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Application of Remote Sensing and GIS for groundwater recharge zone in and around Gola Block, Ramgargh district, Jharkhand, India

M.P. Sharma, Anukaran Kujur

Abstract- In the present scenario of our world's burgeoning population which is becoming increasingly difficult, it is must rather than a challenge for any country to meet the task of providing sufficient quantity of water to each and every person in the face of the changing consumption patterns, impacts of the climate change and degradation of the finite land and water resources. The study area comprises hard rock of Precambrian/Archaean and some part of sedimentary deposits. The intersection zones of lineaments provide potential for ground water accumulation and ground water recharge. Occurrence of groundwater in such rocks is essentially confined to fractured and weathered zones. The present paper aims to establish basic information for site selection of rainwater harvesting /artificial recharge structures to the aquifer systems by preparing various thematic maps such as geology, geomorphology, drainage pattern, drainage density, lineaments, Landuse/ Landcover etc. which have been prepared on visual interpretation techniques using the remote sensing data with the help of GIS techniques and topographic information along with secondary information and limited field checks of the study area, that falls in and around Gola block, Ramgarh district, Jharkhand, India. It is an attempt to suggest for maintaining the proper balance between the groundwater quantity and its exploitation.

Index Terms- Artificial Recharge sites, GIS, Groundwater recharge structures, Remote Sensing, weightage overlay

I. Introduction

Groundwater is the most important natural resource of the earth which is required for drinking, irrigation and industrialization. Its availability depends upon the presence of rock types and their physical properties such as porosity, permeability, transmisivity and storage capacity. Scarcity of groundwater depends upon the development activities of the area. Continuous failure of rain falls, increasing demand and overexploitation of groundwater cause to depletion of groundwater. These problems could be sorted out to certain extends by artificial recharge to the aquifers by construction of small water harvesting structures across streams/watersheds. When the natural recharge rate cannot be sufficient to maintain the demand for water, the balance is disturbed and hence require for artificial recharge on a country wise basis. The main objective of artificial recharge is to provide sustainability to ground water by restoring supplies to aquifers depleted due to excessive draft and to enhance recharge to the aquifers lacking adequate natural recharge both in space and time. In hard rock terrains, groundwater availability is of limited extent. Occurrence and movement of groundwater in such rocks is confined in fractured zones and depth of weathered rocks. Extensive hydrogeological studies have been carried out by several workers in delineating groundwater potential zones in hard rock terrain (Agarwal *et al*., 1992; Rao *et al.*, 2001). Remote sensing and GIS are playing a rapidly increasing role in the field of hydrogeology and water resources development. Remote sensing provides multi-spectral, multi-temporal and multi-sensor data of the earth's surface (Choudhury, 1999). Satellite data provides quick and useful baseline information on the parameters like geology, geomorphology, lineament, Landuse/Landcover etc. All thematic maps are integrated in the Geographic Information System (GIS) and a final composite map has been

