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APPLICATION OF REMOTE SENSING AND GIS TECHNIQUES FOR GROUND WATER POTENTIAL ZONES MAPPING IN AIZAWL DISTRICT, MIZORAM, INDIA

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Abstract

Availability of groundwater in an area depends largely upon the terrains. Mizoram state is blessed with abundant rainfall and number of perennial streams. However, large amount of rain water is lost through runoff due to rugged topography and high degree of slope resulting from complex geologic formation. This leads to the insufficiency of ground water resources which is essential for domestic as well as agricultural purposes within the state. Preparation of ground water potential zonation map is the first and foremost step in exploring and exploiting the ground water resources. In the present study, potential zones for the occurrence of ground water in Aizawl district of Mizoram of have been identified and delineated using remote sensing and GIS techniques. Important factors which are responsible for the potentiality of an area within the district were identified and accordingly, five thematic layers viz., slope morphometry, geological structures like faults and lineaments, lithology, geomorphology and land use / land cover were generated. These thematic layers were ranked and weighted based on their relative importance for the occurrence of ground water. Each class within a thematic layer was assigned an ordinal rating from 1 to 10 as attribute information in the GIS environment. These attribute values were then multiplied by the corresponding rank values to yield the different areas of suitability. The final map shows the different classes of ground water potential zones within the disitrct.

Key words: GIS, Remote Sensing, Ground water potential zones, Aizawl district.

Introduction

Rapid urbanization and growth of human population increases the demand for water supply (Choudhary et al., 1996). Ground water is the most important and the largest accessible source of fresh water which is required for drinking, irrigation and industrialization (Sharma and Kujur, 2012). Hence, locating groundwater potential zones, monitoring and conserving this vital resources has become highly crucial (Rokade et. al., 2004; Kumar and Kumar, 2011).

In hilly areas like Mizoram, even though the rainfall is comparatively high, shortage of water is often experienced in the post-monsoon season, as most of the water available is lost as surface runoff. Springs, the major source of water in such terrains, are also depleted during the post monsoon period (Central Ground Water Board, 2007).

Geologically, Mizoram comprises N-S trending ridges with steep slopes, narrow intervening synclinal valleys, dissected ridges with deep gorges, and faulting in many areas has produced steep fault scarps (GSI, 2011). Hence, Aizawl district also in general, experienced acute shortage of ground water as the monsoon rainfall is rapidly lost as surface runoff. Therefore, ground water potential zones has to be identified so as to adopt proper measures for its conservation and development.

Few attempts were made to study ground water prospect zones within the state of Mizoram. These include Hydrogeological mapping of Aizawl city, Aizawl district (DG&MR, 2003) and Hydrogeological mapping of Champhai town, Champhai district (DG&MR, 2004).

Remote Sensing and GIS techniques have wide-range applications in the field of geo-sciences (Jeganathan and Chauniyal, 2002). Therefore, many researchers have utilised these techniques successfully in groundwater studies (Gustafsson,1993; Saraf and Jain, 1994; Krishnamurthy and Srinivas 1995, Krishnamurthy et. al., 2000).

The same techniques have been proved to be of immense value in the field of hydrogeology and water resources development. (Saraf and Choudhury, 1999;

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Sharma and Kujur, 2012). This has also been validated in the study conducted for the entire state (MIRSAC, 2010).

The main objective of the present study is to utilizes several thematic maps in delineating groundwater prospective areas in Aizawl district and to create vital database for future groundwater development within the district.

STUDY AREA

Aizawl district is located in the northern part of Mizoram, in the north-east corner of India. Aizawl city, the state capital is situated within the district. With a total area of 3576.00 sq km the district is geographically located between 92o 37′ 03"E to 93o 11′ 45" E longitudes and 23o 18′ 17"N to 24o 25′ 16" N latitudes. Location map of the study area is shown in Figure 1. It falls under Survey of India topo sheet No. 83D/15, 83D/16, 84A/9, 84A/10, 84A/11, 84A/13, 84A/14, 84A/15,84E/1, 84E/2, 83H/3 and 83H/4. The climate of the study area ranges from moist tropical to moist sub-tropical. The entire district is under the direct influence of south west monsoon, with average annual rainfall of 3155.3 mm (MIRSAC 2012).

