DYNAMICS OF GROUNDWATER UTILIZATION AND IRRIGATED CROPPING PATTERNS IN TAMIL NADU: AN ECONOMIC PERSPECTIVE

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ABSTRACT
Groundwater has become the most important source of irrigation in India fulfilling 62 per cent of the total irrigation area. Tamil Nadu's hydrology is unique in nature with the presence of two monsoons with little perennial river systems, which has gradually evolved into an irrigation system that is mostly dependent on borewells. The study analyses the trends in the use of groundwater and irrigated cropping patterns in Tamil Nadu during 2010-23. The information on secondary data (ground water depth) was taken from Central Ground Water Board (CGWB) Ground Water Year Books, and cropped area, production and yield data was taken from Directorate of Economics and Statistics (DES), Government of Tamil Nadu for 32 districts. Groundwater level data during pre-monsoon and post-monsoon period (2010-2023) has been analysed with data on irrigated areas for five crops like paddy, sugarcane, banana, coconut and groundnut. Temporal trend analysis was performed as total change (ΔGW) and average annual rate of change; comparative structural analysis of irrigated cropping pattern was undertaken as base triennium (2010–12) versus recent triennium (2021–23) comparison and a crop–groundwater linkage analysis was carried out by categorising districts based on whether they are depleting or improving. Groundwater level decreased by 1.47 m during pre-monsoon and 1.65 m during post-monsoon in the state, which shows net groundwater recovery. Of the 32 districts, 24 have shown improvement, and 8 have shown depletion. The total area of irrigated paddy, coconut, banana has increased and a sharp decrease in the area of sugarcane by 58.7 per cent. The CAGR of Tubewell irrigation was 3.59 per cent per annum. Based on the study, a set of recommendations are forwarded for the district to consider for crop water planning, promotion of micro-irrigation, realignment of agricultural support policies, and enhancing the governance of groundwater.

KEYWORDS: Crop–water linkage; Groundwater depletion; Irrigated cropping patterns; Tamil Nadu; Temporal trend analysis

INTRODUCTION
Agriculture is the backbone of Indian agriculture economy with about 17–18 per cent share in Gross Value Added and about 54 per cent of the total labour force is engaged in agriculture. Irrigation has a significant impact on cropping intensity, yield stability and farm income (1, 2). The widespread installation of private tubewells and borewells in the last 50 years, due to low-cost electricity for agricultural pump sets, better drilling technology and policy support has dramatically changed the irrigation scenario in India (3, 4). India is the world's largest groundwater extractor accounting for almost 25 per cent of global groundwater withdrawal and around 62 per cent of which is used for agricultural irrigation (5). The Central Ground Water Board (CGWB) assessment in 2022 revealed a sharp increase of over-exploited, critical and semi-critical assessment units and identified 1071 out of 6607 assessment units as over-exploited, critical and semi-critical, indicating a severe worsening of the ground water sustainability crisis (5-8). The case of Tamil Nadu is very instructive. Due to its southernmost position on the Indian peninsula, it is influenced by rainfall from both southwest monsoon (from June to September) and northeast monsoon (from October to December) patterns. Subsidized electricity, enhanced drilling equipment and progressive encroachment and deterioration of tank systems, in the post-independence era, led to a massive shift to groundwater irrigation especially in non-delta areas (9). In 2022-23, 63 per cent of the gross irrigated area of 29.20 lakh hectares was through wells of which 23.4 per cent was through canals and 13.7 per cent through tanks (10). The annual groundwater recharge in Tamil Nadu is 21.51 BCM and the groundwater extraction is 14.42 BCM, which is 73.9 per cent of the recharge. Some districts show exploitation levels greater than 100 per cent, which means that the exploitation situation is severe in specific pockets of the district (11, 12). Groundwater availability and irrigated cropping patterns are complex, two-way relationships (2, 13, 14). The choice of cultivation such as use of borewells for crops like sugarcane (requiring 2,000-2,500mm per cycle) and paddy (requiring 1200-1500mm per season), has a strong influence on the groundwater abstraction rate. Therefore, it is vital to understand the crop groundwater linkage at the district level for designing policies that encourage

sustainable use of available groundwater (15). The study aims at conducting the systematic temporal and spatial analysis of the groundwater utilisation and irrigated cropping pattern in Tamil Nadu during 2010-2023 to provide empirical insights for the districts of Tamil Nadu to aid in evidence-based water and crop management policy. The aim of the present study is to: (i)Trace the temporal variations of groundwater in Tamil Nadu district wise for the period of 2010 to 2023. (ii) To analyse the changes occurred in the cropping pattern of the irrigated land in the districts over time in Tamil Nadu during the study period. (iii) To examine the district level linkages among cropping systems and growth trends or status of groundwater.

