Groundwater Potential Zone Delineation using Analytical Hierarchy Process (AHP) and GIS of Nani River Basin

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Abstract

Increasing population and development in industrial sector leads to higher demand of water, shortage of water in domestic, industrial and agricultural fields reflects decrease in the groundwater resource, to meet this condition there is need of sustainable planning and management of groundwater resource in the river basin. The groundwater potential zone (GPZ) delineated using remote sensing data, GIS and analytical hierarchy process (AHP). Various thematic layers such as drainage density, soil, land use and land cover, slope, geology, geomorphology, and rainfall prepared from the various database and analytical method of AHP pair wise matrix was used to evaluate the normalized weight of these thematic layers. The study area has been classified into three classes such as good (59.26 Km^2), moderate (416.63Km^2), and low (11.27 Km^2), groundwater potential zones. Remote sensing data, GIS techniques, and AHP approach is competent to produce accurate and reliable zones for better planning and management of groundwater resource.

Keywords: *Groundwater Potential Zone, Analytical Hierarchy Process (AHP), GIS*

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Introduction

Water and land are fundamental resources on the earth surface for human well being and development.An assessment and management of groundwater resource is significant issue in the sustainable development. Water is extensively and unevenly distributed throughoutthe Earth. On the earth surface only 3 % of total water resource is as freshwater and it is found in form of ice, groundwater, lakes and river. [13, 10] Drastically increasing population, industrial development, and agricultural activities are having pressure on available fresh groundwater resource. Increased demand of groundwater in domestic, industrial and agricultural sector is lowering the level and source groundwater and facing severe issue of water shortage.The invention of the modern pumping system and electrification also increased groundwater extraction and ultimately leads to groundwater depletion. Worldwide groundwater extraction was estimated for household as 36 %, agricultural purpose 42 % and industrial purpose 27%.[30]In India 80-90% rural population is depends on groundwater for domestic water supply and 50 % urban population and industrial sector is depends on groundwater. [1]

Several researcher globally have been studied and identified groundwater potential zones by using remote sensing satellite data, GIS techniques, multi criteria analysis (MCA), multi influencing factor (MIF), analytical hierarchy process (AHP).[14, 25, 26, 28, 31, 32, 15, 3, 4, 19, 10, 2, 29]This study was based on different factors and integration of influencing thematic layers such as rainfall, geology, drainage density, slope, land use and land cover, soil and geomorphology in GIS environment. Analytic hierarchy process (AHP), propounded by Saaty [20] helps to find out the appropriate weight of each layer through pair-wise comparison.The major objective of this present study is to delineate the groundwater potential zones in Nani river basin using remote sensing data, AHP method and GIS technique.

Study Area

The Nani river basin lies between Latitude 17^{0}13’’ to 17^{0}33’ N and Longitude 74^{0}15’ to 74^{0}25’ E and part of Yerala river basin in Maharashtra. The study area covered by survey of India toposheets no 47 K –, 6, 7, and 8,on the scale 1:50,000 it covers total geographical area of 487.16 Km^2 and fall is Satara and Sangli district of Maharashtra state.The average annual rainfall is 530.1 mm in region which is mainly receives from south-west monsoon. Geologically area is covered by basalt rock formation which simple lava flow, megacryst flow and pahoehoe basaltic lava flows. The area has suffered by endogentic movement in the past as evidenced by varying fold, fault and hills located in the western side of study area. The Nani River is main tributary of Yerala River and Yerla is tributary of Krishna River. Drainage network of Nani river is dendritic pattern and flows from west to east in direction (Fig.1).

