ASSESSMENT OF GROUNDWATER POTENTIAL ZONES USING RANDOM FOREST AND GEOSPATIAL TECHNIQUES IN MADURAI CITY

N.Revandh[1], Dr. K. Katturajan[2], Dr.M.Shakthivel[3],

[1] Research Scholar, Department of Geography, Tamilnadu Open University, Chennai. India
[2] Assistant Professor Department of Geography, Tamilnadu Open University, Chennai, India
[3]Former Professor, Department of Geography, University of Madras, Chennai, India

E-mail address: revandhnambu99@gmail.com

ABSTRACT

Groundwater constitutes a critical freshwater resource that sustains domestic, agricultural, and industrial activities worldwide. In Madurai, surface water supply from the Vaigai River is increasingly supplemented by groundwater extracted through bore wells to meet the rising water demand driven by rapid urbanization. However, excessive groundwater extraction without adequate recharge has resulted in a steady decline in groundwater levels and seasonal water scarcity across several parts of the city. In this context, the delineation of groundwater potential zones (GWPZ) becomes essential for sustainable groundwater resource management and informed urban water planning. The present study aims to identify and map groundwater potential zones in Madurai using the Random Forest (RF) machine learning technique. Ten spatial parameters influencing groundwater occurrence were integrated in the analysis, namely geology, geomorphology, soil series, topographic wetness index (TWI), slope, lineament density, rainfall, drainage density, land use/land cover (LULC), and normalized difference vegetation index (NDVI).Based on the RF model outputs, the study area was classified into two categories: groundwater presence and groundwater absence. The obtained AUC value of 0.912 indicates a very high level of prediction accuracy for the Random Forest model. An AUC value above 0.9 is generally considered excellent in spatial prediction studies. This result suggests that the selected conditioning factors and machine learning model are highly effective in identifying groundwater potential zones within the study area. The results highlight spatial variability in groundwater potential across the region. Furthermore, the study recommends the construction of small check dams and other recharge structures to enhance groundwater replenishment and improve water availability. Model performance was evaluated using the Receiver Operating Characteristic (ROC) curve, which indicates a satisfactory level of prediction accuracy.

Keywords: Groundwater Potential Zones, Random Forest, ROC Curve, NDVI, Urban Water Management, Madurai

INTRODUCTION:

Groundwater is one of the most vital freshwater resources supporting domestic, agricultural, and industrial activities across the world. It is essential to maintaining ecological equilibrium, economic growth, and human health. Groundwater is frequently chosen over surface water in many areas because of its more steady quality, extensive availability, and resistance to drought conditions (Todd & Mays, 2005). Many of people rely on groundwater for their livelihood, especially in arid and semi-arid areas, and it makes up a sizable amount of the world's available freshwater resources, according to UNESCO studies. Worldwide water consumption has risen substantially in recent decades due to fast population growth, urbanization, agricultural expansion, and industrial development. As a result, in many regions of the world, groundwater resources are being drained at unsustainable rates (Wada et al., 2010). Groundwater is the main source of water for industrial, agricultural, and home use in nations like India. However, in many areas, excessive abstraction coupled with a lack of natural recharge has led to decreasing groundwater levels and rising water stress (Shiklomanov, 1998; Foster & Chilton, 2003). According to studies, the rising reliance on bore wells and tube wells is causing major groundwater depletion in large urban centers.

In tropical and semi-arid areas where surface water availability is extremely seasonal, the situation is more severe. Groundwater becomes the most dependable source of water supply all year round in these places (FAO, 2012; Edmunds and Shand, 2008). However, declining groundwater tables, reduced well returns, and seasonal water shortages have resulted from poor design and unchecked extraction (Shah, 2007; World Bank, 2010; Central Ground Water Board, 2020). For sustainable groundwater resource management, it is crucial to identify locations with significant groundwater potential (Jha et al., 2007; Elbeih, 2015).

Mapping groundwater potential zones (GWPZs) has become a crucial technique for determining appropriate locations for groundwater development and recharge. Groundwater potential zone delineation promotes effective water resource management and aids planners and decision-makers in understanding geographic variations in groundwater availability. Because they enable the integration and analysis of several spatial variables, remote sensing and geographic information system (GIS) approaches have proven to be quite useful in groundwater potential evaluation, according to research like Jha et al. (2007). In the same manner, Saraf and Choudhury (1998) stressed that assessing groundwater potential is essential for designing water supply plans and locating artificial recharge locations.

A number of Geoenvironmental factors that affect groundwater occurrence and movement must be integrated into the creation of groundwater potential maps (Murthy, 2000; Nag and Chakraborty, 2003; Magesh et al., 2012). Rainfall, drainage density, lineament density, slope, land use/land cover, geology, geomorphology, soil series, topographic wetness index (TWI), and NDVI are examples of these parameters (Horton, 1945; Lattman, 1958; Beven and Kirkby, 1979; Rouse et al., 1974; Rahmati et al., 2015). Each of these elements affects groundwater circulation, storage, and infiltration in the subsurface environment. Researchers can find regions with ideal hydrogeological conditions for groundwater accumulation by integrating these data using geospatial approaches (Malczewski, 1999; Saaty, 1980; Arabameri et al., 2020).

Groundwater potential zone identification is a crucial step in optimizing and preserving water resources (Balasubramani et al., 2020, as cited in Jothiramalingam et al., 2022). Several techniques have been used to delineate groundwater potential zones, including traditional field-based methods, which are often time-consuming and costly (Arulbalaji et al., 2019, as cited in Jothiramalingam et al., 2022). Recently, cost-effective approaches such as multicriteria decision-making, machine learning, and statistical models have been widely applied. Remote sensing and GIS techniques play a significant role in groundwater mapping, particularly in hard rock terrains. The Analytical Hierarchy Process (AHP) and its extension, Fuzzy AHP, are extensively used for improving accuracy and reliability, while the Receiver Operating Characteristic (ROC) curve is commonly used for validation of results (Jothiramalingam et al., 2022).

