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Study on Landuse Pattern to Evaluate Groundwater Potential Zone for Bengaluru Urban Area Using RS &GIS Techniques

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Abstract: Water is the most precious gift of nature, most crucial for sustaining life and is required in almost all the activities of living beings. The scarcity of water increases day by day due to the rapid development of urbanization, natural calamity etc. This paper mainly deals with the integrated approach of Remote sensing and Geographical Information System (GIS) to delineate groundwater potential zones of Bengaluru urban District, Karnataka. The various thematic maps generated for delineating groundwater potential zones are geomorphology, geology, lineament density, drainage density, slope ,NDVI, and landuse/landcover (LULC) were generated using the resource sat (IRS P6 LISS IV FMX)data and survey of India (SOI) toposheets of scale 1:50000. All these themes and their individual features were then assigned weights according to their relative importance in groundwater occurrence and the corresponding normalized weights were obtained based on the Composite Suitability Index (CSI) "importance matrix" has been calculated for each composite unit by multiplying weightages with rank of each parameter and summing up the values of all the parameters. The thematic layers will be integrated using ARCGIS-10 software to identifying the overlay analysis & yield of the ground water potential zone map of the study area. From the overlay analyses of landuse Pattern ,Thus the different ground water potential zones are identified in to 5 classes namely 'good', 'good-moderate', 'moderate' , 'moderate-poor' and 'poor'.

Keywords: GWPZ, RS, GIS, ARCGIS, LULC, Composite Suitability Index (CSI), importance matrix, Weighted overlay
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1. INTRODUCTION

Water is one of the most essential commodities for mankind and the largest available source of fresh water lays underground. It is one of the most significant natural resources which support both human needs and economic development. Groundwater is gaining more and more importance in India owing to the ever increasing demand for water supplies, especially in areas with inadequate surface water supplies. More than 85% of rural and nearly 50% of urban population depend on the groundwater for drinking purposes, while, it accounts for nearly 60% of the total irrigation in the country (NARENDRA,2013). Satellite data provides quick and useful baseline information on the parameters controlling the occurrence and movement of groundwater like geology, lithology /structural, geomorphology, soils, landuse/cover, lineaments etc. The groundwater occurrence in a geological formation and the scope for its exploitation primarily depends on the formation of porosity. High relief and steep slopes impart higher runoff, while topographical depressions increase infiltration. An area of high drainage density also increases surface runoff compared to a low drainage density area. Surface water bodies like rivers, ponds, etc., can act as recharge zones, enhancing the groundwater potential in the neighbourhood (Karanth, 1987; Magesh et al., 2012; Venkatramanan et al., 2012).
Remote sensing provides multi-spectral, multi-temporal and multi-sensor data of the earth's surface. One of the greatest advantages of using remote sensing data for hydrological investigations and monitoring is its ability to generate information in spatial and temporal domain, which is very crucial for successful analysis, prediction and validation. Hence Landuse pattern and remote sensing data has been utilized for delineation of ground water potential zones in Bengaluru urban Area
This paper presents the result of a study to generate a groundwater prospect map by integrating landuse pattern with various thematic maps derived directly or indirectly from both remote sensing and conventional methods using GIS techniques.
The objectives of the present studied are:

- To prepare various thematic layers for the study corridor.
- To assign and compute weightage index & ranking analysis for the thematic layers based on the composite suitability index.
- To demarcate the Ground water potential zone of the study area based on the weightage calculated with more relevance to landuse pattern.

2. STUDY AREA

The study area falls under Bengaluru urban taluk, Southeastern part of Karnataka, lies between latitude is 12°39' 32"N - 13°18'13" N and longitude is 77°22'44"E - 77°52'13"E. The district is bounded in all the directions by Bengaluru rural district except in southeast, where the district is bounded by krishnagiri district of Tamil Nadu state which covers an area of 2190 sq.km. The district is divided into three taluks namely Bengaluru north, Bengaluru south and Anekal taluks and is very well connected to all parts of the country and to different parts of world through air ways (With newly built international Air port), railways and road ways. There are 699 villages in the district with 112 grama panchayats. It has a Population of 95, 88910. The average annual rainfall in the taluk is

1049mm, and also maximum rainfall received in the month of south-west monsoon season.

