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(Research Article)

Identification of groundwater potential zone and Water harvesting Structures using remote sensing and GIS technique in Chilapura Watershed, Davangere district, Karnataka state.

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Abstract

The current study intends to prepare the surface runoff and ground-water prospects for the Rainwater Harvesting Structure. One of the most important resources in our daily lives, water is running out more quickly in both rural and urban regions due to rising home and agricultural demand. Groundwater is becoming more and more important in water resource planning because there is a shortage of high-quality subsurface water and a growing demand for water for industrial, agricultural, and residential use. The monsoon's persistent failure, rising demand, and overuse cause the groundwater table to fall. To some extent, this issue could be resolved by artificially replenishing the potential aquifers. Consequently, the current study uses an integrated approach of remote sensing and GIS Weighted Overlay to evaluate the Rainwater Harvesting Structure in Chilapura watershed Honnali Taluk, Dhavangere District, based on surface runoff and ground water possibilities. utilizing remote sensing and auxiliary data in a GIS platform, this study was conducted utilizing a variety of thematic maps covering drainage, slope, soil, geomorphology, lithology, land use, and land cover isohyet. According to the outcome, there are enough areas for percolation tanks, storage tanks, dam ponds, and exploration dams. Water in the dry area will be saved since the generated map will assist in choosing the best site for water harvesting facilities.An additional benefit over traditional research is the use of remote sensing and GIS analysis of spatial suitability to detect rainwater harvesting facilities. In the research area, appropriate heights for the test dam constructions and storage/percolation tank stop tank are provided.

Keywords: Groundwater potential; Semi-arid; Chilapura watershed; RS and GIS

1. Introduction

Groundwater provides one-third of the world's freshwater abstractions (Das et al., 2018). In parts of the world where water resources are scarce, groundwater supplies are intrinsically and extrinsically necessary for all economic operations. A natural resource required for both social and economic development is groundwater (Kordestani et al., 2019). In a semi-arid country like India, surface water is not always available for many residential applications, thus people there are depending more and more on groundwater supplies to survive. In many parts of India, groundwater is a valuable natural resource that is in short supply due to misguided planning and exploitation methods that lack scientific foundation. Due to the potential for a protracted water crisis, groundwater is in danger of drying up (Mukhopadhyay et al., 2020; Das and Pal, 2019). Porosity and permeability, which are impacted by hydrometeorological and hydrogeological factors such as lineaments, soil type, slope, land use land cover (LULC), and rainfall intensity, are the primary factors influencing groundwater recharge (Chaudhry et al. 2021). Groundwater potential zones are located using standard approaches such as geological, geophysical, and field study. These techniques are costly and require a significant amount of specialized time and work (Shao et al., 2020). Groundwater potential zones have been identified by numerous researchers using GIS and remote sensing techniques (Magesh et al. 2012; Das and Pal 2019; Etikala et al.

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2019). Additionally, major advancements have been made possible by the broad use of geospatial technology for Ground Water Potential Zone (GWPZ) mapping, notably in the application of Multi-Criteria Decision-Making (MCDM) statistical classifiers (Machiwal et al., 2011). Using GIS techniques, this study outlines the possible groundwater zones. In the study area's semi-arid climate, farming is the main economic activity. They have little access to surface water supplies, therefore they must rely on groundwater. Deeper groundwater levels are caused by random rainfall patterns and abandoned extraction. Rainwater harvesting, or RWH, is the best way to address the water problem because there is a severe shortage of clean water. The process of collecting water through drainage and storing it locally for future use using a variety of processes is known as rainwater harvesting. Although the water can also be used domestically, it is beneficial for groundwater replenishment and irrigation activities. We can determine the right type of water collecting structure and the required number of structures with the help of this investigation. Water conservation is the best and most effective strategy to address the water issue in the research area. Thus, the purpose of this study is to use seven groundwater-prospecting criteria to identify the groundwater potential zones in the Honnali Taluk. Selecting the best site for borehole drilling and long-term groundwater management would be made easier for planners and decision-makers with the aid of such a quantitative method using GIS technologies to assess groundwater potential zones.

1.1. Study Area

The area chosen for the study is the Chilapura watershed in Honnalli Taluk of Davanagere District, lying between latitudes 14^0 19' 49.19"N – 14^0 06' 13.06"N and longitudes 75^0 42' 12.10" E - 75^0 27' 46.29" E on Survey of India topographic maps. The catchment's geographical area is 690.809km^2. An average of 166 mm of rainfall falls during the pre-monsoon, 417 mm during the SW monsoon, and 197 mm during the NE monsoon. The research area has a semi-arid environment, and throughout the previous few years, there hasn't been much groundwater development in this area in terms of availability. Because groundwater is scarce, it is mostly used for irrigation through pumping wells and drilled wells, whereas surface water is used primarily for drinking. The study area's location map is shown in Fig. 1

