

Hydrogeological Investigation of groundwater potential in Salem region, India

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Abstract:

This study investigates groundwater potential in the Salem region, India, a semi-arid area facing water scarcity due to limited groundwater resources. A comprehensive hydrogeological approach was employed, integrating geological, hydrogeological, and remote sensing data to identify potential recharge zones and aquifers. Geological mapping and hydrogeological surveys characterized regional geology, hydrogeology, and flow regimes. Remote sensing techniques analyzed land use/land cover, lineaments, and geomorphological features. Analysis of groundwater level data, water quality, and aquifer properties defined the groundwater regime. Results indicate moderate to high groundwater potential in areas with favorable geological and hydrogeological conditions, particularly in valleys and low-lying regions, which are identified as potential recharge and development areas. The study also delineated zones of high groundwater vulnerability and contamination risk. These findings are crucial for policymakers and water resource managers to formulate sustainable groundwater management strategies. Recommendations include artificial recharge, rainwater harvesting, and conservation measures to ensure long-term groundwater viability.

Key words: Groundwater Potential, Salem Region, Hydrogeological Assessment, Recharge Zones, Water Scarcity

I. Introduction

The Salem region in India grapples with significant water scarcity due to its semi-arid climate and limited groundwater resources. Recognizing the critical need for sustainable water management, this study employs a comprehensive hydrogeological approach to investigate and delineate groundwater potential within the region. By integrating geological mapping, hydrogeological surveys, and remote sensing data, this research aims to identify promising recharge zones and potential aquifers. Furthermore, the analysis of groundwater level data, water quality, and aquifer properties provides a detailed understanding of the existing groundwater regime. The findings of this study are crucial for informing policymakers and water resource managers in their efforts to formulate effective strategies for long-term groundwater viability, including recommendations for artificial recharge, rainwater harvesting, and other essential conservation measures.

II. Literature review

Groundwater potential in semi-arid regions such as Salem is highly dependent on geological and climatic factors. Studies by [Muralitharan et al. (2016)] and [Ravi et al. (2020)] reveal that semi-arid zones possess limited recharge opportunities due to low precipitation and high evapotranspiration rates. These challenges are compounded by human-induced stressors such as population growth, unregulated groundwater extraction, and lack of spatial planning for water resources. Salem's unique

geological complexities, comprising crystalline basement rocks, limited primary porosity, and fragmentary secondary porosity, further limit water infiltration and storage.

Several researchers [Chandra et al., 2017; Singh et al., 2021] underscore the importance of comprehensive hydrogeological evaluations for identifying groundwater recharge zones and aquifers. However, they also highlight the lack of interdisciplinary approaches combining geological mapping, hydrogeological observation, and remote sensing.

The role of geology in groundwater distribution has been widely studied. [Krishnamurthy et al. (2020)] examined rock formations and lineaments in Tamil Nadu, including Salem. Their research demonstrated that areas with fractured rocks, such as gneiss and schist, exhibit better groundwater storage potential when overlapping with low-lying regions. Further, [Dhakate and Venkatesh (2019)] emphasize that landforms such as valleys and structural depressions often act as excellent groundwater repositories, while hill regions are typically water-deficient.

The juxtaposition of fractured crystalline formations and sedimentary aquifers in Salem complicates groundwater exploration. Several gaps exist regarding aquifer characterization, particularly in accurately distinguishing confined and unconfined aquifers, which are critical for evaluating storage potential. [Natarajan et al. (2022)] call for more advanced hydrogeophysical surveys utilizing resistivity and magnetic methods for precise aquifer delineation.

Chen, Tianci, et al. (2024) [8] The study introduces a highly autonomous banana-picking robot designed to improve efficiency and reduce labour costs in banana harvesting. Featuring an integrated end-effector and a YOLOv5s-based vision system, the robot achieved a detection precision of 99.23% and a picking success rate of 91.69%. Tested in multiple plantations, it demonstrated an average harvesting time of 33.28 seconds, highlighting its potential for future applications in the field. Zhu LiXue, et al. (2016) [9] This study describes the creation of a wheeling trolley intended for the safe transport of harvested bananas. The trolley features a frame made from Q235-A steel and a bottom frame measuring 1,200 mm × 800 mm. It operates at a speed of 0.7 m/s and can carry up to 450 kg, making it ideal for small-scale banana farming. Weixi Li et al. (2024) [10] This study proposes the design of a banana bunch transport device with an automated fruitshaft bottom-fixing system and a lifting mechanism, aimed at addressing the issues of high labour intensity, expense, and mechanical damage to banana fruit in orchards. With regard to banana bunch transportation in orchards, this study provides a useful and effective approach that has the potential to be widely adopted. The study was conducted with the following major objectives to analyse the development of banana bunch harvesters, to evaluate the performance of existing harvesting technologies and to explore challenges in adoption of mechanized harvesting

