

Title: Quantifying the trade-offs in re-operating dams for the environment in the Lower Volta River.

#### Overall summary

The manuscript quantifies the trade-offs between environmental water uses and hydropower generation in the Lower Volta River Basin using Multi-objective Direct Policy Search. The topic is of general interest given the worldwide boom expansion of new hydropower dams and the environmental and social impacts of dam construction and operations. However, the manuscript's contribution is not clearly presented, nor are the broader implications for Ghana of hydropower reduction discussed.

In terms of the manuscript's contribution is not clear if the authors are presenting a methodological advance or presenting the system trade-offs among different water users in the Lower Volta River basin. If the contribution is methodological, it is not clear how what the author present is different from other previous studies that use EMODPS. If the contribution it is to presents the system trade-offs, the discussion/implications of reducing hydropower generation lack broader consequences for the country and its economy. How could the results be presented to relevant decision-makers in the country if only local 'benefits' (lines 444 to 452) are given to 'validate' the implementation of hydropower reduction to support e-flow implementations? Does Ghana have alternatives to replace cheap and flexible hydropower generation? If the reduction in hydropower is replaced by thermal generation, how will this impact nationally determined contributions (in terms of CO2 emission reduction)? What is the local vs country-wide trade-offs of reducing hydropower generation? I consider these questions need to be answered if the paper aims to be a viable input to any discussion on re-operating the Akosombo and Kpong hydropower plants. I recommend improving the paper's discussion and implications by including a clear discussion of the previously highlighted points.

It is not clear how robust are the presented results in terms of future climate change impacts or upstream water uses changes. The Akosombo and Kpong hydropower plants are located downstream of the Volta River basin, and any change in water availability upstream in the basin could possibly impact the system evaluated in this study. Methods such as Sensitivity Analysis or Exploratory modelling evaluating 'a wider range' of future states of the system could provide more conclusive results and improve the discussion of future impacts of changes in water availability.

I consider the manuscript should be reconsidered after major revisions.

#### Detailed comments

- 1) Lines 23 to 24, "There is uncertainty in climate change effects on runoff in this region." The study evaluates the impact of six climate change scenarios. Are those six scenarios representative of and account for the climate change uncertainty in the Volta River basin? How robust are the presented results of the six evaluated scenarios?

- 2) The literature review only focuses on EMODPS; there is no discussion about other methods used to identify reservoir operations. How does EMODPS compare with other techniques? Also, there is no transition between presenting MOEAs and EMODPS methods. MOEAs should be presented first, as EMODPS uses MOEAs to identify reservoir policies.
- 3) Lines 92 to 93. "As such, the implications of the trade-off on power delivery, energy prices and carbon emissions are not investigated". Dams and hydropower plants are not isolated infrastructures. The state-of-the-art is moving to evaluate the multi-sector implications of human-nature resources systems. Any reduction in hydropower generation not only impacts "the water demands" for this use, its impacts the power system (emission, energy prices, country economy, etc.). I recommend improving the discussion on the real implications of reducing hydropower generation in the country.
- 4) Lines 157 to 165. Is it unclear why the model was calibrated for three years with specific conditions to the system (wet, dry and normal) if the authors have access to historical data from 1981 to 2012? Why do not calibrate the model for the full historical time-series? The calibration process produced only one reservoir operating policy for the wet, dry and normal conditions of the system, or it produces a policy by condition.
- 5) Line 116 "to a steady flow of about 1,000 m<sup>3</sup>/s all year round". Is this steady flow the average flow downstream of Akosombo? Could the authors inform about the Akosombo release seasonality and monthly flow variability?
- 6) Lines 224 to 225. "While the annual firm power requirement from Akosombo Dam is 4415 GWh/year." [GWh] units refer to energy while [GW] units to power. Please, check if you are referring to "firm energy generation".