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Artificial Groundwater Recharge Planning of a Critical Sub-watershed for Kotani Watershed Using Geospatial Techniques

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ABSTRACT: Present study has to be taken to understand the challenges like improper exploitation of groundwater, improper maintenance of water resources and failure of government schemes for rural areas may lead to groundwater and irrigation. The advantage of GIS and remote sensing of spatial, spectral and manipulation of earth surface and subsurface data cover with a short time having a great groundwater potential for accessing, processing and monitoring the groundwater resources. Artificial recharge can be used to manage groundwater resources in a sustainable manner. The goal of present study is to formulate a methodology to delineate the zones favorable for artificial recharge and to recommend sites where artificial recharge structures can be constructed in critical sub-watershed of Kotani watershed of Chhattisgarh for India. In this study remote sensing and GIS technique have been used. Major parameters influencing groundwater recharge *viz.* land use/land cover data, slope, drainage density, geomorphology, geology, lineament density, soil texture, rainfall and ground water fluctuation were used as input in GIS software. To create thematic maps, base maps for all of these impacting aspects were collected from various departments and organizations. Using the Multi-Influencing Component approach, each factor has been given a proper ranking and weightage based on its ability to change the rate of groundwater recharge. It is revealed from that the results, the majority of critical watershed area falls under 'High' recharge potential 30%, 28.64% area falls under 'Very high' recharge potential zone, 23.47% area falls under 'Medium' recharge potential zone and 13.16% were comes under 'Very low' recharge potential zone, Only 2.99% area of critical sub watershed found to be under 'Bad' recharge potential zone. The proposed suitable artificial recharge structures are mainly storage tank, percolation tank, check dam and gabian structures and their numbers are respectively 8, 7, 8 and 5 in the critical sub-watershed (SW8) of *Kotani* watershed.

Keywords: Artificial Recharge, GIS, Groundwater, Remote Sensing.

INTRODUCTION

Groundwater is a significant natural resource supporting well-being of humans, economic development and sustainability of agriculture. More than 90% rural population and around 30% population in urban areas depend upon groundwater for fulfilling their domestic needs (Rodríguez-Huerta *et al.* 2019). Aquifer replenishment with the water available on land surface is known as ground water recharge. Just like precipitation, groundwater recharge is expressed as an average rate of 'mm' of water per year (Bhattacharya, 2010). Excessive utilization of groundwater resources due to increasing population results in mismanagement and degradation of the quality and quantity of this important natural resource in most parts of the India and abroad (Yadav, 2018). One of the best methods to replenish the groundwater is Artificial Recharge. Compared to natural recharge (rainfall), artificial recharge is a better alternative to recharge the groundwater (Saha and Mukharji, 2018). Artificial recharge is used to make a direct entry of the available surface water into the ground by using different techniques such as spreading of water on land surface, constructing recharge wells or influencing the natural hydrologic conditions to increase the rate of infiltration. Geospatial techniques such as Geographic Information System (GIS) and Remote Sensing (RS) can be integrated together to determine the potential areas of groundwater (Samson and Elangovan, 2015). A review of using the integrated approach of these geospatial techniques in mapping the potential zones of groundwater has been presented by Navane and Sahoo, (2017). Identification of groundwater potential is important for the preparation of management plan o groundwater resource in watershed scale. Groundwater potential zone in watershed scale is identified by using GIS and RS satellite data and multi-criteria decision analysis techniques. Different thematic layers *i.e* geological formation, lineament, soil *etc.* were used for the identification of groundwater potential zones (Nigam and Tripathi, 2019).

Delineation of ground water recharge zones (GWRZ) play important role for artificial recharge planning to reduce the ground water reduction. Complete knowledge about the different geologic, geomorphic and structural units present in the study area is required for the study of nature of water resources. Modern technology of remote sensing can be used to study most of these aspects using satellite images. The remotely sensed data that is obtained from the satellites played a significant role in evaluation and development of water resources, and can be used to obtain immediate and important information about the parameters controlling occurrence, circulation and movement of groundwater. The main factors influencing the motion and location of groundwater are lineaments present in the area, geology and geomorphology (Lakshmi and Kumar, 2018). An organized study of all these influencing parameters might leads to better results of the delineation process. The aim of study is to delineate the potential recharge zones and to recommend appropriate recharge structures at the identified locations. This can be fulfilled by preparing of thematic maps of factors which affect the recharge of groundwater assigning proper weightage and ranking using Multi-Influencing Factor technique is being adopted by the researchers can be adopted to identify the locations where recharge structures can be constructed and suggested suitable, economically and viable recharge structures.