The present study focuses on Madurai, an urban area in southern India experiencing rapid growth. Over the past few decades, the city has witnessed significant population increase and urban expansion, leading to a higher demand for water resources. While surface water from the Vaigai River contributes to the city's water supply, there has been a substantial increase in groundwater extraction through bore wells to meet the growing demand. Continuous extraction without adequate recharge has resulted in declining groundwater levels and seasonal water shortages in several parts of the city. In this context, the identification of groundwater potential zones is crucial for the sustainable management of groundwater resources and effective urban water planning in Madurai. The findings of this study are expected to contribute to sustainable groundwater resource management and assist policymakers in identifying suitable locations for groundwater development and recharge.

AIM AND OBJECTIVES: To delineate and analyse groundwater potential zones in Madurai using Remote Sensing (RS) and Geographic Information System (GIS) data, and to integrate these parameters using the Random Forest technique to produce a final groundwater potential map for supporting sustainable water resource management.

The detailed objectives are as follows:

- To identify and prepare thematic layers influencing groundwater occurrence, such as Geology, Geomorphology, Slope, Drainage Density, Rainfall, Soil, Land Use/Land Cover (LULC), Topographic Wetness Index (TWI), Normalized Difference Vegetation Index (NDVI), And Lineament Density using Remote Sensing (RS) and GIS techniques.
- To integrate these thematic layers using the Random Forest technique to delineate groundwater potential zones.
- To validate the delineated groundwater potential zones using borewell yield data and field verification methods.

- To provide recommendations for sustainable groundwater resource management and urban planning in Madurai based on the identified potential zones.

STUDY AREA:

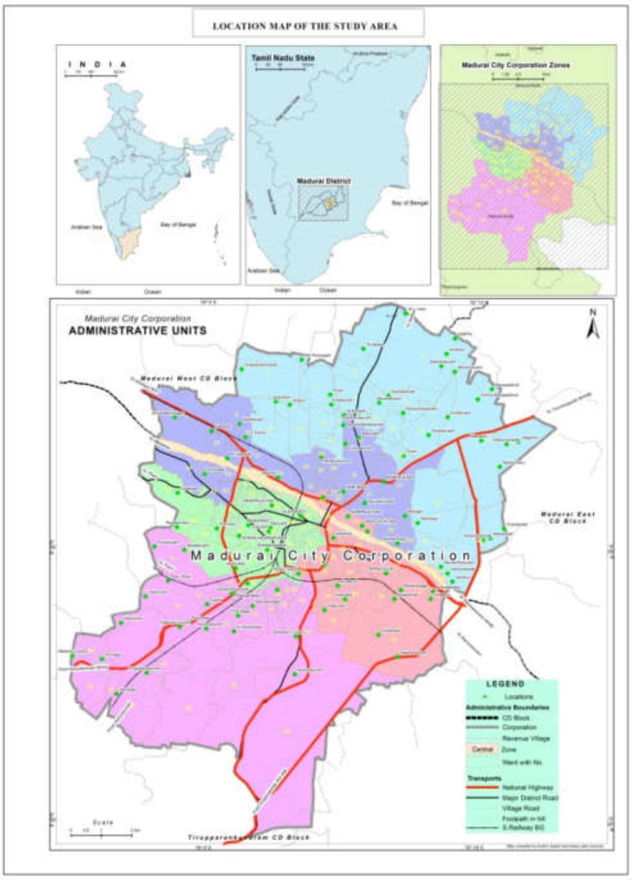

Fig 1(STUDY AREA MAP)

Madurai is the oldest inhabited city in the Indian peninsula. It is referred to as with names like Koodal Maanagar, Temple city. Madurai is surrounded by various hills; Yanaimalai, Nagamalai and Pasumalai are the most prominent. It is located in South Central Tamil Nadu, is the second-largest city after Chennai and is the headquarters of Madurai District. Madurai is located at 9.93°N 78.12°E. It has an average elevation of 101 meters. The city of Madurai lies on the flat and fertile plain of the river Vaigai which runs in the northwest-southeast direction through the city dividing it almost into two equal halves. The Sirumalai and Nagamalai hills lie to the north and west of Madurai. The city has grown on the either side of the Vaigai river and lies at the low attitude and its about 100 M from mean sea level. The major river flowing through Madurai district is Vaigai River. Madurai is well connected with all major cities of the state and the country by Rail, Road and Air. Madurai junction is one of the major rail junctions in Tamilnadu.

And National Highways NH 7 & NH 49 pass through the city. The climatic characteristics of Madurai remain dry and hot for a long term. Three major type whether seasons are noticed in the district namely, summer, winter and monsoon. Monsoon season of the district continue from September to November. Average annual rainfalls of Madurai are about 86 cm.The present study area under the jurisdiction of Madurai Corporation has been extended on 28th September 2010, to include the areas of the city Corporation, 3 Municipalities, 3 Town Panchayats and 11 Village Panchayats located around the Madurai Corporation (See Figure 1: Study Area Map above.)Consequent to this extension, the total area of the Corporation has increased considerably from 51.82 Sq.KM to 147.997 Sq.Km and the numbers of the wards have increased from 72 to 100. The extended Municipal Corporation had a population of 14, 70,755 persons as per 2011 census.

MATERIALS AND METHODOLOGY:

The present study aims to identify groundwater potential zones (GWPZ) in Madurai using the Random Forest technique. A total of ten spatial parameters influencing groundwater occurrence were considered, namely geology, geomorphology, soil series, topographic wetness index (TWI), slope, lineament density, rainfall, drainage density, land use/land cover (LULC), and normalized difference vegetation index (NDVI).

The base map of the study area was prepared using Survey of India topographic maps at a 1:50,000 scale. Geological and geomorphological maps were obtained from the Geological Survey of India, while the soil map was derived from the National Bureau of Soil Survey and Land Use Planning. Slope and TWI layers were generated from ALOS PALSAR Digital Elevation Model (DEM) data using Spatial Analyst tools in ArcGIS. Lineament density was derived using data from Bhuvan thematic services. Rainfall data for the period 1995–2025 were collected from the Surface and Groundwater Data Centre, Taramani, Chennai, and spatial interpolation was carried out using the Inverse Distance Weighting (IDW) method to generate the rainfall distribution map.Drainage density was computed from streams extracted from the ALOS PALSAR DEM using stream order analysis followed by line density analysis.The LULC map was prepared from Landsat 8 imagery using supervised classification techniques. NDVI was derived from Sentinel-2 data.Finally, all thematic layers were integrated using the Random Forest algorithm to delineate groundwater potential zones in the study area.