MATERIALS AND METHODS

The present study was conducted for the state of Tamil Nadu, located on the southeastern coast of the Indian peninsula between 8°4' N and 13°35' N latitude and 76°15' E and 80°20' E longitude. Tamil Nadu covers a geographical area of approximately 1,30,058 sq. km., comprising 38 districts spanning diverse agro-climatic zones, from the humid Cauvery delta tracts in the east and northeast to the semi-arid interior and western districts. The gross irrigated area of the state in 2022–23 was 29.20 lakh hectares. For analysis, all 32 districts with continuous groundwater level monitoring data available from the CGWB for 2010–2023 were included; the remaining districts were excluded due to incomplete monitoring records (5, 10, 11).

The study is based entirely on secondary data from official published sources. District-wise pre-monsoon (March–May) and post-monsoon (October–November) groundwater depth data were compiled from CGWB Groundwater Year Books for 32 districts over 2010–2023. Irrigated area data for five major crops like paddy, sugarcane, banana, coconut and groundnut were drawn from Season and Crop Reports published by the Directorate of Economics and Statistics (DES), Government of Tamil Nadu. Irrigation source data (canals, tanks, open wells, tubewells) were also compiled from the same reports. The five crops were selected because they collectively account for the majority of the state's irrigated area and span a wide range of water use intensities.

The gross irrigated area of the state in 2022–23 was 29.20 lakh hectares, of which wells and borewells accounted for approximately 63 per cent, canals for 23.4 per cent, and tanks for 13.7 per cent (DES, Tamil Nadu, 2023). This irrigation profile makes Tamil Nadu one of the most groundwater-dependent irrigated agricultural economies in India. For the purposes of the present study, all 32 districts for which continuous groundwater level monitoring data were available from the Central Ground Water Board (CGWB) for the period 2010 to 2023 were included in the analysis. The remaining districts including some newly carved districts were excluded due to incomplete or non-continuous monitoring records. The 32 study districts cover all major agro-climatic zones of the state, span both groundwater-dominated and surface-water-dominated irrigation regimes and collectively account for the bulk of the state's irrigated crop area, making them representative of Tamil Nadu's irrigation economy as a whole (5, 10).

Analytical Framework

The study employed three complementary analytical methods to address the three objectives. The analytical framework proceeds from temporal trend analysis of groundwater levels to comparative structural analysis of irrigated cropping patterns and finally to a crop groundwater linkage analysis that integrates the findings of the first two analyses.

Temporal Trend Analysis of Groundwater Levels

To trace district-wise groundwater temporal trends, a longitudinal trend analysis was conducted using district-wise pre-monsoon and post-monsoon groundwater depth (metres below ground level, m bgl) data for the period 2010 to 2023. Two composite seasonal indicators were computed for each district in each year using the following expressions:

$\mathrm{Pre-Monsoon\ Groundwater\ Depth\ (PreM_t)} = (\mathrm{Mar_t} + \mathrm{Apr_t} + \mathrm{May_t}) / 3$ .. (Eqn. 1)

$\mathrm{Post-Monsoon\ Groundwater\ Depth\ (PostM_t)} = (\mathrm{Oct_t} + \mathrm{Nov_t}) / 2$ …… (Eqn. 2)

where:

$\mathrm{Mar_t}$, $\mathrm{Apr_t}$, $\mathrm{May_t}$ = groundwater depth observations (m bgl) for March, April, and May respectively in year t

$\mathrm{Oct_t}$, $\mathrm{Nov_t}$= groundwater depth observations (m bgl) for October and November respectively in year t

It is important to note that in the measurement convention adopted by the CGWB, groundwater depth is expressed as metres below ground level (m bgl), meaning that a higher numerical value indicates a deeper and therefore more depleted water table. Consequently, a decrease in m bgl over time indicates recovery (shallower water table) and an increase indicates depletion (deeper water table) (5).

