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PK Keskar
Research Scholar (SWCE), CAET, Dr. BSKKV, Dapoli, Maharashtra, India

BL Ayare
Professor and Head (SWCE) CAET, Dr. BSKKV, Dapoli, Maharashtra, India

HN Bhange
Associate Professor (CAS) (SWCE), CAET, Dr. BSKKV, Dapoli, Maharashtra, India

PM Ingle
Associate Professor (IDE), CAET, Dr. BSKKV, Dapoli, Maharashtra, India

PR Kolhe
Associate Professor (CAS) (SWCE), CAET, Dr. BSKKV, Dapoli, Maharashtra, India

Corresponding Author:
PK Keskar
Research Scholar (SWCE), CAET, Dr. BSKKV, Dapoli, Maharashtra, India

Identification of groundwater potential zones in Kajali river basin using remote sensing and GIS

PK Keskar, BL Ayare, HN Bhange, PM Ingle and PR Kolhe

Abstract
Groundwater is one of the most natural resources that supports human well-being and ecological diversity. Thematic maps were prepared from digital elevation model (DEM) of shuttle radar topographic mission (SRTM) with 30 m resolution. Various thematic layers such as geomorphology, geology, slope, land use land cover, lithology, drainage density and soil etc were used for generation of groundwater potential zone. The groundwater potential zone map of the Sakharpa watershed was divided into five categories such as 'Very Poor', 'Poor', 'Moderate', 'Good', and 'Very Good' groundwater potential. About 24.61% area falls under the very poor groundwater potential zones category. Poor groundwater potential is available in 42.28%. About 20.32% area falls under the moderate groundwater potential zones category. Good groundwater potential is available in 12.53% and only 0.26% area falls under very good groundwater potential.

Keywords: Groundwater potential zone, weighted overlay analysis, thematic map, remote sensing and GIS

Introduction
Groundwater is one of the most natural resources that supports human well-being and ecological diversity (Waikar and Nilawar, 2014) [7]. Groundwater is water that occurs below the surface of the Earth, where it occupies all or part of the void spaces in soils or geologic strata. It is also called subsurface water. Groundwater is a crucial source of freshwater (Nandishkumar *et al*. 2014) [6]. Groundwater is the most valuable natural resource contributing significantly to the total annual supply. More than 50% of the world's population uses groundwater for drinking purposes. Agriculture is the backbone of the Indian economy. About 70% of groundwater is used for agricultural activities. Water plays an important role in agriculture. As the population increases, the water requirement for agriculture also increases to meet the need for food and fiber. The occurrence, origin, movement, and chemical constituents of groundwater are reliant on geology, lithology, Geomorphology/Landforms, drainage density, rainfall, lineaments, slope, Land use/Land cover, and soil of groundwater regime (Gintamo, 2015) [3].

About 71% of the earth's surface is covered with water. The Earth holds about 326 million trillion gallons of water. The distribution of water on the earth's surface is extremely irregular. About 97% of earth's water is saline which resides in the ocean and only 3% of water is freshwater. Out of 3% of total freshwater, about 68.7% resides in icecaps and glaciers, 30% of water is underground and less than 1% of water is available as surface water and other freshwater. Breakdown of surface water and other freshwater shows most of this is locked up as ice which is about 73.1%, water in lakes is about 20.1%, rivers contribute about 0.46%, swamps, and marshes contain 2.53%, soil moisture 3.52%. this shows that rivers account for only a small amount of freshwater from where we get water.

The region is characterized by high rainfall intensity and runoff. Due to undulating and rocky topography in the region, most of the rainfall is lost as runoff and this causes severe scarcity in the region in the summer months. So, the identification of groundwater potential zones in that area is necessary.

Material and Methodology
Study Area
In Kajali river basin, Sakharpa watershed in district Ratnagiri was selected as study area for present research. Kew river and Gad river are the tributaries of Kajali river. Kew river originates in Sahyadri hills.

Gad river meets the Kew river at Sakharpa and forms a Kajali river. The length of Kajali river is 72 km which is western flowing river and it joins the Arabian Sea at Bhatye near Ratnagiri. The watershed is located at Sakharpa in Sangameshwar Tehsil and Ratnagiri District of Maharashtra. It is bounded by 16°55'N to 17°01'N latitude and 73°47"E to 73°47"E longitude. It covers the geographic area of about 9037.07 ha. The elevation ranges from 71 m to 835 m above mean sea level. The location map of study area is shown in Fig 1.

Data Collection

The digital elevation model (DEM) of shuttle radar topographic mission (SRTM) with 30 m resolution was downloaded from (http://earthexplorer.usgs.gov/). The software QGIS 3.18.3 which is freely available software has been used for processing the remotely sensed data for delineating watershed, extraction of drainage network. Geomorphology, geology and lithology data were downloaded from Survey of India website. Land use land cover map was prepared from the Landsat 8-9 OLI/TIRS C2 L2 (30m resolution) (Date: 30-10-2020) Path-147 Row-048 images downloaded from USGS earth explorer. A hydrological soil group map was prepared by using the data downloaded from Global Hydrologic Soil Groups (HYSOGs250m) for Curve Number-Based Runoff Modelling.

Land Use Land Cover Map:

Land Use Land Cover Map gives the status of land utilization. Land use land cover is main feature which shows direct influence on runoff, evapotranspiration and infiltration. Land use land cover map was divided into 5 general classes *viz,* waterbody, vegetation, settlement, agriculture and barren land etc.

