Plant Archives **Vol. 25, Special Issue (ICTPAIRS-JAU, Junagadh) Jan. 2025 pp. 889-901**
e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.SP.ICTPAIRS-127

IDENTIFICATION OF GROUNDWATER POTENTIAL ZONE OF MEGHAL BASIN USING REMOTE SENSING AND GIS

S.R. Makvana[1]*, P.B. Vekaria[2] and K.V. Prajapati[3]

[1]Research, Training and Testing Centre, Junagadh Agricultural University, Junagadh, Gujarat, India.
[2]Department of Irrigation and Drainage Engineering, CAET, Junagadh Agricultural University, Junagadh, Gujarat, India.
[3]Fanshawe College, London, Ontario, Canada.
*Corresponding author E-mail : makvanasunil87588@gmail.com

ABSTRACT

Artificial groundwater recharge is essential due to the increasing demand for groundwater in agriculture, domestic use, and industrial needs. In general practice, the artificial recharge techniques are being adapted randomly and therefore it may not be harnessed up to the full potential of groundwater. Henceforth, there is a need to divide and demarcate the whole river basin into different groundwater recharge potential zones, so that the site suitability of groundwater recharge can be identified. Also, there is a need to suggest various suitable recharge structures in the different zones of the river basin. That's why objective of this study is to delineate the groundwater potential zones of Meghal basin area using Remote Sensing (RS) and Geographic Information System (GIS) techniques and proposing suitable groundwater recharge structure for different zones. Weighted overlay analysis was used to demarcate the groundwater potential zones. Various thematic layers such as geology, geomorphology, soil, lineament density, drainage density, rainfall and land use maps were prepared. The AHP method was employed, and the weights were objectively evaluated. Subsequently, the use of GIS technology combined with multi-criteria decision analysis offers a more flexible solution for predicting groundwater recharge potential zones. The final groundwater potential map was prepared by assigning appropriate weightage to different thematic maps and adding them to the final groundwater potential map. This study incorporates several factors, including geology, geomorphology, land use/land cover (LULC), lineament density, drainage density, soil, slope, and rainfall, to determine groundwater potential zones in the Meghal River basin. The weighted overlay technique has been utilized to generate these zones. The resulted map is divided into Poor, Fair, Good, Excellent groundwater potential zones and the aerial spread of these categories are 5.09 sq. km 106.44 sq. km. 433.20 sq. km, 10.52 sq. km.

Key words : Analytical Hierarchy process, GIS, Ground Water Potential Zone, Ground Water Recharge Structure, LULC, Remote Sensing.

Introduction

Water is the prime necessity for the sustainability of every living organism, and it applies to all human beings, animals, plants, or any living organism, so it plays a pivotal role in supporting life on the earth. Besides being a crucial element for the existence of life, it serves to be a vital necessity for the social and economic development of the nation as the water has its application in domestic supplies, industrial and agricultural activities.

The total annual groundwater recharge in Gujarat state is 27.35 BCM and annual extractable groundwater resource is 25.41 BCM. The Annual Ground Water Extraction has marginally increased from 13.09 to 13.13 BCM. As compared to 2022 assessment, the change in Annual Ground Water Recharge is because of increase in the recharge by canal network and rainfall whereas the Annual Ground Water Extraction is increased marginally. Hence, the Stage of Ground Water Extraction has improved marginally from 53.23 % to 51.68 %. (Anonymous, 2023).

The artificial recharge of the aquifers dilutes the pollutants as well as prevents saltwater intrusion that helps in maintaining the underground water quality. It is a very tedious and cumbersome task to locate the potential sites for the artificial recharge as it depends on many independent parameters. The existence and movement of groundwater involve various factors such as geomorphology, lineament density, land use and land cover (LULC), lithology, drainage density, soil types, slope steepness, DEM, average rainfall etc.

Conventionally, exploration of the groundwater recharge potential sites was carried out by the ground surveys that were cumbersome and required much more time and money. Due to the upcoming of new technologies such as remote sensing and GIS the task of delineating groundwater recharge potential zones has eased up to several extents.

The remotely sensed data cannot be used directly to observe the groundwater, hence, in several studies, satellite data, topographical sheets obtained from the Survey of India (SOI) and other information along with ground truth verification were used to necessary baseline information on the factors that affects the occurrence and movement of the groundwater such as geomorphology, lineament density, land use and land cover (LULC), lithology, drainage density, etc. Remote Sensing and GIS technologies can be adopted to prepare different thematic maps of various factors affecting the groundwater recharge and as a multi-criteria decision analysis tool. Analytical Hierarchy Process is employed to allocate suitable ranks and weights to all the different categories in each of the thematic maps.

The objectives of this project encompass mapping the thematic features of the Meghal river basin, focusing on delineating its physical and hydrological characteristics. This includes identifying potential zones for groundwater recharge within the basin, crucial for sustainable water resource management. By integrating spatial data and analysis, the project aims to pinpoint specific areas with high recharge potential, informing the strategic placement of recharge structures tailored to the diverse hydrogeological conditions observed across the basin. Through this comprehensive approach, the study seeks to offer practical recommendations for implementing effective groundwater recharge initiatives, thereby enhancing water availability and resilience in the Meghal river basin ecosystem.

Materials and Methods

Study area

The study area of this research was the Meghal basin, which encompasses Keshod, Maliya and Veraval Talukas in Junagadh district of Gujarat state in India. Geographically, it is situated between 20.902°N to 21.289°N latitude and 70.202°E to 70.191°E longitude. The basin covers a geographical area of 555.11 sq. km. There are four main tributaries flowing into Meghal river namely Lathodario, Vrajmi, Meghal and Kalindri. The total length of the river is 70 km including its tributaries. The drainage basin encompasses a total of 53 villages and covers an area of 471 sq. km (Khadeeja and Harshad J. Dalwadi, 2011).

Materials

In this study, an Integrated Remote Sensing and GIS Approach was employed to delineate groundwater potential zones within the Meghal River Basin, Gujarat, India. The investigation utilized several thematic layers, including geology, geomorphology, lineament, slope, drainage, soil, land use/land cover, and rainfall. To create the necessary thematic maps, such as land use/land cover, hydro-geomorphology, soil, slope, drainage, and watershed demarcation, geo-coded SRTM-DEM dated November 16, 2022, were used at a scale of 1:200,000. A comprehensive description of the data is detailed in Table 2.

