IDENTIFICATION OF POTENTIAL SITES FOR RAIN WATER HARVESTING STRUCTURES USING RS, GIS AND MIF TECHNIQUES

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ABSTRACT

Integrated watershed management requires a host of inter-related information to be generated and studied in relation to each other. Remote sensing (RS) technology meets both the requirements of reliability and speed and acts as an ideal tool for generating spatial information needs. The GIS technology provides suitable alternatives for efficient management of large and complex databases. In this study an attempt is made to develop groundwater prospect map for Gundal watershed, Gundalpet taluq, Chamarajanagar district. From which artificial recharge zones can be planned. Morphometric analysis is made to understand the hydrologic characteristics of the Gundal watershed. By using Multi Influence Factor (MIF) technique, weight overlay and decision tree concepts groundwater prospect map is generated in alliance with soil, slope, drainage density, rainfall, land use/ land cover, geology and geomorphology data. Further by using Groundwater prospect map and the Boolean algebra AND and OR operations to arrive at the Artificial groundwater recharge zones by following various criteria's formed as per Integrated mission for sustainable development (IMSD).

Keywords: *Gundal watershed, Watershed management, RS, GIS, MIF technique.*

I. INTRODUCTION

Watershed management implies prudent use of all the natural resources to ensure optimum and sustained productivity. Particularly, concern about widespread soil degradation and scarce, poorly managed water resources. Gundal watershed, Gundulpet taluk, Chamarajnagar district, Karnataka state i.e. study area has led to the implementation of Watershed management activities. In this context, chalking out an Integrated Water Resource Development Plan that involves targeting groundwater potential zones and identifying suitable sites for rainwater harvesting assumes importance and holds the promise of making watershed management simpler and more effective.

II. STUDY AREA

The Gundal watershed is located in the South West of Karnataka state. The location map of the study area is shown in Figure 1. The Gundal watershed lies completely in Gundulpet taluk of Chamrajnagar district and partly in Nanjangud taluk of Mysore district and occupies an area of 1203.85 sq.km. The watershed stretches from 76° 30' to 76° 51'47" E longitude and 11° 40' 13" - 12° 7' 13" N latitude. The Gundal river is the main tributary of river Kabini, which originates in Himavadi Gopalaswamy Betta, Gundulpet taluk and flows over a distance of 59 km and its confluence with river Kabini near Nanjangud town. There are nearly 45 tanks within the watershed and they are seasonal.

III. DATA USED

1. Survey of India (SOI) Topomaps: SOI Topomaps numbers 58A/9, 58A/10, 58A/13, 58A/14, 57D/12, 57D/16 of 1:50,000 scale.
2. Remote sensing data: Cloud free digital data of IRS–R2 and IRS-P6 LISS-III data passing along the path 98 and row 66 on 02/11/2009 and 22/05/2011.
3. Rainfall data: Daily rainfall data for 5 years from January 2010 to December 2014 collected from KSNDMC, Bengaluru.
4. Soil data: Soil map prepared by the KSRAC (2012), Bengaluru.
5. Geological data: Geological map prepared by the Geological Survey of India (December 1992).
6. Land use/land cover data: Land use/ land cover map prepared by KSRAC 2012, Bengaluru.
7. Well inventory data: Central Ground Water Board (CGWB), South Western Region, Bengaluru.

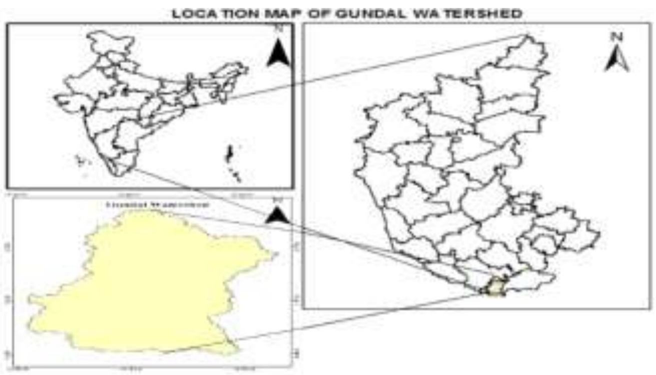


Fig 1. Location map.

