From traditional governance to modern pressures: The transformation of Khettara systems in Draa-Tafilalet Oasis Ecosystems

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ABSTRACT

For centuries, indigenous communities in southern Morocco have developed place-based water management systems to cope with arid conditions and chronic water scarcity. Among these, the khettara, a gravity-driven system for groundwater capture and conveyance, represents a sophisticated socio-ecological adaptation that closely links hydrological processes with collective governance. By relying exclusively on natural aquifer recharge through infiltration along underground galleries, the khettara inherently operates within environmental limits, embodying a form of sustainable water use grounded in ecological balance. Beyond its technical function, the khettara system has historically structured social organization, ensuring equitable water distribution through community-based governance mechanisms. It has played a central role in sustaining oasis socio-ecosystems, providing provisioning, regulating, and cultural services, and contributing to the recognition of Moroccan oases as UNESCO Biosphere Reserves and FAO Globally Important Agricultural Heritage Systems. However, this tightly coupled socio-ecological system is undergoing profound transformations driven by the interaction of climatic, hydrological, and socio-economic factors. This study adopts an interdisciplinary approach combining hydro-climatology, hydrogeology, and socio-ecological analysis to examine how changes in water governance and environmental conditions affect the resilience of the khettara system within Draa-Tafilalet oasis ecosystems. Results indicate that since the 1970s, the shift toward centralized water governance and hydraulic infrastructure development, particularly dam construction, has altered river basin dynamics, disrupted natural recharge processes, and weakened the ecological foundations of the khettara. At the same time, the expansion of motorized and solar-powered groundwater pumping has intensified competition for water resources, contributing to declining flows and system abandonment. These changes are further compounded by recurrent droughts and rural outmigration, which erode collective management practices and exacerbate social inequalities in water access. The decline of the khettara reflects not only hydrological stress but also a breakdown in traditional governance systems that historically ensured equitable and sustainable water use. Recent restoration initiatives, including the integration of khettara into cultural tourism in the Tafilalet oases, highlight emerging efforts to revalorize this heritage. However, these efforts remain insufficient in the face of accelerating climate change and increasing anthropogenic pressures. This study underscores the need to rethink water management strategies in arid regions by reintegrating socio-ecological principles, strengthening local governance, and addressing issues of equity and resilience. It highlights the importance of hybrid approaches that combine traditional knowledge systems with contemporary policy frameworks to ensure sustainable and inclusive water management in river-dependent oasis environments.

Keywords: Khettara system; Water governance; Socio-ecological systems; Oasis ecosystems; Resilience .