The total change in groundwater depth over the study period was computed as:

$\Delta\mathrm{GW} = \mathrm{GW_{2023}} - \mathrm{GW_{2010}}$ ……………….. (Eqn.3)

where:

ΔGW = net change in groundwater depth (m bgl) over the study period

$\mathrm{GW_{2023}}$ = groundwater depth (m bgl) in the terminal year 2023

$\mathrm{GW_{2010}}$= groundwater depth (m bgl) in the base year 2010

A negative value of ΔGW indicates that the water table has risen (become shallower), signifying groundwater improvement or aquifer recovery, while a positive value of ΔGW indicates that the water table has deepened, signifying groundwater depletion. The average annual rate of change was computed by dividing the total change by the number of years in the study period (13 years):

$\text{Annual Rate of Change} = \Delta\text{GW} / 13$ (m bgl per year) …… (Eqn. 4)

Based on the sign of ΔGW computed from the pre-monsoon groundwater depth series, each of the 32 study districts was classified into one of two groundwater trend categories: Improvement (ΔGW change than 0) or Depletion (ΔGW greater than 0). This classification forms the basis for the crop–groundwater linkage analysis.

Comparative Structural Analysis of Irrigated Cropping Patterns

To analyse changes in irrigated cropping patterns, a comparative structural analysis was conducted by comparing two triennia — a base triennium (2010–11 to 2012–13) and a recent triennium (2021–22 to 2022–23) for each of the five selected crops across all 32 study districts. The use of triennia rather than single years smooths year-to-year variability driven by monsoon performance or market fluctuations and provides more robust estimates of structural change. For each crop, the average irrigated area over the base triennium and recent triennium was computed, and the following indicators were derived:

Absolute Change in Irrigated Area:

$\Delta\text{Area} = \text{Area}_{21+22+23} - \text{Area}_{10+11+12}$……………….. (Eqn. 5)

where:

Δ Area = absolute change in irrigated area (hectares) between the recent and base triennia

$\text{Area}_{21+22+23}$= average irrigated area (ha) in the recent triennium (2021–22 to 2022–23)

$\text{Area}_{10+11+12}$= average irrigated area (ha) in the base triennium (2010–11 to 2012–13)

Compound Annual Growth Rate:

In addition to the triennia comparison, Compound Annual Growth Rates (CAGR) were computed for the irrigated area of each crop, for the total gross irrigated area and for the irrigated area under each irrigation source (canals, tanks, open wells, and tubewells) over the full study period using the standard formula:

$Y = ab^t$………. (Eqn. 6)

Taking natural logarithms: $\ln(Y_t) = \ln(a) + bt$………. (Eqn.7)

where:

Y = Variable (e.g., groundwater level, irrigated area)

t = Time (year)

b= Estimated growth coefficient

The Compound Annual Growth Rate (CAGR) is then calculated from the estimated coefficient as:

$\text{CAGR} = (e^b - 1) \times 100$……… (Eqn.8)

Crop–Groundwater Linkage Analysis

To examine the linkages between cropping systems and groundwater trends, a crop–groundwater linkage analysis was undertaken by cross-classifying districts according to their groundwater trend status and examining the direction of crop area change within each groundwater trend category. This structured cross-classification reveals whether districts experiencing groundwater depletion are characterised by different crop area change patterns compared to districts recording groundwater improvement, thereby establishing empirical linkages between the two dimensions. Table 1 indicates the groundwater change indicator (ΔGW) computed from the pre-monsoon groundwater depth series was used to classify districts as follows

For each groundwater trend category, the number of districts recording expansion and contraction in irrigated area for each of the five study crops was tabulated and compared. A co-movement analysis was then conducted to assess whether, across districts, the direction of crop area change was associated with the direction of groundwater change. Specifically, districts where water-intensive crops (paddy and sugarcane) expanded alongside worsening groundwater levels were identified as exhibiting a high-pressure crop–water linkage, while districts where these crops contracted alongside improving water levels were identified as exhibiting a potential sustainability transition(16-18). In addition, a classification of districts by irrigation source dominance was constructed to provide a structural backdrop for the linkage analysis. Table 2 classifies the districts into five categories based on the share of each irrigation source in total gross irrigated area.

