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Investigation of Finite Groundwater Potential Zones through Analytical Hierarchy Process and ArcGIS for the Region of Visakhapatnam District, Andhra Pradesh

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ABSTRACT

Due to the indiscriminate use of limited water sources, the requirement for groundwater evaluation in India expanded substantially. Population growth and unequal distribution, poor irrigation systems, rapid urbanization/industrialization, large-scale deforestation, droughts, and inefficient land use practises contribute to groundwater depletion.As a result, the need for water for agriculture, domestic, and industry soars. The study identifies viable zones in Visakhapatnam's emerging metropolitan metropolis by utilising the Analytical Hierarchy Process (AHP) approach with remote sensing data in ArcGIS software. Thematic layers were created by taking remote sensing data into consideration (drainage density, soil, lineament density, land use land cover, geomorphology, rainfall, slope, and geology). The method is employed to determine the weights of distinct thematic layers by obtaining the normalised weight from a pairwise matrix.To emphasize the groundwater potential zones and create a map with different zones specified, the weights and ranks extrapolated from the AHP approach have been made available in the weighted index overlay analysis tool in ArcGIS.Groundwater availability and recharge are significantly high in the good zone of the present study's four classifications of good, moderate, low, and very low. The groundwater status, potential locations for water extraction, and best practises for groundwater recharging may all be determined with the use of the acquired information from the indication map.

Keywords: analytic hierarchy process; area under curve; groundwater potential zones; receiver operating characteristic curves; weighted overlay analysis.

INTRODUCTION

Groundwater is found beneath the earth's crust and is a major natural resource for fresh water, the source is very significant for any area if there is no availability of on-ground/surface water, there are many uses like domestic, industrial, and irrigation etc.There is a water table below the layers of earth which varies by depth, the availability of ground water is almost everywhere, due to rapid increase in the urbanization across the world there is declination in the ground water table in few areas which again depends on climatic conditions of that region.

The urbanization is the major reason behind the scarcity of water in the cosmopolitan and metropolitan cities, where there is a large consumption of water by different stakeholders resulting in depletion of water in bore wells,storage reservoirs etc., and more importantly paved surfaces and habitations in urban areas, which avoids the natural percolation of waterresulting in percolation deficit and emptiness of water table in the region.

The ground water is the major effecting resource in the 21st Century as most of the houses and communities are extracting groundwater through borewells which increases dependency on groundwater resources though municipalities supplying water to limited stakeholders. This is the major challenge for any city. In the present study, few areas in the Visakhapatnam district are chosen for identifying the potential groundwater resource and proposing the suitable recharge methods for sustainable groundwater management.

The habitation in the agency areas is extremely backward and the region is under continuous drilling of wells shows inadequate source of water resulting scarcity. Analytical Hierarchy Process (AHP) used the best determining technique which utilizes the weights of various thematic layers beneficial for recharge, storage, and location of groundwater (Venkateswara Rao et al., 2021). Water protection is anticipated to remain the major task in the 21st Century (Snyder, 2019).

In thewater resources engineering field Analytical Hierarchy Process (AHP) applied as a multi-criteria decision-making technique which identified as an efficient tool for problems pertaining to many affecting factors (Chenini et al., 2010). Remote sensing and GIS techniques are useful for study of groundwater sources and for the construction of artificial restore structures in the agency areas of Machkund river catchment of Visakhapatnam District, Andhra Pradesh.

Analytical Hierarchy Process (AHP) method is used for obtaining groundwater potential zones which are useful for the efficient implementation of watershed management and sustainable development plans of the specific region (Anandagajapathi Raju et al., 2020). Integrating GIS and Remote Sensing methods are efficient for assessment of various applications in water resources and groundwater planning.

By interaction with atmospherical, hydrological and geological aspects the availability of groundwater could be evaluated Ghosh, et al., (2016); Saravanan, (2012). Study shows the ability of GIS, RS and MCDA methods for identifying the groundwater prospective zones and acquiring the suitable region for urban residential expansion within urban limits (Tiwariet al., 2019). Identifying the potential areas are carried out by applying GIS based multi criteria estimation technique and the result shows large percentage of agricultural area had been renovated to built-up areas and agricultural area will be reduced if no control is imposed (Mohammed et al., 2016).

The extensive availability and usage of satellite data with maps are aided forconception of essential data for evaluating of groundwater potential regions (Singh et al., 2019; Achu, et al., 2019; Chandra et al., 2006; Hewaidy et al., 2015; Ahmedetal., 2020). In the earlier period, requirement for water raises due to human expansion activities and climate change scenario (Taweesin et al., 2018). The elevation of the research region is very steep and bounded by hills.

The generation of thematic layers for the possible groundwater recharge zone growth is done using an integrated RS, GIS, and AHP technique in the current study. Using these multiple thematic maps, locate and define probable groundwater recharge zones. Use of the Receiver Operating Characteristic (ROC) curve to validate the resulting prospective groundwater recharge zone. To provide the most effective and sustainable management and development of groundwater resources, the main goal of defining the groundwater potential zones of the research area is to create a projected reference map for groundwater assessment.

STUDY AREA

The extent of selected area geographically located in 170° 32' 0'' to 17° 43' 23.16'' N latitude and 830 5' 0'' to 83° 18' 18.36'' E longitude under the district of Visakhapatnam (Fig. 1) covering an area of 727.26 km^2. The Visakhapatnam district is a unique geographical location with different climatic conditions throughout the year, the district is surrounded by eastern ghats and Bay of Bengal, there are many perennial watersheds in and around the area, the mountain range of eastern ghats had many valleys and wide range forests, alongside there is Bay of Bengal which is very much prone to cyclones causing stormsthroughout the year, the district is completely covered with greenery.