Study Area. *Kotani* watershed situated between 20°17′56″ to 21°22′57″N latitude and 80°22′57″E to 81°28′48″ E longitude. Drainage area of *Kotani* watershed is about 6951 Km^2 and average annual rainfall of the watershed is 1100 mm. Location of the identified critical sub-watershed of the Kotani watershed shown in Fig.1.

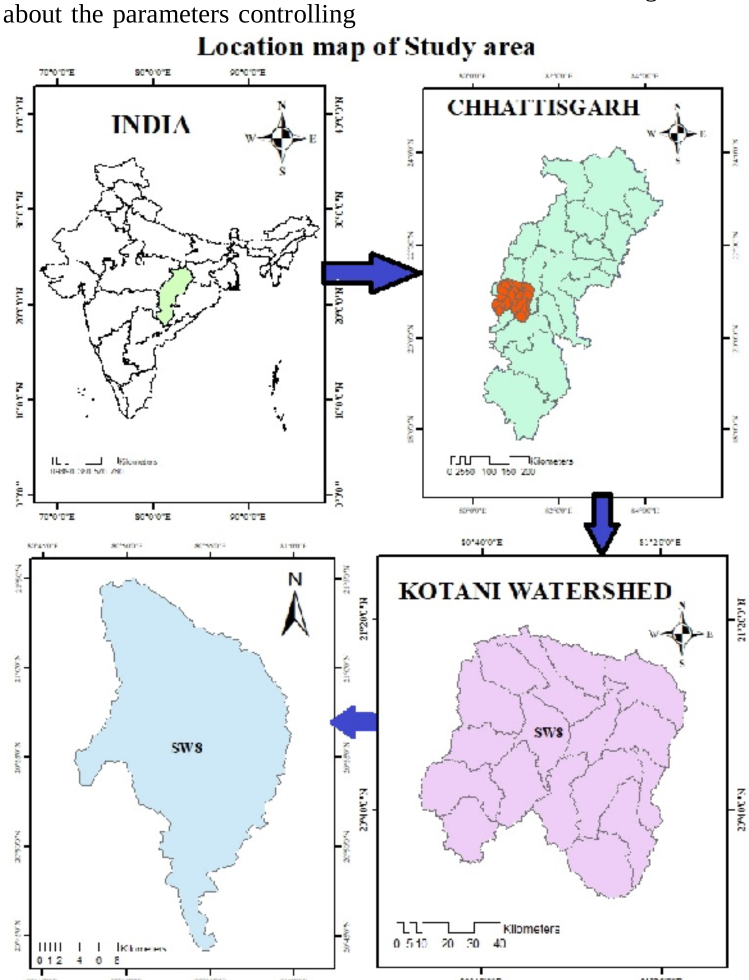

Fig. 1. Identified critical sub-watershed of the Kotani watershed.

MATERIALS AND METHODS

The factor which affects ground water recharge zones are slope, drainage density, geology, geomorphology, lineament density, land use/cover, rainfall, groundwater fluctuation and soil texture. All the considered factors and their sources of base map collection are summarized below in Table 1. Different thematic maps were prepared by the use of base map and data of these factors in the GIS software. The final groundwater potential zone map was obtained after collecting all of the base maps and prepared thematic maps. Fig. 2 illustrates the approach and steps used to create the final outcome map.

Table 1: Factors influencing groundwater recharge and their sources of data collection.

Sr.No.	Factors	Source of collection
1.	Slope	DEM
2.	Drainage	DEM from Earth Explorer United State Geological Survey (USGS)
3.	Geology	Geological Survey of India, Raipur
4.	Geomorphology	Satellite images from Bhuvan (ISRO)
5.	Lineament/Ground water fluctuation	CGWB, Raipur
6.	Land use/ land cover	Landsat image from Earth Explorer USGS
7.	Soil Texture	Chhattisgarh State Watershed Management Agency, Raipur
8.	Rainfall	IWRIS website