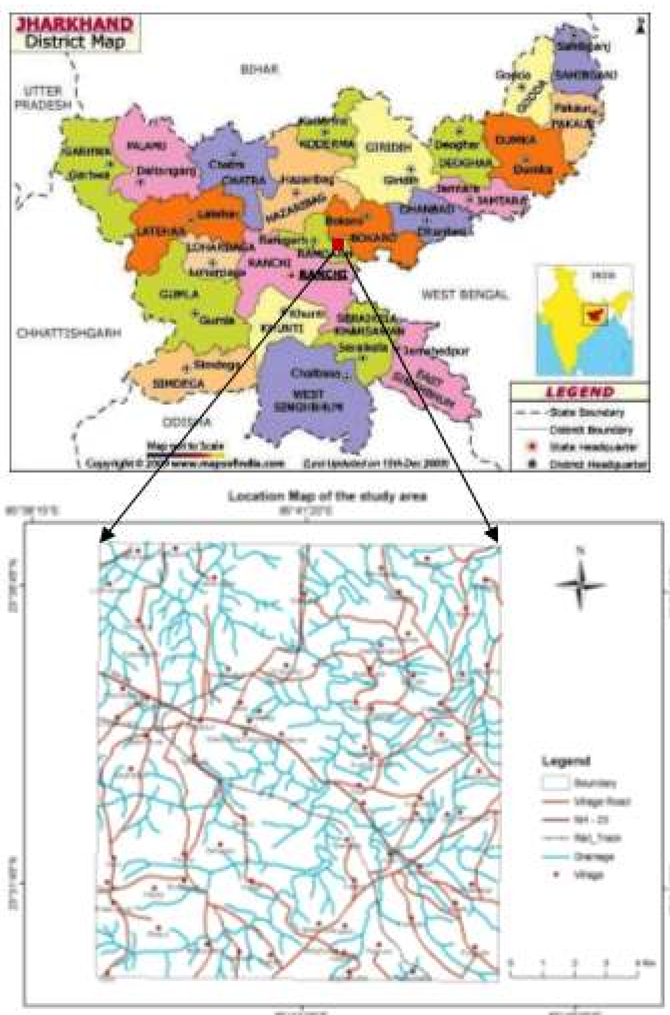

Fig. 1 Location map of the study area

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generated and checked with adequate field data, particularly well inventory and yield data. It is possible to identify the ranges depth, the yield, the success rate and the types of wells suited to different litho units under different hydrogeological units. Based on groundwater development, management and irrigated areas, artificial recharge structures such as percolation tanks, check dams, sub surface dykes, recharge-cure-discharge wells and rainwater harvesting structures can be recommended in upstream of groundwater irrigated areas to recharge the wells in the downstream areas so that it may possible to augment groundwater resources. The present study area is an attempt to identify such suitable zones for artificial recharge to the aquifer system in and around Gola block, Ramgargh district, Jharkhand, India using remote sensing and GIS techniques.

II. MATERIALS AND METHODS

The study area lies in Survey of India toposheet No. 73E/10 falling between latitude 23°30'00"- 23°37'30"N and longitude 85°37'30" - 85°45E in Gola block, Ramgarah district of Jharkhand state and is situated in NNE of Ranchi comprising about 70 kms by road from the city. Remote sensing data, topographic map of Survey of India (SOI) and other published maps and reports constitute the database for the interpretation and delineation of various thematic layers and information. Satellite data IRS-P6, LISS-III, in digital format were used in conjunction with secondary data. Basic technical guidelines are adopted by National (Natural) Resources Information System (NRIS, 2000), and Rajiv Gandhi National Drinking Water Mission (NRSC, 2007) for identifying the ground water recharge zones. The thematic maps of geology, geomorphology, landuse/landcover, drainage and lineaments were prepared using digitally enhanced satellite data. Arc Map version 9.0 software package was used for creation of digital database using on visual interpretation technique, data integration and analysis. Each thematic map assigned weights depending on its influence on groundwater recharge and storage. Knowledge based weight assignment was carried out for each feature and they were integrated and analyzed by using the weighted overlay method. The different units in each theme were assigned ranking from 0 to 4 on the basis of their significance for artificial recharge to aquifer system. The final score of a theme is equal to the product of the rank and weightage. From the composite layer, the delineation of site suitability analysis was made by grouping the polygons into different prospect zones i.e. good, moderate to good, poor or not suitable.

III. RESULTS AND DISCUSSION

A. Geological setup

The study area falls in the Chotanagpur Granite Gneissic Complex. The Hazaribag plateau, separated from the Ranchi plateau by the Gondwana belt, is predominantaly made up of lower Ranchi surface (Mahadevan, 2002). The lower Ranchi surface is broadly in the elevation of the region ranges between of 450-600m amsl. The outliers of Gondwana sediments lie over the Precambrian gneisses and high grade schistose basement formations. Precambrian basements are exposed on the floor of Damodar River and the periphery of eastern part of the Gondwana basin. Main litho units are granite gneiss, mica–schist with quartzite and amphibolites which are interbeded and have been subjected to intense folding.