The study area falls under the zones of GVMC (Madhurawada, Aslimetta, Suryabagh, Gnanapuram, Gajuwaka, Vepagunta) and Anandapurammandal. The selected area has many water sources and receives water from monsoons and cyclones. The natural slope of the district incline towards the Bay of Bengal resulting the natural drain into the sea.

DATA USED AND METHODOLOGY

The area of study is in Andhra Pradesh State, Visakhapatnam District,the area is under the Survey of India (SOI) toposheets of numbers 65 O/1, 65 O/2&3, 65 O/5 and 65 O/6. The required thematic maps for this study area have been accrued/availed from different sources using ArcGIS

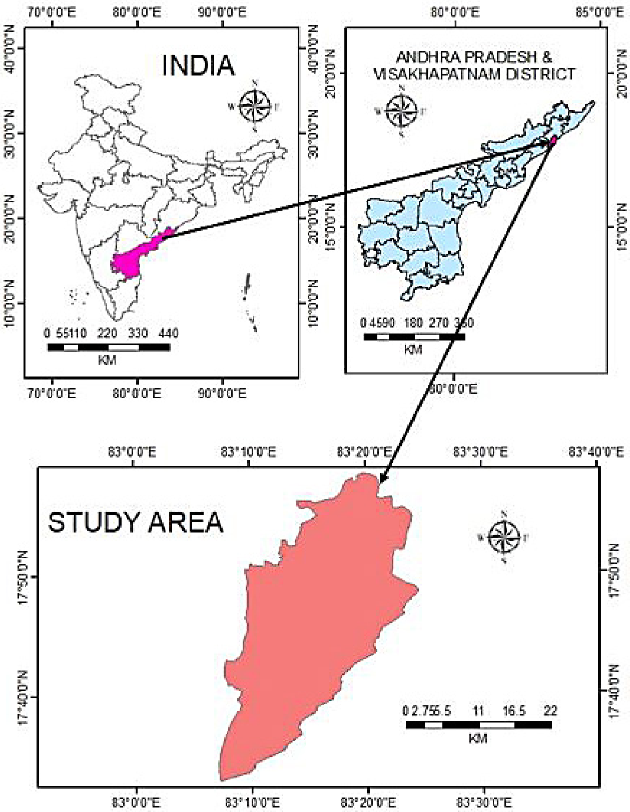

Figure 1. Location map of study region

tools. The eight thematic layers consideredin the study area comprises land use land cover, slope, lineament density, soil, geomorphology, geology, drainage density and rainfallare observed to be changing aspects which are important in evaluating the potentials of groundwater.

The study area geology map obtained from the Geological Survey of India (GSI). Rainfall data in grid format were achieved from the Global Climate Database and spatial allocation was generated by Kriging tool in ArcGIS. Land useland cover map prepared from Landsat-8 and generated by executing the supervised classification algorithm in GIS. The Shuttle Radar Topography Mission (SRTM) for theDigital Elevation Model (DEM) data of 30 meters resolution downloaded from the USGS portal and slope map generated using ArcGIS Tools.

The thematic layers were in UTM (Universal Transverse Mercator) coordinate system and WGS84 with spatial reference (WGS84-UTM-Zone44N). Soil and geomorphologymaps extracted utilizing Web Map Service (WMS) in the ArcGIS platform from APSAC portal. Thegroundwater prospect maps data acquired from NRSA (National Remote Sensing Agency) shown in Table 1.

Table 1. Data resources utilized for groundwater potential map

Factors considered	Data source	Data location
Toposheet	Geological Survey of India	https://surveyofindia.gov.in/
Rainfall	Global climate database	https://crudata.uea.ac.uk/cru/data/hrg/CRU TS 4.06
Soil	APSAC	https://apsac.ap.gov.in
Land use land cover	Landsat 8 07-12-2020	https://earthexplorer.usgs.gov/
Geology	Geological Survey of India	https://www.gsi.gov.in/webcenter/portal/OCBIS
Groundwater prospect maps	National Remote Sensing Agency	https://www.nrsc.gov.in/
Geomorphology	APSAC	https://apsac.ap.gov.in
Lineament density	Bhukosh, Geological Survey of India, GOI, Kolkata, India Dt: 19/12/2022	https://bhukosh.gsi.gov.in/Bhukosh/Public

Analytic hierarchy process

Analytic Hierarchy Process (AHP) is the major crucial methods in multi-criteria executive established by (Saaty 1980, 1990). The process is analysis based when compared the parameters of one another, each parameter is assigned with weights and normalized, to check the reliability the CI & CR are computedas proposed by (Saaty, 1980; Pinto et al., 2017; Jha et al., 2010). The normalized weights are accepted if the computed CR is small and less than 10% as per (Saaty, 1990). The diagonal pair wise matrix is generated when the upper portion of triangle is filled, and the priority is as per the influencing factor of one another parameters. In consideration with upper triangle the lower triangle is reciprocal of upper triangle elements. All element weights are subsequently stabilized. the flow chart is presented in Figure 2. The mean weight of a factors estimated by averaging the normalised weight of row's parameters. The consistency vector (λ) is computed by multiplication of mean weight of each parameter in normalized matrix with the summation of weights in a column of the corresponding factors in the pair wise matrix. The Consistency Ratio (CR) and Consistency Index (CI) are calculated from the pair-wise comparison matrix from all the factors using the Eq. (1) and Eq. (2).

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \quad (1)$$

$$CR = \frac{CI}{RI} \quad (2)$$

where: λ_{max} – summation of consistency vector (λ); n – count of parameters considered. Random Index (RI) is specified as CI, anticipated from order values of a matrix, and are given in Table 2 (if the number of parameters is 8, then RI = 1.41).