RESULTS AND DISCUSSION

Temporal Trends in Groundwater Levels in Tamil Nadu (2010–2023)

Figure 1 depicts the temporal analysis of pre- and post-monsoon groundwater depth for Tamil Nadu over the period 2010 to 2023 reveals a clear pattern of three distinct phases. During 2010–2012, groundwater levels were relatively moderate and stable, with pre-monsoon depth averaging around 6.56 m bgl and post-monsoon depth at 6.34 m bgl. Between 2013 and 2019, groundwater depth increased substantially, reaching a peak pre-monsoon value of approximately 9.50 m bgl in 2019, indicating intensifying extraction pressure during this period. From 2020 to 2023, a notable recovery was observed, with pre-monsoon depth declining to 5.08 m bgl and post-monsoon depth to 4.67 m bgl by 2023. The aggregate change and annual rate of change in groundwater depth over the study period are presented in Table 3.

The total change in pre-monsoon groundwater depth was −1.47 m (annual rate: −0.10 m/year), and the total change in post-monsoon depth was −1.65 m (annual rate: −0.11 m/year). The negative sign of ΔGW indicates that water tables have become shallower that is, closer to the surface over the study period, signifying net aquifer recovery at the state level. Post-monsoon recovery is marginally stronger (−1.65 m) than pre-monsoon recovery (−1.47 m), suggesting that seasonal monsoon recharge has been relatively more effective in recent years, likely supported by better rainfall in the 2020–2023 period and the partial contraction of water-intensive crops such as sugarcane. These state-level averages, however, mask substantial spatial heterogeneity across districts. The district-wise trend classification, based on pre-monsoon ΔGW, reveals that 24 out of 32 study districts recorded improvement (shallower water tables) between 2010 and 2023, while 8 districts experienced depletion (deeper water tables). This spatial distribution is presented in Figure 2, which shows the magnitude of ΔGW for the 8 depletion districts and a representative subset of 10 of the 24 improvement districts.

Among the 8 depletion districts, Vellore recorded the highest depletion with ΔGW of +1.82 m, followed by Salem (+1.54 m), Sivagangai (+1.31 m), Namakkal (+1.18 m), Tiruchirappalli (+0.95 m), Dindigul (+0.88 m), Coimbatore (+0.72 m), and Karur (+0.61 m). These districts are predominantly located in the groundwater-dominated interior and western zones of Tamil Nadu, where borewell-based irrigation is intensive and natural recharge through hard-rock aquifers is limited. In contrast, the 24 improvement districts include both delta districts, where surface water irrigation has historically been dominant and groundwater extraction pressure is relatively lower and several non-delta districts that have experienced reductions in water-intensive crop cultivation over the study period. Among the improvement districts, Tiruppur (−3.42 m) and Villupuram (−2.98 m) recorded the highest magnitudes of improvement, reflecting substantial reductions in groundwater depth over the study period.

Changes in Irrigated Cropping Patterns in Tamil Nadu (2010–2023)

The comparative analysis of irrigated crop area between the base triennium (2010–11 to 2012–13) and the recent triennium (2021–22 to 2022–23) reveals significant structural shifts in Tamil Nadu's irrigated agriculture. Table 4 presents the absolute change and percentage growth in irrigated area for the five study crops at the state level. Figure 3 provides a visual summary of the direction and magnitude of these changes in the irrigated crops.

Irrigated paddy area recorded the largest absolute expansion, increasing by 4,79,218 ha (+31.0 per cent) between the two triennia. This expansion reflects the continued importance of paddy as the primary food crop of Tamil Nadu and the spread of groundwater-based paddy cultivation to non-traditional growing districts (19). Coconut cultivation expanded by 82,066 ha (+22.8 per cent), reflecting the growing importance of perennial horticultural plantations in groundwater-dominated districts such as Tirupur, Thanjavur, and Erode. Banana cultivation recorded a moderate expansion of 17,029 ha (+16.8 per cent), with Erode (+9,758 ha), Villupuram (+5,235 ha) and Tiruvannamalai (+4,659 ha) being the leading districts. Groundnut area expanded modestly by 7,500 ha (+5.4 per cent), with mixed trends across districts 17 districts recording expansion and 21 recording contraction.

In contrast, irrigated sugarcane area declined by 1,97,798 ha (−58.7 per cent) between the two triennia, representing the most dramatic structural change in Tamil Nadu's irrigated crop composition over the study period. This contraction was widespread, affecting 28 of the 32 study districts. Villupuram recorded the largest absolute decline (−62,300 ha), followed by Tiruvannamalai (−25,047 ha), Cuddalore (−18,519 ha) and Dharmapuri (−15,492 ha). Only 10 districts recorded any expansion in sugarcane area, the largest being Tirunelveli (+2,544 ha) and Coimbatore (+2,066 ha). The district-wise changes in paddy and sugarcane area are presented in Figure 4. The contraction of sugarcane is attributable to multiple converging factors. First, rising groundwater extraction costs driven by increasing pump depths and energy inputs have eroded the profitability of sugarcane cultivation in many non-delta districts. Second, delayed payments and pricing disputes between sugarcane farmers and sugar mills have reduced the attractiveness of this crop. Third, the availability of alternative commercial crops such as banana and coconut, which offer comparable or higher returns at lower water use intensities, has induced farmers to diversify away from sugarcane (16, 17, 19, 20).

