Effects of climate changes on hydropower profits in the Zambezi river basin

Report by.

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Summary

This document presents the study on hydropower Profit for 4 Dams in the Zambezi watercourse under climate change scenario. It is the result of a comprehensive modelling process as well a data analysis.

The study then contributes to understand the water management at basin level. A number of scenarios, associated with climate risk, as well business as usual, are then analysed. The specific objectives of the plan are thus: (i) Analyse the trends of the main variables influencing water supply (flow in) and demand (flow out) in the Kafue, Kariba and Cahora Bassa reservoirs; (ii) Estimate the effects of climate change scenarios on hydropower profits; More detailed information on each scenario can be found in the document. Each measure then provides the impact on turbines water flow, expected impact on the energy production and the related profit.

With regard to the simulated scenarios, all scenarios under dry conditions showed the impact to reduce the water flow hence the profit. The very best scenario is the one that foreseen an increase of available water (“Wet” scenario).

1 Introduction

There are many issues that links water, energy and climate change nexus. Therefore, the interaction of the water-energy nexus, received growing attention in research and political debates in the past decade (Dai et al., 2017). Among the many available energy sources, the hydropower still remains the most used in the world (Savelsberg, Schillinger, Schlecht, & Weigt, 2018). Therefore, due to climate constraints, the hydropower production in the wet years yield higher revenue while dry years yield the opposite. (Savelsberg et al., 2018). It is known that climate change and market liberalization may hamper investments due to the evolution of water runoffs and electricity prices, such that, both alter expected revenue and bring uncertainty (Gaudard, Gabbi, Bauder, & Romerio, 2016).

Nowadays it is recognized that Climate warming is likely to affect hydropower's supply/generation, demand, and pricing simultaneously (Guegan, Madani, & Uvo, 2012). Therefore, in this work, we focus on the impact of climate change in hydropower production, mainly for Kariba, Kafue and Cahora Bassa reservoirs and the respective economic feedback. The study includes the modelling approach and economic analysis. This modelling approach enables us to detect the quantitative changes in water availability, turbine flow and the respective variation in electricity hydropower generation, then to calculate the revenues/profit for hydropower operators under market constraints. The modelling is done under WEAP model (Water Evaluation And Planning).

1.1 Location and Area description

Zambezi river basin is located in Southern Africa (Figure 1). The Zambezi River lies within the fourth-largest basins in Africa after the Congo, Nile, and Niger, covering 1.37 million km^2. The Zambezi. River has its source in Zambia, 1,450 meters above sea level (World Bank, 2010).

Besides the main river course, it has many tributaries and in Mozambique the delta is distinguished by a wide, flat, marshy area with extensive floodplains. The river has three distinct stretches: the Upper Zambezi from its source to Victoria Falls, the Middle Zambezi from Victoria Falls to Cahora Bassa which includes the major tributary the Kafue River, and the Lower Zambezi from Cahora Bassa to the delta (Tilmant et al., 2010).

The Zambezi River Basin currently has approximately 5000 MW of installed hydropower generation capacity. Major dams include Kariba and Cahora Bassa dams on the mainstream Zambezi River, Itezhi-Tezhi and Kafue Gorge Upper dams on the Kafue River, and the Kamuzu Barrage that partially regulates Lake Malawi (Beilfuss, 2012).

Figure 1. Zambezi River basin Map (Source: World Bank, (2008)

1.2 Current and Potential Hydropower in the basin

Due to its location and landscape characteristics, the Zambezi River Basin has considerable hydropower potential, estimated at greater than 13000 MW basin wide. In addition to the 5000 MW of developed capacity, 6634 MW is proposed for development before 2025 and several other major sites are identified for construction over a longer time-frame (Beilfuss, 2012). Table 1 shows the existing hydropower projects and the respective types.