Methodology

Geomorphology

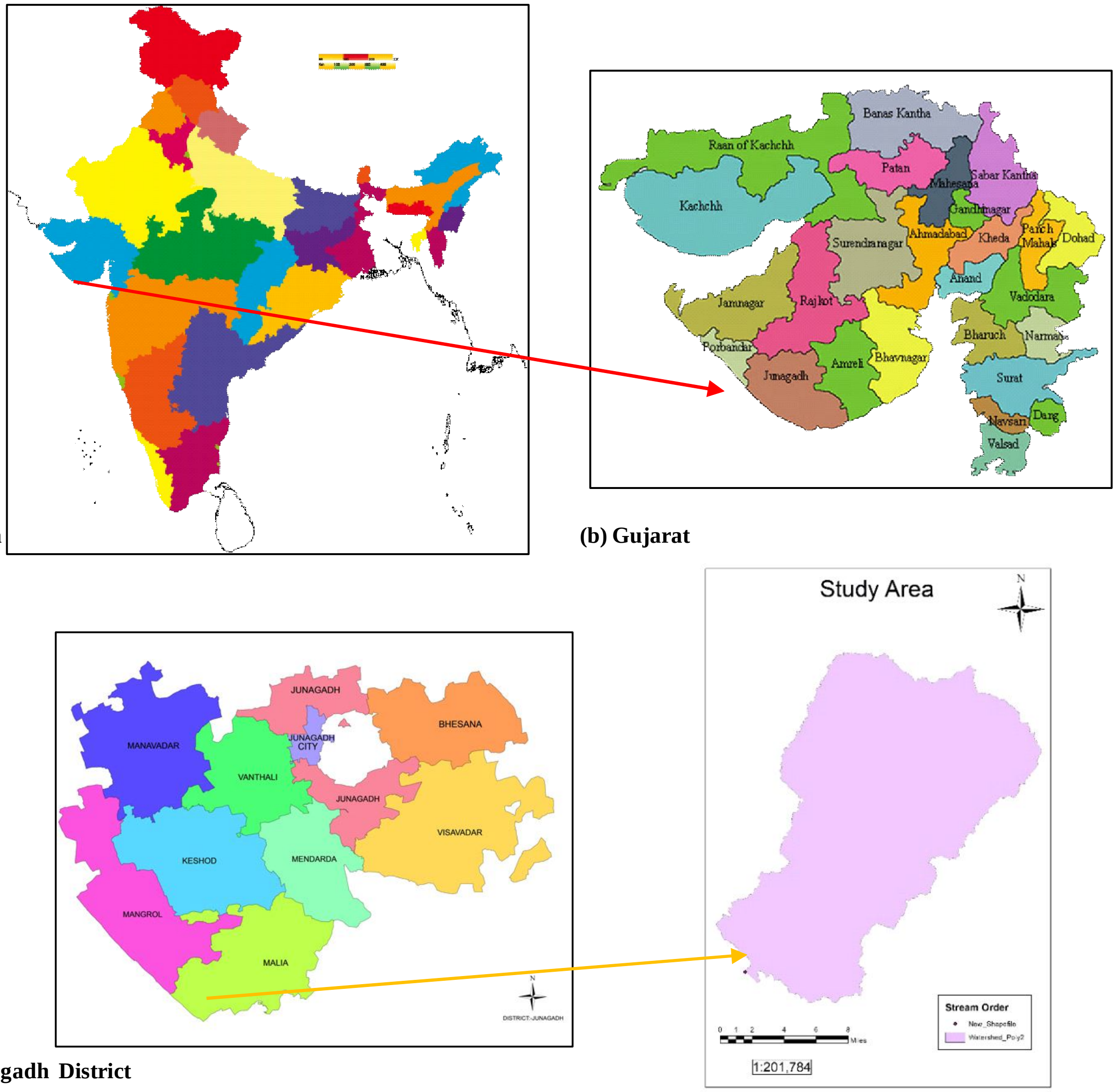
Geomorphology, which pertains to the study of topography and landforms, is a key factor in delineating groundwater recharge potential zones. A geomorphology map provides crucial information regarding the origin,

Table 1 : Geometry of basin.

S. no.	Parameters	Result
1	Area	555.12 km^2
2	Basin Perimeter	143.21 km
3	Basin Length	37.31 km
3	Form Factor	0.398
4	Compactness Coefficient	1.714
6	Circulatory Ratio	0.34
7	Elongation Ratio	0.712

Table 2 : Raw Data collection.

Name of Dataset	Acquisition Date	Source
DEM	November 16, 2022	BHUVAN
Lineament	-	BHUVAN
Soil Type	-	NBSS
Geological map	-	BHUKOSH
Geomorphology map	-	BHUKOSH
Rainfall Data	Last 30 year	SWDC-Gandhinagar



(a) India

(b) Gujarat

(c) Junagadh District

(d) Meghal Basin

Map 1 : Location map of study area.

occurrence, and movement of groundwater. In geomorphological landforms such as alluvial plains, floodplains, and pediplains, the occurrence of groundwater is primarily influenced by factors such as lithologic conditions, slope, drainage patterns, infiltration rates and runoff (Sathiyamoorthy *et al.*, 2023). Digital geomorphological data for Gujarat State, India, were obtained from the open-access Bhukosh-Geological Survey of India. To facilitate a detailed analysis, a vector file representing the geomorphology of the Meghal River Basin was also created. The identified geomorphological units encompass various landforms, including alluvial plains, coastal plains, flood plains, highly dissected plateaus, low dissected plateaus, moderately dissected hills and valleys, pediment-pediplain complexes and water bodies such as rivers.

Geology

Geological structure plays a crucial role in shaping the landscape. The source and flow of groundwater are different depending on the type of rock on which it is located. The type of rock in each area has a significant impact on the availability and recharge of groundwater (Selvam *et al.*, 2016). The digital data for the geology of India was obtained from open-source data of the Bhukosh-Geological Survey of India and the Geology Map of the Meghal River Basin was constructed.