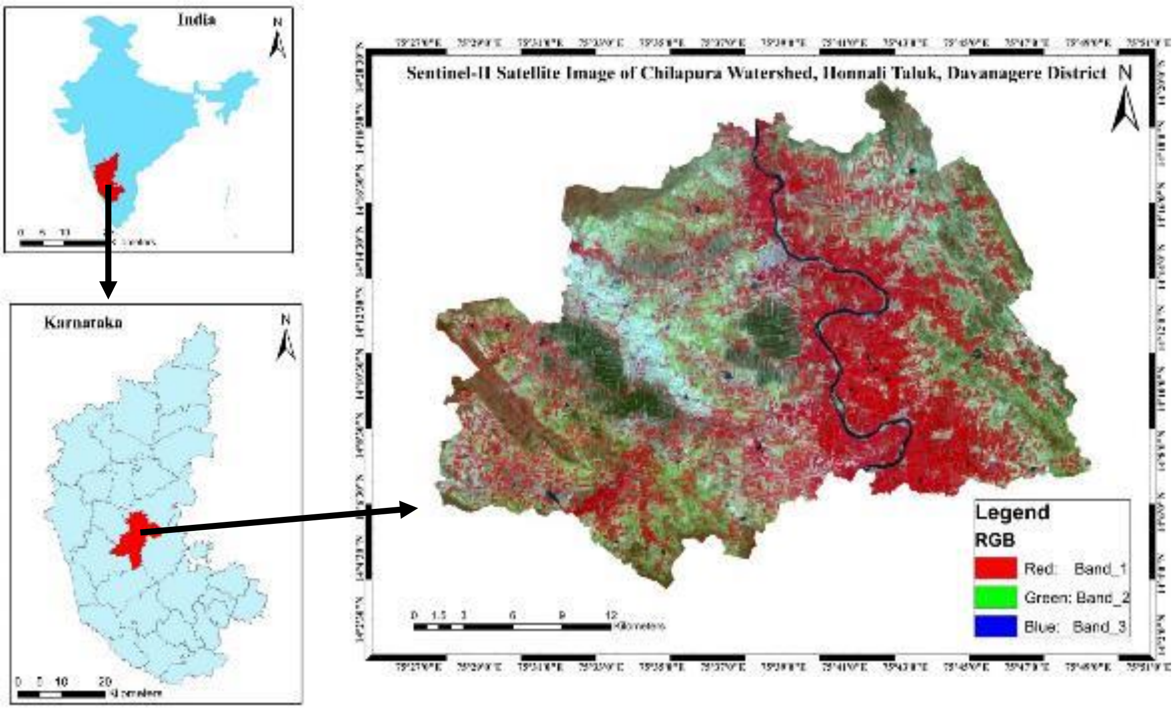

Figure 1 Location map of the study area

2. Data and Methodology

Table 1 The thematic maps for this study area were prepared using following datasets, which are listed in detail below:

Data name	Resolution/ Time period	Thematic maps	Source
Topographic Map	-	Drainage, lithology,	https://surveyofindia.gov.in/
Sentinel-2	10meter	LULC, soil, lithology, geomorphology,	http://earthexplorer.usgs.gov
Aster DEM	30 meter	Drainage, slope, Lineament	

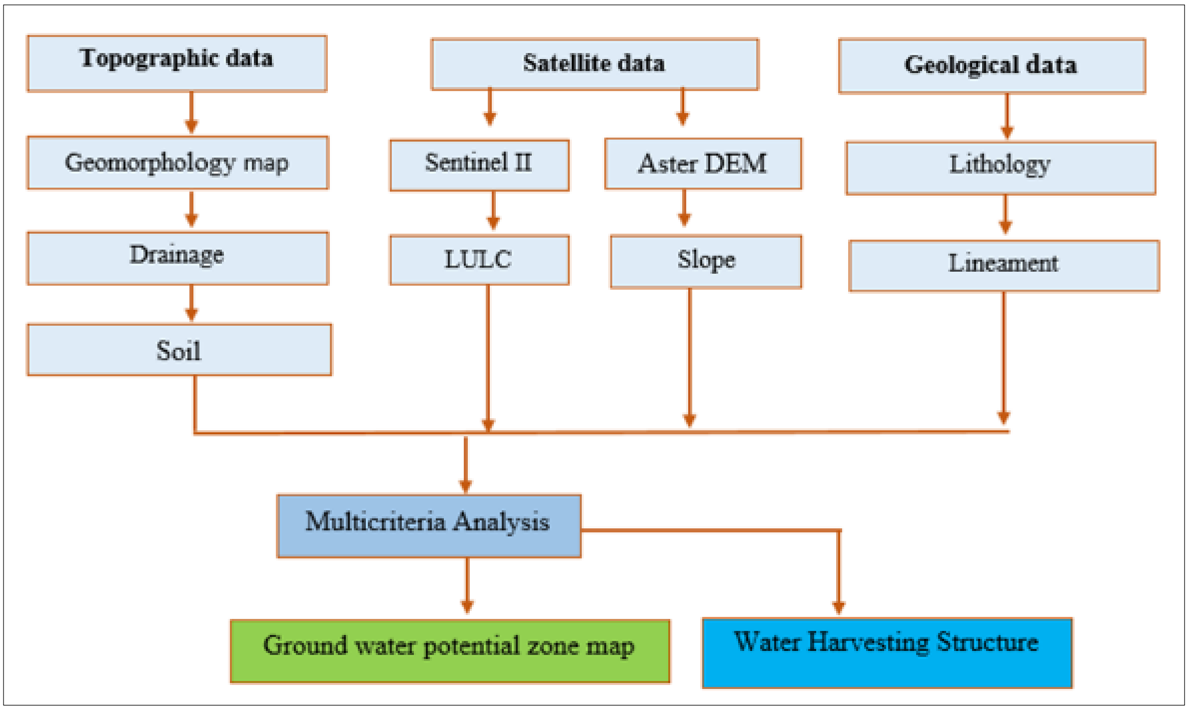

Figure 2 Flow chart of the methodology used in this study

Table 2 Categorization of factors influencing Groundwater Potential Zones

Factors	Assigned weight	Domain of effect	Rank
Geology	5	Amphibolite	7
		Ferruginous chert / BHQ /BFQ	1
		Granite	3
		Argillite	3
		Chlorite Sericite Schist	1
		Banded iron formation	5
		Manganiferous phyllite and chert	2
		Metabasalt	7
		Meta-ultramafite	3
		Migmatites gneiss	5