III. Methodology

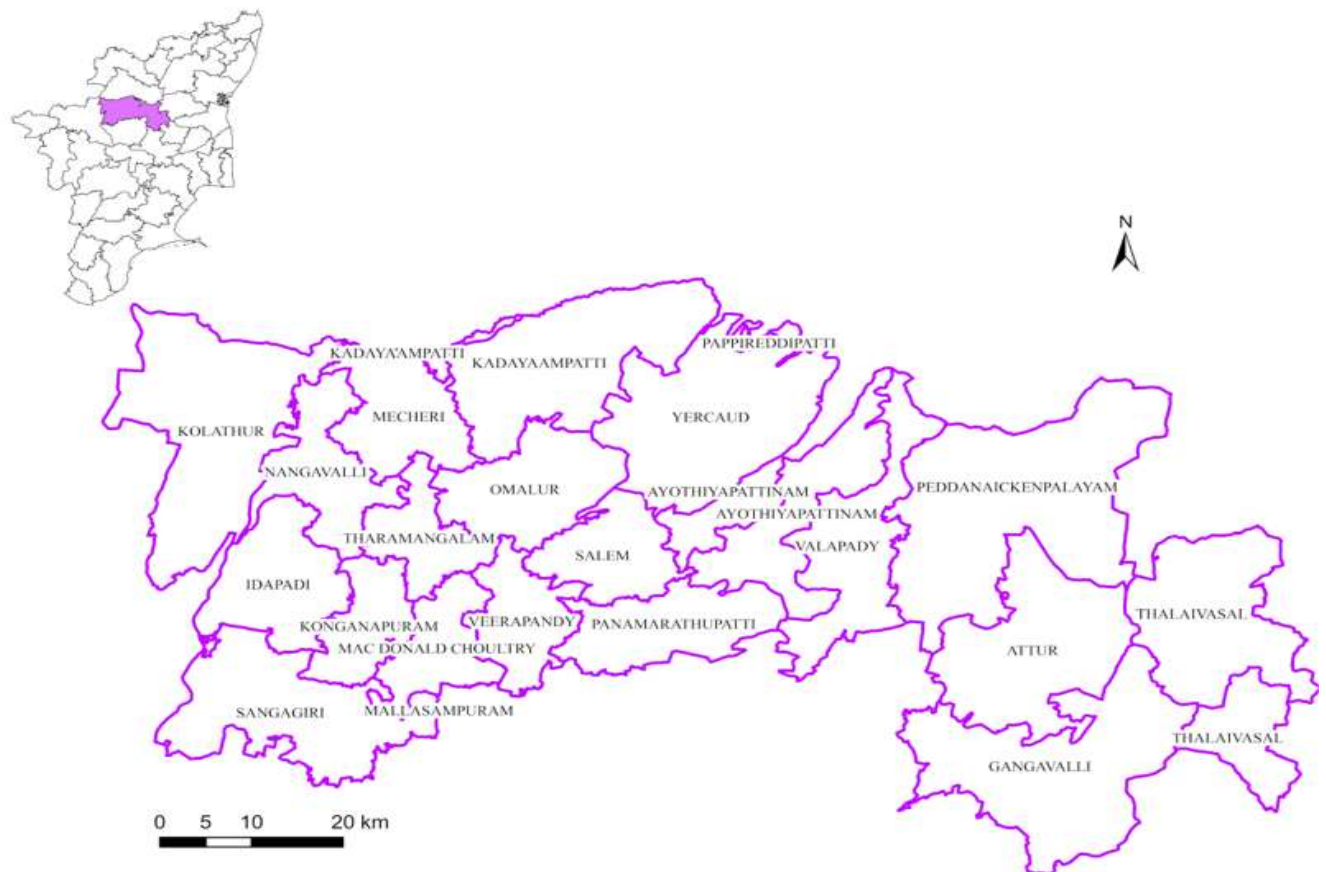


Data Acquisition and preparation

Study Area Characterization General

Salem District is situated in the north-western part of Tamil Nadu, India. Geographically, it lies between approximately 11° 14' and 12° 53' North Latitude and 77° 44' and 78° 50' East Longitude. The district encompasses a total geographical area of approximately 5,205 to 5,245 sq km. It is bounded by Dharmapuri District to the north, Namakkal and Trichy Districts to the south, Kallakurichi and Perambalur Districts to the east, and Erode District and the state of Karnataka to the west. The city of Salem, a major urban agglomeration, is located near the center of the district at coordinates around 11.65°N, 78.15°E. Administratively, the district is divided into several Revenue Divisions, Taluks (such as Salem, Attur, Mettur, Omalur, Sankari, Yercaud, Edappadi, etc.), Blocks/Firkas, and numerous Village

FIG 1. SALEM DISTRICT MAP



Topography and Geomorphology

The Salem region's physiography features undulating plains (average 278m elevation) surrounded by prominent hills like the Shevaroy Hills (over 1500m). Geomorphologically, it's shaped by erosion and structural processes on hard rock, creating:

- **Hills:** Elevated runoff zones (e.g., Shevaroy, Kanjamalai).
- **Pediments:** Sloping transition zones at hill bases.
- **Pediains:** Extensive, eroded plains crucial for groundwater, especially where deeply weathered.
- **Valley Fills/Colluvial Deposits:** Material accumulations in valleys, forming potential shallow aquifers.

This interplay dictates water flow from hills to plains, with flatter, weathered areas (pediplains, valley fills) and transitional pediments being key for water infiltration and groundwater recharge.

