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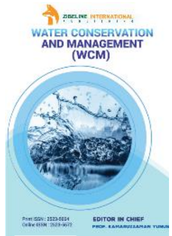

RESEARCH ARTICLE

USING THE GEOGRAPHICAL INFORMATION SYSTEM (GIS) AND REMOTE SENSING TECHNIQUES FOR MAPPING THE GROUNDWATER POTENTIAL ZONES IN KG TIMBANG DAYANG, KOTA BELUD, SABAH

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ABSTRACT

The growing demand for groundwater is due to several reasons such as the increment of population, agriculture, pollution, industrialization and urbanization. This study aims to map the groundwater potential zones by using the Geographical Information System (GIS) with remote sensing techniques in the study area. The study area is located at Kg Timbang Dayang and its surrounding at Kota Belud, Sabah. Eight parameters were studied that affect the occurrence of groundwater in the study area. Those parameters are obtained from existing maps, remote sensing imagery and associated databases. The parameters are; lithology, rainfall distribution, drainage density, lineament density, soil types, elevation, slope steepness and landuse. All these parameters will be used to create the thematic maps based on the given weightage values. Finally, all the thematic maps will be integrated to produce the final groundwater potential map of the study area. The groundwater potential map is classified into three categories which are low, moderate and high.

KEYWORDS

GIS, Remote Sensing, Groundwater Potential.

1. INTRODUCTION

Water is one of the most important basic needs of all life on earth. Human dependence on water in daily activities causes the demand for clean water to increase over time. There are two main sources of water, namely surface water and groundwater. Surface water is water found on the earth's surface such as rivers, lakes, swamps and oceans (Winter et al., 1998). Groundwater is water found in cavities, pores or cracks in rock formations resulting from atmospheric processes either through absorption from rain or directly through rivers or lakes (Ojo et al., 2012).

Geographic Information System (GIS) is an information system that is capable of storing, retrieving, managing, processing, analyzing and displaying non-spatial data as well as spatial or geographical data for the purpose of problem solving and decision making in the context of a particular organization (Ruslan and Noresah, 1998). Remote Sensing is a technique for obtaining information through analysis using special equipment without touching objects (Avery and Berlin, 1992). Groundwater is defined as water that fills the space, cavities, pores, and cracks in the soil, rock or regolitos below the earth surface (Abdullah and Mat Akhir, 1990). The integration of GIS techniques followed by the observations in the field has known as a very effective method in groundwater mapping and exploration. Over the last decade, the international scientific community has shown great interest in this study, and many researchers have used this method in their studies (Sabin, 1987; Sikdar et al., 2004).

1.1 Objective

Two main objectives of this study are:

i) Identify the contributing parameters that affect the occurrence of groundwater.

ii) Mapping the groundwater potential zone at the study area.

1.2 Study Area

The study area is located at the district of Kota Belud in the Northwestern part of Sabah. The study area is bounded by latitude 06° 22' 0'' N to 06° 24' 30'' N and longitude 116° 22' 30'' E to 116° 26' 0'' E (Figure 1). The study area includes the Crocker Formation aged Late Eocene to Early Miocene and the Quaternary Sediment.

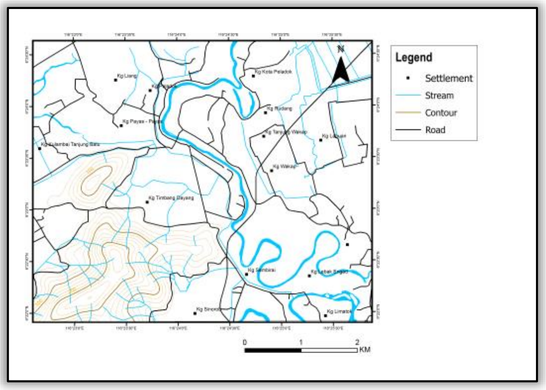

Figure 1: The study area

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2. Materials and Methods

Preliminary studies conducted include the desk study of the area as well as the GIS, remote sensing and the groundwater study. Basic data were collected such as geological map, drainage map, soil type map, rainfall distribution data and topographic map. In addition, the Landsat TM satellite images were also used to produce the lineament and landuse map for the study area. All these data will be combined with data from fieldwork to conduct analysis such as the attribute analysis, polygon classification, the weightage values to produce thematic maps according to all parameters in this study. Once all thematic maps are generated, these maps will be integrated by using the Index Overlay Method to produce a groundwater potential map in the study area. Figure 2 shows the flow chart of the processes involved in this study.

