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Identification of Artificial RechargeZones in Thalasseri Taluk, Kannur, Kerala, India

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Abstract

The depletion of groundwater resources has become a significant concern in many regions, including Thalassery Taluk in Kerala, where over-extraction and limited natural recharge are exacerbating water scarcity. The study aim focuses on the identification and evaluation of potential artificial recharge zones in Thalassery Taluk for augmenting the availability and sustainability of groundwater. This study proposes a methodology to delineate artificial recharge zones as well as to identify favorable artificial recharge sites using integrated remote sensing (RS) and geographical information system (GIS) for augmenting groundwater resources in the Thalassery district in Kerala. The thematic layers considered in this study are geomorphology, geology, drainage density, slope, lithology, rainfall, aspect, land use land cover, lineament, and soil, which were prepared using RS imagery and conventional data. Different themes and their corresponding features were assigned proper weights based on their relative contribution to groundwater recharge in the area, and normalized weights were computed using the Weighted Overlay Method (WOM). The artificial recharge map thus obtained divided the study area into five zones, viz., 'very high,' 'high', 'moderate', 'low', and 'very low' according to their suitability for artificial groundwater recharge. The western portion of the study area was found to be suitable for artificial recharge and the eastern portion of the study area was found to be unsuitable for artificial recharge. The results of this study could be used to formulate an efficient groundwater management plan for the study area so as to ensure sustainable utilization of scarce groundwater resources.

1. Introduction

Water is the most critical constituent of life on Earth, covering about 71% of the Earth's surface and playing a major role in the functioning of ecosystems, weather patterns, and human societies. Composed of two hydrogen atoms that are covalently bonded with a single atom of oxygen (H_2O), water comes in three forms or phases: liquid, solid, and gas—as ice, vapor; it gets cycled through the environment via the hydrological cycle. It is the cycle through which water moves in processes such as evaporation, condensation, precipitation, and runoff between the atmosphere, land, and oceans. Water is essential not only for drinking and personal hygiene but also for agriculture, industry, and energy production. It is the lifeblood of ecosystems and maintains biodiversity and climate control. Without enough and clean water, as we know it, life would not exist.

The term 'water resources' simply means sources and supplies of water available for human use and environmental sustainability. Broadly, they are divided into surface water and groundwater. Surface water has rivers, lakes, artificial man-made reservoirs, and wetlands that are readily accessible and largely utilized for drinking, irrigation, industry, and recreation. On the other hand, groundwater refers to water that is generally stored in aquifers below the Earth's surface. It comprises stratified layers of either permeable rock, sand, or gravel that help retain moisture. Groundwater is an important source of potable water in arid and semi-arid areas where other sources of water are at a premium. These resources need to be managed to ensure sufficient water for communities and the environment now and into the future, given the increasing demand for these resources and the pressures brought by climate change.

Artificial recharge of groundwater goes hand in hand as strategies towards sustainable water management. Water conservation helps to avoid loss of water through wastage and promotes its efficient use within households, agriculture, and industry in order to sustain both surface and groundwater resources. By reducing demand, pressures on natural systems are eased through conservation. Artificial recharge to groundwater, on the other hand, is the artificial introduction of water into aquifers through infiltration basins and recharge wells to replenish the reduced levels of groundwater. Artificial recharge is dependent on various local factors, which include the climate, surface and subsurface geology, and the nature of the water slated for recharging. This would help store the recharge water during the monsoon periods when there is excess water on the Earth's surface and use the same in processes like recharging, thus preventing floods in many places.

Effective management of water resources is actually one of the huge challenges of the 21st century. The three major imperatives are: making water available, maintaining its quality, and managing its distribution. IWRM refers to Integrated Water Resources Management, which is the overall concept recognizing both the interdependence of surface and groundwater and the multifaceted uses of water in different sectors. It provides greater emphasis on the sustainable use of water, thus balancing the needs of the population, industries, and ecosystems. In the same breadth, good water resource management broadly has such main components as pollution control, efficient use of the available water, and infrastructure betterment. With the growth of populations and the effects of climate change on the availability of water, the need for water is increasing. Therefore, careful management practice can ensure that there is enough clean water remaining for future generations, while also protecting the ecosystem, which heavily depends on these resources.