Compound Annual Growth Rates of Irrigation Sources and Crop Variables

To provide a dynamic perspective on the structural transformation of irrigated agriculture in Tamil Nadu, Compound Annual Growth Rates (CAGR) were computed for major irrigation sources and irrigated crop variables over the full study period (2010–11 to 2022–23). The results are presented in Figure 5

Among irrigation sources, tubewell-irrigated area recorded the highest CAGR of +3.59 per cent per annum, substantially outpacing canal (+1.02%) and open well (+1.22%) growth rates. This confirms the deepening structural dependence on borewell-based irrigation in Tamil Nadu's agricultural economy. Tank-irrigated area declined at −1.19 per cent per annum, reflecting the continued deterioration and encroachment of traditional tank systems and the progressive displacement of tank irrigation by borewells, particularly in districts such as Vellore, Kancheepuram, and Ramanathapuram. The total groundwater irrigated area (wells and borewells combined) grew at a CAGR of +1.90 per cent, while the gross irrigated area across all crops and sources grew at the highest rate of +6.20 per cent, indicating a broad expansion of irrigated agriculture in the state during the study period.

Among the irrigated crop variables, coconut recorded the highest positive CAGR (+2.99%), followed by paddy (+2.18%) and banana (+1.29%). Sugarcane was the only crop to record a negative CAGR of −2.63 per cent per annum, consistent with the large absolute and percentage decline. The positive CAGR of tubewell-based irrigation alongside the positive CAGR of coconut and paddy cultivation provides quantitative support to the hypothesis that Tamil Nadu's irrigated agriculture is simultaneously expanding in area and shifting its composition toward crops that can be sustained under borewell irrigation over the medium to long term. The declining CAGR of sugarcane, on the other hand, signals a partial unwinding of the high-extraction cropping pattern that characterized the state's non-delta districts during the 2000s and early 2010s.

Crop–Groundwater Linkage Analysis

To examine the empirical association between cropping systems and groundwater dynamics at the district level, a crop–groundwater linkage analysis was conducted by cross classifying the 32 study districts by their groundwater trend status (depletion vs. improvement) and examining the direction of crop area change (expansion vs. contraction) within each category. Figure 6 provides a comparative visual representation of crop area change patterns across the two groundwater trend categories.

The linkage analysis reveals several important patterns.

(i)In groundwater depletion districts, paddy, banana and coconut continued to expand in the majority of cases paddy in 4 out of 8 districts, banana in 5 and coconut in 6 indicating that irrigated crop expansion has not been effectively moderated by groundwater stress in these regions. Farmers in depletion districts appear to have deepened their borewells and continued irrigation-intensive cultivation rather than shifting to less water-demanding crops, reflecting the persistence of economic incentives and the absence of effective demand-side restrictions on groundwater extraction.

(ii) Sugarcane cultivation has contracted substantially even in groundwater depletion districts only 2 out of 8 depletion districts recorded any sugarcane expansion, while 6 recorded contractions. This suggests that sugarcane withdrawal in Tamil Nadu is not primarily driven by groundwater conservation behaviour but rather by economic factors such as unfavourable farm-gate prices, mill payment delays, and the availability of more remunerative crop alternatives. In this sense, the contraction of sugarcane represents an economically driven, rather than ecologically driven, structural adjustment in the irrigated cropping system (16, 17).

(iii) In groundwater improvement districts, the pattern is broadly consistent with the state-level trends in paddy, banana, and coconut have expanded in the large majority of districts (17, 17, and 19 respectively), while sugarcane has contracted in 19 out of 24 districts. The strong co-movement between groundwater improvement and sugarcane contraction in these districts provides some empirical support for the hypothesis that reduced water-intensive crop cultivation contributes to aquifer recovery, though the causal direction cannot be conclusively established from the present analysis, as improved rainfall conditions during 2020–2023 may also have contributed to both trends simultaneously (21, 22).