Published geological map of the Geological Survey of India (GSI, 1995) was used for delineating different geological units of the study area. Geologically major part of the basin is occupied by deccan trap. Apart from this occurrence of undiff.fluvial / aeolian / coasta & glacial

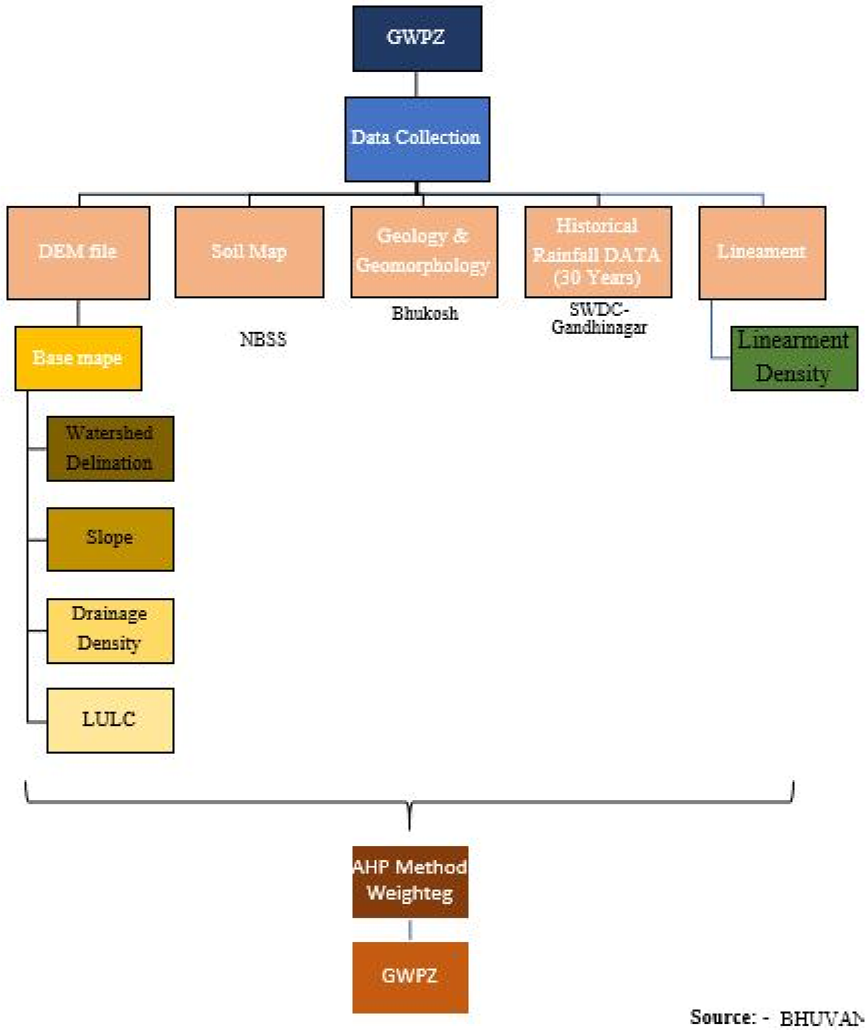


Fig. 1 : Flow chart of process to find GWPZ.

sediments is also noticed in the area. Dwarka fm, gaj fm. both are cover 2.5% of area.

Slope

The slope is an important topographic feature that represents the steepness of the topographic surface. Slope provides crucial information about the types and nature of geological and geodynamic processes that occur at the regional level. The slope significantly affects surface runoff and infiltration rate. A larger slope results in a decrease in recharge, because rainwater will quickly flow down the steep slope when it rains, so there is not enough residence time to infiltrate and fill the saturated zone, and vice-versa is also true (Arulbalaji *et al.*, 2019). The DEM data was considered that for the construction of the slope map. The raster file of Slope Map, in percentage, was developed using the special analyst tool option, in particular, the slope tool in the Arc Map software.

Table 3 : Area of geomorphology subclasses.

S. no.	Geomorphology features	Area (sq. km)	Area (%)
1	Alluvial Plain	0.93	0.17
2	Coastal Plain	11.70	2.11
4	Flood Plain	0.48	0.09
5	Highly Dissected Plateau	10.50	1.89
6	Low Dissected Plateau	83.39	15.02
7	Moderately Dissected Hills and Valleys	0.16	0.03
8	Pediment Pediplain Complex	440.80	79.41
9	Waterbody- River	7.15	1.29

Soil

Soil type plays an important role in the amount of water that can seep into the ground and therefore affect the formation of subsurface and the recharge of the groundwater. Soil texture and hydraulic properties are the main factors to be considered while evaluating the permeability (Arulbalaji *et al.*, 2019).

Hydraulic soil group of the meghal river basin

According to the recommendations of Gundalia (2016); the soil map is classified according to hydraulic soil categories according to soil texture and order characteristics. Four different types of HSG are important key elements along with LULC, hydrological conditions, and management methods and are used to determine the runoff CN: The description of the four HSGs is as follows:

The soil map is as shown in Fig. In study area, there were (HS-B) means composed of 10-20% clay and 50-90% sand and have sandy loam or loamy sand texture,

Table 4 : Area and weightage of different geology subclass.

S. no.	Geomorphology features	Area (sq. km)	Area (%)
1	Undiff. Fluvial/Aeolian/Coasta & Glacial Sediments	109.65	19.75
2	Dwarka Fm.	10.58	1.91
3	Gaj Fm.	2.47	0.45
4	Deccan Trap	432.42	77.90

Table 5 : Area of different slope type.

S. no.	Slope	Area(sq. km)	Area(%)
1	0-2%	227.81	41.04
2	2-5%	276.16	49.75
3	5-7%	36.12	6.51
4	7-15%	13.61	2.45
5	>15%	1.39	0.25

Table 6 : Area of different soil group.

S. no.	HSG	Area (sq.km.)	Area (%)
1	B	18.51	3.33
2	C	454.84	81.80
3	C/D	7.20	1.29
4	D/D	75.42	13.56

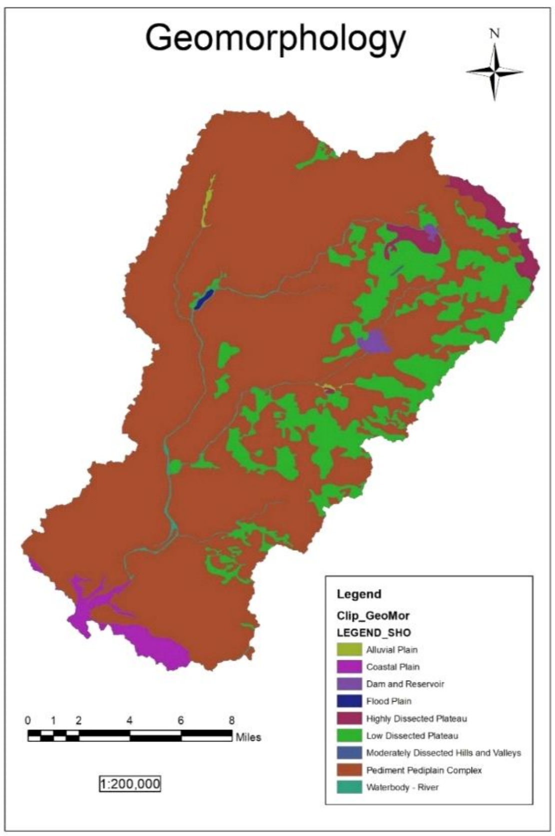


Fig. 2 : Geomorphology.