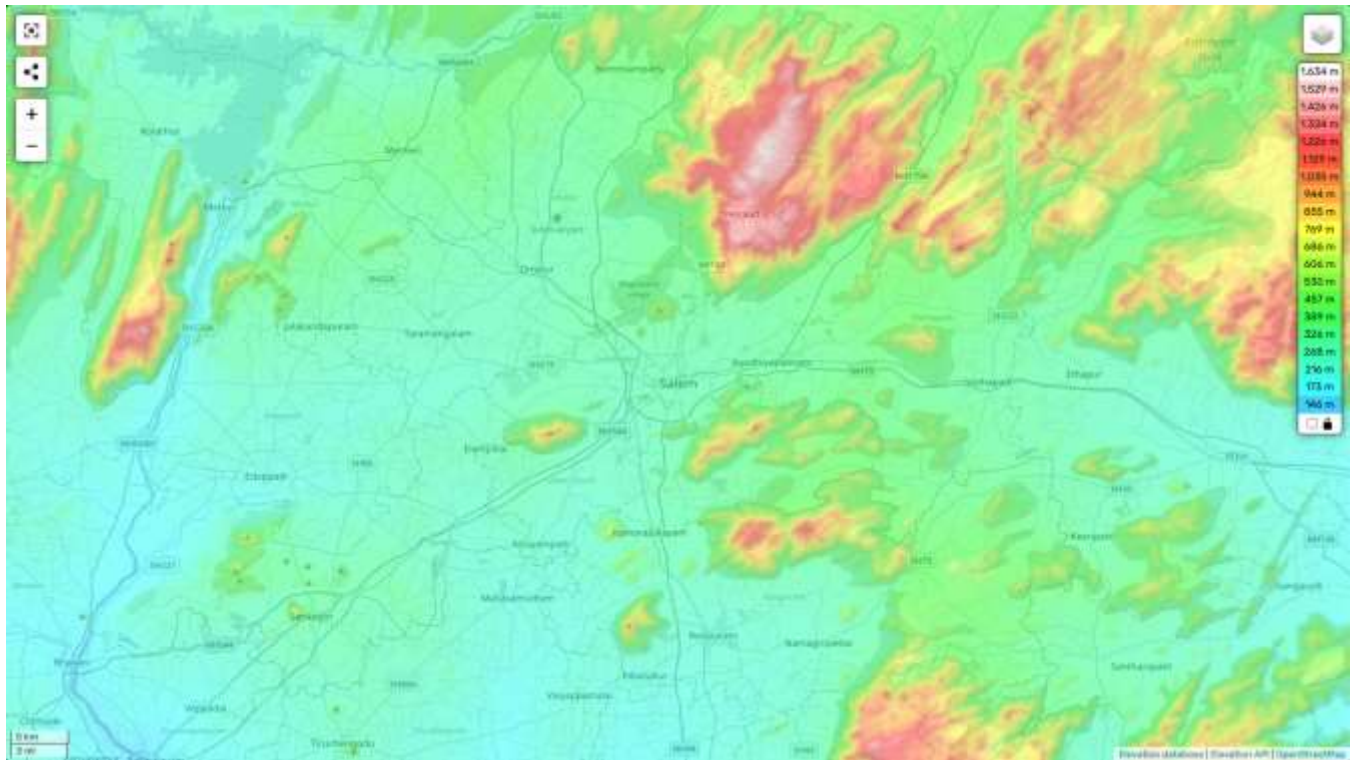
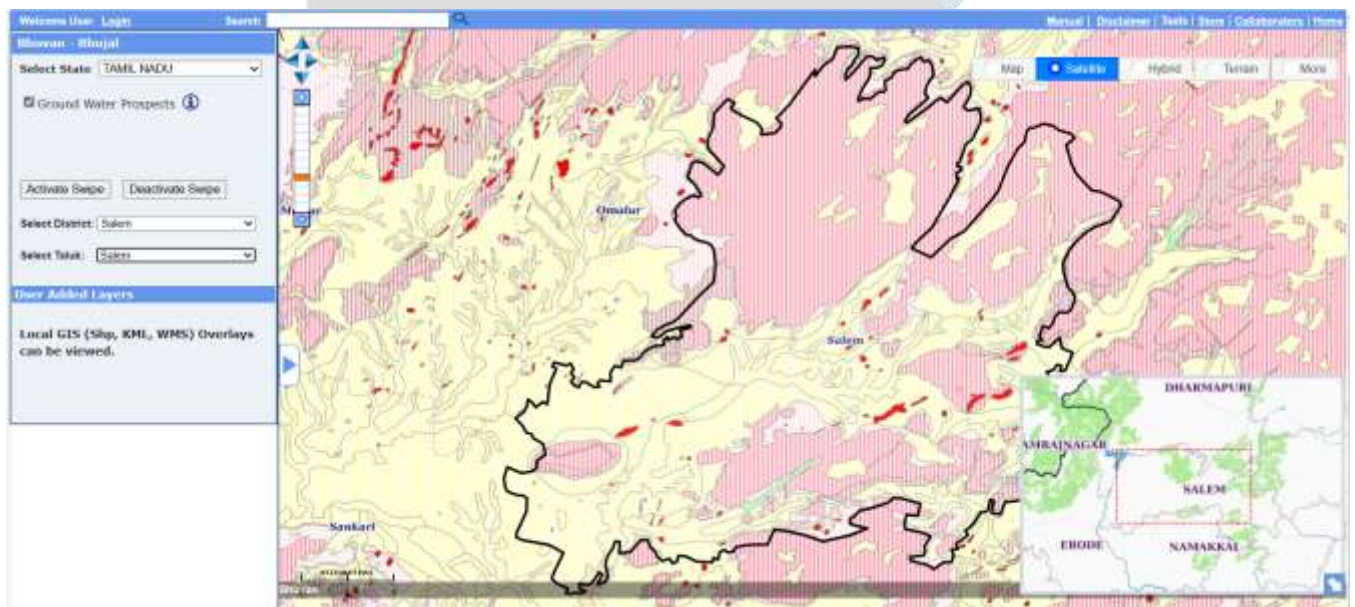
FIG 2. SALEM DISTRICT TOPOGRAPHY**FIG 3. SALEM DISTRICT GEOMORPHOLOGY**

Table 1 Summarizing the topography and geomorphology of the Salem district, based on the report:

Feature Type	Description	Reference Snippets
Overall Topography	Predominantly undulating terrain interspersed with prominent hill ranges (Nagaramalai, Jarugumalai, Kanjamalai, Godumalai, Shevaroy Hills). Average elevation of plains is ~278 m above mean sea level.	
Geomorphological Processes	Landforms shaped mainly by denudational and structural processes acting on hard rock terrain.	
Major Geomorphological Units		
Structural & Denudational Hills	Elevated portions (Shevaroy, Kanjamalai, etc.) acting primarily as runoff zones due to steep slopes and lower infiltration capacity.	
Pediments	Gently sloping surfaces at the foot of hills, often covered by eroded material; transition zones between hills and plains.	
Pediaplain	Extensive, gently undulating plains formed by erosion; significant areas for groundwater occurrence and recharge, especially where weathering is deep.	
Valley Fills / Colluvial Deposits	Accumulations of transported material along stream courses and in valleys; can form localized but potentially productive shallow aquifers.	

