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Assessing Groundwater Resources Sustainability Using Groundwater Footprint Concept

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Over-pumping, water table depletion and climate change impacts require effective groundwater management. The Groundwater Footprint (GWF), introduced by Gleeson et al. in 2012 expresses the area required to sustain groundwater use and groundwater dependent ecosystem services. GWF represents a water balance between aquifer inflows and outflows, focusing on environmental flow requirements. Developing the water balance, precipitation recharge and additional recharge from irrigation are considered as inflows, whereas outflows are considered the groundwater abstraction from the aquifer of interest and the quantity of groundwater that is needed to sustain ecosystem services. The parameters required for GWF calculation can be estimated through in-situ measurements, observations and models outputs. The actual groundwater abstraction is often difficult to be estimated with a high accuracy. Environmental flow requirements can be calculated through different approaches; the most accurate of which are considered the ones that focus on hydro-ecological data analysis.
As the GWF is a tool recently introduced in groundwater assessment and management, only a few studies have been reported in the literature to use it as groundwater monitoring and management tool. The present study emphasizes on a case study in Southern Europe, where awareness should be raised about rivers' environmental flow. GWF concept will be applied for the first time to a pilot area in Greece, where the flow of the perennial river that crosses the area of interest is dependent on baseflow. Recharge and abstraction of the pilot area are estimated based on historical data and previous reports and a groundwater flow model is developed using Visual Modflow so as to diminish the uncertainty of the input parameters through model calibration. The groundwater quantity that should be allocated on surface water body in order to sustain satisfactory biological conditions is estimated under the assumption that surface water and groundwater contribute to the environmental flow in an equally proportion as in case of natural flow. In order to express baseflow as a percentage of natural mean flow, a precipitation-runoff model is developed. The environmental flow of the river of interest is estimated as a percentage of the river's average flow (Tennant method). Subsequently, the groundwater contribution is calculated as a percentage of the environmental flow equal to the percentage of the baseflow in the natural flow. GWF is finally compared with the actual size of the area of interest in order to assess the groundwater use and sustainability of this area.