Table 1 Existing hydropower projects, reservoirs and types in the Zambezi River Basin

Name	Utility	River	Country	Type	Capacity (MW)
Victoria Falls	ZESCO	Zambezi	Zambia	Run-of-river	108
Kariba	ZESCO/ZESA	Zambezi	Zambia, Zimbabwe	Reservoir	1470
Itezhi -Tezhi	ZESCO	Kafue	Zambia	Reservoir	N/A
Kafue Horge Upper	ZESCO	Kafue	Zambia	Reservoir	990
Mulungushi	ZESCO	Mulungushi	Zambia	Reservoir	20
Lunsemfwa	ZESCO	Lunsemfwa	Zambia	Reservoir	18
Lusiwasi	Private	Lusiwasi	Zambia	Run-of-river	12
Cahora Bassa	HCB	Zambezi	Mozambique	Reservoir	2075
Wovwe	ESCOM	Wovwe	Malawi	Run-of-river	4
Nkua Falls A&B	ESCOM	Shire	Malawi	Run-of-river	124
Tedani	ESCOM	Shire	Malawi	Run-of-river	90
Kapichira Stage I	ESCOM	Shire	Malawi	Run-of-river	64

Source: Beilfuss, 2012

1.3 Data

The data for the study were obtained from ZAMCOM (Zambezi Watercourse Commission). The data included, climate, dam characteristics, water flows and discharges, turbines and other important information relevant to the modelling assessment. Most of the data ranged from 70´s up to 2008/2010.

Figure 2 reports a schematic layout of the Zambezi Basin. It represents the reservoirs, dams, abstraction points such as towns, irrigation projects and return flows.

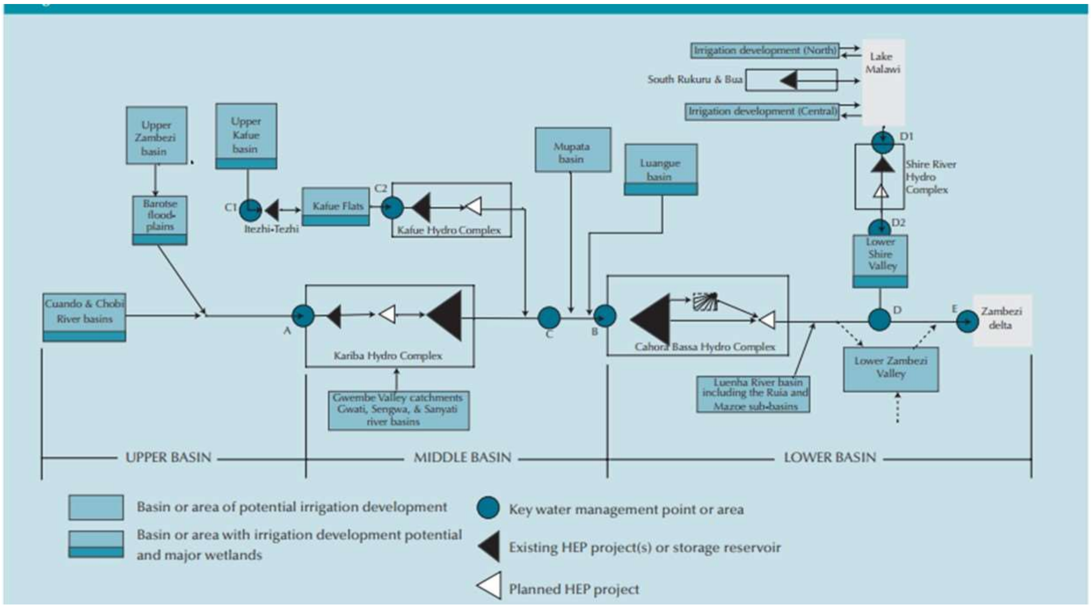

Figure 2. Schematic of Zambezi river basin (Source: World Bank, 2008)

2 Methodology

Current report presents an attempt to simulate the impact of Climate change on future hydropower revenue which is determined by runoff from the reservoirs and electricity prices. The modelling process comprised the calibration process (1976-2010) and the simulation (2010-2070) based on climate change derived by future climate projections. We used the assembled WEAP model supplied by ZAMCON under Non-Discloser Agreement. In order to verify the reliability of the model observed data were compared with simulated ones. More details are presented in chapter 3, under model parametrization and model evaluation.