Slope Map

Slope map of study area was generated by using Digital Elevation Model (DEM) from the Shuttle Radar Topographic Mission (SRTM) of 90m resolution data from USGS earth explorer. The high value of slope indicates high runoff and vice versa. The lower value of slope shows the flatter terrain and higher value of slope shows the steeper terrain. For identification of groundwater potential zones, slope factor acts as important parameter. In present research work slope map was prepared by using QGIS 3.18.3 software.

Geomorphology Map

Geomorphology is the study of landforms that are found on the Earth. Landforms include hills, plains, beaches, rivers, mountains, moraines, cirques, sand dunes, and spits. The amount and rate of infiltration are determined by geomorphology (Alsharhan and Rizk, 2020) [1]. In the present study, the geomorphology map was prepared by using lithology data downloaded from the Bhukosh Survey of India portal (http://bhukosh.gsi.gov.in/Bhukosh/Public).

Lithology Map

Lithology includes the study general physical properties of rocks as well as chemical, mineral composition of rock. It describes the properties of unit rock. Sedimentary rock, igneous rock and metamorphic rock are the three main types of rocks. Lithology plays an important role in groundwater potential because properties of rocks such as porosity and permeability affect infiltration and groundwater flow. The permeability and porosity of a geologic formation control its ability to hold and transmit water. In the present study, the lithology map was prepared by using lithology data downloaded from the Bhukosh Survey of India portal (http://bhukosh.gsi.gov.in/Bhukosh/Public).

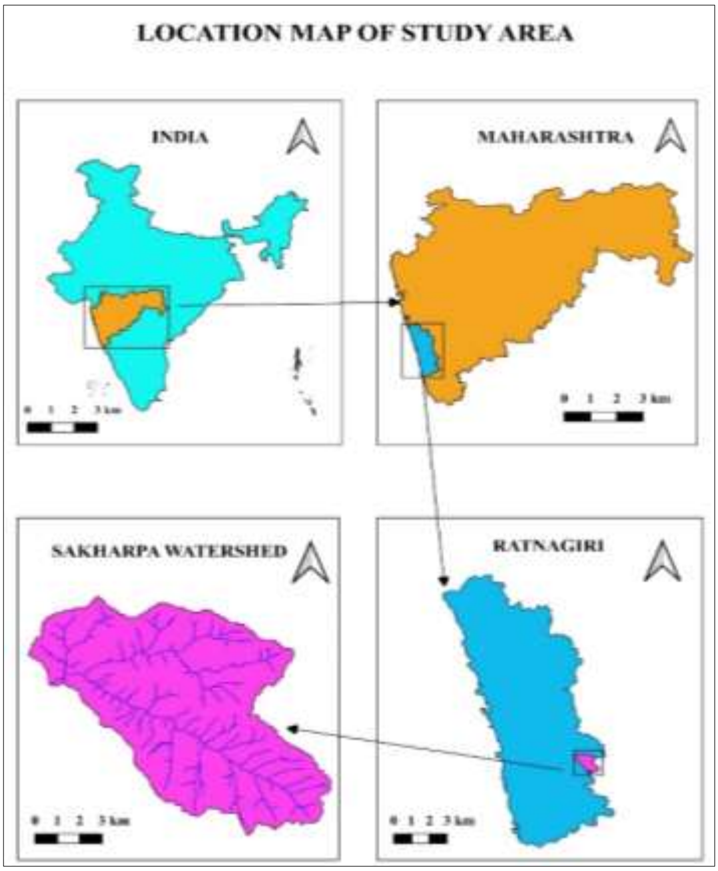

Fig 1: Location map of the study area

Geology Map

Geology is the branch of science which study the composition and the process of formation of rock and change in rock over time. Geologic formations act as aquifers. Geology affects the groundwater potential, as the geologic formations changes. In the present study the Geology Map was prepared by using lithology data downloaded from the Bhukosh Survey of India portal (http://bhukosh.gsi.gov.in/Bhukosh/Public).

Drainage density Map:

Drainage density of watershed helps to give the information related to runoff, relief, infiltration and permeability. Characteristics of surface and subsurface formations are reflected by the drainage network. The drainage density map was prepared in QGIS from drainage/stream network.

Integration of thematic maps for groundwater potential map

After integration of all thematic maps new thematic map of groundwater potential categorized in poor, moderate and good groundwater zone category was generated. Fig 2 shows the flowchart for estimation of groundwater potential zones. By using weighted overly analysis method in QGIS, groundwater potential prospect zone was gained. These thematic layers were then rasterized and reclassified and assigned suitable weightage following the methods used by Krishnamurthy *et al.* (1996) [5] and Bhange *et al.* (2016) [2]. Weight have been given according to influence of thematic layer and rank have been given to different parameters in every thematic layer. The weightages assigned to the different thematic layers are given in Table 1.