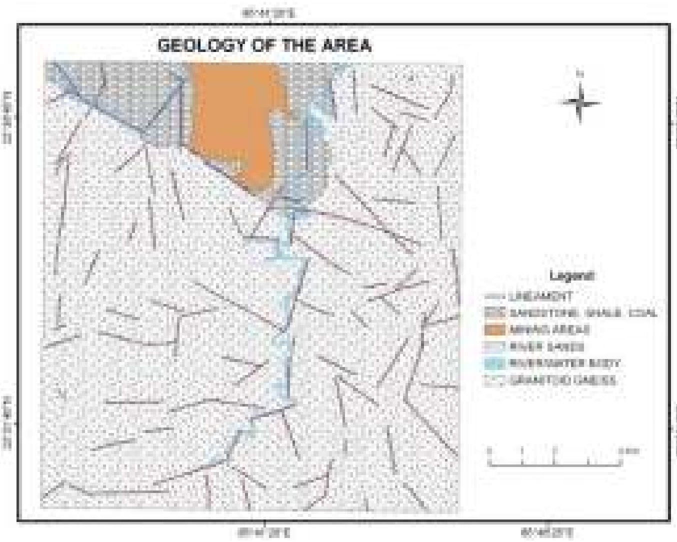

Fig. 2 Geological map with lineaments of study area

Barakar formation, the main lithounit sequences of coalfield, is deposited over Talchir. It is composed of coarse grained to pebbly sandstone, medium to fine grained sandstone, grey and carbonaceous shale along with coal seams. Among intrusive igneous rocks lamprophyres are found in south eastern region of the Rajrappa project, which has resulted in the formation of columnar joints within shale.

Table.1 Generalized geological succession of the area

Division	Description of beds	*Age*
Barakar	Coarse grained feldspathic sandstone	Lower Permian
Karharbari	*Fine grained sandstone, Medium to coarse grained, sand stone with interbeded coal seam*	Upper Carboniferous to Lower Permian
Talchir	Boulder Conglomerate/ Olive green shale	Upper Carboniferous
Archaean	Metamorphic rocks, Granite gneiss, Quartzite, mica schist schists.	Archaean

B. Lineaments/Structures

Lineaments are linear or curvilinear structures on the earth surface, it depicts the weaker zone of bed rocks and area is considered as secondary aquifer in hard rock regions. These lineaments are mapped with the help of satellite data and can be correlated with faults, fractures, joints, bedding planes and lithological contacts. The study area is found to have a number of criss-crosed lineaments. The intersection of lineaments is considered as good occurrence of groundwater potential zones. For analysis purposes lineament density have been prepared and categorized in four classes: low, medium, high and very high. Higher density of lineament is very good favorable zones for ground water recharge than lesser one therefore weightage are

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assigned high for higher density and low for lower density (Fig 3).

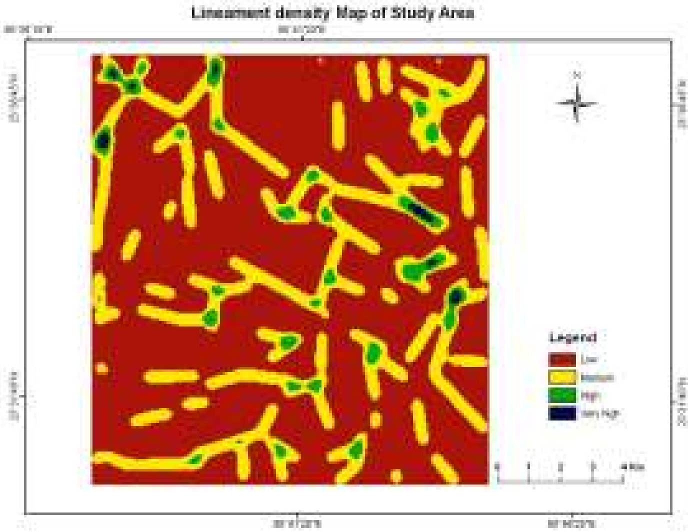

Fig.3 Lineament density map of the study area

C. Geomorphological setup

An integrated study of the geology and evolution of landforms is useful to understand the occurrence of porous and permeable zones (Karanth, K. R., 1999). The study area has complex geomorphic features, which are describe as follows.

