Mapping groundwater recharge potential using AHP multi-criteria analysis in the Kou sub-basin, Burkina Faso

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ABSTRACT

Faced with the growing pressure on groundwater resources in semi-arid regions, exacerbated by climate variability and the intensification of various water uses, their sustainable management requires a better spatial understanding of their renewal. In this context, mapping groundwater recharge potential constitutes an essential decision-support tool for identifying and locating areas favorable to recharge. This study aims to propose a mapping of aquifer recharge potential in the sedimentary zone of the Kou sub-basin by combining a multi-criteria analysis using the Analytic Hierarchy Process (AHP) method with the contributions of a systematic literature review. The methodological approach is based on two complementary steps. The first consists of an exhaustive literature review that identified and ranked the factors most frequently used in recharge potential mapping at the international scale. Nine factors were retained: rainfall, geology/lithology, pedology, slope, land use and land cover (LULC), drainage density, weathering thickness, the Normalized Difference Vegetation Index (NDVI), and lineament density. These factors act jointly on infiltration and percolation processes toward aquifers, and their relative importance varies according to the hydrogeological context. From the normalized weights extracted from the literature, three pairwise comparison matrices were constructed based on the minimum, mean, and maximum reported values, in accordance with Saaty's scale. The second step focuses on the statistical validation of these matrices through Monte Carlo simulation, enabling the assessment of weighting robustness and the calculation of 95% confidence intervals for each factor. The Consistency Ratio (CR) was verified for all matrices to ensure the reliability of the comparative judgments. The results reveal that all three constructed matrices present CR values below 0.1, confirming the consistency and robustness of the obtained weightings. Weathering thickness emerges as the dominant factor in the minimum scenario, with a weight of 37.1%, reflecting its predominant role in the storage and transmission capacity of weathered basement aquifers. In contrast, in the mean scenario, geology ranks first at 19.4%, while the maximum scenario highlights land use and land cover as the leading factor at 18.2%. These contrasts illustrate the sensitivity of AHP weightings to geographic context and the methodological choices of individual authors. The confidence intervals derived from Monte Carlo simulations confirm the relative stability of factors such as geology, pedology, and slope, while indicating greater uncertainty for variables such as NDVI. This study demonstrates the relevance of an AHP approach grounded in a quantitative synthesis of the literature for guiding the weighting of recharge factors, while highlighting the need for local adaptation through expert consultation. It provides a reproducible methodological framework for mapping recharge potential in semi-arid sedimentary zones, opening perspectives for better integration of recharge into sustainable groundwater management strategies.

Keywords: Analytic Hierarchy Process (AHP); Groundwater recharge potential; Multi-criteria analysis; Sedimentary zone.