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Valuing hydrological alteration in Multi-Objective reservoir management

S. Bizzi, F. Pianosi, and R. Soncini-Sessa
Dipartimento di Elettronica e Informazione, Politecnico di Milano, Italy

Water management through dams and reservoirs is worldwide necessary to support key human-related activities ranging from hydropower production to water allocation for agricultural production, and flood risk mitigation.
Advances in multi-objectives (MO) optimization techniques and ever growing computing power make it possible to design reservoir operating policies that represent Pareto-optimal tradeoffs between the multiple interests analysed. These progresses if on one hand are likely to enhance performances of commonly targeted objectives (such as hydropower production or water supply), on the other risk to strongly penalize all the interests not directly (i.e. mathematically) optimized within the MO algorithm.
Alteration of hydrological regime, although is a well established cause of ecological degradation and its evaluation and rehabilitation are commonly required by recent legislation (as the Water Framework Directive in Europe), is rarely embedded as an objective in MO planning of optimal releases from reservoirs. Moreover, even when it is explicitly considered, the criteria adopted for its evaluation are doubted and not commonly trusted, undermining the possibility of real implementation of environmentally friendly policies.
The main challenges in defining and assessing hydrological alterations are: how to define a reference state (referencing); how to define criteria upon which to build mathematical indicators of alteration (measuring); and finally how to aggregate the indicators in a single evaluation index that can be embedded in a MO optimization problem (valuing).
This paper aims to address these issues by: i) discussing benefits and constrains of different approaches to referencing, measuring and valuing hydrological alteration; ii) testing two alternative indices of hydrological alteration in the context of MO problems, one based on the established framework of Indices of Hydrological Alteration (IHA, Richter et al., 1996), and a novel satisfying the mathematical properties required by widely used optimization methods based on dynamic programming; iii) discussing the ranking provided by the proposed indices for a case study in Italy where different operating policies were designed using a MO algorithm, taking into account hydropower production, irrigation supply and flood mitigation and imposing different type of minimum environmental flow; iv) providing a framework to effectively include hydrological alteration within MO problem of reservoir management.

Richter, B.D., Baumgartner, J.V., Powell, J., Braun, D.P., 1996, A Method for Assessing Hydrologic Alteration within Ecosystems, Conservation Biology, 10(4), 1163–1174.