In the Kannur district, there is phreatic groundwater in the weathered mantle comprising crystalline rocks, laterites, and unconsolidated coastal sediments. Under semi-confined to confined conditions, it occurs in deep-seated fractured aquifers related to crystalline rocks and Tertiary sediments. Charnockites, pyroxene granulites, gneisses, and schistose rocks form the geological base of the district, which was largely concealed by Tertiary deposits and coastal alluvium. Hydrogeological units include consolidated formations, semi-consolidated sediments, and unconsolidated coastal alluvial deposits. Long-term water level fluctuation analysis from 2002 to 2011 indicates an increasing trend in about 75% of wells during the pre-monsoon period and 70% during the post-monsoon period, while some wells show a decreasing trend for both periods. The fluctuation magnitude varies; the increasing trends go as high as 0.8277 m/year and the decreases have been as low as -0.5056 m/year.

The Annual Extractable Ground Water Recharge of the district is 412.55 MCM and the existing Gross Ground Water Extraction is of the order of 187.85 MCM. The Stage of Ground Water Extraction is 46%. Out of 11 blocks in the district, 3 have been categorized as 'Semi-critical' viz; Kannur, Thalassery, and Panur and 8 blocks as 'Safe'. The storage groundwater resources of the phreatic zone (unconfined aquifer) are is 486.76 MCM, the semi-confined zone is 265.01 MCM and the confined zone is 329.01 MCM. The total groundwater resources of the district are 1492.12 MCM.

2 Study Area

Thalassery taluk is located in the south-western part of Kannur district in Kerala. It covers an area of 1,206 km^2 bounded by the North latitudes 11°45'0" and 12°0'0" and East longitudes 74°25'0" and 74°50'0". It is bordered by the districts of Mahé (Pondicherry), Kozhikode, Wayanad, Kasaragod, and Kodagu (Karnataka). Thalassery is situated at an altitude ranging from 2.5m to 30m above mean sea level. The taluk has a total population of 973131 persons with 455549 males and 517582 female's population with a literacy rate of 85.17%.

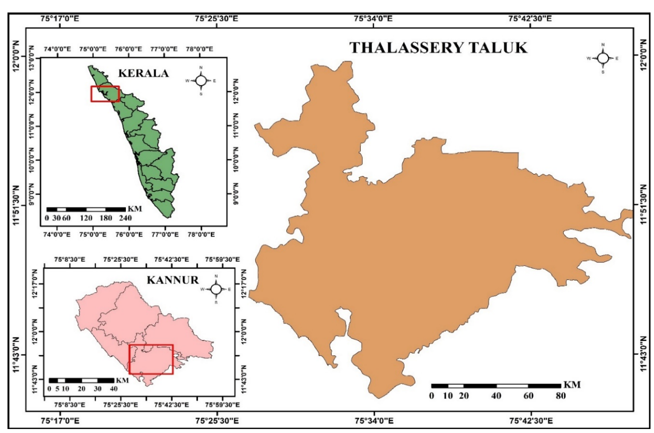

Fig. 1. Study area map-Thalassery taluk

2.1 Geomorphology

Thalassery is primarily a coastal town with a mix of flat plains, gentle slopes, and low-lying coastal areas. The region is defined by sandy beaches, estuaries, and backwaters that are characteristic of the Kerala coast. The town is bordered by the Arabian Sea to the west and is interspersed with small rivers, such as the Anjara Kandy River, which plays a significant role in shaping the local landscape. The geomorphology of the area includes lateritic plateaus and undulating terrains that transition from coastal lowlands to the more rugged terrain of the Western Ghats to the east. The Pediment Pediplain Complex is one of the largest sections of this taluk, lying predominantly in its southern and central parts.

2.2 Soil

The predominant soil types in Thalassery are lateritic soils, which are common in the coastal regions of Kerala. These soils are rich in iron and aluminum oxides, giving them a distinctive reddish color. Lateritic soils are generally acidic, low in fertility, and well-drained but can be made suitable for agriculture through proper management, including the addition of organic matter and fertilizers. Along the coast, sandy soils are prevalent, which support coconut plantations and other coastal vegetation.

2.3 Rainfall

Thalassery taluk receives a total annual rainfall ranging from 3,000 to 3,500 mm. Taluk experiences heavy rainfall during the South West monsoon season followed by North East monsoon. South West monsoon from June to September contributes 70 % of the total rainfall of the year. There is also a lesser influence of the northeast monsoon during October and November. It contributes only about 30%.

