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Potential Sites for Aquifer Replenishment using Resistivity and Geospatial Techniques in Kiliyar Sub-Basin, Kanchipuram District, South India

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Abstract

Groundwater depletion in hard rock terrains necessitates scientifically validated approaches for identifying suitable aquifer replenishment sites. This study integrates geophysical resistivity surveys with geospatial multi criteria analysis to delineate recharge potential zones in the Kiliyar Sub-Basin of the Palar River Basin, Tamil Nadu. Seven thematic layers, geomorphology, land use/land cover (LULC), lineament density, drainage density, slope, resistivity layer properties, and depth were generated using Landsat ETM+, SRTM DEM, and 32 Vertical Electrical Sounding (VES) points. These parameters are converted to raster format and assigned rank and weights then computed from the Normalized Weight Method (NWM). All the layers have been integrated to generate final layer to assess the artificial recharge structures in the Kiliyar Sub-Basin. The final output zones are classified into five suitability categories: least suitable (5.66%), poorly suitable (22.91%), moderately suitable (29.25%), highly suitable (30.19%), and very highly suitable (12%), and the resulting recharge zonation map groups the basin into the same five classes from least to very highly suitable. The study area boundaries and drainage framework provide important spatial context for interpreting recharge behavior. This aquifer replenishment zone map will be useful for extraction and management of groundwater in the study area.

Keywords: Aquifer Replenishment, GIS, Resistivity Survey, Multi-criteria Analysis, Kiliyar Sub-Basin, Remote Sensing

Introduction

Groundwater is a vital resource in peninsular India, especially in hard rock terrains where storage and movement are highly heterogeneous, and its demand continues to rise with the growing population. Also, the decreasing rainfall duration, irregular monsoon patterns, intensive agricultural extraction and increasing intensity reduce the groundwater recharge quantity, which leads to groundwater exploitation (Aeschbach-Hertig and Gleeson, 2012, Mondal *et al.*, 2019; Hashemi *et al.*, 2020; Alikhanov *et al.*, 2021; Halder *et al.*, 2021). Studies across the Palar River Basin indicate a persistent imbalance between groundwater recharge and abstraction due to land use change, declining surface water retention, and limited natural infiltration pathways (Jha and Sinha, 2009; MacDonald *et al.*, 2016). A growing body of global research further shows that unsustainable extraction and inadequate management practices have led to rapid groundwater depletion in alluvial aquifers (Aeschbach Hertig and Gleeson, 2012; Bonsor *et al.*, 2017; MacDonald *et al.*, 2015), while natural recharge processes have been significantly disrupted by rapid urbanization, population growth, and other anthropogenic pressures, creating a widening gap between recharge and abstraction rates (Jha and Sinha, 2009).

To contextualize the hydrogeological setting, the study area location and drainage network are shown in the study area map (Fig. 1), which highlights the spatial distribution of tanks, stream courses, and major geomorphic units that influence surface runoff and infiltration dynamics. Groundwater recharge is a key determinant of the hydrological balance and long-term sustainability of subsurface water regimes (Amanambu *et al.*, 2020). Although recharge processes are predominantly governed by atmospheric inputs such as precipitation and evaporation, recent shifts in global climate have markedly affected both the quantity and quality of groundwater replenishment (Cuthbert *et al.,* 2019; Albuquerque *et al.,* 2022). Consequently, effective groundwater management relies heavily on understanding the spatiotemporal dynamics of recharge (Amanambu *et al.,* 2020; Judeh *et al.,* 2021). Direct, in-situ quantification of recharge is often challenging; hence, various indirect approaches including empirical equations, process-based modelling, and geophysical methods such as electrical resistivity and electromagnetic surveys are increasingly employed for recharge estimation (Jourde and Wang, 2023). However, reliance on conventional techniques may introduce additional uncertainties, particularly when evaluating climate-change impacts on recharge processes (Aquilina *et al.*, 2023).

