Hydrology and Earth System Sciences Discussions

Interactive comment on "Optimal operation of a multipurpose multireservoir system in the Eastern Nile River Basin" *by* Q. Goor et al.

Anonymous Referee #2

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The paper analyzes the positive and negative externalities of planned infrastructural initiatives in the upper part of the Nile River Basin on hydropower generation and agriculture in Ethiopia, Sudan and Egypt. A large hydro-economic model of the Blue Nile and downstream River Nile, including the optimal operation of storage systems, is developed and 3(+1) different planning scenarios are evaluated.

The topic addressed is of great interest both in terms of socio-political impact of the work as the well-known disputes for water in the region are still a big unresolved issue, and for its scientific contribution, as the (sub)optimal operation of such large system is still a challenge.

Overall, this is a good paper, however, in my opinion, there are three main macro-

aspects that need to be improved to make it suitable for publication on HESS:

1. Assumptions and limitations of the work must be better outlined both in the introduction and the conclusions. Indeed:

    a. all the analyses are conducted using the historical hydro-climatological conditions, while the reference time horizon for the planned infrastructures is 2025. Authors should mention this.

    b. the environmental impacts of flow pattern alteration, mainly due to the increased routing of the flow in the Ethiopian part of the river basin, and of the consumptive water use in Sudan are not taken into account. This should be clearly outlined among the limitations of the work.

    c. clearly, the optimal operation of a such a large system requires to resort to approximate approaches. The SSDP approach adopted is basically working by converting a non-linear optimal control problem into a constrained linear programming problem. It would be very useful for the reader (and the decision-makers) to have a feeling of the effects of this approximation, especially considering that most of the facilities are only planned and not yet operated, and therefore the reference to the current operation, which would be the natural one, is missing. For instance, a comparison of SSDP and SDP on a single reservoir or a subpart of the system. Moreover, considering that the strong advantages of SDP in dealing with non-linearities are not exploited because of the many linearizations, while not to use another optimization approach like policy search approach or ISO?

2. The mathematical formulation of SSDP and the problem has to be improved. I would suggest to make it more compact and less detailed but clearer. Specifically:

a. there are a number of weakness in using the mathematical notations. Some examples. (i) The function notation is wrongly used (and changing in the text): (line 6, page 4336) 'benefit-to-go function F_{t+1}', (line 4, page 4338); 'the net benefit function $\hat{f}_{t_f}^{i,(d)}(y_{t_f}^d)$'. While the former is acceptable, the latter is not a function but the value provided by the function. The correct notation would be $f(\cdot)$, where the functions arguments are replaced by dots. This notation is wrongly used in equation (7). (ii) the adoption of bold for vectors must be always used in the text to avoid confusion. For instance, you are dealing with a network of reservoir and in fact the storage is defined as a vector at line 17, page 4335. In the subsequent parts it becomes a scalar (see, e.g., eq (3)). The same holds for many other variable. (iii) while the meaning of t_f is clear, formally its use is not correct. For example, equation (4) is saying that irrigation benefit at month t is equal to something that does not change with t. (iv) a state variable is by definition deterministically known, so it cannot be defined as y_{t+1}. Indeed, in equation (8) and (13) you correctly use y_t as a state variable. So, what you should define as state variable is the storage at the end of the (previous) period, i.e. y_t. (v) the notation for the crop benefit is changing from when it is first defined and then used. First is a function of the demand site, then it becomes a function of the demand site and the crop. I would define it in the right way from the beginning.

b. how did you address stochasticity? the SSDP is originally (eq (1)) formulated using expectation to filter the uncertainties associated to hydro-climatology (h_t). This expectation operator disappear in eq. (8). However you then mention you are using PAR model for the inflow, so the model is a stochastic one. On the other hand, if you add the expectation operator to eq (8), eqs (10) and (14) are ill-posed because they are formulated on random variables and should therefore be in the form of chance constraints.

c. the linear constraint system in eq. (3) and especially the one in eq (15) and

(16) should deserve some more explanation (e.g. why H approximations, how is H selected, etc), otherwise it is totally useless here and can be removed (maybe the best option) and substituted for few explanation words and reference to the literature (they are already there). Please notice, that at line 3 of page 4341 there should be an error in the number of equations defining the optimization problem.

d. the finite time horizon adopted for the optimization is very short (84 time steps). Did you consider any penalty on the end-of-horizon state?

3. Results presentation.

The result discussion is very well organized and effective. However, I would suggest to also show results in terms of benefit ($) as using a CBA approach this would be the more natural way of looking at them (otherwise, why not to use multi-objective analysis?). This would be particularly useful for agriculture, since you are showing how the total withdrawal change globally, but not its distribution along the seasons and its comparison with the crop demand. I'm not sure that your way of formulating the agricultural benefit is taking into account the intra-seasonal distribution of water deficit and the associated risk for plant stress. The dummy storage being the same at the end of the season, is your objective able to distinguish between an operation policy that generate many small deficit and one that concentrate the same accumulated volume in few days so causing high stresses?

Also for the hydropower, looking also at the benefit and not only the production would be quite interesting.

Typos and minors errors: - cost and prices are sometime US$ and sometimes simply $

- line 16, page 4337: vector -> vectors

- line 27, page 4344: project -> projects