The groundwater games: modelling cooperation in groundwater basins using agent-based models

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Human interactions with groundwater systems often exhibit complex features that hinder the sustainable management of the resource. This leads to costly and persistent conflicts over groundwater at the catchment scale. One possible way to address these conflicts is by gaining a better understanding of how social and groundwater dynamics coevolve using agent-based models (ABM). Such models allow exploration of 'bottom- up' solutions (i.e., self-organised governance systems), where the behaviour of individual agents (e.g., farmers) results in the emergence of mutual cooperation among groundwater users. There is significant empirical evidence indicating that this kind of 'bottom-up' approach may lead to more enduring and sustainable outcomes, compared to conventional 'top-down' strategies such as centralized control and water right schemes (Ostrom 1990). New modelling tools are needed to study these concepts systematically and efficiently. Our model uses a conceptual framework to study cooperation and the emergence of social norms as initially proposed by Robert Axelrod in 1986, which we adapted to groundwater management. We developed an ABM that integrates social mechanisms and the physics of subsurface flow. The model explicitly represents feedback between groundwater conditions and social dynamics, capturing the spatial structure of these interactions and the potential effects on cooperation levels in an agricultural setting. Using this model, we investigate a series of mechanisms that may trigger norms supporting cooperative strategies, which can be sustained and become stable over time. For example, farmers in a self-monitoring community can be more efficient at achieving the objective of sustainable groundwater use than government-imposed regulation. Our coupled model thus offers a platform for testing new schemes promoting cooperation and improved resource use, which can be used as a basis for policy design. Importantly, we hope to raise awareness of agent-based modelling as a new tool for studying complex human-groundwater systems.