IV. METHODOLOGY

The Survey of India (SOI) toposheets for the study area have been procured, scanned and geometrically rectified so that each point represents correct geographical coordinates. Satellite images of IRS-R2 LISS-III have been georeferenced with respect to toposheet and mosaiced. The drainage network and the catchment have been identified from the mosaiced toposheet and updated from satellite imagery. Based on the topography and drainage pattern, the catchment has been divided into 6 watersheds. Horton’s and strahler method has been adopted for ordering the streams of the watershed. Figure 3 shows the stream order map of the study area.

Watershed	1	2	3	4	5	6
Area (sq. km)	218.67	127.84	177.87	233.30	232.42	213.78
Perimeter (km)	104.67	68.67	94.18	81.69	111.91	92.7

V. MORPHOMETRIC ANALYSIS

The catchment is divided into 6 subcatchmets (Figure 2) and morphometric analysis is done. The work has been carried out using ARCGIS 10.1 software.

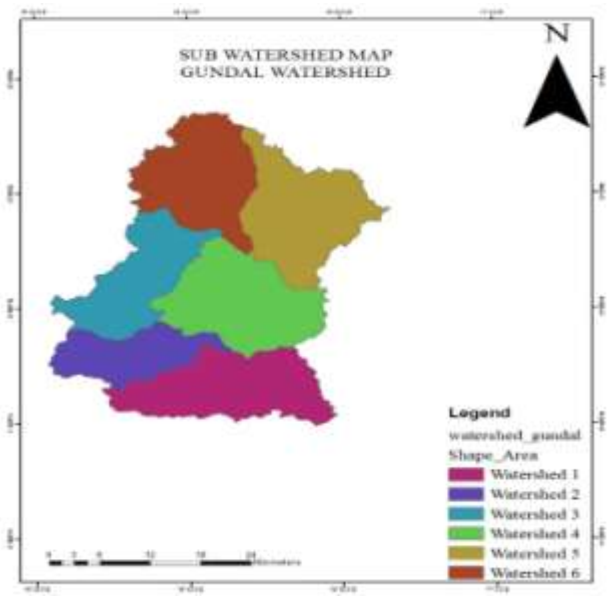


Fig.2 Gundal Subcatachment map

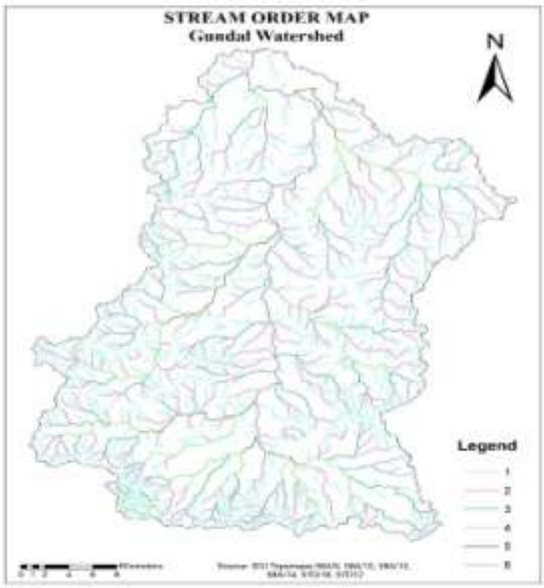


Fig.3 Drainage map

Table 1. Subcatachment area and perimeter

Table 2. Morphometry results of Gundal Watershed

Sl. No	Watershed Parameters	Units	Watershed No					
			1	2	3	4	5	6
1	Watershed area	sq.km	218.67	127.84	177.87	233.30	232.42	213.78
2	Perimeter of the Watershed	km	104.67	68.69	94.18	81.69	111.91	92.70
3	Highest stream order	No.	6	6	5	6	5	6
4	Maximum length of watershed	km	11.63	8.02	16.52	16.58	19.65	18.77
5	Maximum width of watershed	km	25.87	21.09	11.97	20.61	17.43	15.33
6	Cumulative stream segment	km	458	209	304	306	225	214
7	Cumulative stream length	km	396.14	213.78	302.25	368.68	303.43	256.04
8	Drainage density	km /sq.km	1.81	1.67	1.70	1.58	1.31	1.20
9	Constant of channel maintenance	sq.km/ km	0.55	0.60	0.59	0.63	0.77	0.83
10	Stream frequency	No/sq. km	2.09	1.63	1.71	1.31	0.97	1.00
12	Form factor		1.62	1.99	0.65	0.85	0.60	0.61
14	Shape factor		0.62	0.50	1.53	1.18	1.66	1.65
15	Circularity ratio		0.25	0.34	025	0.44	0.23	0.31
16	Elongation ratio		1.44	1.59	0.91	1.04	0.49	0.88
17	Compactness coefficient		1.99	1.713	1.99	1.51	2.07	1.79
18	catchment relief	km	0.21	0.43	0.29	0.16	0.12	0.24
19	Relief ratio		0.018	0.054	0.0017	0.0095	0.0059	0.013
20	Relative relief		0.0021	0.006	0.0003	0.002	0.0011	0.003
21	Ruggedness Number		0.004	0.007	0.005	0.003	0.002	0.003