Groundwater potential zones delineation by utilizing weighted overlay assessment

The considered thematic layers are reclassified initially, rankings are allocated while considering the effect of factors and their corresponding classes on calculating prospective regions. The purpose

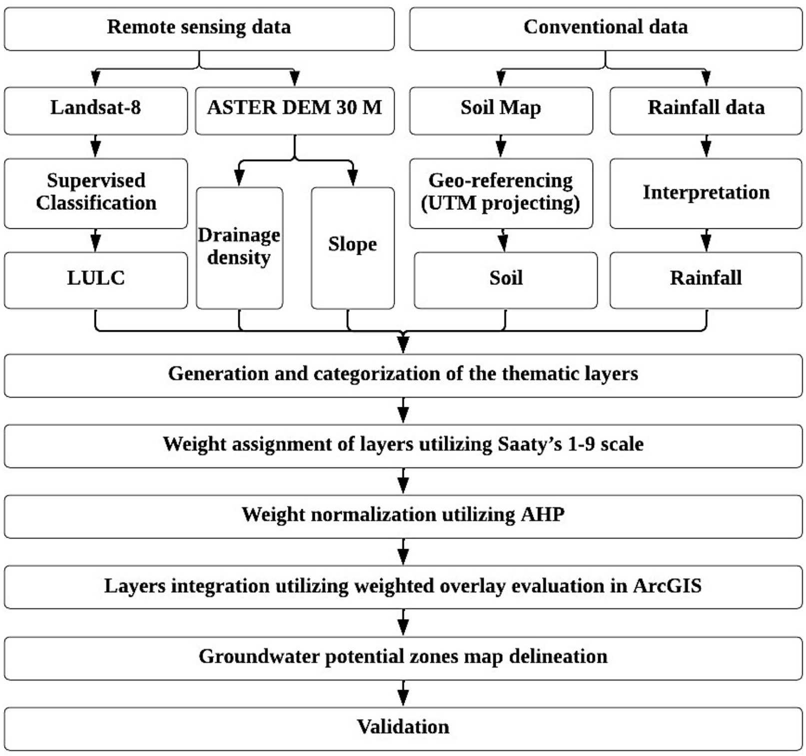

Figure 2. Flow chart for the classification of groundwater potential zones

Table 2. Random index (RI) values are determined by Saaty (2008)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

of generating various weights and classes is to determine, the finest feasible variations. The ranks along with weights are allocated to each factor and their respective classes established on their relative prospective influence represented in Table 5. Here, this is accomplished through a researcher's experience and insights into present literature, position, and other specified area variables like (soil, rainfall, slope, lineament density, geomorphology, geology, lulc, and drainage density). The equation (3) is a raster estimation of considered factors which are integrated into ArcGIS software, there by creating a potential zone map.

$$GWP = (RF_w \times RF_{wi}) + (S_w \times S_{wi}) + \\ +(LD_w \times LD_{wi}) + (DD_w \times DD_{wi}) + \\ +(SL_w \times SL_{wi}) + (GM_w \times GM_{wi}) + \\ +(LU_w \times LU_{wi}) + (G_w \times G_{wi}) \quad (3)$$

Here, GWP indicates the groundwater potential regions and where, RF, LD, LU, SL, S, DD, GM, and G are the rainfall, lineament density, Land use, drainage density, slope, geomorphology, soil, and geology. The layer, weights and ranks of certain classes is characterised by *w* and *wi* which, are related to a pixel basis represented in Eq. (3).

Groundwater potential zone validation

The research area's potential map is prepared with eight different thematic layers (lulc, rainfall, slope, lineament density, geomorphology, geology, soil, and drainage density) were validated by using the data on pumping borewells. Information from pumping borewells is extracted from groundwater prospect maps which obtained from survey of India. Borewell information extensively utilized for the authentication intent throughout the world and at regional level (Naghibi et al., 2016: Altural, et al., 2013, Pourghasemi et al., 2012a).

Bore wells data which obtained from groundwater prospect maps was processed in ArcGIS and overlaying the map of the study area's groundwater prospective zones. The precision of the groundwater prospective zonesmap as established by the Receiver Operating Characteristics Curve (ROC)and Area Under Curve (AUC). The ROC approach utilizes a numerical curve range of 0.5 to 1.0 to assess the model's precision. (Nandi and Shakoor, 2009). The AUC is equal to 0.5, if the model does not anticipate the groundwater potential zones.

RESULTS AND DISCUSSION

The study area is considered with eight thematic layers are applied to evaluate potential zones. Utilizing weights of eight thematic layers (lulc, rainfall, slope, lineament density, geomorphology, geology, soil, and drainage density) from this AHP analysis, a weighted overlay evaluation was performed. The thematic layers assessed to one another for carrying out hierarchy evaluation and weights are allocated to them depending on their relative importance for groundwater storage and movement and shown in Table 3.

The weights of eight thematic layers were stabilized and average weights have been established in Table 4. The consistency vector (λ) determined by multiplying the average weightage of individual thematic layer in Table 4 with the cumulative weights in its column of Table 3. Consistency Index (CI) and Consistency Ratio (CR) derived using equations (1) and (2) to ensure consistency of weights of eight thematic layers. The established values of CI and CR

Table 3. Pair wise matrix

Layers	Lulc	Slope	Geomorphology	Lineament density	Soil	Drainage density	Rainfall	Geology
Lulc	1.00	2.00	0.50	3.00	2.00	3.00	2.00	2.00
Slope	0.50	1.00	0.33	0.50	2.00	2.00	3.00	0.50
Geomorphology	2.00	3.00	1.00	2.00	0.67	2.00	3.00	0.50
Lineament density	0.33	2.00	0.50	1.00	2.00	3.00	4.00	0.33
Soil	0.50	2.00	1.50	0.50	1.00	2.00	2.00	0.50
Drainage density	0.33	0.50	0.50	0.33	0.50	1.00	2.00	0.33
Rainfall	0.50	0.33	0.33	0.25	0.50	0.50	1.00	0.25
Geology	0.50	2.00	2.00	3.00	2.00	3.00	4.00	1.00
Total	5.67	12.83	6.67	10.58	10.67	16.50	21.00	5.42

from this study are respectively 0.066 and 0.043. The Consistency Ratio (CR) is under 10%, and hence the estimated weights are acceptable as per (Saaty, 1980).

