Designing Cost-Efficient Strategies for Managed Aquifer Recharge: A Spatial Multi-Objective Approach Applied to Southern Morocco

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Managed aquifer recharge (MAR) is increasingly seen as a practical way to address groundwater depletion in water-scarce regions. Still, identifying feasible recharge locations remains challenging, as it requires balancing technical, economic, and spatial constraints that do not always align.

This study introduces a spatially explicit optimization framework to support MAR planning, combining infrastructure-based indicators, remote sensing data, and multi-objective decision analysis. Instead of relying only on conventional suitability mapping, the approach is anchored in existing water infrastructure particularly wells and traditional khettara systems which provide direct and realistic indications of aquifer accessibility.

The methodology is built around three main components. First, satellite data are used to detect surface water availability, especially during temporary flow conditions. Second, least-cost path analysis within a GIS environment is applied to identify potential transfer routes while accounting for terrain and land surface characteristics. Third, a multi-objective optimization module is used to explore trade-offs between competing criteria. Feasibility is evaluated through a cost function that includes elevation differences, transfer distance, energy requirements, infrastructure costs, and potential treatment needs.

The framework is applied to the Draa Oued Noun Basin in southern Morocco, a region characterized by severe water stress and declining groundwater levels. Several surface water sources are assessed, and different transfer scenarios toward accessible aquifers are examined. The results reveal clear trade-offs between cost components, allowing the identification of cost-efficient solutions under budget constraints. Sensitivity analysis indicates that elevation lift is the dominant factor influencing overall costs, while gravity-driven transfer and solar-powered pumping can significantly improve economic feasibility where conditions allow.

Overall, this framework translates physical and spatial constraints into a practical decision-support tool for MAR planning. Its reliance on existing infrastructure and its multi-criteria perspective make it adaptable to other arid regions facing similar groundwater management challenges

Key -words: Managed Aquifer Recharge (MAR), Multi-objective optimization, Least-cost path analysis, Remote sensing.