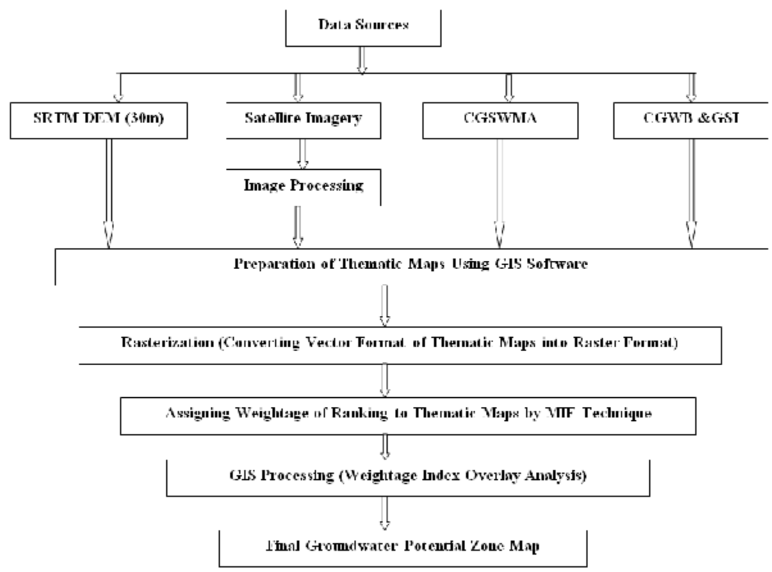

Fig. 2. Flow chart showing delineation process.

Multi-Influencing Factor Technique. In this technique individual weight was assigned to each factor which has been considered. Each factor under consideration has impacts with some other factor but the effect varies from factor to factor. Multi-Influencing Factor (MIF) technique is done with the help of inter-relationship among different factors. According to their impact on groundwater recharge all the relations are weighted. The representative total weightage of any factor is the sum of all the weights from other factors. The factors that have a major and minor impact on the factor under consideration are given in the Table 2. Groundwater potential is influenced more by factors with a high total weightage value than by factors with a lower total weightage value. The final groundwater potential zone map is formed by combining all of these parameters, as well as their potential weights, using the Weighted Overlay Index tool in ArcGIS software.

Weighted Overlay Index Technique. The MIF technique is used to investigate the impact of one factor on other components. All the thematic layers were overlaid on top of each other to get the final groundwater recharge zone map in a weighted combination after the calculation of individual potential weights of each factor. Thematic layers with the most weight should be placed on top. All of the subsequent layers are superimposed in decreasing weight order. The 'weighted overlay' analysis tool is used when the sequence of overlaying is completed. The final map is created using a weighted overlay analysis tool in GIS software, which splits the entire research area into different potential zones.

Table 2: Inter-relationship between the factors concerning groundwater recharge zone.

Sr. No.	Factors	Major Impacts	Minor Impacts
1.	Slope	Geology	LULC, geomorphology
2.	Geology	Drainage density, slope, soil and lineament density	—
3.	Soil	LULC	
4.	Drainage density	LULC	Lineament density
5.	Geomorphology	LULC	Drainage density, soil
6.	Land use/cover	Drainage density, geomorphology	Lineament density, soil, slope, and geology
7.	Lineament density	Drainage density, LULC	—
8.	Rainfall	Drainage density	Soil
9.	Water fluctuation	Rainfall	

RESULTS AND DISCUSSION

By using methods and techniques all the thematic maps are prepared which described in the preceding. The initial step for preparation of thematic maps was the collection of base map. The procedure used and the resulting thematic maps are given and discussed in the present section.

Preparation of Thematic Maps

Slope Map. The infiltration capacity of water into the groundwater is influenced by slope, which can be used as an important suitability parameter for groundwater recharge. Surface runoff will be smaller and infiltration will be greater as slope values are less. Variation in the value of slope in critical sub watershed (SW8) of *Kotani* watershed identified by Sediment Yield Index Method, ranging from 0 to 24%. Maximum area under this sub-watershed falls under 0 to 4 per cent which covers 411.28 km^2 (97.77 %), 4-8 per cent area covers 6.90 km^2 (1.64%). About 1.28 km^2 (0.30%) comes under 8 to 12 per cent of slope and 12-16 per cent of slope very nominal area about 0.50 km^2 (0.11 %) comes under this category and greater than 16 per cent cover only 0.24 km^2 (0.05%). The final map of critical sub-watershed (SW8) is shown in Fig. 3(a).

Soil Texture Map. Soil type and texture of any area largely influence the seepage and percolation of surface water into the groundwater, hence directly influencing the recharge capacity of the soil. Soils having high infiltration rate will be best suitable for artificial recharge whereas soils having low infiltration are not considered good for artificial recharge. Gravelly sandy loam, sandy loam and loamy skeletal soils having high infiltration rate will be best suitable for artificial recharge whereas clay loam and fine loamy soils having moderate infiltration rate in the identified critical sub-watershed (SW8). Soil texture map of critical sub-watershed is given in Fig. 3(b).

