International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Analysis of Remote Sensing & GIS Data to Investigate Regional Groundwater Potential Zones in Ambon Island, Moluccas Province, Indonesia

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Abstract: ***Ambon Island have some region that scarce water. Groundwater is one of solution that can solve this problem, but exploration of groundwater in region with scarce water resources requires the implementation some of effective tools that save time and money and minimize the risk. The increasing demand of water has brought tremendous pressure on groundwater resources. Groundwater utilize in ambon primarily for daily use activities and become the primary needs. groundwater is prime source of water. The integration between advanced techniques for groundwater exploration is necessary to protect and to manage the resources. The objective of this study was to explore and delineation groundwater potential zones in Ambon Island, Moluccas Province, Indonesia. GIS-based modelling was used to integrate remote sensing data to delineate groundwater potential zones and separate it into several area that prospect or not for groundwater exploration for community in Ambon. In the present study, Landsat 8 Operational Land Imager and Thermal Infrared Sensor, ASTER global digital elevation model generate various thematic maps, visualization, geomorphology, land use, geology, lineament density, drainage density, slope. Based on this integrated approach, the groundwater availability in the Ambon Island was classified into three categories, poor, fair, and good. The zones with high lineament density, high drainage density, low steep slope were categorized as good groundwater potential zones while areas with low lineament density, low drainage density, high steep slope as poor groundwater potential zones. The results reveal that the modelling assessment method proposed in this study is an effective tool for delineate groundwater potential zones for management of groundwater resources. The study showed that remote sensing and GIS provided efficient tools for mapping promising sites for groundwater exploration. However, the data of groundwater wells would enhanced the delineation of groundwater potential zone.***

Keywords: Groundwater, Remote Sensing, GIS, Moluccas

1. Introduction

Groundwater is a vital natural resource for the reliable and economic provision of potable water supply in both urban and rural environment [16]. Hence it plays a fundamental role in human well-beings, as well as that of some aquatic and terrestrial ecosystems [16]. Remote Sensing and The Geographical Information System (GIS) with their advantages of spatial, spectral and temporal availability and manipulation of data covering large and inaccessible areas within a short time have become very handy tools in accessing, monitoring and conserving groundwater resources [21]. It also has been found that remote sensing, besides helping in targeting potential zones for groundwater exploration, provides input towards estimation of the total groundwater resources in an area [21]. GIS and remote sensing tools are widely used for the management of various natural resources [1] [16]. Delineating the potential groundwater zones using remote sensing and GIS is an effective tool [16]. In recent years, extensive use of satellite data along with conventional maps and rectified ground truth data, has made it easier to establish the base line information for groundwater potential zones. Remote sensing not only provides a wide-range scale of the space-time distribution of observations, but also saves time and money [18]. In addition it is widely used to characterize the earth surface (such as lineaments, drainage patterns and lithology) as well as to examine the groundwater recharge zones [21].

Applications of remote sensing and GIS for the exploration of groundwater potential zones are carried out by a number of researchers around the world, and it was found that the involved factors in determining the groundwater potential zones were different, and hence the results vary accordingly [16].

[24] relied only on the lineaments for groundwater exploration and others merged different factors apart from lineaments like drainage density, geomorphology, geology, slope, land-use, rainfall intensity and soil texture [21]. The derived results are found to be satisfactory based on field survey and it varies from one region to another because of varied geo-environmental conditions.

Integration of remote sensing and GIS method for preparing various thematic layers, such as lithology, drainage density, lineament density, slope, land-use maps with assigned weightage in a spatial domain will support the identification of potential groundwater zones. It was the purpose of this investigation to explore groundwater potential zones in Ambon Island, Moluccas Province, Indonesia using Remote

Sensing, Geographic Information System and Geophysical data analysis.

The study area lies at Ambon Island is part of the Maluku Islands of Indonesia (Figure 1). The island has an area of 775 km^2 (299 sq mi) and is mountainous and fertile. Ambon Island consists of two territories. The main city and seaport is Ambon (with a 2009 population of 284,809), which is also the capital of Malukuprovince and Maluku Tengah (with a 2009 population of 370,931).

