

IDENTIFICATION OF SUITABLE SITES FOR RAINWATER HARVESTING FACILITIES AND NATURAL AQUIFER RECHARGE USING GEOSPATIAL TECHNIQUES IN PANJKORA BASIN

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Abstract

Water is a fundamental natural resource essential for sustaining life and supporting ecosystems. However, due to increasing population, climate change, and erratic rainfall patterns, many regions especially arid and semi-arid mountainous areas are experiencing growing water stress. The Panjkora River Basin, located in the eastern Hindukush region of northern Pakistan, is one such area where the depletion of groundwater and seasonal water scarcity pose serious socio-economic and ecological challenges. To address these issues, this study integrates advanced geospatial tools and multi-criteria decision-making techniques to identify suitable sites for Rainwater Harvesting (RWH) and Natural Aquifer Recharge (NAR). Three different but complementary methodological approaches were employed: the Multi Influencing Factor (MIF) and Analytical Hierarchy Process (AHP) models for identifying RWH sites, and the Natural Aquifer Recharge (NAR) index for locating zones with high recharge potential. Each technique was applied using Geographic Information System (GIS) and Remote Sensing (RS) technologies, incorporating a range of thematic layers including land use/land cover, slope, soil type, drainage density, lineament density, rainfall, geology, depth to water table, proximity to roads and settlements, elevation, and runoff data. For the RWH analysis using MIF and AHP, suitability classes were derived for various harvesting structures. The MIF model classified the study area into 80.22 km² as less suitable, 1681.99 km² as moderately suitable, 3116.10 km² as suitable, 844.86 km² as highly suitable, and 35.10 km² as very highly suitable. The AHP model showed similar but slightly different distributions. To validate these models, the Receiver Operating Characteristic (ROC) curve and Area Under Curve (AUC) scores were calculated, with the MIF model yielding an AUC of 0.724 and the AHP model 0.692, indicating good predictive accuracy. In parallel, the NAR index model was used to evaluate artificial recharge potential, where eight key parameters were integrated. The model classified 165,760.26 hectares as not suitable, 238,259.40 hectares as moderately suitable,

174,780.58 hectares as highly suitable, and 82.87 hectares as very highly suitable for aquifer recharge. Ground-truthing using 69 groundwater well data points provided a validation accuracy of 74% using AUC-ROC testing. In another detailed assessment using the Soil and Water Assessment Tool (SWAT) for runoff estimation, various RWH structures were evaluated. The total area found most suitable for farm pond construction was 1128.395 km², while 954.756 km² was moderately suitable. For check dams, 350.58 km² was classified as suitable and 245.31 km² as moderately suitable. In the case of gully plugs, 1572.518 km² was identified as highly suitable and 3742.38 km² as moderately suitable, indicating significant potential for rainwater retention and erosion control. Overall, more than 72% of the basin was assessed as having moderate to very high potential for artificial recharge, with approximately 30.19% categorized as highly suitable and 1.01% as very highly suitable. The integrated findings from these three studies offer a robust spatial framework for planning site-specific interventions in water conservation, aquifer recharge, and drought resilience. This research not only contributes to improving water availability and sustainability in the Panjkora River Basin but also provides a replicable model for similar hydro-climatic and topographic settings. It emphasizes the importance of using geospatial decision-support tools for evidence-based water resource planning, especially in vulnerable mountainous ecosystems.

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