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How does uncertainty affect cooperation strategies in transboundary water resources systems? A case study on the Zambezi River Basin

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Nowadays, about one-half of the earth's land surface and more than half of global freshwater is covered by about 260 transboundary river basins worldwide, which are often managed by multiple, institutionally independent decision makers. Most of these international basins are characterized by the presence of many stakeholders with conflicting interests, leading to the rise of water conflicts over distribution, co-management, and utilization of the water resource. In particular, upstream and downstream conflicts arising from the development of new water infrastructures are inevitable and expected to intensify in the near future. This will put additional pressure on water resources, together with growing water/energy demands and increasing water scarcity induced by climate change. Water resources management in transboundary river basins has often been addressed from a single, centralized decision maker perspective, assuming full cooperation and information exchange among multiple stakeholders. Yet, this assumption rarely reflects the real socio-political framework in an international basin. On the other side, game theory has been used to represent individual decision makers and develop more acceptable solutions. However, this approach often overly-simplifies physical and social dynamics shaping transboundary contexts, and the non-linearities between them.
In this work, we present a novel, robust decision-analytic framework to explore and compare different cooperation settings among multiple, conflicting stakeholders by means of an optimization approach based on Evolutionary Multi-Objective Direct Policy Search (EMODPS). The framework is tested on the Zambezi river basin in Africa, where we first quantify the differences in system performance achieved under three different cooperation levels under historical hydro-climatic and socio-economic conditions. Then, an a-posteriori robustness assessment step is conducted in order to explore how deep uncertainties in hydrological (e.g., streamflow) and socio-economic (e.g., energy demand, irrigation water demand) variables affect different optimal cooperation strategies in a transboundary context. Our results show the benefits of implementing a centralized rather than a non-centralized management strategy, assessing the value of full information exchange and basin-wide objectives needed to robustly maximize the system performance at the entire basin level under a variety of uncertain futures.