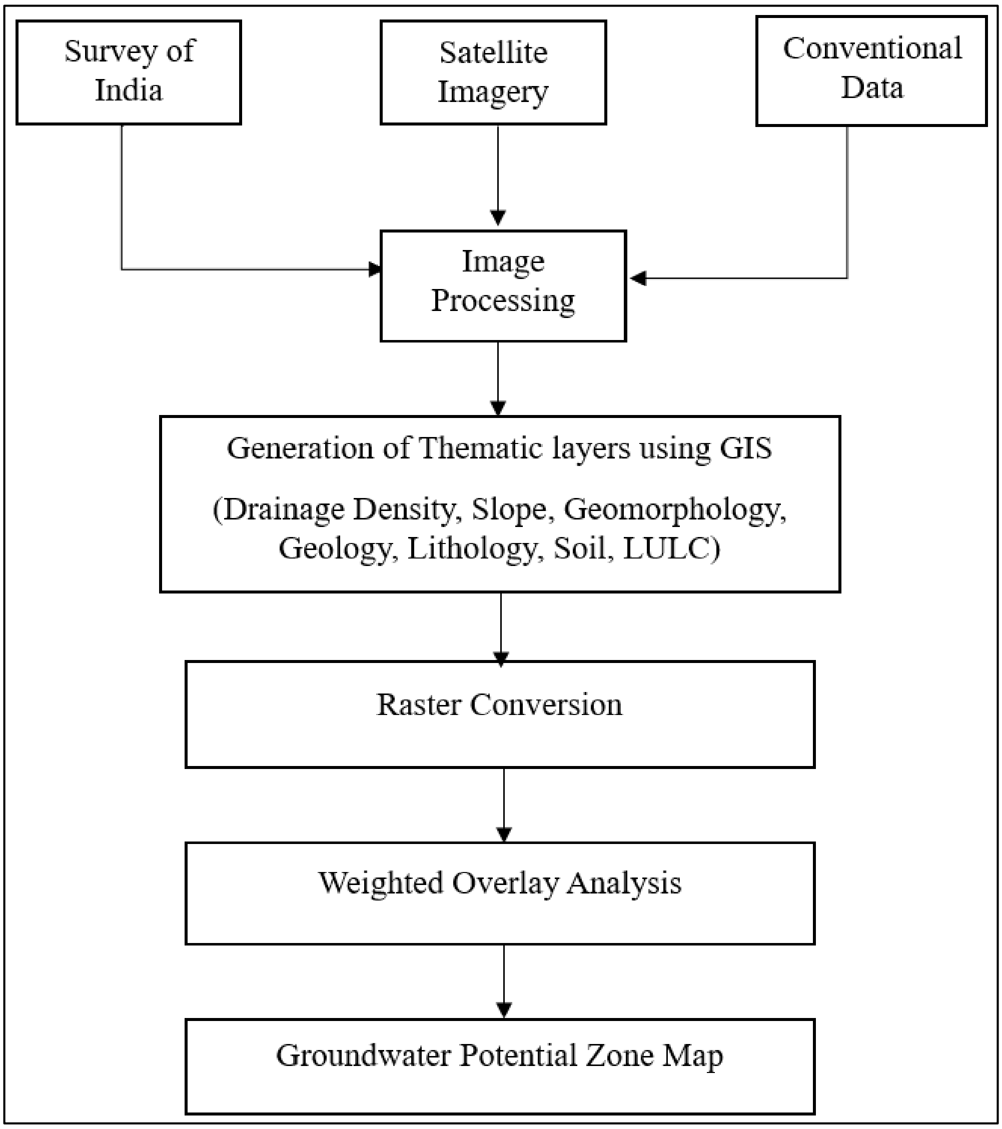

Fig 2: Flowchart for estimation of groundwater potential zones

Table 1: Weights assigned to different layers with ranking for preparation of groundwater potential map.

Layer	Weight Assigned (%)	Feature Classes	Rank
Geomorphology	20	Moderately Dissected Plateau	1
		Highly Dissected Plateau	1
		Pediment	4
		Scarp	3
		Water body/River	5
Lithology	15	Basalt	5
		Laterite	3
Slope	15	Very Good (0-5%)	5
		Good (5-10%)	4
		Moderate (10-15%)	3
		Poor (15-20%)	2
		Very Poor (>20%)	1
Drainage Density	15	0-1	5
		1-3	4
		3-5	3
		5-8	2
		>8	1
Land use/Land cover	15	Settlement	1
		Barren Land	1
		Vegetation	3
		Waterbody	4
		Agriculture Land	5
Geology	10	Deccan Trap	5
Soil	10	Loam	5
		Sandy loam	4