1. Cuesta **-** Cuesta (from Spanish: “slope”) is a ridge formed by gently tilted sedimentary rock strata in a homoclinal structure (http://www.Britannica.com/eb/topic- 14944, cuesta). Prospect of groundwater in cuesta is rated good. The cuesta is identified in the northern part of the study area.

2. Inselberg - These are isolated hills of massive rocks with steep side slope, which act as runoff zone. These features are found in the south-western part of study area.

3. Pediment inselberg complex - Pediments, small erosional surfaces, with individual units are not mappable. In Pediment Inselberg Complexes contributes limited to moderate recharge is reported.

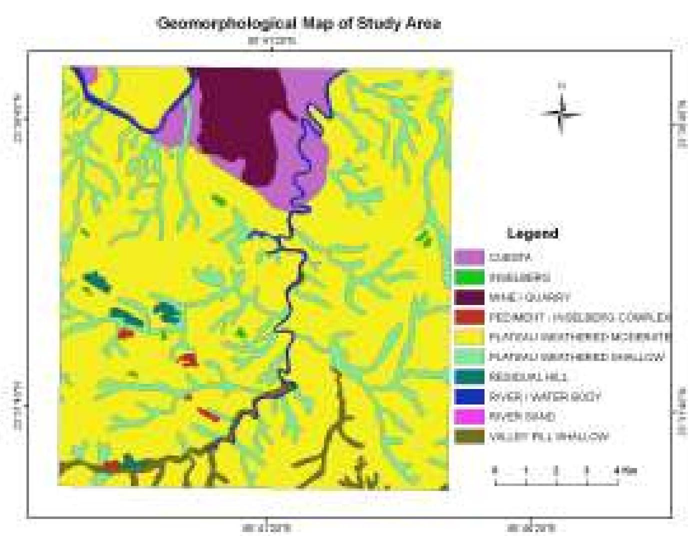

Fig. 4 Geomorphological map of the study are

4. Residual hills - These geomorphic features are isolated bodies seen in the south western part of the study area and in this area have very poor recharge and limited prospect of ground water.

5. Plateau weathered - Weathered rocks being porous and permeable possess very good storage and yield capacity of groundwater in hard rock terrain. Study area is observed to contain moderate to shallow weathered rocks. The study area is reported weathered zones are up to 20m depth.

6. Valley fills - The valley fill constitute unconsolidated materials deposited by the southern part of the study area in narrow nallas/rivers in narrow valleys and are found in patches. Depth of the valley area is reported less than 5m depth.

D. Drainage pattern and drainage density

Drainage pattern depict history of the evolution of the earth crust. The study area has been drawn drainage - pattern map with the help of Survey of India topographic map and updated from satellite data. The streams present in the study area have been ordered using Strahler’s system of stream ordering (Strahler1957).