Out of the six watersheds, watershed number 1, 2, 4 and 6 are 6th order, watershed number 3 and 5 are 5th order. The drainage density reflects the land use, affects the infiltration and watershed response time between precipitation and discharge. The drainage density of the area varies from 1.2 to 1.81 km/sq.km indicating that the area is very coarse and coarse texture. Stream frequency value for the watershed varies from 0.97 to 2.09 this indicates that the stream frequency is low to moderate. The circularity ratio varies from 0.23 to 0.44 for the watersheds. Its low, medium and high values are correlated with youth, mature and old stage of the cycle of the tributary watershed of the region. The elongation ratio ranges from 0.88 to 1.59 which indicates that the watershed is circular. The values of relief vary from 120 m to 430 m indicates that the watershed has enough slope for the runoff to occur from the remote point of the watershed to mouth. The relative relief ratios are ranging from 0.0003 to 0.006. The high relative relief indicates that it is composed of resistant rock patches and low relief ratio indicates less resistant patch of rocks.

VI. SPATIAL DATABASE ANALYSIS

The Groundwater prospect map has been prepared using Multi Influence Factor (MIF) technique (Biswas Arkoprovo et al., 2013) and rainwater recharge structures has been identified by using area specific and location specific activities (Chowdary et al., 2010).

6.1 Multi influencing factors of groundwater potential zones

Seven influencing factors, such as geology, slope, land-use/land-cover, geomorphology, drainage, soil, and rainfall have been identified to delineate groundwater potential zones. Interrelationship between these factors and their effects are shown in Figure 4.

6.2 Weightage calculation

The effect of each influencing factor may contribute to delineate the groundwater potential zones. Moreover, these factors are interdependent. The effect of each major and minor factor is assigned a weightage of 1.0 and 0.5 respectively (Figure 4). The cumulative weightage of both major and minor effects are considered for calculating the relative rates (Table 3). This rate is further used to calculate the score of each influencing factor. The proposed score for each influencing factor is calculated by using the formula.

$$\frac{A+B}{\Sigma(A+B)} * 100 \qquad (1)$$

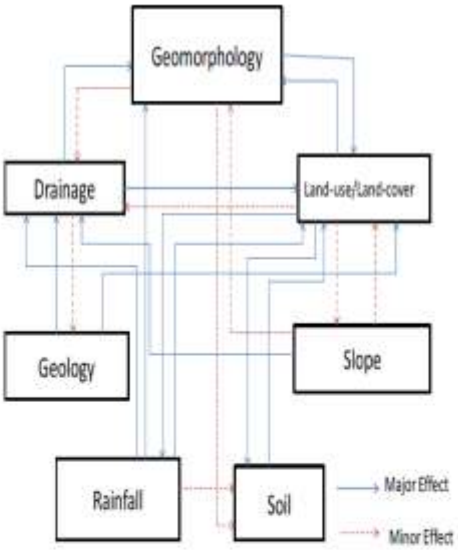
where,

A is Major effect.

B is Minor effect.

6.3 Delineating Groundwater Potential Zones

The identification of groundwater potential zones for the study area was made by grouping of the interpreted layers through weighted multi influencing factor and finally assigned different potential zones. The groundwater potential zone of this study area can be divided into five grades, namely very good, good, moderate, poor, and very poor (Manikandan.J et al., 2014). The ground water potential zone for the study area is shown in Figure 5. Spatial distribution ground water potential zone for Gundal watershed is shown in Table 3.



