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Evaluation of Index-Based Methods for Analyzing Seawater Intrusion Vulnerability in a Coastal Alluvial Aquifer of Eastern India

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The present study aims to explore seawater intrusion vulnerability in a coastal alluvial aquifer of West Bengal state, eastern India, using two GIS-based indexing techniques, viz., GALDIT and DRASTIC. The study region, with an area of 6358.70 km^2, is underlain by two main aquifer systems ('leaky confined' and 'confined' aquifers). Daily rainfall data of 2020–2021, Pre-Monsoon (PRM) and Post-Monsoon (POM) seasons' groundwater-level and groundwater-quality (EC, Cl^- and HCO_3^-) data of 2021 for leaky confined aquifer, and lithology logs data were used. The GALDIT method incorporates six hydrogeochemical parameters as inputs, viz., groundwater occurrence (G), aquifer hydraulic conductivity (A), groundwater elevation (L), distance from the seashore (D), impact of existing seawater intrusion status (I), and aquifer thickness (T). Conversely, inputs to the DRASTIC method are: depth to groundwater level (D), net recharge (R), aquifer media (A), soil media (S), topography (T), impact of vadose zone (I), and aquifer hydraulic conductivity (C). All these thematic layers and their features were assigned weights and ratings, respectively, following original GALDIT and DRASTIC methodology. Seasonal seawater intrusion vulnerability maps were prepared using weighted overlay analysis in ArcGIS environment. Based on GALDIT Vulnerability Indices (GVI), the study area was delineated into three vulnerability zones, viz., 'low' (GVI=2.5–5.0), 'moderate' (GVI=5.0–7.5), and 'high' (GVI>7.5). Similarly, the whole area was categorized into three vulnerability zones depending on DRASTIC Vulnerability Indices (DVI), viz., 'low' (DVI=18–61), 'moderate' (DVI=61–104), and 'high' (DVI=104–146). Results of the GALDIT method indicated 19–31% of the total area under 'low', 66–78% under 'moderate' and 3–4% under 'high' vulnerability classes in different seasons. Outcomes of the DRASTIC method revealed 21–78% area under 'moderate' and 22–79% under 'high' vulnerability classes. Finally, results of GALDIT and DRASTIC methods were validated with measured Electrical Conductivity (EC) concentrations. As per drinking and irrigation suitability, seasonal EC maps were categorized into three classes, viz., 'acceptable/low hazardous' (EC<750 μS/cm), 'permissible/moderate hazardous' (EC=750–3000 μS/cm), and 'not suitable/high hazardous' (EC>3000 μS/cm). The GALDIT method predicted 50–64% less area as 'low', 47–61% higher area as 'moderate', and 3–3.5% more area as 'high' vulnerable zones compared to the corresponding EC classes. Conversely, the DRASTIC technique estimated

81–84% less area as ‘low’, 2–61% higher area as ‘moderate’, and 22–79% more area as ‘high’ vulnerable zones. Moreover, moderate correlations were found between GVI and EC in both PRM ($r=0.518$) and POM ($r=0.589$) seasons, whereas poor correlations were found among DVI and EC in both PRM ($r=0.442$) and POM ($r=0.118$) seasons. Additionally, Receiver Operating Characteristic (ROC) curves revealed high Area Under the Curve (AUC) values for the GALDIT method in both PRM ($AUC=0.872$) and POM ($AUC=0.891$) seasons, whereas lower AUC values were obtained for the DRASTIC method in both PRM ($AUC=0.810$) and POM ($AUC=0.573$) seasons. Therefore, these results suggest that the GALDIT method delineated seawater intrusion vulnerable zones much better than the DRASTIC method. The outcomes of this research will aid in identifying priority zones (moderate-to-high vulnerable) to implement efficient groundwater-quality management programs.