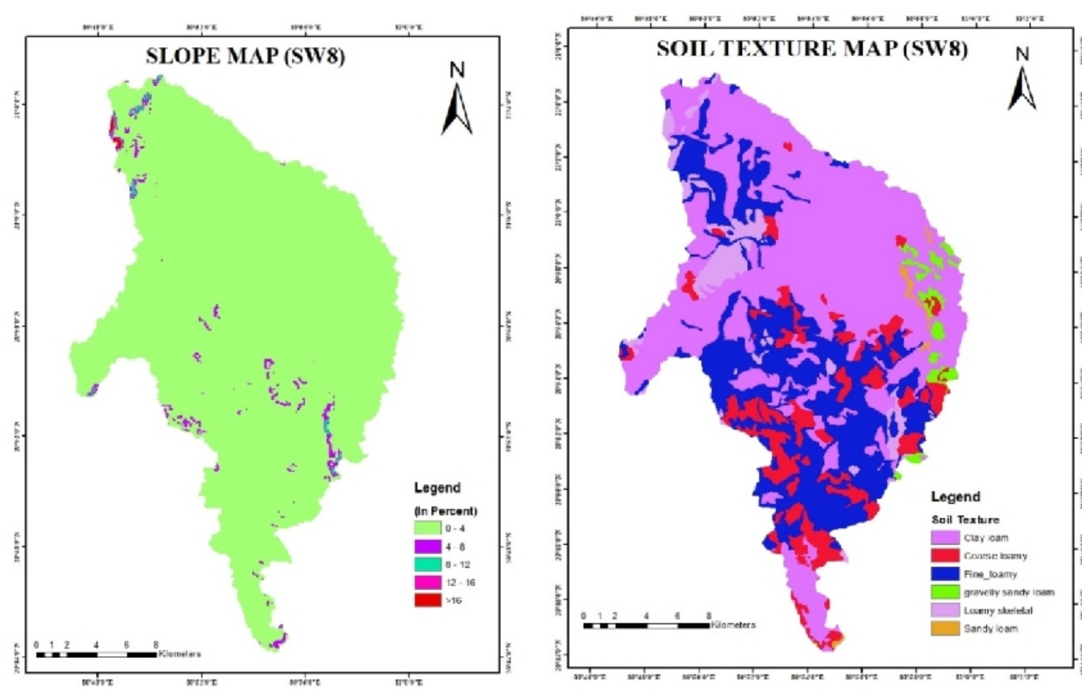

Fig. 3. Slope (a) and Soil Texture map (b) of the critical sub watershed

Geomorphology Map. The underground flow of water is controlled by geomorphic units present beneath the surface. Recharge capacity of any surface is greatly influenced by geomorphology of the watershed. Major geomorphic units present in watershed are (i) Pediment pedi plain complex and (ii) Moderately dissected hills & valleys. Satellite image downloaded from National Remote Sensing Centre (NRSC), Bhuvan is used to obtain the Geomorphology map of sub-watershed (SW8). A Geomorphic units present in sub-watershed (SW8) is shown in Fig. 4(a).

Land Use Land Cover Map. Different types of LULC units present in this critical sub-watershed (SW8) are forests, water body, settlement, current fallow and agricultural land. LULC is prepared using Landsat image downloaded from Earth Explorer United State Geological Survey (USGS). Fig. 4(b) shows the final LULC map which is prepared using 'Maximum Likelihood Classification' tool in GIS 10.3 software. The vegetative cover at any area is directly related to surface runoff hence also influence recharge capacity. More the density of vegetative cover greater will be infiltration rate and smaller will be runoff from the surface. Water bodies show the highest recharge capacity whereas for settlement area recharge is almost negligible because of the construction of paved surface which facilitates large runoff.

