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Enhancing Groundwater Management Through Multi-Criterion Weighted Overlay Analysis Using Geospatial Analysis

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Abstract

In the semiarid part of the Dharmapuri district, Marandahalli Firka, Tamil Nadu, which covers an area of approximately 132 km², groundwater is important for meeting the needs of both people and farms. This study identified groundwater potential zones by combining remote sensing (RS) and geographic information system (GIS) methods. This was done using inverse distance weighting (IDW) interpolation to generate well-yield distribution maps and confirm spatial patterns. Satellite data and other maps were used to create thematic layers that showgeology, lineament density, land use/land cover, drainage density, normalised difference vegetation index, and normalised difference water index. The multi-criteria weighted overlay index was used to assign weights to each layer so that a combined groundwater potential index (GWPI) could be demarcated. The results classified the study area into three groundwater potential zones: 49.25% of the area had low groundwater potential, 47.76% had moderate potential, and the remaining 2.98% had high groundwater potential. Field validation was conducted to find groundwater and help the Dharmapuri Marandahalli Firka manage its water resources sustainably. Future studies may incorporate long-term groundwater monitoring data and analyses of climate variability to understand temporal variations in groundwater resources. The application of advanced modelling techniques, such as machine learning, alongside groundwater quality and socioeconomic considerations, could further enhance the accuracy and sustainability of groundwater management in the study area.

Keywords: Groundwater Potential, NDWI, NDDI, NDVI, GIS, Multicriteria Analysis.

Introduction

Groundwater is one of the most widely distributed natural resources on Earth and serves as a major source of water for drinking, industrial activities, and irrigated agriculture. It provides a reliable and consistent supply with uniform quality and temperature, low turbidity, and minimal pollution levels, while also experiencing negligible evaporation losses compared to surface water resources. Water resources are inevitable for all sectors. The need for the assessment of water resources increases every year owing to the lowering water levels and changes in atmospheric water. Water resources are essential for all uses. Groundwater is essential for domestic and irrigation purposes in arid and semiarid regions (Phaisonreng Kom et al., 2023). Most of the global inhabitants rely on groundwater for daily use. In regions such as arid and semiarid regions, it has become the main water supply for domestic, agricultural, and industrial purposes (Kom et al., 2021). There are numerous methods of evaluation. Evaluation through geospatial technology is noteworthy because of its current results. In the present study, an attempt was made to use satellite data-based demarcation of water resources by analysing lineaments and lineament density, landuse/land cover, normalised difference vegetation index, normalised difference water index, and normalised difference drought index, which were derived using higher-resolution Resource Sat LISSIV satellite data. The surface water resources, such as drainage and surface water bodies, were also mapped from the Survey of India Toposheet and cross-checked with Google Map data. The changes in the water bodies are another interesting result in the present study. The new appearance and disappearance of water resources are another highlight.

Groundwater is closely interconnected with surface water resources and the hydrologic cycle, and plays a vital role in maintaining the overall water balance. Global-scale studies have highlighted the spatial and temporal variability of groundwater resources (De Graaf et al., 2015; Döll & Fiedler, 2008; Jin & Feng, 2013), while increasing attention has been paid to assessing groundwater recharge potential using diverse techniques (Kadam et al., 2020; Singh et al., 2019). Recently, the world has been facing serious water-related challenges, including physical and economic water scarcity, as well as growing competition for water among different sectors and regions. Rapid population growth and economic development have significantly increased the demand for groundwater resources. At the same time, groundwater resources are under increasing pressure due to poorly regulated pumping and contamination (Herbert & Döll, 2019; Scanlon et al., 2023). Moreover, the widening gap between water demand and supply continues to intensify, further aggravated by continuous population growth.

