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Delineation of Groundwater Recharge Zones in West Jaintia Hills District, Meghalaya, India

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Abstract: *Groundwater is an important natural resource as it serves as a source for potable drinking water. But due to population explosion and improper management, this resource is being depleting drastically. To overcome this problem, technological innovations like Geo-informatics and Remote Sensing are widely used for delineating the groundwater recharge zones. In this study, an attempt has been made to identify and delineate the groundwater recharge zone in parts of Nangbah-Nartiang, West Jaintia Hills District, Meghalaya using GIS and Remote Sensing. Various thematic layers such as geology, land use/land cover, lineament density and drainage density were generated. These thematic layers were extracted from Landsat ETM+ image, topographic sheet, digital elevation models and other secondary data source repositories. Based on Overlay Weighted Model, an influencing factor were assigned to each thematic layer and rank value was assigned to each feature within the thematic layer. The factor value ranges from 1-9, whereby the value 9 is given to a feature that has the maximum recharge capability and it goes in a descending order to a value 1. The groundwater recharge zone derived, have been classified into four classes of groundwater recharge zones as poor, low, moderate and good.*

Keywords: *Groundwater recharge zone, Thematic layer, Overlay Weighted Model, Geology, Land-use/ Land-cover, Lineament, Meghalaya.*

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I. Introduction

Groundwater is a dynamic and replenishable resource but its availability and occurrence is very limited. Ground water studies have become crucial not only for targeting groundwater availability zone, but also for monitoring and conserving it. Groundwater investigations through test drilling and stratigraphy analysis are the most reliable and standard methods but this approach is very costly, time-consuming and requires skilled manpower. However, with the emergence and application of Geo-informatics technology in the field of hydrogeology has proved to be a very useful tool for the assessment, monitoring and management of groundwater resources. Various thematic layers including geology, land use/ land cover, surface water bodies, used as indicators to demarcate the groundwater recharge zones. In the present study Geo-informatics technology is used to delineate groundwater recharge zone in and around Nangbah- Nartiang villages of West Jaintia hills district of Meghalaya with the help of different thematic layers that influence the groundwater occurrence.

II. Study area

Nangbah and Nartiang are two adjoining villages in West Jaintia Hills district, Meghalaya, the study area is bounded by North latitudes at 25°30' and 25°37' and East Longitudes at 92°11' and 92°17' (Figure 1). It is included in parts of Survey of India Topographic Sheet Numbers 83 C/2 and 83 C/6.

The climate of the study area is directly controlled by the southwest monsoon originating from the Bay of Bengal. The climate shows a variation from the warm, humid tropical to temperate climate. The climatic conditions vary from place to place due to wide differences in altitude. Therefore, according to the prevailing weather condition over the years, the area can be grouped into four conspicuous seasons namely winter season, pre-monsoon season, monsoon season and retreating season.(CGWB,2009)

The average annual rainfall in the area is 9793 mm for 2015, recorded at Rymphum seed farm in Jowai, headquarter of West Jaintia Hills district. The monthly maximum rainfall of 2864 mm was recorded in June at the same rain gauge station. (Department of Agriculture, Meghalaya)

The drainage pattern is sub-parallel to parallel. The drainage system of the area is controlled by topography and structural elements. It is being controlled by joints and faults as indicated by the straight courses of the rivers and streams with deep gorges.