		Chert	3
		Chlorite schist	1
		Conglomerate	5
		Dolerite	7
		Dolomitic Limestone	3
		Fuchsite Quartzite	7
		Quartz-Kyanite Schist	4
		Quartz Vein/Reef	9
		Quartzite	7
		Banded Magnetite Quartzite	7
		Basaltic Komatiite	9
		Dolomite	6
		Graywacke	3
		Meta-Gabbro	7
		Meta-Rhyolite	9
		Grey Granite	7
Geomorphology	1	Inselberg	3
		Linear Ridge/ Dyke	2
		Moderately weathered/ moderately buried Pediplain	7
		Pediment - Inselberg Complex	2
		Pediment/ Valley Floor	9
		Pediplain shallow weatherd under canal command	5
		Residual Hill	2
		Ridge type Structural Hills (Small)	2
		Shallow weathered/ shallow buried Pediplain	5
		Structural Hills	2
		Valley Fill/ filled-in valley	9
		Pediplain Eroded	5
		Valley	1
		Water Body Mask	7
Slope	6	Gentle Slope	4
		Moderate Slope	3
		Moderately Steep Slope	2
		Nearly Level	9
		Strong Slope	2
		Very Gentle Slope	6
		Very steep slope	2
		Clayey over Sandy	4

Soil	7	Clayey Skeletal	4
		Clayey over loamy	4
		Fine	5
		Fine Loamy	5
		Habitation mask	2
		Loamy	4
		Loamy Skeletal	4
		Rock outcrops	3
		Coarse Loamy	4
		Waterbody mask	1
LULC	4	Agricultural land	2
		Forest Plantation	5
		Builtup	7
		Waste land	7
		Waterbody	7
Drainage Density	3	0-91.48 (Very Low)	9
		91.48-135.99(Low)	7
		135.99-174.31(Moderate)	5
		174.31-215.11 (High)	4
		215.11-315.25 (Very High)	3
Lineament Density	2	0.–13.30 (Very Low)	3
		13.30–33.87 (Low)	4
		33.87–56.86 (Moderate)	5
		56.86–86.50 (High)	7
		86.50–154.25 (Very High)	9

Table 3 Percentage of influence assign to each factor for weighted overlay method

Criteria	**Priority**	**Rank**	**Criteria**
1	Geomorphology	25.1 %	1
2	LULC	13.1 %	4
3	Geology	10.7 %	5
4	Lineament density	19.1%	2
5	Soil	9.2 %	7
6	Drainage density	13.5 %	3
7	Slope	10.3 %	6

Consistency Ratio CR = 0.05 Principal eigen value = 10.878 Eigenvector solution: 6 Iterations, delta = 1.8 E-7

3. Results and Discussion

3.1. Lithology

The geologic environment has a major impact on the distribution and occurrence of groundwater in any terrain (Yeh, H.-F. et al. 2016). Groundwater storage and outflow are enhanced by the geologic units' high porosity and permeability (Yıldırım, Ü. 2021). Lithologic is one of the main rock kinds in the study area. Acid Volcanics (51.9308 km^2) Amphibolitic Metapelitic Schist/Pelitic Schist,Cal (12.9122 km^2) Basal Polymict Conglomerate (27.0218 km^2) Greywacke / Argillite (0.2124 km^2) Manganese And Iron Formation With Phyllite (0.3752 km^2) Migmatites And Granodiorite - Tonalitic Gneiss(420.0800 km^2) and Quartz Chlorite Schist (2.1552 km^2) are found in the study area. The hydrological relevance of the rock in respect to the local geology is taken into consideration. When determining the rank, factors such as rock types, provenance and occurrence, weathering, and so on are taken into account. Fig. 3 displays the lithology of the research area.

