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Publication date
2020

Document Version
Final published version

Citation (APA)
Carimo, L., Crosato, A., van der Wegen, M., Paron, P., & Khan, O. (2020). *Assessing changes in the Zambezi River after dam construction and the impacts on the delta*. 94-95. Abstract from NCR Days 2020, Nijmegen, Netherlands.

Assessing changes in the Zambezi River after dam construction and the impacts on the delta

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Keywords — Zambezi river, morphology

Introduction

The Lower Zambezi is the downstream reach of the Zambezi River, a 600 km length starting from the Cahora Bassa Dam to the Indian Ocean, presented on Figure 1. This reach has been changing over the last decades since the construction of two major dams upstream, the Kariba Dam (1959) and the Cahora Bassa Dam (1974), as a consequence of their operation and design. The structures transformed the hydrograph of the river and cut sediment supply to the Lower Zambezi. A dam causes two opposite effects on the river downstream (Kondolf, 1997, Pasanisi, et al., 2016), while the reduction of sediment supply may result in bed incision and extra bank erosion, the reduction of peak discharges reduces the sediment transport of the river flow. In the study area, the morphological effects of the Cahora Bassa Dam propagate downstream and eventually will reach the Zambezi Delta, an important natural area. Some changes were already reported by Ronco, et al. (2010) and Davies, et al. (2000): deepening of river bed, vegetation growing on bars and floodplains, tendency of the river to anabranch, loss of small channel connections to floodplains and wetlands. What remains unknown are the time scales of the propagation of this changes, and if the changes happening in the Lower Zambezi as consequence of the dam construction have already reached the downstream Delta.

Goal of the Study

This study deals with the morphological effects of damming, on the Lower Zambezi River, with the following goals: (1) define the water balance of the Lower Zambezi, including all tributaries from Cahora Bassa outlet to the upstream end of the delta (Caia) before and after dam constructions; (2) define sediment balance of the same area before and after dam constructions, (3) discuss uncertainties and their causes; (4) study the time scale of the morphological adaptation of the Zambezi River to dam operation.

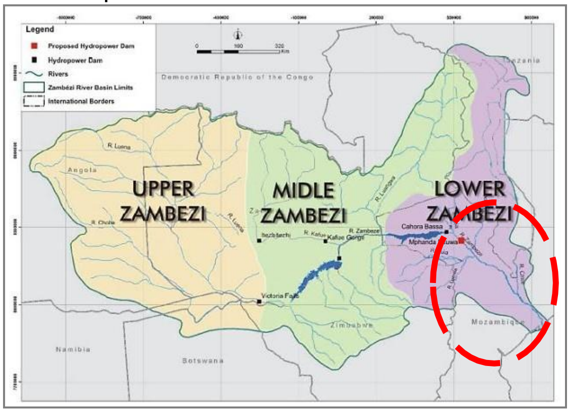

Figure 1. Zambezi Catchment and study area, the Lower Zambezi, Source: Adapted from Impacto and ERM (2011)

Approach

The study is based in the following approaches to achieve the goals: (1) a data analyses and characterization of the lower Zambezi River; (2) sediment and water balances based on available data and simple modelling taking into account relationship between discharge and sub-catchment area; (3) identify cause of uncertainty, as for instance, lack of data, choice of sediment transport formula and river schematization plus simplifications; and (4) study the time of morphologic adaptation by setting up a morphodynamic model based on Deflt3D-FLOW.

For the characterization of the Lower Zambezi changes, data from the period previous and after the construction of the dam was compared at different points of the reach. This data comprises the geometry (width, slope, depth and elevation), sediment size, sediment load and flow hydrographs. Although the data is limited, this is the first approach to assess the

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changes, and is used as an input for the next steps of the study. The flow under natural condition in the upstream of the delta were determined by the inflow from Cahora Bassa and the tributaries. The sediment balance it is determined by transport equations; and for the conditions previous to the dam construction, some data is available to generate rating curves. Both of the data obtained by the transport equations and rating curve will be compared to other author's outcomes of sediment production in the Zambezi River, to establish the scale of sediment load. The morphological modelling is being implemented representing part of the Lower Zambezi reach, 500 km, in a simple straight river with one and two cells in the cross section. From the model, different input will be changed in such a way that we can estimate the river response to different factors, including change of hydrograph and sediment supply. The time scales of changes observed in the model will be compared to De Vries (1975) formula.

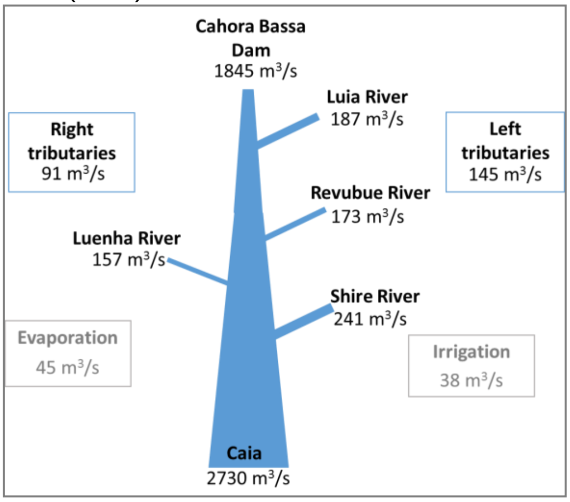

Figure 2. Water Balance of the Lower Zambezi

Preliminary results

The results of the study obtained at this point are from the data analysis and water balance. The preliminary data analysis for the geometry shows a widening of the river, decrease of the slope, and deepening of the main channel. This data is just a comparison from two years 1962 and 2007. The sediment in the bed of the river became, in general coarser, form 1964 to 2010. Flow analysis and water balance were made to get an estimation of the hydrological year under natural and dammed conditions, as well as the contribution of the tributaries (Figure 2). It is observed that the tributaries contribute with about one third of the discharge of the Lower Zambezi. The peak flow decrease analysing daily data shows about 40% reduction (Figure 3).

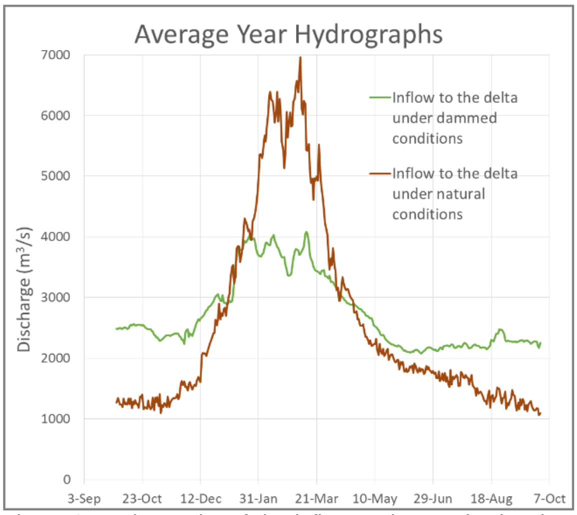

Figure 3. Hydrographs of the inflow to the Zambezi Delta under natural and dammed conditions

Conclusions

The complexity of the dynamics of a river and its response to interventions makes it difficult to analyse and connect the changes happening. Even though, all the geometrical changes found from data analysis are the ones expected to occur. With further data obtained from other remote sensing tools and the LiDAR produced in this area, it could be improved the evidences of the geometry change.

Establishing a water balance is an important step for the comparison of the situation before and after dam. The estimations made to obtain all the inflows might be rough estimations, but are important to the analysis of the study and input in the morphological model.

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