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Application of Multi Influencing Factor (MIF) for Groundwater Potential Mapping in Varthur catchment area of Dakshina Pinakini River Basin, Karnataka

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Abstract: Groundwater is one of the most precious natural resources for the substance of life on the earth. The present study aims to assess the groundwater potential zones in the Varthur Catchment of Dakshina Pinakini River Basin, Karnataka using remote sensing, geographical information system (GIS) and multi influencing factors. The first step, the groundwater influencing factors such as drainage density, geology, slope, lineament density, geomorphology, land use / land cover and soil are generated using geospatial techniques. Each every theme is converted to raster format and assigning scores and weights computed from multi influencing factor (MIF) technique. Then, all the parameters are statistically computed and integrated to assess the groundwater potential zones in the study area. The output map is classified into five categories like very low, low, moderate, high and very high. The demarcated groundwater potential map is validated with the well location data using R-index method. The results will be useful for extraction and management of groundwater in the study area.

Keywords* — *Geospatial technology, MIF, R-index, groundwater potential, Varthur Catchment

I. INTRODUCTION

Groundwater is a vital natural resource available in the planet earth. Depending on its usage and consumption it can be a renewable or a non renewable resource. It is estimated that approximately one third of the world's population use groundwater for drinking (Nickson et al. 2005). Remote sensing based integrated studies were carried out in drought prone area of Dharmapuri district of Tamil Nadu (Anbazhagan, 1993). Krishnamurthy et al. (1996) have used remote sensing and GIS in diverse geological set up for the demarcation of groundwater potential zones in Kochang, Korea and Marudiyar river basin, in Tamil Nadu, India respectively. The GWPI (groundwater potentiality index) values are computed based on the corresponding GWFI values of the groundwater controlling parameters. Subba Rao et al. (1997) have used IRS -1B satellite data along with Survey of India topographic maps to generate hydrogeomorphology and to delineate groundwater potential zones.

The use of Remote Sensing technology involves large amount of spatial data management and requires an efficient system to handle such data. GIS integration analysis has successfully applied for mapping of fractured aquifer system in central part of Tamil Nadu for charactering the aquifer behaviors (Ramasamy and Anbazhagan, 1997). Lillesand and Kiefer (1994) defined GIS as a computer base system that can deal with virtually any type of information about features that can be referenced by geographical locations. This system is capable of handling both location data and attribute data about such features. Manap et al (2009) discussed the groundwater potential zone at upper part of Langat basin using index overlay method of GIS modeling. Geoinformatic technology has been successfully adopted for groundwater studies and sustainable development (Anbazhagan and Jothibasu, 2016a). Anbazhagan and Jothibasu (2016b) have derived groundwater sustainability indicators in the area of overexploitation of groundwater zone in Southern India. The main objective of the present study is to assess the groundwater potential zones in the Varthur Catchment of Dakshina Pinakini River Basin, Karnataka using remote sensing, geographical information system (GIS) and multi influencing factors.

II. STUDY AREA

The study area Varthur Lake is situated in the southern parts of the Karnataka State, between 12°48′24.52″ and 12°53′59.85″ North latitude and 77°24′59.95″ to 77°30′6.72″ East Longitude and spreads over a region of 241 sq.km (Figure 1). It gets precipitation from both upper east and the southwest storms with yearly aggregate precipitation of around 900 mm. Bengaluru city is for the most part depleted by part of the Arkavathi river catchment toward the west and South Pennar River toward the east. The versatility, presence and aquifer refill of groundwater

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event are dominated by the measure of weathering, fracture pattern, geomorphological setup and rainfall. The Bangalore urban district contains crystalline storm cellar, fundamentally gneisses and rocks meddled by essential dykes. These arrangements have been modified to laterite along the eastern edge of the city. The city is intensely reliant on groundwater for its household and commercial needs.