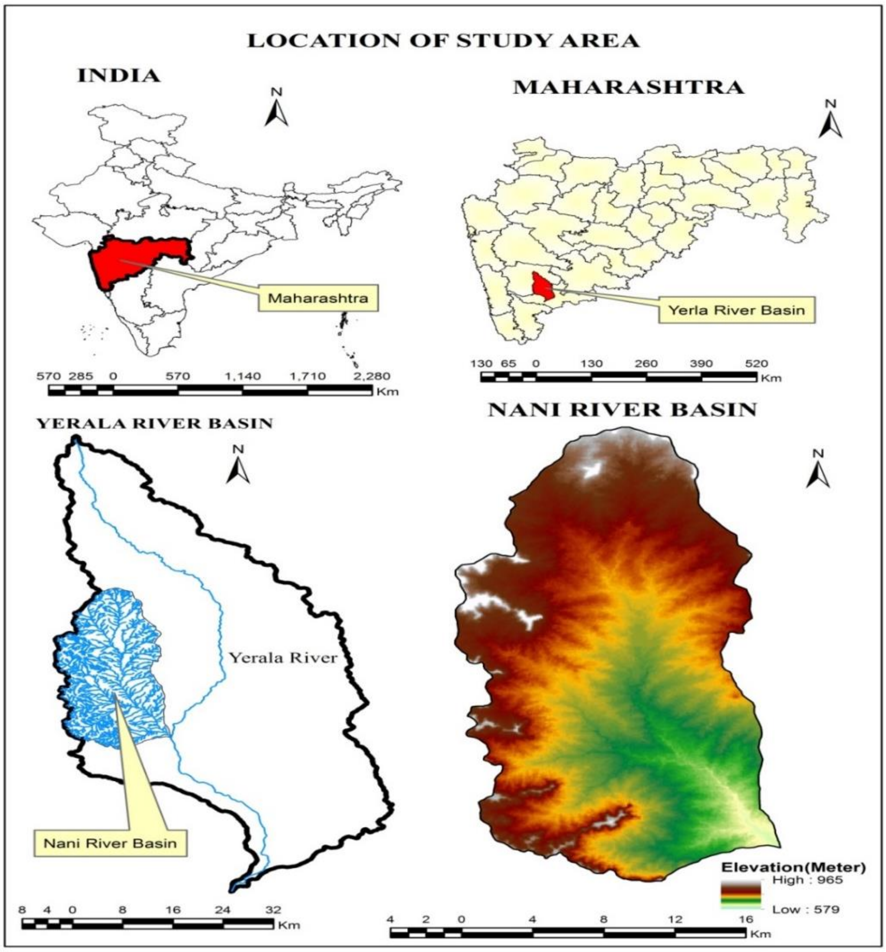

Fig.1 Location of Study Area

Materials and Methods

Groundwater potential zones are delineated using various thematic layers and AHP method. In the present study firstly different thematic layers prepared and then weight is assigned to each parameter through AHP method.

Preparation thematic layer

Seven thematic layers used such as geology, geomorphology, drainage density, rainfall, soil, slope, and land use and land cover (LULC). Different database was used for the preparation of all thematic layers (Fig.2). The base map of the Nani river basin is derived from Survey of India toposheet no.47 K 5, 6 and 7 with 1:50000 scale. Geology and geomorphology data is obtained from district resource map of Geological Survey of India (GSI). Drainage network of the Nani river is digitized from SoI toposheet and drainage density is prepared by using line density tool in GIS. Landsat 8 data is downloaded from USGS portal (http://earthexplorer.usgs.gov) with 30 meter spatial resolution of 2019 to derive land use and land cover (LULC). Soil map was generated from the earlier soil map prepared by the National Soil Survey and Land Use Planning Office (NBSS and LU) of the Indian Council of Agriculture Research (ICAR). Rainfall data of the basin was collected from the year 2000 to 2017 from the Indian Meteorological Department (IMD), Pune and processed using IDW interpolation method. Slope map was generated using SRTM data which is freely downloaded from the GLCF website (http://glcf.umd.edu/data/srtm) and processed using spatial analyst tool.

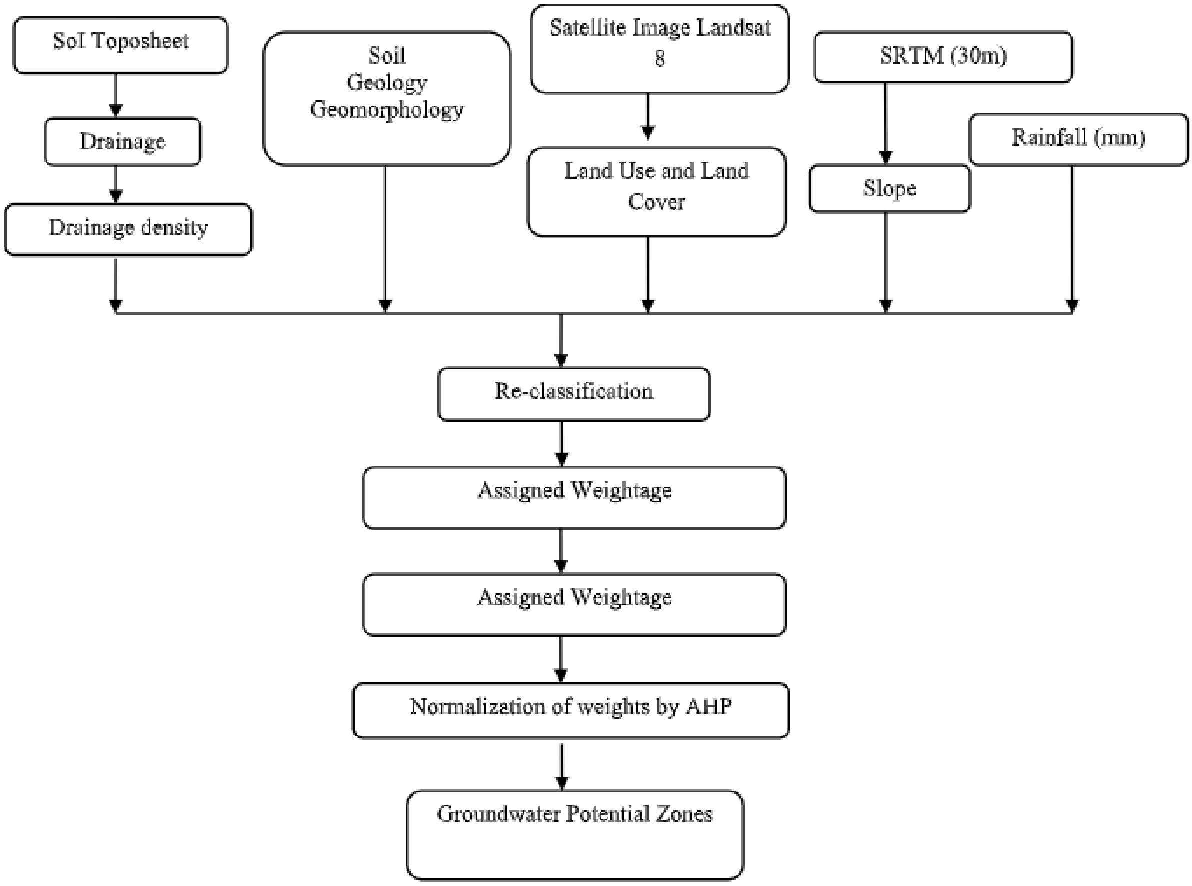

Fig. 2 Flowchart for delineation of groundwater potential zones

Normalized weights of thematic layers using AHP method

The normalized weight is assigned to each thematic layer in the present study using analytical hierarchal process (AHP) method developed by Saaty in1980. In the multi criteria decision making procedure AHP is mostly utilized for natural resource management, hazard assessment, groundwater potential zones mapping, and suitability analysis.[2]For multi parameter analysis AHP method is very helpful. [20] The relative importance of each thematic layer is resolved with Saaty's 1- 9 scale (Table 1)in which a score of 1 represents equal importancebetween the two parameters, and a score of 9 indicates extreme less important. [20]

Table 1 Saaty's ratio index for different values of n

N	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.89	1.12	1.24	1.32	1.41	1.45

The weights of each thematic layer were determined by judgment of comparison rating on Saaty' scale and field experts. The Consistency index (CI), as a measure of Consistency, is derived from the following equation (1).