Climate and Rainfall Patterns

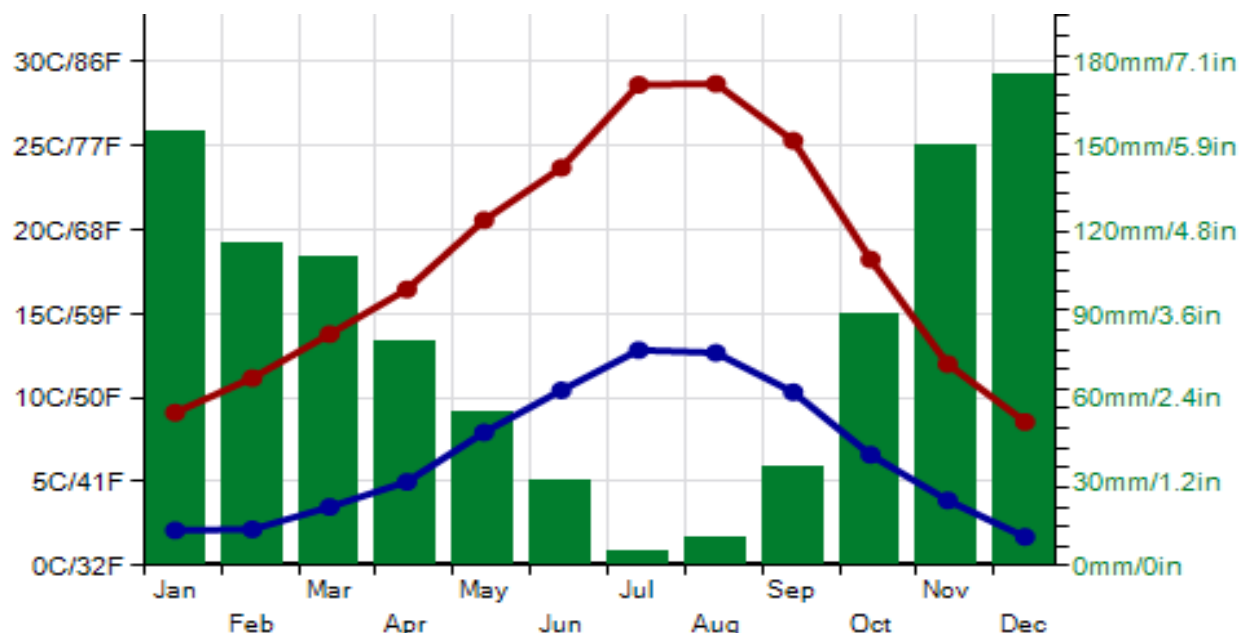
The Salem region has a semi-arid to tropical savanna climate, part of Tamil Nadu's North Western agro-climatic zone. It experiences hot temperatures year-round, except during monsoons, and relies heavily on seasonal rainfall.

Key climate aspects:

- **Rainfall:** The primary water source. Average annual rainfall varies (759 mm to 844 mm in some studies, with a district normal around 998 mm).
 - **Seasonal Distribution:** Dominated by the Northeast Monsoon (NEM, Oct-Dec, 40-48% of total) and the Southwest Monsoon (SWM, Jun-Sep, 33-40%). Summer and winter rainfall is scant.
 - **Variability:** Spatially variable due to topography (e.g., Attur Gap, rain shadow effects). The region can experience significant rainfall deficits and is prone to monsoon failures, leading to water scarcity and drought.
- **Temperature:** Generally high.
 - Mean daily maximums: 37-38°C (can exceed 40°C in summer, Mar-May).
 - Mean daily minimums: 19-25°C (coolest Dec-Feb).
 - High temperatures cause significant evaporation losses.
- **Water Resource Implications:** The semi-arid climate with high temperatures and concentrated monsoon rainfall limits natural groundwater recharge. Potential evapotranspiration often exceeds precipitation. Intense monsoon rainfall can lead to more runoff than infiltration. This, combined with high demand, makes the region vulnerable to water stress and contributes to groundwater over-exploitation.

Table 2 CLIMATE AND RAINFALL

Parameter	Value / Range	Period / Source Reference
Climate Type	Semi-Arid / Tropical Savanna	
Average Annual Rainfall	~ 998 mm (Normal)	(Note: Varies, e.g., 759-844 mm in studies)
Northeast Monsoon (Oct-Dec) Contribution	~ 40-48%	
Southwest Monsoon (Jun-Sep) Contribution	~ 33-40%	
Mean Daily Max Temp	~ 32-38 °C	
Mean Daily Min Temp	~ 19-25 °C	
Hottest Months	March - May	
Coolest Months	December - February	

FIG 4 GRAPH : RAINFALL IN SALEM FOR A YEAR

Drainage network and LULC

Drainage:

Salem district lies within the Cauvery and Ponnaiar river basins. The perennial Cauvery River forms its western and southern boundaries. Important tributaries originating in the district's hills (Shevaroy, Kollimalai, Chitteri) include the Sarabanga, Tirumanimuthar, Swetha, and Vasishta rivers. These internal rivers are monsoon-dependent, with flows mirroring seasonal rainfall. The drainage pattern is mainly dendritic. This reliance on seasonal rainfall for local surface water highlights the critical role of groundwater, especially during dry periods.

Land Use and Land Cover (LULC):

Salem's land use features a mix of agriculture, significant forest cover, and industrial activity.

- **Agriculture:** The dominant sector (30-43% of the population), with a net sown area of 1.9-2.2 lakh hectares. Key crops include food grains (Paddy, Cholam, Ragi, Maize), cash crops (Tapioca, Cotton, Sugarcane, Groundnut), and horticultural/plantation crops (Mango, Coffee in Yercaud).
- **Forests:** Cover about 1.25 lakh hectares (approx. 24% of the district), crucial for watershed protection and recharge.
- **Other Uses:** Include barren/uncultivable lands, non-agricultural lands (urban, rural, industrial), water bodies (rivers, tanks for irrigation/recharge), and fallow lands.
- **Industry:** Salem is known as the "Steel City" (Salem Steel Plant). Mettur is another industrial hub. Key industries include sago, textiles, cement, chemicals, mining (Magnesite, Bauxite, Iron Ore, Granite), and thermal power.