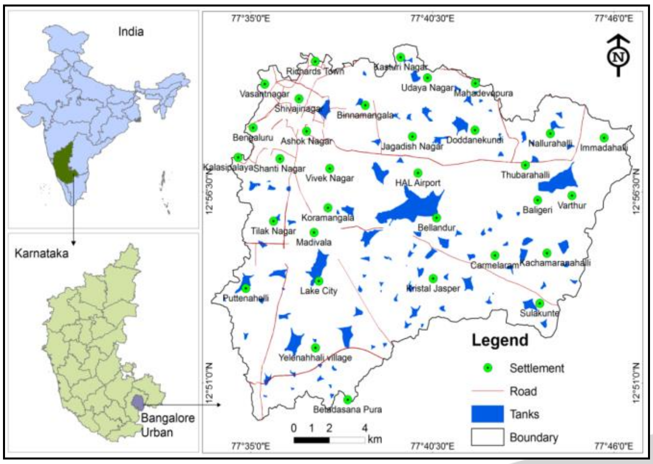

Figure 1: Location of the Varthur Catchment of Dakshina Pinakini River Basin, Karnataka

III. METHODOLOGY

The topographical map along with Landsat TM data, SRTM satellite image and secondary data is used for the preparation of groundwater influencing parameters such as drainage density, geology, slope, lineament density, geomorphology, land use/land cover, and soil. These thematic maps extracted through the digitization process were converted into raster format using the feature to raster tool in ArcGIS 10.2 software. The scores and weights for each influencing factor and sub-classes were assigned by using the multi-influencing factor (MIF) technique. Then all the thematic maps were integrated using the weighted overlay method in the GIS environment to identifying groundwater potential zones of the study area. The resultant map was validated with well location data using the R-index method.

3.1 Groundwater influencing factors

3.1.3 Land use / land cover

Land use and land cover is one of the important parameters for groundwater occurrences indirectly through infiltration, runoff, and evaporation. The presence of vegetation cover minimizes evaporation and runoff while it increases infiltration. Varthur catchment areas have been classified into water bodies, cropping land, built-up land and fallow/grass land features (Fig.2). These features were assigned rank and weight based on importance of groundwater occurrences.

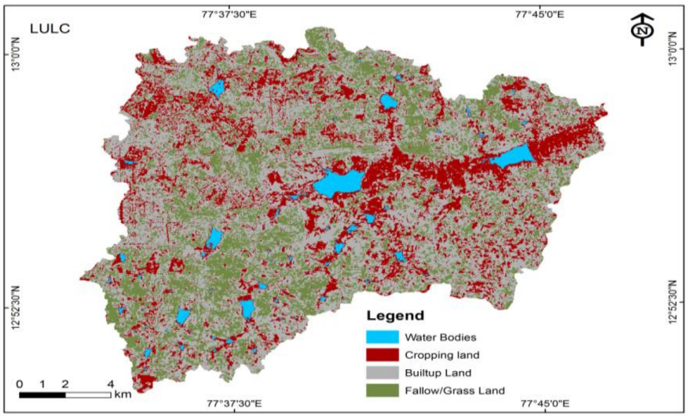

Figure 2: Land use / land cover in the study area

3.1.2 Geomorphology

Geomorphology is one of the essential components for understanding the landforms evolutions that control the movement and occurrence of groundwater (Raju thapa et al. 2017). The geomorphic features interpreted in the satellite data such as deep pediment, structural hill, residual hill, pediment inselberg complex, valley fill, moderate pediment and shallow pediment (Fig.3). Among these valley fill and pediments are good in groundwater potential.