2.1 Modelling Scenarios

The modelling set-up was done in the WEAP model. Five Scenarios were studied. The scenarios comprise actual climate, future climate and future development in the basin. For this study, besides the baseline conditions, the two main scenarios are characterized as Wet Scenario or Dry Scenario. These scenarios were taken from Spalding-Fletcher et al. (2014). The dry scenario is referred in the Zambezi River Basin WEAP model as Business as Usual dry (BAU Dry) and Grand deal dry while the Wet Scenario is referred as BAU Wet and Grand

Deal wet. The business as usual (BAU) is referred to do things as usual while climate is changing. For the Grand Deal is to incorporate the Future developments (i.e. population growth, increasing of agricultural areas, industry and others) related to increasing water demand in the basin while the climate is changing at the same time. In this regard the model was projected for base year 2010 up to 2070 under each of the combined climate and development scenarios (e.g. "BAU Dry", "BAU Wet", "Grand Deal Dry" and "Grand Deal Wet"). The Grand deal is also related to major investments and technology shift in the basin. These scenarios cover a range of AR4 scenarios.

2.2 Effects of climate changes on hydropower profits

The hydropower cost benefit analysis is dependent on the demand on the existing water uses and consumers in the basin. The profit outcome will always be connected to the amount of water withdrawal and turbine flow. The diagram bellow shows the flowchart for Hydropower cost benefits analysis (Figure 1). As it is known hydropower plants withdraw large amounts of water to run through their turbines, while the lakes they rely on can also consume water quickly by evaporation; however, lakes can be used for multiple purposes, such as domestic use, agricultural irrigation, flood control, and recreation, as well as environmental needs. Figure 1 shows the flowchart of that relation among different possible users that affects the turbine flow hence the hydropower profit.

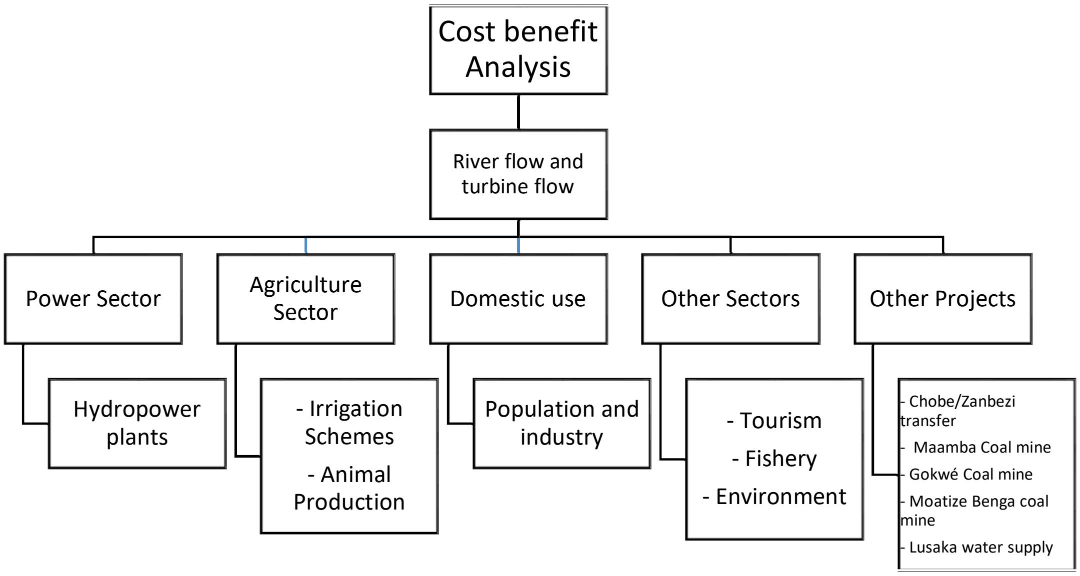

Figure 3 Flowchart for cost benefits analysis for Hydropower in the Zambezi river basin

