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Spatial Distribution of Groundwater Potential in a Rural Sub-watershed using GIS

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Abstract- Groundwater is a natural, dynamic, and replenishment resource. Spatial identification of groundwater prospects is required for sustainable groundwater management. This paper deals with the spatial distribution of groundwater potential in the upper Manimuktha sub-watershed of Tamilnadu, India. Toposheets and IRS imageries were used for preparing various thematic maps viz: soil, land use/cover, slope, runoff, geology, geomorphology, hydrologic soil groups, lineament density and drainage density maps. Based on the parameters influencing the groundwater recharge, the parameters were weighted, ranked and integrated by ArcGIS software and finally the groundwater potential areas were generated and delineated as high, moderate, less and poor areas of 10.86%, 37.93%, 35.11% and 16.10% respectively. Sustainable artificial groundwater recharging methods are recommended to develop the poor and the less groundwater potential areas.
Keywords: Watershed, Groundwater, Thematic maps, RS, ArcGIS

1. INTRODUCTION

Due to the uneven distribution of rainfall, surface water resource for irrigation engaged the development of groundwater resource which is a hidden natural resource [1,2]. The usage of groundwater was raised from 10-20 km^3 for every prior year 1950 to 240-260 km^3 by 2000 [3]. The groundwater potential varies from place to place and even within the same geological formation [4]. Further, the indiscriminate exploitation of groundwater has led to decrease in groundwater assets and quality. So it is necessary to identify the groundwater potential and develop it sustainable. Several methods are employed to delineate the groundwater potential zones such as geological, hydro-geological, geophysical, remote sensing techniques, etc. The main advantage of Remote Sensing (RS) technique is to cover large areas and access even in inaccessible places. Many researchers have reviewed the technique of RS and GIS for surveying, checking and generating groundwater potential maps [5-13]. The scope of the study is to sustain the use of groundwater more effective for agricultural and non-agricultural activities. The objective of this study is to identify the spatial distribution of groundwater potential in the upper Manimuktha sub-watershed in Tamilnadu, India.

2. STUDY AREA

The study area is upper Manimuktha, a rural sub-watershed (Fig.1) in Villupuram district of Tamilnadu, India. It extends from 78°43'9.22''- 78° 59' 21.73" E to 11° 46' 12.80''- 11° 53' 42.38'' N of toposheets 58 I/9 and 58 I/13. The western part is covered by Kalrayan hill (85.761 km^2) and the rest is almost plain area (165.390 km^2). Agriculture is the main source which depends on groundwater.

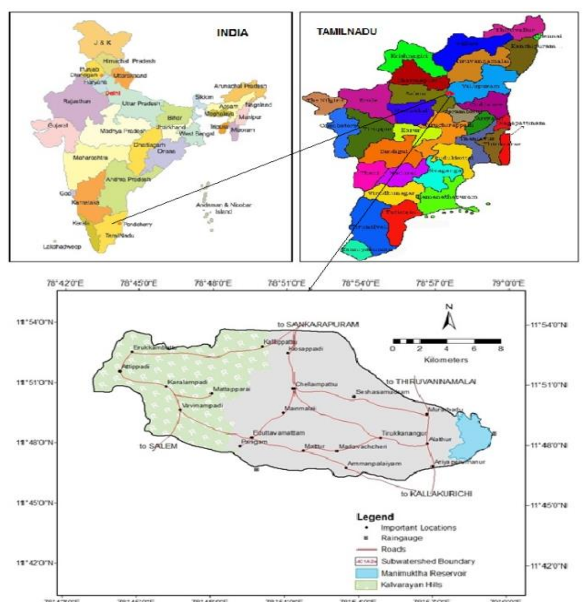

Fig.1. Study area map

3. METHODOLOGY

In this study the following data are used (Fig.2)

- Base map of the study area (Source: IRS, Anna University, Chennai).
- Remote sensing data (Source: IRS, Anna University, Chennai)
- Soil and Geology data (Source: Geological Survey of India)
- Hydrologic Soil Group and Runoff data (Source: NRCS-CN method, Ministry of agriculture, India)

According to the influence of groundwater recharge, the weightage of data were assigned as in the Table 1 and overlaid by ArcGIS software.