CONCLUSION

This study examined groundwater dynamics and irrigated cropping patterns across 32 districts of Tamil Nadu over 2010–2023 using temporal trend analysis, structural comparison of irrigated area, and a crop–groundwater linkage framework. At the state level, groundwater conditions recorded a net improvement, with pre-monsoon and post-monsoon depths declining by 1.47 m and 1.65 m, respectively, over the study period. However, 8 districts—predominantly in the hard-rock aquifer zones of the interior and western regions—continued to experience groundwater depletion, underscoring the spatial heterogeneity of aquifer recovery. The structural analysis revealed a contraction of sugarcane cultivation across the state, an expansion of paddy, coconut, and banana, and a growing dependence on borewell-based irrigation alongside a declining share of tank irrigation. The crop–groundwater linkage analysis provides partial empirical support for a co-movement between sugarcane contraction and groundwater improvement, while also highlighting the persistence of irrigation-intensive cropping in depletion districts. Overall, Tamil Nadu's irrigated agriculture is undergoing a gradual structural realignment, yet the sustainability of its groundwater-dependent irrigation economy remains incomplete and fragile, necessitating targeted policy interventions aligned with district-level aquifer conditions

Policy Implications

The findings carry important policy implications for sustainable groundwater and agricultural management in Tamil Nadu. First, the District-specific crop–water planning frameworks should be developed for the 8 groundwater depletion districts, promoting water-efficient crops such as millets, pulses, and short-duration vegetables through differentiated input subsidies, guaranteed procurement prices, and market linkage support.

Second, Tiered or time-of-day electricity pricing for agricultural pump sets, combined with transparent groundwater monitoring and farmer awareness campaigns, should be introduced in over-exploited blocks to reduce excessive extraction, leveraging the Atal Bhujal Yojana (ABY) framework for implementation.

Third, Micro-irrigation adoption—particularly drip and sprinkler systems for coconut, banana, and sugarcane—should be accelerated under the Tamil Nadu Micro Irrigation scheme and Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), Per Drop More Crop (PDMC), prioritising groundwater-dominated districts with streamlined subsidy disbursement and post-installation monitoring (14, 21, 22).

Agricultural support policies—including Minimum Support Prices, crop insurance, and institutional credit—should be extended to low water-use crops such as pulses, groundnut, and minor millets in depletion districts, to provide the economic security required for farmers to shift away from water-intensive cropping without bearing excessive income risk.

Automated groundwater monitoring should be expanded to all critical and semi-critical blocks, with data made publicly accessible at district and block level. Periodic groundwater resource assessments should be updated more frequently, and the implementation capacity of the Tamil Nadu Ground Water Authority (TNGWA) and panchayat-level institutions should be strengthened for effective local-level governance of borewell regulation (12, 23).

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Table 1. Classification of Districts by Groundwater Trend Status

Condition	Category	Interpretation
ΔGW less than 0	Improvement	Net aquifer recovery over the study period; extraction pressure easing
ΔGW more than 0	Depletion	Net aquifer declines over the study period; extraction pressure increasing
ΔGW ≈ 0 (change < ±0.5 m bgl)	Stable	Water table broadly unchanged; no net depletion or recovery

***m bgl –** meters below ground level

Table 2. Classification of Districts by Irrigation Source Dominance

Condition	Category
Groundwater share (wells + borewells) more than 70% of gross irrigated area	Groundwater Dominated (GW)
Groundwater shares 40–70% of gross irrigated area	Groundwater–Surface Water Mixed (GWDSW)
Surface water share (canals + tanks) more than 70% of gross irrigated area	Surface Water Dominated (SW)
Total gross irrigated area negligible relative to gross cropped area	Rainfed Dominated (RF)

Table 3. State-level Change in Groundwater Depth, Tamil Nadu (2010–2023)

Indicator	Pre-Monsoon (Mar–May)	Post-Monsoon (Oct–Nov)
Base Year Depth — 2010 (m bgl)	6.56	6.34
Terminal Year Depth — 2023 (m bgl)	5.08	4.67
Total Change ΔGW (m)	−1.47	−1.65
Annual Rate of Change (m/year)	−0.10	−0.11
Trend Classification	Improvement (ΔGW less than 0)	Improvement (ΔGW less than 0)