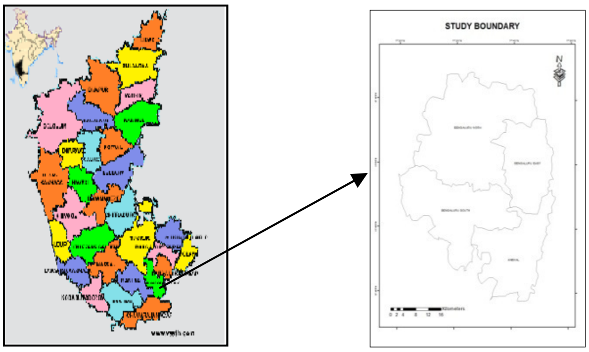

Figure 1: Location of the Study Area-Bengaluru Urban District

3.MATERIALS & METHODS

In order to delineate the ground water potential zone of the study area, a multiparametric dataset s was used. The details of the Primary & Secondary data used for this study are mentioned as follows

3.1Primary Data

SOI topographic maps which surveyed on 1975 (Major details were updated during 2007-09) are used for generation of base map and contour map & Drainage Map.

Table 1: Details of Toposheet(Sources:SOI,Bengaluru).

Toposheet No	Scale
D43R3,D43R4,D43R5,D43R6,D43R7, D43R8,D43R9,D43R10,D43R11,D43R12, D43R13,D43R14,D43R15,D43R16	1:50,000

The satellite data taken for this study are the multispectral Linear Imaging Self Scanning-IV (LISS-IV) sensor data of the RESOURCESAT I (IRS-P6) acquired on 21st December 2012.

Table 2: Details of Satellite Data (NRSC, Hyderabad)

Satellite used	RESOURCESAT-2(IRS –P6)
Sensor	L4FMX
Path/Row	100/64
Data Acquisition	21/12/2012

3.2 Secondary Data

The secondary data used are geology and Geomorphology map (1: 2, 50,000) which are needed for generation of Lithological features& Lineament features.

Table 3: Secondary Data Used

Existing Map	**Scale**	**Source**
Geology	1:2,50,000	Geological survey of India (GSI)
Geomorphology	1:2,50,000	Geomorphology Atlas of India
Geohydrological	1:5,00,000	CGWB, Bengaluru.
Soil	1:5,00,000	National Bureau of soil Survey & Landuse Planning.(ICAR)

3.3 Software Used:

The software used for this study includes

- ERDAS IMAGINE 9.1
- ArcGIS 10.1
-

3.4Methodology

In order to identify the ground water potential zone in the study area the primary and secondary data are used. The collected toposheets of study area were scanned, registered and mosaicked using Erdas imagine 9.1 software. Satellite data were collected pre-processed & geo-corrected with respect to registered toposheet. Secondary data were collected & geo-corrected with respect to registered toposheet. Contours from toposheet were digitized and digital elevation modal (DEM) for the study area was obtained. Thematic layers on geology, geomorphology, geohydrological, slope, aspect, drainage, lineament density, NDVI, Landuse/landcover are developed for the study area. The weight of each themes and individual features and its corresponding normalized weight were derived based on the composite suitability index. Maximum value is given to the feature with high ground water potentiality. These thematic layers were finally integrated using overlay analysis of landuse pattern the impact of the ground water potential zones of the study area were demarcated.