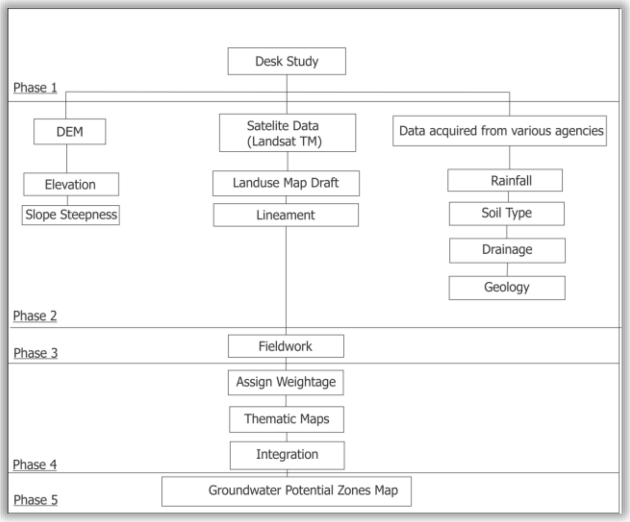

Figure 2: Flow chart of the processes involved in this study.

3. Results and Discussion

All the thematic maps that have been produced are presented on Figures 3 through 9. A lithology map of the studied area is shown in Figure 3. The highest weightage value of 50 was given to alluvium due to its characteristics of high porosity and permeability. While the muddy sandstone was given weightage value of 30 (Table 1).

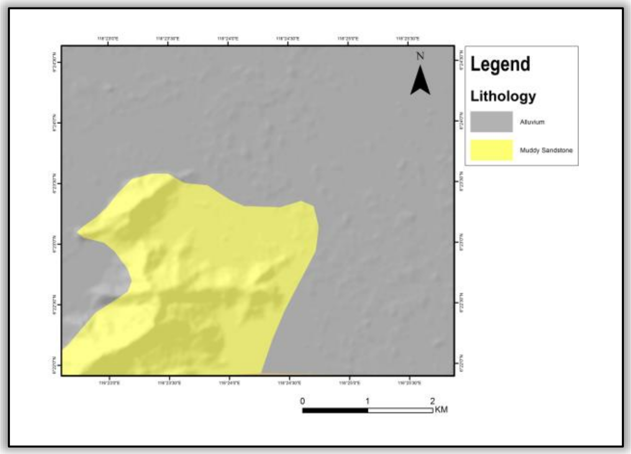

Figure 3: A lithology map of the studied area.

Table 1: Distribution of the weights for lithology type at the studied area.		
Parameter	**Sub-Parameter**	**Weightage**
Lithology	Alluvium Muddy Sandstone	50 30

A rainfall distribution map of the studied area (based on one rainfall observation station) presented in Figure 4. The rainfall distribution map is classified into five classes and was given the appropriate weightage for its contribution to groundwater (Table 2). Areas that received the highest amount of rainfall are given the highest weightage value, while the lowest weightage value for areas that received the lowest amount of rain and vice versa.

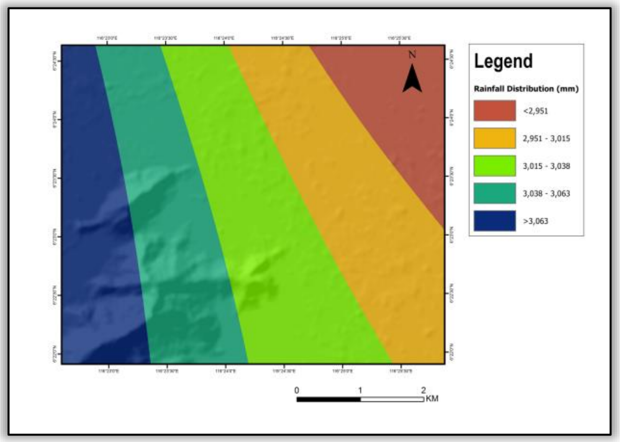

Figure 4: Rainfall distribution map of the studied area.