GEOLOGY	**Geological survey of India**
GEOMORPHOLOGY	**Geological survey of India**
SOIL	**NBSS**
LULC	**LANDSAT 8**
NDVI	**Sentinel 2**
SLOPE	**Alos Palsar**
DRAINAGE DENSITY	**Alos Palsar**
RAINFALL	**State Ground and Surface Water Resource Data Centre**
TWI	**Alos Palsar**
LINEAMENT DENSITY	**Bhuvan**

Table 1: (Parameter and Source)

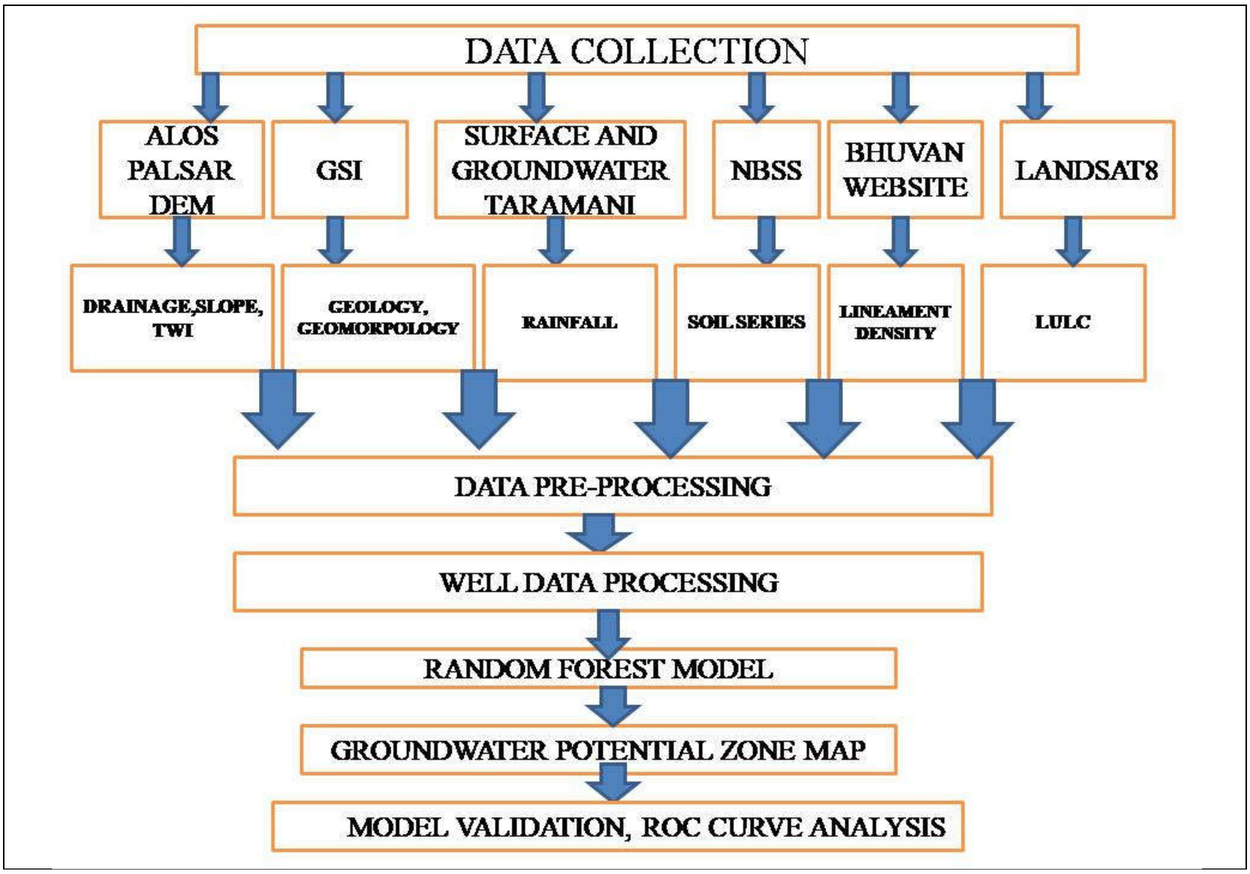

Fig 2(METHODOLOGY FLOW CHART)

Pre-Processing of Spatial Data

Before applying the Random Forest model, all thematic layers were subjected to several preprocessing steps to ensure consistency and reliability of the spatial datasets. These steps were necessary to prepare the input variables and groundwater well data for machine learning analysis.

First, all thematic layers such as slope, drainage density, land use/land cover, topographic wetness index, and vegetation index were collected from different sources and converted into a uniform spatial format. The datasets were projected into a common coordinate system to maintain spatial compatibility within the study area of Madurai.

Second, raster datasets were resampled to a common spatial resolution to avoid scale mismatch between variables. This ensures that each pixel represents the same ground area across all layers used in the analysis. The layers were then clipped according to the boundary of the study area.

Third, continuous variables such as slope, TWI, and NDVI were normalized and converted into raster grids suitable for modelling. Categorical layers such as geology and land use/land cover were reclassified into appropriate classes representing their influence on groundwater occurrence.

Groundwater well location data were also processed before modelling. The well point dataset was converted into spatial point format and checked for duplicate or erroneous records. The dataset was then randomly divided into training and validation samples to build and evaluate the Random Forest model.

Finally, all processed raster layers were converted into a structured dataset where each pixel contained attribute values of all conditioning factors. This dataset was used as input for the Random Forest algorithm to generate the groundwater potential model.

Interpretation of Random Forest Modelling and ROC–AUC Validation:

Groundwater potential zones were delineated using the Random Forest model integrated with GIS-based thematic layers. Random Forest is an ensemble learning technique that constructs multiple decision trees and combines their outputs to improve classification accuracy and reduce over fitting. This method has been widely used in groundwater potential mapping because it can effectively model complex nonlinear relationships between environmental variables and groundwater occurrence.