Water Resource Implications:

The combination of irrigated agriculture, industrial demand, and urban growth heavily pressures the limited groundwater. Irrigation (wells) is the largest groundwater user. Urbanization reduces natural infiltration, while agricultural and industrial/urban waste can threaten groundwater quality. Forest cover and water bodies like tanks can enhance recharge. This complex interplay presents challenges for managing Salem's groundwater.

FIG 5 DRAINAGE MAP SALEM

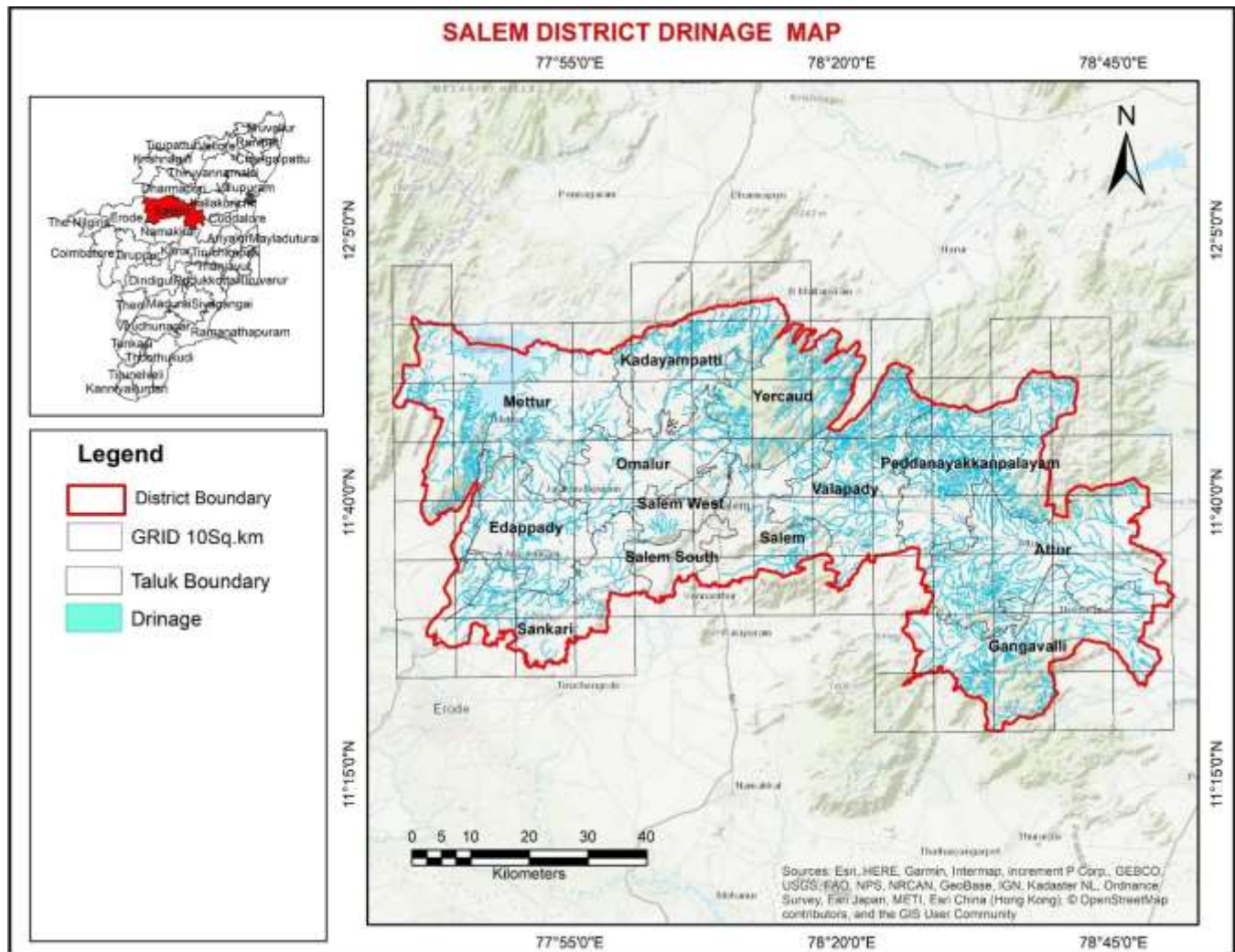
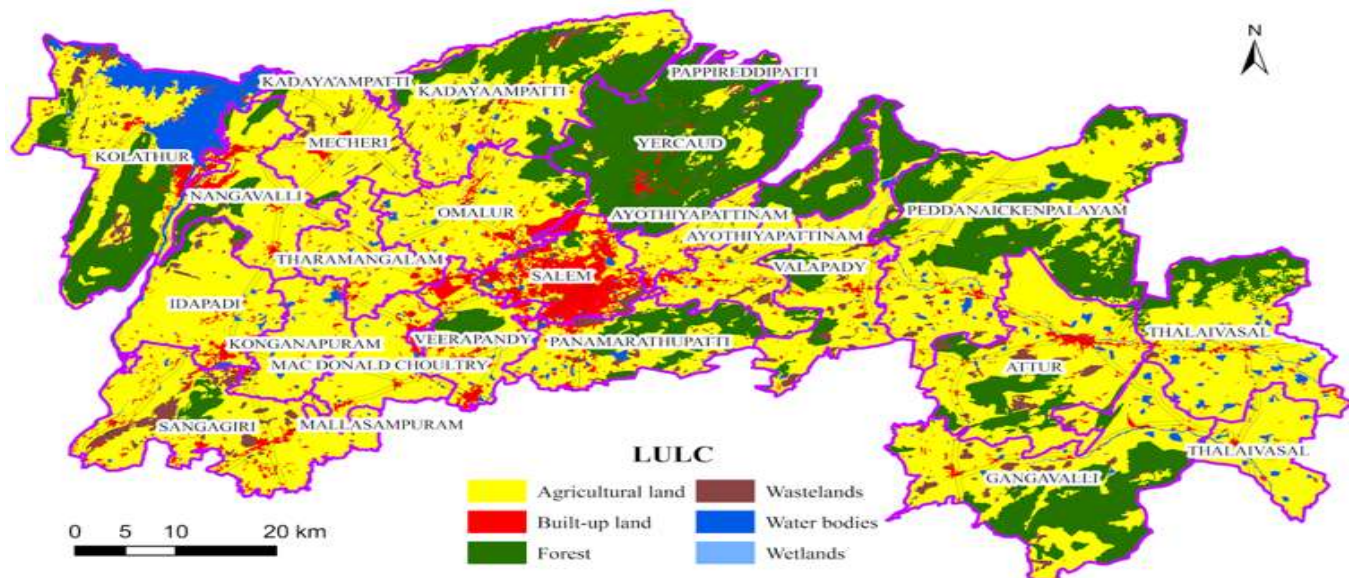