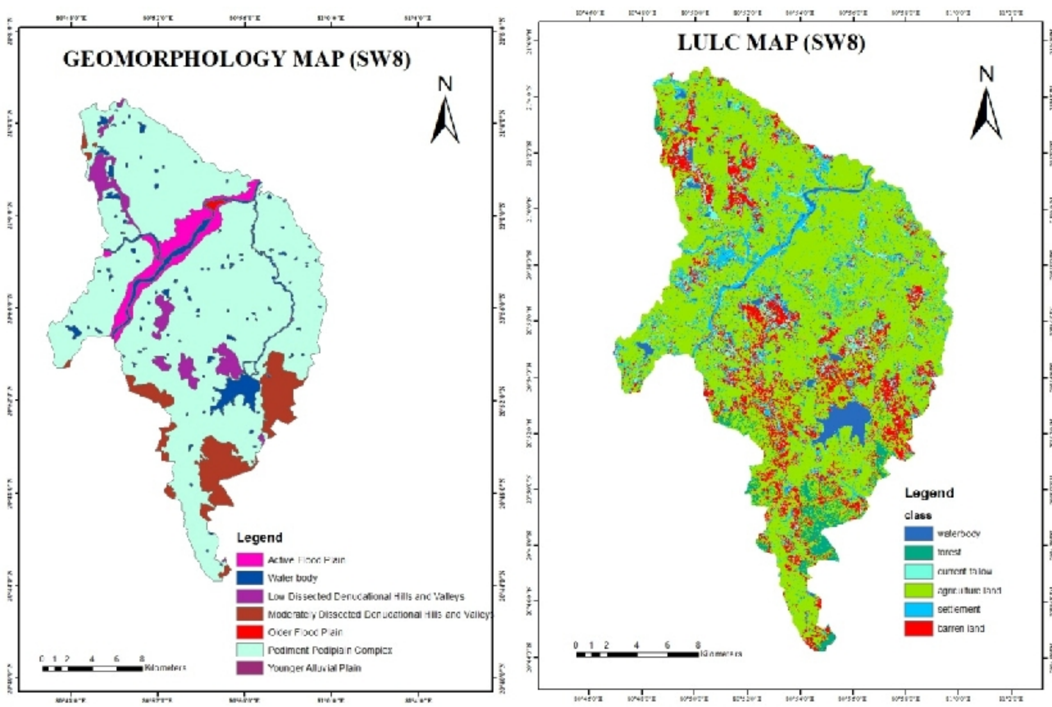

Fig. 4. Geomorphology (a) and LULC Map (b) of the critical sub watershed.

Drainage Density Map. Generally, ratio of total distance travelled by all the major and minor rivers to the total surface area is defined as Drainage Density expressed as km/km^2. To evaluate the groundwater prospects at any area drainage density is an important parameter since it is always related to porosity and permeability of any surface. Higher value of drainage density results high runoff and low infiltration, which directly affects the recharge capability. Fig. 5(a) shows drainage density variation of the critical sub-watershed (SW8).

Geology Map. Various geological units present in critical sub-watershed (SW8) area are (i) Kodwa formation, (ii) Dongargardh granite, (iii) Churmuria, (iv) Chandarpur, (V) Limestone, (vi) Karultola and (vi) Nandgaon group. The geology map is prepared using ground water prospects map collected from Geological Survey of India, Raipur (C.G.). Major area of sub-watershed (SW8) is covered by Nandgaon group. Geology map of critical sub-watershed (SW8) is shown in Fig. 5(b).

Lineament Map. Linear features such as joints, fractures and folds that are present beneath the surface of earth constitute Lineaments of the critical sub-watershed. Water holding capacity of these lineaments is very good and acts as a good conductor of water transmission. Presence of lineaments in any area is considered good as they increase the porosity, hydraulic conductivity and permeability of land surface. The lineaments exist in critical sub-watershed are given in Fig. 6.

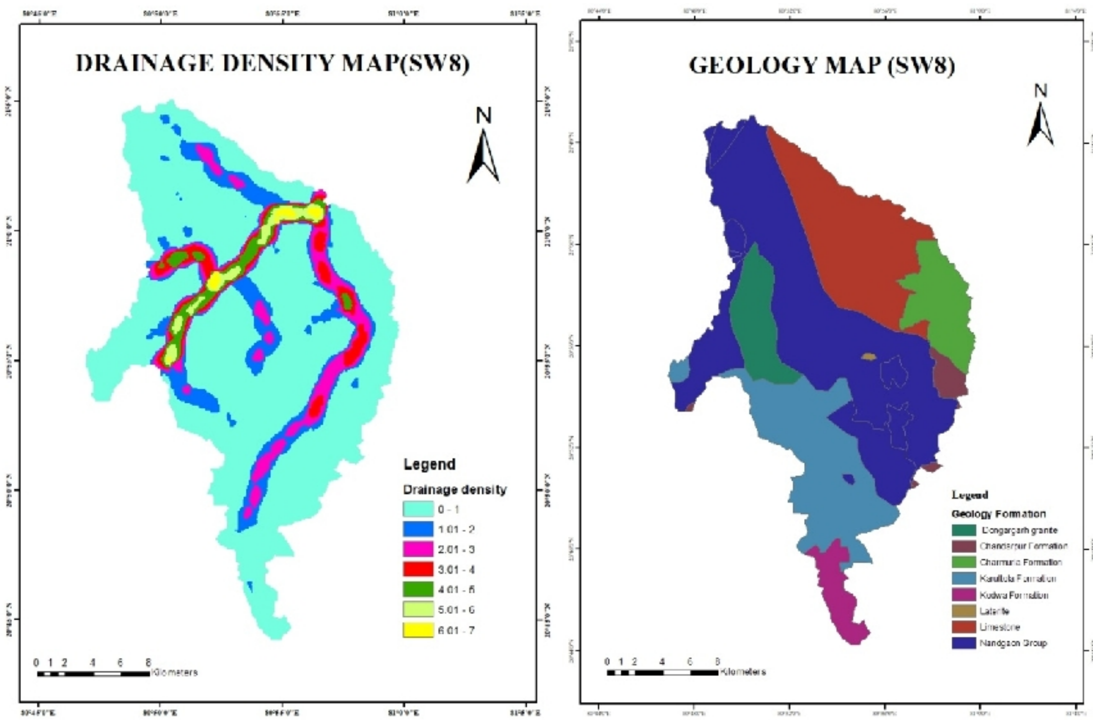

Fig. 5. Drainage density (a) and Geology map (b) of the critical sub watershed.