Numerous studies have endeavoured to delineate water resources using various methodologies. The utilisation of remote sensing data and digital elevation models in GIS and ERDAS facilitated the identification of the spatial distribution of the parameters. The feature class weights are straightforward and beneficial for overlay analysis (Pragadeeshwaran et al., 2026) (Bagyaraj et al., 2014). Geographic Information Systems (GIS) serve as an effective instrument for the mapping and analysis of spatial datasets (Nijagunappa et al., 2007), (Pragadeeshwaran et al., 2026).

Despite the extensive application of remote sensing (RS) and geographic information system (GIS) techniques in groundwater potential zone mapping, several limitations still exist in previous studies. Most earlier investigations relied primarily on conventional hydrogeological parameters, such as geology, slope, drainage density, and land use/land cover, with limited incorporation of satellite-derived indices that reflect vegetation conditions, surface water availability, and drought characteristics. The integration of dynamic indices, such as the normalised difference vegetation index (NDVI), normalised difference water index (NDWI), and normalised difference drought index (NDDI), for assessing groundwater potential has not been adequately explored in many regional-scale studies. Furthermore, the use of high-resolution satellite data to identify temporal variations in surface water bodies and their influence on groundwater potential has not been sufficiently addressed. In addition, the absence of field-based validation using groundwater level and well yield data in several studies reduces the reliability and practical applicability of the delineated groundwater potential zones. Therefore, there is a need for a comprehensive and integrated approach that combines hydrogeological parameters, satellite-derived indices, and field validation to improve the accuracy of groundwater potential zone mapping.

Hence, the objective of this study was to 1. To prepare a detailed geology of the study area and its influence on groundwater. 2. To explore satellite data-based thematic maps of groundwater resources. 3. Integrate all the maps by giving due weightages in GIS and demarcate groundwater potential zones. The present study attempts to address this research gap by employing a GIS-based multi-criteria weighted overlay analysis using high-resolution Resource Sat LISS-IV data, along with groundwater level and well yield data for validation.

Study Area

The coordinates of Marandahalli are 12.389° N, 77.985° E. The area covers about 132 Sq.km. Marandahalli is bounded on the north by the Palacode (Palakkodu) region, while its southern boundary touches the Krishnagiri district limit. To the east, it is bordered by the Rayakottai–Denkanikottai side, and to the west, it extends towards the Karimangalam–Dharmapuri region. These boundaries place Marandahalli within the southeastern part of Palacode Taluk in Dharmapuri District. Marandahalli Firka receives an average annual rainfall of approximately 965 mm, with most of the rain falling during the northeast monsoon months. The region experiences a warm to hot climate, in which the summer temperatures range from approximately 26 to 41 °C, while winter temperatures are much milder. The elevation of Marandahalli is approximately 580–585 m above sea level, which results in slightly cooler conditions in the area compared to the surrounding plains. Overall, the Firka's moderate elevation and monsoon-based rainfall pattern strongly influence its seasonal climate and groundwater recharge.

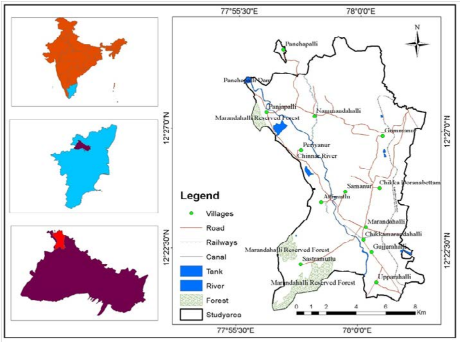

Figure 1 Study Area Map of Marandahalli Firka

Geology

The bedrock around Marandahalli belongs to the Archaean high-grade metamorphic terrain of the Peninsular Gneissic Complex. The study region covers charnockites — medium to coarse-grained metamorphic rocks composed mainly of quartz and feldspar with pyroxene and biotite. Other rock types, which include my study area, are Epidote Hornblende Gneiss, Migmatite, and Peninsular Gneissic Complex.