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

where λ_{max} is the significant eigenvalue of the pair wise comparison matrix
n = no. of classes and consistency ratio (CR) was calculated from the following equation (2)

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

RI = Ratio Index

The value of RI value for different criteria is shown in (Table 1). The value of consistency should be less than 0.1 [20], otherwise one should assign revaluated and recalculated weights of individual layer. The comparison matrix of thematic layer was developed in pairs (Table 2). The weights given to each thematic layer and each class of layers were normalized using analytical hierarchal process (AHP) method (Table 3). The groundwater potential zones prepared using all thematic layers of assigned weights and rank by overlaying in GIS environment.

Table 2 Pair wise comparison decision matrix

Thematic Layer	Rainfall	LULC	Slope	Geology	Drainage Density	Geomorphology	Soil	Normalized Weight
Rainfall	1	1.00	1.00	2.00	2.00	2.00	1.00	0.19
LULC	1.00	1	1.00	1.00	1.00	1.00	1.00	0.14
Slope	1.00	1.00	1	1.00	1.00	1.00	1.00	0.13
Geology	0.50	1.00	1.00	1	1.00	0.50	1.00	0.12
Drainage Density	0.50	1.00	1.00	1.00	1	0.50	1.00	0.12
Geomorphology	0.50	1.00	1.00	2.00	2.00	1	2.00	0.16
Soil	1.00	1.00	1.00	1.00	1.00	0.50	1	0.14

Table 3 Assigned and normalized weights to feature class

Sr.No.	Thematic Layer	Weight	Normalized Weight	Feature Class
1	Geology	12	0.12	Megacryst flow and
				Simple lava flow
				Pahoehoe basaltic lava flows
2	Geomorphology	16	0.16	Denudational Slope
				Older Flood Plain
				Denudational Hills and Valley
3	Drainage Density	12	0.12	0 - 0.70 Km/Km^2
				0.71 - 1.83 Km/Km^2
				1.84 - 2.91 Km/Km^2
				2.93 - 6.40 Km/Km^2
4	Land Use and Land Cover	14	0.14	Agricultural Land
				Built-up
				Fallow and Barren land
				Forest
				Water body
5	Soil	14	0.14	Clay Calcareous Soil
				Loamy Soil
				Fine Calcareous Soil
				Clayey Soil
6	Rainfall	19	0.19	437.86 - 487.68 mm
				487.68 - 513.72 mm
				513.72 - 539 .19 mm
				539 .20 - 582.22 mm
7	Slope (Degree)	13	0.13	0 - 3.21
				3.22 - 8.49
				8.50 - 15.96
				15.97 - 32.83

Result and Discussion

Groundwater potential zones was delineated using following different thematic layers and analytic hierarchy process (AHP) for the assigning the weight to each parameter by using the weight overlay analysis in GIS environment.

Geomorphology

Geomorphology map shows the landforms on the earth surface by various erosional and depositional activities. Geomorphological aspect is having importance in the groundwater availability. The geomorphological structures and topographic controls are interrelated to the capacity of groundwater. [19] Nani River basin was divided into three geomorphological landform groups (Fig.3**)** which aredenudational slope,denudational hills and valley and older flood plain. Denudational slope covered highest area and having slope so it is not suitable for the groundwater infiltration. The older flood plain area is having well for the groundwater potential.