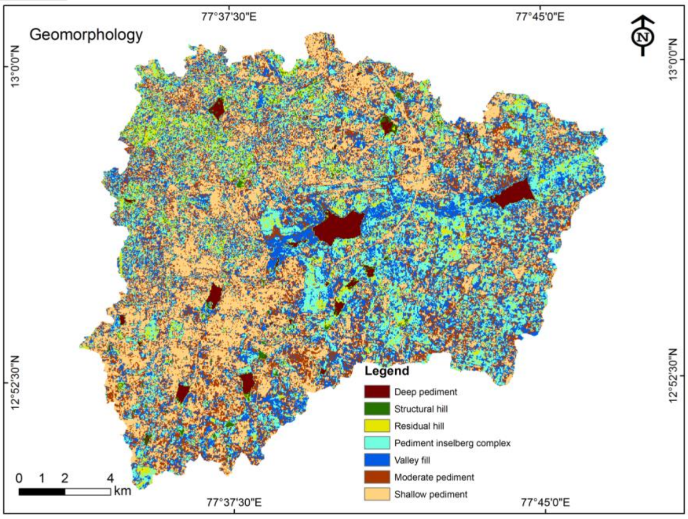

Figure 3: Geomorphological features in the study area

3.1.3 Aquifer thickness

Lithology plays a vital role in the distribution and occurrence of groundwater. The lithology affects both the porosity and permeability of aquifer rocks (Ayazi et al. 2010; Chowdhury et al. 2010). The rocks became aquifers through the development of weathering and fracturing and secondary porosity (Sener et al. 2005). In the context, aquifer thickness was taken from geophysical resistivity method (Fig.4).

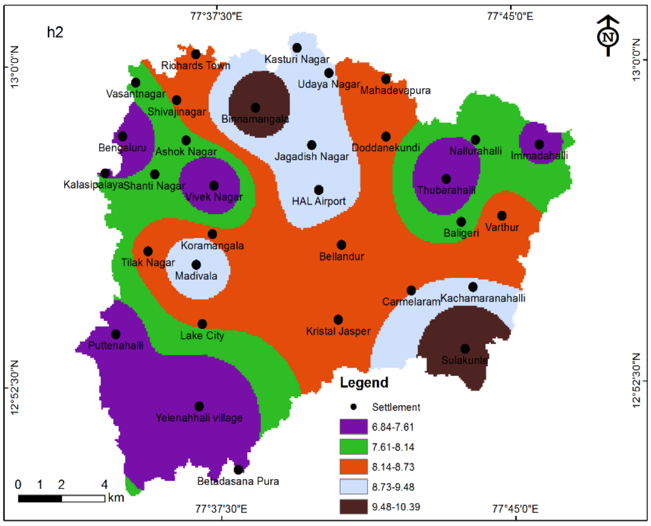

Figure 4: Aquifer thicknesses in the study area

3.1.4 Topographic Wetness Index (TWI)

There is a vital role for topography in the spatial variation of hydrological conditions such as soil moisture and groundwater flow. Therefore, the secondary topographic indices have been used for describing spatial soil moisture patterns (Moore et al. 1991). It has been widely used to explain the impact of topography conditions on the location and size of saturated source zones of surface runoff generation. Recently, TWI has been used for groundwater potential mapping (Davoodi Moghaddam et al. 2013; Nampak et al. 2014) and describing spatial wetness patterns (Pourghasemi et al. 2012a; Pourtaghi and Pourghasemi 2014). It is defined as (Moore et al. 1991):

$$TWI = ln\left(\frac{A_s}{tan\beta}\right) \quad (1)$$

where, A_S is the cumulative upslope area draining through a point (per unit

contour length) and

β is the slope gradient (in degree).

In this study, TWI map is grouped into four classes using quantile classification scheme (Tehrany et al. 2014) (Fig.5).