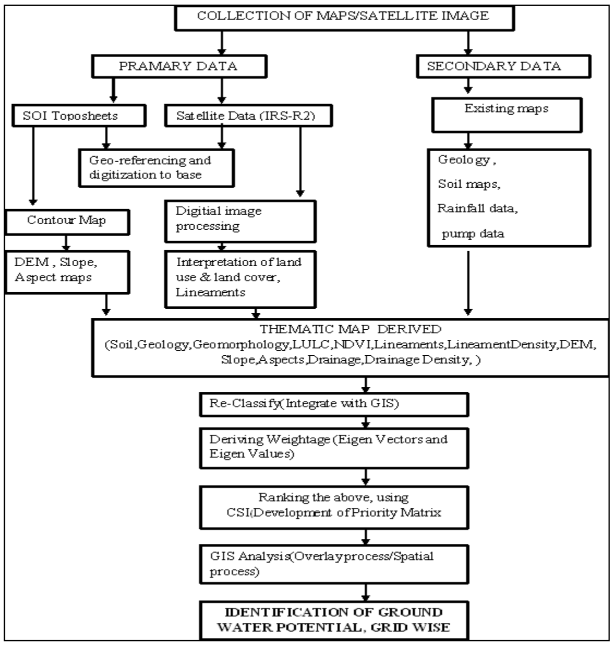

Figure 2: Flow chart showing methodology

Drainage Density Map

The drainage density map shows the flow of water throughout the study area.Drainage density is defined as total stream length per area . Drainage Density which indicates closeness of spacing of channels as well as the nature of surface material.More the density high would be the runoff.Drainage Density it is group in to 5 classes:0-0.6 km;0.6-1.0 km;1.0-1.47 km;1.47-1.97 km;1.94-3.20km.The suitability of groundwater potential zones is indirectly related to drainage density because of its relation with surface runoff and permeability.

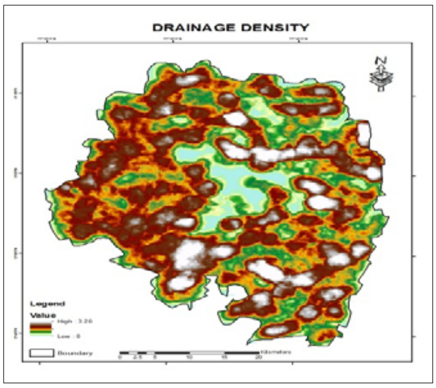

Figure 3: Drainage Density Map

Slope Map:

Slope is an important factor for the identification of groundwater potential zones into subsurface. Higher degree of slope results in rapid runoff. The contour ma (20 m interval) is generated from the SOI toposheet and the DEM (Digital Elevation Model has been derived from contour map. The slope has categorised in to 6 classes. (0-1%)- Nearly level; (1-3%)-Very Gentle; (3-5%)-Gentle; (5-10%)- Moderate; (10-15%)- Moderate Steep; (15-35%) - Steep; >35%- Very Steep.

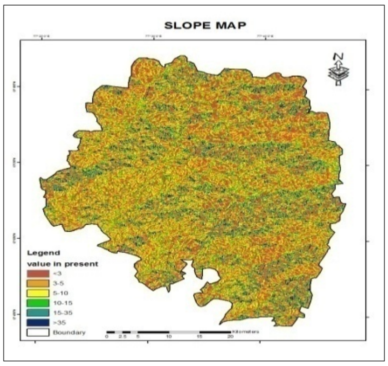

Figure 4: Slope Map.

Geomorphology Map:

Geomorphology map has been prepared from GSI geomorphological map (1:2,50000) by digitizing each feature as polygon in Erdas 9.1. This Area has divide in Denudational plateaus(75.25sq.Km); Valleyflat (8.89 sq.Km); Pediment /Pediplain(15.3 sq.Km); Denudational Hills(1.076 sq.Km).

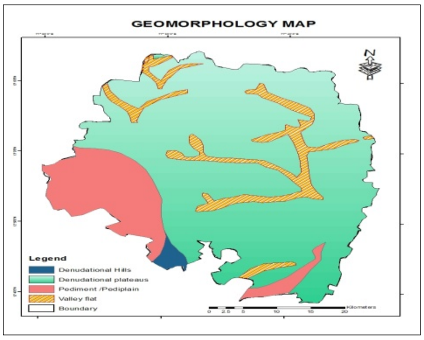

Figure 5: Geomorphology Map

Geology Map:

One of the most important requirement for ground water occurrence and flow is the geological horizon be porous and permeable .The area comprises of granite and gneissic.The major rock exposures are Charnockite, Ultramafics, Quartzite/Banded, Pink & Grey granite, Gneiss/Migmatite/Granite.