FIG 6 LAND USE AND LAND COVER (LULC) MAP



IV GROUNDWATER REGIME ANALYSIS

GROUNDWATER LEVEL DYNAMICS:

TABLE 3 Summary Of Groundwater Level Data (Ranges, Trends) For Salem District

Parameter	Period / Season	Typical Range (m bgl)	Average (m bgl) (TWAD, 2020-24)	Remarks	Source Reference Snippets
Depth to Water Level (DTWL)	Pre-Monsoon (May)	G.L. to ~15.0 (up to 11.46 in '06)	9.01 (5-yr avg)	Shallow wells (<12m) may dry. Levels vary year to year (6.00 - 12.05).	
DTWL	Post-Monsoon (Jan)	G.L. to ~17.15 (in '07)	6.33 (5-yr avg)	Significant recovery post-monsoon. Levels vary year to year (3.83 - 9.07).	
Seasonal Fluctuation	Annual	Several meters	~ 2.7 m (based on 5-yr avg)	Indicates strong dependence on monsoon recharge & dry season draft.	
Long-Term Trend	Decadal	Declining in North, West, Central	Up to ~0.8 m/year fall reported	Attributed to over-exploitation and monsoon failure.	

Note: m bgl = meters below ground level. G.L. = Ground Level. Ranges and averages derived from cited sources.

GROUNDWATER QUALITY ASSESSMENT

Table 4 Summary Of Groundwater Quality Parameters In Salem Region Vs. BIS 10500 Drinking Water Standards

Parameter	Unit	Observed Range in Salem Studies	BIS 10500 Desirable Limit	BIS 10500 Permissible Limit	Key Reference Snippets
pH	-	6.8 - 8.6	6.5 - 8.5	No Relaxation	
Electrical Conductivity (EC)	μS/cm at 25°C	210 - 6880 (up to 11550 reported for TDS)	-	-	
Total Dissolved Solids (TDS)	mg/L	124 - 4270 (up to 11550 reported)	500	2000	

Parameter	Unit	Observed Range in Salem Studies	BIS 10500 Desirable Limit	BIS 10500 Permissible Limit	Key Reference Snippets
Total Hardness (as CaCO ₃)	mg/L	75 - 2250	200	600	
Calcium (Ca ²⁺)	mg/L (or meq/L)	12 - 590 mg/L (or 1.2 - 9.9 meq/L)	75	200	
Magnesium (Mg ²⁺)	mg/L (or meq/L)	335 - 1385 mg/L? (error likely); 0.9 - 6.6 meq/L	30	100	
Sodium (Na ⁺)	mg/L (or meq/L)	7 - 840 mg/L (or 1.5 - 15.68 meq/L)	-	-	
Potassium (K ⁺)	mg/L (or meq/L)	5 - 258 mg/L (or 0.01 - 0.52 meq/L)	-	-	
Bicarbonate (HCO ₃ ⁻)	mg/L (or meq/L)	Variable (e.g., 2.6 - 9.9 meq/L)	-	-	
Chloride (Cl ⁻)	mg/L (or meq/L)	Variable (e.g., 2.1 - 17.8 meq/L)	250	1000	
Sulphate (SO ₄ ²⁻)	mg/L (or meq/L)	Variable (e.g., 45 - 372 mg/L; 0.02 - 0.85 meq/L)	200	400	
Fluoride (F ⁻)	mg/L	0.1 - 14.7	1.0	1.5	
Nitrate (as NO ₃ ⁻)	mg/L	1 - 588	45	No Relaxation	

GROUNDWATER RESOURCE STATUS

TABLE 5 Groundwater Resource Categorization For Salem Firkas (Based On 2024 Assessment Cited By TWAD)

Category	Stage of Extraction	No. of Firkas	Percentage of Firkas	Example Firkas
Over-Exploited	> 100%	34	77.3%	Alagapuram, Attur, Belur, Edappadi, Ernapuram, Gangavalli, Kadayampatti, Karippatti, Kattukkottai, Kondalampatti, Konganapuram, Malliyakarai, Mecheri, Mettur, Nangavalli, Omalur, Palamalai, Pethanaickanpalayam, Poolampatti, Pottaneri, Suramangalam, Salem Town, Sankari East, Sankari West, Semmandappatti, Thalaivasal

Category	Stage of Extraction	No. of Firkas	Percentage of Firkas	Example Firkas
Critical	90% - 100%	2	4.5%	Karupur, Panamarathuppatti
Semi-Critical	70% - 90%	3	6.8%	Mettur Town, Thevur, Karuppur (Note: Karuppur listed in both Critical & Semi-Critical in source, likely an error; listed here per Semi-Critical entry)
Safe	< 70%	5	11.4%	Arunoothumalai, Kalrayanmalai, Puthur(S), Vellakkadai, Yercaud Town
Saline	-	0	0.0%	-
Total		44	100.0%	

Source: citing 2024 assessment data.