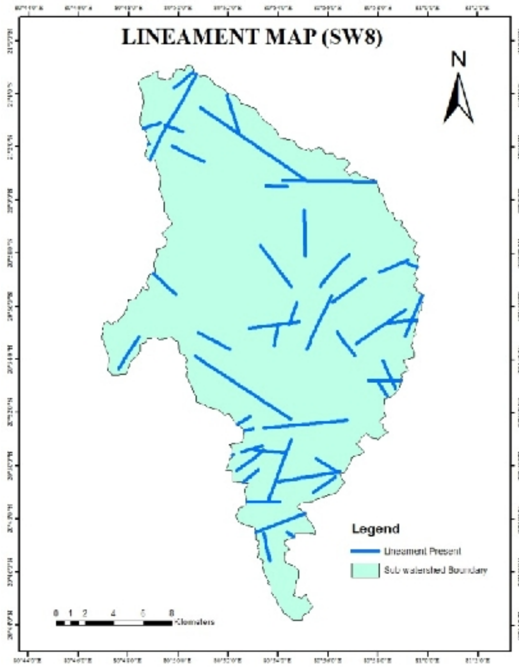

Fig. 6. Lineament Map of the critical sub watershed.

Assigning of Weightage and Ranking. Weights and ranks are provided to each factor and the parameter associated with factor. Individual weights are allotted to each factor using Multi-influencing Factor Technique. Weightage given for each major impact is 1 where 0.5 weightage is given for minor impact. The summation of all the weights will give the individual weight of each influencing factor. The individual weights given to each factor are given in Table 3.

The proposed score or the final individual weight is calculated using the formula given below

$$\frac{\mathrm{P}+\mathrm{Q}}{\sum(\mathrm{P}+\mathrm{Q})} \times 100$$

Here, P shows major impacts and Q shows minor impacts between two influencing factors.

Table 3: Relative rates and final individual weights for each influencing factors.

Sr. No.	Factors	Major Impact Score (P)	Minor Impact Score (Q)	Relative Rates (P + Q)	Final Individual Weightage
1.	Slope	1	0.5+0.5	2	11
2.	Geology	1 + 1 + 1 + 1		4	21
3.	Soil	1		1	5
4.	Drainage density	1	0.5	1.5	8
5.	Geomorphology	1	0.5 + 0.5	2	10.5
6.	Land use/cover	1 + 1	0.5 + 0.5 + 0.5 + 0.5	4	21
7.	Lineament density	1 + 1		2	10.5
8.	Rainfall	1	0.5	1.5	8
9.	Ground water fluctuation	1		1	5
Total				**19**	**100**

Table 4: Rank and weightage allotted to various factors and parameters.

Sr. No.	Factors	Associated parameters	Ranks in words		Rank in weightage number (%)
1.	LULC	Settlement	Very high	1	**21**
		Water bodies	Very poor	5	
		Forest	Moderate	3	
		Current fallow	High	2	
		Barren land	Poor	4	
		Agricultural land	High	2	
2.	Geology	Dongargarh granite	Poor	4	**21**
		Chandarpur formation	Very high	1	
		Churmuria formation	Very high	1	
		Karultola formation	High	2	
		Kodwa formation	Poor	4	
		Laterite	Moderate	3	
		Limestone	Very High	1	
		Nandgaon group	Poor	4	
3.	Lineament density	0 - 0.9	Poor	3	**10.5**
		0.9 - 1.8	High	2	
		1.8 - 2	Very high	1	
4.	Geomorphology	Moderately dissected hills & valleys	Poor	4	**10.5**
		Pediment Pedi plain complex	Very high	1	
		Low dissected hills & valleys	Moderate	3	
		Active flood plain	High	2	
		Waterbody	High	2	
		Older flood plain	Moderate	3	
		Younger alluvial plain	High	2	
5.	Slope	0 – 4%	Very high	1	**11**
		4 – 8%	High	2	
		8– 12%	Moderate	3	
		12– 16%	Poor	4	
		>16%	Poor	4	
6.	Drainage density	4 – 5 km/km	Very poor	5	**8**
		3– 4 km/km	Poor	4	
		2– 3 km/km	Moderate	3	
		1– 2 km/km	High	2	
		0 – 1 km/km	Very high	1	
7.	Soil type	Clay Loam	Moderate	3	**5**
		Coarse loamy	High	2	
		Fine loamy	Moderate	3	
		Gravelly sandy loam	Very High	1	
		Loamy skeletal	High	2	
		Sandy loam	High	2	
8.	Rainfall (average monsoon in mm)	198-199	Low	3	**8**
		199-200	High	2	
		200-202	Very high	1	
9.	Ground Water fluctuation	1-3	Low	3	**5**
		3-4	High	2	
		4-5	Very high	1	