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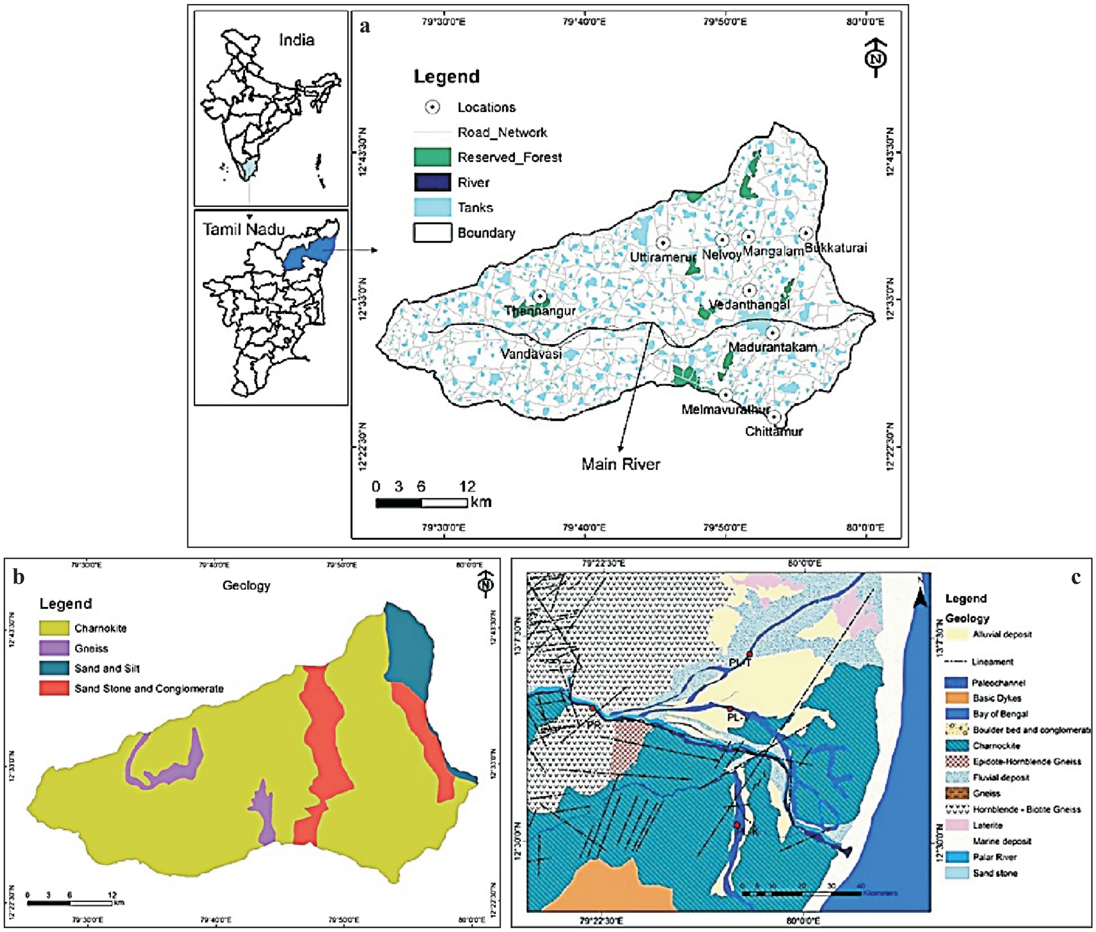

Fig.1. (a) Location of the Study area Kiliyar Sub-basin, (b) Geology of the Study area and (c) Geological settings of the Kanchipuram District.

Jeyaseelan *et al.* (2024) has been studied the water spread area changes of Kiliyar Sub-Basin of Palar River Basin, Tamil Nadu, India. The results indicated a 6.19% reduction in the distribution of water bodies within the study area. This decline is primarily attributed to encroachment by settlements and various developmental activities. Baboo and Thirunavukkarasu (2014) has assessed the geometric correction in high resolution satellite imagery using mathematical methods for groundwater recharge in the Kiliyar Sub-Basin. Sakthivel *et al.* (2023) has been evaluated the Tank Water Spread Area in Cheyyar Sub-basin using Sentinel 1A Data.

The knowledge of subsurface structures is extremely important for construction and development of artificial groundwater recharge schemes in any area. Numerous studies were carried out on the surface (using remote sensing and GIS) and subsurface (using electrical resistivity method) on artificial recharge (Eid *et al.*, 2006; Ghayoumian *et al.*, 2007; Jasrotia *et al.*, 2007; Acharya *et al.*, 2017). Resistivity survey is widely used worldwide for ground water studies in soft rock as well as hard rock areas (Van Overmeeren 1989; Urish and Frohlich 1990; Ebraheem *et al.*, 1997; Jha *et al.*, 2008). A set of weights for the many themes and each of their unique attributes were determined based on subjective assessments and an appraisal of their relative relevance from the perspective of artificial recharging. These thematic maps were then incorporated into a GIS system to determine the appropriate zones for artificial recharge zones (Malmir *et al.*, 2022; Jafari *et al.*, 2021). The comprehensive approach significantly improved the accuracy and reliability of site selection for recharge implementation.

Aim and Objectives

The aim of this study is to identify and validate potential aquifer replenishment zones in the Kiliyar Sub-basin through integrated analysis of geophysical resistivity data and geospatial thematic layers for sustainable groundwater management. The specific objectives of the study are: a) to map geomorphology, land use/land cover, drainage density, slope, and lineament characteristics using geospatial datasets, b) to acquire and interpret Vertical Electrical Sounding (VES) resistivity data for subsurface characterization, c) to integrate surface and subsurface thematic layers using the Normalized Weight Method (NWM) for recharge zonation, d) to delineate suitability classes for aquifer replenishment using a Composite Suitability Index (CSI) and e) to validate the recharge zones using contour and drainage data.