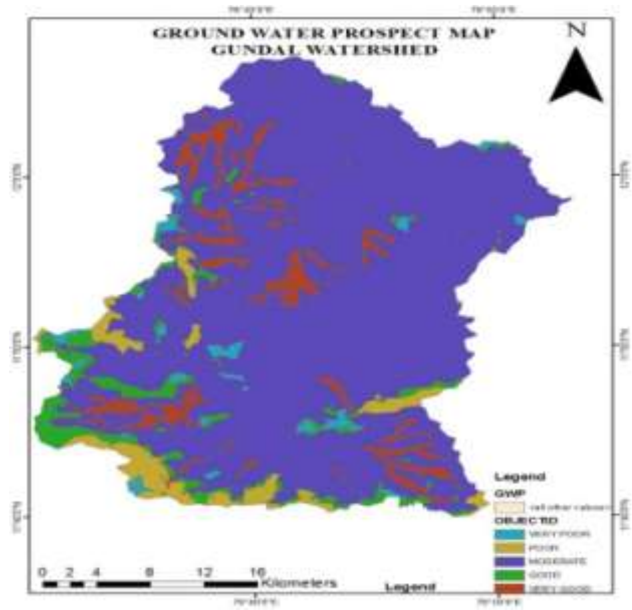


Fig 4. Interrelationship between Multi Influencing factors

Fig 5. Groundwater prospect map

Table 3. Effect of influencing factor, relative rates and score for each potential factor

Factor	Major effect (A)	Minor effect (B)	Proposed relative rates (A+B)	Proposed score for each factor
Slope	1	0.5+0.5	2	12
Drainage density	1+1	0.5	2.5	15
Rainfall	1+1+1	0.5	3.5	20
LULC	1+1+1	0.5+0.5	4	23
Soil	1	0	1	6
Geology	1+1	0	2	12

Geomorphology	1	0.5+0.5	2	12
			∑17	∑100

By integrating land use/land cover map, slope map and ground water prospect map by using Intersection tool in ArcGIS 10.1, using Boolean AND and OR operations and by using set of criteria's mentioned by Integrated Mission for Sustainable Development (IMSD-1995) suitable site for various area specific activities are identified and shown in Figure 6. Then by integrating Land use/Land cover map, slope map, stream order map and soil map by using Intersection tool in ArcGIS 10.1, using Boolean AND and OR operations and by using set of criteria's mentioned by IMSD suitable site for various locale specific activities are identified and shown in Figure 7 (Jankowski P, 1995).

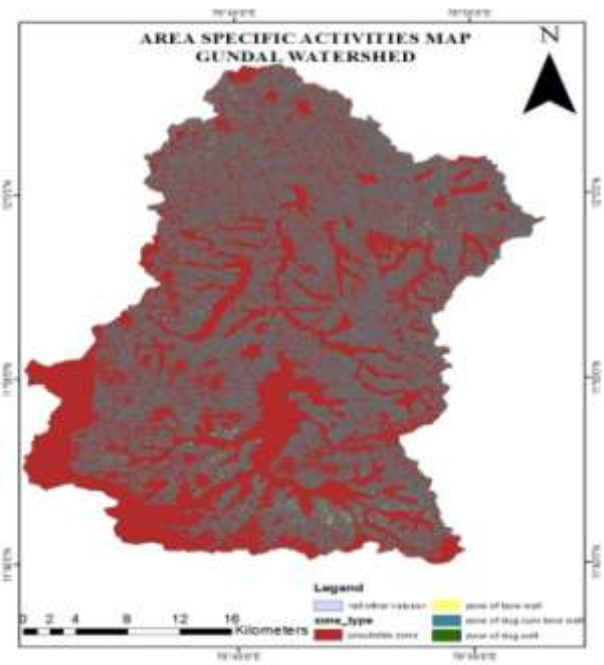
Table 4. Classification of weighted factors influencing the potential zones

Factor	Domain effect	Weightage	Ground water prospect
Slope	0% - 1%	12	Very good
	1% - 3%	11	Very good
	3% -5%	9	Good
	5% -10%	7	Good
	10% - 15%	5	Moderate
	15% - 51%	2`	poor
Drainage density	0.12 – 1	15	Very good
	1.0 – 1.5	13	Good
	1.5 – 2.0	10	Good
	2.0 – 2.5	6	Moderate
	2.5 – 3.7	5	Poor
Rainfall	484 – 550	8	Poor
	550 – 600	11	Moderate
	600 – 650	14	Good
	650 – 700	17	Very good
	700 – 786	20	Very good
LULC	Forest & plantations	17	Moderate
	Crop land	21	Good
	Hills & settlements	10	Poor
	Water bodies	23	Very good
Geology	Amphibolites	12	Good
	Granodiorite gnesiss	9	Moderate
	Meta ultramatics	4	Poor