After deciding the individual weights, rank is being provided to each associated parameter on the basis of their influence on groundwater recharge. Concerned weights and the ranks given to each parameter are described in Table 4.

Groundwater Recharge Zone Map. After successfully deriving the weightage of each factor using MIF technique, all the thematic maps are integrated together with the derived weights and ranks during weighted overlay analysis in ArcGIS 10.3.1 software to obtain the final groundwater potential zone map [Fig. 7(a)]. It is observed from Fig 7(a) that 28.64% of the critical sub-watershed (SW8) areas found to be 'Very high' recharge capability. 'High' recharge capability areas was found to be 30.79%, 'Medium recharge capacity area was 23.47% whereas 'Low' recharge potential was found in the critical sub-watershed (13.16%) and very little area falls under 'Poor' recharge capability in the sub-watershed.

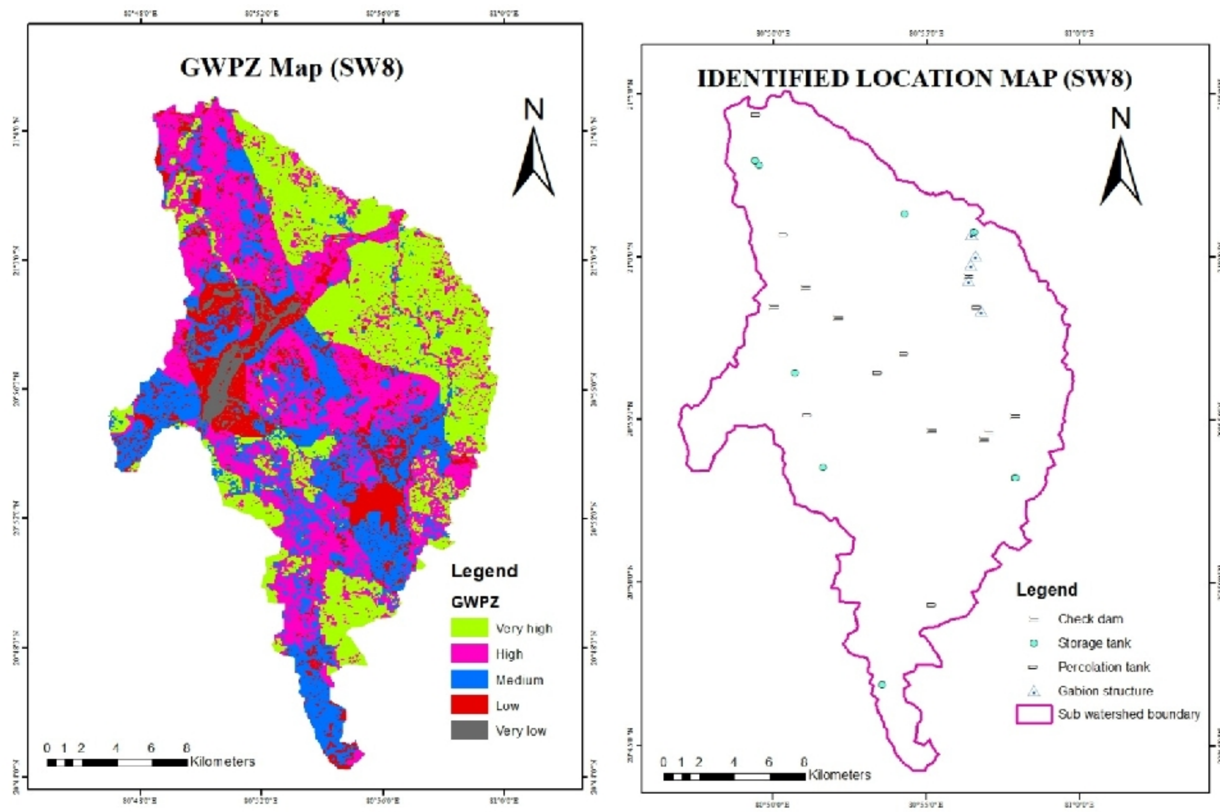

Fig. 7. Distribution of Groundwater Potential Zone (a) and Identified location map (b) of the critical sub-watershed.