In this study, several conditioning factors influencing groundwater occurrence were used as input variables for the model. These parameters included topographic, hydrological, and land surface characteristics derived from remote sensing and GIS datasets. Groundwater well locations were used as training and validation data for the model. The available well data were divided into training and testing datasets to build and validate the Random Forest classifier.

The model generated a groundwater potential map by analyzing the relationships between groundwater occurrence points and the conditioning factors. The Random Forest algorithm evaluates the relative importance of each factor through multiple decision trees, allowing the model to identify areas with higher probability of groundwater occurrence.

The predictive performance of the model was evaluated using the Receiver Operating Characteristic Curve and the Area Under the Curve. The ROC curve compares the true positive rate with the false positive rate for different classification thresholds. The dashed diagonal line in the ROC graph represents random classification, while curves positioned closer to the upper left corner indicate better predictive performance.

The obtained AUC value of 0.912 indicates a very high level of prediction accuracy for the Random Forest model. An AUC value above 0.9 is generally considered excellent in spatial prediction studies. This result suggests that the selected conditioning factors and machine learning model are highly effective in identifying groundwater potential zones within the study area.

Overall, the integration of Random Forest modelling with GIS-based thematic layers provides a reliable approach for groundwater potential zone mapping. The high AUC value obtained from the ROC analysis confirms the robustness and predictive capability of the model, making it suitable for groundwater resource assessment and management.

RESULTS AND DISCUSSION:

Geology in Madurai city:

Geological formation influences porosity and permeability, which in turn controls groundwater occurrence and movement. Madurai contains three primary lithological units: acid intrusive rocks, sedimentary formations, and Peninsular Gneiss (Bhavani Group). Acid intrusive rocks dominate the research area (63.6%) and have limited primary permeability; but weathered and fractured zones improve groundwater storage via secondary porosity. Sedimentary formations (34.8%), primarily associated with the Vaigai River, are composed of alluvial deposits such as sand, silt, and gravel, which have high permeability and promote groundwater recharge. Peninsular Gneiss (1.5%) is made up of hard crystalline rocks in which groundwater is controlled by fractures and weathered zones.

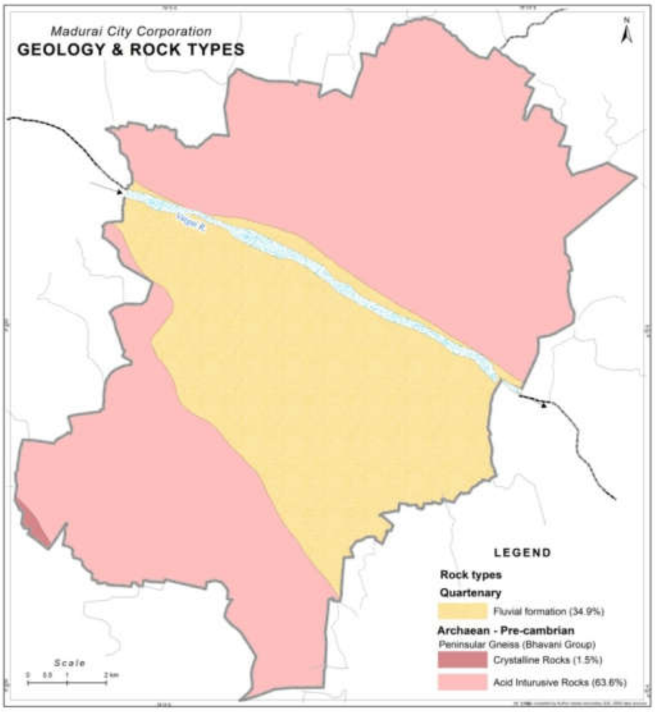

Fig3 (Geology Map)

Overall, sedimentary formations have the largest groundwater potential, Peninsular Gneiss has a moderate potential, and acid intrusive rocks have the lowest potential, indicating that lithology influences groundwater availability and flow.

Geomorphology in Madurai city:

Geomorphology has an a major effect on groundwater recharge by influencing surface and subsurface conditions such as infiltration, runoff, and storage. Geomorphic units in Madurai are generally characterized as either denudational or depositional landforms.

Denudational landforms, such as residual hills, uplands, and linear ridges, are generated by the protracted weathering and erosion of hard rocks. These locations have poor groundwater potential due to steep slopes and limited soil cover; nonetheless, fractures and weathered zones may increase secondary porosity, allowing for limited groundwater storage.

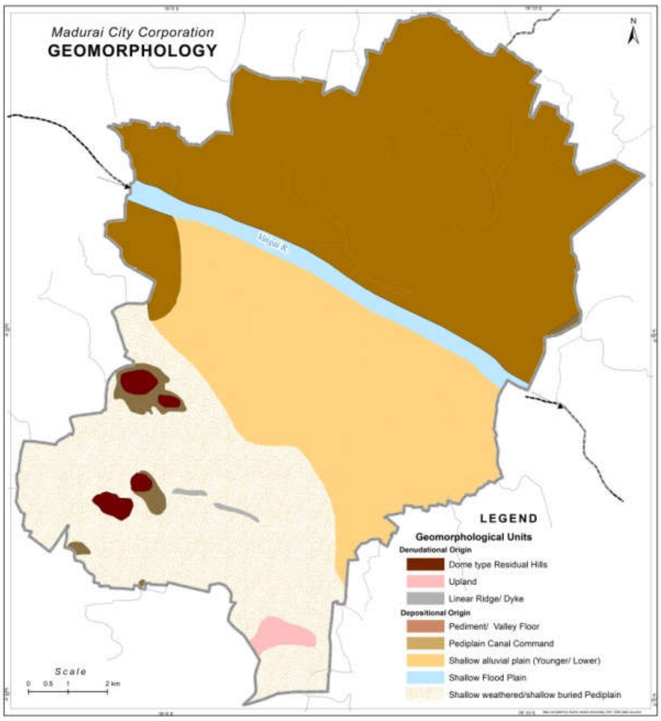

Fig4(Geomorphology Map)

Depositional landforms, such as pediments, valley bottoms, alluvial plains, and floodplains, form as sediments accumulate. These formations are often porous and permeable, allowing for greater infiltration, storage, and movement of groundwater. As a result, groundwater potential is relatively low in denudational terrains but high in depositional landforms, demonstrating the considerable influence of geomorphology on groundwater occurrence.