***m bgl –** meters below ground level

Table 4. Change in Irrigated Crop Area, Tamil Nadu

Crop	Base Triennium Avg. Area (ha)	Recent Triennium Avg. Area (ha)	Δ Area (ha)	Percentage Growth	Trend
Paddy	15,45,865	20,25,083	+4,79,218	+31.0 per cent	Expansion
Coconut	3,59,694	4,41,760	+82,066	+22.8 per cent	Expansion
Banana	1,01,360	1,18,389	+17,029	+16.8 per cent	Expansion
Groundnut	1,38,889	1,46,389	+7,500	+5.4 per cent	Expansion
Sugarcane	3,36,906	1,39,108	−1,97,798	−58.7 per cent	Contraction

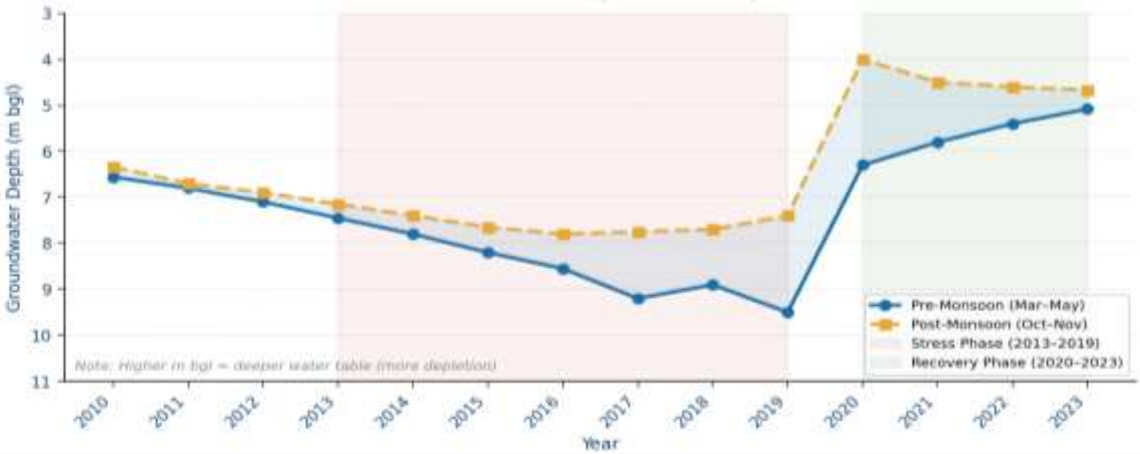