	Metapelite schist	7	Moderate
Geomorphology	Hills and ridges Pediments Inselberg complex Pediplain Residual hills River/stream Valley fill	3 9 5 7 2 12 12	Poor Good Moderate Moderate Very poor Very good Very good

Table 5. Spatial distribution ground water potential zone for Gundal watershed

Sl. No.	Ground water prospect	Area (Sq.km)	Area (%)
1	Very good	65.39	6
2	Good	968.10	80
3	Moderate	56.88	5
4	Poor	80.03	7
5	Very poor	24.04	2
		1204	100



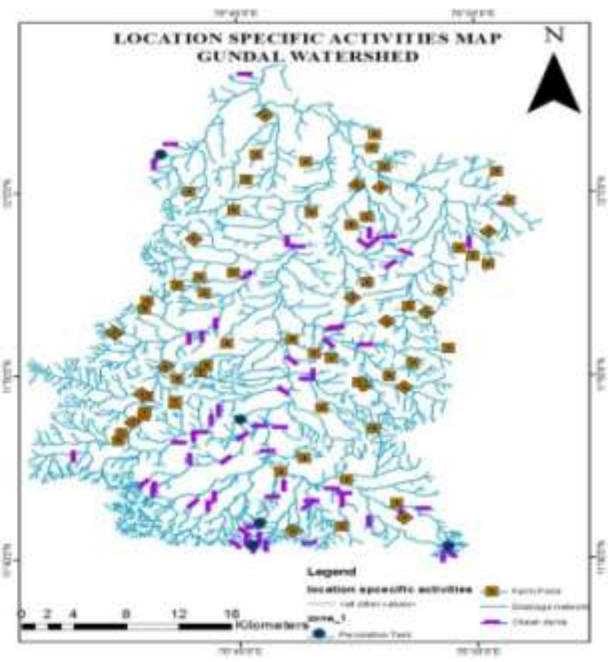


Fig 6. Area specific activities **Fig 7. Location specific activities**

VII. RESULTS AND DISCUSSIONS

To understand the accuracy of prospective groundwater zones, an attempt is made to verify the results of the study area , for this purpose well inventory data or bore wells locations data by CGWB (2012), Bengaluru has been used. There are 26 existing well data taken in the study area for their suitability in terms of GIS environment. . Zone 1, Zone 2 and Zone 3 corresponds to Zone of Bore wells, Zone of Dug-cum Bore wells and Zone of Dug well respectively. Zone 4 refers to unsuitable zone for groundwater exploitation. Out of 26 wells, 2 are found in the Zone 4 i.e. unsuitable for groundwater exploitation, 10 dug cum bore wells are found in Zone 2, 12 bore wells in Zone 1, 2 dug wells in Zone 3.

VIII. CONCLUSIONS

Area of 968.10 sq.km (80% of the study area) has moderate level of groundwater potential zone. 54 suitable sites for check dam, 57 suitable sites for farm ponds, 5 suitable sites for percolation tanks were found in the watershed. These may serve the purpose of soil and water conservations and groundwater augmentation. The percentage of accuracy of locations of area specific activities are 92.30%. Firstly, these structures reduces runoff velocity there by minimizes erosion and secondly allow the retained water to percolate and thus results in increase recharge in the wells located downstream of the structure. In hard rock areas, the underlying lithological units do not have sufficient primary porosity and permeability. Thus, additional recharge by location specific activities becomes necessary to augment the groundwater in regions where it is insufficient. Further, these area and local specific actions involve the application of set of criteria resulting from GIS analysis of scientific factors, which needs to be integrated with social factors also. Detailed field inspection are likely to improve the results of this analysis. This limitation can be further reduced with the help of high spatial resolution satellite data and small scale of mapping for different thematic layers. The suggested water resource development plan is expected to result in the transformation of the existing land use practices into sustainable ones that will meet the needs of the present population and future generation without endangering environment.

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