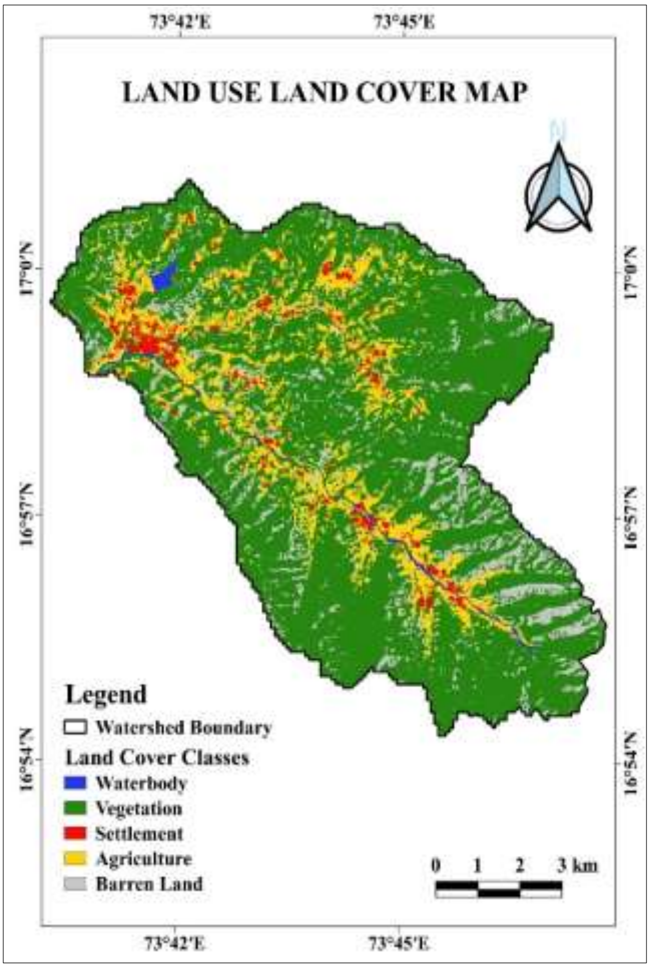

Fig 3: Land Use Land Cover map of Sakharpa watershed

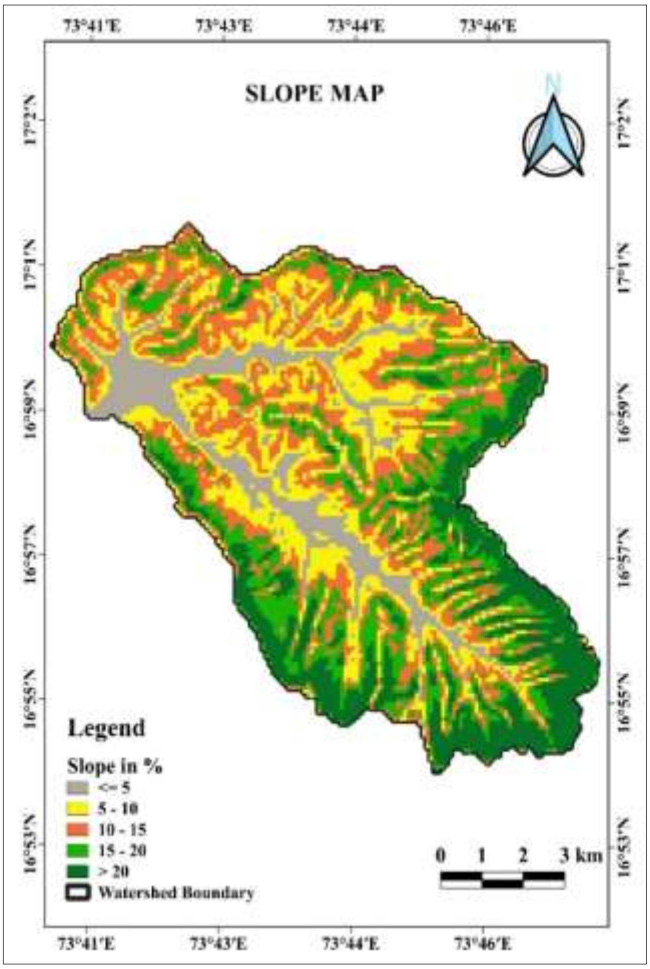

Fig 4: Slope map of Sakharpa watershed

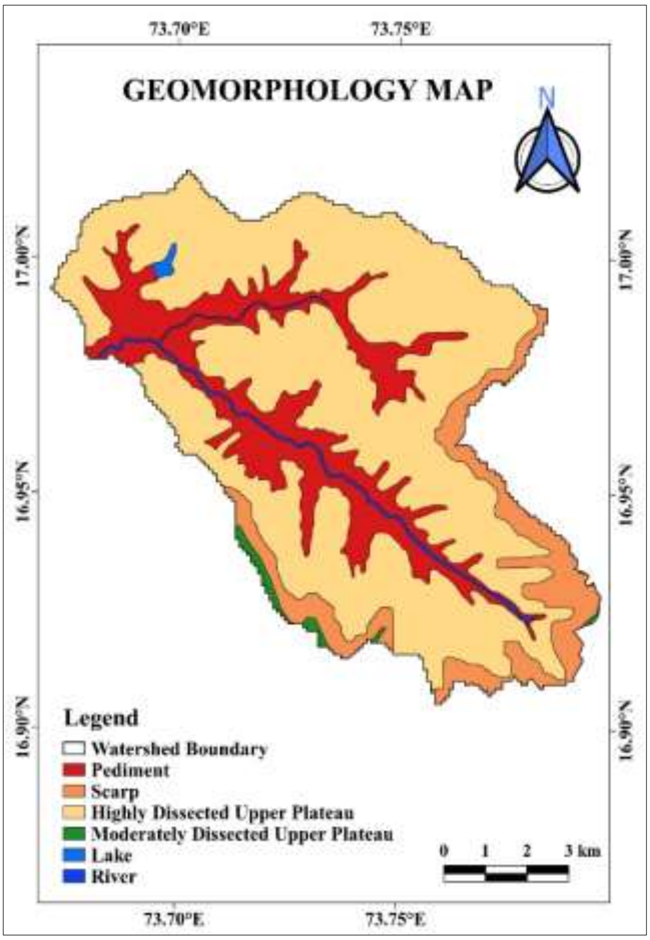

Fig 5: Geomorphology map of Sakharpa watershed

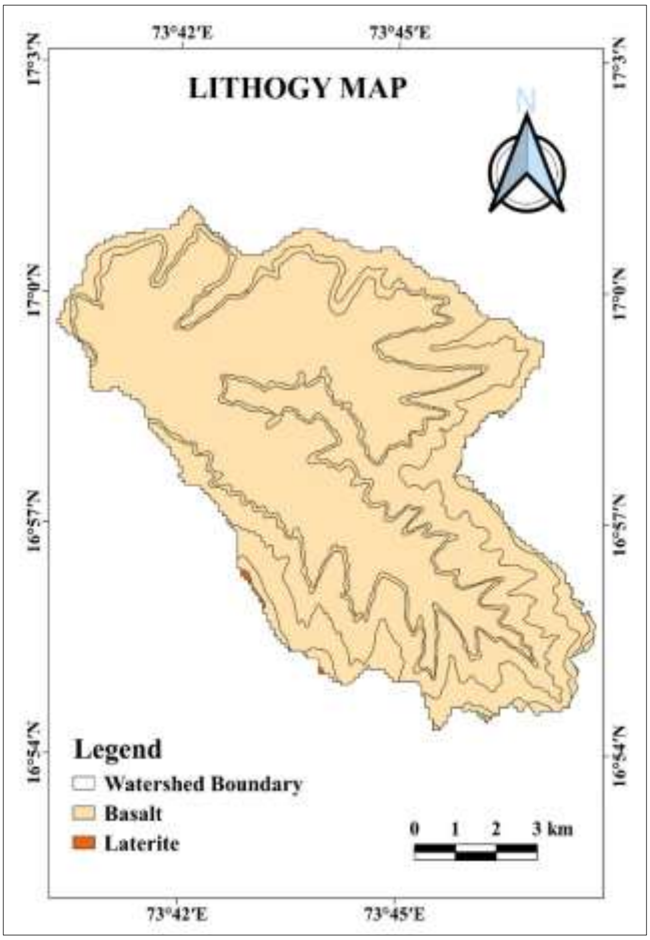

Fig 7: Lithology map of Sakharpa watershed

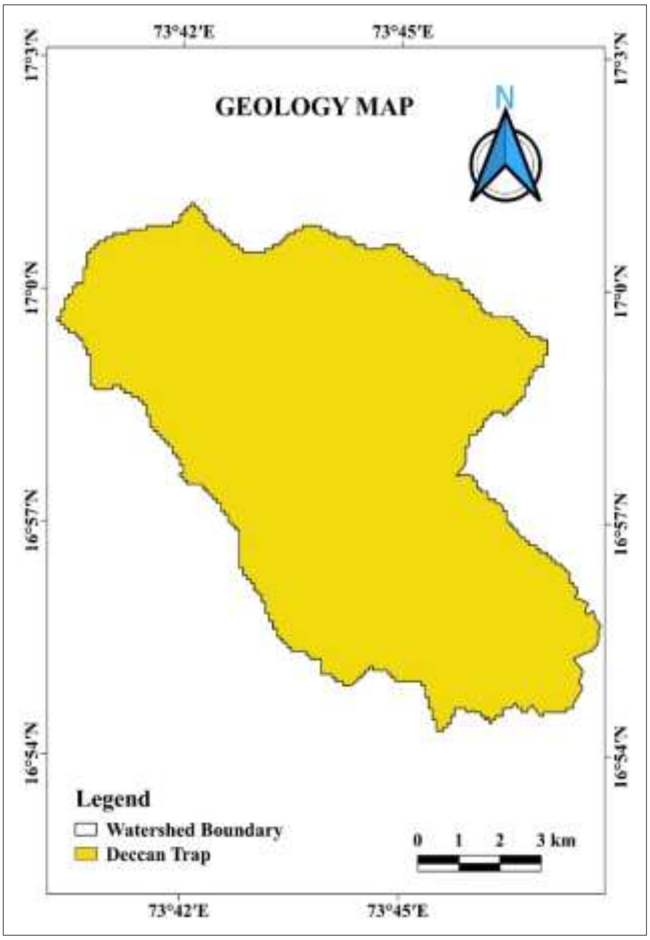

Fig 6: Geology map of Sakharpa watershed

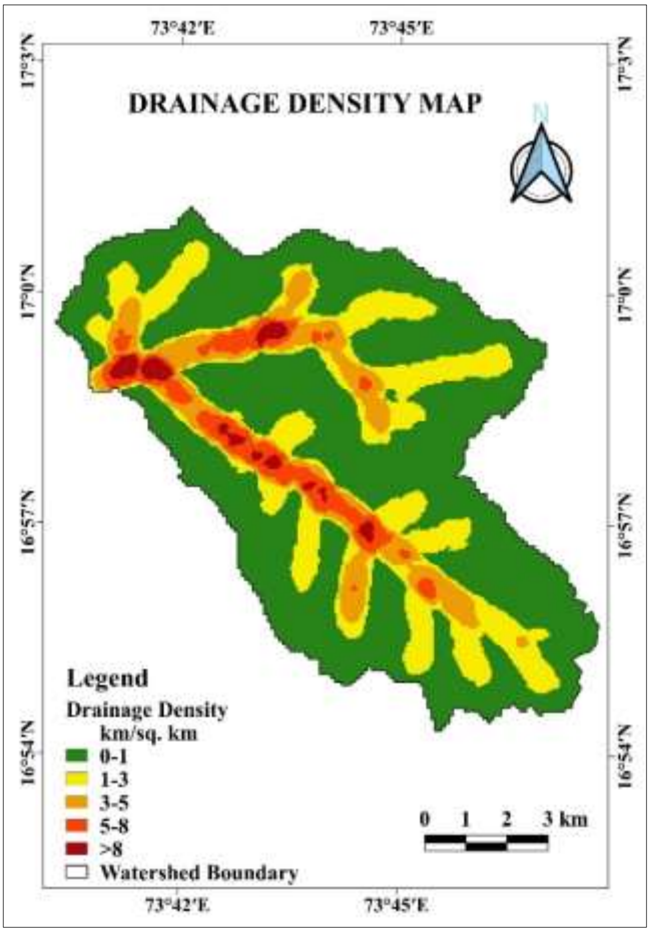

Fig 8: Drainage density map of Sakharpa watershed

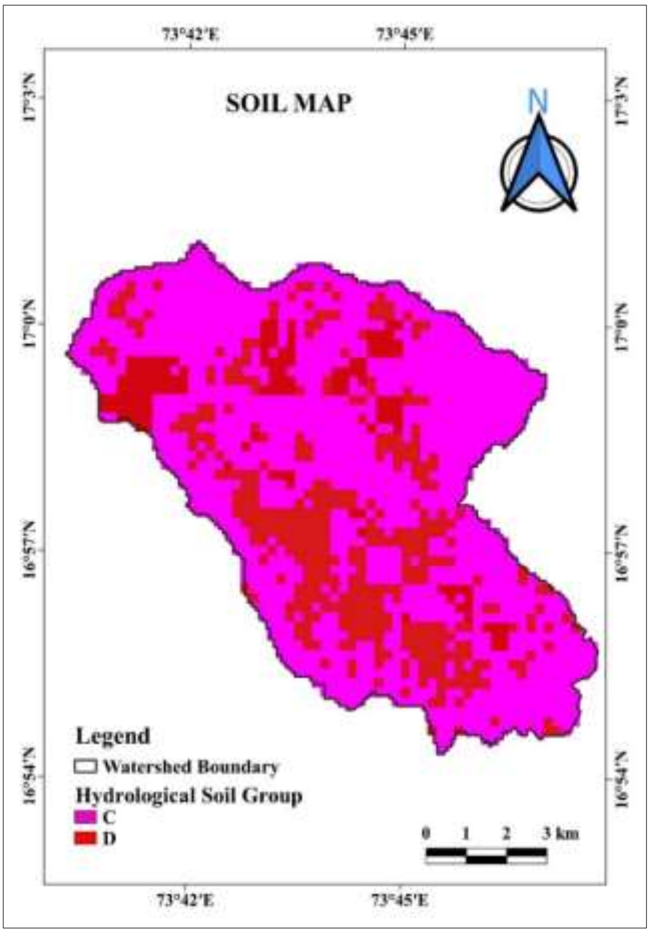

Fig 9: Soil map of Sakharpa watershed