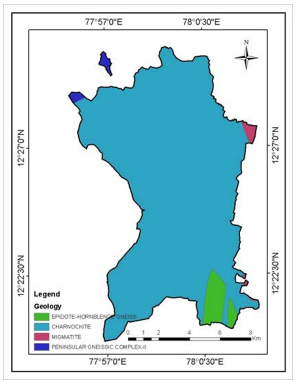

Figure 2 Geology Map of the Study Area

Field Work

A field investigation was conducted in December 2025 to study the geology of the area based on both the megascopic and microscopic characteristics of the rock units (Figure 3). Representative rock samples were collected, and preliminary mineral identification was performed in the field using macroscopic properties, such as colour, texture, grain size, and structure. Fresh and unweathered samples were selected for thin-section preparation to examine their mineralogical composition and microstructural features under a microscope.

The integration of field observations and petrographic analysis provides insight into the lithological characteristics, degree of fracturing, porosity, and permeability of the rock units, which are critical factors controlling groundwater occurrence and movement in the area. The results of this investigation contribute to the assessment of the groundwater potential by identifying favourable lithologies and structural features that may enhance groundwater storage and flow.

Figure 3 Field photos

Methodology

Groundwater potential mapping in the Marandahalli Firka was conducted using an integrated remote sensing (RS) and geographic information system (GIS) approach. The methodology adopted for preparing the groundwater potential zone map integrated Survey of India topo sheets, remote sensing datasets, and GIS-based spatial analysis. Initially, the topo sheets were geo referenced and interpreted to extract the drainage network and major water bodies, which play a crucial role in groundwater recharge and surface subsurface hydrological interactions. Thematic layers influencing groundwater occurrence, including geology, lineament density, drainage density, land use/land cover (LULC), normalised difference vegetation index (NDVI), normalised difference water index (NDWI), and normalised difference drought index (NDDI), were prepared and analysed. Satellite imagery, topographic, geological, soil, and rainfall data were collected, geo referenced, and resampled to a uniform resolution. The images were registered with their coordinates, and geometric corrections were applied with the UTM-WGS 84 projection using ArcGIS (Chrisben Sam & Gurugnanam, 2022). Balasubramanian et al., (2022). The geographic phenomena, together with their spatial dimensions and associated attributes (such as table analysis, classification, polygon classification, and weight classification), are well employed in GIS, and the results are then reclassified and assigned suitable weightage and spatial distribution (Gurugnanam et al., 2010). All maps were digitised. Their attributes were edited and analysed in ArcGIS. GIS overlay analysis is highly useful for identifying groundwater potential zones (Karung Phaisonreng Kom et al., 2018; Kom et al., 2024) (Gurugnanam et al., 2008a). Each layer was classified into subclasses based on its influence on groundwater potential. Weighted layers were then integrated using GIS-based overlay analysis to generate a groundwater potential index, which was categorised into very high, high, moderate, and low potential zones. The final map was validated using existing well yields and groundwater level data, providing a reliable basis for sustainable groundwater management and planning. The statistical validation of the groundwater potential zones was performed using correlation analyses between the predicted potential zones and observed groundwater levels and well yields from field measurements. A flowchart of the methodology is illustrated in Figure 4.

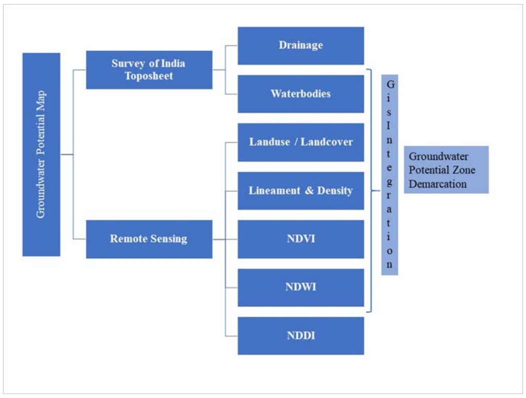

Figure 4 Detailed Methodology Flow Chart

Results and Discussion

Surface Water Body

Surface water features, such as Eri and ponds, are delineated with topo sheets and satellite imagery. It is directly related to water resources. The water body zone was buffered by 20 meters. A comparatively greater emphasis is placed on water resource mapping. The entire area of the tank and river in the study area is 0.86 km² and 1.03 km², respectively, while the total length of the canal in the study region is 0.9 km (Figure 5). The output results are presented in Table 1.