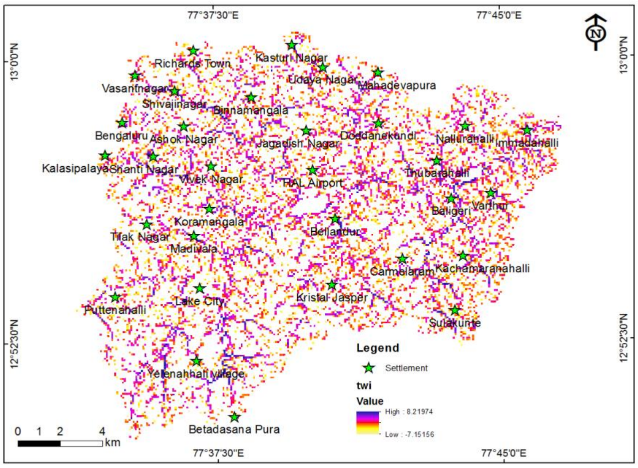

Figure 5: Topographic wetness index of the study area

3.1.5 Drainage density

Drainage density is the closeness of the spacing of stream channels. It is a measure of the overall length of the stream segment for all orders per unit area. The drainage map was interpreted from the survey of India's topographical map. From the drainage, the density was prepared using line density in spatial analysis tools in ArcGIS. The drainage density of the study area varies from 0 to 4.12 km/sq.km and reclassified into five classes by equal interval method and shown in Fig.6. The higher drainage density represents the good potential for groundwater prospects.

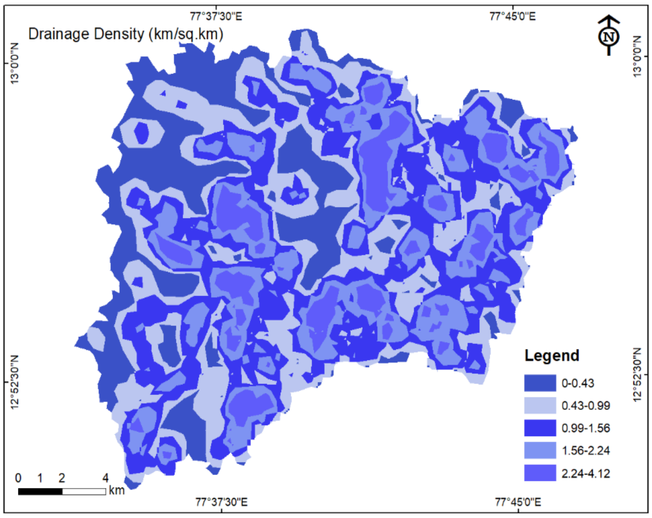

Figure 6: Drainage densities in the study area

3.1.6 Lineament density

Groundwater availability and flow directions depend upon the linear features such as drainages, linear vegetation, weaker plain, secondary porosity, and permeability. Remote sensing data provides the synoptic view of the large surface area which helps to understand the occurrence of lineament. Linear features spatial map prepared from Landsat TM data. The higher the lineament density is suitable for high groundwater prospecting. In the study area, lineament density varies from 0 to 186 km/sq.km shown in Fig.7. It is reclassified into five classes by equal interval method and given higher weight is assigned to 94.22-186.29 km/sq.km and least weight to 0-15.64 km/sq.km.

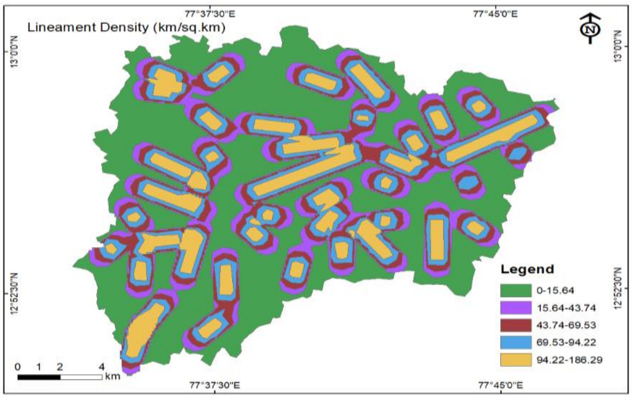

Figure 7: Lineament densities in the study area

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3.1.7 Slope

The slope is one of the important terrain parameters which affect the occurrence and movement of groundwater. Infiltration of the surface is directly influenced by the slope gradient. In the lower slope area, the surface runoff is slow and the infiltration rate is higher than the steeper slope. The slope map of the study area was prepared from an SRTM satellite image. The majority of the study area falls under the gentle slope category with a slope less than 0.77°. On the basis of the slope angle, the entire study area is divided into five classes such as 0-0.77, 0.77-1.37, 1.37-1.99, 1.99-2.80, and 2.8-6.59° and shown in Fig.8.