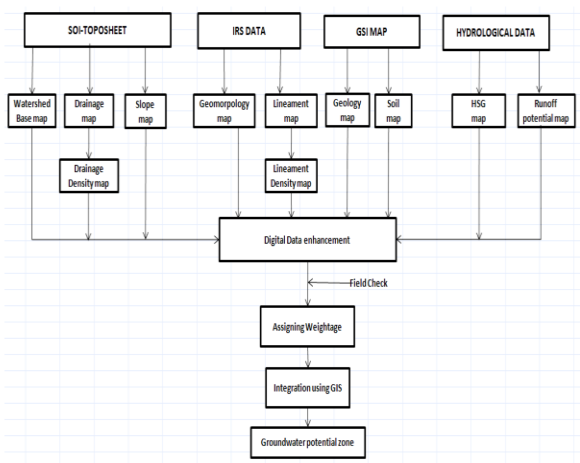

Fig.2. Flow chart shows the methodology

3.1. Geology

The study area is mainly underlain by charnockite type hard rock and others are metaggabbro, pyroxenite, pyroxene granulite, ultrabasic, and hornblende-biotite gneiss rocks (Fig.3). Recharge of groundwater is moderately in gneiss types compared to charnockite rock. [8-10] pointed out that the groundwater recharge mainly depends on the porosity and permeability of fracturing of underlain rocks which exposed to the surface.

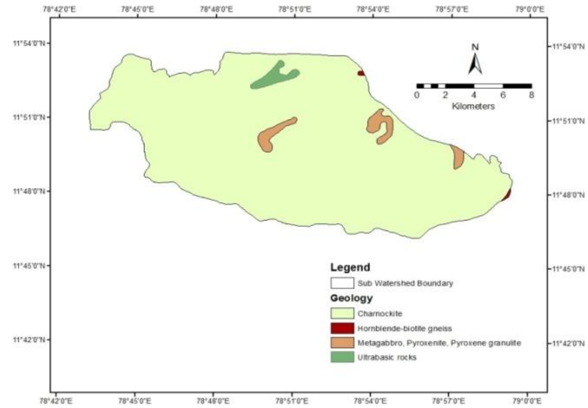

Fig.3. Geology map

3.2. Geomorphology

Valley floor, ridge type structural hills, upper piedmont slope, dome type residual hills, linear ridge/dyke, inselberg, shallow buried pediment and weathered, moderately weathered buried pediment, pediplain canal command and water body mask are the geomorphic units in the study area (Fig.4). The good groundwater prospects are along the pediplain and weathered areas.

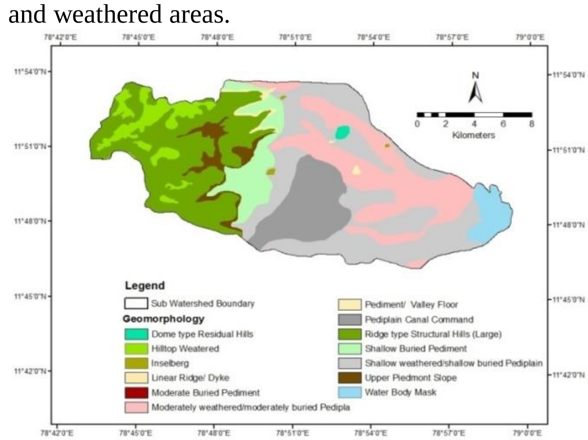

Fig.4. Geomorphology map

3.3. Soil

Soil is important for agricultural development activities, and also determining the recharge and quality parameters of groundwater. Alfisols, entisols, hillsols, reserve forest, inceptisols, and vertisols are the main types of soil in the study area (Fig.5). Vertisols soil has more favor for groundwater recharge.