In this study we apply the methodology used by Hirsch, Schillinger, Weigt, & Burkhardt-holm, (2014) to analyse the effects of climate change scenarios on profitability of the hydropower. Therefore, for estimating the effects of climate change scenarios on hydropower profits, the objective function to be optimized is expressed as follows:

$$Max\ Profit = Sum\ (Pt_j * Gt_J\ ) \qquad (1)$$

with Pt_j being the energy price at time *t* and hydropower *j* and Gt_j the energy generated in time *t* at hydropower *j*. The hydropower *j* is equal to 1 (Kariba), 2 (Kafue L and U) and 3 (Cahora Bassa).

The electricity price was taken as an average from local company prices reported in Southern African Power Pool (ECA, 2009).

The profit maximization problem described above is constrained by power generation function (equation 2), water balance equation of reservoir (equation 3), water storage bound (equation 4), discharges for hydropower production bounded by turbine capacity (equation 5) and minimum discharges bounded by residual flows (equation 6)

$$Gt_j=\mu*\lambda*Wt_j*Ht_j \qquad (2)$$

$$St_j=St_j\text{-}1+It_j\text{-}1\text{-}(Wt_j\text{-}1+Rt_j\text{-}1) \qquad (3)$$

$$St_j\min \leq St_j \leq St_j\max \qquad (4)$$

$$Wt_j\min \leq Wtj \leq Wt_j\max \qquad (5)$$

$$Rt_j\geq rt_j\min \qquad (6)$$

In the equation 2, the amount of energy generated Gtj is a function of the water discharge through the turbine at time t and hydropower j (Wt_j), the average head of reservoir at time t and hydropower j (Htj) and operational efficiency factor λ. The conversion factor μ converts the specific water flows Wt_j into electricity Gt_j (in MWh).

In the equation 3, the storage level at time t of the reservoir where is located the hydropower j (Stj) depends on the previous time(t-1), storage level (St-1), the natural inflows It-1 between t and t-1 , the amount of turbinated water at previous period t-1 (Wt_j-1) and the residual flow at previous period t-1 (Rt_j-1). The storage level at time t at hydropower j (St_j) is bounded by minimal and maximal discharge (equation 4) and the discharge at hydropower (Wtj) is also bounded by its minimal and maximal discharges. Additionally, the water flow at time t in the reservoir where is located the hydropower j (Rtj) should be greater than the minimal flow stipulated by law (rt_j).

Different scenarios of sensitivity analysis of hydropower profits will be simulated under the different conditions of water discharge through the turbine (Wtj), average head of reservoir (Htj), storage level of the reservoirs (Stj) and residual water flows (Rtj) using WEAP. Furthermore, Excel was used to organize and summarize the data.

3 WEAP Model description

WEAP is a modelling system used worldwide to simulate water allocation. WEAP ("*Water Evaluation and Planning*" system) (SEI, 2015) is a user-friendly software tool that takes an integrated approach to water resources planning. It has a user-friendly graphic interface and transparent simulation approach that makes it easier to present results to stakeholders and stimulate their feedback on the modelling. All the parameters and results can be shown in scenario format, and choices on water allocation are explicit in each scenario, so that policy makers can provide direct inputs and see the implications of changes in the system. The model has the built-in capability to link with different tools, including, among others, energy, water quality, groundwater and parameters estimation modelling tools (i.e. the LEAP, QUAL2K, MODFLOW, MODPATH, PEST, Excel and GAMS model). The model can be used for the evaluation of full and different ranges of water development and management options, taking into account multiple and competing water uses. WEAP operates on the basic principle of water balance and can be applied to municipal and agricultural systems, a single watershed or complex transboundary river basin systems. Moreover, WEAP can simulate a broad range of natural and engineered components of these systems, including rainfall-runoff, base flow, and groundwater recharge from precipitation; sectoral demand analyses; water conservation; water rights and allocation priorities, reservoir operations; hydropower generation; pollution tracking and water quality; vulnerability assessments; and ecosystem requirements.