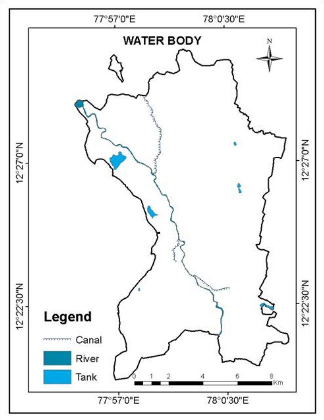

Figure 5 Spatial Distribution Map of Surface Waterbodies

Table 1 Spatial Distribution Results of Surface Water Bodies

Surface Water Bodies	Weightage	Area in Km²
River	3	1.03
Canal	2	0.9 (length)
Tank	1	0.86

Drainage and Drainage Density

Drainage refers to the surface trajectory of precipitation. It consistently progresses toward a diminished gradient. This region serves as a conduit for groundwater replenishment. The area surrounding the drainage zone, at approximately 30 meters, is the most likely zone for groundwater. The drainage of the research is derived from the Topo sheet and is presented in Figure 6. The study's results are presented in Table 2. The drainage density analysis classified the study area into low, moderate, high, and very high categories with corresponding weightages of 4, 3, 2, and 1, covering areas of 46 km², 43 km², 34 km², and 10 km² respectively. Spatial distribution indicates that low and moderate drainage density zones together occupy nearly two-thirds of the total area, as evident from the drainage density map. These zones are characterized by widely spaced stream networks, gentle slopes, and higher infiltration capacity, which favor groundwater recharge and subsurface storage. High and very high drainage density zones are limited in extent and are associated with closely spaced channels, increased surface runoff, and comparatively lower infiltration, indicating less favorable conditions for groundwater occurrence.

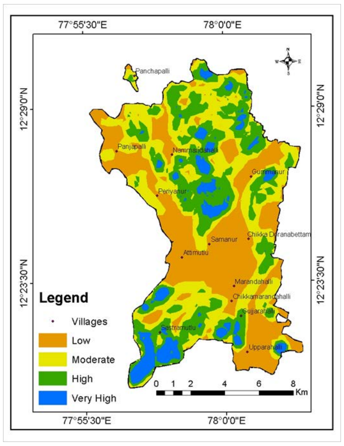

Figure 6 Spatial Distribution Map of the Drainage Density

Table 2 Spatial Distribution Results of Surface Water Bodies of Marandahalli Firka

Drainage Density	Weightage	Area(km²)
Low	4	46
Moderate	3	43
High	2	34
Very high	1	10

Remote Sensing

Lineament and Lineament Density

A lineament is a subdued natural linear feature of considerable length. The lineament map was created via satellite images (Figure 7). This is directly related to water resources. The lineament density is derived from satellite photography. Increased linemanet density correlates with a heightened likelihood of groundwater presence. The weights for the lineament density zone were determined from this property (Table 3). The results were taken into the GIS platform. Contour Interpolation mapping was prepared (Gurugnanam. et al., 2009). Thematic maps were converted to raster form with a 30 m cell size to achieve considerable accuracy (Prabhakaran. N et al., 2009). The lineament density analysis of the study area was classified into four categories: very high, high, medium, and low, with corresponding weightages of 4, 3, 2, and 1. The spatial analysis reveals that very high lineament density covers about 5 km², high density about 10 km², and medium density about 9 km², while low lineament density dominates a major portion of the area, covering approximately 109 km². The lineament density map shows that zones of high to very high density occur as localized pockets around areas such as Nammadahalli, Periyanur, Sastramuttu, Upparahalli, and parts of Panjapalli. These zones represent regions of intense fracturing and structural weakness, which enhance secondary porosity and permeability, thereby facilitating groundwater movement and storage. In contrast, areas with low lineament density indicate massive and less fractured rock formations, which restrict groundwater circulation.