The weights and rankings of each constraint in AHP are shown in Table 5. Each sub-element inside the constraint is multiplied by the weights. For each constraint, AHP weights are assigned

Table 4. Normalized comparison matrix

Layers	Lulc	Slope	Geomorphology	Lineament density	Soil	Drainage density	Rainfall	Geology	Weightage	λ
Lulc	0.18	0.16	0.08	0.28	0.19	0.18	0.10	0.37	0.19	1.08
Slope	0.09	0.08	0.05	0.05	0.19	0.12	0.14	0.09	0.10	1.30
Geomorphology	0.35	0.23	0.15	0.19	0.06	0.12	0.14	0.09	0.17	1.12
Lineament density	0.06	0.16	0.08	0.09	0.19	0.18	0.19	0.06	0.13	1.33
Soil	0.09	0.16	0.23	0.05	0.09	0.12	0.10	0.09	0.11	1.23
Drainage density	0.06	0.04	0.08	0.03	0.05	0.06	0.10	0.06	0.06	0.97
Rainfall	0.09	0.03	0.05	0.02	0.05	0.03	0.05	0.05	0.04	0.94
Geology	0.09	0.16	0.30	0.28	0.19	0.18	0.19	0.18	0.20	1.06

Table 5. AHP Rankings and weightage of individual thematic layers

No.	Parameters	Classes	AHP ranking	Weightage
1	Drainage density (km/km^2)	0.00 – 0.64 0.64 – 1.12 1.12 – 1.58 1.58 – 2.14 2.14 – 3.82	9 8 7 6 5	6%
2	Rainfall (mm)	1258.06 – 1290.54 1290.54 – 1313.67 1313.67 – 1336.79 1336.79 – 1362.67 1362.67 – 1398.45	5 6 7 8 9	5%
3	Slope (in degrees)	0.00 – 0.401 0.40 – 10.80 10.80 – 19.59 19.59 – 28.63 28.63 – 64.04	9 5 4 3 2	10%
4	Soil	- Loamy to clayey skeletal deep reddish-brown soils. - Clayey to gravelly clayey moderately soils. - Gravelly loamy moderately deep grass land soils. - Light gray deep sandy soils. - Moderately deep calcareous black soils.	3 5 7 8 9	11%
5	Land use land cover	Water bodies Barren lands Urban area Forest Agricultural lands	9 5 4 7 6	19%
6	Lineament density (km/km^2)	0.01- 1.10 1.10 – 6.10 6.10 – 11.10 11.10 –16.10 16.10 - 21	4 6 7 8 9	12%
7	Geomorphology	Flood plain shallow Hills and valleys Pediment Pediplain shallow Water bodies	5 3 6 7 9	17%
8	Geology	Bauxitic laterite Charnockite Quartzite Migmatite group Khondalite	5 6 7 8 9	20%

based on subclass, with ranks ranging from 1 to 9. The weights are computed such that the significance of interaction between each criterion is enhanced.

Drainage density

The surface water runoff will be significant if the drainage density is higher, and the infiltration will be less as a result, according to the reverse function of the permeability of lithological structures. The high density is examined all along the mainstream of highest order in the researcharea wherethe infiltration rate is less and surface runoff is more, in the Pediplain-pediment complex region low drainage density is observed (Figure 3). The map of drainage densitycategorized into five classes. The lower value will be given a higher ranking of drainage density and the high value is assigned a lower ranking in Table 5.

Rainfall

The major source of water is rainfall, which is associated with the availability of groundwater. However, the percolation factor is affected by the area's topography and soil type. Figure 3 shows that rainfall varies significantly, with a minimum of 1258.06 mm and a maximum of 1398.45 mm