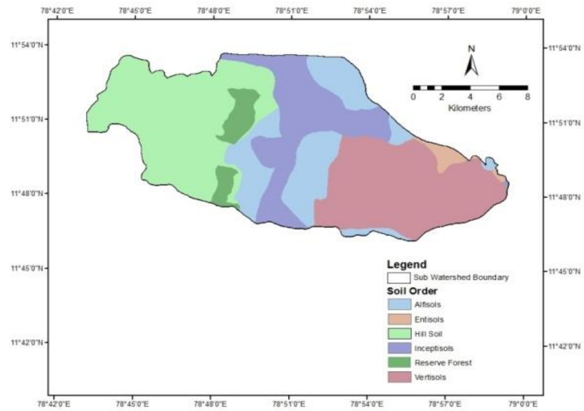

Fig.5. Soil map

3.4. Hydrologic Soil Group

Based on the soil texture, hydrologic soil groups (HSG) A, B, C and D are identified in the study area (Fig.6). Group A type soil has high infiltration and good recharging rate of surface water, whereas D type has very low infiltration soil group.

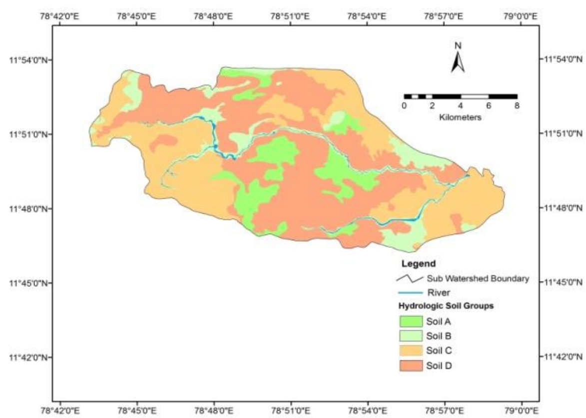

Fig.6. Hydrologic soil group map

3.5. Drainage Density

Most of the drainage originates from the Kalrayan hills in the western part of the study area. The drainage pattern is generally dendritic to sub-dendritic (Fig.7). Drainage density=LWS/AWS, where LWS = total length of streams in the sub-watershed and AWS = area of the sub-watershed. Lesser the drainage density is the probability of higher recharge or potential of groundwater.

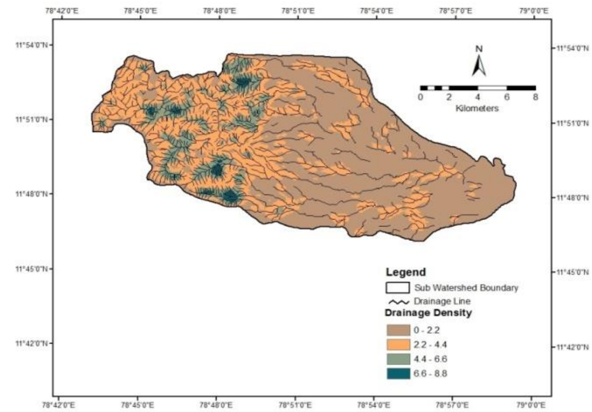

Fig.7. Drainage Density map

3.6. Lineament Density

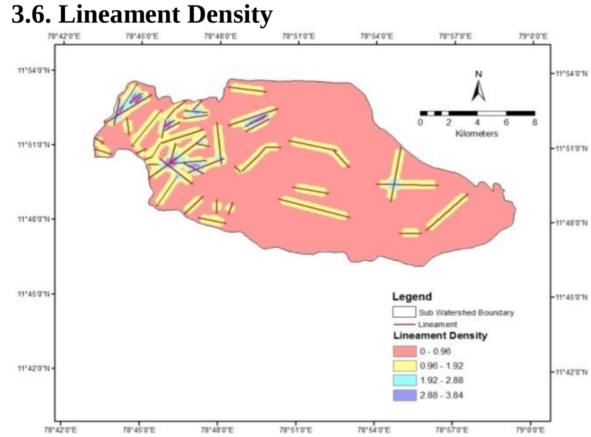

Fig.8. Lineament Density map

The directions of the lineaments are NW–SE and NE–SW. Faulting and Fracturing of hard rock terrains increases the secondary porosity and permeability which are good for groundwater recharge [11,12]. The lineament density map was prepared by ArcGIS software (Fig.8). Therefore, high lineament densities are more favored for groundwater potential.

3.7. Slope

The gradient is one of the factors that directly influence the infiltration of surface runoff [13]. Slope varies from 0 to more than 55% (Fig.9). Most of the study area occupies the very flat slope of 0-5% except hilly terrain. The hilly region indicates more surface runoff and no infiltration to groundwater.