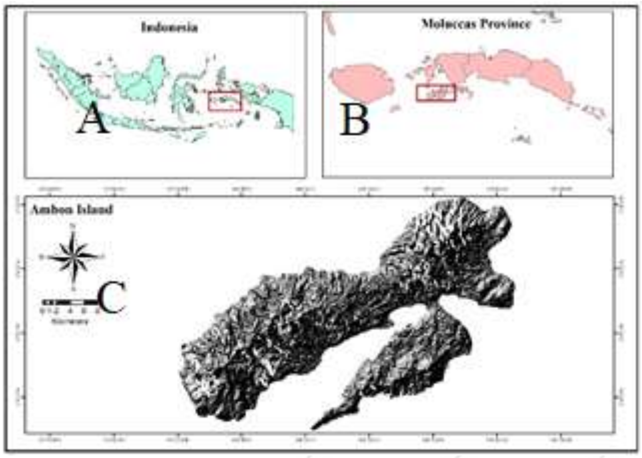

Figure 1 Location map of the study area. (A) Indonesia Map (B) Moluccas Province Map (C) Ambon Island Map

2. Regional Geology

Ambon Island is located at the margin of three large lithospheric plates, the Australian, Southeast Asian, and Southwest Pacific, and its geology records their complex interaction. Ambon, and the nearby islands of Ceram and Baru, represent slivers of continental crust that were faulted off of New Guinea. Paleomagnetic data indicate these slivers have moved westward and northward during, and perhaps preceding, Miocene time [14].

Although the island has a complex history, the stratigraphy of Ambonis relatively simple. The oldest exposed rocks are part of Kanikeh Formation of Triassic to Jurassic age. Lithologically this formation consist of interbedded sandstone, shale, siltstone, with intercalations of conglomerate and limestone. The detrital sediments include arkose and graywacke.

The next youngest rocks are ultrabasic rocks of Jurassic and Cretaceous age. Lithologically this unit contains harzburgite, dunite, serpentinite, and gabbro. The relation of the ultrabasics to the Kanikeh Formation is not clearly indicated on Ambon, but on Seram, show it to be structural contact, with the ultrabasics thrust over the Kanikeh Formation. ultramafics represent oceanic crust formed in a passive margin about 14.5 Ma ago. They believe the oceanic crust was obducted onto Ambon, Baru and Seram Islands before 4.4 Ma ago, at which time the Ambon volcanic rocks were erupted.

The Ambon volcanic rocks are composed of andesite, dacite, breccia, and tuff. K/Ar geochronology of the Ambon volcanic rocks has yielded dates of 3.4 to 4.4 Ma . The volcanic rocks are intruded by the Ambon Granite which consists of biotite granite and biotite cordierite granite. While the Ambon volcanic rocks are widely distributed across the island, the Ambon Ganite only crops out in the western half of the northern peninsula. The outcrops of Ambon granite occur within an area about 20 kms long and 10 kms wide, and have a crude radial pattern, reflecting the distribution of the stream drainages.

the Ambon volcanic rocks and intrusive rocks were formed as the result of thrusting of continental slivers beneath the Banda ridges. Alternatively, [14] suggest that the volcanic rocks and intrusive rocks are the result of mixing magma derived from partial melting of pelitic rocks due to obduction of the oceanic crust, with basaltic/andesitic magmas emplaced along transform faults. They believe the transform faults had left lateral movement and were the mechanism for moving Ambon, Baru and Seram Islands north and westward in a counter-clockwise rotation. The pattern of the fault shown on the geologic map of Ambon is consistent with left lateral movement.

Quarternary coral limestone crops out at many places on the island. The occurence of Quarternary limestones at elevations up to 500 meters above sea level attest to the rapidity of recent uplift on Ambon Island. The youngest unit on the island is Quarternary alluvium which on Ambon is principally beach material.