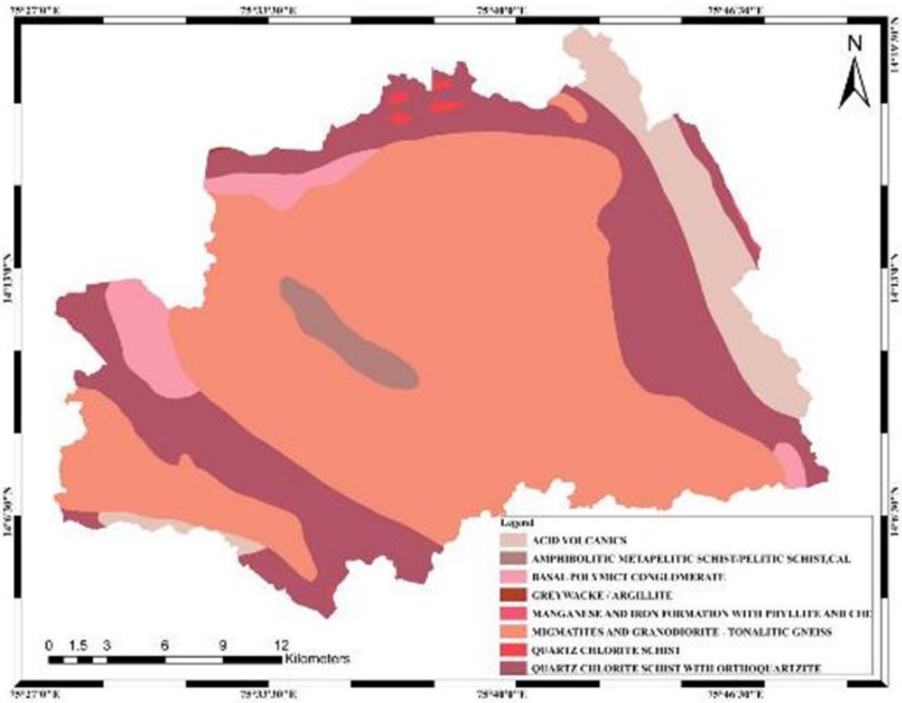

Figure 3 Lithology Map of the study area

3.2. Geomorphology

Geomorphology, or the topography and landform of a location, is one of the most crucial aspects to take into account when evaluating the prospect and potential zones for groundwater because it regulates subterranean groundwater circulation (Andualem and Demeke, 2019). The geomorphology of the examined region is important for groundwater existence because it affects groundwater occurrence, storage, and recharge over the surface of the earth (Shao et al., 2020). The main geomorphological features in the research region are divided into many classes, including Denudational Hills (4.6295 km^2) Inselberg (1.3906 km^2) Moderately weathered/ moderately buried Pediplain (19.4089 km^2) Pediment - Inselberg Complex (8.2621 km^2) Pediment/ Valley Floor (24.1789 km^2) Pediplain Shallow weathered under canal command (61.0008 km^2) Residual Hill (3.2768 km^2) Shallow weathered/ shallow buried Pediplain (361.8460 km^2) Structural Hills (77.9543 km^2) Valley (21.2275 km^2) Valley Fill/ filled-in valley (87.6903 km^2) and Water Body Mask (20.3175 km^2). Valley fills and water bodies, as well as shallow weathered sections in Pediplains, receive the highest grade. Conversely, the least valuable hills are those that are denudational, residual, and structural. Fig. 4 displays the geomorphology of the research region.