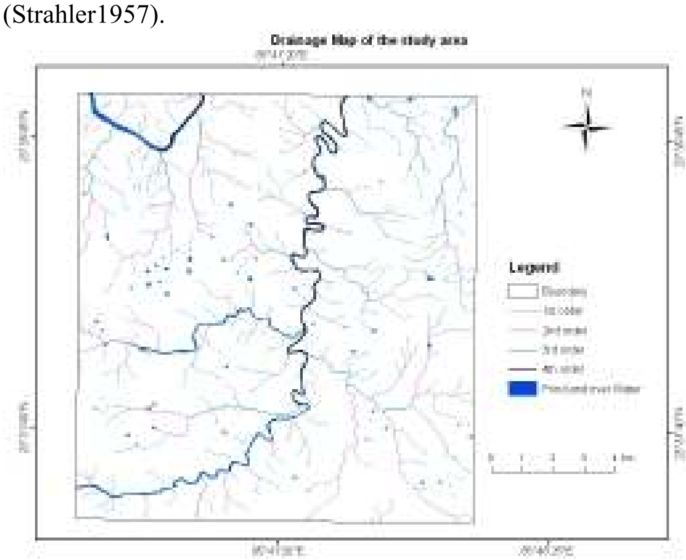

Fig. 5 Drainage map of the study area

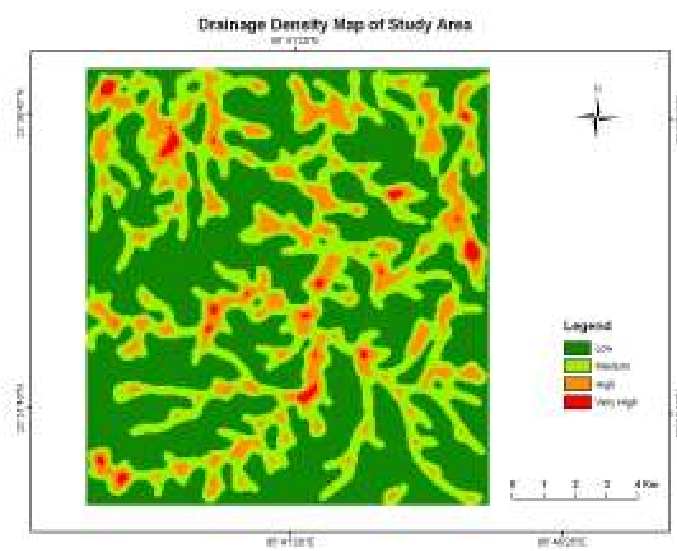

Fig. 6 Drainage density map of the study area

The smallest initial tributaries are designated as 1st order and when two first order channels join, the channel segment formed is 2nd order stream and so on. The highest order of stream found in the area is of 4th order developed in and around Gola block. The study area has dendritic drainage pattern which is typical character of granitic terrain. The drainage density map reveals density value ranging from 0 to 6 km/km^2. For analysis purposes they were regrouped into four category i.e. > 3 high, 3 – 2 medium, 2 – 1 low and 1 – 0 very low km/km^2. Considering from recharge point of view more weightage is assigned to very low drainage density regions where as low weightage assigned to very high drainage density (fig-5 and fig-6).

E. Landuse / Landcover

Remote sensing data and GIS techniques provide reliable basic information for landuse mapping and play very important role in determining land use pattern by visual interpretation. In the study area major landuse pattern includes cropland (Kharif and Ravi), fallow land, forest area, barren rocky area, land with scrubs and without scrubs, mine area etc. following the guidelines of IMSD and NRIS.

Cropland mainly Rabi and Kharif crops have been identified by the light medium red tone, fine/medium texture. Land with scrubs have been identified in uplands and plains with gentle to moderate slopes, uplands and plains with cultural lands it appears light yellow to greenish blue tones and irregular shapes. The forest gives light reddish and fine to medium texture with irregular shape and varying size. Forest area has good water recharge potential zone but it is categorized as poor, keeping in mind that these areas are generally restricted.