Geological Settings

The Kiliyar Sub-Basin is a tributary of the Cheyyar watershed within the Palar basin, originating in the Thiruvannamalai district and terminating in the Kanchipuram district. The study area is covered by Survey of India toposheets of 57P/6, 57P/7, 57P/10, 57P/11, 57P/14 and 57P/15. Kiliyar watershed extends between east longitudes 7953'26” and 7925'10” and North latitudes 1241'9" and 1222'32". Kiliyar Sub-Basin boundary of the Palar Basin is chosen for the study as presented in Fig.1a (Gokulnath and Gandhi, 2025). Kiliyar River, a tributary of the Palar River, originates from the surplus waters of the Melpadi Tank in Vandavasi taluk. It flows for about 39 km before emptying into the Madurantakam Tank. Thereafter, the river acts as surplus course of Madurantakam tank and confluences into Palar River near Isur village after travelling 13 km. Kiliyar receives drainage from its free basin, besides surpluses of tanks in Cheyyar, Vandavasi, Uthiramerur and Madurantakam taluks in Kanchipuram District. The branches of Kiliyar River are Salavedu Maduvu and Nelvoy Maduvu. The total area of Kiliyar Basin is 932.00 sq.km. In this project, 8 blocks are covered in this sub basin namely Acharapakkam, Madurantakam, Chithamur, Uthiramerur, Vandavasi, Peranamallur, Thellar and Anakkavur.

The Kiliyar Sub-Basin lies within the larger Palar River system in Kanchipuram (Kancheepuram) district on the eastern flank of the southern Peninsular Shield. The regional bedrock is dominated by Archaean crystalline rocks chiefly granitoid gneisses, charnockites and other high-grade metamorphic units with narrow to extensive Quaternary alluvial and fluvial deposits along the Palar and its tributaries (Fig.1b). These alluvial fills and flood-plain sediments form the principal shallow groundwater reservoirs within the sub-basin, whereas fractured crystalline rock hosts groundwater in deeper, discontinuous fracture zones. Bedrock depth and weathering thickness vary markedly across the basin, with reported weathering depths commonly from a few meters to tens of meters depending on local lithology and geomorphology (Gururani *et al.*, 2023). The hydrogeological behavior is therefore bimodal: (a) higher specific yield and rapid vertical percolation in sandy alluvium and colluvial deposits; (b) slower, fracture-controlled storage and anisotropic flow in the underlying crystalline basement. Recent basin-scale assessments emphasize that ~10–15% of the Palar Basin area is covered by sedimentary/alluvial units that disproportionately control recharge and shallow storage, while the remainder is hard rock with variable weathering profiles (Pious and Raj, 2025).

Kanchipuram district is underlain predominantly by an Archaean crystalline basement composed mainly of Charnockite (Fig.1c), biotite-hornblende gneisses and related metamorphic rocks (with occasional dolerite-dyke intrusions), but in the northern and coastal parts the basement is overlain unconformably by sedimentary and Quaternary cover including Lower Cretaceous-Jurassic sandstones and shales Pliocene–Pleistocene gravel beds (locally known as "Kancheepuram Gravels"), and recent alluvium, laterite and beach-sand deposits; this dual geology (hard-rock basement + variable sediment and unconsolidated cover) creates a mixed aquifer regime in which groundwater occurs both in weathered/fractured crystalline rock and in semi-consolidated/ alluvial formations, with lithology, drainage density, soil texture and thickness of weathered/cover materials identified in a 2025 GIS-based groundwater-potential study as the most critical controls on groundwater availability and recharge potential in the district (Ajayakumar *et al.*, 2025). These conditions highlight the importance of integrating geophysical and geospatial methods in delineating recharge favorable zones within the Kiliyar sub-basin.

Materials and Methods

This study integrates remote sensing, GIS-based multi-criteria evaluation, and geophysical resistivity survey data to delineate aquifer replenishment sites. The Landsat ETM+ satellite data were utilized for creation of geomorphology, land use and land cover mapping and lineament extraction. The Shuttle Radar Topography Mission (SRTM) DEM image in 90 m spatial resolution used for topography and slope mapping. Geophysical resistivity measurements were carried out at 32 locations. The various terrain parameters and aquifer replenishment factors were generated as spatial map using GIS software ArcGIS 10.2.2. The integrated procedure used in the study is shown in Fig. 2. For the current investigation, the seven aquifer replenishment factors of geomorphology, land use / land cover, lineament density, drainage density, slope angle, resistivity layer, layer of thickness, groundwater depth were used.

Aquifer Replenishment Factors

Geomorphology

Geomorphology and its features are essential components for understanding the landforms evolutions that control the movement and occurrence of groundwater and recharge (Raju Thapa *et al.*, 2017). The geomorphology map was prepared using IRS P6 LISS II satellite data. There are 12 geomorphological parameters present in the study area. The moderately buried pediment and sedimentary low land is the majority in that area which is more suitable for recharge (Fig.3a).

Land Use / Land Cover

For artificial groundwater recharge investigation, land use land cover is among one of the important parameters. Each land use / land cover has a certain influence on groundwater occurrences indirectly through infiltration, runoff, and evaporation. The agricultural land, built-up land, forest cover, grass land and water bodies are the land use and land cover of the study area (Fig.3b).

