ABSTRACT

Groundwater is a dynamic and replenishable natural resource which plays a significant role in meeting the fresh water needs of mankind. Its demand has tremendously increased due to population growth, rapid urbanization, industrialization and, agricultural expansion. The unmanaged groundwater extraction and inadequate aquifer recharge are the major causes of groundwater depletion. Systematic estimation and budgeting of groundwater resources based on spatio-temporal distribution, its allocation for meeting the competing demands for irrigation, industrial and domestic usage and, conjunctive use of surface and groundwater resources are essential for optimal utilization of available groundwater on a sustained basis.

An integrated Remote Sensing (RS) and Geographical Information System (GIS) approach provides convergent analysis of large spatial data and decision making for groundwater studies. Identification of pertinent hydrological, geological, geomorphological parameters, preparation of corresponding thematic maps with high quality remotely sensed data, assigning appropriate weights and integration in a sophisticated GIS environment ensure and enhance the prediction accuracy of groundwater potential.

Chennai, the capital city of Tamil Nadu, is the fourth populous (4.681 million) metropolis in India. The surface water reservoirs, groundwater abstracted from bore wells drilled in Araniar river basin and, surface water transfer from Srisailam reservoir to Poondi reservoir of Tamil Nadu as part of inter-basin development cater to the drinking water needs of Chennai city. In addition to meeting the drinking water needs, the Araniar river also caters to the irrigation needs of the areas along its course.

The Araniar river originates near Karvetinagar forest in Andhra Pradesh and the river basin lies between 13° 15' 12" N and 13° 32' 00" N latitudes and 79° 24' 40" E and 80° 20' 54" E longitudes, partly in Thiruvallur District of Tamil Nadu and partly in Chittoor District of Andhra Pradesh. The river flows over a length of 131.6 km from west to east and covers an area of 1281.3 sq. km. The elevation of the river basin ranges from 3 m above mean sea level at the coastal area in the eastern side to 1040 m in the upper reaches at Narayanavanam forest in the north-west region and, to 565 m at Karvetinagar forest in the west. The basin is semi-arid and receives an average annual rainfall of 1187 mm.
The maximum and minimum temperatures vary between 37 °C to 44 °C and 18 °C to 27 °C respectively with mean monthly relative humidity ranging between 67 % and 74 %. The recharge into the aquifers of the basin is from precipitation, flow through river beds, water bodies and return flow from irrigated fields.

The basin suffers from erratic rainfall with wide spatial and temporal variations, insufficient surface water availability, unreliable inter-state water transfer and, saline water intrusion in the coastal areas. These led to significant increase in water demand and necessitate optimal tapping of groundwater resources of the basin. The objectives aimed at meeting these requirements include micro-level morphometric analysis to prioritize the sub-basin for groundwater potential, delineation of groundwater potential zones, identification of suitable sites for artificial recharge structures for effective groundwater resources management and, groundwater quality assessment for drinking and irrigation purposes. The requisite data to carry out groundwater studies were collected from the Survey of India (SOI), Geological Survey of India and, Central and State Ground Water Departments.

The micro-level morphometric analysis of the basin was carried out by dividing the basin into six sub-basins, viz., Venugopalapuram (WS1), Pattur (WS2), Pitchatur (WS3), Nagalapuram (WS4), Nindra (WS5) and Ponneri (WS6). The linear, areal and relief morphometric parameters were combined using compact factor analysis and overlay analysis for prioritization of groundwater potential zones of the basin. The linear, areal and relief aspect maps of the sub-basins were overlaid to delineate groundwater potential zones of the basin and substantiated the results with geomorphology map.

The compact factor analysis prioritized Ponneri (WS6) as very good to excellent zone of groundwater potential followed by Nindra (WS5) as good to very good category. The overlay analysis of linear, areal and relief aspect maps also revealed similar results. The elongated shape, favourable drainage network, permeable geologic formation and low relief characteristics of sub-basins WS6 and WS5 make them the promising groundwater potential zones of the basin.

The study also makes an attempt to develop Groundwater Potential Index (GWPI) map of Araniar basin. The thematic maps of rainfall, slope, soil, geology, geomorphology and land use/land cover were developed, rasterized, grouped into
classes and assigned appropriate weights. The integration of the thematic layers was carried out using Weighted Linear Combination (WLC), to obtain GWPI map. As there are no standard weights for each of the themes involved, an attempt has been made to standardize the weights during WLC process using correlation analysis by following step-wise procedure. The analysis revealed that a maximum correlation coefficient of 0.922 was obtained with weights as 0.49 for rainfall, 0.20 for geology, 0.17 for soil, 0.05 for slope and geomorphology each, and 0.04 for land use/land cover map.