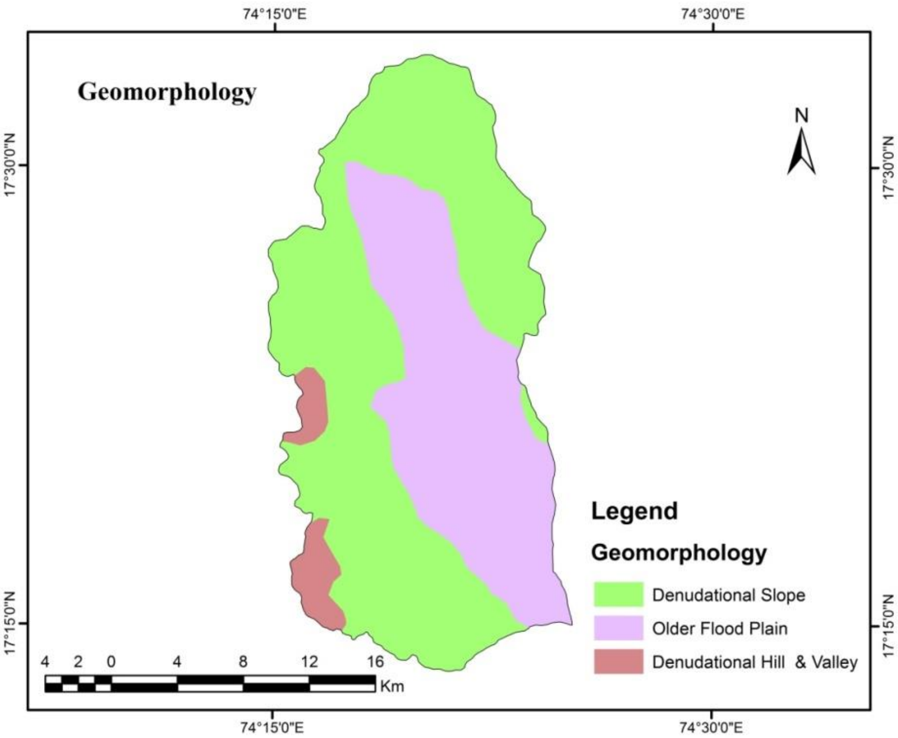

Fig. 3 Geomorphology

Geology

Geology is the determining factor of distribution and occurrence of groundwater. The river basin is formed by basalt rock in Deccan trap. It consists of Diveghat formation and Purandhargarh formation includes simple lava flows, pahoehoe basaltic lava flows and megacryst flow (Fig.4).Diveghat formation consists of 10 - 12 flows of alternating Aa and pahoehoe flows, varying in thickness from 5 – 35 m to 100 – 330m. Aa flows are moderately to highly porphyritic and at places shows mixed character. Purandargarh formation comprises of eight basaltic flows. A megacryst compound pahoehoe flows developed on the top of Purandargarh Formation is about 30 m and quite extensive. The rock is highly porphyritic with plagioclase laths up to 5 cm in length.

Drainage Density

Drainage density is the proximity of the distance of the stream channels per unit area of basin. It is having inverse relationship with permeability and therefore having importance in delineation of groundwater potential. Higher drainage density areas are favorable for surface runoff and hence it indicates a low potential of groundwater. [32, 18, 2]The lower drainage density shows permeable soil, low relief of area and vegetation cover, while the higher drainage density low permeability, steep slope and less vegetation cover. [12] The drainage density in the basin was classified into 4 classes (Fig.5) such as 0 - 0.70, 0.71 - 1.83, 1.84 - 2.91, 2.92 - 6.40 Km/Km^2.

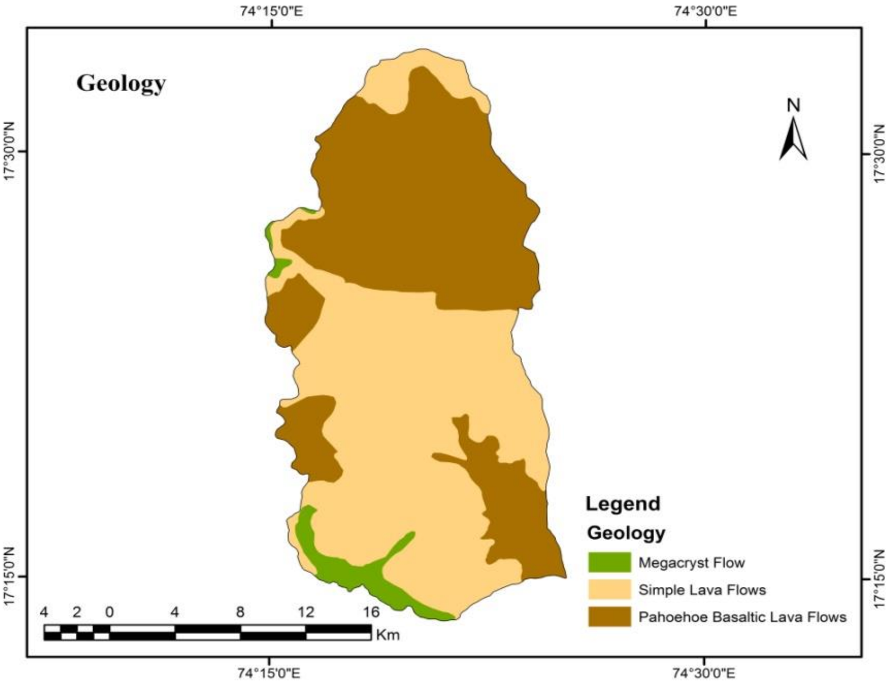

Fig. 4 Geology

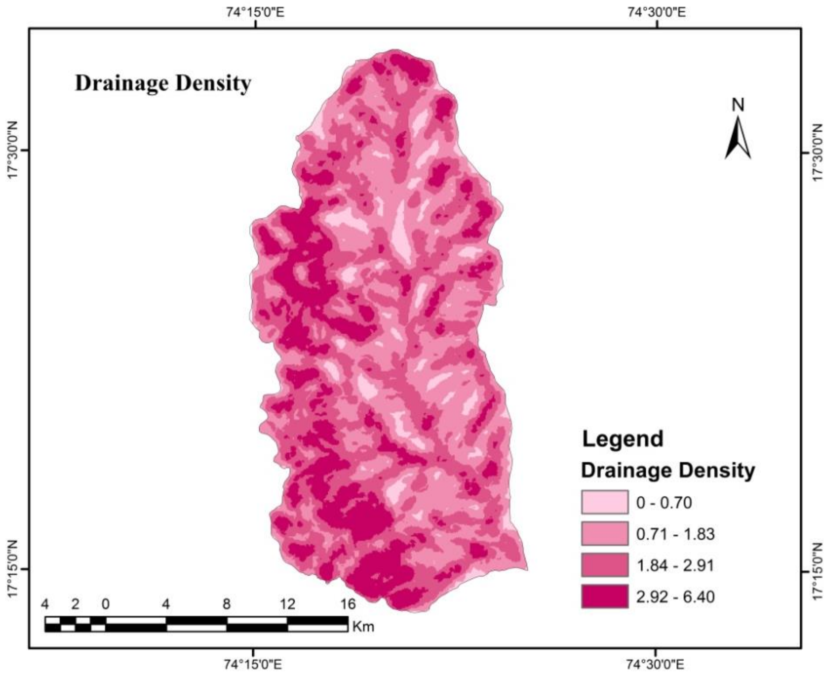

Fig. 5 Drainage Density

Land Use and Land Cover (LULC)

