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Managing water-use trade-offs in a semi-arid river delta to sustain multiple ecosystem services: a modeling approach

Abstract

Managing trade-offs among water uses in a river basin to sustain multiple ecosystem services is crucial for adaptation to changing river flow regimes. Here we analyze the trade-off between irrigation and fisheries in the Amudarya, a semi-arid river basin in Central Asia, using an optimal control and an agent-based modeling approach. With the optimal control approach (OCA), we identify the economic and ecological conditions for water sharing in a regime where a social manager controls water withdrawals and fish harvesting. With the agent-based model (ABM), we relax some of the assumptions of the OCA to investigate how localized, individual agents with varied water use histories adapt their water use activities to local resource conditions. Variation in the farmers' initial labor allocations to the two activities results in regimes with only one activity or both. Global returns and income equality are highest in a mixed regime. The mixed regimes also are more robust to water variability because fishing activities can compensate for decreased agricultural performance in the midstream regions. Thus, allowing for multiple uses can improve the coupled social-ecological system's performance and its resilience. We also observe a lock-in effect similar to the current situation in the Amudarya, where agriculture is the dominant water use and transition to a more balanced allocation has proven to be extremely difficult. As in the ABM, this can to some extent be attributed to the difficulties of achieving sufficient revenues from fishing when agricultural activities upstream are high. Regulations or incentives are needed to overcome those barriers, and to facilitate progress towards integrated water management.

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