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Hydrology and Earth System Sciences Discussions

Interactive comment on "Assessing water resources management and development in Northern Vietnam" *by* A. Castelletti et al.

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We wish to thank the reviewer for his/her useful comments and suggestions. We hope we addressed all the issues raised and we are willing to modify the paper accordingly. Below is a list of specific replies to the reviewer comments.

General comments

The authors mention in the introduction that only two papers on the operation of the Hoa Binh reservoir have been published and that their paper is a step forward in different ways. The paper can, therefore, be regarded as a novel contribution *for this particular area. However, it is unclear whether similar studies have been done for other river basins (i.e. reservoirs) in the world using the same or similar models and algorithms. Therefore, please provide an over view of the most relevant studies focusing on other reservoirs in the world and indicate the differences of those studies compared to the study reported in this paper. This might also reveal the methodological novelty besides the study area related novelty.*

Reply: Some of the reservoir optimization techniques employed in this study are well established (DDP), while others (MOGA) are rather novel. Still, in our opinion the methodological contribution of the paper is not in the development/improvement of optimization methods themselves but rather in the way they can be used to infer knowledge about the system functioning and assess the space for improvement of the Hoabinh operation. A detailed review of reservoir optimization methods and applications goes beyond the scope of this paper. References to state-of-the-art review and MOGA method are given in section 3 (we can enrich the bibliography with specific references for MOGA application to reservoir operation, see below).

The immediate costs associated with the three policy objectives are calculated using simplified equations including some rough coefficients. The reservoir and downstream river network are simulated with relatively simple models as well. This is acknowledged by the authors. The relative simplicity of the models has not be a limiting factor of this study. Moreover, the evaluation shows that the models generally are quite accurate. However, this might be caused by the overlap of the evaluation period and the cali- bration period. In particular, the values of the coefficients used in the calculation of the immediate costs (alfa, beta, delta, n, m) seem to be somewhat arbitrarily chosen. It is recommended to assess the sensitivity of the results to different values of these coefficients (and for different months) to test the robustness of the results. What is a plausible range for these coefficients? What is the corresponding uncertainty in the results?

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Reply: We thank the reviewer for rising this point. Yes, the models used in this work are rather simple however we think they are adequate at the space and time scale considered in this study. We can improve the description of such models (even if for a detailed discussion the reader is referred to the literature, specifically (Quach, 2011)), by adding some comments on the validation of the hydropower plant model (see reply below) and motivations for the coefficients (alfa, beta, delta, n, m) used in the immediate costs. Specifically, the pattern of coefficient “alfa” (hydropower cost) is based on the analysis of the energy deficit and consequent import from China in the different season. Coefficient “beta” (water supply) is doubled from January to March, because in that period the diverted flow from the Red River is the only source for the submersion of paddy fields for winter-spring rice crop, while in the rest of the year the submersion is also supported by rainfall. The rational behind coefficients “delta” and “m” (flood control) is that flood risk comes from either the overtopping of the levees or the levee breaches. The latter are more probable in August because the mean water level is 8.29 m (against 4.53 m in the rest of the year) and thus the fraction of the levee saturated with water is larger. Water level excesses are thus given more weight in August. Further, the total force on the levee, which is the driver of collapse, increases with the square of the water level, which motivates the choice of power 2 in Eq. (3). In conclusion, the choice of these coefficients is not “arbitrary” since it follows from various considerations about the system functioning, socio-economic priorities, etc., however it certainly is “subjective”, since these coefficients do not represent any physical quantities (for whom a “correct” value exists, although unknown) but rather they concur to representing the value given to physical quantities (power production, water deficit, water level). Furthermore, we think it is not possible to apply a standard sensitivity analysis to these coefficients. In fact, one cannot compare objective values obtained with different coefficients since the objectives have different meaning once the coefficient values have been changed, and thus they cannot be compared anymore.

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Specific comments

Title

p7177: The title can be more focused on the topic of this paper: multi-objective optimization of reservoir operation in Northern Vietnam.

Reply: The focus of the paper is on assessing the current operation and the space for improvement (including infrastructural expansion) in a large water system, the Red River Basin, including uncontrolled tributaries and the planning of new reservoirs. The suggested title is, in our view, restricting the scope of the paper to the technical aspect of designing the operation.

Abstract

p7178, l1-13: Try to incorporate more specific information about methods and results in the abstract. The current version of the abstract is too general.