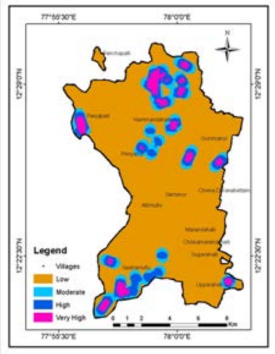

Figure 7 Spatial Distribution Map of Lineament Density

Table 3 Spatial Distribution Results of Lineament Density of Marandahalli Firka

Lineament Density	Weightage	Area(km²)
Very High	4	5
High	3	10
Medium	2	9
Low		109

Landuse/Land Cover

The land usage and land cover map was generated from satellite data. The data was obtained from USGS Explorer. The data was imported into ArcGIS, and the FCC was generated. The supervised classification utilises ground control data to delineate the several land use and land cover regions within the research area. The specifics of the spatial distribution are shown below. Urbanisation and industrial expansion result in the depletion of agricultural land, vegetation, forested areas, water bodies, and mineral resources (Arulbalaji & Gurugnanam 2014b). The relative significance is allocated to the maps for groundwater potential assessment. The Land Use/ Land Cover (LULC) analysis of the study area, Fig. 8 and Table 4, was classified into six categories: vegetation, settlements, barren land, water bodies, agricultural land, and roadways, with assigned weightages of 5, 1, 3, 6, 4, and 2, respectively. The spatial distribution shows that barren land occupies the largest area (41 km²), followed by vegetation (31 km²), agricultural land (20 km²), roadways (23 km²), water bodies (13 km²), and settlements (5 km²). The LULC map indicates that water bodies and vegetated areas are mainly distributed in the central and southern parts of the study area, contributing to higher infiltration and groundwater recharge. Agricultural lands also support moderate recharge due to irrigation return flow and relatively permeable soils. In contrast, settlements and roadways are associated with impervious surfaces that limit infiltration and increase surface runoff, thereby reducing groundwater recharge potential.

Table 4 Spatial Distribution Results of Land use and Land Cover of Marandahalli Firka

LULC	Weightage	Area(km^2)
Vegetation	5	31
Settlements	1	5
Barren Land	3	41
Waterbody	6	13
Agricultural Land	4	20
Roadways	2	23

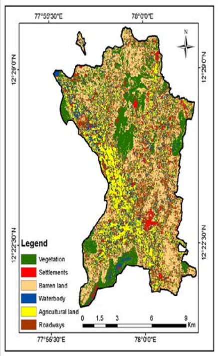

Figure 8 Spatial Distribution Results of Land use / Land cover

Normalised Difference Vegetation Index

The Normalised Difference Vegetation Index (NDVI) is a way to measure the health and density of plants using remote sensing. The amount of light that plants reflect in the visible (red) and near-infrared (NIR) bands of the electromagnetic spectrum is used to figure it out. Plants that are green and healthy scatter more NIR light and take in more red light for photosynthesis. With the help of GIS and geospatial technology on the plant index, the water zone can be found and marked ((Arulbalaji & Gurugnanam 2014a).

Because of how their leaves are built, plants scatter a lot of near-infrared light and take in red light for photosynthesis. NDVI uses these changes in reflectance to come up with a number that can be anywhere from -1 to 1.

Formula: The formula is: NDVI (NIR-Red) / (NIR+Red).

Higher values indicate dense, healthy green vegetation (e.g., values between 0.5 and 1.0).

Lower values: Indicate areas with little to no vegetation, such as barren land, water, or snow (e.g., values close to 0 or negative). The results of the NDVI map are given in Fig.9 and in Table 5.