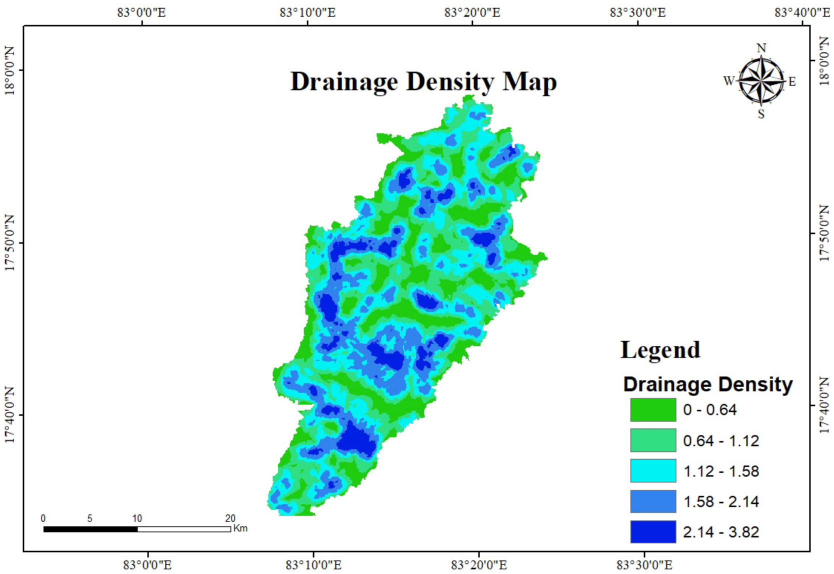

Figure 3. Drainage density map

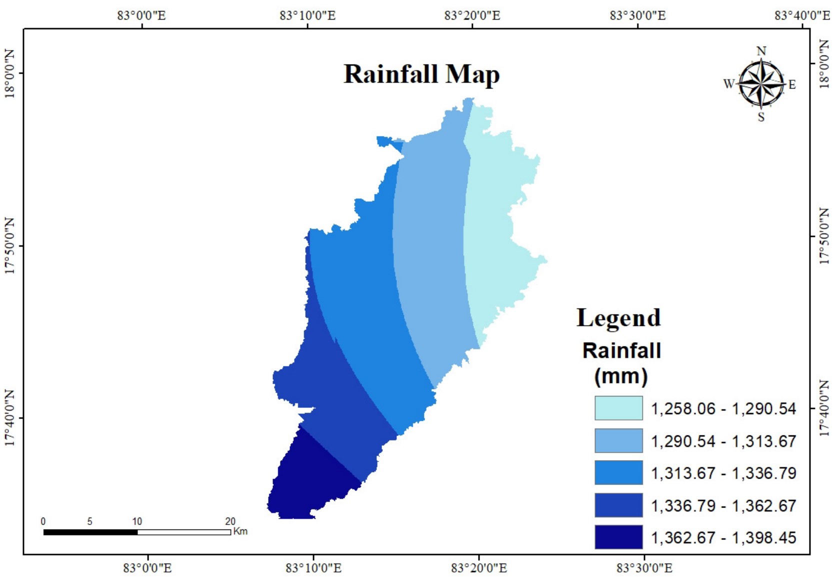

Figure 4. Rainfall map

in the research region Figure 4. Higher rainfall in the study region ranges from 1362.67–1398.45 mm and assigned a higher rank (9), whereas low rain-fed regions 1258.06–1290.54 mm were assigned a lower rank (5) shown in Table 5.

Slope

Slope influences runoff, which also influences rainwater infiltration. The study area's mountainous part has a steep slope, although the whole area has a mild slope and a good groundwater prospect. The slope is categorized under five classes in Figure 5 and assignedas for slope degree, with slope < 1° due to low runoff a plain area with low slope has been considered, which makes a very good recharge zone. Lower slopes of 1° to 4° received a high ranking, while 28.63°–64.04° received the lowest ranking shown in Table 5.

Soil

Water infiltration through soils is an important hydraulic property for agriculture and water research, with the ability to penetrate water into the subsurface, soils are highly important inputs for characterizing groundwater potentialzones (Todd 1980). Infiltration rate is influenced by influence by intensity of rainfall,