MATERIALS AND METHODS

Data used:

Indian Remote Sensing Satellite (IRS) LISS III data having spatial resolution of 23.5m and Cartosat-I stereo-paired data having spatial resolution of 2.5m were used as the main data. Quickbird data were also referred . SOI topographical maps and various ancillary data were also referred in the study.

Thematic layers:

Thematic layers generated using remote sensing data like geology, geomorphology, land use/land cover, lineaments etc., can be integrated in a Geographic Information System (GIS) and can be utilize for delineating ground water potential zones(Chaudary et al., 1996; Kumar and Kumar, 2011).

The present study utilised five thematic layers to define groundwater potentiality of the study area. The different layers are as follows-

Land use / Land cover:

Remote sensing data and GIS techniques provide reliable basic information for landuse mapping and play very important role in determining land use pattern by visual interpretation (Sharma and Kujur, 2012). The study area was divided into four classes, viz., Dense Vegetation, Sparse Vegetation, Scrubland and Built-up areas.

The land use/land cover plays an important role in facilitating natural ground water recharge to the aquifers. Forest, pastures and grasslands, and water bodies are important for ground water recharge. Rapid urbanization and impermeable pavements act as obstacles to natural recharge process. Infiltration and runoff are greatly depending on land use/land cover. It is well known that recharge is high in the cultivable land and irrigated land compared to the wasteland and settlements. (NRAA, 2011; Valliammai et al., 2013).

The different land use / land cover classes in the study area are shown in Table 1 and Figure 2.

Table 1: Land use/land cover type and area

Land use Class	Area [Sq.Km.]	Percentage
Dense Vegetation	1057.32	29.57
Sparse Vegetation	1822.93	50.98
Scrubland	633.19	17.71
Built up	48.27	1.35
Water body	14.29	0.40
Total	**3576.00**	**100**

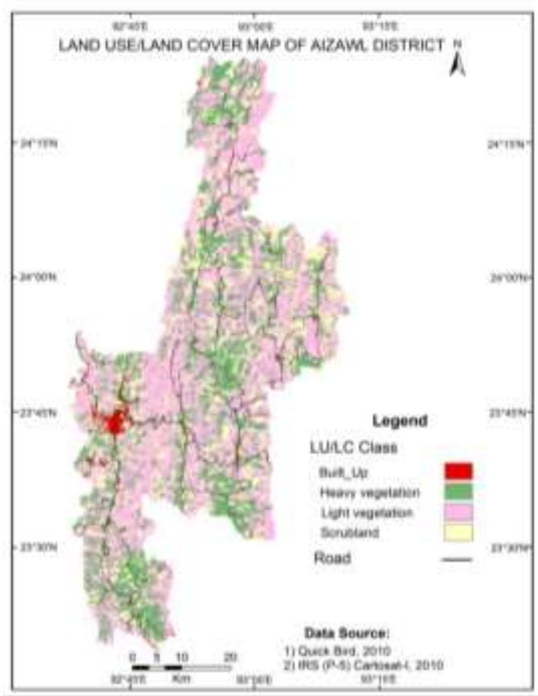

Figure 2: Landuse/land cover map of Aizawl District

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Slope:

Steep slopes acts as a high runoff zone whereas gentle slope promotes water infiltration and ground water recharge (CGWB, 2000; Kumar and Kumar, 2013; Al-Bakri1 and Al-Jahmany, 2013). Base on this concept, weightage values are assigned in accordance with the steepness of the slope in such a way that areas having gentle slope are given high weightage and those which are having steep slope were given less weightage. Slope map was generated from Digital Elevation Model (DEM) which is prepared utilising the Cartosat-I stereo-paired data in a GIS environment. The slopes of the area are represented in terms of degrees, and are divided into eight slope classes, viz., 0-15, 15-25, 25-30, 30-35, 35-40, 40-45, 45-60 and above 60 degrees. Slope classes and area covered are given in Table 2, and the slope map is shown in Figure 3.