Table 2: Distribution of the weights for rainfall at the studied area		
Parameter	**Sub-Parameter**	**Weightage**
Rainfall Distribution	<2951 mm 2951 – 3015 mm 3015 – 3038 mm 3038 – 3063 mm >3063 mm	10 20 20 40 50

The streams that abound in the areas of high drainage density cause surface runoff rush toward the main river. This causes the absorption of water into the soil be low. Whereas, in areas with a low drainage density, the rate of absorption of water into the soil is high due to the velocity of surface runoff that has become weak (Figure 5). Therefore, the high weightage value was given to the areas with a low drainage density (Table 3).

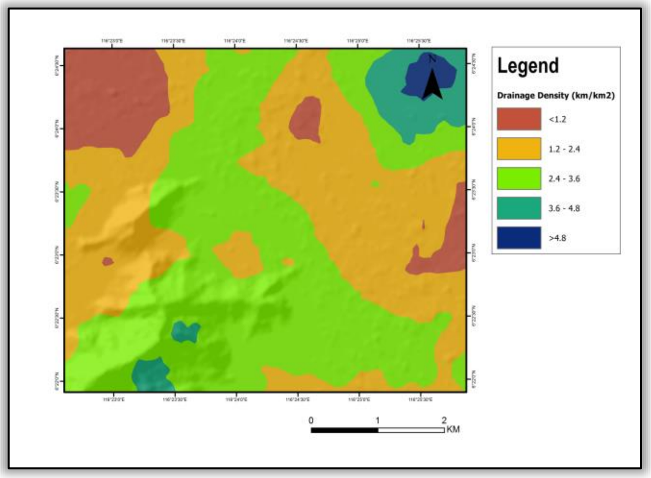

Figure 5: Drainage density map of the studied area.

Table 3: Distribution of the weights for drainage density at the studied area.		
Parameter	**Sub-Parameter**	**Weightage**
Drainage Density	<1.2 km/km^2 1.2 – 2.4 km/km^2 2.4 – 3.6 km/km^2 3.6 – 4.8 km/km^2 >4.8 km/km^2	50 40 30 20 10

The areas with a high lineament density indicate the presence of numerous faults and fractures in the area. Therefore, the characteristics of secondary porosity and permeability were high in the areas with a high lineament density (Figure 6). Distribution of the weightage was also given a high value in the areas of high lineament density, and low weightage value for areas of low lineament density (Table 4).

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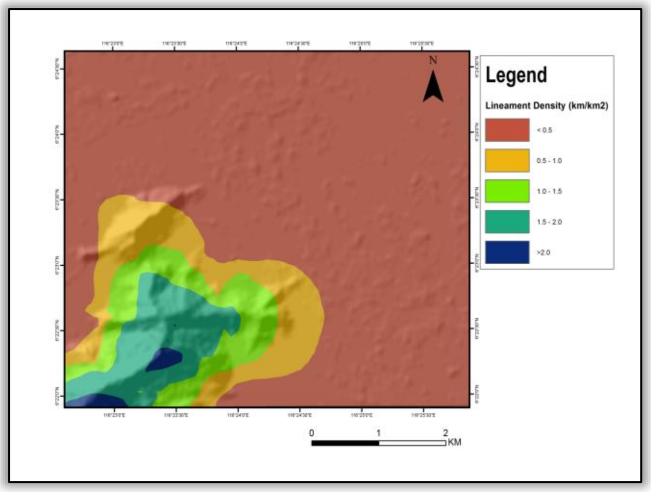

Figure 6: A lineament density map of the studied area.

Table 4: Distribution of the weights for each lineament density at the studied area.		
Parameter	**Sub-Parameter**	**Weightage**
Lineament Density	<0.5 km/km^2 0.5 – 1.0 km/km^2 1.0 – 1.5 km/km^2 1.5 – 2.0 km/km^2 >2.0 km/km^2	10 20 30 40 50

A soil type map of the studied area (Figure 7) explains that the weightage value that was given to each soil types depends on their percentage contents of sand, silt, and clay. For soil that contained a high percentage of sand, the weightage value is high due to its nature of high porosity and permeability. Then, it depends on the percentages of silt and clay contents. The weightage value for each soil types is shown in Table 5.

