ABSTRACT

In view of growing problems of water scarcity and unsustainable use of groundwater in several parts of the world including India, the present study was carried out with an overall objective of groundwater evaluation and simulation and optimization modeling for efficient groundwater utilization in a deltaic aquifer system of Odisha, India. The major works accomplished under this study include field investigations, analysis of hydrologic and hydrogeologic data, groundwater potential assessment using geospatial tools and probabilistic modeling, subsurface formation characterization by hybrid artificial neural network (ANN) models, development of two-layered groundwater-flow model, and the development of a simulation-optimization model for optimal land and water resources utilization in the study area. The stratigraphic analysis of the basin indicated the existence of an uppermost unconfined aquifer of thickness 3.4 to 46.5 m and a lower confined aquifer of thickness 3.1 to 80.3 m, separated by a confining layer (aquitard) of thickness 2.1 to 60.0 m. For groundwater prospect mapping, the performance of the analytic hierarchy process (AHP) technique was found much superior (prediction accuracy = 77%) to the probabilistic models. Of the three ANN models, the self-organizing featured network (SOFN) models were found to have the highest prediction accuracy in characterizing lithology for all the depth classes followed by the genetic algorithm (GA)-based ANN models.

Moreover, the multi-aquifer groundwater-flow model was successfully calibrated and validated using Visual MODFLOW software. The calibrated hydraulic conductivity of the unconfined aquifer varies from 8.3 to 48.6 m/day, while that of the confined aquifer varies from 13.0 to 85.0 m/day. The specific storage of the confined aquifer ranges from 1.46×10^{-6} to 7.76×10^{-4} and the specific yield of unconfined aquifer ranges from 0.032 to 0.23. The spatial variation of annual recharge ranges from 213.7 to 333.7 mm/year. The sensitivity analysis of the groundwater-flow model revealed that the model is most sensitive to the hydraulic conductivities of both the aquifers followed by the vertical hydraulic conductivity of the aquitard, specific yield of the unconfined aquifer, specific storage of the confined aquifer and rainfall recharge of the unconfined aquifer. The simulation of management scenarios indicated that an increase or a decrease in pumping rates up to 25% and 50% has significant effects on groundwater levels, but the effect is more pronounced in the confined aquifer than in the unconfined aquifer. The long-term simulation results indicated that if the existing hydrologic conditions and abstraction level continue until the year 2031, there will be no serious threat to groundwater decline in the study area. Based on the simulation-optimization model, the net annual income from the optimal cropping patterns yielded by the linear programming (LP) technique is estimated at Rs. 3.7 billion with a gross annual irrigation requirement of 487.58×10^{6} m^3, while the GA technique yields a net annual income of Rs. 4.2 billion and a gross annual irrigation requirement of 449.36×10^{6} m^3. The performance of the GA optimization technique was found superior to that of the LP optimization technique in the optimal allocation of available land and water resources in the basin study area.

Keywords: *Groundwater prospecting; Geospatial techniques; Multi-criteria decision analysis; Probabilistic modelling; Lithology prediction, Hybrid neural network modeling, Self-organizing feature map, Genetic algorithm; Groundwater-flow modeling, Simulation-optimization modeling, Visual MODFLOW*