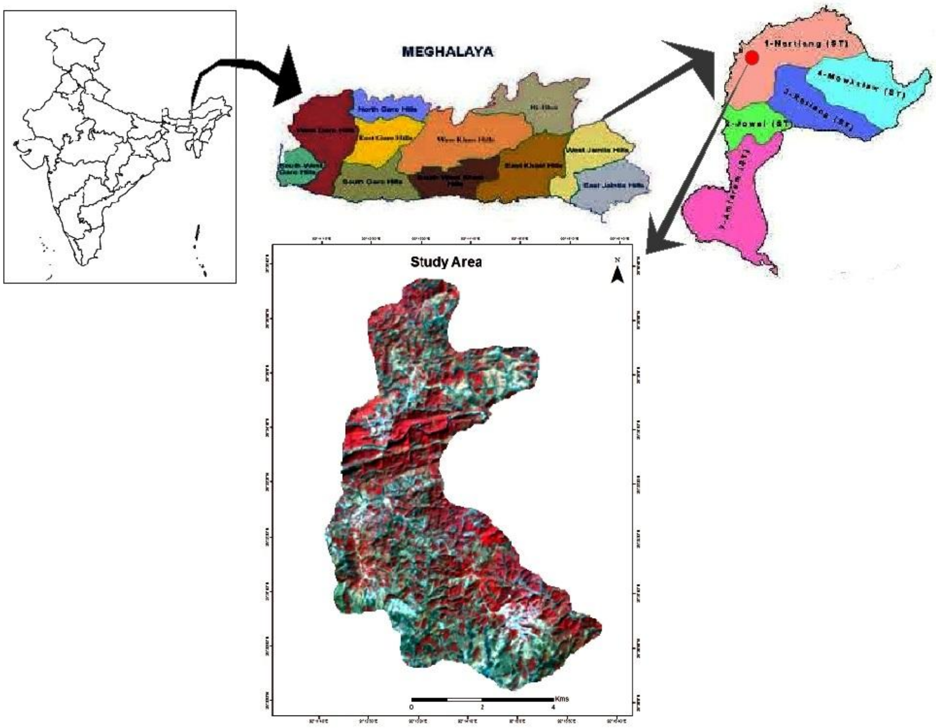


Figure 1: Location map of Nangbah-Nartiang region

III. Materials and Methodology

The occurrence of groundwater is an interdependent phenomenon where multiple parameters such as geology, geomorphology and slope, governs the rate of infiltration and storage potential. In the present study the thematic layers such as Geology, Slope, Land-use/land-cover, Lineament and its Density, Drainage and its Density were demarcated using Arc GIS 10.3. After preparing the layers, the layers were converted to raster format before running the Overlay Weighted technique. Since each of the thematic layers where interdependent for groundwater recharge factor, a conceptual graph of interrelationships (figure 2) was made. Based on this graph an influential factor was generated for each thematic layer. A major interrelationship between two factors is assigned a weight of 10 whereas a minor interrelationship between two factors is assigned a weight of 5. Finally, the total influential factor of each layer is the representing weight into the number of major/ minor interrelationship. For example, in land use/ land cover, the major interrelationships exist for drainage and the minor relationships exist for geology, lineament and slope. Therefore, its evaluated weight is 25 {(1*10) + (3*5)=25}. The higher the influencing factor higher is the influences on groundwater recharge. Table 1 shows the process for determining the relative influencing factor of each thematic layer.

Table 1:

Thematic layer	Calculating Process	Influencing factor
Geology	3 *10(major)	30
Land use/ Land cover	1*10(major) +3*5(minor)	25
Lineament Density	2*10 (major)	20
Slope Gradient	1*10 (major) + 1*5(minor)	15
Drainage Density	1*10(major)	10
Sum		100

A rank value was assigned to each feature based on the knowledge upon their significance to groundwater recharge. The division standard of Shaban et al. (2006) and Yeh et al. (2009) was used to define the weight division standard of every recharge factor in the study area, as shown in Table 1. In this study a rank value of 1-9 was considered, the higher the influence of the feature the higher is the rank value. The distribution of the weighted factor is shown in Table 1 and the framework used for methodology is given in Figure 3.