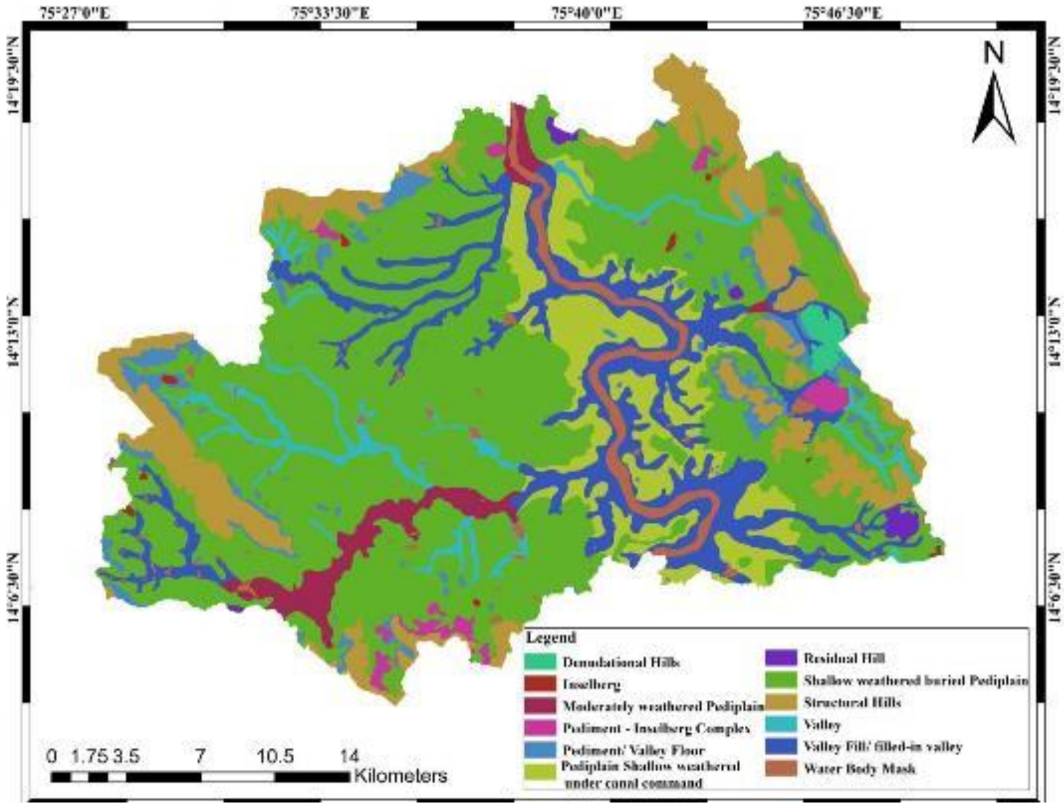

Figure 4 Geomorphology Map of the study area

3.2.1. Land use and Land cover (LULC)

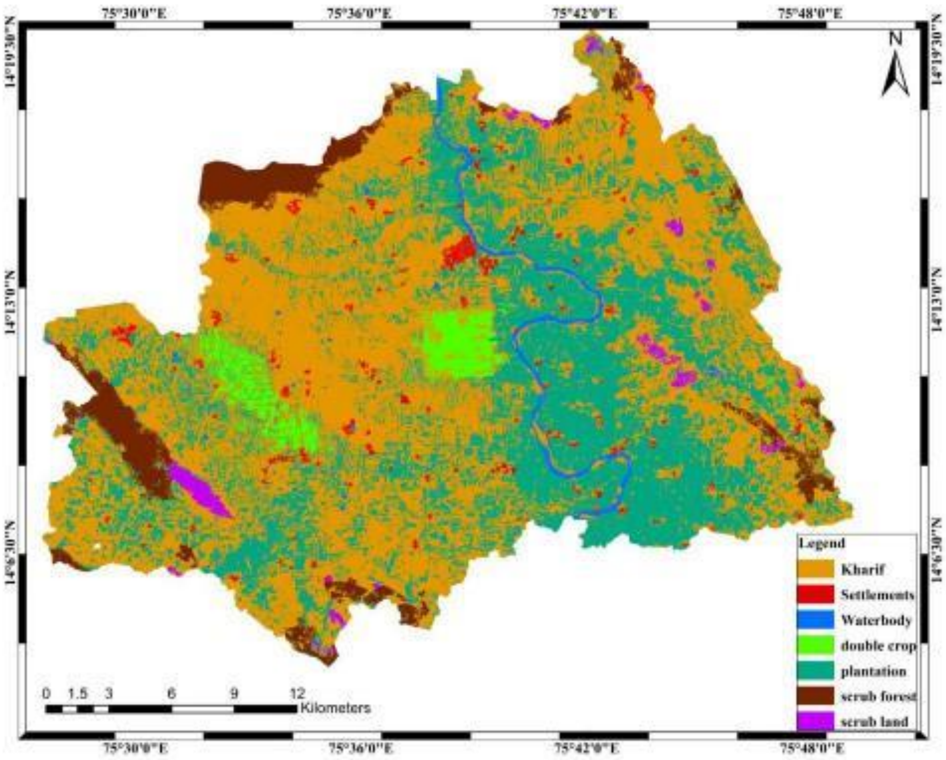

Figure 5 Land use/land cover Map of the study area

Evapotranspiration, infiltration, and condensation may occur depending on the type of plant and soil moisture content. A number of factors, including land use and land cover pattern, can affect surface runoff. Thus, groundwater recharge is significantly impacted by LULC. Thus, LULC provides essential information on infiltration, soil moisture, surface water, and other groundwater requirements (Yeh, H.-F. et al., 2016). A map of land usage and land cover was produced using Sentinel 2A and ERDAS Imagine satellite photos with supervised categorization. Several land cover and land use categories, including double crop (18.97 km^2), are separated out on the LULC map. Kharif (380.84 km^2), Plantation (226.93 km^2), Scrub forest (36.88 km2),Scrub land (7.44 km^2) Settlements (9.80 km^2)and Waterbody (9.84 km^2) Plantations, double crops, water bodies, and kharif are ranked top. Conversely, villages, stony waste, shrub land, and built-up regions are ranked lowest. Figure 5 displays the research area's land cover and land usage.

3.3. Slope

The slope is one significant element that directly influences surface runoff, infiltration, and percolation in a certain area (Das, 2021). Because it takes longer for rainwater to penetrate the subsurface in low slope regions, previous research has indicated that these areas have a good potential for storing groundwater; on the other hand, landscapes with higher runoff negatively affect groundwater potential in steep slope regions (Igwe et al., 2020). The slope map was made using the ASTER DEM image from the spatial analysis tool in ArcMap 10.4. As shown in Fig. 6, the slope map was divided into seven categories: "Very close" (0–1%)."Gentle slope" (3-5%), "Very gentle slope" (5-10%), and "Moderate slope" (1-3%) The three categories of slopes are "Very steep slope (35-50%), strong slope (15-35%), and moderate steep slope (10-15%). The finest slopes are those that are virtually level and gentle, whereas the worst slopes are those that are steep and very steep.

