GROUNDWATER PROSPECTS STUDIES OF KOLASIB DISTRICT, MIZORAM, INDIA USING REMOTE SENSING AND GIS.

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Abstract

Exploration of groundwater in areas having complex geologic formation like Mizoram requires implementation of effective tools that save time and money. Kolasib district of Mizoram, India 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 slopes. This leads to the insufficiency of water resources within the district. In this study, geographic information systems (GIS) tools and remote sensing data were used to detect the promising sites for groundwater exploration. Important geospatial factors which are responsible for the occurrence of groundwater within the district were identified. Accordingly, five thematic layers viz., land use / land cover, slope morphometry, geomorphology, lithology, geological structures like faults and lineaments were generated. These thematic layers were ranked and weighted based on their relative importance in deriving the potentiality 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 of the thematic layers. The final map shows the different classes of ground water potential zones within the district which can be utilize for exploration and development of groundwater resources.

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

Introduction

Due to fast urbanization and phenomenal growth in human population, the demand for water supply increases rapidly (Choudhary et al., 1996). Groundwater is one of the most important natural resources and the largest accessible source of fresh water (Sharma and Kujur, 2012; Neelakantan and Yuvaraj, 2012). Therefore, 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 amount of 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).

The geology of Mizoram state 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, Kolasib 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 need 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).

Advent of Remote Sensing and GIS techniques permit fast and cost effective natural resources survey and management (Ramakrishna et. al., 2013). Hence, these techniques have wide-range applications in the field of geo-sciences including groundwater prospecting (Jeganathan and Chauniyal, 2002; Anirudh, 2013). Interpretation of satellite data in combination with adequate ground truth information makes it possible to identify and outline various ground features such as geological structures, geomorphic features and their hydraulic characteristics that may serve as indicators of the presence of groundwater (Raju et al., 2013)

Therefore, many researchers have utilized 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 not only in the field of hydrogeology but also in water resources development as well. (Saraf and Choudhury, 1999; Sharma and Kujur, 2012).

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

Study Area

Kolasib district is located in the northern part of Mizoram, in north-east India. With a total area of

1382.00 sq km., the district is located between 92^{o} 31′ 55" to 92^{o} 54′ 08" E longitudes and 23^{o} 51′ 17" to 24^{o} 31′ 14" N latitudes. It falls under Survey of India topo sheet No. 83D/11, 83D/12, 83D/14, 83D/15, 83D/16, 84A/9 and 84A/13. Location map of the study area is shown in Figure 1. 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 2892.40 mm (Lalzarliana, 2013).

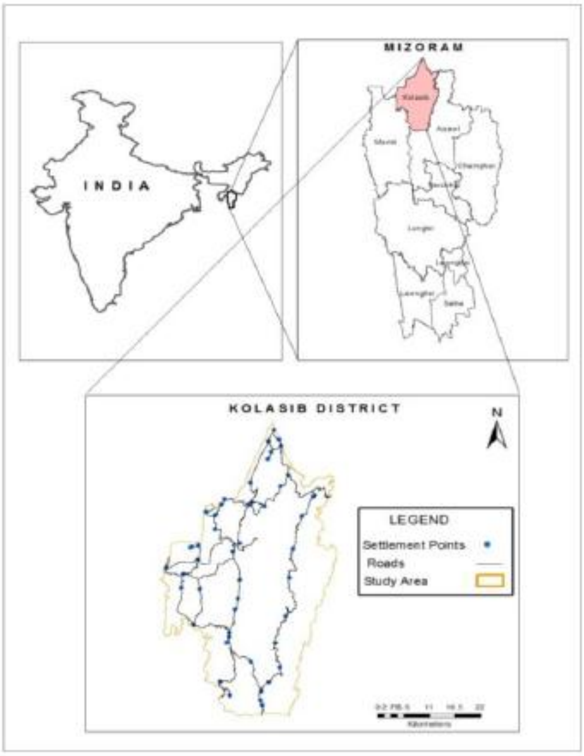

Figure 1: Location map of study area

Material 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. 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 utilized 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.

Land use/land cover has a close relation with the sub-surface moisture content and water yielding capacity and plays an important role in facilitating natural ground water recharge to the aquifers (Anirudh, 2013). Forest, pastures and grasslands, and water bodies are important for groundwater recharge. Impermeable pavements and other structures due to urbanization 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). Considering the above facts, weightage values were assigned for the different classes of land use/land cover of the area.