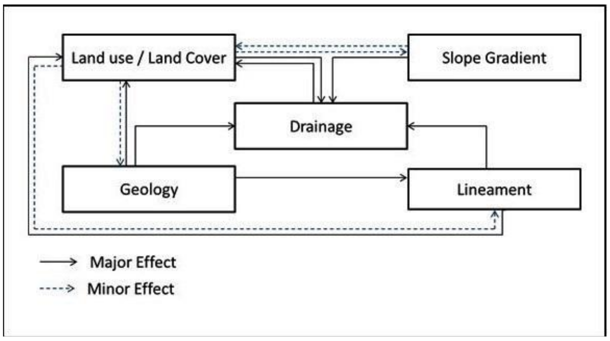


Figure 2: The interactive influence of factors concerning the recharge property (modified after Shaban et al. 2006)

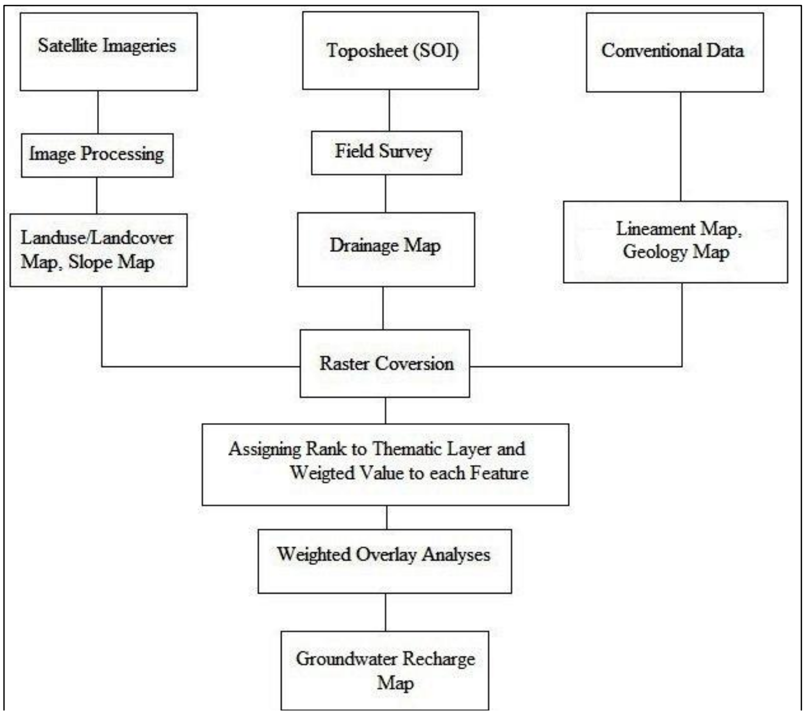


Figure 3: Framework used for methodology

Table 1: Distribution of the Weighted Factor

Thematic Layer	**Influencing Factor (f)**	**Feature**	**Rank (r)**	**Weights (w=f*r)**
Geology	30	Ferrigenous, Sandstone, Clay, Pebble, Coal	9	270
		Phyllite	7	210
		Quartzite, Phyllite, Shales, Quartz, Sericites, Schist	5	150
		Porphyritic Biotite Granite	3	90
		Migmatite	1	30
Land-use/Land-cover	25	Water body	7	175
		Agricultural Land	5	125
		Forest	2	50
		Settlement	1	25
Lineament Density (km/km^2)	20	1.26-1.70	9	180
		0.76-1.25	8	160
		0.56-0.75	6	120
		0.26-0.55	5	100
		0.05-0.25	3	60
Slope Gradient (°)	15	1-9	9	135
		10-18	8	120
		19-27	6	90
		28-36	4	60
		37-45	2	30

Drainage Density (km/km^2)	10	241-300	8	80
		181-240	6	60
		121-180	5	50
		61-120	3	30
		0-60	2	20

IV. Results and Discussion

4.1 Geology

The geology of the area was extracted from geological maps of 1:50000 scale (GSI, NER, 2013-14). The geological map is shown in Figure 4 (a) and its geological units found in the area are:

a) Ferrigenous Feldspathic Sandstone, Limestone, Clay, Pebble, Coal- Jaintia group- Palaeocene
b) Porphyritic Biotite Granite-Mylliem Granitoid group- Neo proterozoic
c) Phyllite- Shillong group- Palaeoproterozoic
d) Quartzite, Phyllite, Shale, Quartz, Sericite, Schist- Shillong group- Palaeoproterozoic
e) Migmatite- Assam Meghalaya Gneissic Complex-Archaen