(HSG-C) consist of 20% to 40% clay and less than 50% sand, (HSG-C/D) That's type of group high runoff potential unless drained less than 50% sand 20 - 40 % clay., (HSG-D/D) High runoff potential unless drained (<50% sand and >40% clay) groups.

The aerial distribution of soil taxonomy of the basin is as given in table. It could be seen from the (table) that about 50% of the basin area is having C type Hydrology Soil Group.

Drainage density

Drainage density plays a very decisive role in the availability of groundwater. The drainage network depends on the lithology and provides an important indicator of permeability. Drainage density is inversely proportional to permeability. It is an important parameter to determine the demarcation of the groundwater potential zone in the watershed. High drainage density means less infiltration and therefore does not significantly support the recharge of groundwater in the area. Low drainage density means high infiltration, thus increasing the recharge of the groundwater (Arulbalaji *et al.*, 2019).

Drainage density was obtained by dividing the total length of all rivers in the watershed by the total area of the watershed (Horton, 1932).

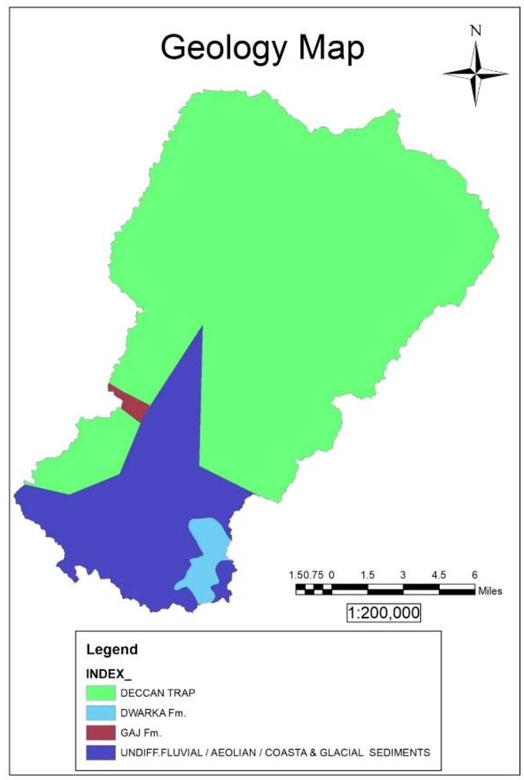


Fig. 3 : Geology.

$$Dd = \frac{\sum_{u=1}^{k}\sum_{i=1}^{N} Lui}{A} \quad (1)$$

Where,

Dd = Drainage density in km/sq. km.

Lui = total length of channels in the basin in km.

A = total area of the basin in sq.km.

The drainage density of the area of interest was calculated from the streams generated using the DEM data in the Arc GIS 10.3.1 environment. The raster file

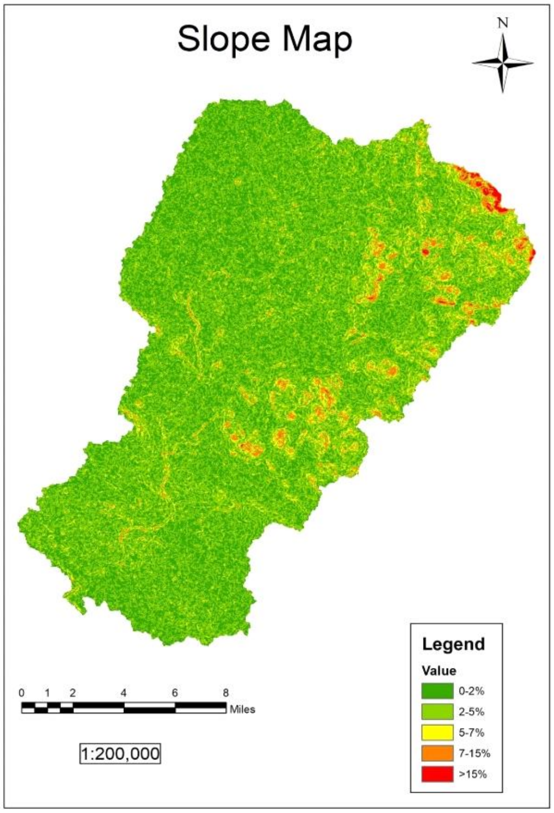


Fig. 4 : Slope.

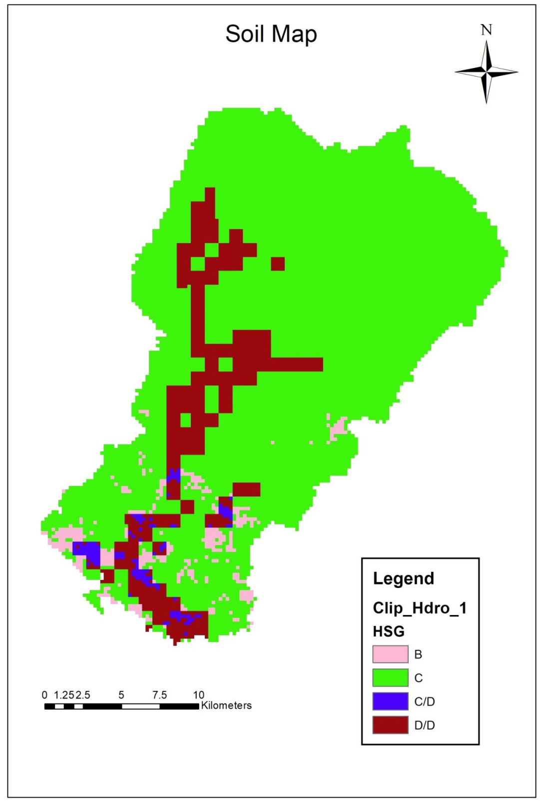


Fig. 5 : Soil.

Table 7 : Area and Weightage of Drainage Density subclasses.

S. no.	Drainage Density(km/sq. km)	Area (Sq.km)	Area (%)
1	0.0033 - 2.30	220.68	39.75
2	2.30 - 4.59	222.03	39.99
3	4.59 - 6.89	89.52	16.12
4	6.89 - 9.19	20.70	3.72
5	9.19 - 11.48	2.16	0.38

of the drainage density of the Meghal River Basin was prepared with the help of the line density tool.

To determine the drainage density of a watershed, the first step is to identify the stream order of the watershed. Once the stream order is mapped, the line density command can be applied to this stream order map to calculate the drainage density. This command quantifies the density of stream lengths per unit area, providing valuable insights into the drainage characteristics of the watershed. This process is crucial for hydrological analysis and effective watershed management.