2.4 Meteorological Parameters

Apart from the rainfall, the meteorological parameters play an important role in groundwater balance estimation and other types of relevant studies.

2.4.1 Temperature

The temperature is higher during the months of April to May and is lower during December and January. The average means monthly maximum temperature ranges from 25°C to 35°C (77°F to 95°F), with high humidity. Humidity ranges from 77 to 88 % in the Taluk.

2.4.2 Evaporation

Evaporation is more during the summer months of March to May and low during the months of June to November. The mean evaporation ranges from 2.6 to 5.7 mm/day.

2.4.3 Sunshine

Hours Generally good sunshine hours are recorded in the month of November to May. January to March records the maximum sunshine hours of more than 9.1 hours/day. The months of June to August record the minimum sunshine due to the cloudy sky.

2.4.4 Wind

Wind speed ranges from 2.1 to 3.3 km per hour with a mean speed of 2.6 km/hr. The wind speed is high during the period from March to June and low during the period from September to December.

Thalassery Taluk in Kannur experiences lower underground water recharge compared to other taluks due to a combination of geographical and environmental factors. The region's lateritic soil, known for its porous nature, allows rapid water drainage, limiting the percolation needed for aquifer recharge. The coastal topography, characterized by higher elevations and steeper slopes, causes water to run off quickly into rivers and the sea, further reducing the infiltration rate. Additionally, the vegetation cover in Thalassery might be less dense than in other areas, leading to decreased water retention in the soil. Urbanization and land use changes have introduced more impermeable surfaces, such as roads and buildings, preventing water from seeping into the ground. Moreover, climatic factors like lower rainfall or higher evaporation rates could exacerbate the situation, resulting in less water available for groundwater recharge. Together, these factors contribute to Thalassery Taluk's relatively lower levels of underground water recharge compared to other regions in Kannur.

3 Result and Discussion

3.1 Rainfall map

On the basis of rainfall data the map illustrates the rainfall distribution in Thalassery taluk, Kannur district, Kerala. The southwestern part(2055399mm) of the region experiences the highest rainfall, indicated by the darkest blue, while the central areas show medium to high rainfall. In contrast, the northeastern and northwestern sections (less than 470000mm) receive the least rainfall, marked by light blue. The gradient suggests large variations in rainfall across Thalassery, with the western areas much wetter as opposed to the drier northeastern parts, most probably due to geographical factors like topography and distance from water bodies**.**

3.2 Geology map

The geological map of Thalassery Taluk, Kannur District, Kerala, depicts the three major rock types that fill the landscape in space: Charnockite, Vengad, and Wayanad. Charnockite is a dark-colored metamorphic rock that extensively occurs