Land use is feature created and developed by human activities such as building, roads, canal, agriculture, and industry, while land cover is land occupied by natural features like natural lake, river, vegetation, hills and mountains. Land use and land cover control surface runoff, evapotraspiration and soil infiltration rate. [34, 7, 11] Land use and land cover classification was done using Landsat 8 satellite data and using supervised classification techniques and classified as agricultural land, forest, built-up, barren land and water bodies (Fig.6). The agriculture area, water bodies and forest are favorable for holding groundwater and infiltration and having highest potential of groundwater, while barren land and settlement area are having low infiltration and poor groundwater potential. [6]

Rainfall

Rainfall is most essential factor for groundwater potential zones. The basin receives rainfall mainly from south west monsoon and having spatial and temporal variation. Rainfall data for the study region was collected from the Indian Meteorological Department (IMD) for the year 2000 to 2017 and rainfall distribution map was processed using IDW interpolation method in GIS environment. Rainfall map was classified in four classes as 437.86 - 487.68 mm, 487.69 - 513.72 mm, 513.73 - 539.19 mm and 539.20 - 582.22 mm (Fig.7).

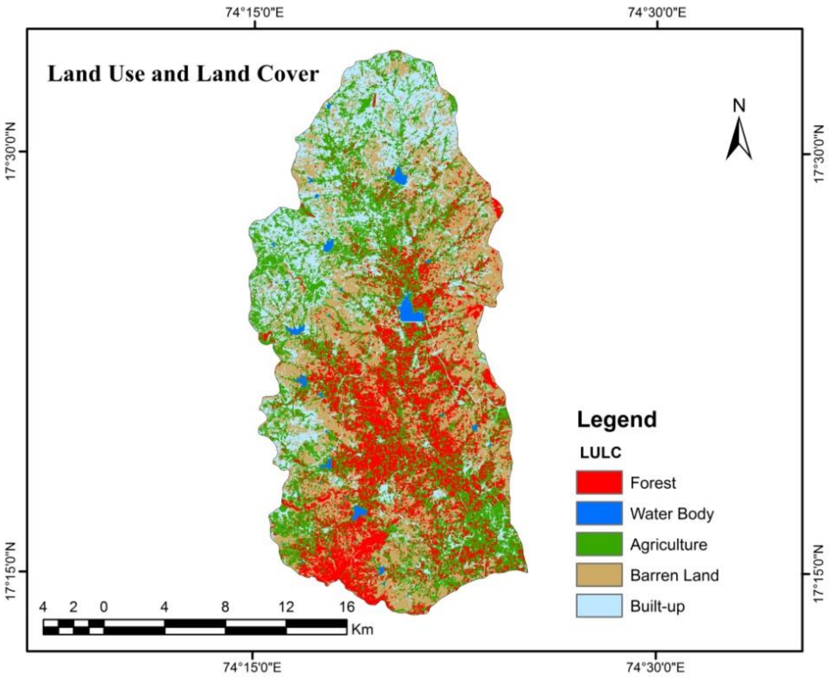

Fig. 6 Land Use and Land Cover

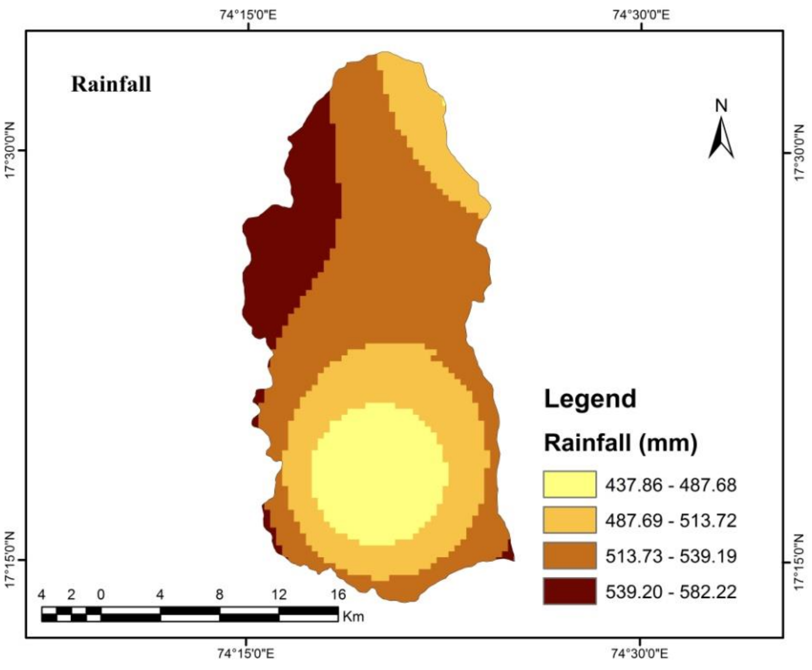

Fig. 7 Rainfall

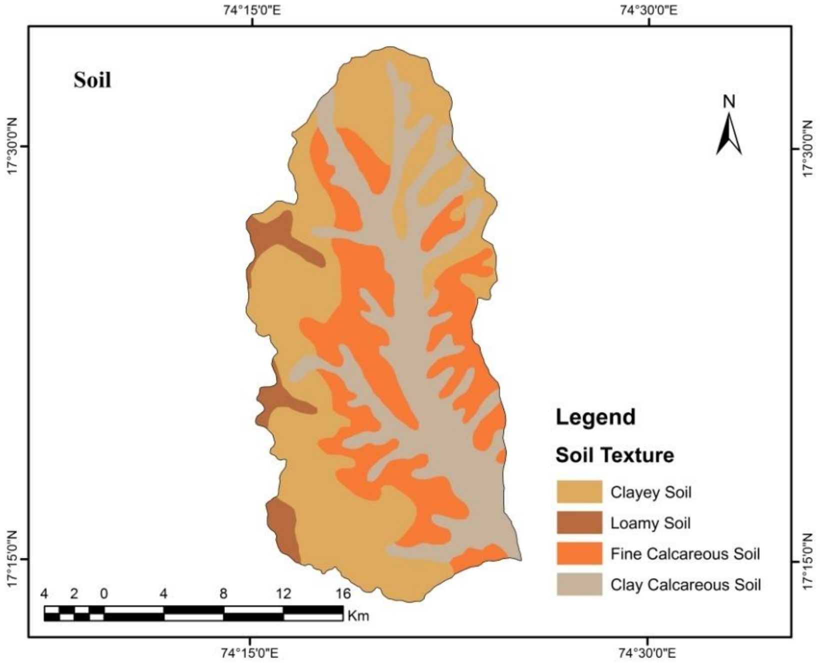

Fig. 8 Soil

Soil

Soils play significant role in the groundwater movement in the unsaturated zone. [2]The thematic map of soil obtained from National Soil Survey and Land Use Planning Office (NBSS and LU) of the Indian Council of Agriculture Research (ICAR), rectified using UTM projection and digitized in the GIS environment (Fig.8). Basin is having four type of soil texture, in which major part of basin is covered by clay soil (39.63%), followed by clay calcareous soil (30.35%), fine calcareous soil (25.80%) and very less portion is covered by loamy soil (4.22%). Clay soil is having low infiltration rate and resulting into low potential of groundwater. Loamy soil and calcareous soils are having high infiltration rate and good for groundwater potential.