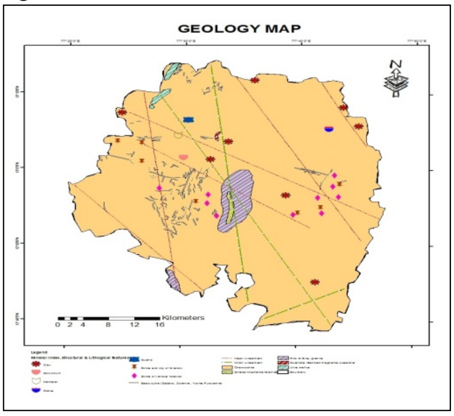

Figure 6: Geology Map

Lineament Density

Lineaments are structurally controlled linear or curvilinear features, which are identified from the satellite imagery by their relatively linear alignments. Lineaments represent the zones of faulting and fracturing resulting in increased secondary porosity and permeability. Areas with high lineament density are good for groundwater potential zones (Haridas et al., 1998).

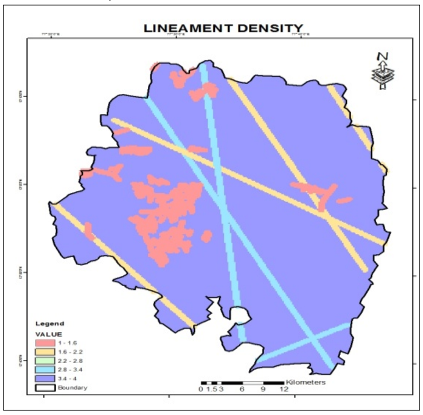

Figure 7: Lineament Density

Soil Map:

Soil is an important factor for delineating the groundwater potential zones. The analysis of the soil type reveals that the study area is predominantly covered by Red loamy and sandy soils, Laterite soil.

Red loamy and sandy soils generally occur on hilly to undulating land slope on granite and gneissic terrain.

It is mainly seen in the eastern and southern parts of Bangalore north and south taluks.

Laterite soils occur on undulating terrain forming plain to gently sloping topography of peninsular gneissic region. It is mainly covered in Anekal taluk and western parts of Bangalore North and south taluks.

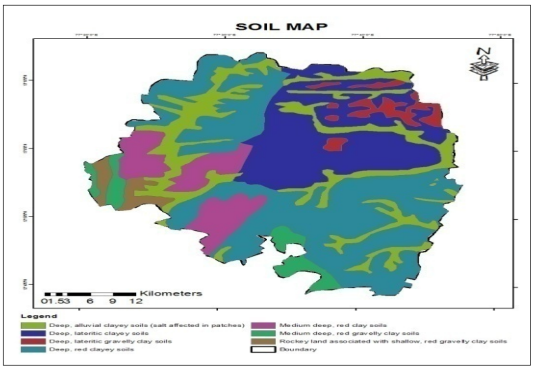

Figure 8: Soil Map

Land use Land cover Map:

The Land use map shows the different types of land cover pattern present in the study area. The land use map of the area was prepared from the remote sensing data by digitizing each feature as polygon in Erdas 9.1. The study area is characterized by the dense forest, agricultural land, plantation , barren land, scrub and built-up area using classification techniques. Major part of the study area settlement.

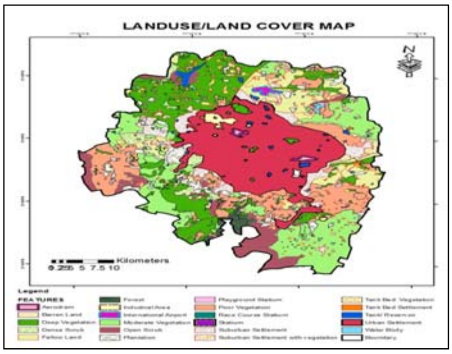

Figure 9: Landuse/Land Cover Map.

NDVI:

These spectral reflectances are themselves ratio of the reflected over the incoming radiation in each spectral band individually; hence they take on values between 0.0-0.6. The area with higher values represent healthy vegetation, those with lower values represent weak vegetation.