Table 5 Spatial Distribution Results of NDVI of Marandahalli Firka

NDVI	Weightage for Water Resources	Area (Km^2)
Water body	3	27
0.5-1	2	39
Close to 0 and a negative value	1	67
Low		109

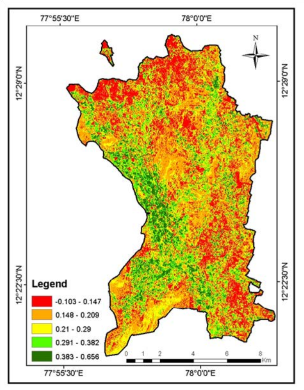

Figure 9 Spatial Distribution Map of NDVI of Marandahalli Firka

Normalised Difference Water Index

The Normalized Difference Water Index (NDWI) is a satellite-based spectral index widely used for delineating open water bodies and assessing moisture conditions in vegetation and soil. The index is computed using the green and near-infrared (NIR) bands of satellite imagery by subtracting the NIR reflectance fromthe green reflectance and dividing the result by their sum. Higher NDWI values generally indicate the presence of water or higher moisture content.

NDWI is particularly useful for several hydrological and environmental applications. It enables accurate mapping of water bodies such as rivers, lakes, and reservoirs by effectively distinguishing them from surrounding land areas. The index is also used to evaluate vegetation water content, which is essential for monitoring plant health and water stress. In agricultural studies, NDWI supports irrigation management by identifying areas requiring water and reducing excessive water use. Additionally, it plays a vital role in drought monitoring by aiding the assessment of soil moisture conditions and water scarcity.

The NDWI is calculated using the following formula:

NDWI = (Green − NIR) / (Green + NIR)

The resulting NDWI values range from −1 to +1. Water bodies typically exhibit values greater than 0.5, whereas vegetation shows comparatively lower values, allowing clear differentiation from open water. Built-up and constructed areas generally display positive NDWI values ranging between 0 and 0.2. The spatial distribution and quantitative analysis of NDWI values for the study area are presented in Figure 10 and Table 6.

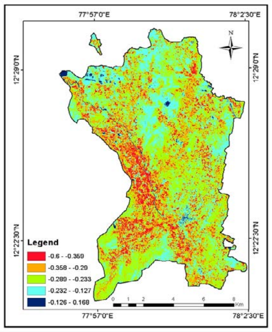

Figure 10 Spatial Distribution Map of NDWI of Marandahalli Firka

Table 6 Spatial Distribution Results of NDWI of Marandahalli Firka

NDVI	Weightage for Water Resources	Area (Km²)
Water body	3	27
0.5-1	2	39
Close to 0 and a negative value	1	67
Low		109

NDDI

The NDDI is the normalised difference drought index, a remote sensing instrument utilised for monitoring and quantifying drought severity. This is a remote sensing indicator utilised to evaluate drought by examining a satellite's spectral bands, chiefly the near-infrared (NIR) and shortwave infrared (SWIR) bands. The calculation employs the normalised difference vegetation index (NDVI) and the normalised difference water index (NDWI). Values span from -1 to 1, with increasingly negative values signifying greater drought stress severity. It aids in assessing water stress in vegetation and is essential for addressing drought-related issues in agriculture and water management. The NDDI map was generated using satellite data, as illustrated in Figure 11.