Slope

Slope is having inverse relationship with groundwater percolation. Steep slope lead to higher surface runoff and less percolation of water, while flat terrain slow runoff and higher the water percolation. The steep slopes will lead to quick runoff, greater soil erosion rates with a little groundwater recharge. [16, 17]The study categorized into various classes they are 0°–3.21°, 3.22°– 8.49°, 8.50°– 15.96°, and 15.97°– 32.83° (Fig. 9).For groundwater potential analysis lower the degree of slope assigned higher rank, whereas higher the slope in degree which had assigned lower rank according to runoff. In the study region major portion is having slope 0 - 3.21°.

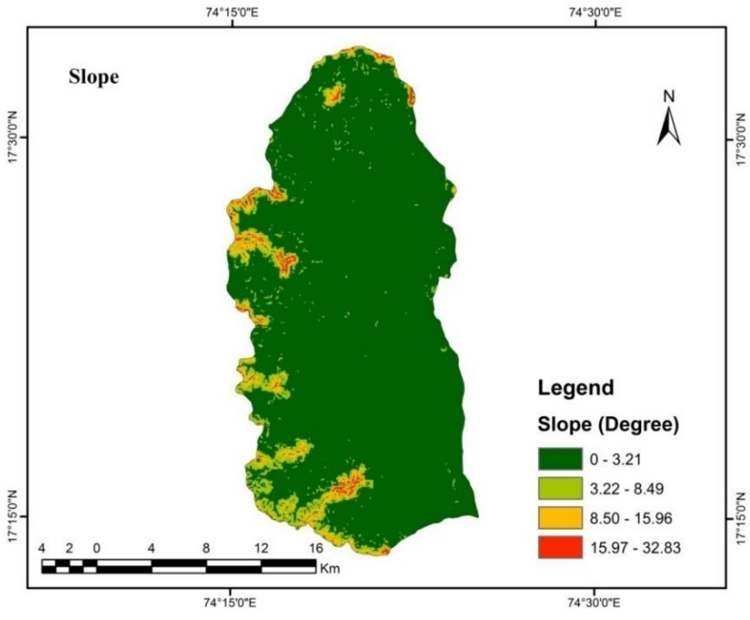

Fig. 9 Slope

Groundwater potential zones

The groundwater potential zones were delineated using various thematic layers which are geology, geomorphology, rainfall, land use and land cover, soil, slope and drainage density. Remote sensing satellite data and conventional data was integrated in the GIS environment using weighted overlay technique for mapping of groundwater potential in Nani river basin. From the seven thematic layers, consequently four layers were having more influence to determine the groundwater potential rainfall (19), geomorphology (16), Land use and land cover (14), and soil (14) based on the assigned weight through analytical hierarchy process (AHP) method and remaining three thematic layers were having minor influence which are slope (13), drainage density (12), and geology (12). The groundwater potential map is categorized in to three classes such as good, moderate and poor zone of potential (Fig.10). The area of good potential zone is 59.26 Km^2, moderate zone covers 416.63 Km^2 and poor zone covers 11.27 Km^2 in the present study area (Table 4).