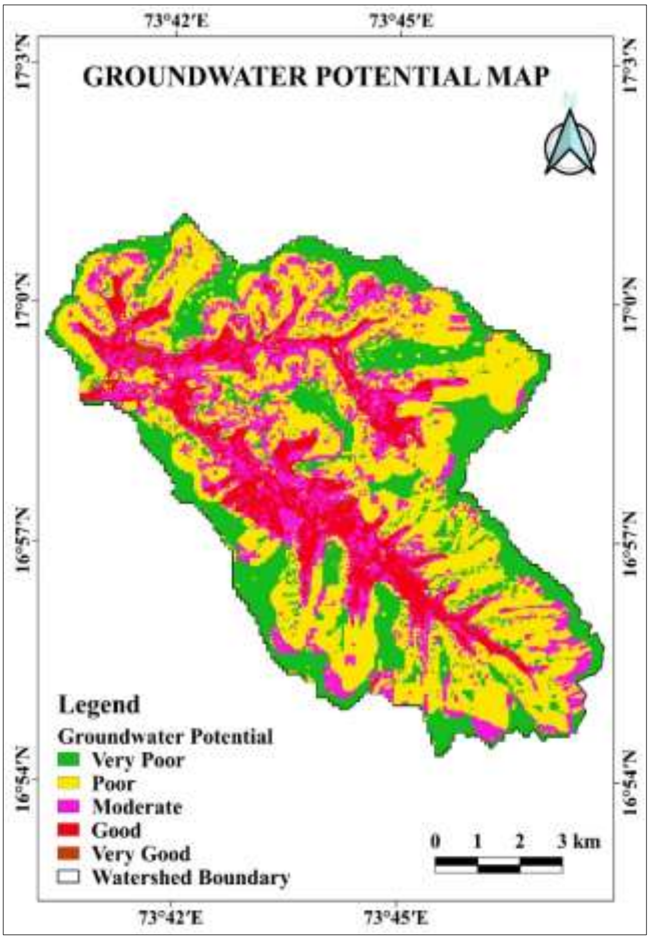

Fig 10: Groundwater potential map of Sakharpa watershed

Results and Discussion

Land use Land cover Map (LULC)

Land use land cover plays a significant role in the generation of runoff as well as development of groundwater resources. The hydrogeological processes in the water cycle *viz.*, infiltration, evapotranspiration, surface runoff, etc are affected by land use land cover. LULC map of Sakharpa watershed is divided into 5 classes i.e water body, vegetation, agricultural land and barren land. An area covered by different land use land cover classes in Sakharpa watershed is shown in Table 2. Supervised classification of study area shows that, major portion of land use is vegetation covering area 6426.09 ha, agriculture covering area 1311.93 ha., barren land covering area 997.38 ha, settlement covering area 237.69 ha and waterbody covering 77.67 ha area. in settlement and barren land rate of infiltration is low while in the agriculture land and vegetation areas, infiltration would be more and runoff would be less. Agriculture areas are considered very good groundwater potential whereas settlement is considered poor potential. Land use land cover map was prepared in QGIS is shown in Fig 3.