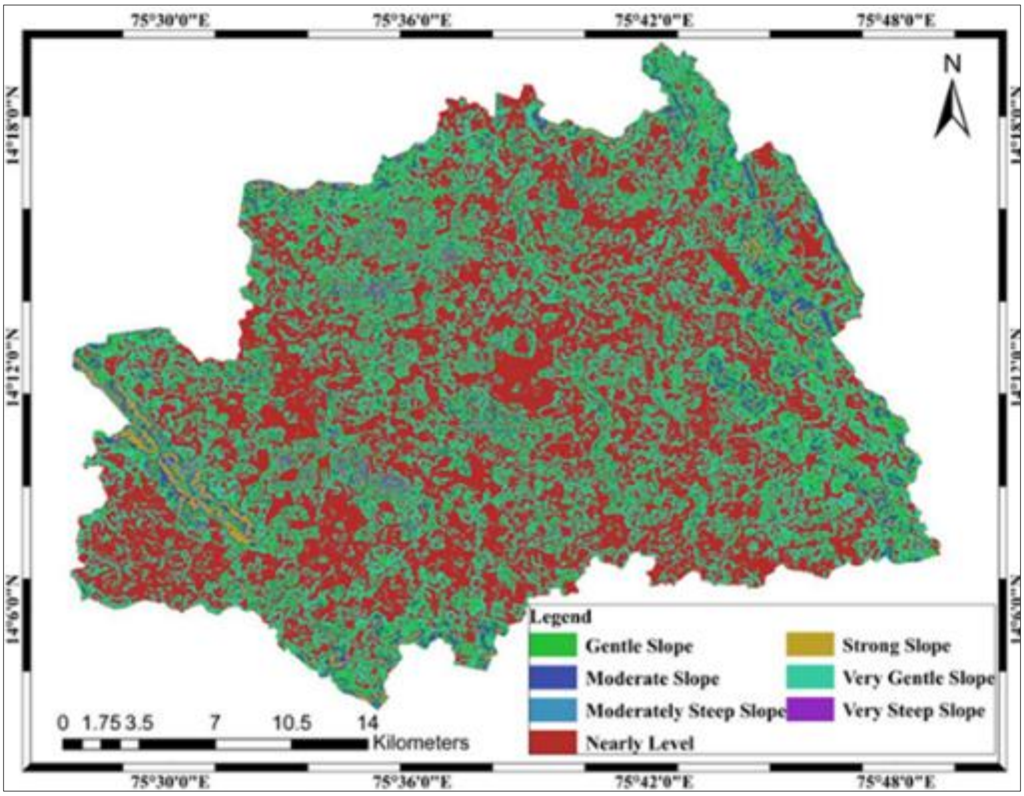

Figure 6 Slope Map of the study area

Soil: Because surface water percolates and infiltrates the earth in large part due to the kind of soil in the research region, the amount of recharge water that seeps into the ground is highly dependent on the state of the soil (Ahmad et al., 2020). The potential for groundwater is higher in soil types with coarse-grained matrices (lithosols, for example) than in soil types with fine-grained matrices (ferralsols). As a result, the rate of infiltration has been used to weigh soil texture. In comparison to coarse textures, which have a higher infiltration rate, fine textures are ranked lower and have a lower infiltration rate. The research region has a variety of soil types, including Clayey Over Loamy(1.89km^2), Clayey Over Loamy(6.03km^2), Clayey Skeletal(132.95 km^2), Coarse Loamy(67.81 km^2), Fine(365.45km^2), Fine Loamy(7.18km^2), Habitation Mask(16.07 km^2), Loamy(1.89km^2), Loamy Skeletal, (73.50 km^2)) and Water Body Mask(20.27 km^2). Fig. 7 displays the study area's soil map.

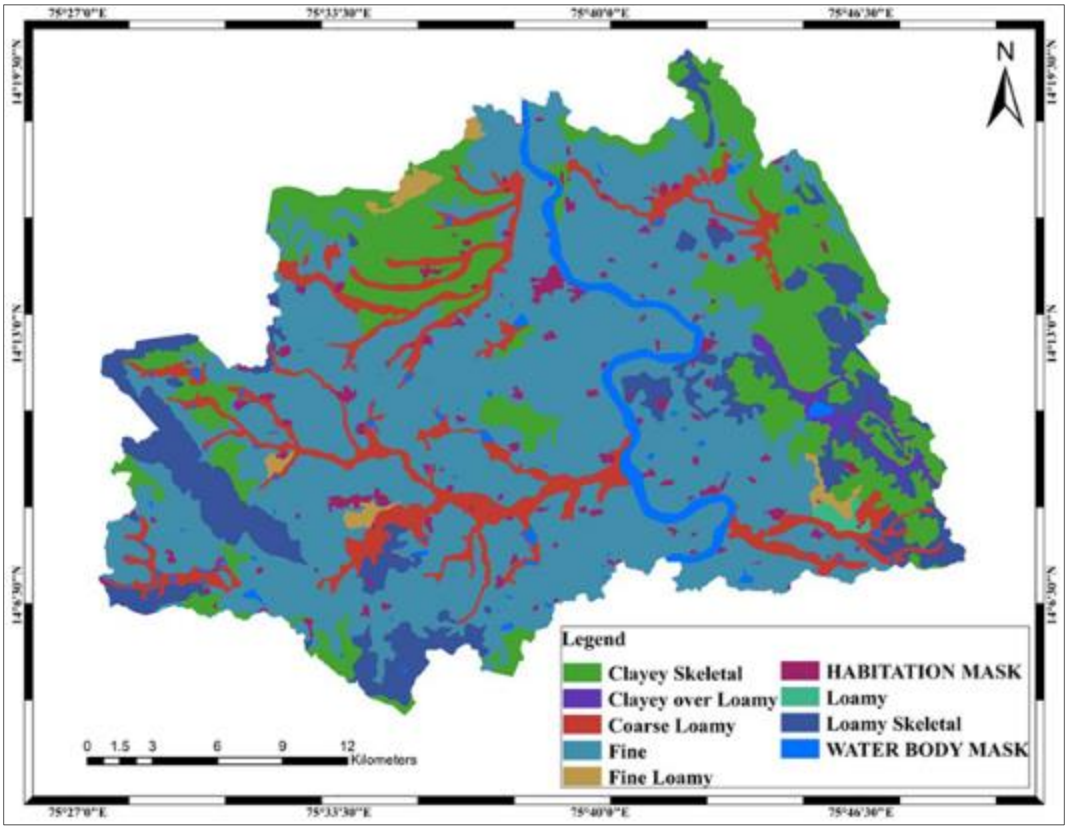

Figure 7 Soil Map of the study area

3.4. Assessment of groundwater potential zones

The groundwater potential map's objective is to identify regions with a higher potential for groundwater development within any particular geographic area (Diaz-Alcaide & Martinez-Santos, 2019). To identify groundwater potential zones, seven groundwater potential influencing variables were merged using a GIS-based multi-criteria decision technique. The following parameters have been taken into account for the sample: soil, slope, groundwater level, LULC, lineament density, drainage density, lithology, and geomorphology. A weighted overlay analysis based on multi-criteria (Table 3) was used to create the GWPZ map. Five categories very good (152.62 km2), good (312.54 km2), moderate(136.99 km2), poor (69.55km2) and very poor (19.46km2) with corresponding spatial extents are depicted on the resulting map (Fig. 8).