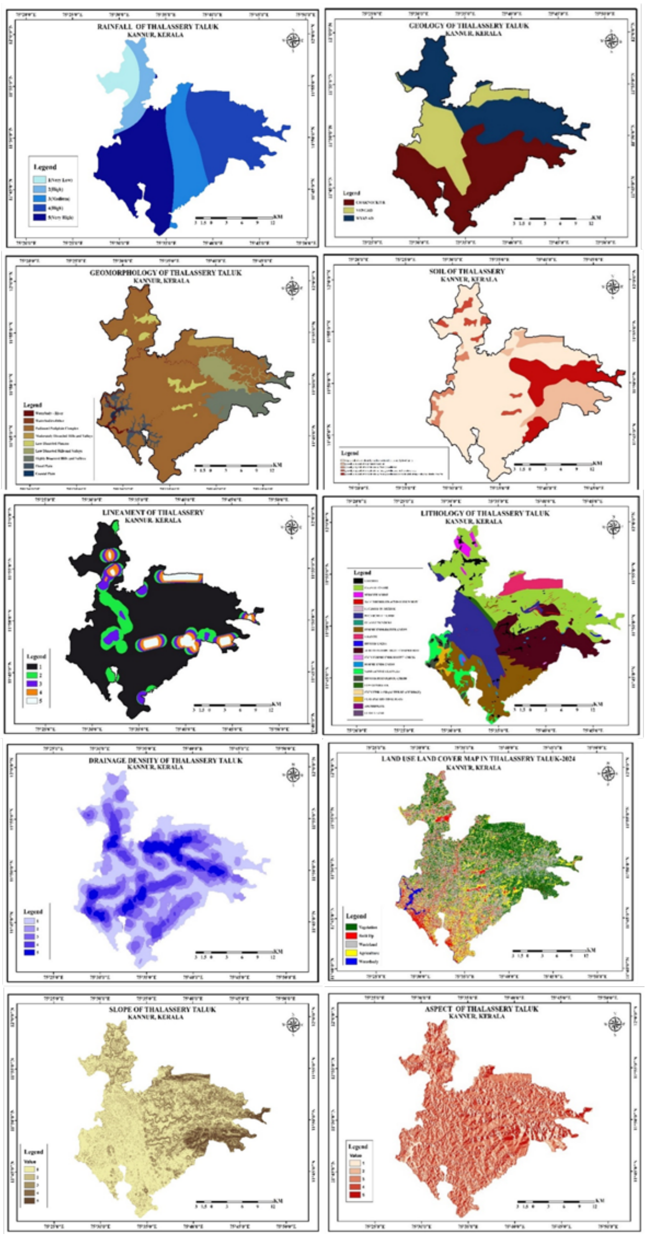

Fig. 2. Results of the study

in the southern and eastern parts of the Taluk. Vengad is another metamorphic rock, lighter in color, found in the central and northern parts, while the Wyanad Sedimentary formation occupies a relatively small area in the north-western part of the taluk. The map contains a legend, scale, and north arrow for reference. In general, the geological map provides an overview of the geological diversities in Thalassery Taluk with the predominance of metamorphic rocks along with minor or restricted occurrences of sedimentary rocks.

3.3 Geomorphological map

On the basis of geomorphology, it represents the various landform units within the region. The Pediment Pedi Plain Complex is one of the largest sections of this taluk, lying predominantly in its southern and central parts. Other significant landform features include Moderately Dissected Hills and Valleys, Low Dissected Plateaus, and Low Dissected Hills and Valleys, which are common throughout the taluk. The map also depicts Highly Dissected Hills and Valleys, primarily located in the eastern and north-western parts. Coastal Plains are found along the western coast, while Flood Plains are situated along the sides of the rivers. The map provides an informative summary of the geomorphological characteristics of Thalassery Taluk by highlighting its mountainous and plateau features with the presence of coast and rivers.

3.4 Soil map

The map representing five major soil types based on their characteristics and distribution in Thalassery taluk, Kannur. The most dominant class is the clayey soil with a moderately shallow water table on nearly level lands represented in light beige color and occupies most of the central and western parts of the area. This soil type seems to have conditions suitable for cultivation based on its ability to retain moderate amounts of water within it. Gravelly clay soil, made of cohesive material and colored light brown, provides scattered instances mostly in the northern and southern regions of zones with somewhat reduced arable land, which may still offer utility for specific crops or plantations. The map further delineates gravelly clay soil with a moderate degree of surface gravelliness and laterite mounds, as indicated by the dark brown color in the main south-eastern parts. This indicates the extent of very difficult topography that is more prone to erosion. In fact, red areas, meaning the gravelly clay soil on moderately steeply sloping laterite mounts with ironstone, are concentrated in a northeastern part of the map. That would imply highly mineral-rich soil but perhaps less fitting for most aspects of agriculture because of its stony nature. Last but not least, the darkest areas stand for gravelly clay soil on moderately steeply sloping laterite mounts, scattered in this taluk.

3.5 Lineament map

The map focuses on different lineament features around the study area. Different colors represent lineament classes, which are numbered 1 to 5. 1 is the high lineament area and 5 is the low lineament area. Each color corresponds to a particular type of lineament or geological feature. The complex pattern of lineaments can assist in geological studies related to fault line identifications, mineral explorations, and tectonic movement understanding in the Thalassery area. This cartographic representation may serve as an important resource for researchers and planners involved in land utilization, resource administration, and environmental evaluations within this region of Kerala.

3.6 Lithological Map

It shows the distribution of various rock types and geological structures in the region. Prominent geological formations consist of Laterite (black), Granite Gneiss (light green), Sericite Schist (pink), Talc Tremolite Actinolite Schist (magenta), Fuchsite Quartzite (grey), Mica Schist/Schist (blue), in addition to a variety of gneisses and schists that prevail across the terrain. Granite genesis, acid to intermediate charnockite, hornblende-biotite genesis, and mica schists are the dominant lithologic feature in this area. The additional lithological types, such as Laterite and Quartz Vein/Reef, spread over the area show regions of special geological importance. The spatial arrangement of these rock formations indicates a diversified geology with processes of sedimentation, metamorphism, and igneous activities. This lithological map is a basic tool for geologists, researchers, and planners in that it provides an overall understanding of the geological structure of Thalassery Taluk, knowledge which is essential for mineral exploration, construction, water resource management, and analysis of the tectonic environment of this region.