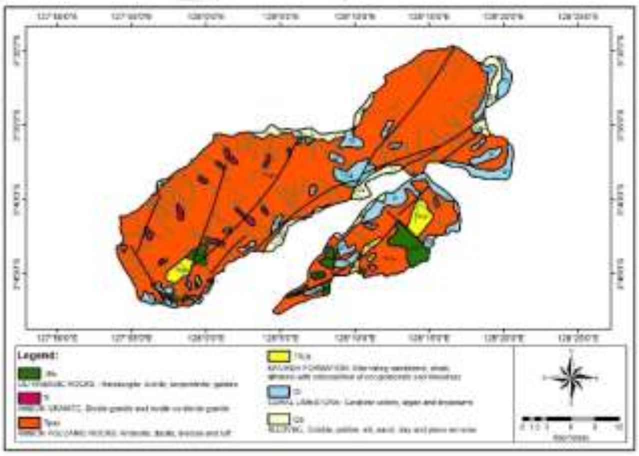

Figure 2: Geological map of the study area.

Hydrogeology

Groundwater resource in the Ambon Island, consist ofconfined and unconfined aquifer. Unconfined aquifer contained in the aquifer system at various different lithology, and will appear on the surface in the form of springs or by tapping into the aquifer through wells.

from wells Data scattered across the area of Ambon Island, it is known that the groundwater level of unconfined aquifer controlled by the morphology, and the general pattern of contour lines reflect a stripe pattern similarity of groundwater hydraulic head of unconfined aquifer. It found that there was a relationship between unconfined aquifer with surface water. Ground water plains generally supplied by surface water, ground water while the hills, ground water surface water supply.

In highland areas are generally free ground water stored in the aquifer is composed of loose material measuring fine sand to gravel, but be some place most of the groundwater stored in the aquifer limestone coral, such as in the area of Ambon, Kairatu, Kawa and Masohi the South.

3. Methods

Satellite data provides quick and useful baseline information on the parameters controlling the occurrence and movement of groundwater, e.g. geology, geomorphology, soils, landuse, lineaments etc[16].

In this study, basic maps such as lineaments and geologic maps in a digital form were produced to analyze and to interpret the satellite data. The satellite data registration, correction (geometric and atmospheric) and other image processing (such as enhancement, filtering, classifications, resolution merge). All the available spatial data were assembled in a digital form, and properly registered to make sure the spatial component overlapped correctly. This produced mapped layers, includinggeology, lineament density, topographic elevation, slope, drainage density and landuse. Various analyses, such as table analysis and weight calculation, were made for extracting this data. Suitable weights were assigned for different parameters to assess groundwater potential (Table 1). The values of the weightages are based on [19], [16], and [10][11].

The methodology of this study was based on approacheswhere layers of lithology, drainage patterns and lineaments were used to derive the most promising sites for groundwater exploration[24]. approach is based on the hypothesis that lineaments and drainage patterns would be the most important factors for evaluating the potential concentration of water in the fracture zone aquifer.

Table 1. Classification of weighted factors influencing the potential zones.

Parameter		Weight
Lithology	Alluvium	60
	Coral Limestone	50
	Kanikeh Formation	40
	Ambon Volcanic Rocks	30
	Ambon Granite	20
	Ultrabasic Rocks	10
Landuse	Urban	10
	Shrub and Brush	30
	Forest	20
	Agriculture	40
Slope Gradient	$\leq 10^0$	50
	$10\text{-}20^0$	40
	$20\text{-}30^0$	30
	$30\text{-}50^0$	20
	$\geq 50^0$	10
Topography (m)	≤190	10
	190-400	20
	400-1000	30
	1000-2500	40
	≥2500	50
Drainage Density (km/km^2)	≤0.15	10
	0.15 – 0.4	20
	0.4 – 0.7	30
	0.7 – 1.5	40
	≥1.5	50
Lineament Density (km/km^2)	≤0.4	10
	0.4 – 0.8	20
	0.8 – 1.2	30
	1.2 – 1.7	40
	≥1.7	50