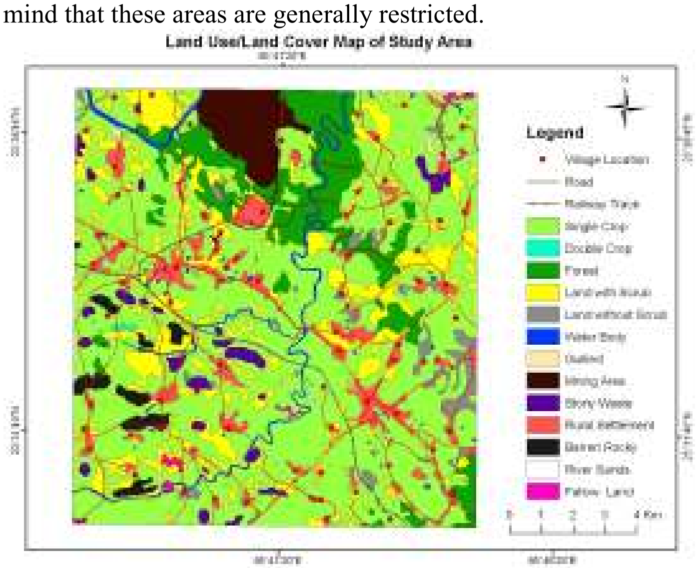

Fig. 7 Landuse/Landcover map of the study area

F. GIS Analysis

To delineate the ground water recharge zones in the study area all the thematic maps like Geology, geomorhphology, Landuse/Landcover, Drainage density and lineament density are assigned knowledge based weightages to each thematic features after considering their importance with respect to groundwater recharge. All the thematic maps were integrated in GIS environment and the polygons have been regrouped into different classes.

G. Weight Assignment

All thematic layers such as geomorphology, geology, landuse, lineaments density and drainage density maps have been considered for site suitability analysis. Based on the available knowledge each parameter has been considered and assigned weightages of 24, 22, 20, 18 and 16 for geomorphology, geology, lineament density, drainage density and landuse respectively. Again each of these layers has been further classified into different classes. Each of the classes, is based on suitable of groundwater infiltration has been given ranks 4, 3, 2, 1&0. Finally, scores have been calculated as the product of the weightage and rank. Rank, weightage and scores for the various themes for site suitability modeling. Artificial recharge sites of the study area have been identified based on the number of parameters loaded such as 4, 3, 2, 1 & 0 parameters, again the study area is classified into priority I, II, III & IV (Poor, Poor to Moderate, good and Very good fig.8) suggested for artificial recharge sites based on the number of parameters loaded using GIS integration.

Table 2 Weightage assigned of the features

Geomorphic Unit Weigtage - 24		
Geomorphic Unit	Ran-k	Sco-re
Cuesta	2	48
Inselberg	1	24
Pediment Inselberg Complex	1	24
Residual Hills	0	0
Plateau Weathered Moderate	3	72
Plateau Weathered Shallow	2	48
Mine/Quarry	0	0
River Sands	0	0
River Water	0	0
Valley Fill	4	96
Geological Unit Weightage-22		

Land use/Land cover Unit Weightage-16		
Single Crop	4	64
Double Crop	4	64
Forest	0	0
Land with Scrub	2	32
Land without Scrub	2	32
Water	0	0
Gullied	1	16
Mining	0	0
Stony Waste	1	16
Rural Settlement	0	0
Barren Rocky	0	0
River Sand	0	0

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Mine/Quarry	0	0	Fallow Land	3	48
Barakar Sand Stones	4	88	Lineament Density Unit Weightage- 20		
Chotanagpur Granitoid Gneiss	3	66	Low	1	20
Drainage Density Unit Weightage-18			Medium	2	40
Low	4	72	High	3	60
Moderate	3	54	Very High	4	80
High	2	36			
Very High	1	18			