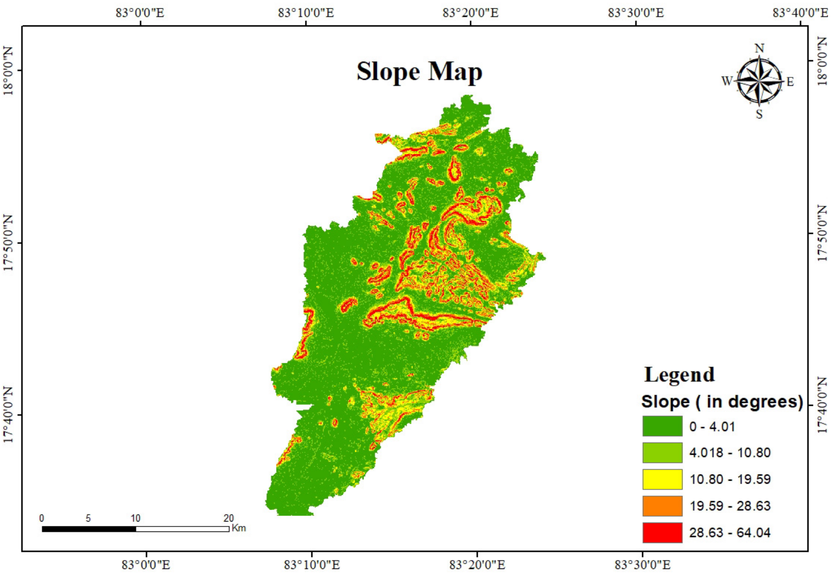

Figure 5. Slope map

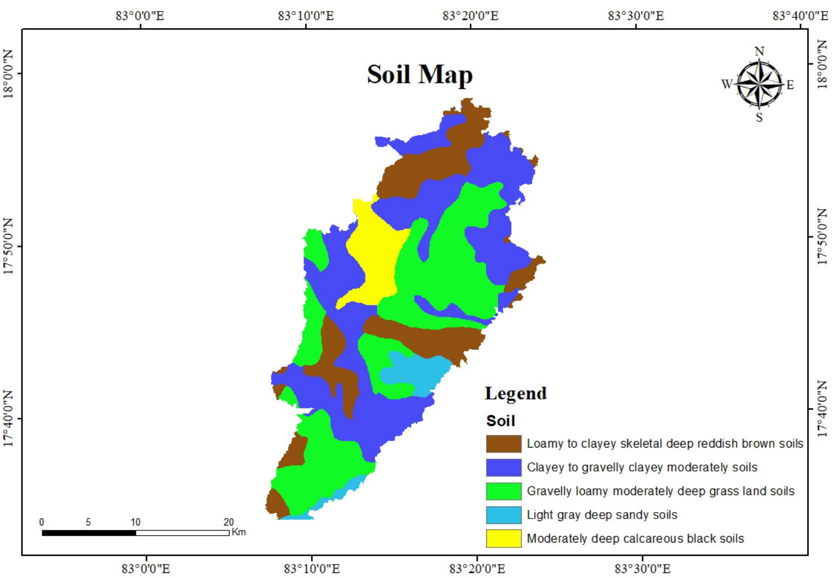

Figure 6. Soil map

soil texture, surface topography, and vegetation cover (Suja Rose et al 2009). Five soil categories have been identified in the study region shown in Figure 6 such as gravelly loamy moderately deep grassland soils, clay to gravelly clay moderately soils, light gray deep sandy soils and moderately deep calcareous black soils and loamy to clayey skeletal deep reddish-brown soils. Soils with higher rankings have a higher infiltration rate shown in Table 5.

Land useland cover

Land use landcover reveal the type of the surface material that governs infiltration and surface runoff, as well as the human effect on groundwater. (Barik et al., 2017; Roy et al 2019). Land use patterns such as built-up, forest, agriculture, barren land, andwater bodies were identified in the research area shown in Figure 7. Water bodies were assigned higher rank followed by forest, agriculture, barren land, and lower rank allocated for urban areas shown in Table 5.

Geology

Geology is most important influencing aspect in recharge of groundwater. Porosity, permeability, and degree of weathering of the parent rock,

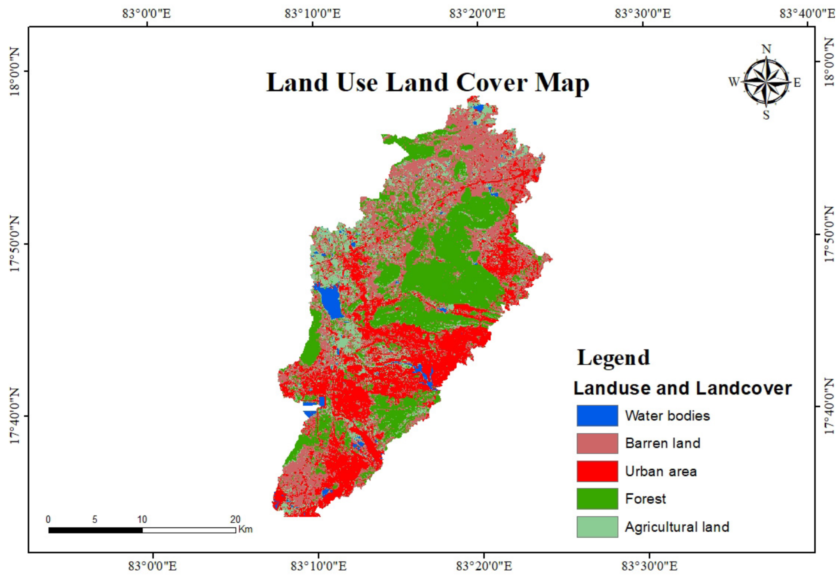

Figure 7. Land use land cover map

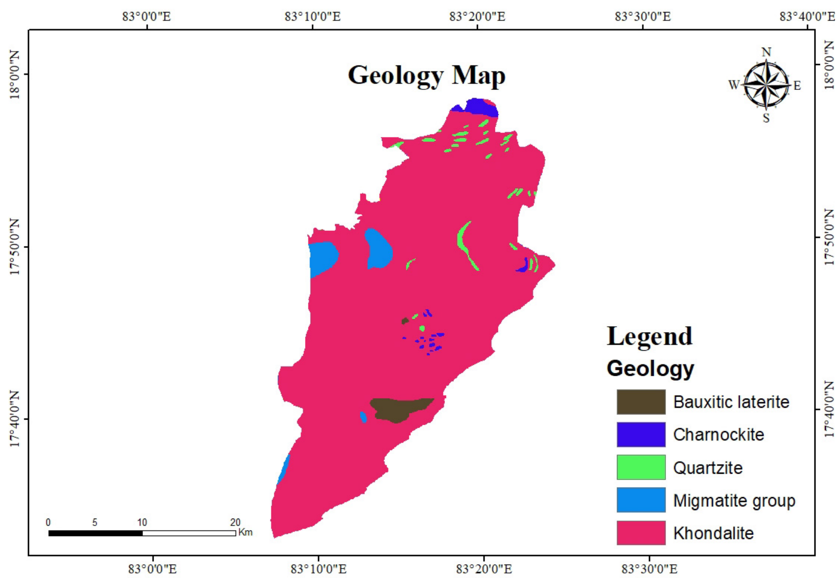

Figure 8. Geology map

which control water transport and occurrence, are key factors in determining possible groundwater zones (Akinlalu et al., 2017). The geology map for the research region was generated utilizing the Visakhapatnam district resource map in Andhra Pradesh Figure 8.

The research area is mostly occupied by quartzites, khondalites, and migmatites and few pockets of bauxites and charnockites of Eastern Ghats. The existence of groundwater is good in khondalites, due to its highly weathered nature. Except a dense network of fracturing and faulting occurs, charnockites produce very poor aquifers. The migmatites, quartzites, and bauxitic rocks, also create moderate aquifers (Subba Rao, 2012). Based on the level of weathering the ranks have been allocated as nine for khondalites, eight for migmatite rocks, seven for quartzites, eight for charnockites and five for bauxitic rocks shown in Table 5.