Soil series in Madurai city:

Soil plays a vital role in groundwater recharge by influencing infiltration and percolation through its texture, structure, and hydraulic properties. In Madurai, the soil map reveals seven major soil series, namely Irugur, Anaiyur, Madukkur, Padugai, Palaviduthi, Vyalogam, and Vyalogam/Anaiyur complex, along with miscellaneous soil types.

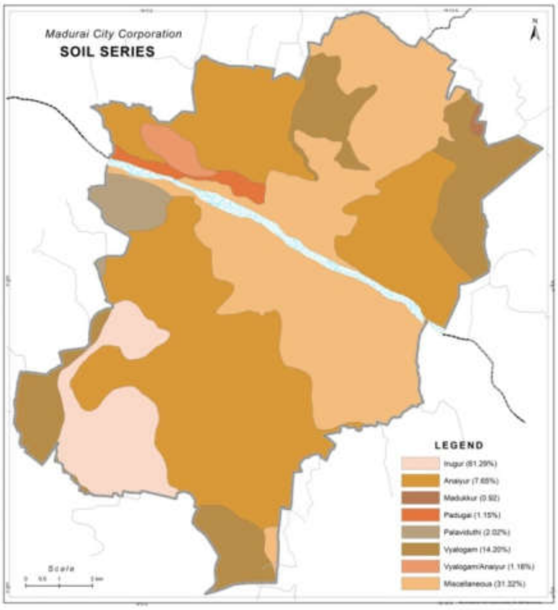

Fig5(Soil Series Map)

Miscellaneous soils account for 31.32% of the study area, indicating diverse soil conditions driven by urban development and alluvial processes. Vyalogam soils (14.20%) and Anaiyur soils (7.65%) have medium permeability and contribute to moderate groundwater recharge. Irugur soils (6.29%) have high drainage and moderate infiltration capacity.

Padugai soils (1.15%) are mostly limited to the Vaigai River zone and are alluvial deposits with a higher infiltration capacity. Madukkur (0.92%) and Palaviduthi (0.20%) soils have a narrow spatial distribution, whereas the Vyalogam/Anaiyur complex (1.16%) has intermediate soil features. Overall, soil types with higher permeability and alluvial characteristics have more groundwater potential, whereas heterogeneous and less permeable soils have lower recharge capacity.

Drainage density in Madurai city:

Drainage density is a key indicator for analyzing groundwater potential since it represents the spacing of stream channels as well as the balance between infiltration and surface runoff. Lower drainage density suggests greater infiltration capacity, whereas higher drainage density indicates more runoff and less recharging.

In Madurai, drainage density is divided into four categories: very low, low, moderate, and high. Very low drainage density locations, primarily in the outlying regions, have sparse drainage networks and a higher groundwater recharge potential. Low drainage density zones suggest moderate runoff. The majority of the studied region has moderate drainage density, indicating balanced infiltration and runoff characteristics. Overall, groundwater potential is higher in places with low drainage density and diminishes as drainage density increases. High drainage density is a hydrological statistic that indicates a high concentration of streams within a basin. It is determined by dividing the total stream length by the total area. It denotes a highly divided environment, often resulting in fast surface runoff, higher flood risk, and limited water penetration. It frequently occurs in locations with impermeable rock, steep slopes, or scant vegetation in Madurai.

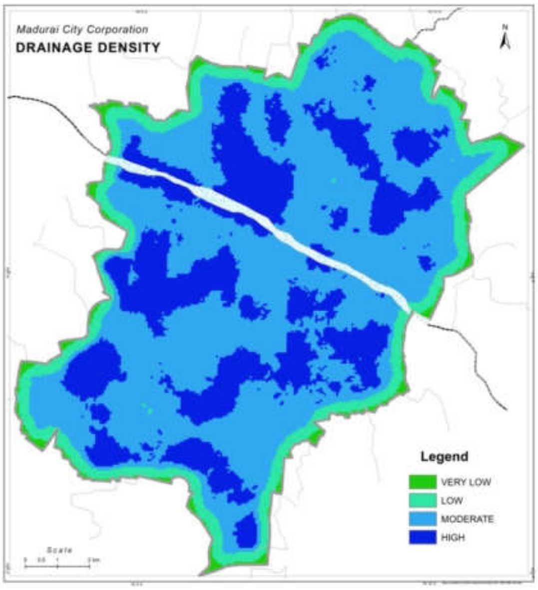

Fig5(Drainage density Map)

Topographic Wetness Index (TWI) in Madurai city:

The Topographic Wetness Index (TWI) is a hydrological parameter produced from Digital Elevation Models that describes the spatial distribution of soil moisture and water accumulation. Higher TWI values indicate low-lying places, such as valleys, with more water accumulation, whereas lower values indicate elevated or steep regions with rapid drainage and limited moisture retention.

Madurai City Corporation's TWI map is divided into five categories: very low, low, moderate, high, and very high moisture zones. The majority of the study area has low to moderate wetness, indicating balanced drainage conditions and considerable potential for infiltration and groundwater recharge, especially in the central and northern areas.

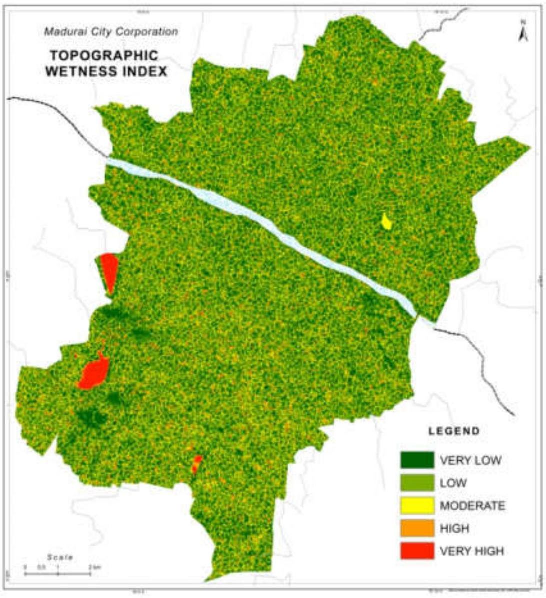

Fig6(Topographic Wetness Map)

Slope in Madurai city:

Slope measures the rate of elevation change and has a substantial impact on runoff, erosion, and groundwater recharge. It was derived from the Digital Elevation Model (DEM) and divided into five categories: <2°, 2-5°, 5-10°, 10-30°, and > 30°.Madurai City has mostly gentle slopes (<2°), especially in its central and northern districts. These flat terrains provide higher infiltration and lower runoff, which improves groundwater recharging. Gentle slopes (2-5°) are also common and promote mild infiltration. Moderate slopes (5-10°) occur in smaller, dispersed regions, where runoff increases slightly, lowering infiltration.