Lineament Density

Groundwater availability and flow directions depend upon

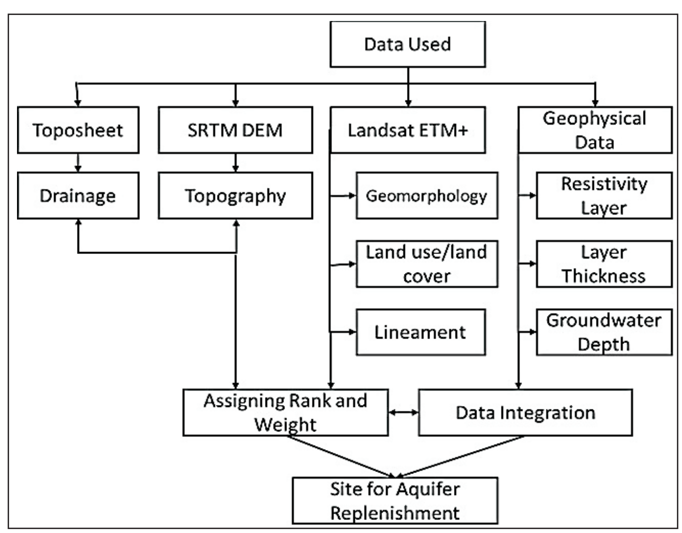

Fig.2. Flow chart of methodology adopted in the present study

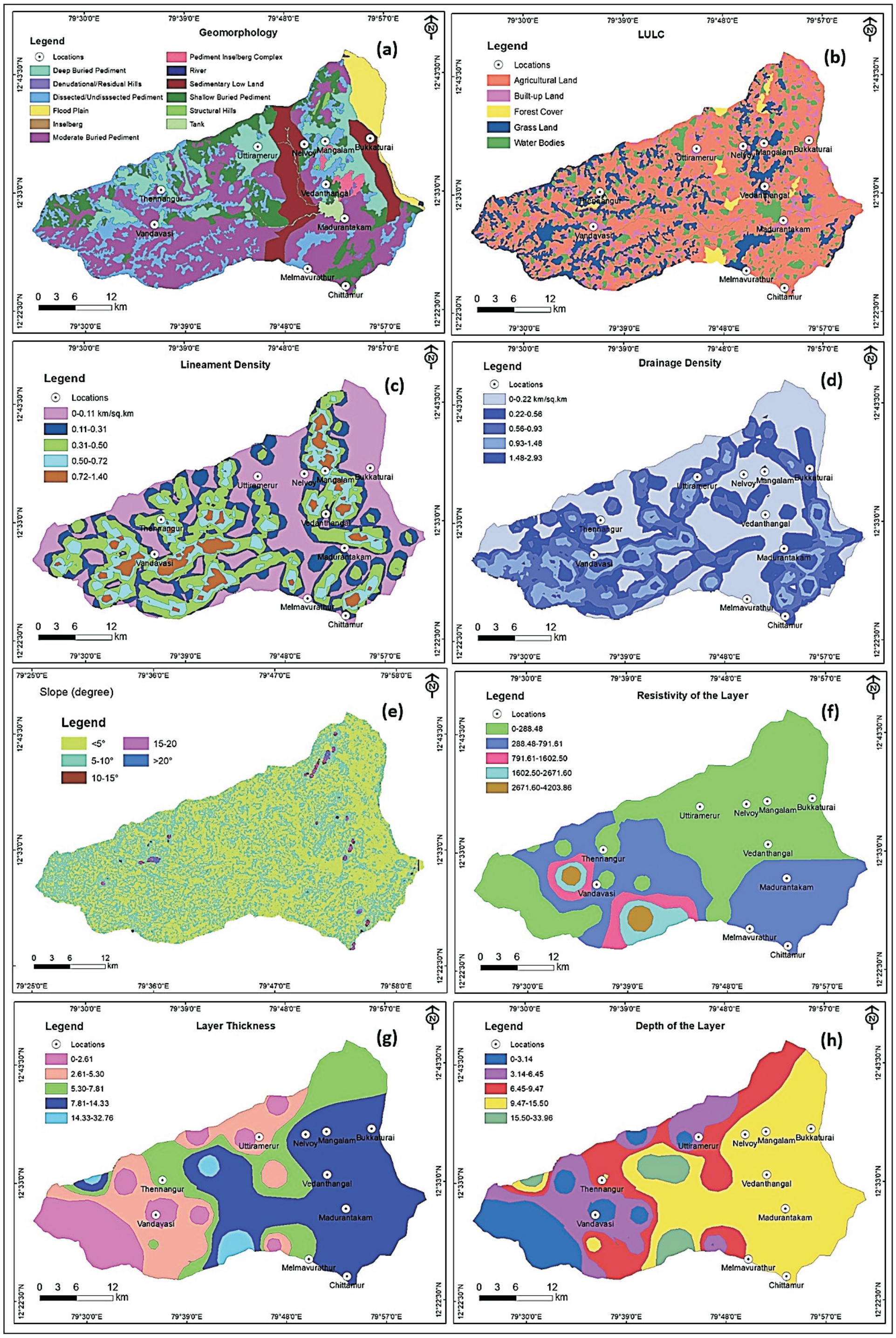

Fig.3. Aquifer replenishment factors in the study area

the linear features such as drainages, linear vegetation, weaker plain, secondary porosity, and permeability. Remote sensing data provides the synoptic view of the large surface area which helps to understand the occurrence of lineament. Lineament density of an area can indirectly reveals the groundwater potential recharge, since the presence of lineaments usually denotes a permeable zone. Areas with high lineament density are good for groundwater potential recharge zones (Haridas *et al.*, 1998). The lineament density map reveals the presence of high lineament density in the center of the study area with a value ranging from 0 to 1.40 km/km^2 (Fig.3c).