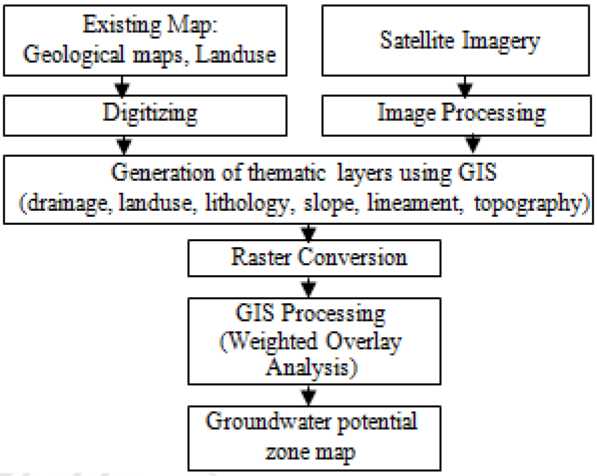

Figure 3 Flowchart for delineating the groundwater potential zone

4. Result and Discussion

a) Lineament Analysis

Lineaments can be defined as mappable, simple or composite linear features of a surface, whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differs distinctly from the patterns of adjacent features and presumably reflects a subsurface phenomenon [20].

Often, these represent faults, fractures, sharp anticline fold axes, geological rock formation contacts or vertical beds such as flat irons or hogbacks. Generally, lineaments are underlain by zones of localized weathering and increased permeability and porosity. The significance of lineaments in groundwater exploration has been described by many authors [13]. Lattman and Parizek showed that the bedrock beneath fracture traces in carbonate rocks of Pennsylvania, USA, yielded significantly more than wells sited away from fracture traces.

Lineaments give a clue to movement and storage of groundwater [22] and therefore are important guides for groundwater exploration. Recently, many groundwater exploration projects made in many different countries have obtained higher success rates when sites for drilling were guided by lineament mapping [24].

In the research area, the lineaments have been identifiedwith the aid of lineament filters and visual comments on the Landsat 8 band. The main trends observed in the lineament map could be recognized in these diagrams, showing strongly major trend in N-S, and the subdominant directions were in NW-SE. Area with high density of lineament located at the NE Ambon Island and SW Ambon Island.. Minimum lineament length is 1 m and the longest lineament observed was 1785 m. A lineament density map was prepared by IDW interpolation method used with one grid cell per square km (Fig. 4).

Inverse Distance Weighting (IDW) is a type of deterministic method for multivariate interpolation with a known scattered set of points. Suitable weightages for lineament density are shown in Table 1. The values of the weightages were proposed by Krishnamurty et al. [10]. Groundwater potential in the area increases with higher lineament density.

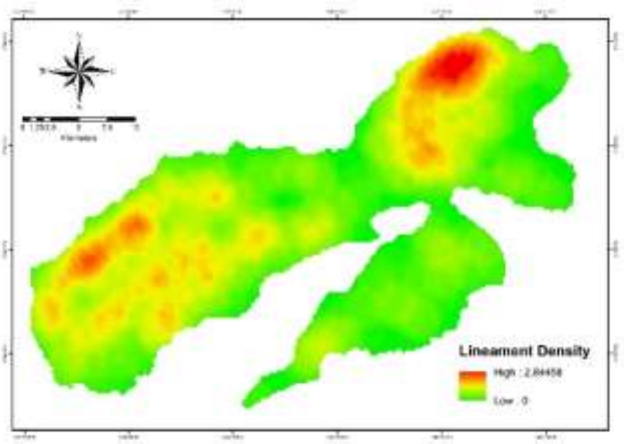

Figure 4 Lineament density map of the study area.

b) Drainage Density

Drainage pattern is one of the most important indicators of hydrogeological features, because drainage pattern, texture and density are controlled in a fundamental way by the underlying lithology. In addition, the creek pattern is a reflection of the rate that precipitation infiltrates compared with surface runoff. The infiltration-runoff relationship is controlled largely by permeability, which is in turn, a function of the rock type and fracturing of the underlying rock or bedrock surface [3].

Drainage density was considered as one of the indirect indicators of recharge potential. High drainage density reveals that permeability is low and fractured or weathered zones are not well developed. On the other hand, high lineaments density in hard rock and karstic terrains means that fracture zones and weathered zones may be developed and cause good potential of groundwater. Therefore, the ratio of lineament density and drainage density represents the recharge potential and permeability condition, whereas, high value of lineament density ratio to drainage density indicates high potential of groundwater and low runoff in a given area.

A drainage density map was prepared from drainage length per square km (Fig. 5).In addition, a table of suitable weightages for drainage density was also prepared and presented in Table 1.