Reply: Thank you. The abstract can be changed as follows: "In many developing countries water is a key renewable resource to complement carbon-emitting energy production and support food security in the face of demand pressure from fast-growing industrial production and urbanization. To cope with undergoing changes, water resources development and management have to be reconsidered by enlarging their scope across sectors and adopting effective tools to analyze current and projected infrastructure potential and operation strategies. In this paper we use multi-objective deterministic and stochastic optimization to assess the current reservoir operation and planned capacity expansion in the Red River Basin (Northern Vietnam), and to evaluate the potential improvement by the adoption of a more sophisticated information system. To reach this goal we analyze the historical operation of the

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major controllable infrastructure in the basin, the HoaBinh reservoir on the Da River, explore its re-operation options corresponding to different tradeoffs among its three main objectives (hydropower production, flood control and water supply), using multi-objective optimization techniques, namely Multi-Objective Genetic Algorithm. Finally, we assess the structural system potential and the need for capacity expansion by application of Deterministic Dynamic Programming. Results show that the current operation can only be relatively improved by advanced optimization techniques, while investment should be put into enlarging the system storage capacity and exploiting additional information to inform the operation."

Introduction

p7178, l21-25: Could you quantify the importance of hydropower as primary renewable energy resource and the importance of irrigated agriculture as economic driver?

Reply: Hydropower is the primary renewable energy resource in the country (33% of the total electric power production). Agriculture (76% of whose product comes from irrigated land) contributes for 18% to the GDP, but employees 70% of the population. We can add this figures in the paper introduction

p7179, l11-12: Try to formulate a more specific objective of this paper, the 'current management of the Red River Basin' includes much more than the optimization of the Hoa Binh reservoir described in this paper.

Reply: Both in the abstract and in the introduction the general scope of the paper (management of the RRB) is subsequently detailed by specifying that the paper focus on the operation of the largest controllable infrastructure in the basin, the HoaBinh reservoir.

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p7180, l4: Please provide a brief outline of the paper here.

Reply: Yes we can do it.

System and models

p7181, l13: Please explain "...but not with the timetable."?

Reply: We agree the sentence was not clear. We meant that the energy price does not change within the day or the week.

p7181, l21: What are the units in equation (1)?

Reply: Power production (equation 5) is measured in GWh. In the submitted version of the paper, coefficient "alfa" is defined as adimensional, and thus the immediate cost g is also expressed in GWh (mind that we found an error in the unit of measurements of power production throughout the paper: all figures should be multiplied by 1000: for instance, the historical annual production, mentioned in section 2.2.1 and in the conclusion, is 7.82 TWh, and not 7.82 x 10^9 kWh). However, we are considering changing this notation and give "alfa" the dimension of GWh^{-1}, so that the immediate cost becomes adimensional and it is clear that it should be regarded as a (negative) "value" and not a physical quantity. We should do the same with the other immediate costs ("beta"=[m3/s]$^{-2}$; "delta"=[cm]$^{-2}$) so that all objectives would be adimensional.

p7185, l16-18: What do you mean with "...the feasibility constraints in computing the actual release are not estimated properly."? And how is the outflow of the Da catchment estimated?

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Reply: As stated some lines above, the release decision is implemented only if comprised between the minimum and maximum release values, which depend on the current storage and inflow, taking into account the rating curves of the reservoir gates (these are the "feasibility constraints"). As for the outflow of the Da catchment, we used historical time series of measured flow in an upstream gauging station.

p7186, l8-10: What is the model performance on a daily basis?

Reply: It is much higher (relative absolute error is about 11%). However, this figure may be due to measurement errors in the daily release observation that was used to feed the hydropower plant model, rather than to the inaccuracy of the model itself. We can add this comment in the paper. Also, notice that in the remaining of the paper we compare performances of the various operating policies and the historical values simulated by our model (e.g. not the measured hydropower production but rather the one estimated by our model when fed by historical hydrological data). Therefore, whatever the source of the model error (measurement error in the model input or structural error), it is not really influencing the comparison between different operating policies.

p7186, l21: Please use another symbol for parameters ei since this symbol is also used for surface evaporation in equation (4).

Reply: ok.

p7187, l13-15: Which residuals are minimized? Are the policy objectives (hydropower production, flood control, water supply) taken into account in this optimization (minimization)?

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Reply: The model residuals, i.e. the deviation of model output from observed flow at SonTay (or level at HaNoi). The policy objectives are not accounted for at this stage.

Re-operation of the Hoa Binh reservoir by MOGA

p7189, 111-13: Why is MOGA used?