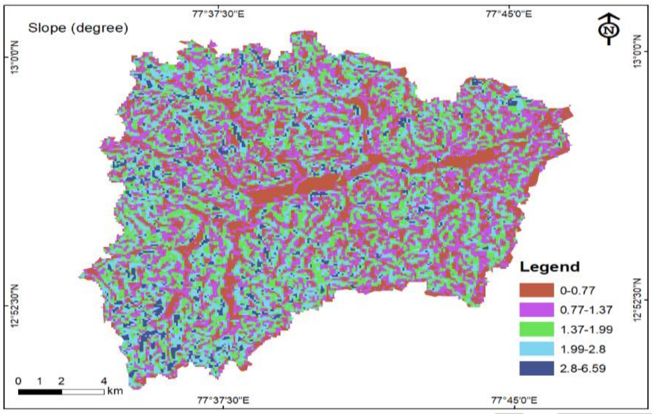

Figure 8: Slope (degree) in the study area

3.1.8 Elevation

The elevation is also one of the deciding factors which affect the availability of groundwater in any area. Elevation was created directly from the SRTM satellite image and classifies into five categories (854-879, 880-892, 893-905, 906-920, 921-959 m) based on an equal interval method and shown in Fig.9. Higher elevation areas had a higher runoff, whereas lower elevation area has more recharge and high infiltration.

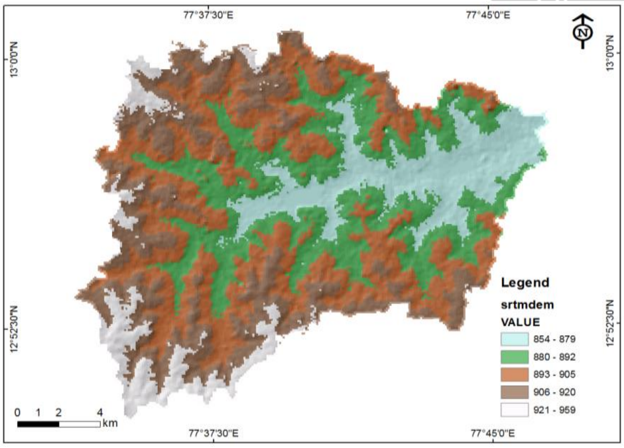

Figure 9: Elevation in the study area

3.1.9 Well location

The well location data were collected from the central groundwater board (CGWB) reports and extensive field surveys. The total numbers of well locations in the study area are 29 (Fig.10). These wells will be assigned for the validation purpose of the study results.

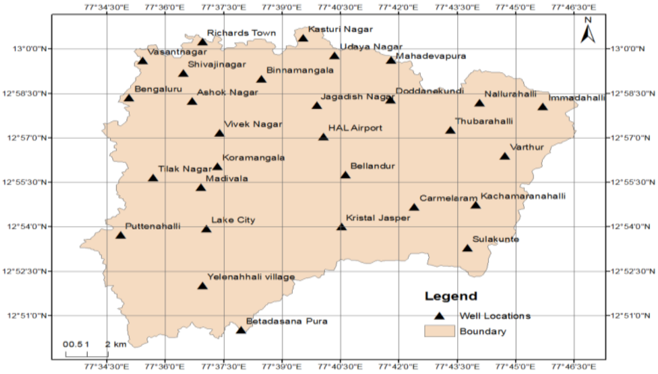

Figure 10: Well locations in the study area

3.2 Multi influencing factors of groundwater potential zones

A multi influencing factor is one of the multi-criteria decision-making techniques which are useful for analyzing unbiased decision making. The weights of each factor were determined using MIF techniques. According to the multi influencing factor technique, each influencing factor has some major and minor effects based on groundwater prospect. The interrelationship between these factors and their effect is shown in Fig.11. Factors having a major influence were marked as major effect and assigned a weight of 1.0 while minor influence was marked as minor effect and a weight of 0.5 was assigned as shown in Table 1 (Magesh et al. 2012). The combined proposed score of each influencing factor of the major and minor effects is computed out using Eq.2.

$$\text{Proposed score} = \left[\frac{(X+Y)}{\sum(X+Y)}\right] \times 100 \qquad (2)$$

Where X represents the major effect of factors and Y represents the minor effect of factors. The proposed score of each influencing factor reclassified to the subclasses (Table 2). For groundwater potential, weights were assigned for subclasses of each individual factor and are shown in Table 2. The proposed score of each individual factor is multiplied by the weights of subclasses.