Land Use/Land Cover (LULC)

The earth's surface topographical conditions are reflected through the land use/land cover. The LULC maps are essential for the planning, development, and management of groundwater. The LULC in semiarid regions changes quickly due to climate change and water scarcity. The recharge of surface water to the aquifer is mainly influenced by land use/land cover, and also it helps to identify the groundwater-potential zones. The study area is covered by water bodies, sandy areas, plantations, forests, and built-up land. The LULC classes, such as water bodies and sandy areas, hold a sufficient amount

Table 8 : Area of LULC subclass.

S. no.	LULC	Area(sq. km)	Area(%)
1	Agricultural Land	475.37	85.63
2	Built Up	9.87	1.78
3	Forest	15.51	2.79
4	Wastelands	42.97	7.74
5	Waterbodies	11.40	2.05

Table 9 : Area of Lineament density.

S. no.	Lineament Density (km/ sq. km)	Area (sq. km)	Area (%)
1	0 - 0.305	487.58	87.82
2	0.306 - 0.609	56.98	10.26
3	0.61 - 0.914	7.96	1.43
4	0.915 - 1.22	1.33	0.24
5	1.23 - 1.52	1.34	0.24

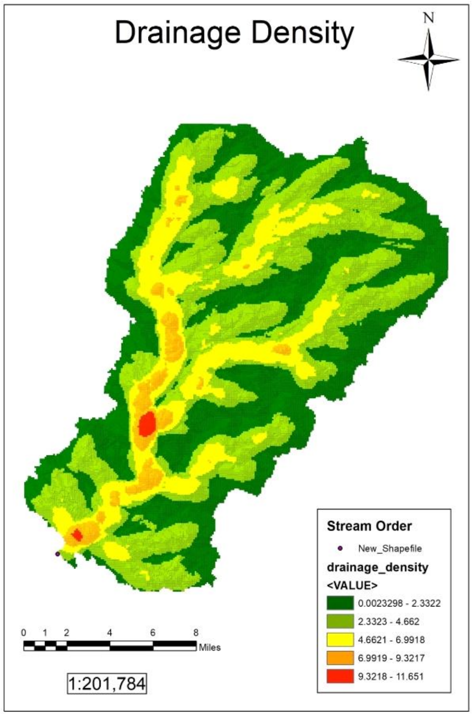


Fig. 6 : Drainage density.

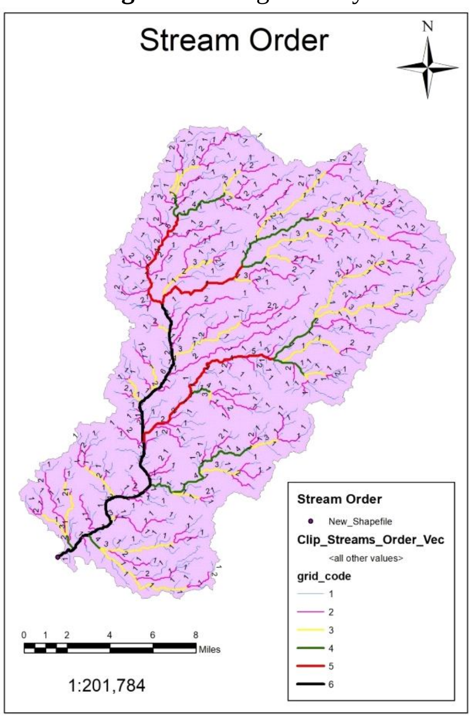


Fig. 7 : Stream order.

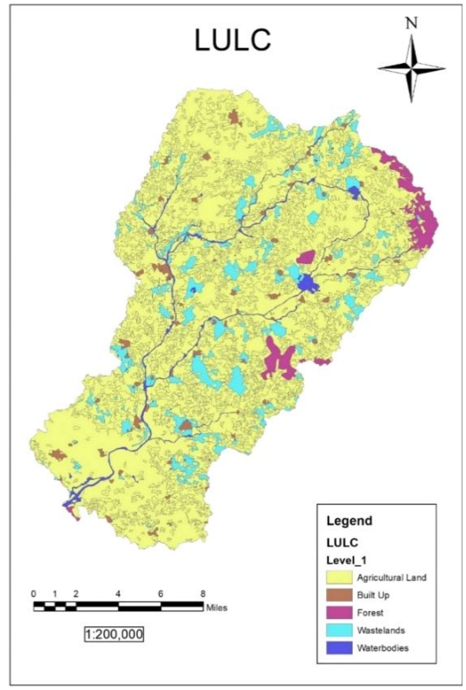


Fig. 8 : LULC.

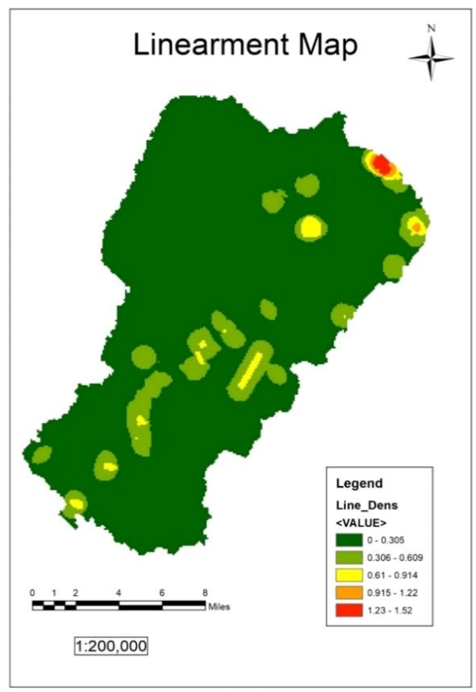


Fig. 9 : Linement Density.

of groundwater than other LULC classes. Moreover, the water bodies also serve as groundwater recharge zones, and the infiltration rate is high in the sandy area. Thus, water body and sandy area are grouped as ‘very good’ and ‘good’ categories, respectively. The plantation is considered as ‘medium’ and the forest is categorized as ‘poor’. Generally, it is observed that the infiltration is less in built-up land, resulting in a high runoff, and therefore, it is categorized as ‘very poo’.

Land use refers to man’s actions on land, including numerous purposes, whereas land cover refers to features that have come from land transformation. Remote sensing data primarily records information on the land surface, from which land use information must be extrapolated. To prepare a thematic map of land use and land cover, remote sensing data from BISAG in Gandhinagar is utilized. This data ensures the creation of accurate and

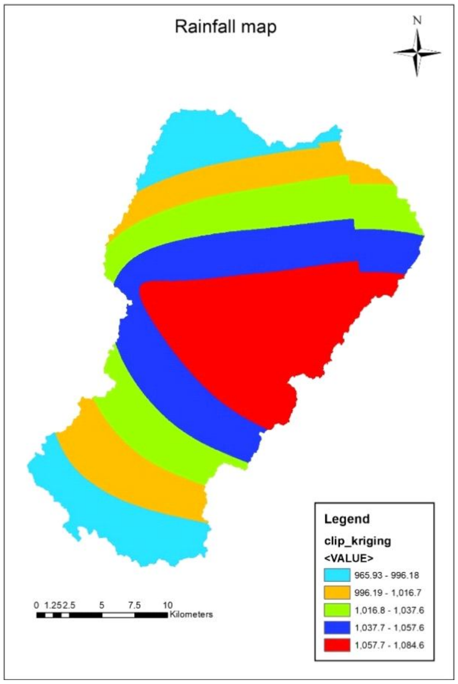


Fig. 10 : Rainfall.