Reply: The reason for choosing MOGA is that it is quite effective, especially in multi-objective problems (it provides an approximation of the entire Pareto front in one optimization run), and rather simple-to-apply (few tuning parameters to be set; computer programming is a minimum because one only has to integrate the simulation module with the optimization code). We can insert this comment in the paper and add references to other studies employing MOGA for reservoir operation, e.g.
Oliveira, R., and Loucks, D.P.: Operating rules for multireser voir systems, Water Resour. Res., 33, 839–852, 1997.

p7189, l22: Are parameters a, bi, ci and di the same as the parameters in equation (7)?

Reply: No, they are not. We will modify the notation in order to avoid confusion.

p7189, l26: What do you mean with "...under exam."?

Reply: We mean the parameterization that constitutes the "individual" or, in the Genetic Algorithm metaphor, its chromosomes. We can modify the sentence as: "the operating policy defined by the parameterization constituting the individual's "chromosome""

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Tables and figures

p7199, Table 2: How have these 20 operating policies been defined?

Reply: It is the subset of the final solutions that proved Pareto-dominant over the historical performances. We will stress this in the revised version of the paper.

p7201, Figure 1: Please provide the complete Red River basin including the Chinese- Vietnamese border, the catchment borders and the delta area.

Reply: ok, see new version of Figure 1.

p7202, Figure 2: This figure should be self-explanatory, i.e. the reader should be able to understand the figure and caption without reading the main text. This is currently not the case.

Reply: ok, see new version of Figure 2.

Technical corrections

p7179, l16: delete "from"
p7179, l23: "Hoa Binh reservoir" instead of "Hoa Binh"
p7179, l26: "these results" instead of "this results"
p7182, l25: "one single" instead of "on single"
Reply: ok, thank you.
p7183, l11: What is the meaning of the question mark?
Reply: Just a mistake in latex referencing, now corrected.
p7184, l11: "The physical model" instead of the "The physical system"?
Reply: ok, thank you.

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p7185, l1: “dynamics are” instead of “dynamics is”
Reply: Singular verb should be used with “dynamics”
p7185, l25: Shouldn’t it be “hydraulic head difference” instead of “hydraulic head”?
p7186, l18: “based on a feedforward” instead of “based on feedforward”
p7187, l13: “trial and error” instead of “trail and error”
p7189, l11: “we used a Multi-Objective” instead of “we used Multi-Objective”
p7189, l17: “thus a small number” instead of “thus small number”
p7191, l6: “threshold” instead of “thereshold”
p7191, l11: “to an imperfect” instead of “to imperfect”
p7191, l11: “inputs” instead of “input”
p7194, l13: Please reformulate this part of the sentence.
p7194, l7: “construction” instead of “constiruction”
p7195, l19: “De Kor t, I.A.T. and Booij, M.J.” instead of “De Kor t, I. and Booij, M.”
p7195, l23: “Draper, A.J. and Lund, J.R.” instead of “Draper, A. and Lund, J.”
p7196, l6-7: What kind of document is this?
p7196, l8: “Stedinger, J.R.” instead of “J. R. S.”
p7196, l15: “Kipkorir, E.C.” instead of : “Kipkorir, E.”
p7196, l24: “Ngo, L.L.” instead of “Ngo, L.”
p7196, l26: “Ngo, L.L.” instead of “Ngo, L.”
p7197, l11: Is Toan et al. (2010) still in press?
Reply: yes, it is
p7197, l15: “Lindenschmidt, K.-E.” instead of “Lindenschmidt, K.”
p7206, Figure 6: “horizontal axis” and “vertical axis”
Reply: ok, thank you.