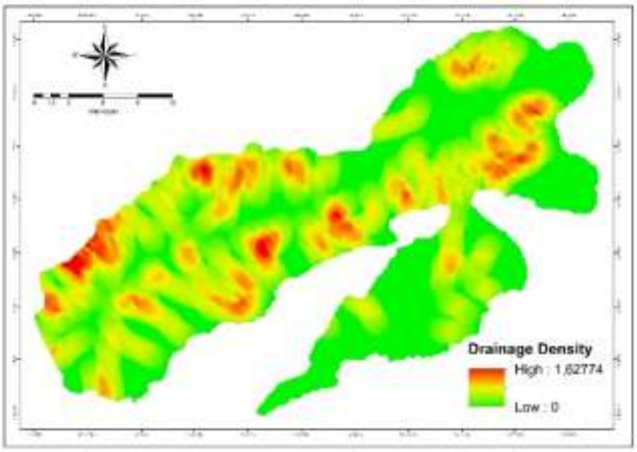

Figure 5 Drainage density map of the study area

c) Topographic slope

Topographic data is a vital element in determining the water table elevations.Rainfall has more opportunity of percolate in ground in gentle sloped lands. On the other hand, karstification in the carbonate rocks in slopes more than 20% can be effectively developed. Therefore, increasing land slope limits the groundwater and recharge potential.

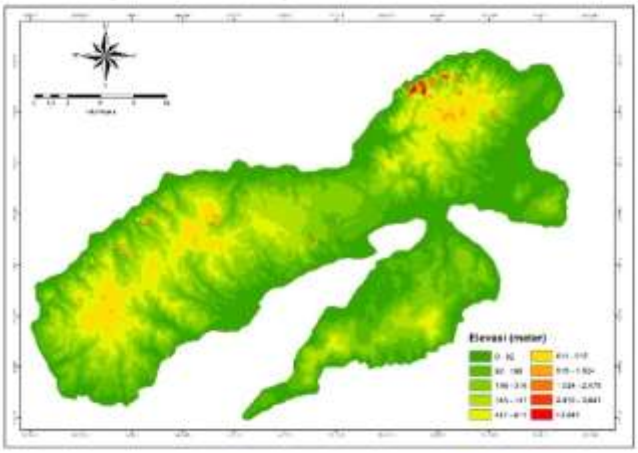

Figure 6: Elevation map of the study area.

Topographic contours obtained used digital elevation model (ASTER GDEM) with 30 m resolution. Values of slope angle were taken from the DEM. Each grid cell represents the value of a slope gradient or slope angle in degrees. The table of suitable weightages for topography and slope are shown in Table 1.

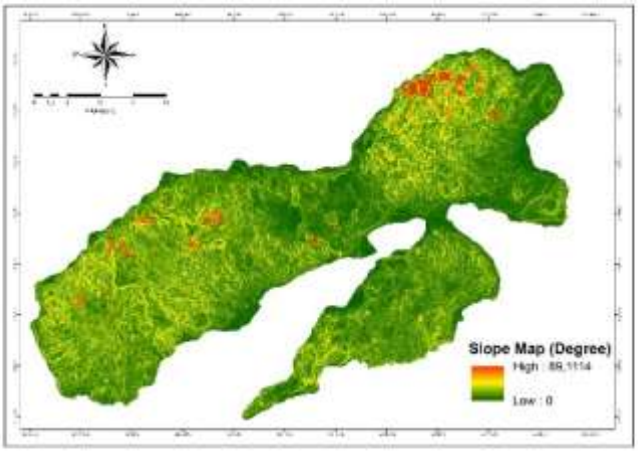

Figure 7: Slope map of the study area.

d) Landuse

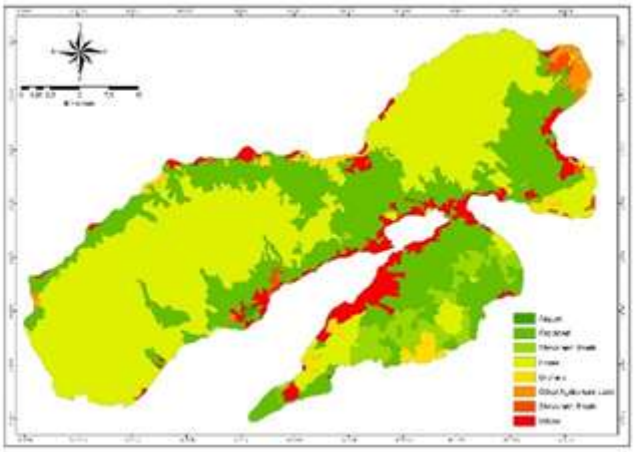

Figure 8 Land-use map of the study area.