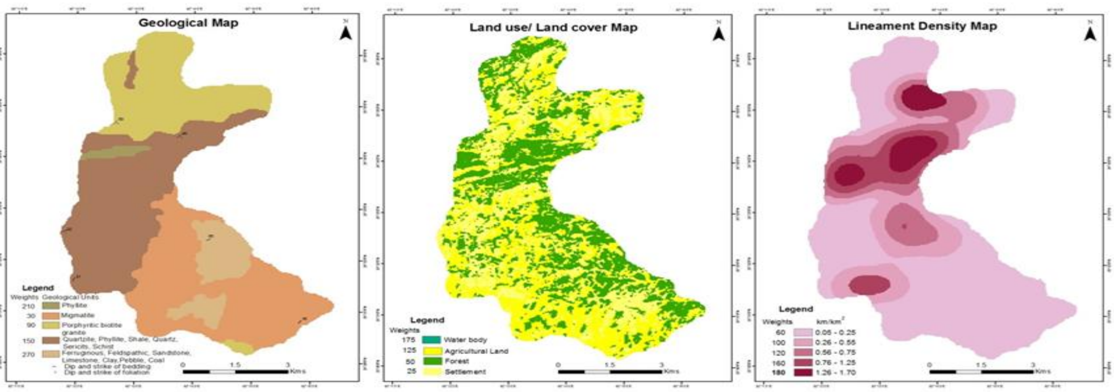
The type of rock exposed significantly affects groundwater recharge ability (Shaban et al. 2006). Lithology affects the groundwater recharge by controlling the percolation of water flow (El-Baz and Himida 1995). The Quartzite, Phyllite, Shale, Quartz, Sericite, Schist covers about 32.56 % (15.38 Km^2) of the total area; secondly 32.56% (14.60 km^2) is covered by Migmatite. The Porphyritic Biotite Granite covers 22.83 % i.e. 10.24 km^2 of the area. The Ferrigenous feldspathic Sandstone, Limestone, Clay, Pebble, Coal unit covers 3.99 km^2 of the area; the presence of ferrigenous feldspathic sandstone and clay gives maximum contribution to the recharge of groundwater when compared to other geological units. Phyllite covers the least area of about 1.34% out of the total area.

4.2 Land use/ Land cover

Land use/land cover is a significant factor affecting the recharge zone for groundwater. This factor involves a number of elements but the major ones are the soil deposits, human settlements and vegetation cover. The human settlement has a definite role in retarding the recharge process. Man-made constructions, such as concrete embankments, buildings, hangars, roads, etc. create a compacted terrain that seals the ground surface, thus preventing water to recharge easily (Bou Kheir et al. 2003). The land use/ land cover is classified to four groups which is mainly composed of forest land (35.08%), settlement (31.44%), agricultural land (28.32%), and river channel (2.32%). The map of land use and cover of the study area are shown in figure 4(b).

4.3 Lineament Density

A lineament is a linear feature in a landscape which is an expression of an underlying geological structure such as a fault. O'Leary et al. defined lineaments as the simple and complex linear properties of geological structures, such as faults, cleavages, fractures, and various surfaces of discontinuity, that are arranged in a straight line or a slight curve, as detected by Remote sensing. These structures are important in rocks as it influences weathering and groundwater movement (Travaglia and Dainelli, 2003). The lineament density map (figure 4(c)) was prepared using the line density tool in Arc GIS. The lineament density in the study area ranges from 0.05 to 1.70 km/km^2. The lineament density is high in the north and central part of the study area and it is directly proportional to the groundwater recharge zones.