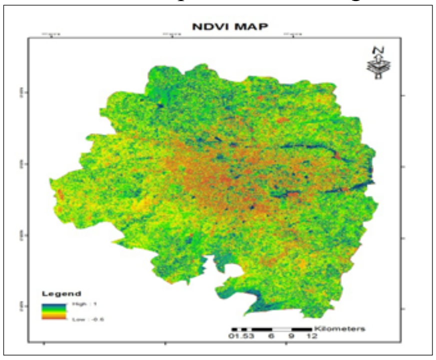

Figure 10: NDVI Map

Depth to water level:

The depth to water level in the core area of Bangalore city has the shallow west water level in the range of (1-5) mbgl. Majority of the stations located in the periphery has deeper water level in the range of 10- 20 mbgl. In general, pre-monsoon depth to water levels of the peizometer ranges from 5 to 30 mbgl. In dug wells, it ranges from 2 to 11 m. The post-monsoon depth to water level ranges of the peizometer varies from 2 to40 mbgl. In dug wells, it ranges from 0.5 to 11 m.

4. RESULT AND DISCUSSION:

Weightage index Calculation based on Suitability Assessment:

There are different ways in which the suitability assessment can be done. There have been studies of suitability assessment employing a "maximization" or "worstcase" Model (Space Applications Centre, 1999), where the "worst" parameter determines the suitability.

Generally, five zones of suitability / priority delineation can be defined based on the

Limitations

a) Zone 1: Minimal Limitations Suitability for selection is high
b) Zone 2: Moderate Limitations
c) Zone 3: High Limitations
d) Zone 4: Maximal Limitations Suitability for selection is low

The weights of the different themes were assigned based on the their influence on the groundwater survival. On a scale of 1to 9 assigned based Saaty's Analytic Hierarchy Process (Rao Mukund et. al., 1991) is a most widely accepted method for scaling the weights of parameters by constructing a pair wise comparison matrix of parameters where entries indicate the strength with which one element dominates over another vis-à-vis the relative criterion. The pair wise comparison of parameters results into the "importance matrix" which is based on a scale of importance intensities. The importance matrix can then be analyzed by various methods " Eigenvector" method or "Least Square" method, to arrive at the weightages of each parameter in the matrix. Experimental analysis has shown that the weightages obtained by these two methods are similar and are comparable. However, in the present study, Eigen vector method is employed for obtaining the weights of different parameters.

Table 4: Criteria for Generating Comparison Matrix

Assigned Value	Definition Explanation
1	***Parameters are of equal importance*** (Two parameters contribute equally to the objective)
3	***3 - Parameter j is of weak importance compared to parameter i*** (Experience and Judgment slightly favour parameter i over j)
5	***5 - Essential or strong importance of parameter i compared to j*** (Experience and Judgment strongly favour parameter i over j)
7	***Very much more importance*** (Criteria i is strongly favoured over j andits dominance is demonstrated in practice)
9	***Absolute more importance*** (The evidence favouring parameter i over j to the highest possible order of affirmation)
2,4,6,8	***Intermediate values between two adjacent judgment*** (Judgment is not precise enough to assign values of 1, 3, 5, 7 and 9)

Table 5: Assigned and weightage and Ranking for the individual features of the different themes

Thematic Layers	Features	Class	Ranking
Geomorphology	Valley flat	Good	4
	Pediplain/pediments	Good-Moderate	3
	Denudational Plateau	Moderate	2
	Denudational hills	Poor	1
Geology	Charnockites	Good	4
	Ultra mafics	Good-Moderate	3
	Quartzite /Banded magnetite quaetzite	Moderate	2
	Pink & Grey granite	Moderate	1
	Gneiss/Migmatite/Granite	Poor	1
Soil	Medium deep, red clay soils	Poor	1
	Deep, alluvial clayey soils (salt affected in patches)	Moderate-poor	2
	Deep, lateritic clayey soils	Moderate	3
	Deep, red clayey soils	Moderate	3
	Medium deep, red gravelly clay soils	Good-Moderate	4
	Deep, lateritic gravelly clay soils	Good	5
	Rockey land associated with shallow, red gravelly clay soils	Very Good	6
Slope	Nearly level/Very gentle, 0–3%	Very Good	6
	Gentle, 3–5%	Good	5
	Moderate, 5–10%	Moderate	4
	Moderate steep, 10–15%	Moderate	3
	Steep, 15–35%	Moderate-Poor	2
	Very steep, 35–50%	Poor	1
Lineament Density	1-1.6	Poor	1
	1.6-2.2	Moderate-Poor	2
	2.2-2.8	Morderate	3
	2.8-3.4	Good-Moderate	4
	3.4-4	Good	5
Drainage Density	0-1 km	Good	3
	0-2 Km	Moderate	2
	0-3 Km	Poor	1
Landuse/Land Cover	Settlement	Poor	1
	Water Body	Good	2
	Fallow Land	Good	3
	Scrub land	Very Good	4
	Plantation	Moderate	5
	Forest	Good	6
	Vegatation	Very Good	7
	Barren Land	Poor-Moderate	8
NDVI	Healthy Vegetation	Good	3
	Moderate Vegetation	Moderate	2
	Weak Vegetation	Poor	1