Fig.1. Temporal trend in Pre & Post Monsoon of Groundwater depth

Fig.2. District-wise Groundwater Trend Classification

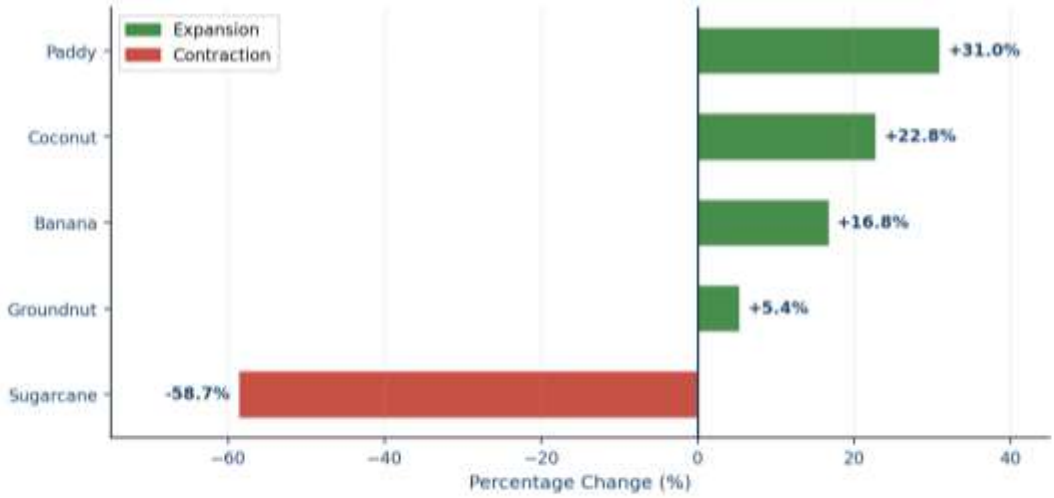

Fig.3. Percentage Change in Irrigated Crop Area

Fig.4. District-wise Change in Irrigated Area: Paddy and Sugarcane, Tamil Nadu

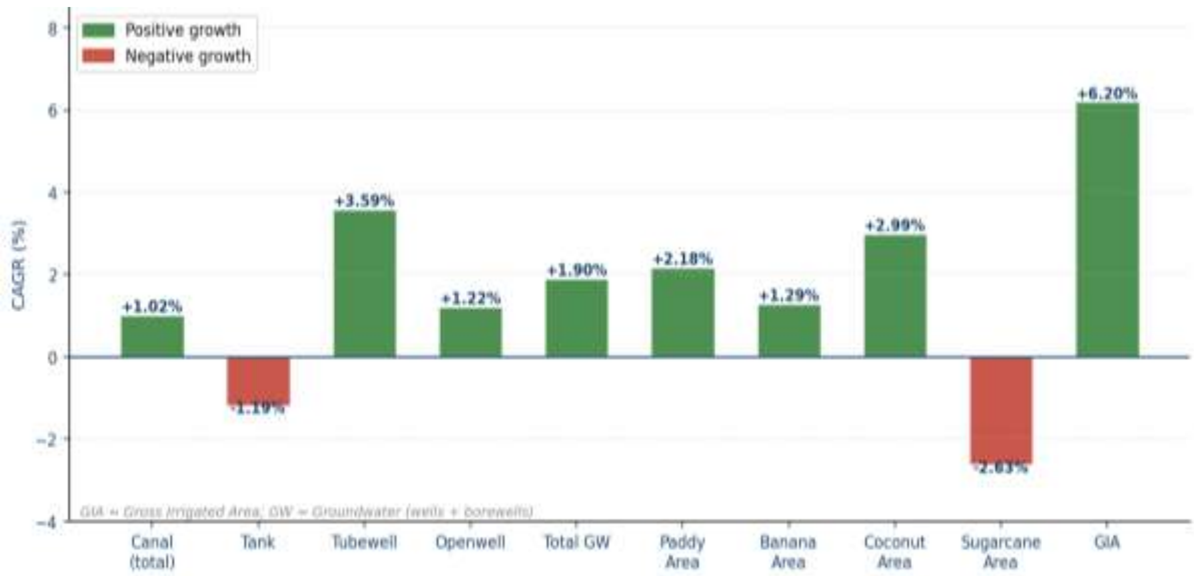

Fig.5. CAGR of Irrigation Sources and Irrigated Crop Variables, Tamil Nadu

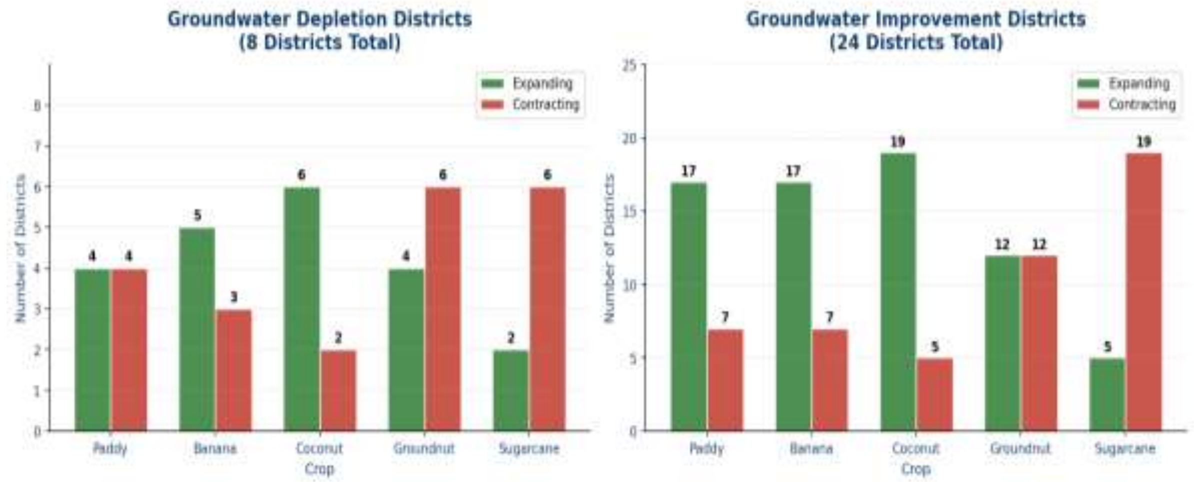

Fig.6. Crop Area Change in Groundwater Depletion vs. Improvement Districts, Tamil Nadu