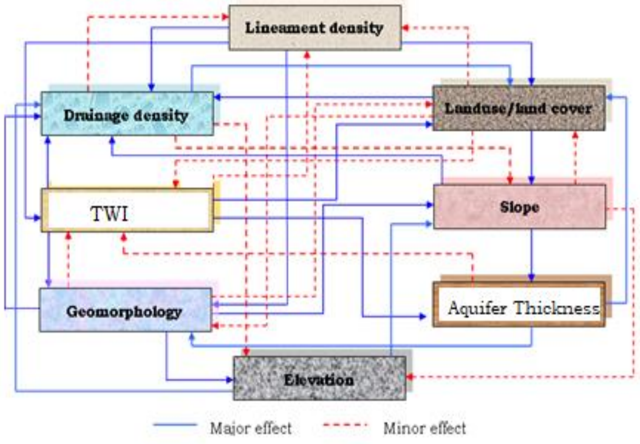

Figure 11: Multi influencing factors for groundwater potential zone mapping

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Table 1: Effect of influencing factor, relative rates and score for each potential factor

Factors	Major effect (X)	Minor effect (Y)	Proposed relative rates (X+Y)	Proposed score of each influencing factor
Land use / land cover	1+1	1.5	3.5	13
Geomorphology	1+1+1	1	4	15
Aquifer thickness	1+1	0.5	2.5	10
TWI	1+1+1+1	0.5	4.5	17
Drainage density	1	1.5	2.5	10
Lineament density	1+1+1+1	0	4	15
Slope	1+1	1	3	12
Elevation	1+1	0	2	8
Total			Σ=26	Σ=100

Table 2 Assigning weightage of sub class of influencing factors

Groundwater Influence factors	Sub-class	Rank	Weight	Score
Land use / Land cover	Water Bodies Cropping land Built-up land Fallow/Grass land	13 10 1 5	13	169 130 13 65
Geomorphology	Deep pediment Structural Hill Residual Hill Pediment inselberg complex Valley fill Moderate pediment Shallow pediment	15 2 1 5 13 14 12	15	225 30 15 75 195 210 180
Aquifer thickness	6.80-8.05 8.05-8.87 8.87-9.84 9.84-11.42 11.42-14.58	10 8 6 4 2	10	100 80 60 40 20
TWI	Very low Low Moderate High Very high	6 9 11 15 17	17	107 153 187 255 289
Drainage Density km/sq.km	Very low (0-0.43) Low (0.43-0.99) Moderate (0.99-1.56) High (1.56-2.24) Very high (2.24-4.12)	2 4 6 8 10	10	20 40 60 80 100
Lineament density km/sq.km	Very low 0-15.64 Low Low (15.64-43.74) Moderate (43.74-69.53) High (69.53-94.22) Very high (94.22-186.29)	2 3 5 7 10	15	30 45 75 105 150
Slope	0-0.80 0.80-1.39 1.39-2.00 2.00-2.76 2.76-6.59	8 7 5 4 1	12	96 84 60 48 12
Elevation	819-879 879-892 892-905 905-920 920-959	7 5 4 3 1	8	56 40 32 24 8

IV. RESULTS AND DISCUSSION

In this study, identification of groundwater potential zones in Varthur catchment all the thematic layers were assigned score and weights by using multi influencing factor techniques. All the layers were converted into raster format with 30m×30m grid cell size and multiplied with derived score and weights. The integrated output map produced from the weighted overlay analysis method using the equation in GIS software. Further, the result of overlay analysis has been classified into five classes as very high, high, moderate, low, and very low groundwater potential zones and shown in Fig.12.