Drainage Density

Drainage density is the closeness of the spacing of stream channels. It is a measure of the overall length of the stream segment for all orders per unit area. The drainage map was interpreted from the survey of India's topographical map. From the drainage, the density was prepared using line density in spatial analysis tools in ArcGIS. The drainage density of the sub-basin varies from 0 to 2.93 km/km^2 and reclassified into five classes by equal interval method (Fig.3d). The higher drainage density represents the good potential for groundwater recharge.

Slope

The slope is one of the important terrain parameters which affects the occurrence and movement of groundwater. Infiltration of the surface is directly influenced by the slope gradient. Slope grid is identified as “the maximum rate of change in value from each cell to its neighbors” (Burrough, 1986). Based on the slope, the study area can be divided into four slope classes. The areas having <5 slope fall into the 'very good' category because of the nearly flat terrain and relatively high infiltration rate. The areas with 5-10 slope are considered as 'good' for groundwater storage due to slightly undulating topography with some runoff. The areas having a slope of 10-15 cause relatively high runoff and low infiltration, and hence are categorized as 'poor' and the areas having a slope >20 are considered as 'very poor' due to higher slope and runoff. Fig.3e illustrates the slope map of the study area.

Geophysical Resistivity Survey

The electrical resistivity method consists of the injection of electrical current into the subsurface by current electrodes and measurement of the change in voltage by potential electrodes (Todd, 1980). Vertical Electrical Sounding (VES) was carried out at 32 locations in the study area. The resistivity instrument measured the direct measurements of resistance and apparent resistivity of particular depth. The field data acquisition was generally carried out by moving two or four of the electrodes used, between each measurement. The average measurement of apparent resistivity value was taken at every depth of investigation. The general electrical parameters and hydrological significance are given in Table 1. The resistivity layer (Fig. 3f), layer thickness (Fig.3g) and depth of the layers (Fig.3h) were generated for aquifer replenishment using the geophysical resistivity survey.

Normalized Weight Method

Normalized Weight Method Analysis (NWMA) is a simple and calculation method for a combined analysis of multiclass maps. Rank indicates the relative importance assigned to each parameter. NWMA method takes into consideration of the parameter to calculate each parameter (Table 2).

Normalized Weight Method:

$$Wti = (K\text{-}ri + 1) / (\Sigma_{1j=1}^{K} \; K\text{-}ri + 1) \quad \text{.... (1)}$$

Whereas, K- Total number of parameters;
ri - sub rank of parameter and
rj- total sub rank of parameter.

Assessment of Erosion Prone Zones
Final integration of Calculated Scores:

$$Score = sub\ rank * Wti\ (2) \quad \text{.... (2)}$$

Composite Suitability Index (CSI)

Grouping of polygons of high ranks of all the thematic layers has helped in delineating the sites that are excellent for construction of water harvesting structures. Based upon the standard deviation, the polygons were grouped into classes suitable for construction of groundwater recharge structures. A Composite Suitability Index (CSI) has been calculated for each composite unit by multiplying weights with the rank of each parameter and summing up the values of all the parameters. Categorization of the CSI is achieved by ranging the CSI into 5 classes.

Class 1 Maximum >CSI > = 4 σ
Class 2 4σ >CSI > = 2 σ
Class 3 3σ >CSI > = 1 σ
Class 4 2σ >CSI > = 1 σ
Class 5 1σ >CSI > = Minimum
Where σ standard deviation

Table 1: Electrical parameters and hydrological significance

S. No.	Resistivity (Ohm-m)	Thickness (M)	Inferred Lithology	Hydrological Significance
1	2- 30	2 -40	Predominantly clay/ clay with kankar, lateritic sand	Generally, lies in unsaturated zone, aquifer at good upper level. & poor at depth
2	30 - 100	5 -50	Highly weathered & jointed shale	Principal aquifer of the area.
3	100 - 300	0 - 48	Hard & compact shale	Poor aquifer
4	> 300	Bottom Layer	Shale hard and compact traversed by dolerite dykes	as Very poor aquifer, act barrier for ground water movement