3.1 Model parameterization

The Zambezi River Basin WEAP model is used to project monthly hydropower generation from 2010 to 2070 under each of the combined climate and development scenarios. The model set-up and parameterization data was supplied by ZAMCOM under a non-disclosure agreement, following the signing of a MoU for promoting collaboration with the ACEWATER2 CoEs. In this modelling process, actual level of development and historical climate are key determinants of the current performance of the hydropower sector, where the actual hydropower production can be used as a baseline (Spalding-fecher, 2018). Some of the model variables were verified against the existing secondary data. For this study, simulated volumes were verified against the available information (observed data). We found a weak point under the irrigated areas and still it is the main concern for this study. The existing databases (e.g FAO, SPAM2005/2010) does not provide detailed information on the irrigated area that can be used directly as a model input. For this a high degree os processing was need in order to match these two data bases. Another concern is related to the fact that in the supplied WEAP model there was no out flow as discharge from some of the big Urban settlements. In this regard we assumed that there is a a return flow link from all main big cities in the basin under the model schematic. This was done by connecting the flow link from cities to the watercourse.

3.2 Model Calibration

Data obtained from field ZAMCOM were used to calibrate the model. The calibration process aimed to minimise the root mean square error (RMSE) between measured (observed) and simulated data (Equation 7). During the calibration process, the target was to minimise RMSE (Yang, Yang, Liu, & Hoogenboom, 2014):

$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{n}(Pi - Oi)^2\right]^{0.5} \tag{7}$$

and relative mean square error (RRMSE) (Jamieson, 1991):

$$\mathrm{RRMSE} = \frac{RMSE}{\bar{\mathrm{O}}} * 100 \tag{8}$$

where P_i is simulated volume value, O_i is observed volume value, $\bar{O}$ is observed average volume and n is number of observations (i.e. number of volume observed and simulated). Equations (1) and (2) were used to compare measured values and simulated reservoir volumes along the studied period, in order to find the best calibrated parameters for volume, flows and Hydropower generation. In this study, model accuracy was considered very good if RRMSE<10%, good if 10%<RRMSE<20%, fair if 20%<RRMSE<30% and poor if RRMSE>30%, as proposed by (Jamieson, 1991).

3.3 Model evaluation

Besides the statistical expressions RMSE (equation 3) and RRMSE (equation 4), the modelling efficiency (EF) was calculated as (Archontoulis and Miguez, 2015; Yang et al., 2014):

$$EF = 1 - \frac{\sum_{i=1}^{n}(Oi - Pi)^2}{\sum_{i=1}^{n}(Oi - \bar{O})^2} \tag{9}$$

The index of agreement (d) was calculated as (Legates and McCabe, 1999; Archontoulis *e*t al., 2014; Yang et al., 2014):

$$\mathrm{d} = 1 - \frac{\sum_{i=1}^{n}(Oi - Pi)^2}{\sum_{i=1}^{n}(|Pi - \bar{O}| + |Oi - \bar{O}|)^2} \tag{10}$$

and the coefficient of residual mass (CRM) was calculated as (Antonopoulos, 1997):

$$\mathrm{CRM} = \frac{(\sum_{i=1}^{n} Oi - \sum_{i=1}^{n} Pi)}{\sum_{i=1}^{n} Oi} \tag{11}$$

where EF and "d" are accuracy measures ranging from minus infinity (-∞) to 1 and 0, respectively (for both, the higher the value the better). An EF between 0 and 1 is acceptable, while values ≤0 indicate no agreement (Yang et al., 2014). The d parameter is dimensionless ($0 \leq d \leq 1$) and a value of 1 indicates good agreement between observed and measured data, while 0 indicates no agreement (D. N. Moriasi et al., 2007). Coefficient of residual mass is an indicator of the model, where a positive value indicates a tendency for underestimation and a negative value a tendency for overestimation (Antonopoulos, 1997).