3.7 Drainage density

it representing the variation in the network of streams and rivers throughout this area. A color gradient from light blue to dark blue is used to display low to high drainage density. High drainage density areas are dark blue, mainly in the central and northeastern parts of the region, showing dense networks of streams and rivers. That means steep landscapes, low permeability of soils, high surface runoff, and increase hazards of erosion and flooding. In contrast, the areas of low drainage density shown in light blue are mostly on the periphery, with a concentrated northern and southern part, which shows flatter terrain with higher infiltration potential, hence more suitable for groundwater recharge and agriculture. This map highlights the hydrological characteristics that are very important for any region in terms of effective water management and land use planning.

3.8 Slope

The slope map of Thalassery Taluk in Kannur, Kerala, depicts the terrain's varying steepness using five color-coded categories. The lightest areas represent flat or gently sloping regions (around 55m from the MSL), while the darkest areas indicate the steepest slopes (above 275m from the MSL), predominantly in the southeastern part of the taluk. The central and northern regions show relatively low slopes, suggesting smoother terrain.

3.9 Aspect map

It is works with a color gradient representing five values from light to dark red to show the orientation of different slopes within the area. This color gradient essentially describes a typical topography that has a slope which may be oriented in any direction. These slopes represent hilly or rugged surfaces typical of those seen in the Western Ghats. These slopes greatly affect the local microclimates, the soil moisture, and the vegetation patterns in a way that the sun-facing slopes (probable darker shades) are much warmer and drier, whereas those facing away may be cooler and more humid. This information will be very important for land-use planning, agricultural practices, and environmental management in the region, since the topographic setting provides a background that heavily controls the suitability of various areas for multiple purposes.

3.10 Land use Land cover

From the map, it is possible to show different land cover classes through a system of color-coded categories. Vegetation is the major type of land cover, colored in green, and covers a large area, particularly in the northern and eastern parts, indicating the presence of a large forest or naturally vegetated area. The built-up area, shown in red, mostly lies along the western coastlines and in scattered pockets throughout the map that reflect urban or developed zones. Wastelands, shown in gray, are scattered around the entirety of the map but mostly occur in the center and parts of the periphery to show unused or barren lands. The agricultural zones are depicted in yellow, hence well-distributed across the site, an indication of effective farming activity with a central and southern area dominance. Water bodies, denoted in blue, are mostly around the southwestern part of the map, hence indicating the presence of rivers, lakes, or reservoirs around this area. The scale bar and the coordinate grid in the map provide spatial reference, while the legend elaborates on the land cover categories. It explains the spatial distribution of land use in Thalassery Taluk in a much more coherent way. This LULC map will be indispensable in land management, urban planning, and environmental monitoring issues in the region.

4 Discussion

The map of Artificial groundwater recharge areas in Thalassery, Kannur District, Kerala, was mapped to clearly visualize the potential of the area for groundwater replenishment. This was done based on criteria divided into five classes, ranging from "Very Low" to "Very High". The central part colored in light blue and extending to a dark blue color class for both the southwestern and southeastern parts indicates high to very high potential for artificial groundwater recharge. In this

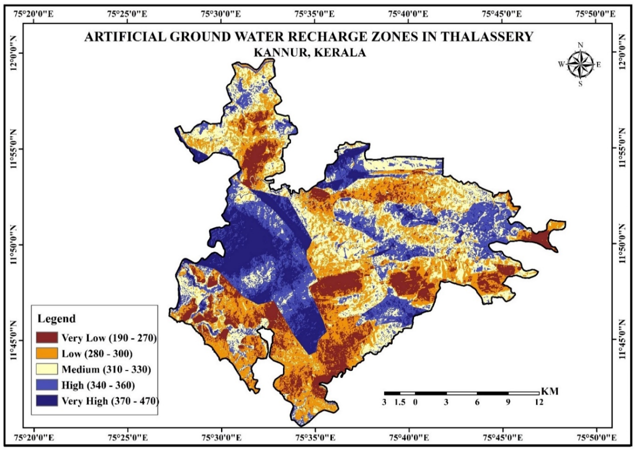

Fig. 3. Artificial groundwater recharge zones in Thalassery

way, these areas can also be described by favorable hydrogeological conditions represented in the porosity of soil and rock formations, which enable productive infiltration and storage of water. Large areas of flat or mildly undulating topography that dominate many basins minimize runoff and maximize recharge to groundwater.