Table 2: Final integration of Calculated Scores

S. No.	Parameters	Features	Rank	Nr
1	Geomorphology	Deep buried pediment	5	0.152
		Denudational/Residual hill	1	0.030
		Dissected/Undissected pediment	2	0.061
		Flood plain	4	0.121
		Inselberg	1	0.030
		Moderate buried pediment	4	0.121
		Pediment inserlberg complex	2	0.061
		River	1	0.030
		Sedimentary low land	4	0.121
		Shallow buried pediment	3	0.091
		Structural hill	1	0.030
		Tank	5	0.152
2	Land Use / Land Cover	Agricultural land	4	0.235
		Built-up land	1	0.059
		Forest Cover	3	0.176
		Grass land	4	0.235
		Water Bodies	5	0.294
3	Lineament Density	0-0.11 km/sq.km	5	0.333
		0.11-0.31	4	0.267
		0.31-0.50	3	0.200
		0.50-0.72	2	0.133
		0.72-1.40	1	0.067
4	Drainage Density	0-0.22 km/sq.km	1	0.067
		0.22-0.56	2	0.133
		0.56-0.93	3	0.200
		0.93-1.48	4	0.267
		1.48-2.93	5	0.333
5	Resistivity (ohm m)	0-288.48	5	0.333
		288.48-791.61	4	0.267
		791.61-1602.50	3	0.200
		1602.50-2671.60	2	0.133
		2671.60-4203.86	1	0.067
6	Layer Thickness (m)	0-2.61	5	0.333
		2.61-5.30	4	0.267
		5.30-7.81	3	0.200
		7.81-14.33	2	0.133
		14.33-32.76	1	0.067
7	Depth of the layer (m)	0-3.14	1	0.067
		3.14-6.45	2	0.133
		6.45-9.47	3	0.200
		9.47-15.50	4	0.267
		15.50-33.96	5	0.333

Results and Discussion

The integration of thematic layers for generating the overall suitability map was performed through a systematic prioritization process. Existing literature highlights the effectiveness of various standardization approaches such as fuzzy membership functions, the Analytical Hierarchy Process (AHP), linear and stepwise transformations, and rating-based methods in ensuring that decision layers are comparable in scale (Rahman *et al.*, 2012; Kamangar *et al.*, 2019; Fuentes and Vervoort, 2020; Papadopoulos *et al.*, 2022). Considering its simplicity and practical applicability in multi-criteria decision-making (Kazakis, 2018; Shadmehri Toosi *et al.*, 2020), the present study employed the rating technique to streamline the analysis.

Artificial recharge has long been recognized as an effective method to improve groundwater quantity and quality by introducing cleaner surface or treated water into the subsurface and diluting contaminants, thereby making previously unusable aquifers suitable for consumption (Ward *et al.*, 2020). In arid cratonic regions, however, artificial recharge implementation remains challenging due to low permeability regolith, high evaporation losses, and limited natural recharge sources that reduce infiltration efficiency (Grzegorz *et al.*, 2023). Several recent studies including the Kayseri region of Turkey (Mouhoumed *et al.*, 2024) and the Mi River Basin (Song *et al.*, 2025) have demonstrated the usefulness of GIS based multi criteria analysis for locating artificial recharge sites. Following these approaches, thematic layers such as lineament density, drainage density, geomorphology, slope, resistivity, depth, fractured zone thickness and land use and land cover were integrated to identify recharge favourable sites in the Kiliyar sub basin. The selection of suitable sites was based on the coincidence of specific conditions such as high lineament density, deeper buried pediments, thick fractured zones, slopes less than five degrees, and deeper water level zones, with flood plains and reaches containing 4th and 5th order drainage being particularly suitable for check dams. Percolation ponds and surface dams were found appropriate in low slope fractured zones, while deep aquifer replenishment through recharge wells was recommended in areas with high lineament density and major lineament buffered zones.

The integrated analysis of geophysical resistivity data and geospatial thematic layers revealed clear spatial variability in subsurface conditions and recharge potential across the Kiliyar Sub-Basin. Electrical resistivity sounding and ERT profiles consistently indicated a three-layered system consisting of a low resistivity topsoil, an intermediate resistivity weathered or fractured aquifer zone, and a high resistivity crystalline bedrock. The thickness and continuity of the second layer showed strong correlation with mapped lineaments and palaeochannel traces, confirming structural control on secondary porosity. These outcomes agree with recent resistivity-based groundwater studies demonstrating the reliability of resistivity and lithology correlations for managed aquifer recharge planning (Mishra *et al.*, 2023; Ali *et al.*, 2025). Further, GIS derived thematic layers showed that high recharge potential zones occurred predominantly in areas with low slopes less than five degrees, moderate drainage density, high lineament density, permeable soil textures, and extensive agricultural and fallow land cover, whereas built up surfaces contributed minimally to high suitability classes. The weighted overlay analysis integrating slope, geomorphology, soil, drainage density, lineaments, land use and land cover, depth to water table and resistivity derived transmissivity produced a final groundwater recharge suitability map with Very High and High classes concentrated along palaeo-channel corridors, tank linked depressions and floodplain tracts. This pattern is consistent with similar GIS based recharge studies that highlight the influence of geomorphology and structural features on recharge distribution (Zhang *et al.*, 2020; Levintal *et al.*, 2023).

The suitable sites identified for aquifer replenishment, where check dams, recharge wells, subsurface dams and percolation ponds are suggested based on terrain and hydrogeological conditions (Fig. 4). The geophysical results further show significant spatial heterogeneity where low resistivity zones correspond to saturated alluvium, weathered layers or clay rich deposits, indicating higher water holding capacity, while moderate to high resistivity zones reflect fractured hard rock or massive crystalline formations that may either facilitate infiltration or restrict it depending on the degree of fracturing. Normalization of all thematic layers was essential as each parameter was expressed in different units and ranges. Min. to max. or rank based normalization helped standardize values from zero to one or one to ten, enabling unbiased integration of heterogeneous datasets. Classes representing favorable recharge conditions such as low slope, permeable materials or fractured zones received higher normalized scores, while less favorable conditions received lower scores.