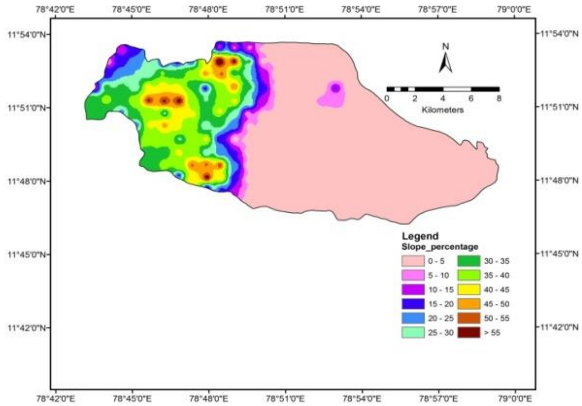

Fig.9. Slope map

3.8. Land use/cover

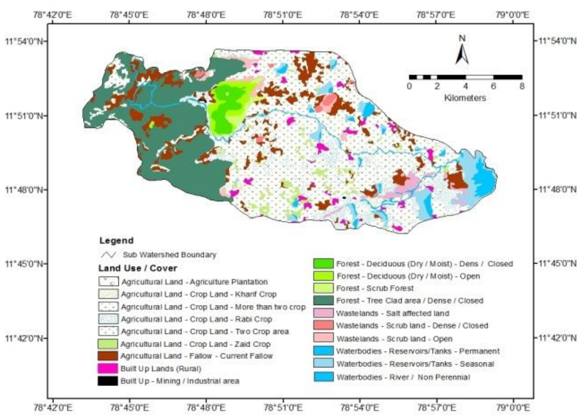

Fig.10. Land use/cover map

Due to changes in land utilization and vegetation, the groundwater level and the amount of recharge are changed [14]. Different land use/cover classes (Fig.10) were weighted based on their water requirement. The agricultural fields have more groundwater potential because of their regular irrigation and infiltration capacity.

3.9. Runoff

By integrating the HSG, land use/cover, hydrologic condition and antecedent moisture conditions (AMC), the curve number (CN) map of the study area was generated by ArcGIS software [15]. The weighted CN for AMC II condition of the study area was ranged from 59 to 89 (Fig.11 and 12). A high CN means high runoff and low infiltration, whereas a low CN means little runoff and high infiltration.

