of leaves with infrared wavelength which is very good as the initial division of vegetation area [9]. NDVI basically calculates the level of absorption of solar radiation by plants, especially by the leaves. The NDVI value is the reflectance difference from the near-infrared and the visible light channels. Vegetation with tight canopy will increase the variation of leaf area index values, so that variations in spectral reflectance values on the same canopy density are caused by differences in leaf area index.

In the next stage, in order to ascertain the distribution of the groundwater potential in the potential zones obtained, there was an under surface review carried out using the geoelectrical resistivity method [10]. The aim of the investigation was to find out the presence of rock layers that function as aquifers (layers of water carriers) [11]. The groundwater potential in an area is strongly related to the characteristics of aquifer [12]. The characteristics of aquifer that have direct effect on the groundwater potential are materials, stratigraphy (rock layers), and aquifer thickness [13]. The research in identifying aquifers using the geophysical method has been carried out by Vicente-Serrano [14], using the geoelectrical resistivity.

This research aimed to detect the ground potential of groundwater through imagery, which was combined with geoelectrical resistivity method to determine the distribution of groundwater potential that is useful for the regional development of Palu City.

2. Materials and methods

2.1. Location and Time of Research
Geographically, the research was conducted on 0°38′ S and 119°46′ E to 0°57′ S and 120°00′ E. The research was conducted from April to June 2018. The data used in this research were in the form of imagery and resistivitymeter data.

2.2. Materials
Tools and materials used in this study were Microsoft Excel, Envi, Progress, GIS, Microsoft Word, Garmin GPS, Satellite Imagery (Spot-7), STRM imagery, and a set of resistivity analyzers.

2.3. Methods
This research was conducted in several stages as follows. The first stage was conducted by taking satellite imagery data (Spot-7), as the data obtained from satellite imagery were mapped in the form of thematic maps such as vegetation fertility and density maps. Furthermore, the geomorphological data were collected obtained from SRTM imagery, with a resolution of 30 m, in order to determine the morphological form. Vegetation classification in the imagery was done using the Maximum Likelihood Supervised Classification method [15]. While the thematic maps of vegetation fertility and density were made using ENVI and the geomorphology was conducted using ArcGis 10.1.

The Second Stage was conducted by overlaying the vegetation fertility, vegetation density and geomorphological factors. The determination of the effect from each of these factors was made using Analytical Hirarchy Process (AHP) [16].

The Third Stage was conducted by measuring the geoelectrical resistivity using Wenner and Schlumberger configuration. The data were processed using Res2dinv (Wenner data processing) and
Progress (Schlumberger data processing) applications. Based on the value of resistivity obtained, it was associated with the value of rock formations for interpretation of rock layers or aquifer. The interpretation of rock layers was adjusted for geological conditions (stratigraphy).

3. Results and Discussion

3.1 Remote Sensing Method

Analysis of responses to the value of the spectrum of vegetation fertility in Palu City shows that most areas of Palu City in the hills are dominated by shrubs. The spectrum response value that shows fertile vegetation is found in the Palu Valley region and a small part of the mountains in the eastern part of Palu City (figure 1).

![Figure 1. Map of fertile vegetation](image)

The classification of vegetation density based on NDVI shows that dense vegetation is found in Palu Valley and eastern hills and a small part in the western hills. The moderate dense vegetation is located in the eastern part of Palu City, while the non-dense vegetation is spread in the eastern and western hills (figure 2).

The morphological form of Palu City consists of valleys, lowlands, hills, mountains, sea and rivers. The western part is dominated by relatively high mountain areas, the northern part bordered by the sea, the eastern part bordered by mountains and hills, the southern bordered by lowlands, and the center, consists of the settlements, is dominated by valleys (figure 3).

The distribution of groundwater potential in Palu City was analyzed based on three thematic maps that have been made previously, namely fertility, density and geomorphological maps. These three factors were scored to see the effect of each factor when getting overlay using the AHP method. This scoring process was obtained based on the effect on the distribution of the presence of groundwater. The higher the score, the higher the effect of these factors on the distribution of the presence of groundwater in an area. Based on data processing, the scores were obtained for each of the factors that had successive effect: vegetation fertility has a score of 39, vegetation density 33 and geomorphology 16 (figure 4).
Figure 2. Map of vegetation density

Figure 3. Map of geomorphology
Figure 4. Graph of the effect of groundwater presence total score

3.2 Geoelectrical Resistivity Method
Measurement using Wenner Configuration: Based on the results of research that the Talise region and South Palu regions have high groundwater potential. It can be seen from the first and the second layers in the form of clay and aquifer with a resistivity value of 10-50 Ωm (figure 5 and figure 6). The potential of this high category groundwater is the same as the resistivity value of Innocent Muchingami et al, which is <50 Ωm, the reading of low resistivity values indicates high groundwater potential and vice versa the large resistivity value indicates low water potential. This condition is in line with the results obtained from the analysis of satellite imagery that the valley area is an area with fertile and dense vegetation that shows high groundwater potential.

Figure 5. The cross section of 2D geoelectric results of Talise Village

Figure 6. The Cross section of 2D Geoelectric results of South Palu
Measurement using Schlumberger Configuration: Based on the results of the three survey locations in Tadulako University, Poboya and Kawatuna, it is shown that the area has a low groundwater potential, in which the groundwater potential is far below the surface (77 m dmt). It can be seen from the first and the second layers consisting of sandy rocks. The aquifer layer is characterized by the presence of an impermeable layer (clay) which is directly carried by the aquifer (figure 7). The amount of resistivity value for determining the aquifer layer, the range of resistivity 15-70 Ωm is the same for some researchers [17, 18]. Geoelectric results this condition is in line with the results obtained from the analysis of satellite imagery that this area has infertile vegetation with low density.

3.3 The Analysis of the Distribution of Groundwater Potential

The weighting calculation carried out shows that the distribution of groundwater is strongly influenced by the vegetation fertility. The condition of vegetation fertility in a location can indicate whether the groundwater potential is good or bad. The overlay of thematic maps as the factors in the distribution of groundwater, resulted in three classifications of groundwater in Palu City, namely, low, moderate, and high distribution of groundwater potential. This is also supported by the results of field surveys based on the geoelectrical resistivity method obtained that the depth ranges between 0-20 dmt is categorized as high potential, 20-40 dmt as medium potential, and depth > 40 dmt as low potential.

![Figure 7. 1D cross section of geoelectric: a, Campus UNTAD, b, Poboya, c, Kawatuna](image)

Based on this research, it was found that the high distribution of groundwater potential is in the Palu valley, the eastern shore, the eastern mountain and a small part in the western mountain. The moderate groundwater potential is in the eastern hills and a small part in the western hills. While the low distribution is in the western hills and eastern part of Palu City. This can happen because the Palu...
valley is a place for the flow of various rivers in Palu and the subsurface flow into this valley. The distribution of groundwater potential in Palu City is shown in figure 8.

Figure 8. Map of distribution of groundwater potency

4. Conclusion
Based on the integration between the two methods, the distribution of groundwater potential in Palu City is classified as follows; The high distribution of groundwater potential is generally in the Palu valley, while the moderate distribution is in the eastern hills and a small part in the western hills and the low distribution is in the western hills and eastern part of Palu City. The value of groundwater potential of 0-20 m dmt is categorized as high potential, while the depth of 20-40 m dmt is categorized as medium potential, and the depth of > 40 m dmt as low potential.

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