The geomorphology of the Kiliyar Sub-Basin (Fig. 3) includes buried pediments, valley fills, sedimentary lowlands and denudational hills, each exerting a strong influence on recharge behavior. Buried pediments and valley fills with weathered and permeable materials align with moderate to high recharge suitability classes, consistent with findings in crystalline terrains (Thapa *et al.*, 2017). In contrast, denudational hills, structural uplands and residual hills composed of massive crystalline rocks exhibit limited weathering and reduced permeability, contributing minimally to natural recharge. The spatial pattern of geomorphic units indicates that the central and western sectors of the basin are most favorable for artificial recharge structures. Land use and land cover analysis (Fig. 4) further shows agricultural fields and plantations supporting greater infiltration through irrigation induced recharge, consistent with Halder *et al.* (2021), whereas built up surfaces restrict infiltration and promote rapid runoff. Water bodies such as tanks and ponds serve as natural recharge points during monsoonal periods and align with favorable recharge zones. Structural characteristics from the lineament density map (Fig. 5) confirm that high lineament density regions represent fractured bedrock conducive for groundwater movement (Haridas *et al.*, 1998), with fracture intersections serving as ideal locations for recharge wells. Drainage density values ranging from zero to 2.93 km per square kilometer indicate that moderate drainage density enhances infiltration while preventing excessive channel incision (Ghayoumian *et al.*, 2007). Nearly half the basin lies in low slope classes less than five degrees that enhance infiltration by increasing residence time, while slopes greater than fifteen degrees promote rapid runoff and reduce recharge potential (Detty and McGuire, 2010).

Resistivity interpretation supports these findings, identifying low resistivity values between 10 and 50 Ωm indicating saturated alluvium, moderate values between 50 and 200 Ωm representing weathered or fractured rock, and high values above 200 Ωm corresponding to massive crystalline bedrock (Ebraheem *et al.*, 1997). Moderately low resistivity zones spatially correlate with

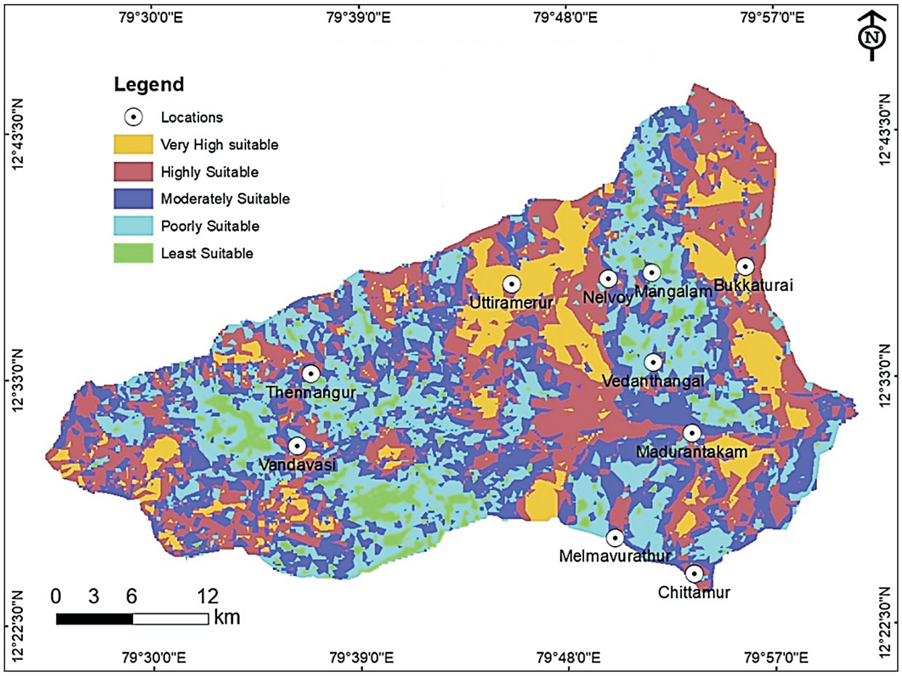

Fig.4. Normalized Weight Analyzed Classification of aquifer replenishment zones

buried pediments and valley fills, validating the thematic interpretations and strengthening confidence in the integrated recharge delineation. Integration through the Normalized Weighted Method (NWM) resulted in a Composite Suitability Index (CSI) map delineating five suitability classes from least to very high, with approximately 42% of the basin falling within the high and very high classes. Similar distributions have been reported in other GIS based recharge studies (Malmir *et al.*, 2022). Based on CSI zonation and terrain characteristics, check dams are recommended in moderate slope reaches intersecting 4th and 5th order streams, percolation ponds and surface dams in low slope alluvial tracts, recharge wells in deeper fractured zones, and subsurface dykes in local alluvial depressions.