V WEIGHTED OVERLAY AND AHP

Table 6 Influences and Weights of Thematic Layers and its Parameters

Thematic map	Parameter	Boolean Overlay Rank	Influence percentage	WIOA Rank	Fuzzy Logic Rank
Geology	Leptinite	1	13	4	0.80
	Gneiss	1		4	0.80
	Amphibolite	0		1	0.20
	Charnockite	1		3	0.60
	Alluvium	1		5	0.99
	Calcareous gneiss and lime stone	0		1	0.20
	Amphibole gneiss	0		1	0.20
	Dunite and magnesite	1		4	0.80
	Dolerite	0		1	0.20
	Trap shoten gneiss	0		1	0.20
Geomorphology	Hill plateau	0	26	1	0.20
	Composite slope	0		1	0.20
	Bazada zone	1		5	0.99
	Pediment	0		1	0.20
	Shallow pediment	0		1	0.20
	Buried pediment	1		4	0.80

	Structural hill	NA		NA	NA
Soil	Red in situ	1	20	4	0.80
	Red colluvial	1		5	0.99
	Black soil	0		1	0.20
	Brown soil	0		1	0.20
	Mixed soil	0		1	0.20
	Soil association	0		1	0.20
	Reserved forest	NA		NA	NA
	Mining area	0		1	0.20
	Built up land	1		2	0.40
Land use / Land cover	Water bodies	1	8	5	0.99
	Mining area	0		1	0.20
	Built up land	1		2	0.40
	Dense forest	NA	9	NA	NA
	Open forest	NA		NA	NA
	Crop land	1		4	0.80
	Scrub forest	1		2	0.40
	Gully land	1		4	0.80
	Land with scrub	0		1	0.20
	Land without scrub	1		2	0.40
	Fallow land	1		4	0.80
	Stony waste	0		1	0.20
Lineament density (km/km ²)	0-0.500	0	9	1	0.20
	0.500-1.000	1		2	0.40
	1.000-1.500	1		3	0.60
	1.500-2.000	1		4	0.80
	2.000-2.600	1		5	0.99
Drainage density (km/km ²)	0-0.600	1	6	5	0.99
	0.600-1.200	1		4	0.80
	1.200-1.800	1		3	0.60
	1.800-2.400	1		2	0.40
	2.400-3.000	0		1	0.20
Slope	45° - 87 °	0	18	1	0.20
	15 ° - 45 °	1		2	0.40
	3 ° - 15 °	1		3	0.60
	1 ° - 3 °	1		4	0.80
	0 ° - 1 °	1		5	0.99

Table 7 Validation of the Identified Groundwater Potential Zones

S.No	Village Name	Identified Groundwater Potential			Pumping Rate (GPM)	Evaluation
		Boolean Overlay	WIOA	Fuzzy Logic Model		
1	Vaikundam	Nil	Moderate	Moderate	poor	“+”
2	Reddiyur	Present	M to G	M to G	2.19	“+”
3	Ammapalayam	Present	M to G	M to G	2.19	“+”
4	Thumbipadi	Present	M to G	M to G	6.05	“+”
5	Vanavasi	Present	M to G	M to G	6.05	“+”
6	Uthankattuvalu	Present	M to G	M to G	6.05	“+”
7	A.kumarapalayam	Present	M to G	M to G	6.05	“+”
8	Gangavalli	Present	M to G	M to G	6.05	“+”
9	Kumarasamipatti	Present	M to G	M to G	6.05	“+”
10	Korimedu	Present	M to G	M to G	8.05	“+”
11	Semmankudal	Present	M to G	M to G	8.89	“+”
12	Naduvalur	Present	M to G	M to G	9	“+”
13	M.Kalipatti	Present	M to G	M to G	10	“+”
14	Karippatti	Present	M to G	M to G	10	“-”
15	Anuppur	Present	M to G	M to G	10	“+”
16	Thalaivasal	Present	M to G	M to G	10	“+”
17	Ulipuram	Present	M to G	M to G	12	“+”
18	Pakkaliyur	Present	M to G	M to G	12.4	“+”
19	Kattiyanur	Present	M to G	M to G	12.4	“+”
20	Kudumalai	Present	M to G	M to G	12.4	“+”
21	Pottaneri	Present	M to G	M to G	12.4	“+”
22	Edanganasalai	Present	M to G	M to G	12.4	“+”
23	Akkamapettai	Present	M to G	M to G	12.5	“+”
24	Modikadu	Present	M to G	M to G	16.7	“+”
25	Chandrapillaivalasu	Present	M to G	M to G	16.7	“+”
26	Veeranam	Present	M to G	M to G	16.7	“+”
27	Veerapandi	Present	M to G	M to G	21.7	“+”
28	T.Pudupalayam	Present	M to G	M to G	21.7	“+”
29	Chinna Agraharam	Present	M to G	M to G	21.7	“+”

30	Seernganur	Present	M to G	M to G	23	“+”
31	Muthampatti	Present	Good	Good	27.5	“+”
32	Irupali	Present	Good	Good	27.5	“-”
33	Magudanchavadi	Present	M to G	Good	27.5	“-”
34	Vavvalthoppu	Present	Good	Good	27.5	“+”
35	Seshenchavadi	Present	Good	Good	34.2	“+”
36	Kuppampatti	Present	M to G	Good	34.2	“-”
37	Kalleripatti	Present	Good	Good	35	“+”
38	Pethanaickenpalayam	Present	Good	Good	41.8	“+”
39	Anupoor	Present	Good	Good	41.8	“+”
40	Vilvanur	Present	Good	Good	50	“+”
41	Uthankarai	Present	Good	Good	56	“+”
42	Veergoundanur	Present	Good	Good	70.2	“+”
43	Chinnappampatti	Present	Good	Good	82	“+”

