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Should hydro-economic models be agent-based? Should they include non-economic behaviors and metrics?

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Should hydro-economic models be agent-based? Should they include non-economic behaviors and metrics?

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Abstract: Hydro-economic analysis represents the standard hydrological and engineering realities of water resource system along-side economic drivers and impacts. Often optimization is used to simulate profit-maximizing behavior which is assumed to drive most water use decisions. Recently, different modeling trends have bumped against traditional hydro-economic modeling and challenging it in new directions. One is agent-based modeling, understood as a field of analysis where the behavioral rules of individuals help understand/predict how the whole system functions. This challenges hydro-economic models to include non-economic driven rules or behaviors in addition to economic optimization. Multi-criteria optimization also challenges social-economic models to assess other performance metrics besides monetary ones. This extended abstract and talk will show two case-studies and discuss how these two areas could help progress the practice of hydro-economic modeling.

Keywords: hydro-economic modeling, agents, multi-criteria search, water management modeling.

1. Introduction

Hydro-economic models represent spatially distributed water resource systems, infrastructure, management options and economic values in an integrated manner (Harou et al. 2009). In these tools water allocations and management are either driven by the economic value of water or evaluated by that measure to provide policy insights and reveal opportunities for better management. Classical optimization-driven hydro-economic models have typically focused on the potential system-wide economic gains from water trading. Recent research has identified that economic analysis linked to space-time discretized water models can take on a variety of forms. The use of centralized optimization has been questioned for water management modeling outside of systems with well-functioning water markets. For example agent behavior has been represented within a decentralized optimization-based framework (Yang et al. 2009), moving away from the assumptions of full information sharing to analyze different levels of cooperation between agents (Giuliani and Castelletti 2013) . New approaches aim to represent more realistic 'agent' behavior (Berger et al. 2007; Bonabeau 2002; Giuliani and Castelletti 2013; Yang et al. 2009; Zhao et al. 2013). 'Agent' in this context refers to water users and in some cases a wider array of actors including institutional ones. For modeling water markets however, centralized optimization is still appropriate (Britz et al. 2013; Erfani et al. under review).

Another new direction for hydro-economic modeling involves identifying pareto-optimal 'efficient' solutions rather than least-cost of maximum economic benefit ones. These solutions present themselves as trade-off curves or surfaces where each point is an individual pareto-optimal plan. Increasingly this approach uses heuristic optimization approaches such as many objective evolutionary optimization (Reed et al. 2013) linked to advanced visualization tools (Kollat and Reed 2007). The approach can be used to optimize management (operational variables), investments (binary yes/no decisions) or a combination of both. This offers considerable flexibility beyond traditional linear or nonlinear optimization models where network flows and storage are optimized. The premise here is that many objectives cannot be monetized and thus presenting trade-off curves between monetized and non-monetised benefits will be informative to stakeholders and decision-makers. Many factors of economic performance are effectively compared to non-economic measures of system performance.

2. Case-studies

The talk will review two examples of these approaches. The first is an optimization model to simulate short-term pair-wise spot market trading of surface water abstraction licenses (water rights) (Erfani et al. under review). The purpose of the proposed model is to assess potential hydrologic and economic outcomes of water markets and aid policy makers in designing water market regulations. The model is applied to the Great Ouse River basin in England. The model assesses the potential weekly water trades and abstractions that could occur under different hydrological conditions. Agents from 4 water using sectors are included in the nearly 100 active licensed water diversions represented. Each license's unique environmental restrictions are represented and weekly economic water demand curves are estimated. Rules encoded as constraints represent current water management realities and plausible stakeholder-informed water market behaviors. The model uses a mix of optimized and rule-based behaviors to attempt to simulate how a water market could manifest.

The second study (Matrosov et al. under review) links a water resource management simulator to multi-criteria search to reveal the key trade-offs inherent in planning a real-world water resource system. We consider new supplies and water conservation options while identifying the trade-offs between the best portfolios of schemes to satisfy projected water demands. Alternative plans are evaluated using metrics that minimize costs and energy use while maximizing various performance criteria subject to level of service constraints. Our analysis shows many-objective evolutionary optimization coupled with state-of-the art visual analytics helps planners discover the best plans and their inherent trade-offs. The approach is applied to the London's water resource and water supply system. We investigate how certain proposed options are distributed throughout the pareto set. This study highlights that traditional least-cost reliability constrained planning of water supply masks plans whose benefits only become apparent when more planning objectives are considered.

3. Conclusion

New areas of hydro-economic analysis are emerging that can widen the use of joint economic and water resource system engineering analysis. This includes models that include non-economic behaviors and approaches that identify pareto optimal trade-offs of investments. The talk will describe case-studies using both approaches and will discuss the implications for future use of hydro-economic analysis.

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