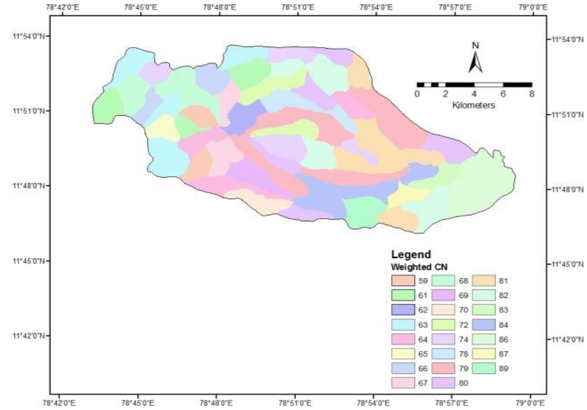

Fig.11. Curve Number map

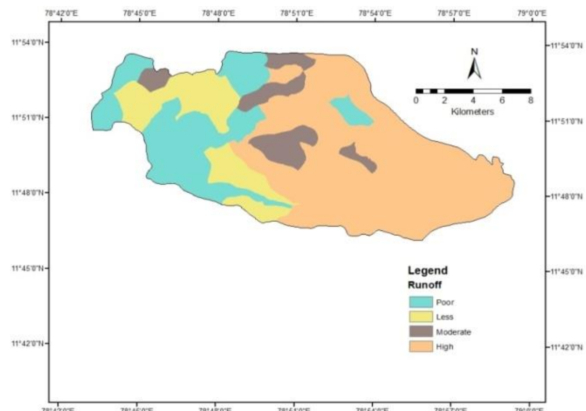

Fig.12. Runoff potential map

4. RESULTS AND DISCUSSION

All thematic maps were superimposed by weighted overlay method using ArcGIS software (Table 1). Based on the groundwater potential, the entire study area was categorized into four groundwater potential areas such as high, moderate, less and poor (Table 2 and Fig.13). High groundwater potential means the parameters of the layers are significantly good influence to groundwater recharges and potential. This study revealed that high potential areas of 27.271 km^2 (10.86%) were found in plain areas due to the presence of highly fractured and weathered rocks; moderate potential areas occupy 95.256 km^2 (37.93%) which are mostly in the plan region; less potential areas spread over an area of 88.172 km^2 (35.11%) and fall in the hills and the plain region; poor groundwater potential areas of 40.452 km^2 (16.10 %) are confined mostly in hilly terrain which acts as high runoff and the regions where more withdrawal of groundwater takes place.

Groundwater Potential = Geology + Geomorphology + Soil + Hydrological soil group + Drainage density + Lineament density + Slope + Land use/cover + Runoff

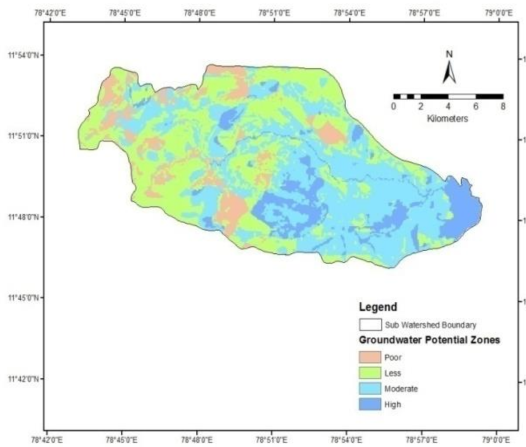

Fig.13. Groundwater Potential map

Table 2 Spatial Distribution of Groundwater Potential

Groundwater Potential	**Area** in km^2	**Area** in %
High	27.271	10.86
Moderate	95.256	37.93
Less	88.172	35.11
Poor	40.452	16.10

5. CONCLUSION

The study area falls in the poor to the high groundwater potential area. After conducting site suitability investigation, the agricultural oriented artificial groundwater recharging methods are recommended in the poor and the less groundwater potential areas. Hence, RS and GIS are very efficient techniques for identifying the spatial distribution of groundwater potential. The groundwater potential map could be useful for sustainable groundwater development.

Table 1 Rank and weightage of different parameters for groundwater potential

Criteria	**Classes**	**Weightage**	**Rank**	**Groundwater Prospect**
Geology	Charnockite		1	Poor
	Metaggabbro, Pyroxenite, Pyroxene granulite	18	2	Less
	Ultrabasic rocks		3	Moderate
	Hornblende-biotite gneiss		4	High
Geomorphology	Residual hills, Linear ridge, Inselberg, Valley floor, Structural hills, Upper piedmont slope		1	Poor
	Shallow buried pediment, weathered	13	2	Less
	Moderate buried pediment, weathered		3	Moderate
	Water body mask, Pediplain canal command		4	High
Soil	Hill soils		1	Poor
	Inceptisols, Reserve Forest	12	2	Less
	Alfisols, Entisols		3	Moderate
	Vertisols		4	High
Hydrologic Soil Group	A		4	High
	B	7	3	Moderate
	C		2	Less
	D		1	Poor
Drainage density	6.60-8.80		1	Poor
	4.40-6.60	8	2	Less
	2.20-4.40		3	Moderate
	0.00-2.20		4	High
Lineament density	0.00-0.96		1	Poor
	0.96-1.92	10	2	Less
	1.92-2.88		3	Moderate
	2.88-3.84		4	High

Slope in %	>15		14	1	Poor
	10-15			2	Less
	5-10			3	Moderate
	0-5			4	High
Land use/cover	Scrub, Waste, Barren lands		8	1	Poor
	Deciduous forest, Tree clad area			2	Less
	Plantation, Fallow lands			3	Moderate
	Water bodies, Agricultural lands			4	High
Runoff	<66	Poor runoff	10	4	High
	66-70	Less runoff		3	Moderate
	71-75	Moderate runoff		2	Less
	>75	High runoff		1	Poor

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