The Landuse map based from government of Moluccas province is used. The landuse of the research area is characterized by amixture of forest cover, agricultural activities, residential area and water bodies. These were interpretable from satellite image and landuse maps. A table of suitable weightages for landuse is shown in Table 1.

Spatial Analyses

The final stage involves combining all thematic layers using the method that is modified from Musa et al. 2000.The formula of the groundwater potential model (GP) as shown below:

$$GP = Lt + Ld + Lu + Te + S + Dd$$

Where;

Lt Lithology (geology)

Ld Lineament density

Lu Land use

Te Topography elevation

S Slope

Dd Drainage density

A groundwater potential zone map of the research area was prepared (Fig. 9). In order to produce the map, a GIS model was used to integrate the thematic maps; geology, lineament density, drainage density, topography elevation, slope and land use. Each thematic layer consisted of a grid cell. The grid cell in each of the thematic layers was categorized, depending on the contribution to groundwater potential. Finally, all the thematic layers were integrated using the groundwater potential model to produce the final derived layers. In addition, a general evaluation table was built using data given in Table 1. The outputs were then re-classed into three groups, poor, fair, and good groundwater potential area.

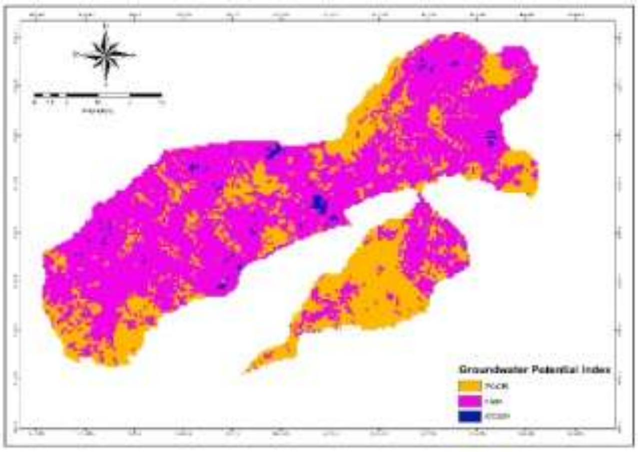

Figure 9: Groundwater potential zone map of the study area.

Based on the geological map of ambon, the ambon is dominated by tertiary ambon volcanic rock formations consisting of andesite, dasite, breccia and tuff. While on the coastal plain consists of quarternary alluvial sediment and limestone coral. Based on rainfall data, the intensity of rainfall in the islands is quite high about 5041 mm / year. The aquifer system in ambon is a fracture aquifer system where water flows through cracks of rocks. This aquifer system forms springs in several places on the island of Ambon. This spring is a potential water resource to be a source of raw water for the surrounding community. While the free aquifers are local and in some coastal areas water intrusion has been encountered in groundwater.

5. Conclusion

The indicators of groundwater occurrence are related to land use, geology, topographic elevation, slope and drainage features of the area. result has proven to be very useful for surface study, especially in detecting surface features and characteristics such as lineaments and geology. In order to predict the groundwater potential zones, different thematic maps were prepared. These include land use, geology, lineament density, topography elevation, slope and drainage density.

Integrated assessment of thematic maps using a model developed based on GIS techniques was a suitable method for predicting groundwater potential. In the research area, ambon have low to middle groundwater potential, and because this research area consist of higher mountain that steep, and according to slope and lineament density map data, ambon might be potentially have a groundwater spring that can be exploited to fullfill the city need.

6. Acknowledgements

Author greatly appreciates Mr. Adang Soewali Sadikin for his support to my research and for discussion. Everyone in

Research Center for Water Resources, Research and Development Agency, Ministry of Public Works, Indonesia.

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