Overall, the integration of GIS and geophysical analysis offers a scientifically robust and replicable approach for identifying recharge favorable sites in the Kiliyar Sub-Basin. The spatial coherence between thematic layers, resistivity signatures and predicted suitability classes demonstrates the strength of the integrated method, consistent with multi technique managed aquifer recharge studies that emphasize the superiority of combined surface and subsurface analysis (Mishra *et al.*, 2023). The concentration of favorable zones near traditional tank systems

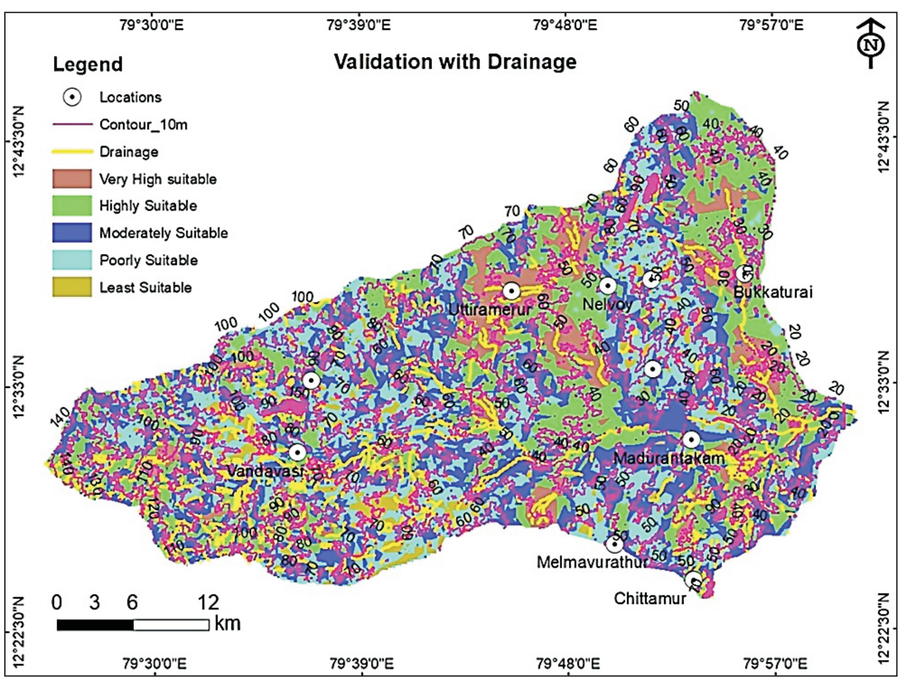

Fig.5. Validation of aquifer replenishment zones with drainages

aligns with regional observations across the Palar basin (Rafeek *et al.*, 2024). The long-term effectiveness of recommended structures such as check dams, percolation ponds, recharge wells and subsurface dykes depends on sediment load management, seasonal monitoring and community maintenance frameworks (Rafeek *et al.*, 2024; Levintal *et al.*, 2023). The findings therefore provide a strong scientific basis for groundwater resource enhancement and offer a replicable methodology for similar crystalline terrain watersheds in South India.

Validation

Thematic layers like geomorphology, land use / land cover, lineament density, slope, drainage density and geophysical data are considered for assessing the aquifer replenishment zones in the study area. Each theme has different importance in the context of determining the susceptible zones. The consideration of relative importance factors often leads to a better representation of the actual ground situation (Choudhury, 1999). A weight represents the relative importance of a parameter with respect to the objective. The ranks are assigned to each category of the thematic layer. The final output validated with the contour and drainage pattern for better accuracy (Fig.5).

Conclusions

The integrated approach adopted in this study, combining geophysical resistivity data with geospatial multi criteria analysis, proved effective in identifying and delineating suitable aquifer replenishment zones in the Kiliyar Sub-Basin. The resistivity measurements provided dependable subsurface information on groundwater bearing formations, while the GIS based integration of geology, geomorphology, slope, drainage density, land use and land cover, and lineament density enabled a systematic evaluation of recharge favorability. The composite suitability index shows that about 42% of the basin falls within the high and very high recharge categories, particularly in buried pediments, valley fills, and structurally fractured regions that support better infiltration and subsurface storage. The close agreement between the predicted recharge areas and the natural drainage and contour patterns confirms the reliability of the integrated model, demonstrating that coupling geophysical investigations with spatial analytical techniques significantly improves the accuracy and confidence of site selection for artificial recharge.

The resulting suitability zones provide a clear scientific basis for planning groundwater enhancement interventions, and the recommended structures such as check dams, percolation ponds, recharge wells, and subsurface dykes align well with the hydrogeological conditions of the basin. The findings align with observations from similar crystalline terrains and show that integrated geospatial and geophysical methods offer a practical and replicable framework for groundwater recharge assessment and decision making. This study contributes to sustainable groundwater management by providing actionable insights for planners, water resource departments, and local authorities, and future work may further strengthen the model by incorporating soil infiltration properties, seasonal groundwater fluctuations, and long-term climatic variability to refine the spatial prediction of recharge potential.

Authors' Contributions

GT: Conceptualization, Methodology, Software, Data curation, Formal Analysis Writing- Original draft preparation. **SGM:** Investigation, Conceptualization, Methodology, Writing - Original draft preparation, Revision, Supervision.

Conflict of Interests

The authors do not have any conflict of interest in terms of financial or personal relationship with a third party whose interests could be positively or negatively influenced by the article's content.

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