Table 2: Slope classes and area covered

Degree of Slope	Area [Sq.Km.]	Percentage
0-15	25.65	0.72
15-25	5.90	0.17
25-30	119.34	3.34
30-35	341.17	9.54
35-40	1370.58	38.33
40-45	1164.65	32.57
45-60	450.31	12.59
>60	98.39	2.75
Total	**3576.00**	**100.00**

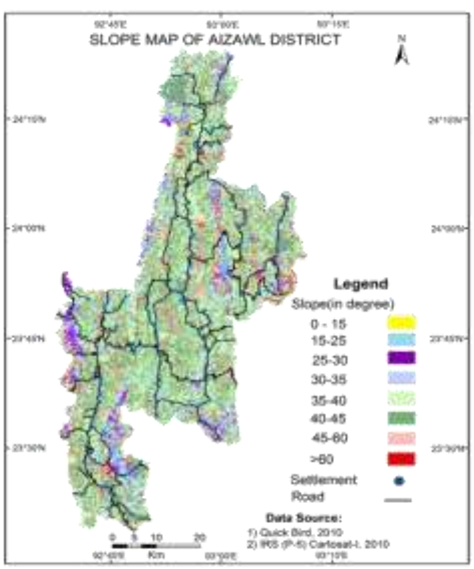

Figure 3: Slope map of Aizawl district

Geomorphology:

Geomorphology controls the subsurface movement of groundwater and hence, it is one of the most important features in evaluating the groundwater potential and prospect, and can be utilized for management of groundwater resources (Kumar and Kumar 2011; Valliammai et al., 2013). This specific parameter is also highly helpful for selecting the artificial recharge sites as well (Ghayoumian, 2007). The study area was divided into High, Moderate and Low Structural Hills with the elevation of above 1200, 900-1200 and below 900 above mean sea level respectively. Other geomorphic classes include Valley fill and Flood plain (MIRSAC, 2006). High elevated areas are less suitable for occurrence of ground water and following this pattern, weightage values were given to each of the geomorphic classes. Valley fills are considered to be the best potential areas (Edet et al., 1998; El-Baz, 1999). The area coverage of different relative relief classes is given in Table 3 and relative relief map of the study area is shown in Fig. 4.

Table 3: Geomorphic classes and area covered

Geomorphic classes	Area [Sq.Km.]	Percentage
High Structural Hill	180.21	5.04
Medium Structural Hill	830.37	23.22
Low Structural Hill	2530.62	70.77
Valley Fill	33.07	0.92
Flood Plain	1.73	0.05
Grand Total	**3576.00**	**100.00**

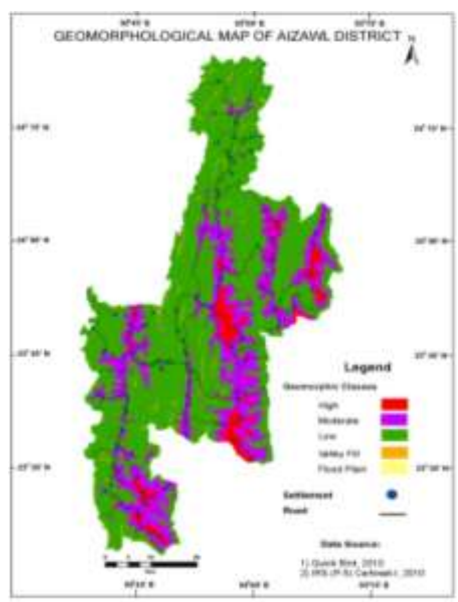

Figure 4: Geomorphological map of Aizawl District

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Lithology:

The earliest recorded work on geology of Mizoram was conducted in 1891 and it was reported that the area consisted of great flysch facies of rocks comprising monotonous sequences of shale and sandstone (La Touche, 1891). The study area lies over Bhuban and Bokabil formations of Surma Group of Tertiary age which consist mainly of arenaceous and argillaceous type of rocks (GSI, 2011). Five litho-units have been established for the study area purely based on the exposed rock types of the area. These are named as Sandstone unit, Siltstone-shale unit, Limestone unit, Gravel, Sand & Silt unit and Clayey Sand unit. Lithology plays an important role in ground water exploration and detailed knowledge of geological features of the area is necessary for selecting the site of recharge area. In particular, the features to be considered are geological boundaries, porosity, lithology, etc (CGWB 2000; Al-Bakri1 and Al-Jahmany, 2013). It was considered that the unconsolidated material units offer more chance for the occurrence of groundwater. The statistics of lithological unit is given in Table 4.