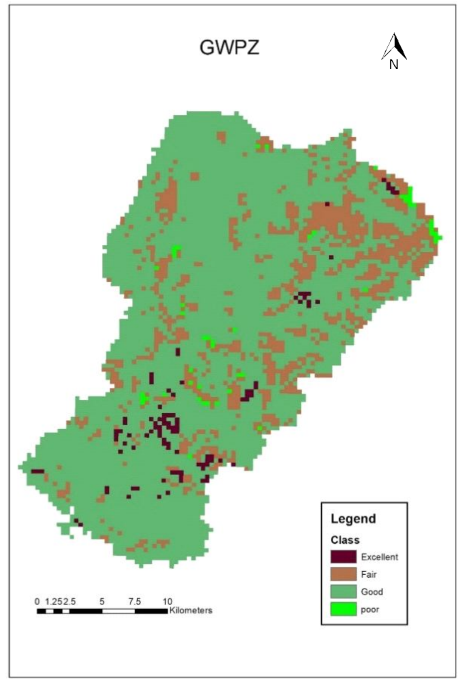


Fig. 11 : GWPZ.

Table 10 : Area of Rainfall distribution.

S. no.	Rainfall (mm)	Area (sq.km)	Area (%)
1	965.93 - 996.18	93.1347	16.78
2	996.19 – 1016.7	94.01702	16.94
3	996.19 – 1016.7	105.4873	19.01
4	1037.7 – 1057.6	119.6046	21.55
5	1057.7 – 1084.6	142.6431	25.70

Lineament-length density (Ld); the total length of all recorded lineaments divided by the area under study (Greenbaum 1985):

$$L_d = \frac{\sum_{i=1}^{n} Li}{A} \tag{2}$$

Where,

$\sum_{i=1}^{n} Li$ is the total length of the lineaments

Table 11 : Saaty's ratio index for different values of N.

The consistency indices of randomly generated reciprocal matrices												
Order of matrix												
N	1	2	3	4	5	6	7	**8**	9	10	11	12
RCI value	0.00	0.00	0.58	0.90	1.12	1.24	1.32	**1.41**	1.45	1.49	1.51	1.48

A is the total area of the watershed

detailed maps, which are essential for urban planning, environmental management, and resource allocation.

Lineament density

Lineaments can be identified by its relatively linear position from the satellite image. These lineaments represent faults and fracture zones, leading to increased secondary porosity and permeability (Arulbalaji *et al.*, 2019). The lineament density of an area can indirectly indicates the potential of groundwater because the presence of the lineaments usually indicates a permeable area. Areas with high lineament density are considered excellent choices for potential groundwater recharge areas (Pinto *et al.*, 2017).

Depending on their character and aerial extent, these lineaments have been classified as major and minor lineaments. Using GIS, a lineament density map was created using the lineament map as the base map. Water level variations have been found to be inversely proportional to lineament density which means the water level is lower in areas having higher lineament density.

The lineament file of the Meghal Basin was downloaded from the BHUVAN database. The resulting lineaments were imported into the ArcGIS environment to calculate the lineament density. The lineament density map of the study area was then computed using the spatial

Table 12 : Pair wise matrix calculation of the weight allocation thematic layer.

Parameters	AW	GEM	SL	DD	LULC	GEO	SO	LD	R	GM	NW
GEM	8	1.00	1.6	1.6	1.14	1.33	1.33	1.33	2	**1.42**	**0.17**
SL	5	0.63	1.00	1.0	0.71	0.83	0.83	0.83	1.25	**0.89**	**0.10**
DD	5	0.63	1.00	1.0	0.71	0.83	0.83	0.83	1.25	**0.89**	**0.10**
LULC	7	0.88	1.4	1.4	1.00	1.17	1.17	1.17	1.75	**1.24**	**0.15**
GEO	6	0.75	1.2	1.2	0.86	1.00	1.00	1.00	1.5	**1.24**	**0.15**
SO	6	0.75	1.2	1.2	0.86	1.00	1.00	1.00	1.5	**1.06**	**0.13**
LD	6	0.75	1.2	1.2	0.86	1.00	1.00	1.00	1.5	**1.06**	**0.13**
R	4	0.5	0.8	0.8	0.57	0.67	0.67	0.67	1.00	**0.71**	**0.08**

Where, AW: Assignment Weightage, GEM: Geomorphology, SL: Slope, DD: Drainage Density, LULC: Land use Land Cover, GEO: Geology, SO: Soil, LD: Linearment Density, R: Rainfall, GM: Geometric Mean, NW: Normalized Weights.

analyst tools, specifically the line density tool.

Rainfall data

The major source of groundwater in the study area is contributed by the strong rainfall relationship that exists between rainfall and groundwater. Rainfall intensity and duration play a significant role in infiltration and surface runoff. (Mahenthiran Sathiyamoorthy) India is a tropical country, and rainfall is the main source of water here. Rainfall or precipitation also has a major role to play in groundwater recharge and other hydrological processes (Ritambhara K. Upadhyay)

Rainfall is the major water source in the hydrological cycle and the most dominant influencing factor in the groundwater of an area. For the present study, the rainfall data of 1992-2022 is used. The annual rainfall ranges from 965mm to 1085mm. Based on the maximum and minimum values, the rainfall has been reclassified into five categories such as Very Low, Low, Moderate, High and Very High rainfall. Infiltration depends on the intensity and duration of rainfall. High intensity and short duration rain influence less infiltration and more surface runoff; Low intensity and long duration rain influences high infiltration than run-of. High weights are assigned for high rainfall and vice versa. Depicts the rainfall spatial interpolation map of the Meghal river basin.

Analytical hierarchy process (AHP)

AHP is one of the most extensively used MCDM methods. It was developed by Thomas L. Saaty in 1980. It is based on a certain stage of planning criteria (determining selection criteria), including evaluation of the criteria weight (relative importance), comparing alternatives for each criterion and determining the overall ranking of alternative options. Here, the AHP method was used and the weights were objectively evaluated. These standards are of relative importance, so information and experience are particularly important for accurate evaluation and analysis. These criteria can be qualitative or quantitative. MCDM based in GIS is an expert-knowledge-based method, which is very helpful for solving complex problems. The use of GIS technology and multi-criteria decision analysis provides a more flexible solution for predicting the recharge of groundwater potential zones.