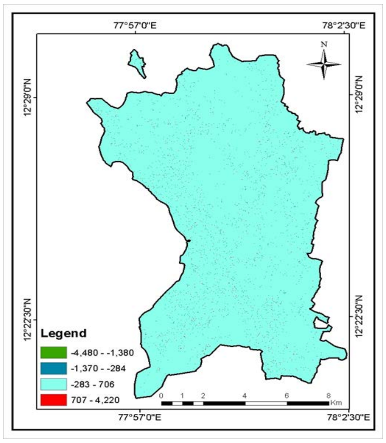

Figure 11 Spatial Distribution Map of NDDI of Marandahalli Firka

Multicriteria Weighted Overlay Index Map for Groundwater Potential Zones

In GIS, the relative weights are assigned concerning water resources. Geographic information systems (GIS) are effective instruments for mapping and identifying groundwater zones ((Gurugnanam et al., 2008b), The Union analysis tool overlays the maps as depicted in the approach. Five thematic maps pertaining to water were developed and combined. All themes were integrated into the

GIS platform. Spatial maps were generated using a GIS platform (ArcGIS) (Kalaivanan et al., 2019). The integration results were categorised into three classifications: good, medium, and bad, regarding groundwater. The application of remote sensing and GIS is highly effective for evaluating groundwater potential zones ((Arulbalaji & Gurugnanam 2016)). The spatial map of the output is presented in Figure 12, and the findings are displayed in Table 7. The groundwater potential assessment was carried out using a weighted overlay analysis by integrating multiple thematic layers, including surface water bodies, drainage density, lineament density, land use/land cover (LULC), NDVI, NDWI, and NDDI. Each thematic layer was assigned a relative weight based on its significance in controlling groundwater occurrence, recharge, and movement. Individual classes within each layer were ranked on a scale of 1 to 5, where higher ranks indicate greater favourability for groundwater potential.

Surface water bodies were assigned a layer weight of 6, with tanks ranked the highest because of their strong influence on localised recharge, followed by rivers and canals. Drainage density and lineament density were assigned weights of 11 each, reflecting their critical role in regulating infiltration, runoff, and subsurface permeability. In both layers, low drainage and lineament density classes were ranked higher, indicating favorable groundwater recharge conditions, while very high density classes were ranked lowest due to increased runoff or limited fracture connectivity.

Land use/land cover was assigned the highest weight (15) owing to its direct impact on infiltration and recharge processes. Water bodies and vegetation were ranked second highest, followed by agricultural land and barren land, whereas settlements and roadways were ranked lowest owing to impervious surface conditions that restrict infiltration.

Spectral indices, such as NDVI, NDWI, and NDDI, were assigned weights of six to incorporate vegetation health, surface water presence, and drought conditions into the analysis. In the NDVI and NDWI layers, water bodies and vegetated areas were ranked higher than barren land, indicating better moisture availability and recharge potential. For the NDDI layer, low drought intensity zones were ranked the highest, as they represent areas with relatively higher soil moisture and better groundwater recharge conditions.

Table 7 Overall Weightage Table for Each Layer

Thematic layer	Layer weight	Class	Rank (1-5)
Surface water body	6	River	3
		Canal	2
		Tank	1
Drainage Density	11	Low	4
		Moderate	3
		High	2
		Very High	1
Lineament Density	11	Low	4
		Moderate	3
		High	2
		Very High	1
Land use/Land cover	15	Vegetation	5
		Settlements	1
		Barren land	3
		Water bodies	6
		Agricultural Land	4
		Roadways	2
NDVI	6	Water body	3
		Vegetation	2
		Barren land	1
NDWI	6	Water body	3
		Vegetation	2
		Barren land	1
NDDI	6	Low	3
		Moderate	2
		High	1

