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Resolving Multi-Stakeholder Robustness Asymmetries in Coupled Agricultural and Urban Systems

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The evolving pressures from a changing climate and society are increasingly motivating decision support frameworks that consider the robustness of management actions across many possible futures. Focusing on robustness is helpful for investigating key vulnerabilities within current water systems and for identifying potential tradeoffs across candidate adaptation responses. To date, most robustness studies assume a social planner perspective by evaluating highly aggregated measures of system performance. This aggregate treatment of stakeholders does not explore the equity or intrinsic multi-stakeholder conflicts implicit to the system-wide measures of performance benefits and costs. The commonly present heterogeneity across complex management interests, however, may produce strong asymmetries for alternative adaptation options, designed to satisfy system-level targets.

In this work, we advance traditional robustness decision frameworks by replacing the centralized social planner with a bottom-up, agent-based approach, where stakeholders are modeled as individuals, and represented as potentially self-interested agents. This agent-based model enables a more explicit exploration of the potential inequities and asymmetries in the distribution of the system-wide benefit. The approach is demonstrated by exploring the potential conflicts between urban flooding and agricultural production in the Lake Como system (Italy). Lake Como is a regulated lake that is operated to supply water to the downstream agricultural district (Muzza as the pilot study area in this work) composed of a set of farmers with heterogeneous characteristics in terms of water allocation, cropping patterns, and land properties. Supplying water to farmers increases the risk of floods along the lakeshore and therefore the system is operated based on the tradeoff between these two objectives. We generated an ensemble of co-varying climate and socio-economic conditions and evaluated the robustness of the current Lake Como system management as well as of possible adaptation options (e.g., improved irrigation efficiency or changes in the dam operating rules).

Numerical results show that crops prices and costs are the main drivers of the simulated system failures when evaluated in terms of system-level expected profitability. Analysis conducted at the farmer-agent scale highlights alternatively that temperature and inflows are the critical drivers leading to failures. Finally, we show that the robustness of the considered adaptation options varies spatially, strongly influenced by stakeholders' context, the metrics used to define success, and the assumed preferences for reservoir operations in balancing urban flooding and agricultural productivity.