Lineamentdensity

Lineaments are structurally controlled linear or curved properties. The satellite photographs show rather straight alignments, making them easier to locate. Lineaments are regions of

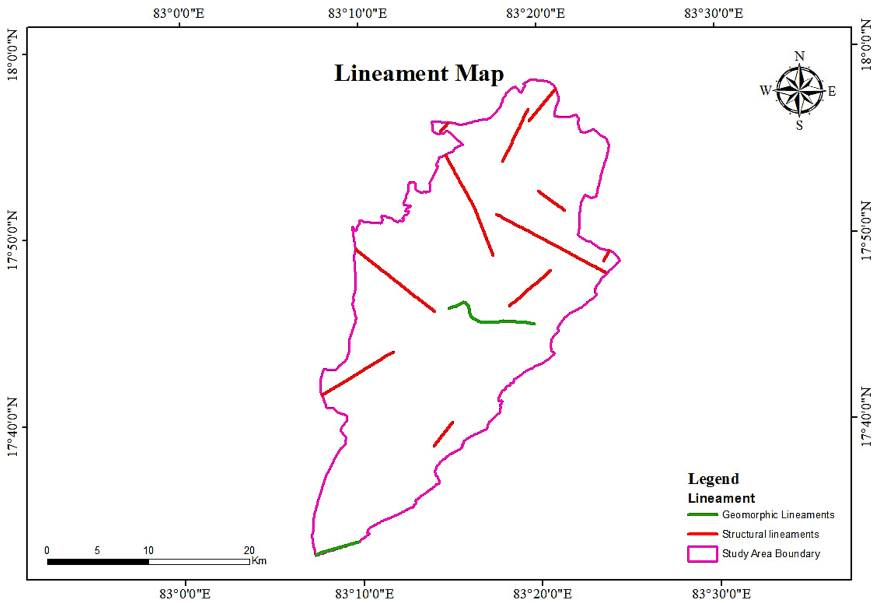

Figure 9. Lineament density

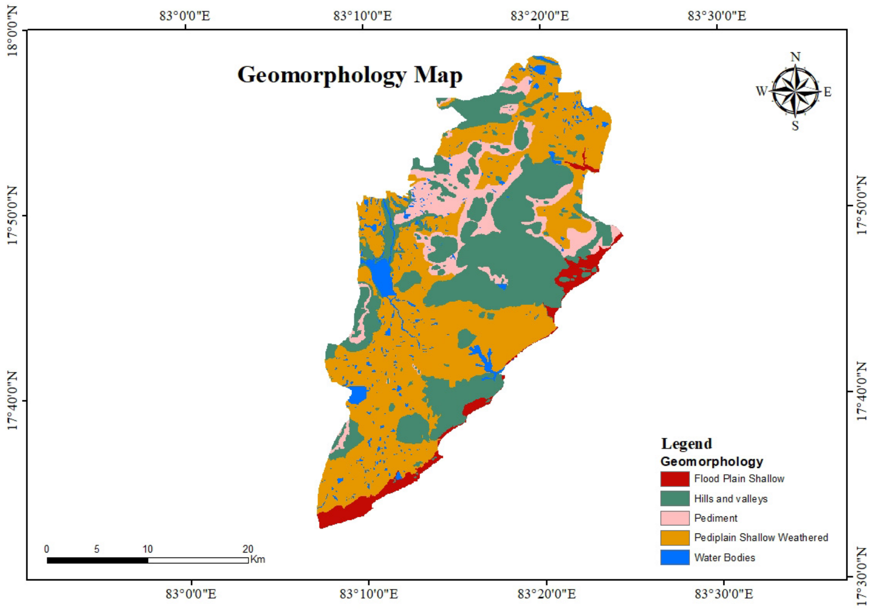

Figure 10. Geomorphology

faulting and fracture that result in increased permeable and secondary porosity. The rankings for lineament density are provided based on the proximity of the lineaments. High weight and low weight are assigned to classes with high and low densities, respectively, in the created lineament density map. The spatial data for the Lineaments map Figure 9 was taken from the BHUKOSH Geological Survey of India website.

Geomorphology

The precise geomorphologic map is critical for understanding the multiple geological constraints, such as plateaus, that are essential for the presence and movement of groundwater (Singh et al., 2011). The research region is distinguished by steep topography to the north and a low-lying plateau to the south. In the research region, the primary geomorphic features include substantially dissected hills of morphological form, pediment, pediplain shallows complex of landform origin, flood plain of fluvial origin, and water bodies shown in Figure 10. Most of the study region is comprised of shallow pediplain complex landforms, which are categorized as moderate to high zones for groundwater accumulation.

Delineation of prospective groundwater zones

All individual classes and each normalised weighted parameter are obtained as results for delineation of groundwater potential zones, and each parameter is incorporated into ArcGIS using the weighted overlay approach. The research region is categorized into four zones as per weighted overlay assessment shown in Figure 11 i.e the area comes under good 3% (21.89 km^2), area covers under moderate 45% (306.22 km^2), area under low 48% (327.11 km^2), and area covers undervery low 4% (25.42 km^2). The low and very low potential areas are observed more in the study area of Northern region and regions of East, which are mostly covered by eastern ghats and wildlife sanctuary. Moderate and good potential were observed in the regions of South and west, with reservoir, water bodies and agriculture lands. The importance of groundwater prospects recognised under the quartzite associated with various gneisses appear in various zones of the study area. Charnockite is distinguished by their interfering connection with the host khondalite group of rocks. All around the research region, well-drained soils are present. Rainfall has a significant influence in the research region, and the south-west portions have a moderate amount of groundwater potential. The probable zones of good and low groundwater are mostly located on steep slopes and elevations.