In GIS, the relative weightings pertain to water resources. Geographic information systems (GIS) serve as an effective instrument for mapping and identifying groundwater zones. The union analysis tool integrates the maps as depicted in the technique by sequentially overlaying them. All thematic maps pertaining to water were compiled and included in a unified map. The integration results were categorised into three classifications: high, moderate, and low, regarding groundwater. Remote sensing and GIS are particularly effective for evaluating groundwater potential zone. The spatial map of the output is illustrated in Figure 12, and the results are consolidated in Table 8. The groundwater potential zonation of the study area was delineated using a GIS-based weighted overlay analysis integrating multiple thematic layers, including surface water bodies, drainage density, lineament density, land use/land cover, NDVI, NDWI, and NDDI. The resulting groundwater potential map classifies the area into three categories: high, moderate, and low groundwater potential. The spatial analysis indicates that low groundwater potential zones cover the largest area (approximately 66 km²), followed by moderate potential zones (64 km²), while high groundwater potential zones are limited in extent (4 km²). High-potential zones are mainly observed in localised pockets around structurally controlled and recharge-favorable areas, particularly near regions with high lineament density, proximity to surface water bodies, dense vegetation, and low drainage density. Moderate groundwater potential zones are widely distributed across the central and southern parts of the study area, indicating balanced recharge and subsurface conditions. Low-potential zones are predominantly associated with areas of high drainage density, low lineament density, barren land, settlements, and regions affected by higher drought intensity.

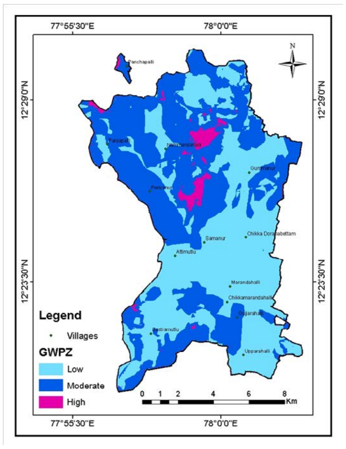

Figure 12 Spatial Distribution Map of Groundwater Potential Zones of Marandahalli Firka

Table 8 Spatial Distribution Results of Groundwater Potential Zones of Marandahalli Firka

Groundwater potential	**Weightage for Water Resources**	**Area (Km²)**
High	3	River
Moderate	2	64
Low	1	66

Limitations

Despite the effectiveness of the integrated RS–GIS approach in delineating groundwater potential zones, the present study has certain limitations. The accuracy of the generated groundwater potential map largely depends on the quality and resolution of the input thematic layers derived from satellite data and secondary sources. Weighted overlay analysis subjectively assigns weights to different thematic layers based on their relative influence on groundwater occurrence, which may introduce uncertainty into the final output. In addition, temporal variations in groundwater levels due to seasonal fluctuations are not fully captured in the analysis, as the validation is based on available groundwater level and well-yield data. Furthermore, the limited availability of field-based hydrogeological data may affect the precision of model validation. Therefore, the delineated groundwater potential zones should be considered indicative rather than absolute representations of groundwater availability in the study area.

Future Recommendation

The findings of this study can be used for sustainable groundwater management/SDG6. Groundwater levels in poor groundwater zones must be monitored continuously. To improve groundwater levels in this area, artificial recharge structures must be constructed.

Conclusion

The integrated geospatial analysis of hydrogeological and remote sensing–based thematic layers enabled a comprehensive assessment of groundwater potential in the study area, resulting in the delineation of low-, moderate-, and high-groundwater potential zones. The study reveals that the area is predominantly characterised by low to moderate groundwater potential, with high-potential zones occurring only in limited pockets associated with favourable conditions, such as low drainage density, high lineament density, proximity to surface water bodies, dense vegetation, and suitable land use patterns. Low drainage density areas were found to be most conducive for groundwater recharge and development, while high drainage density zones exhibited poor groundwater prospects due to rapid runoff and limited infiltration. Although low lineament density dominates much of the region, localized high and very high lineament density zones significantly enhance groundwater occurrence by increasing fracture connectivity and subsurface permeability. Land use and land cover also play a critical role, with water bodies and vegetated areas showing very good groundwater potential, agricultural lands exhibiting moderate to good potential, and settlements and roadways limiting recharge due to impervious surfaces. Based on these findings, groundwater development should be prioritised in high- and moderate-potential zones, whereas low-potential areas require cautious utilisation and the implementation of artificial recharge measures, such as check dams and percolation tanks. Overall, the study provides a reliable scientific framework to support sustainable groundwater development, effective resource management, and long-term conservation in the study area.

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