M to G – Moderate to Good

VI SUSTAINABLE GROUNDWATER MANAGEMENT

TABLE 9.1 Evaluation Of Artificial Recharge/Rainwater Harvesting Methods For Salem District

Method	Suitability for Salem Context	Potential Effectiveness	Cost Considerations	Key Limitations / Considerations
Check Dams / Gabions	High (Valleys, streams in undulating/hilly areas)	Localized recharge, erosion control; effectiveness depends on streambed permeability & flow duration	Moderate	Siltation requires maintenance; storage volume limited; impact mainly along stream course.
Percolation Tanks	High (Wider valleys, depressions with suitable geology)	Potentially significant recharge over larger area; depends heavily on site conditions (30-45% percolation in gneiss reported)	Higher	High siltation potential requiring regular desilting; evaporation losses; site-specific effectiveness varies greatly; land acquisition.
Recharge Shafts / Dug Well Recharge	Moderate (Areas with impermeable top layers or need for deeper recharge)	Can bypass low-permeability surface layers; directly targets aquifers	Moderate to High	Requires careful site selection & design; risk of contamination if source water quality is poor; clogging potential.
Subsurface Dykes	Moderate (Valleys)	Effective in raising	Higher	Requires detailed

Method	Suitability for Salem Context	Potential Effectiveness	Cost Considerations	Key Limitations / Considerations
	with significant subsurface flow)	upstream water table in valley fills		subsurface investigation; suitable geological conditions needed.
Contour Bunding / Trenching	High (Hill slopes, watershed treatment areas)	In-situ moisture conservation, reduces runoff & erosion; contributes to overall recharge	Lower	Primarily a soil/water conservation measure; direct recharge impact may be less quantifiable than storage structures.
Rooftop RWH	High (Urban areas, institutions, individual houses)	Provides direct water source or localized recharge; reduces runoff	Lower (per unit)	Requires individual adoption; storage/recharge capacity limited by roof area & rainfall; maintenance of filters needed.
Farm Ponds	High (Agricultural areas)	Provides supplemental irrigation; localized recharge	Moderate	Evaporation losses; requires farmer adoption & land; siltation.

VII. CONCLUSIONS AND RECOMMENDATIONS

Summary of Key Findings

This hydrogeological investigation of the Salem region reveals a groundwater system under significant stress, facing challenges related to both quantity and quality.

- **Severe Water Stress:** The region's semi-arid climate and predominantly hard rock geology limit natural recharge. Decades of intensive extraction for agriculture, industry, and domestic use have led to widespread over-exploitation, with over 80% of administrative units (Firkas) classified as 'Over-Exploited' or 'Critical', manifested in long-term declining water levels.
- **Localized Groundwater Potential:** Despite overall stress, moderate to high groundwater potential exists locally in zones with deeper weathered profiles, significant fracture/lineament density, valley fills, and pediplains. However, the hard rock aquifer system is highly heterogeneous.
- **Significant Quality Concerns:** Groundwater quality is a major issue. Geogenic Fluoride contamination is endemic. Anthropogenic Nitrate pollution from agricultural inputs and sewage is also widespread. High Salinity (TDS/EC) and Hardness further affect water suitability.
- **Aquifer Vulnerability:** Significant portions of the aquifer, particularly shallow and permeable zones, exhibit high intrinsic vulnerability to surface contamination. Overlap with intensive agriculture and unsewered settlements creates high pollution risks.
- **Need for Integrated Management:** Addressing Salem's groundwater challenges necessitates a multi-pronged, integrated approach focusing on supply augmentation, demand management, water quality protection, and robust governance.

Recommendations

Based on the findings, the following recommendations are proposed for sustainable groundwater management in the Salem region:

Resource Assessment & Monitoring:

1. **Enhance Monitoring & Characterization:** Strengthen the groundwater level and quality monitoring network, especially in high-potential, over-exploited, and vulnerable zones, including routine Nitrate and Fluoride analysis. Conduct targeted geophysical investigations in high-potential zones to map aquifer geometry and guide well/AR placement.

2. **Contaminant Hotspot Mapping:** Undertake detailed studies to map Fluoride and Nitrate contamination hotspots and investigate local hydrogeochemical controls and pollution sources.

Supply Augmentation:

3. **Targeted Recharge & Harvesting:** Strategically implement Artificial Recharge (AR) schemes (Check Dams, Percolation Tanks, Recharge Shafts) in scientifically selected locations. Vigorously promote Rooftop Rainwater Harvesting (RWH) and farm-level conservation.
4. **Maintain Recharge Structures:** Establish mechanisms for regular inspection and maintenance (especially desilting) of all AR structures.
- 4 Demand Management:
5. **Improve Agricultural Water Use:** Implement large-scale programs for micro-irrigation (drip, sprinkler) and support crop diversification towards less water-intensive options.
6. **Urban & Industrial Conservation:** Enforce water audits, promote water recycling/reuse, and reduce losses in municipal supply systems.
- 5 Quality Management:
7. **Ensure Safe Drinking Water & Control Pollution:** Prioritize safe drinking water provision in contaminated areas through alternative sources or treatment. Strictly enforce pollution control regulations for industrial and municipal discharges.
8. **Promote Agricultural Best Management Practices (BMPs):** Encourage soil-test-based fertilizer application, integrated nutrient management, and efficient manure management to minimize Nitrate leaching.

Policy & Governance:

9. **Strengthen Regulation & Integrated Planning:** Effectively implement groundwater abstraction regulations in stressed areas. Integrate groundwater potential and vulnerability maps into land use and agricultural development planning.
10. **Foster Participation & Awareness:** Support participatory groundwater management through local user associations. Conduct sustained awareness campaigns on conservation and efficient water use.
11. Implementing these recommendations requires a concerted effort from government agencies, research institutions, NGOs, and local communities, utilizing a long-term, adaptive management approach.

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