Therefore, for the parameters that affect decision-making, a decision matrix is generated according to the scale ranging from 1 to 9. The criteria in the scoring scale were as follows: (1) least important, (2) very less important, (3) less important, (4) moderately less important, (5) equally important, (6) moderately important, (7) more important, (8) very important, (9) extremely important (Saaty, 1980, 1990).

The AHP pair-wise matrix is developed by input values of scale weights of themes and their features based on relative influence on groundwater occurrence, the literature reviewed and expert opinion. Thereafter, a pair-wise comparison matrix was constructed using Saaty's analytical hierarchy process (Saaty, 1980) to calculate normalized weights for individual themes and their features.

$$Geometric\ Mean = \prod_{i=1}^{n} x_i^{\frac{1}{n}} \quad (3)$$

Where,

x_i is the elements whose geometric mean is to be calculated, n is the number of elements

$$Normalized\ Weights = \frac{Geometric\ Mean}{Total\ Geometric\ Mean} \quad (4)$$

For calculating the consistency ratio (CR), the (1) Principal Eigenvalue (λ) and (2) Consistency Index (CI) were computed as follows (Kumar *et al.*, 2019).

Table 13 : Weightage allocation to various features of the thematic layers.

Parameters	Thematic layer NW(%)	Subclass	Subclass Weight
Slope	10	0-2%	9
		2-5%	8
		5-7%	7
		7-15%	3
		>15%	1
Lineament	13	0 - 0.305 (km/ sq. km)	1
		0.306 - 0.609 (km/ sq. km)	2
		0.61 - 0.914 (km/ sq. km)	4
		0.915 - 1.22 (km/ sq. km)	6
		1.23 - 1.52 (km/ sq. km)	8
Rainfall	8	965.93 - 996.18 (mm)	4
		996.19 - 1,016.7 (mm)	5
		1016.7 - 1037.7 (mm)	6
		1,037.7 -1,057.6 (mm)	7
		1,057.7 - 1,084.6 (mm)	8
Drainage Density	11	0.0033 - 2.300 (km/ sq. km)	7
		2.300 - 4.597 (km/sq. km)	6
		4.597 - 6.893 (km/ sq. km)	5
		6.893 - 9.190 (km/ sq. km)	4
		9.190- 11.48 (km/ sq. km)	3
Soil	13	B	8
		C	7
		C/C	3
		C/D	4
Geomorphology	17	Alluvial Plain	2
		Coastal Plain	4
		Flood Plain	9
		Highly Dissected Plateau	8
		Low Dissected Plateau	9
		Moderately Dissected Hills and Valleys	7
		Pediment Pediplain Complex	6
		Waterbody-River	7
Geology	13	Undiff.Fluvial/ Aeolian / Coasta & Glacial Sediments	7
		Dwarka Fm.	5
		Gaj Fm.	3
		Deccan Trap	4
LULC	15	Agricultural land	7
		Built Up	5
		Forest	3
		Wastelands	2
		Waterbodies	9
		Wetland	8

Table 13 continued...

$$\lambda_{\max} = \frac{\sum_{i=1}^{n}(P)}{Parameters\ in\ row} \tag{5}$$

$$CI = \frac{\lambda_{\max} - N}{N-1} \tag{6}$$

Where, N is the number of factors used in the analysis.

Consistency Ratio is defined as,

$$CR = CI/RCI \tag{7}$$

Where, RCI = Random consistency Index value, whose values were obtained from the Saaty's standard.

Saaty has opined that a CR of 0.10 or less is acceptable to continue the analysis. If the consistency value is greater than 0.10, then there is a need to revise the judgment to locate causes of inconsistency and correct it accordingly. If the CR value is 0; it means that there is a perfect level of consistency in the pair-wise comparison. If the value is not exceedingly above 0.1, which means the judgments matrix is reasonably consistent.

Results and Discussion

Integration of various thematic maps to demarcate various groundwater potential zones (GWPZ)

Various thematic maps consisting of several categories along with their normalized weights were integrated into the Arc GIS 10.2.2 environment. To compute Groundwater Recharge Potential Zone Index (GWPRZI), all thematic maps were integrated with the GIS environment using equation (3.8), as proposed by Malczewski (1999):

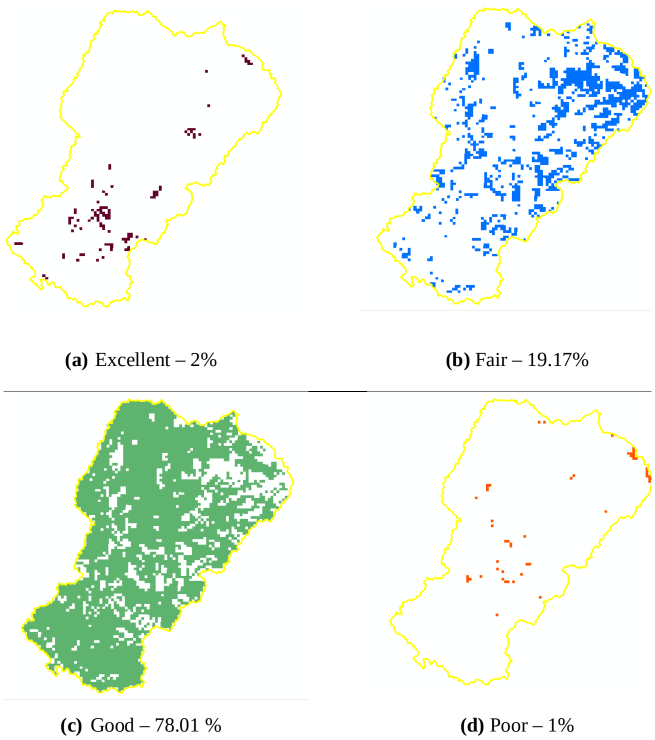


Fig. 12 : Different area according to GWPZ classification.

Fig. 13 : Different zone wise area.

Table 14 : GWPZ area classification.

S. no.	Class	AreaSq. km	Area%
1	Poor	5.09	0.91
2	Fair	106.44	19.17
3	Good	433.20	78.01
4	Excellent	10.52	1.89

Table 15 : Area of Excellent zone with its coordinates.