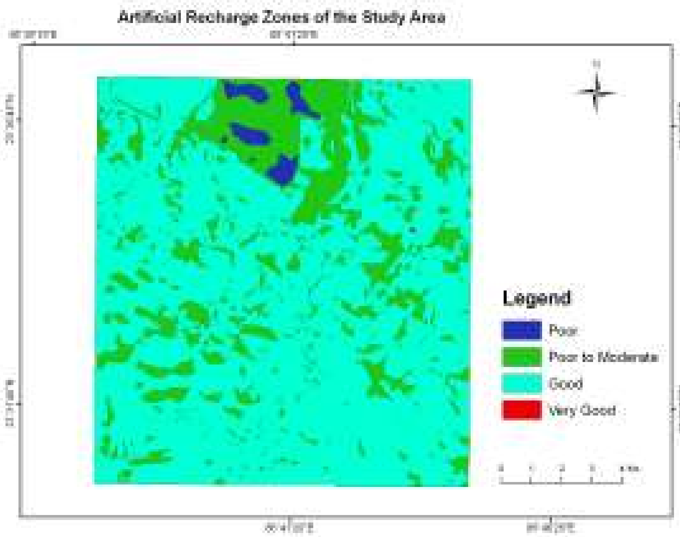

Fig. 8 Artificial recharge zones map of the study area

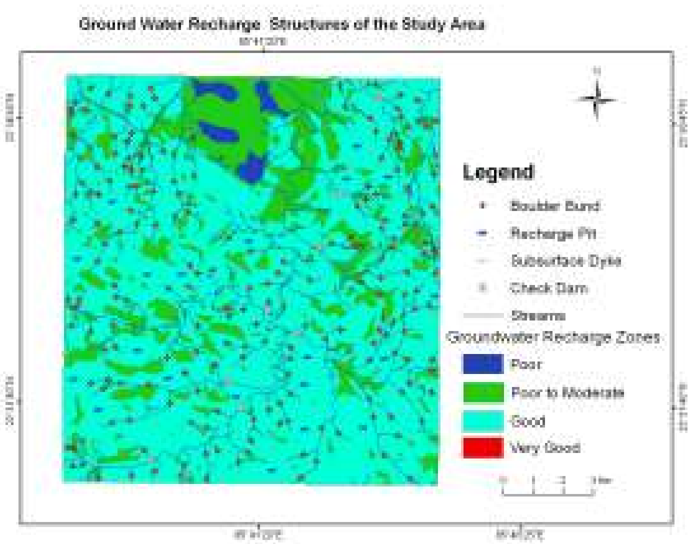

Fig. 9 Suggested artificial recharge structures map of the study area

IV. PROPOSED GRLOUNDWATER HARVESTING/ARTIFICIAL RECHARGE STRUCTURE (FIG. 9)

A. Boulder bunds

Boulder bunds are low cost structures. They are made across 1st to 3rd order stream in upper reaches catchments area. It may be constructed in a series of height bunds. Its purpose is to stabilize the erosion of soil and improve the groundwater recharge by checking flow of rainwater. They are generally recommended at the foot of the upstream.

B. Check Dams

Check dames are Engineering structures constructed across the higher order greater than 3rd order stream has minimum average area 25 hectares. These are constructed checking the run-off of the stream and store the rainwater for use in lean period and it also recharge the groundwater reservoir systems.

C. Recharge Pit

Recharge pits are excavated pit or embankment across a water course or combination of both. These structures are recommended in single crop area for providing to irrigation to limited area in critical period.

D. Sub Surface dyke

These structures are generally proposed across water course to arrest the lateral Flow of groundwater through subsurface dykes that helps to recharge the groundwater aquifer systems. The structures should be below at least 2meters from ground surface to the bed rocks.

V. CONCLUSION

The groundwater conditions in hard rock terrain are multivariate due to the heterogeneous nature of the aquifer owing to the varying composition, compaction and density of weathering. The site suitability modeling for locating the artificial recharge structures to ground water aquifer system using GIS analysis has an added advantage over conventional survey. The multilayer integration viz., geomorphology, landuse, geology, lineament (density) and drainage (density) gives smaller suitability units as a composite layer structures site of the study area. The interlayer ranking and intralayer weightages further intensify the interpolation. These zones are then compared with the Landuse/Landcover map and ordering of drainage for the further adopting the suitable structures for rain water harvesting/artificial recharge to the aquifer system in the particular structures.

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First Author – Dr. M.P. Sharma, Reader (Retd) Department of Geology, Ranchi University, Ranchi 834008

Second Author – Anukaran Kujur Reasearch Scholar, Department of Geology, Ranchi University, Ranchi 834008

Correspondence Author – Anukaran Kujur, e-mail Id: anukaran.kujur@rediffmail.com