The study area features a very gentle slope, loam soil, plantations with exceptional infiltration ability, significant rainfall, low runoff, and high groundwater recharge. It also has greater water holding capacity of soils, high lineament density, and low drainage density. There are zones with good and good to moderate groundwater potential in the research area. Zones with excellent groundwater potential are located near bodies of water, indicating a good relationship between the aquifer system and surface water bodies. This means that there is a lot of groundwater potential on the land, which opens the door to more extensive groundwater management.

A moderate groundwater potential zone is one that has a moderate slope, experiences more runoff, and has shorter percolation times than an excellent potential zone. A ridge, stony wastes, vegetated terrain, modest lineament density, and a gentle slope characterize these regions. Thus, there must be enough economic activity in addition to effective surface and groundwater management. The steep slopes in the poor and very poor groundwater potential zones cause a lot of runoff and short-term percolation. These zones are characterized by high drainage density, low lineament density, rocky terrain, steep slopes with thin soil, built-up regions, significant runoff, minimal groundwater recharge, and a significant distance from water bodies. These places have very deep groundwater levels, with a shallow weathered zone that is usually found in hilly areas. In areas with little groundwater potential, artificial groundwater recharge structures can considerably raise the water table.

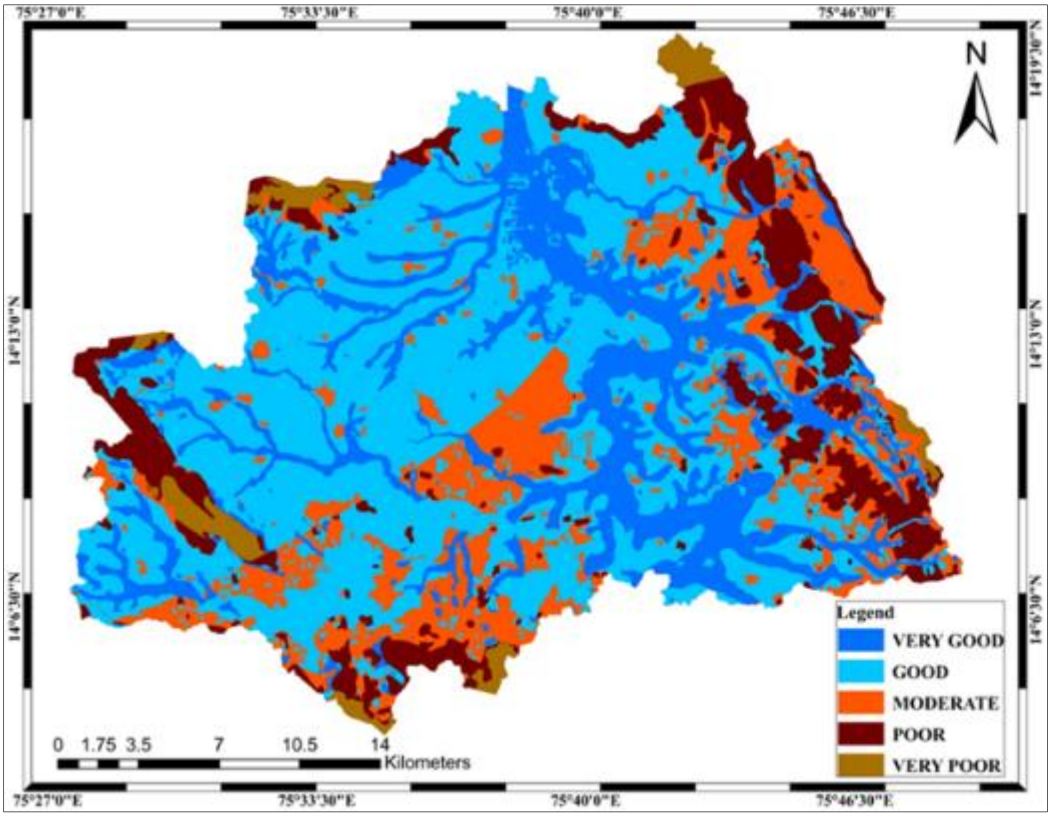

Figure 8 Ground water potential zone Map of the study area

3.5. Rain Water Harvesting Systems

Storage tanks- One of the buildings used to store surface water is the storage tank. These buildings are excellent for collecting rainwater. Storage tanks typically have a permanent or floating roof, a flat bottom, and a cylindrical shape that is perpendicular to the ground. According to a study conducted in the Chilapurawatershed Honnali Taluk, Dhavangere District, the best places for storage tanks are those that are open, have steep slopes, sandstone, and are free of scrub vegetation. In the area, more than 70 locations for storage tank building have been proposed. These locations meet every prerequisite for the installation of storage tanks.

- **Percolation tanks-** Groundwater is replenished by buildings called percolation tanks. These are typically built to impound a portion of the runoff water across larger valleys and streams. Areas beneath terrain with scrub, a moderate slope, basalt, and a high density of lineaments are suggested for percolation tanks in the Chilapurawatershed Honnali Taluk, Dhavangere District research. There are sixty locations in the Area where percolation tanks can be built. These locations meet all the requirements needed to build percolation tanks.
- **A stop dam-** is a masonry structure that is constructed to divert water flow in shallow rivers and streams so that water can be collected for irrigation, human and animal usage, and household purposes. The areas of open woodland, mild slopes, and third- to fourth-order streams are suggested for cease dam construction in the Chilapurawatershed Honnali Taluk, Dhavangere District research. In the Area, thirty-two locations for cease dam development are recommended. These regions meet all the prerequisites for the installation of stop dams.
- **Check dams -** are little structures that are put across a drainage ditch or natural or artificial channel. They can be composed of rock, sandbags, gravel bags, sediment retention fiber rolls, or another proprietary product. By lowering flow velocity and promoting sediment settlement, a check dam built, maintained, and designed correctly will lessen scour and channel erosion. Areas with double crop, sandstone, a relatively mild slope, and fifth and sixth order streams are suggested for check dam construction in the Honnali Taluk study. In the Honnali, fifteen locations for check dam construction are recommended. These regions meet all the prerequisites for the construction of check dams.