Table 4 Groundwater potential zones

Ground water potential zone	Area (Km^2)
Good	59.26
Moderate	416.63
Poor	11.27

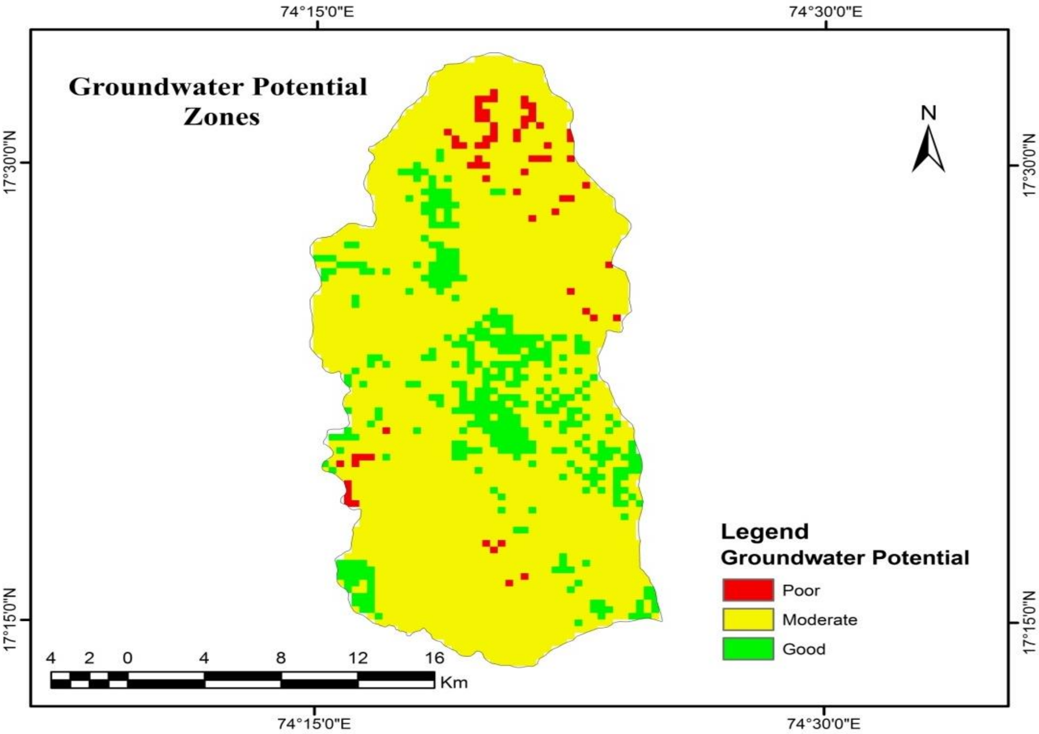

Fig. 10 Groundwater potential zones

Conclusion

The present study deals with delineation of groundwater potential zones (GPZ) using GIS and analytical hierarchy process (AHP) of Nani river basin. The satellite image of Landsat 8, SRTM elevation data, topographical maps, conventional data, soil data, district resource map and rainfall data used to prepare all thematic layers of geology, soil, geomorphology, land use and land cover, slope, drainage density, and rainfall. The different thematic layers, assigned weightage using (AHP) method processed using weighted overlay analysis technique in GIS environment for the generation of groundwater potential zones. The result shows that the Nani river basin categorized into three groundwater potential zones. They are good potential zone (59.26 Km^2), moderate zone (416.63 Km^2) and poor potential zone (11.27 Km^2). The poor groundwater potential zone location in upper part of the basin where rainfall is low and land under the barren land and it indicate least favorable for groundwater resource whereas the good potential zones for the most favorable region. In the present study are moderate potential zone cover larger part of the basin and favorable for groundwater resource. The results of the present study are helpful for the future planning of management of groundwater in the basin.

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Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