Steeper slopes (10-30° and >30°) are scarce and mostly found in isolated parts of the southwestern region, where runoff dominates and groundwater recharge is negligible. The Vaigai River valley has mild slopes that promote surface water circulation and groundwater recharging.

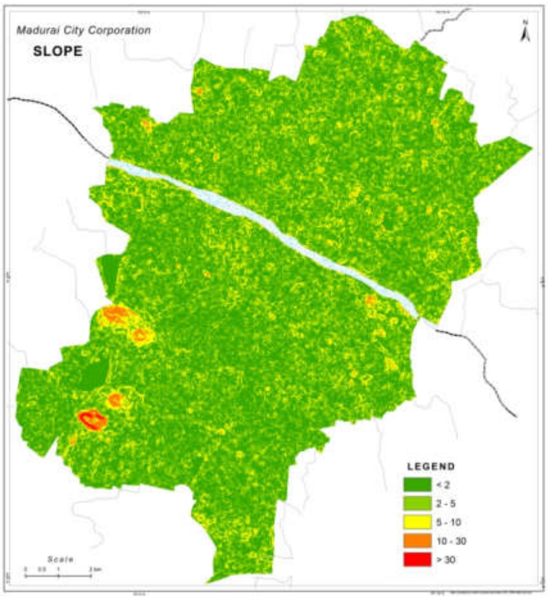

Fig7(Slope Map)

Lineament density in Madurai city:

Lineament density maps represent the distribution and concentration of structural features, which are important indicators of groundwater movement and storage. High lineament density reflects intense fracturing and structural weakness, resulting in increased permeability and better groundwater potential zones, whereas low density indicates relatively stable and less fractured formations.

Lineament density (Ld) is calculated as:

LD= $\sum_{i=1}^{n} L_i / A$

The study area is classified into five categories: very low (<0.20), low (0.20–0.40), moderate (0.40–0.70), high (0.70–0.90), and very high (>0.90). Most of the area falls under very low to low lineament density, indicating limited structural discontinuities.

However, a distinct zone of high to very high lineament density extends diagonally from northwest to southeast across the central part of the study area. This suggests the presence of major fractures or fault zones that enhance secondary porosity and significantly influence groundwater recharge and movement.

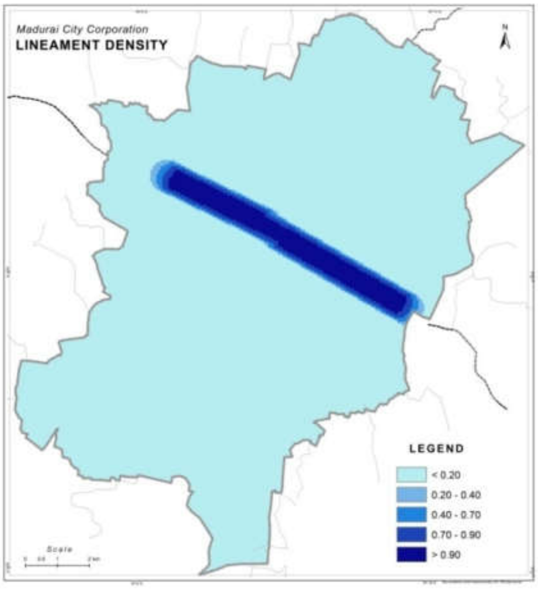

Fig8(Lineament density Map)

Rainfall in Madurai city:

Rainfall is a key component of the hydrological cycle and the primary source of groundwater recharge. It influences soil moisture, surface runoff, and overall water availability in a region. The rainfall distribution in the study area is classified into five categories: very low, low, moderate, high, and very high. Very low rainfall zones are mainly located in the eastern and southeastern parts, indicating limited precipitation and reduced recharge potential. Low rainfall areas form a transitional belt adjoining these regions.

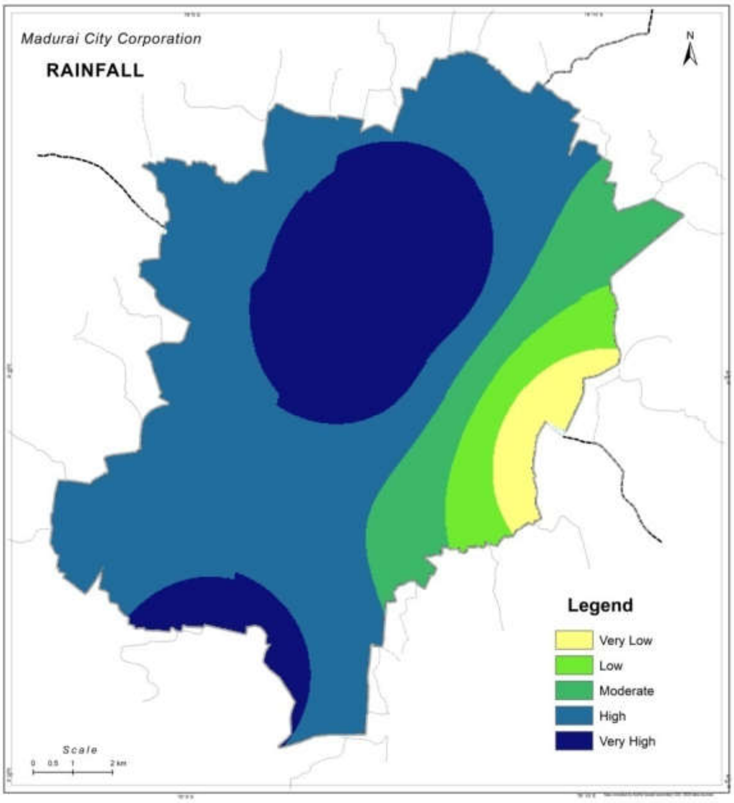

Fig9(Rainfall Map)

Moderate rainfall is observed in the central parts, reflecting balanced precipitation conditions. High rainfall dominates much of the central and western regions, suggesting favorable conditions for groundwater recharge and soil moisture retention. Very high rainfall zones occur in localized patches, particularly in the central and southwestern areas, contributing significantly to both surface runoff and groundwater replenishment.