The GWPI map showed excellent (295 - 361 lpm) and very good (211 - 294 lpm) groundwater potential zones occurring in the Ponneri (WS6) sub-basin and good groundwater potential zones with an yield of 127 - 210 lpm were observed on the downstream of Pitchatur (WS3), Nindra (WS5) and Nagalapuram (WS4) sub-basins. The groundwater potential zones demarcated are mostly in agreement with the prioritization carried out through compact factor and overlay analyses of morphometric parameters, barring a few exceptions. The groundwater level fluctuation map when overlaid with geology, geomorphology, slope and GWPI maps facilitated to identify suitable sites for artificial recharge. Suitable locations for the construction of percolation ponds were identified at Puttur (WS2), Nagalapuram (WS4), and Nindra (WS5) sub-basins and, other recharge measures such as contour trenching and construction of gabion structures were recommended for Venugopalapuram (WS1) and Pitchatur (WS3) sub-basins.

An attempt has also been made to study the spatial and temporal variations of physico-chemical constituents of groundwater of the river basin for assessing its suitability for drinking and irrigation purposes. The suitability for drinking purpose was evaluated by comparing physico-chemical parameters with drinking water quality standards prescribed by WHO and BIS. The spatial distribution maps of physico-chemical parameters were developed for post-monsoon and pre-monsoon periods and, classified as desirable, maximum permissible and areas exceeding maximum permissible limit based on WHO guidelines. The geochemical evaluation of groundwater of Araniar basin was demonstrated with the help of Piper trilinear diagram. The drinking water quality index (DWQI) maps of the basin for post- and pre-monsoon periods were also prepared.
In the irrigation water quality evaluation of Araniar basin, post and pre-monsoon maps of irrigation water quality parameters were evaluated based on USDA standards. The spatial maps of Electrical Conductivity representing salinity hazard, a combined Electrical Conductivity and Sodium Absorption Ratio criterion representing infiltration and permeability hazard, Cl and Na representing specific ion toxicity hazard, F representing trace element toxicity hazard, and HCO₃ and pH representing miscellaneous effects hazard were prepared. These maps were reclassified into irrigation suitable classes as high, medium and low as per FAO guidelines, and overlaid by assigning weights to obtain Irrigation Water Quality Index (IWQI) maps for post- and pre-monsoon seasons.

Interpretation of physico-chemical data revealed that groundwater in the basin was slightly alkaline. The cations such as Na⁺ and K⁺ and anions such as HCO₃⁻ and Cl⁻ exceeded the permissible limits of drinking water standards (WHO and BIS) in certain pockets in the north-eastern part of the basin during pre-monsoon period. The higher TDS concentration in the north-eastern part of the basin may be due to the presence of higher concentrations of HCO₃⁻, SO₄²⁻, Cl⁻ and NO₃⁻ in the area. The other parameters such as Ca²⁺, Mg²⁺, SO₄²⁻, NO₃⁻ and F⁻ were within the limits in both the seasons.

The spatial distribution of total hardness map showed that groundwater of the area falls in between desirable and permissible categories as per WHO standards. This may be due to leaching of Ca²⁺ and Mg²⁺ ions into groundwater, and in near future, the areas with permissible limit for drinking purpose may tend to areas falling in the category of exceeding maximum permissible limit during both the seasons. Also, an increase in areal extent of permissible category of most of the parameters during post-monsoon season indicates that monsoon plays a significant role in decreasing the concentration of TDS, Na⁺, HCO₃⁻ and Cl⁻ and thereby improving the drinking water quality.

The hydrogeochemical evaluation of groundwater of the basin demonstrated with the Piper trilinear diagram indicated that the groundwater samples of the area represent Ca²⁺ - Mg²⁺ - Cl⁻ - SO₄²⁻, Ca²⁺ - Mg²⁺ - HCO₃⁻ and Na⁺ - K⁺ - Cl⁻ - SO₄²⁻.
types during post-monsoon period and, \( \text{Ca}^{2+} \cdot \text{Mg}^{2+} \cdot \text{Cl}^{-} \cdot \text{SO}_4^{2-} \), \( \text{Na}^{+} \cdot \text{K}^{+} \cdot \text{Cl}^{-} \cdot \text{SO}_4^{2-} \) and \( \text{Ca}^{2+} \cdot \text{Mg}^{2+} \cdot \text{HCO}_3 \) types during pre-monsoon period.

The DWQI maps for the basin revealed that 90.24\% and 73.46\% of the basin area possess good quality water during post- and pre-monsoon seasons respectively. The IWQI maps indicated that 75\% of the basin area possesses highly suitable irrigation water during post-monsoon, while the medium suitability (90.75\% of the basin) predominates during pre-monsoon.

The compact factor and overlay analyses of morphometric parameters are useful in the prioritization of sub-basins for groundwater potential of Araniar river basin. The groundwater potential index map, drinking and irrigation water quality index maps developed for the basin may help the planners and developers to adopt suitable management strategies for sustainable groundwater resources of the basin.