

EGU2020-12418

<https://doi.org/10.5194/egusphere-egu2020-12418>

EGU General Assembly 2020

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Participatory-Exploratory Modeling of Coupled Socio-Economic and Environmental Systems for Adaptive Management of Water Resources

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Water and environmental resources exist in complex and deeply uncertain systems of social-economic and environmental components. As such, natural resource systems are impacted simultaneously by the diverse effects of many interacting human-environmental components. While conventional environmental planning commonly stresses estimation and prediction, preferring top-down initiatives and technocratic solutions, this approach often overlooks socio-economic impacts and interactions, leading to unexpected long-term outcomes. In response, it is now widely acknowledged that frameworks capturing the complex dynamics of society and the environment are needed to develop more sustainable environmental and water resources management strategies. Moreover, for robust policy-making, the performances of potential policies must be considered under multiple plausible conditions to enhance the chances of desired outcomes and limit the risk of undesirable results. This research addresses these challenges by considering deep uncertainty in coupled socio-economic and environmental systems. In this study, a computational model-based approach to support adaptive decision-making under deep uncertainty is developed and applied to adaptive policy-making of sustainable water resources management for human-water systems in developing countries. The Rechna Doab region of Pakistan is considered as a case study. Qualitative-quantitative participatory exploratory modeling is performed by incorporating a physical-socioeconomic system dynamics model, a systematic scenario selection method and a scenario discovery approach. The Driver-Pressure-State-Impact-Response (DPSIR) model is used through storytelling approaches to identify vulnerabilities in policy options in the coupled socio-economic and environmental system by considering its response to drivers, pressures, states, and impacts. Storytelling methods are used to develop qualitative storylines in order to support a detailed and stakeholder-led description of future adaptive management policies. The proposed methodology is used for systematic scenario discovery to uncover vulnerabilities across a range of possible futures and test the performance of stakeholder proposed policies. Also, the tradeoffs between water resources management alternatives, in terms of stakeholder objectives, and their robustness to deep uncertainty are assessed. The proposed approach simulates qualitative and quantitative cause-effect relationships between the environmental system and socio-economic interactions to assess candidate policies, their vulnerabilities and associated adaptive strategies.