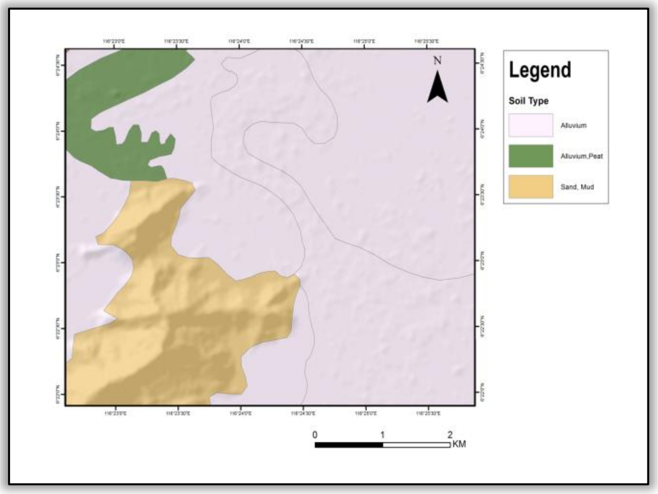

Figure 7: A soil types map of the studied area.

Table 5: Distribution of the weights for the soil type at the studied area.		
Parameter	**Sub-Parameter**	**Weightage**
Soil Type	Alluvium Alluvium, Peat Sand, Mud	50 40 20

In the highland areas, rainfall and surface water will continue running down through valleys and rivers to lowlands and to the sea. Thus, the low weightage value will be given in these areas, because it does not augment the groundwater well as in low-lying areas (Figure 8). Weightage values for this elevation zones were shown in Table 6.

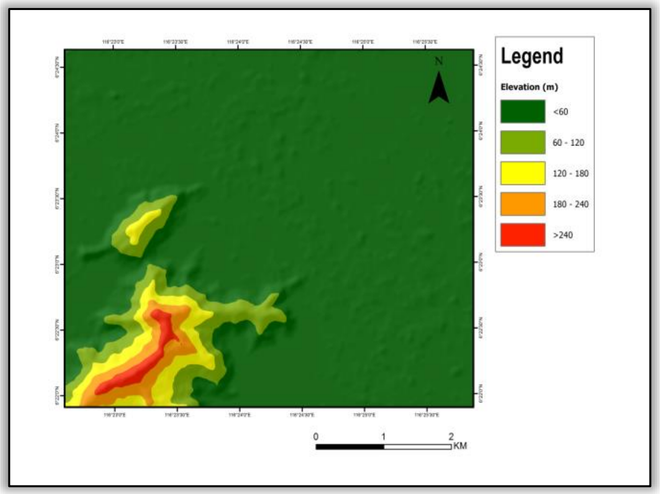

Figure 8: A topographic elevation map of the studied area.

Table 6. Distribution of the weights for elevation zones at the studied area.		
Parameter	**Sub-Parameter**	**Weightage**
Elevation	<60 m 60 – 120 m 120 – 180 m 180 – 240 m >240 m	50 40 30 20 10

A slope steepness map of the studied area is presented in Figure 9. This map also shows the same characteristics as the topographic elevation map. The weightage values were given based on the rate of runoff on steep zone which is higher than in the flatlands. Therefore, the steep zone will be given the higher weightage value, while the low weightage value is for the flat-land areas (Table 7).

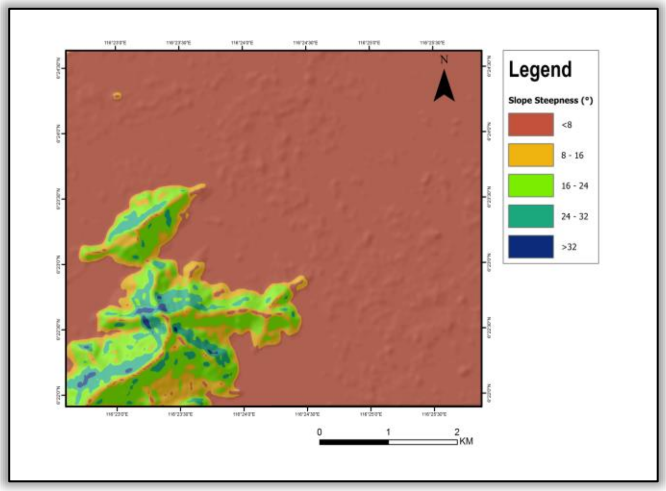

Figure 9: A slope steepness map of the studied area.