1. Agarwal, R., & Garg, P. K. (2016). Remote sensing and GIS based groundwater potential & recharge zones mapping using multi-criteria decision making technique. Water Resources Management, 30(1), 243–260.
2. Ajay Kumar, V., Mondal, N.C. & Ahmed, S.(2020) Identification of Groundwater Potential Zones Using RS, GIS and AHP Techniques: A Case Study in a Part of Deccan Volcanic Province (DVP), Maharashtra, India. J Indian Soc Remote Sens 48, 497–511. https://doi.org/10.1007/s12524-019-01086-3
3. Chavare Subhash, (2011), "Morphometric Analysis using GIS Techniques: a case study of Valheri River basin, tributary of Tapi River in Nandurbar District (M.S.)" Shodh, Samiksha aur Mulyankan International Referred Research Journal, Vol. III (31), pp. 62-63
4. Chavare Subhash, (2011), "Analysis of Relief of Kolhapur District using SRTM Data and GIS Techniques", Research Analysis and Evaluation, International Referred Research Journal, Vol. III (26), pp. 12-13
5. Chavare Subhash, (2012), "Geomorphology Mapping of Salem District of Tamil Nadu, Using Remote Sensing and GIS" Young Researcher, 1 (2) pp 20-25
6. Chavare Subhash, S.D. Koli, and S. D. Shinde (2013), "Ground Water Potential Mapping Using Geo-Spatial Technology: A Case Study of Sidhewadi Village of Sangli District", Neo Geographia Vol. II., Issue. I pp 140-144
7. Chavare Subhash (2015), "Application of Remote Sensing and GIS in Land Use and Land Cover Mapping of Sub-watershed of Wardha River Basin", Proceedings of National Conference on Development & Planning For Drought Prone Areas"
8. Dar, I.A., Sankar, K., Dar, M.A., (2010), "Deciphering Groundwater Potential Zones in Hard Rock Terrain Using Geospatial Technology", Environmental Monitoring and Assessment 173, pp.597 - 610.
9. Dar, I. A., Sankar, K., & Dar, M. A. (2010). Remote sensing technology and geographic information system modeling: An integrated approach towards the mapping of potential groundwater recharge zones in Hardrock terrain, Mamundiyar basin. Journal of Hydrology, 394, 285–295.
10. Das B., Pal S. C (2019) Combination of GIS and fuzzy-AHP for delineating groundwater recharge potential zones in the critical Goghat-II block of West Bengal, IndiaHydroResearch 2 (2019) 21–30 https://doi.org/10.1016/j.hydres.2019.10.001
11. Guzhaa, A. C., Rufinoa, M. C., Okoth, S., Jacobsa, S., & Nobregae, R. L. B. (2018). Impacts of land use and land cover change on surface runoff, discharge and low flows: Evidence from East Africa. Journal of Hydrology: Regional Studies, 15, 49–67
12. Harlin, J. M., & Wijeyawickrema, C. (1985). Irrigation and groundwater depletion in Caddo county, Oklahoma. JAWRA Journal of the American Water Resources Association, 21(1), 15–22.
13. Holden, J., 2014. Water Fundamentals. In Water Resources – An Integrated Approach by Joseph Holden. Routledge, New York.
14. Krishnamurthy, J., Venkatesa Kumar, N., Jayaraman, V., Manivel, M., 1996. An approach to demarcate ground water potential zones through remote sensing and a geographical information system. Int. J. Remote Sens. 17 (10), 1867–1884.
15. Magesh, N. S., Chandrasekar, N., & Soundranayagam, J. P. (2011a). Morphometric evaluation of Papanasam and Manimuthar watersheds, parts of Western Ghats, Tirunelveli district, Tamil Nadu India: A GIS approach.Environmental Earth Science, 64, 373–381.
16. Magesh, N. S., Chandrasekar, N., & Soundranayagam, J. P. (2012). Delineation of groundwater potential zones in Theni district, Tamil Nadu, using remote sensing, GIS and MIF techniques. Geoscience Frontiers, 3(2), 189–196.
17. Magesh, N. S., Chandrasekar, N., & Vetha Roy, D. (2011b). Spatial analysis of trace element contamination in sediments of Tamiraparani estuary,southeast coast of India. Estuarine, Coastal and Shelf Science, 92, 618–628**.**
18. Pinto, D., Shrestha, S., Babel, M. S., & 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
19. Rajasekhar M, Sudarsana Raju G, Bramaiah C, Deepthi P, Amaravathi Y, Siddi RR (2018c) Delineation of groundwater potential zones of semi-arid region of YSR Kadapa District, Andhra Pradesh, India using RS, GIS and analytic hierarchy process. Remote Sens Land 2(2):76–86
20. Saaty TL (1980) The analytic hierarchy process: planning, priority setting, resource allocation. McGraw-Hill, New York
21. Saaty TL (1999) Fundamentals of the analytic network process. In: International symposium of the analytic hierarchy process (ISAHP), Kobe, Japan
22. Saaty TL (2004) Fundamentals of the analytic network processmultiple networks with benefits, costs, opportunities and risks. J Syst Sci Syst Eng 13(3):348–379.
23. Saaty TL (2008) Decision making with the analytic hierarchy process. Int J Serv Sci 1(1):83–98
24. Senanayake I.P., D.M.D.O.K. Dissanayake, B.B. Mayadunna, W.L. Weerasekera (2015) An approach to delineate groundwater recharge potential sites in Ambalantota, Sri Lanka using GIS techniques, Geoscience Frontiers 7 (2016) 115-124 http://dx.doi.org/10.1016/j.gsf.2015.03.002
25. Sener, E., Davraz, A., Ozcelik, M., 2005. An integration of GIS and remote sensing in groundwater investigations: a case study in Burdur, Turkey. Hydrogeology Journal 13 (5e6), 826e834.
26. Shaban, A., Khawlie, M., Abdallah, C., 2006. Use of remote sensing and GIS to determine recharge potential zones: the case of Occidental Lebanon. Hydrogeol. J. 14 (4), 433–443.

27. Shahid, S., Nath, S., Roy, J., 2000. Groundwater potential modelling in a soft rock area using a GIS. Int. J. Remote Sens. 21 (9), 1919–1924.
28. Solomon, S., Quiel, F., 2006. Groundwater study using remote sensing and geographic information systems (GIS) in the central highlands of Eritrea. Hydrogeology Journal 14 (6), 1029e1041.
29. Tanveer Dar, Nachiketa Rai & Aadil Bhat (2020): Delineation of potential groundwater recharge zones using analytical hierarchy process (AHP), Geology, Ecology, and Landscapes, DOI: 10.1080/24749508.2020.1726562
30. Taylor, R. G., Scanlon, B., Döll, P., Rodell, M., van Beek, R., Wada, Y., Treidel, H. (2013). Ground water and climate change. Nature Climate Change, 3(4), 322–329.
31. Tweed, S.O., Leblanc, M., Webb, J.A., Lubczynski, M.W., 2007. Remote sensing and GIS for mapping groundwater recharge and discharge areas in salinity prone catchments, southeastern Australia. Hydrogeology Journal 15 (1), 75e96.
32. Yeh, H. F., Lee, C. H., Hsu, K. C., & Chang, P. H. (2009). GIS for the assessment of the groundwater recharge potential zone. Environmental Geology, 58(1), 185–195
33. Yeh, H-F, Cheng, Y-S, Lin, H-I, & Lee, C-H. (2016). Mapping groundwater recharge potential zone using a gis approach in hualian river, taiwan. Sustainable Environment Research, 26(1), 33–43. doi:10.1016/j. serj.2015.09.005
34. Yimer, F., Messing, I., Ledin, S., & Abdelkadir, A. (2008). Effects of different land use types on infiltration capacity in a catchment in the highlands of Ethiopia. Soil Use and Management, 24(4), 344–349.