Table 2: Area covered by different land use land cover classes in Sakharpa watershed

Sr. No.	Land Use	Area (ha)	Area percent
1	Waterbody	77.67	0.86
2	Forest or Vegetation cover	6426.09	71
3	Settlement	237.69	2.63
4	Agriculture	1311.93	14.5
5	Barren land	997.38	11.01
Total		9037.07	100

Slope of watershed

The slope of Sakharpa watershed varies from 0 to 48%. The slope map of Sakharpa watershed is shown in Fig 4. About 64 percent area of the watershed is in the range of steep slopes. The steep slope terrain of the watershed indicated the high runoff potential and low infiltration capacity. The slope map of the Sakharpa watershed is divided into 5 classes i.e., gentle, moderately gentle, steep, moderately steep and very steep as shown in Table 3. Around 12.59% (1138.16 ha) area shows a gentle slope i.e., ≤5%. 23.40% (2114.99 ha) area shows a moderately gentle slope i.e., 5-10%. The maximum area of the watershed shows a steep slope i.e., 10-15% which covers area up to 2400 ha (26.56%). 20.62% (1863.75 ha) area shows a moderately steep slope (15-20%). Around 16.82% (1520.17 ha) area shows a Very Steep slope (>20%).

Table 3: Spatial distribution of slope classes in the Sakharpa watershed

Sr. No	Slope (%)	Class	Area (ha)	Area (%)
1.	≤5	Gentle	1138.16	12.59
2.	5-10	Moderately Gentle	2114.99	23.40
3.	10-15	Steep	2400	26.56
4.	15-20	Moderately Steep	1863.75	20.62
5.	>20	Very Steep	1520.17	16.82
Total			9037.07	100

Geomorphology map

The structural evolution of geological formations affects the geomorphology of an area. The geomorphology map of the Sakharpa watershed is shown in Fig 5. Sakharpa watershed falls under the following geomorphic units:

1. Highly Dissected Upper Plateau

2. Moderately Dissected Upper Plateau
3. Pediment
4. River
5. Lake

Plateaus are flat-topped residual mountains seen in plains. In the sakharpa watershed, the highly dissected upper plateau occupies an area of about 6034 ha i.e., almost 66.77 percent of the total area. highly dissected upper plateau shows less storage of groundwater. Medium storage of groundwater appears in the moderately dissected upper plateau which occupies about 77.52 ha area of the watershed. The pediment is the plain or low relief area that is formed at the foots of the mountains. The pediment is seen on the second large portion of the basin with an areal extent of 1825.78 ha i.e., 20.20 percent. Pediment act as good to moderate for storage of groundwater potential zones. Waterbody act as very well for groundwater potential zones. The study area falls under the waterbody category, river and lake. The area of 127.42 ha falls under waterbody category. Area covered by different geomorphic units is shown in Table 4.

Table 4: Area covered by different geomorphology classes in the Sakharpa watershed.

Sr. No.	Geomorphic units	Area (ha)	Area (percent)
1.	Highly Dissected Upper Plateau	6034	66.77
2.	Moderately Dissected Upper Plateau	72.52	0.80
3.	Scarp	977.62	10.82
4.	Pediment	1825.78	20.20
5.	River	105.28	1.16
6.	Lake	22.14	0.24
Total		9037.07	100

Geology map

The type of rock visible at the surface significantly affects the groundwater recharge (Yeh, 2016) [8]. The whole area of Sakharpa watershed is occupied by Deccan Trap. The geology map of sakharpa watershed is shown in Fig 6. This deccan trap in study area is of late cretaceous – palaeocene age. Deccan trap of Sahyadri hills shows good groundwater potentiality.

Lithology map

Sakharpa watershed is divided into two groups of lithologic formations which are

1. Basalt rock
2. Laterite rock

Basalt rock formation has moderate to good groundwater potential while the laterite rock formation shows low water holding capacity, low infiltration and thus higher runoff generation. The lithology map of Sakharpa watershed is shown in Fig 7.

In this study, basalt rock formation occupies a majority portion of sakharpa watershed. Basalt rock formation in Sakharpa watershed occupies around 9028.54 ha (99.90%) area of total area of watershed. Only 8.54 ha (0.10%) area occupies a laterite rock formation which is considered poor groundwater potential. Area covered by different lithology classes in Sakharpa watershed is shown in Table 5.

Table 5: Area covered by different lithology classes in Sakharpa watershed.