4 Results

4.1 Volumes and Turbine flows

For this study volumes and turbine flows were taken as a variable test for the WEAP model. Turbine flows are dependent on the available water in the watercourse and in the reservoir.

4.1.1 Simulated and Observed Volume

Our first approach was to understand the actual climate and the impact on the stored volumes in the studied reservoirs (Cahora Bassa, Kafue and Kariba). The calibration process comprised the comparison between observed and modelled volumes from 1976 to 2010 in the stated reservoirs. The data supplied by ZAMCOM does not have the information from KAFUE volumes, therefore the Cahora Bassa and Kariba reservoirs were used as an indicator of model performance (Figure 3).

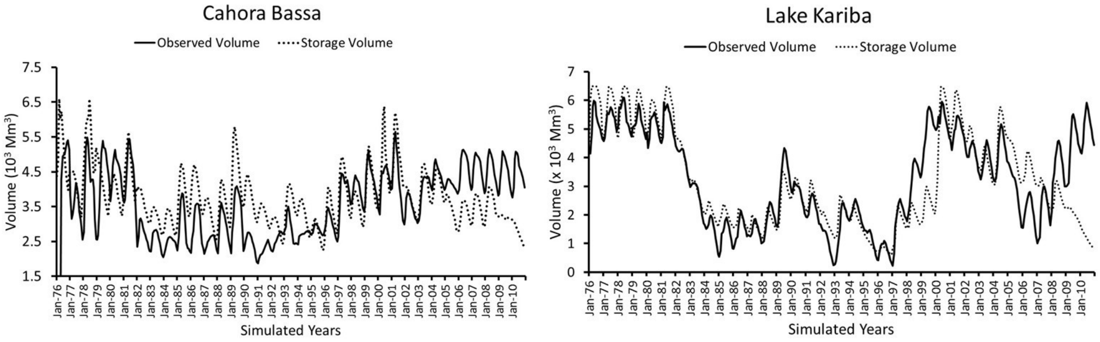

Figure 4 Simulated and Modelled storage volumes (1976-2010)

The data for model calibration ranged from January 1976 up to December 2010. The Relative Root Mean Square Error (RRME) for Kariba reservoir was 34.8%, while the model efficiency was 52.01% and Model agreement was 88.1%. For the same period, Cahora Bassa had a value of 25.9% for RRMSE, 2% for modelling Efficiency and 66.6% for modelling Agreement. For Cahora Bassa, the Coefficient of residual mass (-0.05) indicates that the model is overestimating the storage volumes, while a value of 0.011 for Kariba indicates that the model in underestimating the stored volume. Therefore, the overall model performance is acceptable.

4.1.2 Modelling Turbine Flows

Figure 4 shows the turbine flow from Kariba, Cahora Bassa, Kafue Gorge U and Kafue Gorge L under different climate scenarios from 2010-2070.

Based on the simulated flows of Kariba Reservoir, the Wet scenarios both for BAU and Grand deal showed higher turbine flow compared to the others. This increased water flow is not constant for all years, such that there are periods with great reduction in water flow regimes. The BAU Dry and Grand Deal Dry scenarios shows the reduction of turbine flows. For this later scenarios there is an overlap, meaning that despite the future development in the Kariba region the water flow in the turbines will reduce due to drier environment.

On the other hand, Cahora Bassa Reservoir showed a different pattern for different scenarios. The Wet scenarios as was in the Kariba tended to show higher flow turbines compared to others. Overall, the Dry Scenarios, both for Grand deal and BAU presented the lower turbine flows, meaning that the reduction of precipitation will impact negatively the future turbine flow.