Zone	Latitude (N)	Longitude (E)
Excellent	70.226383	21.033272
	70.32575	21.031939
	70.343642	21.039363
	70.321562	21.062206
	70.308998	21.063348
	70.313948	21.071343
	70.31528	21.052117
	70.2806535	21.060302
	70.286917	21.068107
	70.286917	21.052307
	70.311283	21.077815
	70.305001	21.097612
	70.317755	21.088856
	70.373149	21.086952
	70.378098	21.093424
	70.411696	21.155528
	70.4148	21.149247
	70.404914	21.15959
	70.420405	21.15046
	70.47024	21.229141
	70.47552	21.226276
	70.421578	21.218135
	70.429387	21.181651

$$GWPZI = \sum_{j=1}^{m}\sum_{i=1}^{n}(w_j * x_i) \quad (8)$$

Where,

x_i is the normalized weight of the i^{th} class of thematic layer and w_j is the normalized weight of the j^{th} thematic layer, m is the total number of thematic layers and n is the total number of subclasses in a thematic layer.

The parameters that are considered here are geology, geomorphology, LULC, lineament density, drainage density, soil, slope, rainfall. The weighted overlay method

Table 16 : Ground water recharge structures for different potential zones.

GWRS	Potential Ground water recharge zone	Suitable area in zone Sq. km
Check Dam	In good/excellent groundwater potential zones, generally for slope up to 15%, where the permeability is low and can be built across the stream of stream order 2nd, 3 rd, and 4th.	443.73
Farm pond	In good groundwater recharge potential zone, generally for the gentle slope up to 5%	433.20
Open Well	In Good / Excellent groundwater recharge potential zone, where the land use is cropland/ fallow land/ wasteland and slope up to 3%.	443.73
Tube well	In Good / Excellent groundwater recharge potential zone, where the land use is cropland/ fallow land/ wasteland and slope up to 5%	443.73

has been applied to generate the groundwater potential zones in the Meghal river basin.

The output map was reclassified based on their final weight into 5 categories, *viz*., excellent, good, moderate, poor, and very poor. The class with the lowest weight represents very poor recharge potential for the groundwater and the class with the highest weight represents excellent recharge potential for the groundwater.

Recommendation of suitable Groundwater Recharge structures in different Zones

Meghal river is a non-perennial river. Therefore, during the dry period, people need to resort to groundwater for irrigation and domestic demand. As a result, it becomes crucial to maximizing the recharge of the groundwater. Groundwater recharge.

Conclusion

The identification of groundwater potential zones was conducted using remote sensing, GIS and AHP techniques by overlaying and assigning weighted values to thematic maps such as geomorphology, geology, soil, slope, rainfall, lineament density, and drainage density. The results categorized the watershed land area into four types: poor (0.91%, 5.09 sq.km), fair (19.17%, 106.448 sq.km), good (78.01%, 433.20 sq.km) and excellent (1.89%, 10.529 sq.km). Zones classified as good and excellent exhibit high infiltration rates and permeability, whereas those categorized as poor and fair have low infiltration rates. The different zones were demarcated with distinct colors on the map, and latitude and longitude coordinates were provided for the excellent zones, enabling farmers to identify areas with very high groundwater levels.

We recommend suitable groundwater recharge structures for different zones. For areas classified as good and excellent groundwater potential zones (GWPZ) with slopes up to 15%, we suggest constructing check dams. In regions with good GWPZ and slopes up to 5%, farm ponds are recommended. For good or excellent zones where the land use is cropland or wasteland with slopes up to 3%, open wells are advisable. Additionally, in good or excellent zones where the land use is cropland-fallow land or wasteland with slopes up to 5%, tube wells are recommended. These targeted recommendations aim to optimize groundwater recharge and sustainable water management for different land use and slope conditions.

References

Anonymous (2023). Ministry of Jal Shakti. Department of Water Resources, RD & GR. Central Ground Water Board. 2023. Master Plan for Artificial Recharge to Groundwater in India – 2023. Faridabad, India.

Anonymous (2023). Available at, https://bhukosh.gsi.gov.in/ accessed on 10th April, 2023.

Anonymous (2023). Available at, https://bhuvan.nrsc.gov.in/ home/index.php, accessed on 17th march, 2023.

Arulbalaji, P., Padmalal D. and Sreelash K. (2019). GIS and AHP techniques-based delineation of groundwater potential zones: a case study from southern Western Ghats, India. *Scientific Reports*, **9(1)**, 1-17.

Greenbaum, D. (1985). Review of remote sensing applications to groundwater exploration in basement and regolith. *British Geological Survey Report,* **OD-85(8)**, 36

Gundalia, M.J. (2016). Modelling runoff using modified SCS-CN method for middle south Saurashtra region (Gujarat-India). *Ph.D. (Civil Engg,). Thesis (Unpublished)*. Gujarat Technological University, Ahmedabad.

Horton, R. (1932). Drainage Basin Characteristics. *American Geophysical Union Trans*, **13**, 350-361.

Khadeeja, P. and Dalwadi H.J. (2011). Water use and productivity: a river basin analysis. *ii. River basin geology*, **1(1)**, 1-2.

Kumar, S., Machiwal D. and Parmar B.S. (2019). A parsimonious approach to delineating groundwater potential zones using geospatial modeling and multicriteria decision analysis techniques under limited data availability condition. *Engineering Reports*, **1(5)**, e12073.

Malczewski, J. (1999). *GIS and multicriteria decision analysis*. John Wiley & Sons.

Pinto, D., Shrestha S., Babel M.S. and Ninsawat S. (2017). Delineation of groundwater potential zones in the Comoro watershed, Timor Leste using GIS, remote sensing and analytic hierarchy process (AHP) technique. *Applied Water Science*, **7(1)**, 503 519.

Saaty, T.L. (1980). *The Analytic Hierarchy Process*. McGraw-Hill, New York, NY.

Saaty, T.L. (1990). Decision making for leaders: the analytic hierarchy process for decisions in a complex world. RWS Publications, Belmont, California.

Sathiyamoorthy, M. (2023). Sustainability of Groundwater Potential Zones in Coastal Areas of Cuddalore District, Tamil Nadu, South India using Integrated Approach of Remote Sensing, GIS and AHP Techniques. *Sustainability*, **15**, 5339.

Selvam, S., Dar F.A., Magesh N.S., Singaraja C., Venkatramanan S. and Chung S.Y. (2016). Application of remote sensing and GIS for delineating groundwater recharge potential zones of Kovilpatti Municipality, Tamil Nadu using IF technique. *Earth Science Informatics*, **9(2)**, 137-150.

Upadhyay, R.K. (2023). Groundwater Potential Zone Mapping in the Ghaggar River Basin, North-West India, using Integrated Remote Sensing and GIS Techniques. *Water 2023*, **15**, 961.