A hydrological-economic model for sustainable groundwater use in sparse-data drylands: Application to the Amtoudi Oasis in southern Morocco, northern Sahara

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A hydrological-economic model is introduced to describe the dynamics of groundwater-dependent economics (agriculture and tourism) for sustainable use in sparse-data drylands. The Amtoudi Oasis, a remote area in southern Morocco, in the northern Sahara attractive for tourism and with evidence of groundwater degradation, was chosen to show the model operation. Governing system variables were identified and put into action through System Dynamics (SD) modeling causal diagrams to program basic formulations into a model having two modules coupled by the nexus 'pumping': (1) the hydrological module represents the net groundwater balance (G) dynamics; and (2) the economic module reproduces the variation in the consumers of water, both the population and tourists. The model was operated under similar influx of tourists and different scenarios of water availability, such as the wet 2009-2010 and the average 2010-2011 hydrological years. The rise in international tourism is identified as the main driving force reducing emigration and introducing new social habits in the population, in particular concerning water consumption. Urban water allotment (P<inf>U</inf>) was doubled for less than a 100-inhabitant net increase in recent decades. The water allocation for agriculture (P<inf>I</inf>), the largest consumer of water, had remained constant for decades. Despite that the 2-year monitoring period is not long enough to draw long-term

conclusions, groundwater imbalance was reflected by net aquifer recharge (R) less than P<inf>I</inf> + P<inf>U</inf> (G < 0) in the average year 2010-2011, with net lateral inflow from adjacent Cambrian formations being the largest recharge component. R is expected to be much less than P<inf>I</inf> + P<inf>U</inf> in recurrent dry spells. Some low-technology actions are tentatively proposed to mitigate groundwater degradation, such as: wastewater capture, treatment, and reuse for irrigation; storm-water harvesting for irrigation; and active maintenance of the irrigation system to improve its efficiency.

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Groundwater degradation

Oasis

Southern Morocco

Sustainability

Tourism

Agriculture

Aquifers

Economics

Groundwater

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Irrigation

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Wastewater reclamation

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