Two Kafue (Upper and Lower) reservoirs were simulated. The simulated scenarios in both the reservoirs showed a non-consistent behaviour along the studied period. In the Kafue Gorge U, the BAU and the Grand deal Wet scenarios show an overlapped behaviour along the period but with tendency of increase in turbine flows than others scenarios.

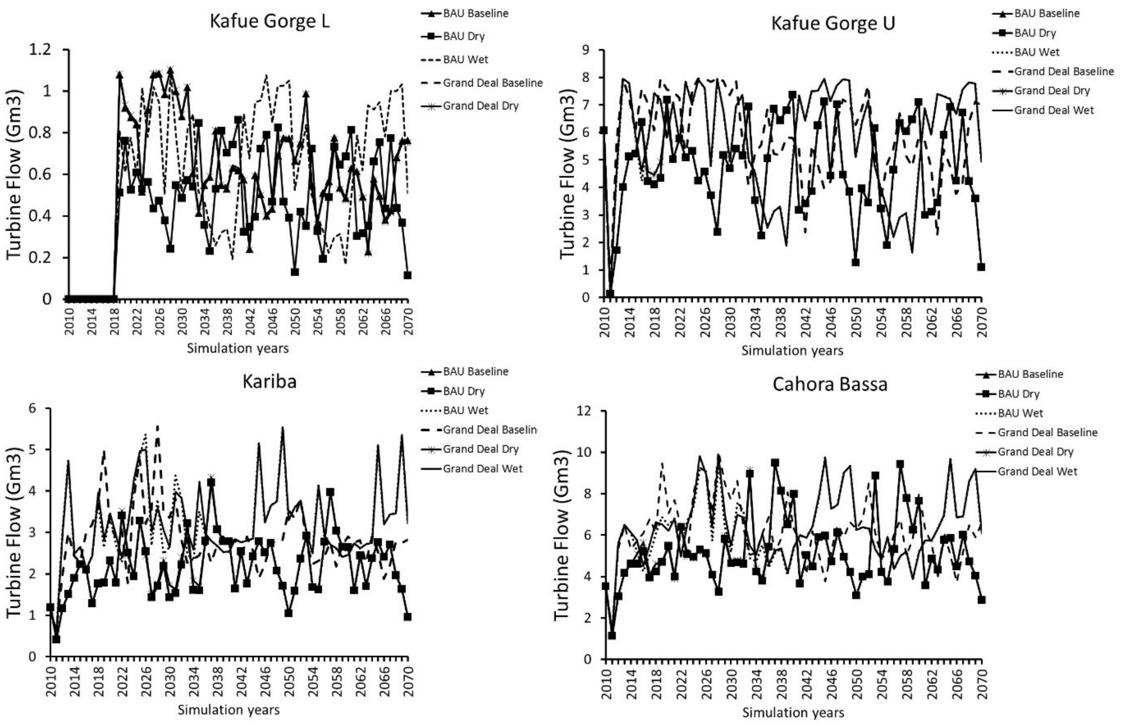

Figure 5 Simulated Turbine flow for Kariba, Cahora Bassa, Kafue Gorge U and Kafue Gorge L from 2010-2070

Figure 5 shows the time of exceedance (%) for different scenarios. The scenarios show high variation of Hydropower generation for Kariba, Cahora Bassa and Kafue Gorge U and Kafue Gorge L. In all scenarios the “Wet” scenario is the scenario that tended to present higher values than other. It is expected that with the increased water availability to have more hydropower generation compared to dry scenarios.

In Kariba, with the BAU baseline, the time of exceedance is equal to all dry scenarios (this is overlapped and not visible in the graph), meaning that under all future climate scenario the actual power generation will look like the same as is in the future climate when dry. Under dry scenario 54% of the time will exceed 1.4 MGj of power generation, therefore 92% of the time it will exceed 0.4 MGj. On the other hand, around 8% of the time under dry conditions will exceed 2.5 MGj and under wet conditions will be 3.2 MGj.