Table 7: Distribution of the weights for the slope steepness zones at the studied area.		
Parameter	**Sub-Parameter**	**Weightage**
Slope Steepness	<8° 8 – 16° 16 – 24° 24 – 32° >32°	50 40 30 20 10

Figure 10 displaying a landuse map of the studied area. Areas far from resident and development are given higher weightage value. This is because, these areas are away from the pollution that caused by human activities. Therefore, forest areas are given a higher weightage value than resident and development areas. Weightage value for each category of landuse was given depended on its contribution in appending groundwater (Table 8).

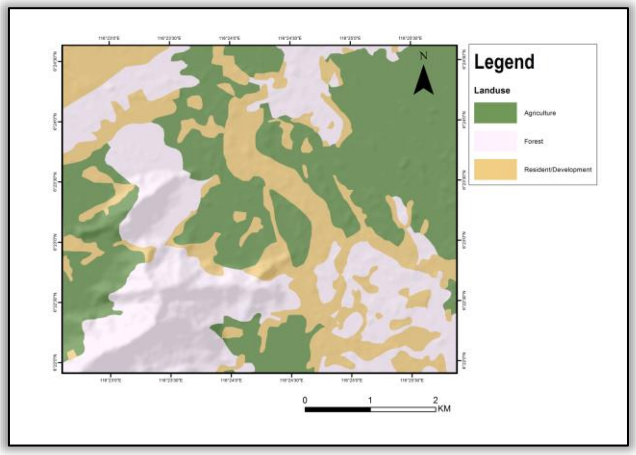

Figure 10: A landuse map of the studied area.

Table 8: Distribution of the weights for the landuse at the studied area.

Parameter	Sub-Parameter	Weightage
Landuse	Resident/Development Agriculture Forest	10 20 40

After all the thematic maps are generated, the Index Overlay Method is carried out to produce the groundwater potential map of the study area. The final map after the integration process was shown in Figure 11. The result (Table 9) revealed that the groundwater potential can be divided into three classes or zones (based on their recharge rate) which are;

- Low
- Moderate
- High

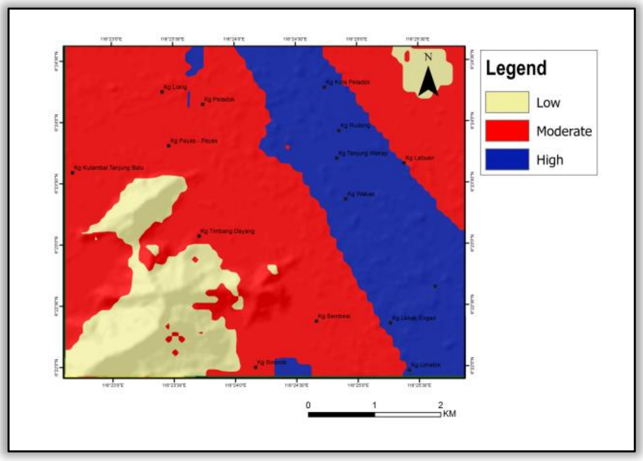

Figure 11: The groundwater potential map of the study area.

Table 9: Summary from groundwater potential map of the studied area.

Map	Low	Moderate	High
Lithology	Muddy sandstone	Alluvium	Alluvium
Rainfall Distribution	High - very high 3038 – 3036 mm	Medium - high 3015 – 3038 mm	low - medium 2951 – 3015 mm
Drainage Density	Medium – high 3.6 – 4.6 km/km²	Low – medium 2.4 – 3.6 km/km²	Very low – low 1.2 – 2.4 km/km²
Lineament Density	Very high 2.5 km/km²	Very low <0.5 km/km²	Very low <0.5 km/km²
Elevation	Very high >240 m	Very low <60 m	Very low < 60 m
Slope Steepness	High – very high 24° - 32°	Very low <8°	Very low <8°
Soil Types	Lokan	Kinabatangan	Tuaran, Kinabatangan
Landuse	Forest	Agriculture, Forest, Resident/Development	Agriculture, Forest, Resident/Development

4. Conclusion

The result shows that about 15.93% of the study area falls under low-potential zone, while 57.17% on moderate-potential zone and 26.9% on high-potential zone. Four major factor that affecting the occurrence of groundwater in study area are lithology, drainage density, elevation and slope steepness.

Acknowledgement

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