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Assessment of Spatio-Temporal Changes in Groundwater Quality Using Water Quality Index and Its Irrigation Suitability in Puducherry Region, Southeast India

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Abstract

Groundwater sustains life in Puducherry coastal regions but faces threats from urbanization and land- use change. The study evaluated 70 groundwater samples in 2022, considering their suitability for drinking and irrigation purposes using water quality index, Canadian council of ministers of the environment-water quality index, and irrigation indices like sodium adsorption ratio, Percent Sodium, permeability index, Kelly's ratio, and residual sodium carbonate. Sentinel-2A satellite images indicated that urban areas increased from 104.7 km² (35.1%) in 2010 to 105.7 km² (35.4%) in 2024, while agricultural land decreased marginally, mirroring urban pressure. Approximately 77.1% of the groundwater samples belonged to Fair to Marginal categories for drinking, and just 1.4% was rated Excellent under canadian council of ministers of the environment-water quality index. Salinity and nitrate were of primary concern, particularly in urbanised areas such as Solai Nagar and Kuruchikuppam, where water quality had been rated as Poor. For irrigation, 57.1% of pre-monsoon and 65.7% of post-monsoon samples were of the C3S1 class, reflecting low sodium hazard but high salinity, whereas 4.3% of pre-monsoon and 1.4% of post-monsoon samples encountered medium sodium hazard with very high salinity (C4S2). Kelly's Ratio was greater than 1 in 21.4% of pre-monsoon and 34.3% of post-monsoon samples, reflecting sodicity risks, while 98% of the samples had safe residual sodium carbonate values less than 2.5 meq/L. Regions with high urbanisation or intensive farming always exhibited high sodium adsorption ratio, Percent Sodium, and electrical conductivity, affirming a real correlation between land-use /land cover patterns and decreasing groundwater quality. To prevent these risks, the study suggests combined land-water planning, strict wastewater control, and the promotion of sustainable irrigation practices to ensure Puducherry's water resources and agricultural yield.

Keywords: Water Quality Index, Salinity Hazard, Land-Use, Land cover, Remote Sensing, Puducherry

Introduction

Groundwater is a vital resource with considerable importance and is a source of drinking water worldwide (Das and Nag, 2022). The increasing population, coupled with rapid urbanization, agricultural intensification, and land use/land cover (LULC) changes, has significantly intensified the demand for freshwater resources (Mishra, 2023), in dry, semi-arid, and isolated rural regions where groundwater is heavily relied upon for household, agricultural, and potable needs (Makki *et al.*, 2021). In these areas, dependence on groundwater becomes even more pronounced during droughts, when surface water supplies are scarce (Adimalla *et al.*, 2020; Dube *et al.,* 2020). Investigating land suitability for irrigation is a crucial aspect of multi-objective planning in developing and managing water resource projects involving irrigation. The availability of irrigation often drives changes in land use and encourages more intensive cropping practices. However, the mismanagement or improper application of irrigation water can lead to environmental degradation, reducing land productivity and compromising its quality for future agricultural use (Kumar *et al.*, 2002).

In recent years, Water Quality Index (WQI) models have gained popularity for evaluating both surface and groundwater quality, as they offer a more simplified and accessible approach compared to traditional methods (Aljanabi *et al.,* 2021). These models transform various water quality parameters into a single, unitless numerical value that effectively represents the overall water quality status (Sutadian *et al.,* 2016). Groundwater is highly vulnerable to contamination from various human activities, including mining, intensive farming, urban expansion, and industrialisation (Chen *et al.,* 2023; Schwarzenbach *et al.,* 2010). Deterioration in water quality poses a serious risk to public health (Fida *et al.*, 2023). The association between LULC and water quality can differ depending on the spatial scale of analysis (Tanaka *et al.,* 2016). Recent studies in landscape ecology and forecasting

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