Table 4: Lithological units and area covered

Rock Types	**Area [Sq. Km.]**	**Percentage**
Sandstone	1279.52	35.78
Siltstone & Shale	2264.12	63.31
Limestone	1.47	0.05
Gravel, Sand & Silt	5.36	0.15
Clayey Sand	25.52	0.71
Grand Total	**3576.00**	**100**

Geological Structure:

Remote sensing data can be utilised to delineate and analyse the lineaments like faults, fractures, joints, etc. (Kanungo et al., 1995). Lineaments provide the pathways for groundwater movement and provide potential for ground water recharge as (CGWB, 2000; Sankar, 2002 and Sharma et al., 2012). It was observed that the rocks exposed within the study area were traversed by several faults and fractures of varying magnitude and length (MIRSAC, 2006). The geological map of the study area is given in Fig. 5.

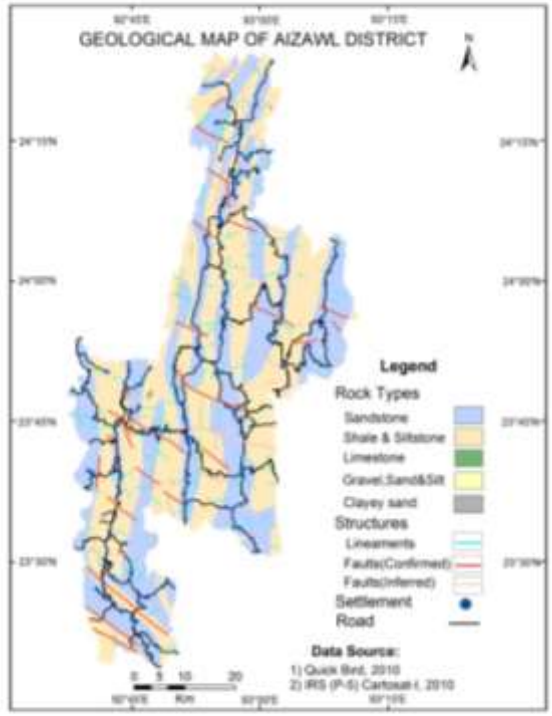

Figure 5: Geological map of Aizawl district

DATA ANALYSIS

The geo-environmental factors like slope morphometry, land use/land cover, relative relief, lithology and geological structure are found to be playing significant roles in delineating groundwater potential zones within the study area. Individual classes in each parameter are carefully analysed so as to establish their relation to select the suitable sites. Weightage value is assigned for each class based on their suitability in such a manner that less weightage represents the least influence and more weightage having higher influence. The assignment of weightage value for the different categories within a parameter is done in accordance to their assumed or expected importance based on the apriori knowledge of the experts. All the thematic layers have been considered for potentiality of the ground water. Based on the available knowledge on the role of each of these parameters in controlling the occurrence, storage and distribution of groundwater, weightages were assigned for all the layers (Kumar and Kumar , 2011). Limited ground information within the study area were also considered. All the thematic layers were integrated and analysed in a GIS environment using ARCINFO

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(10.1 version) to derive suitable sites map. The scheme of giving weightages in the study is shown in Table 5.

Parameter	Rank (%)	Category	Weight
Lithology	10	Sandstone	5
		Shale & Siltstone	4
		Clayey Sand	6
		Gravel, Sand & Silt	8
Land Use / Land Cover	15	Dense Vegetation	3
		Sparse Vegetation	4
		Scrubland	7
		Built-up	1
		Barren land	2
Slope in degrees	25	0 - 15	8
		15-25	7
		25-30	6
		30-35	5
		35-40	4
		40-45	3
		45-60	2
		>60	1
Structure: Faults and Lineaments	25	Distance Buffered	8
Geomor-phology	25	High Structural Hill	1
		Medium Structural Hill	2
		Low Structural Hill	5
		Valley fill	9
		Flood plain	8

Table 5: Ratings for Parameters on a scale of 1-10

RESULTS AND DISCUSSION

Combining all the controlling parameters by giving different weightage value for all the themes, the final map is prepared and categorised into 'Very good', 'Good', 'Moderate', and 'Poor' potential zones. The output map is generated on a scale of 1: 50,000. Various classes are described below:

Very good

This zone generally covers valley fill, flood plains and low-lying areas which are located within the proximity of water bodies, where there will be continual recharge. Besides, it includes the intersection of the structural units, such as lineaments and faults, with valley fill and flood plains. These geological structures offer channels for the sub-surface flow of water. Ground water can easily move through these fractures, and are found to be very suitable sites for ground water occurrence. Lithologically, this zone usually comprises areas where unconsolidated sediments, such as gravel, sand, silt and clayey sand are deposited. These have a high potentiality of retaining water since they allow maximum percolation due to their maximum pore spaces between the grains. This zone spreads over an area of about 116.52 sq. km., and forms 3.26per cent of the study area.