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

Table No. 1: Land use/land cover area of Kolasib district

Land use Class	Area (Sq.Km)	Percentage
Dense Vegetation	254.56	18.42
Sparse Vegetation	999.25	72.30
Scrubland	106.91	7.74
Built up	12.26	0.89
Water body	9.02	0.65
Total	**1382.00**	**100.00**

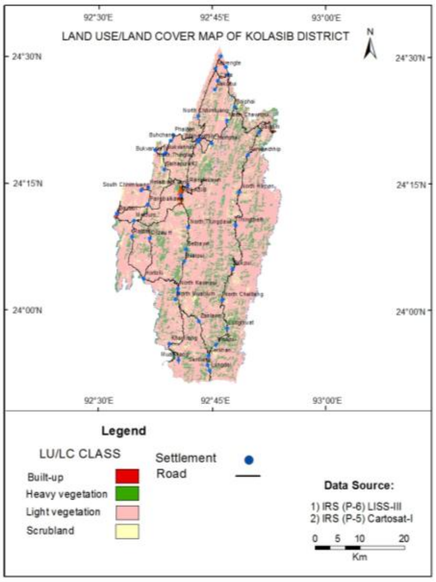

Figure 2: LU/LC map of Kolasib district

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; Siddalingamurthy et. al., 2013). Base on this concept, weightage values were assigned in accordance with the steepness of the slope in such a way that areas having gentle slope were 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	263.39	16.43
15-25	4.54	0.33
25-30	81.27	5.88
30-35	182.53	13.21
35-40	509.05	36.83
40-45	251.12	18.17
45-60	76.20	5.51
>60	13.90	1.01
Total	**1382.00**	**100**

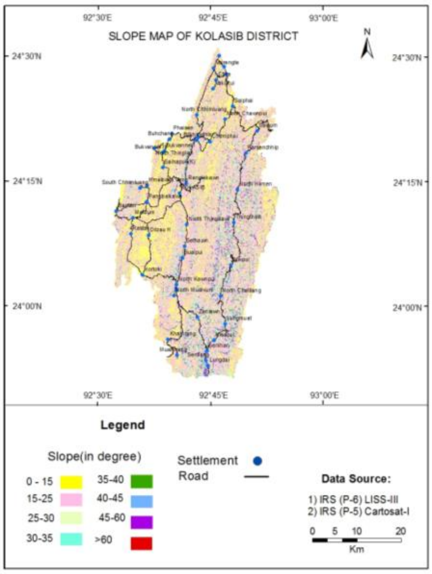

Figure 3: slope map of Kolasib district

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, Raju 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 1000m, 500-1000m and less than 500m 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 geomorphic classes is given in Table 3 and Geomorphological 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	1.94	0.14
Medium Structural Hill	43.1	3.12
Low Structural Hill	1270.61	91.94
Valley Fill	58.51	4.23
Flood Plain	7.84	0.57
Total	**1382.00**	**100**

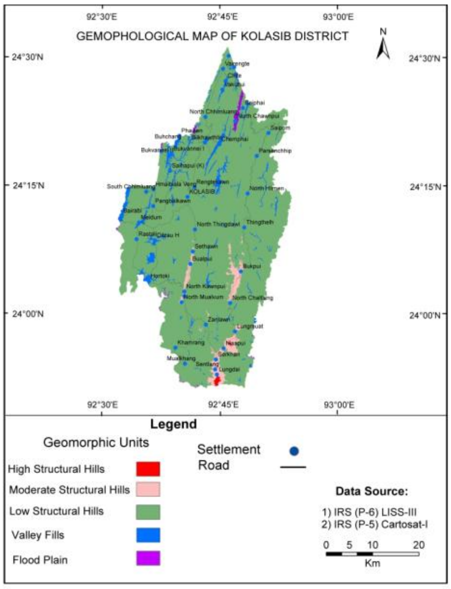

Figure 4: Geomorphological map of Kolasib district

Lithology: Lithology of Mizoram state consists of great flysch facies of rocks comprising monotonous sequences of shale and sandstone (La Touche, 1891). The study area is underlain by rocks of Middle Bhuban, Upper Bhuban and Bokabil formations of Surma Group of Tertiary age. Middle Bhuban and Bokabil formations consist mainly of argillaceous rocks while Upper Bhuban formation compirses mainly of arenaceous rocks (GSI, 2011). Four litho-units have been established for the study area purely based on the exposed rock types. These are named as Sandstone unit, Shale-siltstone unit, clayey unit and Gravel, sand & silt unit. Detailed knowledge lithology is an important factor in ground water exploration. In particular, the features to be considered are geological boundaries, porosity, 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. Considering all these factors, the different lithological units were assigned weightage values. The lithological units and their area covered were given in Table 4.

Geological Structure: Remote sensing data can be utilised to delineate and analyse the lineaments like faults, fractures, joints, etc. (Kanungo et al., 1995). The most obvious structural features that are important from the ground water point of view are the lineaments (Bhatnagar and Goyal, 2012). Lineaments provide the pathways for groundwater movement and provide potential for ground water recharge (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.