VALIDATION OF RESULTS

The groundwater potential map Figure 11 is validated utilizing the Receiver Operating

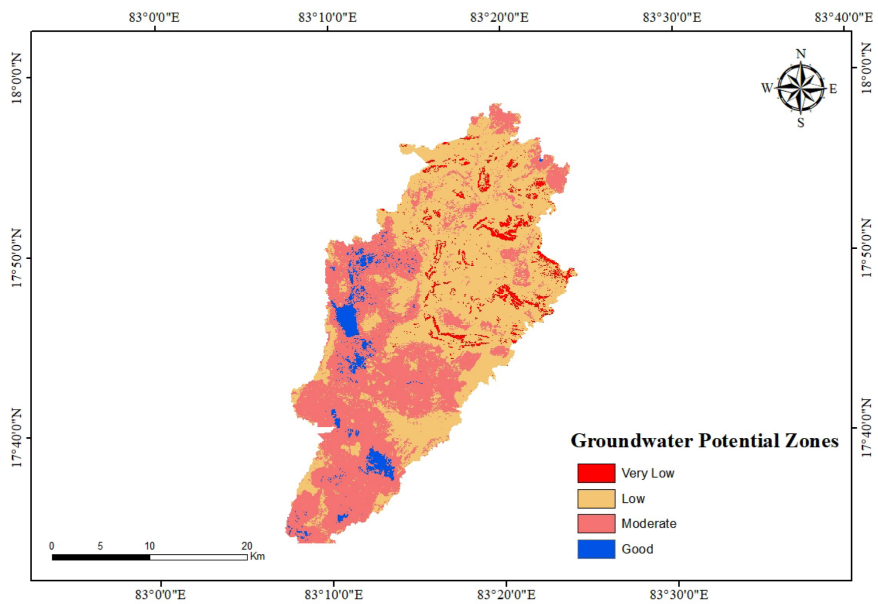

Figure 11. Groundwater potential zones of the study area

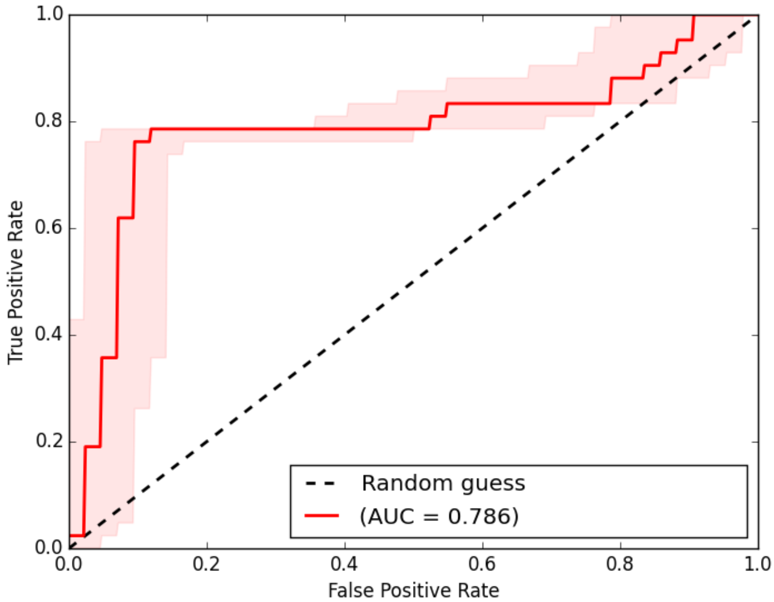

Figure 12. ROC curve for groundwater potential map

Characteristic (ROC) curve. To evaluate the precision of the potential zone map, bore well data from 48 locations were overlaid on the study area of groundwater potential zone map.

Utilizing the ArcSDM (Spatial Data Modeller) tool in ArcGIS software, the ROC curve is generated shown in Figure 12. The result from validation reveals that the AUC of the groundwater potential zone map is 0.786, and it is revealing that AHP method gives a good prediction. An accuracy of 78.6% is accomplished in our research.

This research study is compared with the previous report on groundwater potential zone under GVMC region (Karanam et al., 2014). For the present study it had been considered the selected area extent up to Anandapurammandal beyond the limits of GVMC, to give the details of drainage network of first order streams originated from the hills of Anandapurammandal and are drained throughout the GVMC area, which are the primary sources for groundwater replenishment in the GVMC area.

Analytical Hierarchy Process (AHP) analysis has been considered to assign the weightages to each parameter in the weighted overlay evaluation for the generation of groundwater potential zones. For this analysis, 48 bore wells pumping locations extracted from groundwater prospect maps of NRSC. The extracted pumping well data has been used for the ROC curve generation from this curve an accuracy can be obtained.

CONCLUSIONS

The combination of integrated remote sensing, GIS, and the AHP method has shown to be an effective and efficient tool for finding groundwater potential zones. For groundwater potential zonation, the Analytical Hierarchical Process (AHP) has been applied to assign a suitable weight to certain thematic layers and categories. The groundwater potential map for the research region is divided into four zones: good, moderate, low, and very low. The Area Under Curve (AUC) was determined to be 78.6% when compared to borewell data. It is expected that the groundwater potential map would be relatively accurate. Policymakers and water planners may use the study's results to help them manage water more effectively and sustainably. Proposals for water conservation may include seasonal surface water storage or the modification of irrigation practises in areas with low potential for recharge. Since the alluvial plain is the most conducive to recharge, it is imperative that waste be disposed of in distant regions. The valley may enhance groundwater development by establishing enough groundwater infrastructure. The results of the current study might aid engineers, planners, and water managers in the implementation of strategies, such as where to install artificial recharge structures and where to dig wells to preserve sustainable groundwater consumption. By enhancing natural groundwater recharge, it is anticipated that management practises will significantly increase the amount of water available to the regional population. This is because the city is currently scheduled to become the new executive capital of the state, which will bring a great deal of infrastructure and habitations.

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