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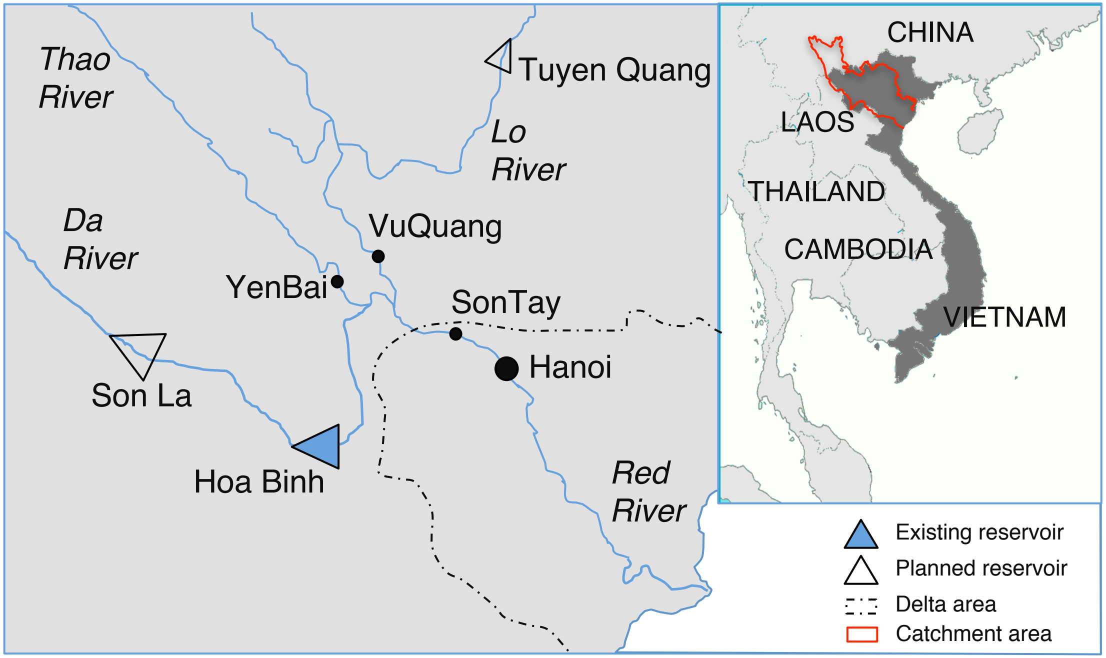

Fig. 1. The Red River Basin in Northern Vietnam.

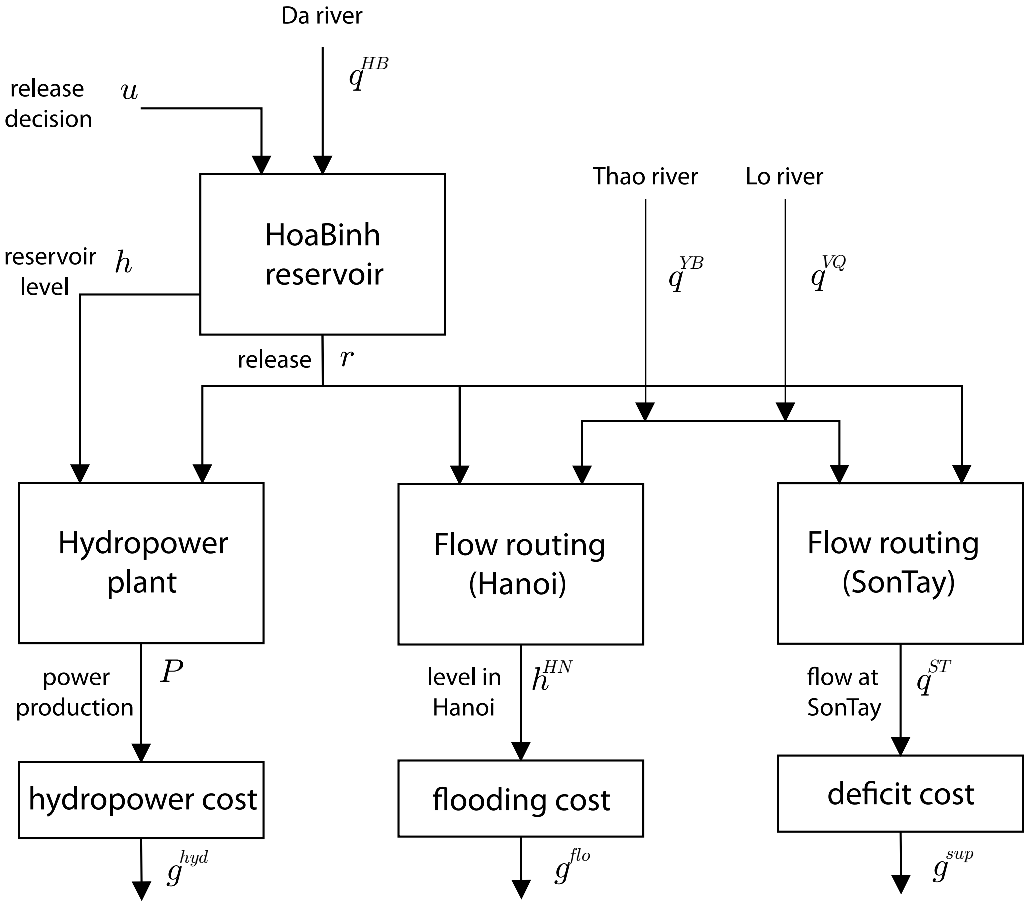

Fig. 2. The model scheme of the Red River Basin and the main system variables.

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