Land use and Land cover in Madurai city:

Land use refers to human activities such as agriculture, settlement, and industry, whereas land cover denotes the physical features present on the Earth's surface. LULC patterns play a significant role in influencing groundwater recharge by controlling infiltration and runoff characteristics.

The LULC of Madurai City is classified into four major categories: built-up area, agricultural land, wasteland, and water bodies. The built-up area is further divided into residential and commercial zones. The spatial distribution of these categories reflects strong interactions between urban growth, agriculture, and natural features, largely influenced by physiography, transport networks, and the Vaigai River system.

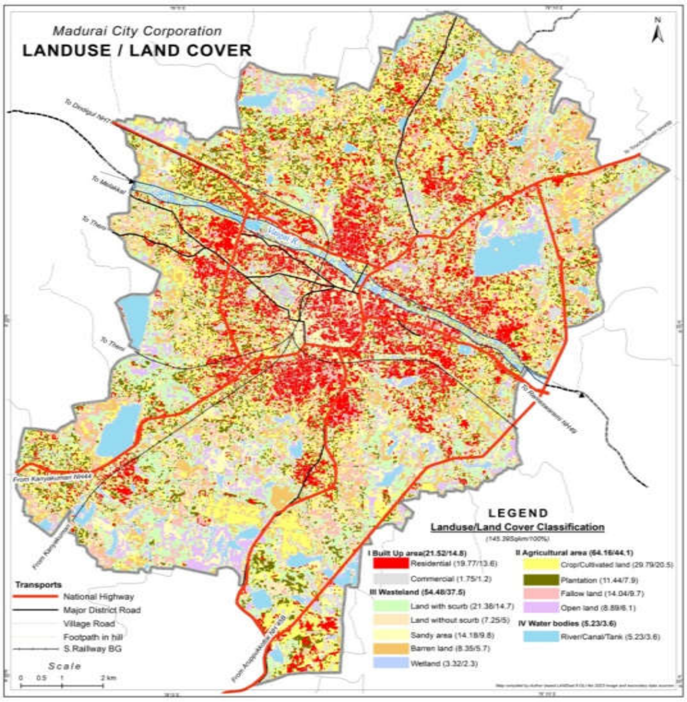

Fig10(LULC Map)

Category	Area
Built-up area	21.51
Agricultural area	41.22
Wasteland	73.99
Water bodies	8.54

Wasteland occupies the largest share (73.99), followed by agricultural land (41.22) and built-up area (21.51), while water bodies cover the least area (8.54), indicating limited surface water resources in the study area.

NDVI Normalized Difference Vegetation Index. in Madurai city

It indicates vegetation density, where higher values represent healthy vegetation and lower values indicate barren or built-up areas. In groundwater studies, higher NDVI values are associated with better infiltration and recharge potential.

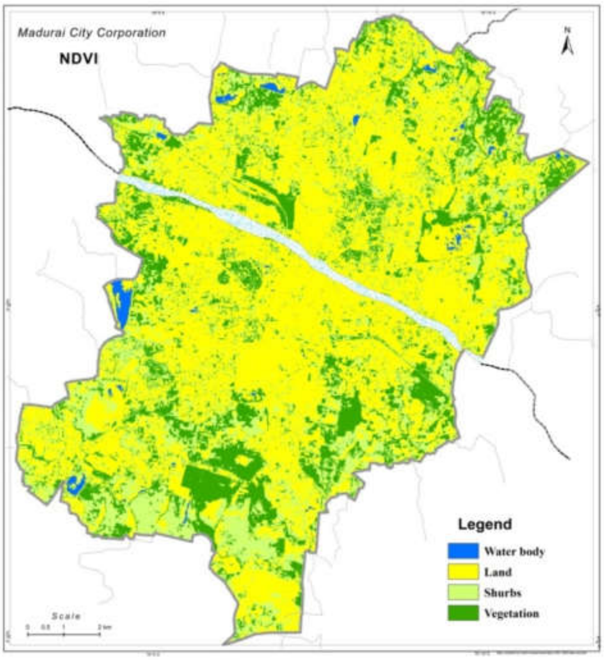

Fig11(NDVI Map)

The NDVI map of Madurai shows four major classes: water bodies, barren/built-up land, shrubs, and dense vegetation. Water bodies, mainly along the Vaigai River, exhibit very low or negative NDVI values. Barren and built-up areas dominate the study region, indicating low vegetation cover. Moderate NDVI values are observed in shrub-dominated peripheral areas, while high NDVI values, representing dense vegetation, are concentrated in the southern and southwestern parts.

GROUNDWATER POTENTIAL PRESENCE IN MADURAI CITY:

Groundwater Presence Mapping and Spatial Analysis

The groundwater presence map (Fig.12) depicts the spatial distribution of groundwater occurrence across Madurai, generated using the Random Forest (RF) algorithm integrated with GIS-based thematic layers in ArcGIS Pro. The dataset was partitioned into 80% training and 20% testing subsets, ensuring robust model calibration and reliable validation of predictive performance.

The classification output delineates two distinct categories: groundwater presence and groundwater absence. The spatial pattern indicates that groundwater presence is predominantly concentrated in the central and northern sectors of the study area. These regions are associated with favorable hydrogeological and geomorphological conditions, including moderate slope gradients, enhanced infiltration capacity, structurally controlled features such as lineaments, and suitable land use/land cover characteristics, all of which collectively promote groundwater recharge and storage.