(a) (b) (c)

Figure 4: (a) Geological map of the study area; (b) Land use/ Land cover map of the study area; (c) Lineament Density map of the study area

4.4 Slope Gradient

Slope plays a major role in groundwater occurrence. Slope gradient directly affects the infiltration capacity of rainfall. Steep slopes have comparatively less recharge potential as water flows rapidly over the surface and minimize the retention time of flowing water. Area with smaller slope serves as better groundwater recharge zone area due to relatively high infiltration rate. The slope gradient in the study area ranges from 0° to 45°. The slope map of the study area is shown in figure 5 (a).

4.5 Drainage Density

The extraction and analysis of the drainage network was carried out from topographic sheet (1:50000) of 83C/2 and 83C/6, Survey of India. Drainage density map was generated using density tool and the area is categorised to 5 categories depending on the density of the drainage. The drainage density map of the study area is shown in figure 5(b) and it ranges from 5.54 to 293.75 km/km^2.

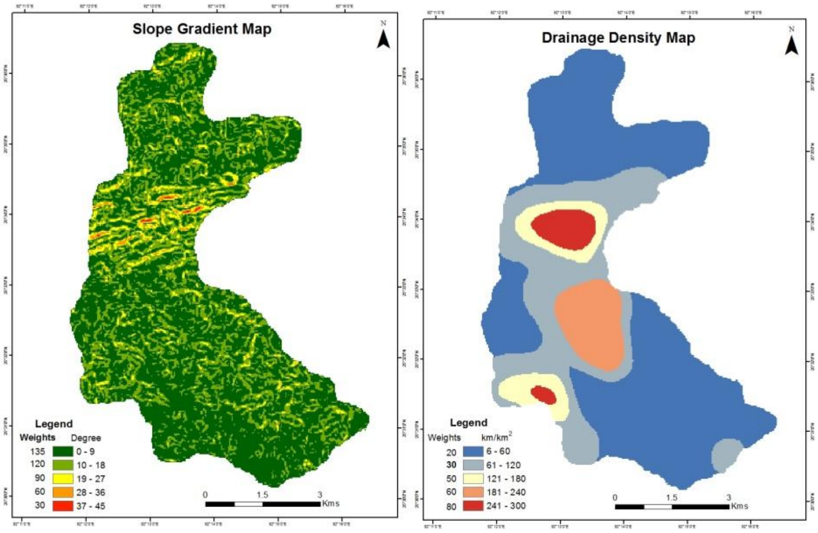


Figure 5: (a) Slope Gradient of the study area; (b) Drainage map of the study area

4.6 Groundwater Recharge Zones

In this study, the calculation for potential groundwater recharge zone was evaluated by the factors and rank accumulation which helps in generating a groundwater recharge potential score. The total weights of different feature in the thematic layer were computed using a weighted linear combination method as follows:

$$GR = GLfGLr + LDfLDr + LLfLLr + SGfSGr + DDfDDr$$

where GR is the groundwater recharge potential index; GL is the score of geology; LD is the score of lineaments density; LL is the score of land use/ land cover; SG is the score of slope gradient; DD is the score of drainage density and where the subscripts "f" and "r" refer to the influencing factor of a theme and the rank of individual features of a theme, respectively. The resultant index values were reclassified into four classes with groundwater recharge zone from poor to good owing to the grading method of equal intervals (Figure 6). This is attributed as: 160-330 (poor), 331-500 (low), 501- 670 (moderate) and 671- 840 (good).

After the overlay weighted analyses, resulted map has been classified into four groundwater recharge zones viz, poor, low, moderate and good occupying 21%, 32%, 23% and 24% of the total area respectively. The groundwater recharge zone map clearly indicates that the area with maximum lineament density has the highest groundwater recharge potential. The study area is composed of hard rocks such as Migmatites and Granites and the aquifers are usually the weathered zones at the contact with lineament /faults, and it was demarcated as good zone. Lineaments may also act as a conduit for groundwater movement which results in increased secondary porosity and therefore, can serve as groundwater recharge zone (Reddy et al. 2000). The study area faces acute water shortage during the winter season although it has the maximum rainfall (9793mm/yr). Thus it can be stated that with proper groundwater recharge and management such water shortages can be overcome.