The study region of Chilapurawatershed Honnali Taluk, Dhavangere District has produced places where different implementations can be done depending on different areas suited for the sustainable development of water resources, as indicated in Fig. 9 for water resource management.

Table 4 Types of structures for rain water harvesting system

Types of Structure	Lithology	Land Use/ Land Cover	Slope	Drainage
Storage Tank	Migmatites And Granodiorite - Tonalitic Gneiss, Argillite	Wasteland	Steep Slope	2nd or 3rd Order Stream
Percolation Tank	Migmatites And Granodiorite - Tonalitic Gneiss, Argillite, Quartz Chlorite Schist With Orthoquartzite,Granite	Land with Scrub	Moderate Slope	2nd, 3rd or 4th Order Stream
Stop Dam	Migmatites And Granodiorite - Tonalitic Gneiss, Argillite	Forest	Very Gentle Slope	3rd and 4th Order Stream
Check Dam	Migmatites And Granodiorite - Tonalitic Gneiss, Argillite	Cropping land	Gentle Slope	5th and 6th Order Stream

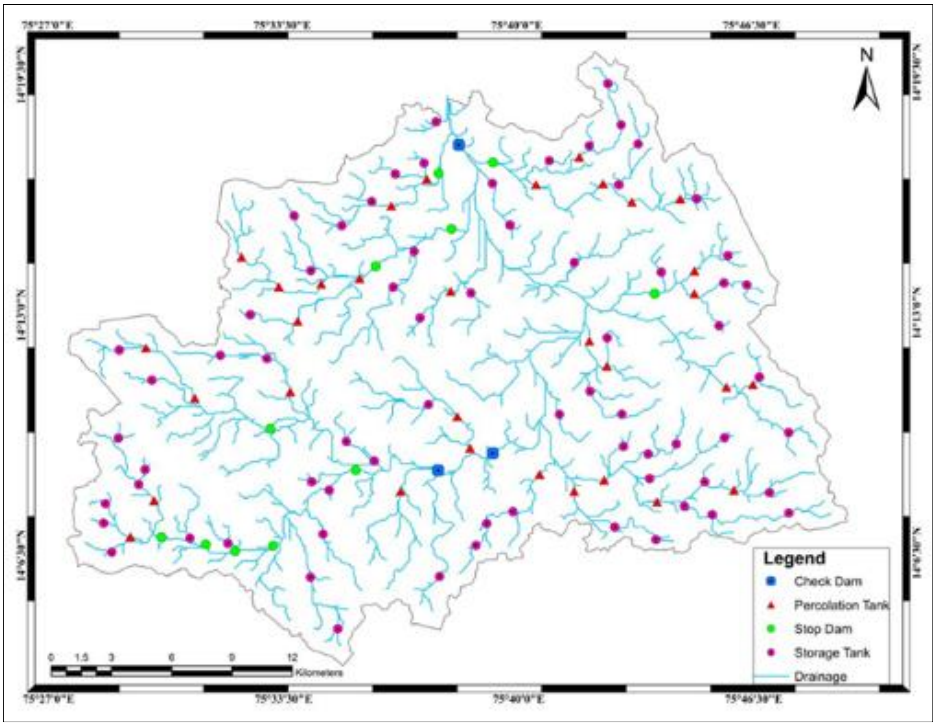

Figure 9 Site Suitability analysis for Water Harvesting Structure Map of the study area

4. Conclusion

It is critical to identify the groundwater potential zone (GWPZ) where human water scarcity is an issue. In India's Chilapurawatershed Honnali Taluk, Dhavangere District, the current study offers compelling evidence in favor of using GIS and remote sensing methods in conjunction with multi-criteria decision-making to identify groundwater potential zones. In this inquiry, eight theme layers were used: soil, LULC, lineament density, drainage density, slope, and drainage. Utilizing the weighted overlay approach, the outcomes were combined in the GIS. The research region encompasses five distinct zones with respect to groundwater potential: very good (152.62 km^2), good (312.54 km^2), moderate(136.99 km^2), poor (69.55km^2) and very poor (19.46km^2). The research region (Chilapurawatershed Honnali Taluk, Dhavangere District) has sufficient space for storage tanks, percolation tanks, dam ponds, and exploratory dams. The map that will be made will help determine the ideal location for water harvesting facilities, preserving water in the arid area. Layers such as lithology, geomorphology, lineaments, and land cover/use all influence the site's suitability for water resource management. It is especially helpful for studies that address the problem of water scarcity in arid and semi-arid countries since it shows potential development locations. Since most of the land is used for agriculture, decision-makers will benefit from studies on the groundwater potential zone map as they plan and manage groundwater resources for both home and agricultural purposes. The research area (Chilapurawatershed, Honnali Taluk, Dhavangere District) is fully equipped with areas for percolation tanks, storage tanks, exploratory dams, and dam ponds. Water in the dry area will be preserved thanks to the map that will be created, which will assist in choosing the best site for water harvesting facilities. Additionally, it will raise agricultural productivity in the area and enhance irrigation systems. Additionally, the methods used in this study will be helpful to other academics throughout the world working on related issues.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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