Sr. No.	Lithologic unit	Area (ha)	Area percent
1	Basalt	9028.54	99.90
2	Laterite	8.54	0.10
Total		9037.07	100

Drainage Density map

Drainage density indicates density of streams in watershed. It gives information about permeability, infiltration and runoff from watershed. Drainage density of Sakharpa watershed is divided into five classes *viz*, 0-1 km/km^2, 1-3 km/km^2 ,3-5 km/km^2, 5-8 km/km^2, >8 km/km^2. based on these classes of drainage density, it is categorized into excellent, very good, good, moderate and poor. Similar results were also observed in Bhange *et al*. (2016) [2].

If drainage density is higher, less will be infiltration and more will be runoff (Horton, 1945) [4]. The area with low drainage density, probability of potential groundwater zone is high. Drainage density map of Sakharpa watershed is shown in Fig 8. Table 6 shows drainage density category of Sakharpa watershed.

Table 6: Drainage Density Category of watershed

Sr. No	Drainage Density	Category	Area (ha)	Area (Percent)
1.	0-1	Excellent	4190.54	46.37
2.	1-3	Very good	2167.2	23.98
3.	3-5	Good	1353.9	14.98
4.	5-8	Moderate	984.83	10.90
5.	>8	Poor	340.6	3.77
Total			9037.07	100

Out of total area, about 46.37% area of the watershed shows very low drainage density covering a 4190.54 ha area, which acts as excellent for groundwater potential zones. The area of 2167.2 ha i.e., 23.98% area covers the very good category, 1353.9 ha i.e., 14.98% area covers the good category and 984.83 ha i.e., 10.90% area covers the moderate category. 340.6 ha i.e., 3.77% area shows drainage density greater than $8km/km^2$ which is poor for groundwater potential zones.

Hydrological soil group

A hydrological soil group map was prepared by using the data downloaded from Global Hydrologic Soil Groups (HYSOGs250m) for Curve Number-Based Runoff Modeling. Sakhapra watershed indicates two types hydrological soil groups *viz*, Soil group C and soil group D. A hydrological soil group map of Sakharpa watershed is shown in Fig 9. Soil group C shows moderate runoff potential whereas soil group D shows high runoff potential.

Table 7 shows the area covered by different Hydrological Soil Groups in Sakharpa watershed. Maximum area of watershed is covered by hydrological soil group C i.e., 71.60% (6470.54 ha) area and hydrological soil group D covers 28.4% (2566.52 ha).

Table 7: Area covered by different Hydrological Soil Groups in Sakharpa watershed

Sr. No.	Hydrological Soil Group	Area (ha)	Area (per cent)
1	D	2566.52	28.40
2	C	6470.54	71.60
Total		9037.07	100

Delineation of groundwater potential zones

All the thematic layers are overlaid by the weighted overlay method in QGIS to generate groundwater potential zones. All the thematic layers were rasterized and reclassified. After that weights were assigned and rank has been given to each parameter in every thematic layer. Similar work was carried by many researchers such as Waikar and Nilawar (2014) [7], Krishnamurthy *et al*. (1996) [5] and Bhange *et al*. (2016) [2]. As show in Table 1 the higher value was given to the higher groundwater potentiality feature and the lower value was given to the feature with lower groundwater potentiality.

As far as geomorphology is concerned, higher rank was given to the pediment and waterbody and lower value was given to the highly dissected plateau. In lithology layer basalt rock formation was assigned with higher value and laterite rock formation was assigned with lower value. In slope layer, higher rank is given to the gentle slope and a lower rank was given to the steep slope. As drainage density is concerned, the area with low drainage density was assigned with higher value and a lower value was given to the area with high drainage density. Agriculture land and waterbody are the good groundwater potential features, so that higher value was given to it and low rank was given to barren land and settlement in land use land cover layer. In soil layer loam soil is assigned with higher rank than sandy loam soil.

The groundwater potential zone map of the Sakharpa watershed was divided into five categories such as 'Very Poor', 'Poor', 'Moderate', 'Good', and 'Very Good' groundwater potential. The groundwater potential zone map of the Sakharpa watershed is shown in Fig 10. Table 8 shows the area under various groundwater potential zones. About 24.61% (2223.81 ha) area falls under the very poor groundwater potential zones category. Poor groundwater potential is available in 42.28% (3820.73 ha). 20.32% (1836.43 ha) area falls under the moderate groundwater potential zones category. Good groundwater potential is available in 12.53% (1132.31 ha) and only 0.26% (23.79 ha) area falls under very good groundwater potential.

Table 8: Groundwater potential zones category of Sakharpa watershed

Sr. No.	Potential zones	Area (ha)	Area (percent)
1	Very Poor	2223.81	24.61
2	Poor	3820.73	42.28
3	Moderate	1836.43	20.32
4	Good	1132.31	12.53
5	Very Good	23.79	0.26
Total		9037.07	100

Conclusions

The groundwater potential zone map of the Sakharpa watershed was divided into five categories such as 'Very Poor', 'Poor', 'Moderate', 'Good', and 'Very Good' groundwater potential. About 24.61% area falls under the very poor groundwater potential zones category. Poor groundwater potential is available in 42.28%. About 20.32% area falls under the moderate groundwater potential zones category. Good groundwater potential is available in 12.53% and only 0.26% area falls under very good groundwater potential. Based on the analysis it was found that the watershed had 67 per cent area falls under very poor to poor groundwater potential zone and only 12 to 13 per cent area having good to very good groundwater potential zone. This indicated that the watershed should be treated with soil and water conservation measures to improve the groundwater recharge rate.

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