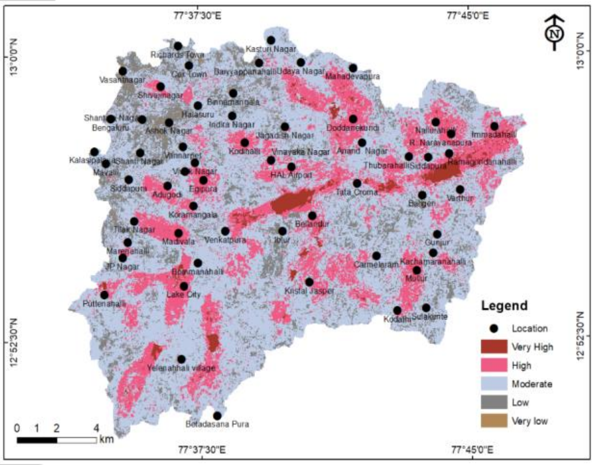

Figure 12: Groundwater potential zones in the study area

4.1 Validation

The potential map was verified using the distribution of well locations. For the verification, the R-index method was used. The R-index method is to evaluate the association between well location points and the groundwater potential map. The aim of validation is to evaluate the performance of the potential of the study area. The index is given by Baeza and Corominas (2001). The R-index as applied to the groundwater potential map is defined as follows:

$$R = (ni / Ni) / \sum(ni / Ni) * 100 \quad (3)$$

Where, ni is the number of wells in the potential class 'i' and

Ni is the number of cells occupying the same potential class

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The R-index for each potential class is represented in Table 3, and the graphical representation (Fig.13) points out the distribution of well locations observed in the classes, indicating the consistency of groundwater potential classes.

Table 3: R-index in groundwater potential zone map

Groundwater potential zones	Area (Sq.km)	Ratio	No. of Wells in class	Ratio	R-Index
Very High	6.62	2.35	2	6.90	30.21
High	61.53	21.81	11	37.93	17.88
Moderate	174.14	61.74	15	51.72	8.61
Low	38.68	13.71	1	3.45	2.59
Very Low	1.10	0.39	0	0	0

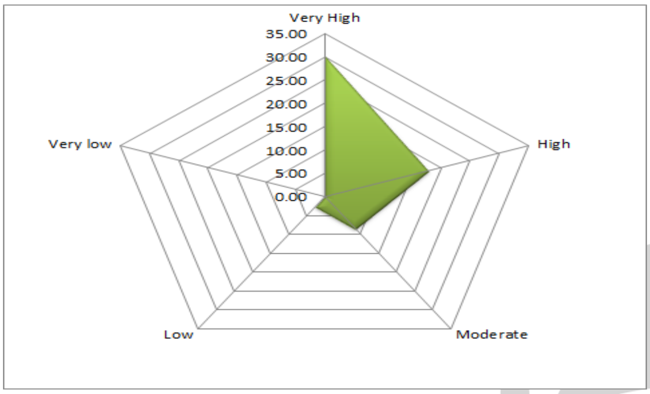

Figure 13 Graphical representation of R-index of groundwater potential zones

V. CONCLUSIONS

In this study, GIS-based MIF techniques were chosen to obtain spatially distributed groundwater potential zones in the Varthur catchment area. High lineament density, drainage density, and valley fill regions were also associated with good groundwater potential. Nearly, 24% of the total area falls from high to very high zones have good groundwater potential. The method outcomes acquired in this research were validated with the GW wells data using the R-index method. The validation of the results showed that the values of very high potential zones of 30.21. It was observed that the R-index increases with the level of the prediction rate. Therefore, based on the result and accuracy the study suggests this method would be suitable for exploring groundwater potential zones. The results of groundwater potential maps can be useful for planning for groundwater exploration, conservation, and management in the study area.

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