Table No. 4: Lithological units and area covered

Lithological units	Area (Sq. Km.)	Percentage
Sandstone	267.00	19.32
Shale & Siltstone	1077.84	77.99
Clayey Sand	22.40	1.62
Gravel, Sand & Silt	14.75	1.07
Grand Total	**1382.00**	**100.00**

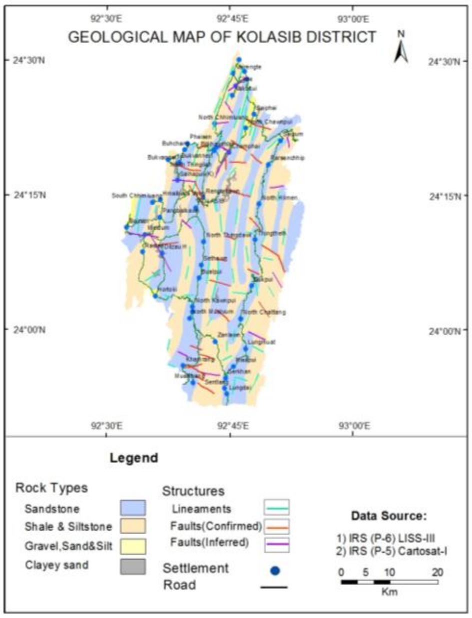

Figure 5: Geological map of Kolasib district

Data Analysis

Geo-environmental factors like land use/land cover, slope morphometry, geomorphology, lithology and geological structure are found to be playing significant roles in delineating groundwater potential zones within the study area. Based on their role in controlling the occurrence, storage and distribution of groundwater, all the thematic layers were assigned different appropriate ranks (Kumar and Kumar, 2011). Individual classes in each parameter are carefully analysed so as to establish their relation in selecting the suitable areas for groundwater occurences. 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 (Neelakantan and Yuvaraj, 2012). All the thematic layers have been considered for potentiality of the groundwater. Limited ground information within the study area were also considered. All the thematic layers were integrated and analysed in a GIS environment using ARCINFO (10.1 version) to derive the final map. The scheme of giving weightages in the study is shown in Table 5.

Parameter	Ranks (in %)	Classes/Units	Weight
Lithology	20	Sandstone	8
		Siltstone & Shale	2
		Gravel, Sand & Silt	9
		Clayey Sand	5
Land Use / Land Cover	15	Dense Vegetation	8
		Sparse Vegetation	7
		Scrubland	5
		Built-up	2
		Water body	9
Slope [in degrees]	15	0 - 15	8
		15-25	7
		25-30	5
		30-35	3
		35-40	2
		40-45	1
		45-60	1
		> 60	1
Structure/ Lineaments	25	Length of Buffer distance on either side	8
Geomorphology	25	High Struct. Hills	1
		Medium Struct. Hills	3
		Low Struct. Hills	5
		Valley Fill	9
		Flood Plain	9

Table No.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 112.88 sq. km., and forms 8.17per 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 297.40sq. km., and forms 21.52per 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 is, 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 457.09sq. km., and occupies 33.07per 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 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 514.63sq. km., which is 37.24 per cent of the total study area.

Table 6: Ground Water potential zones and area covered

Sl No.	Potential Zones	Area (Sq.km)	Percent
1	Very Good	112.88	8.17
2	Good	297.40	21.52
3	Moderate	457.09	33.07
4	Poor	514.63	37.24
Total		**1382.00**	**100**

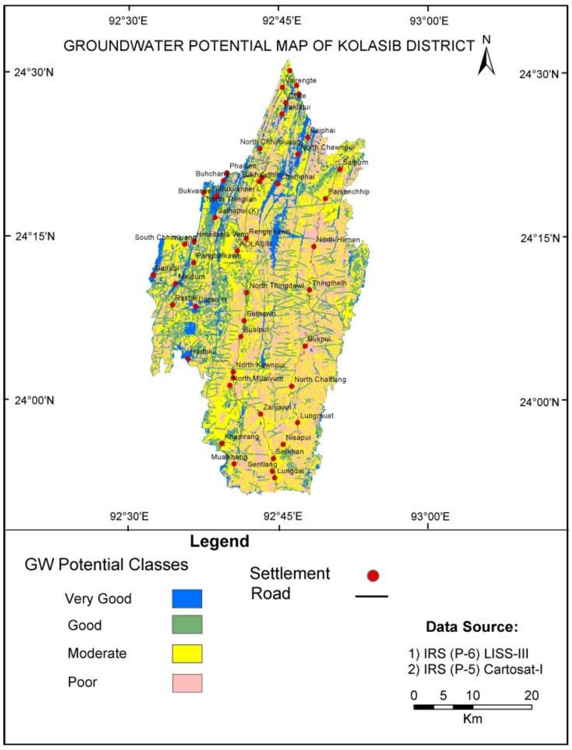

Figure 6: Groundwater potential map of Kolasib district

Conclusion

The present study has proven that geo-environmental factors like land use/ land cover, slope, geomorphology, lithology and geological structure are directly associated with the occurrence of groundwater, and form vital parameters for selecting suitable areas for groundwater exploitation. The study also shows that remote sensing and GIS techniques can be utilized as vital tools in delineating groundwater potential zones.

The final map prepared through the present study shows detailed idea about groundwater potentiality of the area. This, can therefore, forms an important database for developmental activities, and also for identifying critical areas for implementing ground development and management programme,

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