Based on this scale qualitative evaluation of different features of theme was performed with: poor (1-1.5); moderate-poor (2-3.5); good-moderate (4-4.5); good (6-7.5); excellent (8-9). The thematic layers were integrated with one another through GIS using the weighted aggregation method. The following order of sequence was adopted to derive the final integrated map.

Each and every thematic map is overlaid with landuse/land cover pattern.

Geomorphology+ LULC=O1.

Geology+ LULC=O2.

Soil+ LULC=O3.

Slope+ LULC=O4.

Lineament Density+ LULC=O5.

Drainage Density+ LULC=O6

NDVI+LULC=O7.

O1, O2… output layers respectively.

The polygons in the integrated layerO8 (O8=O1+O2+O3+O4+O5+O6=O7) contain the composite detail of all the thematic layers together numerically having maximum weight and minimum weight with standard deviation .

Grouping of polygons of high ranks of all the thematic layers has helped in delineating the sites that are excellent for construction of water harvesting structures. Based upon the standard deviation, the polygons were grouped into classes suited for construction of ground water Potential zone. A Composite Suitability Index (CSI) has been calculated for each composite unit by multiplying weightage with rank of each parameter and summing up the values of all the parameters. Categorization of the CSI is achieved by ranging the CSI into five classes.

Class I : Maximum > CSI >= 4 σ

Class II : 4 σ > CSI >= 3 σ

Class III: 3 σ > CSI >= 2 σ

Class IV: 2 σ > CSI >= 1σ

Class V: 1 σ > CSI > Minimum

Where σ = Standard deviation.

From these the polygons classified as

Category based on the cumulative weight Poor; Moderate-poor; Moderate; Good-Moderate; Good.

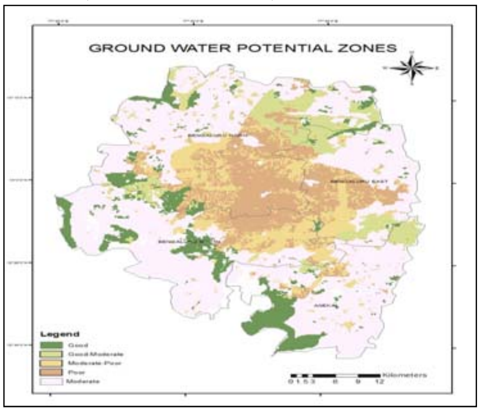

Figure 11: Mapping showing potential of the study area

CONCLUSION:

The suitability index for identifying the ground water potential zone using GIS. Analysis has an added advantage over predictable survey. The multilayer integration viz., geomorphology, landuse, geology, lineament density and drainage density gives smaller suitability units as a composite layer. The inter layer ranking and intra layer weightages further intensify the interpolation. Based upon the standard deviation, the polygons were grouped in to classes suited for construction of ground water recharge structures. A composite suitability index (CSI) has been calculated for each composite unit by multiplying weightage with rank of each parameter and summing up the values of all the parameters. Categorization of the CSI is achieved by ranging the CSI into five classes. Thus deciphered could be useful for various purposes such as development of sustainable scheme for ground water in the area.

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