Good

All the remaining geologically structure controlled areas fall under the Good potential zone. The low-lying areas including parts of flood plains and valley fills are also included in this zone. This is because low and gentle relief areas have much better opportunities for infiltration and subsequent yield of ground water. Among the rock types exposed in the study area, sandstones are generally capable of storing and transmitting water through their interstices and pore spaces present in between the grains, and are considered to be suitable aquifer. Hence, parts of areas where sandstones are exposed also come under this zone. This zone spreads over an area of about 619.07sq. km., and forms 17.31per cent of the study area.

Moderate

This zone mainly comprises areas where the recharge condition and the water-yielding capacity of the underlying materials are neither suitable nor poor. Topographically, it covers gently sloping smooth surface of the hill. Although the lithology may comprise good water-bearing rock formation such as sandstone, the potentiality is minimized by the sloping nature of the topography where run-off is maximum. In general, the moderate zone falls within the poor water-bearing rock formation such as silty shale that are, in turn, characterized by the presence of secondary structures in them. The Moderate zone is evenly distributed within the study area and covers an area of 983.84sq. km., and occupies 27.51per cent of the total study area.

Poor

This zone is mainly distributed in the elevated areas. In the area of high relief, a greater part of precipitation

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flows out as surface run-off, which is a poor condition for infiltration beneath the ground surface. Hence, the ground water yield is generally assumed to be low. Unless the elevated areas are traversed by geological structures, and possess high drainage density and suitable water-bearing rock formation, their ground water yield is generally low. The Poor zone is mainly distributed along the ridges. This zone is predominantly high in terms of aerial extend, and covers majority of the study area.

This zone occupies an area of about 1856.55sq. km., which is 51.92 per cent of the total study area.

Table 6: Ground Water potential zones and area

Sl No.	Potential Zones	Area (Sq.km)	Percent
1	Very Good	116.52	3.26
2	Good	619.07	17.31
3	Moderate	983.84	27.51
4	Poor	1856.55	51.92
Total		**3576.00**	**100.00**

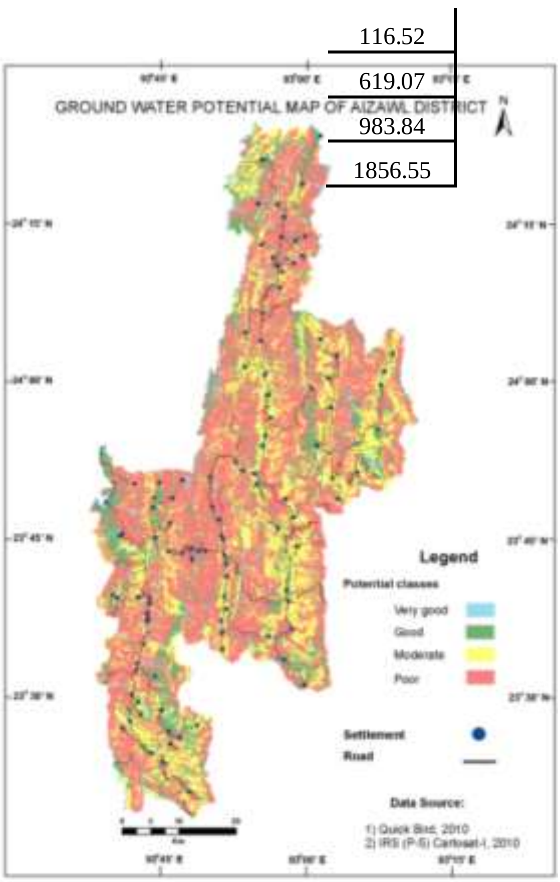

Figure 6: Groundwater potential map of Aizawl district

CONCLUSION

The present study has proven that terrain factors like land use/ land cover, lithology, slope, geological structure and geomorphology are directly associated with the occurrence of ground water, and form vital parameters for selecting suitable areas for ground water recharge.

Proper planning is essential for construction of recharge structures in which the fist step is selecting or mapping the suitable areas. This final map prepared through the present study, can therefore, forms an important database for developmental activities, and also for identifying critical areas for implementing ground water developmental measures.

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