Identified Location Map. One of the major objectives of the study is to recommend artificial recharge structures for the sites identified over the various potential zones. Identification of the accurate locations where these structures are to be built were find out by overlaying drainage density and lineament density thematic maps. The locations where these structures can be constructed are shown in Fig. 7(b). The identification of groundwater potential zones provides the help for locating suitable sites for the water harvesting structures and groundwater recharge structures in low groundwater potential zone. Based on the above developed map of groundwater potential zone as well as depth to water table and slope conditions, we developed a new map to suggest the suitable sites of different types of water harvesting and recharge structures in SW1. The proposed suitable artificial recharge structures are mainly storage tank, percolation tank, check dam and gabian structures and their numbers are respectively 8, 7, 8 and 5. Sub watershed (SW8) is identified as critical on the basis of Sediment yield index; here gabian structures are given to check the sediment of the sub watershed 8 whereas storage tank are suitable for rainwater harvesting and percolation tank is useful for groundwater recharge. Check dams having dual purpose groundwater recharge and rainwater harvesting. Groundwater recharge potential zone wise different recharge structures suggested for identified locations are also listed in Table 5.

Table 5: Groundwater recharge potential zone wise suggested artificial recharge.

Sr. No.	Recharge potential zone	Suggested structures
1.	Very high (28.64%)	Check Dams
2.	High (30.79%)	Storage tank
3.	Medium (23.47%)	Percolation Tanks
4.	Low (13.16%)	Gabian structure
5.	Very low (2.99%)	Gabian structure

CONCLUSION

The results obtained from present study revealed that geospatial techniques are potentially powerful for delineating different potential zones of groundwater considering nine parameters influencing groundwater recharge viz. slope, drainage density, land use/cover, geomorphology, geology, lineament density, soil texture, rainfall and groundwater fluctuation. Suitable ranking and weightage can be assigned to each influencing parameters depending upon their ability to fluctuate the rate of groundwater recharge using Multi-Influencing Factor Technique. On the basis of results of the study it can be concluded that most of the critical areas in sub-watershed (SW8) have 'Very high' recharge capability. 'High' recharge capability areas are 30.79%, 'Medium' recharge capability areas are 23.47% for groundwater augmentation was found in the critical sub-watershed (SW8). 'Low' and 'Very low' areas of recharge capability in critical sub-watershed (SW8) was found to be 13.16% and 2.99% respectively. The results of this study can be used to prepare a judicious management plan for groundwater resources to have a long term sustainability of the limited and precious resource of the critical sub-watershed (SW8). The final groundwater recharge zone map can be obtained in the form of prospects map.

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Conflict of Interest. None.

REFERENCES

Bhattacharya, A. K. (2010). Artificial Ground Water Recharge with a Special Reference to India. *Artif Gr Water Recharg*, *4*(2): 214-21.

Lakshmi, S. V., & Kumar, K. S. (2018). Mapping of Groundwater Potential Zones Using Remote Sensing And GIS. *International Journal of Pure and Applied Mathematics*, *119*(17): 3377-3386.

Navane, V. S., & Sahoo, S. N. (2017). A Review of Integrated RS and GIS Technique in Groundwater Potential Zone Mapping.

Nigam, G. K., & Tripathi, M. P. (2019). Generation of Groundwater Zones for Selection of Prospective Suitable Water Harvesting Structure Sites for Sustainable Water Supply Towards the Agricultural Development. *Agric. Res.*, *9*(2): 148-160.

Rodríguez-Huerta, E., Rosas-Casals, M., & Hernández-Terrones, L. M. (2019). Water Societal Metabolism in the Yucatan Peninsula. The Impact of Climate Change on the Recharge of Groundwater by 2030. *Journal of Cleaner Production*, *235*: 272-287.

Saha, D., Marwaha, S., & Mukherjee, A. (2018). Groundwater Resources and Sustainable Management Issues in India. *In Clean and Sustainable Groundwater in India*, *1*(11). *Springer, Singapore.*

Samson, S., & Elangovan, K. (2015). Delineation of Groundwater Recharge Potential Zones in Namakkal District, Tamilnadu, India using Remote Sensing and GIS. *Journal of the Indian Society of Remote Sensing*, *43*(4): 769-778.

Yadav, S. K. (2018). Groundwater Challenges, Governance, and Management in Nepal. *In Groundwater of South Asia*: 707-734. *Springer, Singapore*.

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