In the central part, wide blue zones indicate the best conditions of the groundwater recharge environment. This area is likely characterized by permeable soils and geological formations that enhance water percolation. Higher rates of infiltration are given both by agricultural landscapes and woodland as opposed to the urbanized area. For the southwestern region with heavy coverage of dark and light blue zones, the proximity to aquatic bodies of rivers or streams should help naturally along with soil types that could be sandy or loamy. The recharge capacity of this area hypothetically could be increased due to human activities by constructing artificial recharge systems including check dams or percolation tanks.

The dark blue and light blue zones in the southeastern part of Thalassery show reasonably to very high potential for groundwater recharge. This area may be favored by favorable climatic conditions, such as increased precipitation that allows for efficient replenishment of groundwater. In addition, fractured rock and highly weathered areas can allow for the movement and storage of groundwater. This could be even more enhanced through good land management practices such as vegetative cover that would lower runoff and boost infiltration. The artificial recharge map thus obtained divided the study area into three zones, viz., 'suitable (blue color zone),' 'moderately suitable (light yellow colour zone)' and 'unsuitable (brown color zone)' according to their suitability for artificial groundwater recharge.

Contrasting these, the northern and far southern areas of Thalassery are represented by dark brown and orange colours, which represent very low to low recharge potential. These soils may be clayey or have impervious characteristics that restrict the entry of water, hence reducing the rate of groundwater recharge. The topography of these areas might be hilly or steep, and such conditions could enhance surface runoff, thus limiting any chance of effective groundwater recharge. Besides, urbanization and intense farming practices with inadequate groundwater management strategies may also contribute to poor groundwater recharge potentials in these areas. For the sustainable management of Thalassery's groundwater resources, emphasis should be given to artificial recharge enhancement in high and very high potential zones by establishing artificial recharge structures such as percolation ponds, recharge trenches, and check dams. Areas identified with low and very low recharge potential should undertake soil conservation, afforestation programs, and the development of rainwater harvesting systems for better replenishment of the groundwater resource base. An Integrated Water Management System includes surface water management, rainwater harvesting practices, and artificial recharge techniques. These will require monitoring and evaluation over time for the conservation of groundwater resources in Thalassery to ensure that water security is maintained with resilience to climate variability.

5 Conclusion

Groundwater recharge is the process by which water from sources such as rainfall and rivers infiltrates the soil to replenish underground aquifers. This natural process is necessary for maintaining a stable level of groundwater. Groundwater is an important source of freshwater for both human consumption and agricultural purposes. Should it deplete, areas highly dependent upon groundwater for their supply would not be able to sustain a water supply over time? Recharge is also critical in sustaining the base flows of rivers, lakes, and wetlands, during dry periods particularly. It also helps mitigate soil subsidence, minimize saltwater intrusion in coastal areas, and naturally filter impurities, thus improving water quality. The role of recharge management will undoubtedly determine the long-term security and health of the water.

In the present world, groundwater is essential for the survival of every living being, including man. Along with this, it also comes under the hazards of growing human and societal activities. In Thalassery taluk, one of the regions with the lowest groundwater availability is the Kannur district. The reason for such extreme variation between the western and eastern sides of Thalassery remains topographical in nature (geomorphology, geology, lithology, lineament, slope, aspect, etc). While the western region has relatively more groundwater, it faces major shortages in the eastern region. The artificial recharge map thus obtained divided the study area into three zones, viz., 'suitable,' 'moderately suitable, and unsuitable' according to their suitability for artificial groundwater recharge. As custodians of natural resources, it is essential that we make conserving groundwater a priority as this resource, which everybody knows, is finite and non-renewable. In this regard, voluntary organizations must ensure effective conservation measures are taken for this important resource to be handled in a sustainable manner. Otherwise, it will lead to scarcity of fresh water in the coming centuries.

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