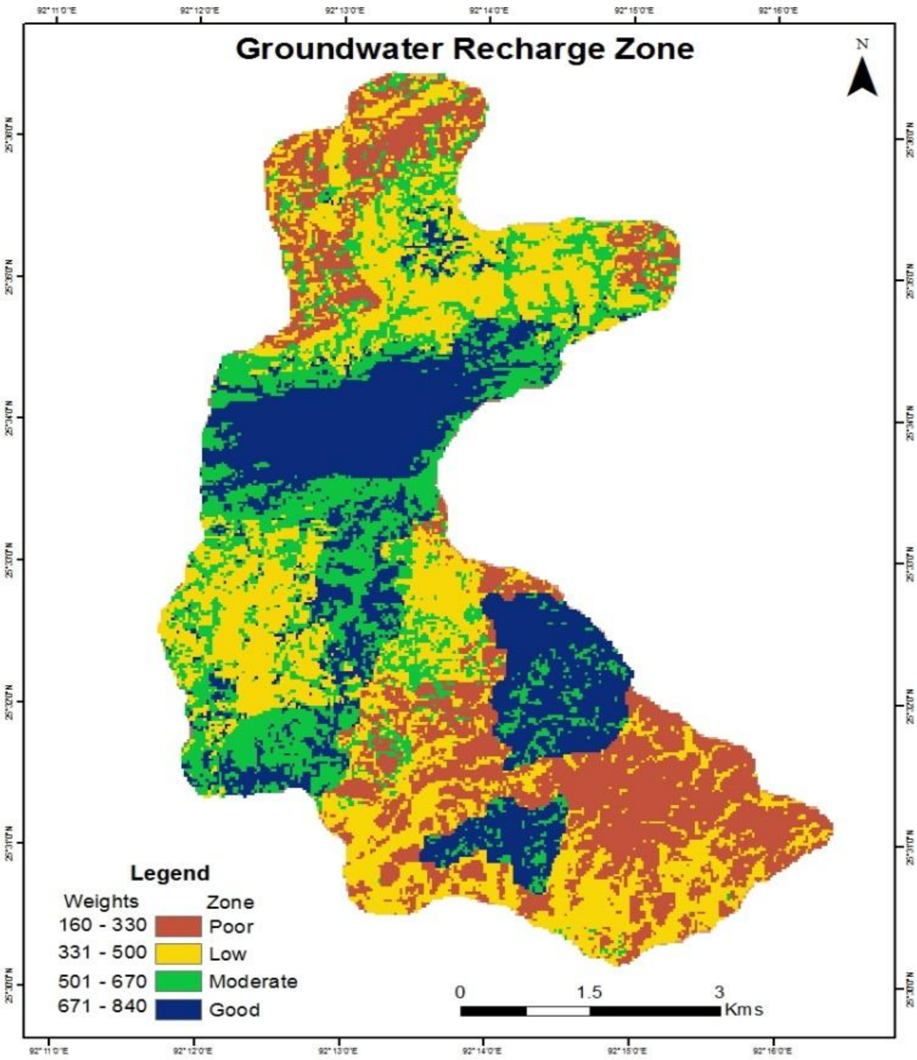


Figure 6: Ground water recharge zones of study area

V. Conclusion

The groundwater recharge map serves as a base map for groundwater extraction, recharge and management. In the study, we have mainly uses surface features including geology and slope gradient and hence it may also be helpful in delineating the shallow aquifer systems. Further, the delineated recharge zones may replenish the ground water resources during the rainy season and hence needs to be protected. The augmented ground water resources can be utilized during the dry periods. Since the study area faces acute water shortage during the winter season, proper recharge zonation and management of the area for ground water extraction can help solve this problem.

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