Localized occurrences of groundwater presence are further observed in the western and southwestern parts, reflecting spatial heterogeneity in subsurface conditions. These zones are likely influenced by relatively low drainage density, permeable soil formations, and fracture-controlled permeability, which facilitate infiltration and groundwater accumulation at a localized scale.

In contrast, groundwater absence is predominantly distributed across the southern and southeastern regions, where limiting factors such as higher surface runoff, steeper terrain, reduced permeability, and constrained recharge potential inhibit groundwater occurrence. This spatial disparity underscores the influence of both natural and anthropogenic factors in governing groundwater distribution.

The RF model demonstrates strong capability in capturing complex, non-linear interactions among the conditioning factors through its ensemble learning framework. Its integration within a GIS environment enhances spatial prediction accuracy and enables the identification of key controlling variables through variable importance analysis. Overall, the results provide a reliable basis for delineating groundwater potential zones and offer critical insights for sustainable groundwater management and urban water resource planning.

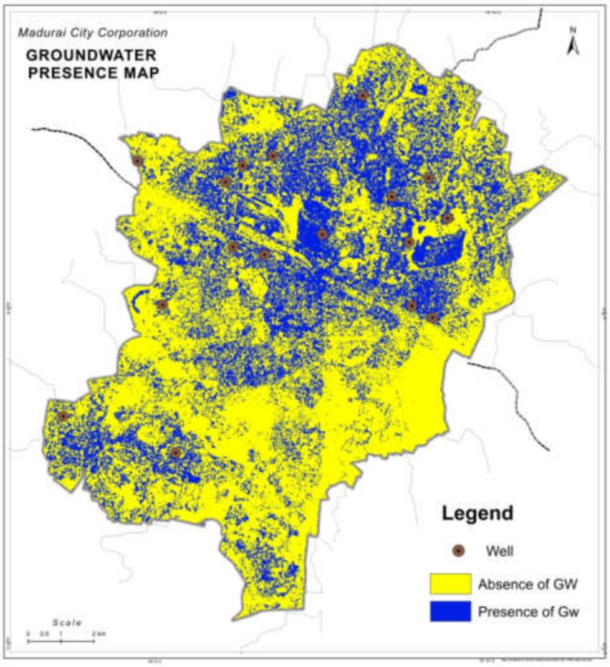

Fig12(Groundwater potential Map)

The distribution of well locations corresponds reasonably well with the predicted groundwater presence zones, indicating the reliability of the model output**.** Overall, the map highlights a heterogeneous distribution of groundwater occurrence, influenced by both natural and anthropogenic factors.

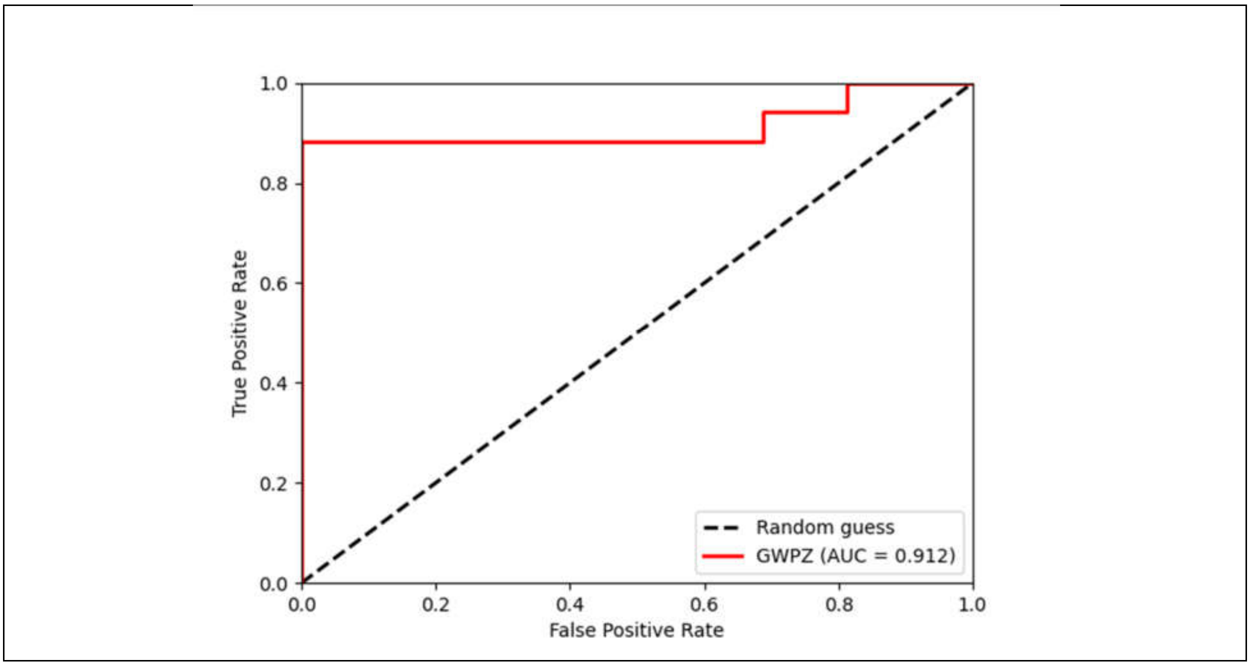

Fig13(ROC AUC Map)

The groundwater presence map of Madurai shows a strong spatial agreement with the ROC–AUC result (0.912), indicating high model reliability. Areas classified as groundwater presence (blue zones) correspond well with the predicted high-potential regions identified by the Random Forest model. The consistency between the spatial distribution and the ROC validation confirms the robustness and predictive accuracy of the model in delineating groundwater potential zones.

CONCLUSIONS:

The study used 10 Parameters to assess the groundwater potential zones by integrating RS, GIS and Random forest technique. Based on the RF values, the study area has been divided into 2 classes: GW presence and GW absent. Further the construction of small check dams can subsequently increase the groundwater level. The accuracy of the study has been quantified using the ROC curve, and it was found that the accuracy of the final result is which is reasonable. Overall, the integration of Random Forest with GIS-based thematic layers provides a reliable and effective approach for groundwater potential mapping and sustainable resource management.

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