For Cahora bassa the trends are similar to those in Kariba. The dry conditions are expected to reduce the power generation and the wet condition increase the power generation. For wet conditions there is a probability that 54% of the time the power generated to be above 4.7 MGj, while under dry scenarios 54% will be 3.4 MGj (38% Less). The overall figure shows a reduction of power supply under a drying future climate.

For both Kafue Gorge L and U, the trends are not different from Kariba and Cahora bassa. Therefore, there is slightly behaviour change in the Kafue L, since the Grand deal dry scenario tend to show higher values than those from BAU dry.

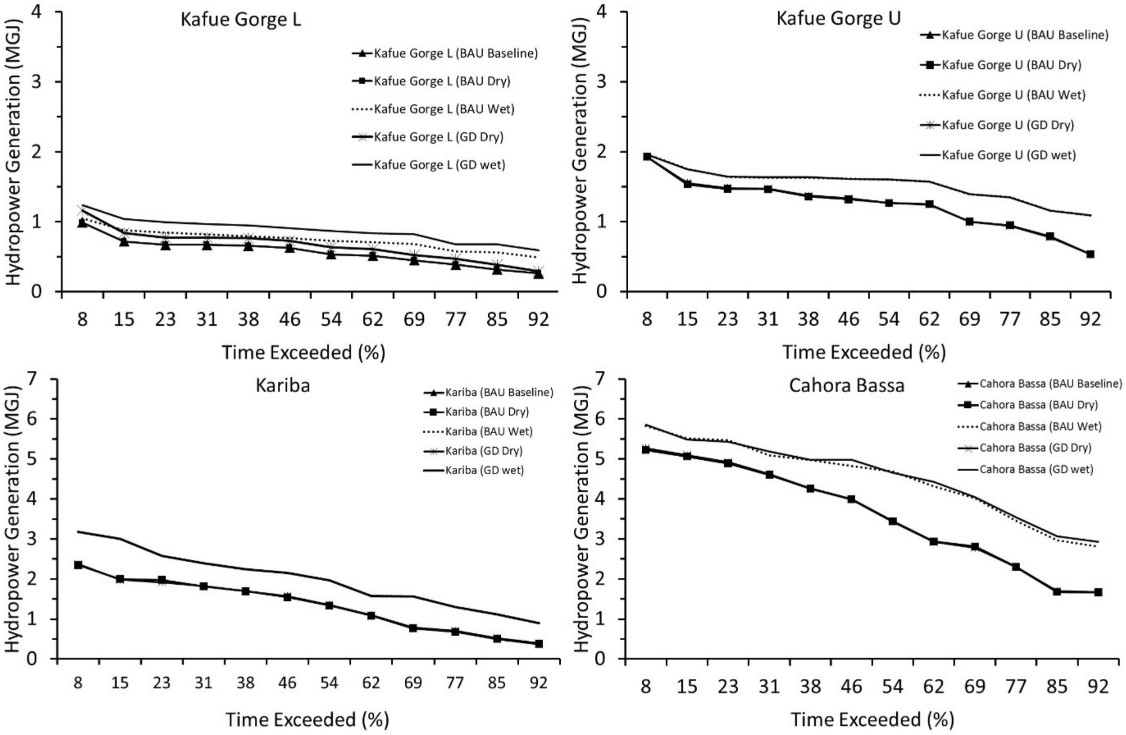

Figure 6. Simulated Time of Exceedance for Hydropower Generation in Kariba, Cahora Bassa, Kafue Gorge U and Kafue Gorge L (scenarios not seen lines are overlapped)

4.2 Hydropower Profit

To determine the Hydropower profit the we used the 2005-2007 and 2014/2015 average tariff for Mozambique (7.5 USc/Kwh) and Zambia (5.9 USc/Kwh) (ECA(2009) and SAPP(2015). Based on the scenarios presented, profit analyses were done. Figure 6 shows different profits under a variety of scenarios. The Business as usual (BAU) baseline scenario shows a profit of around 30 Billion USD, 6 Billion USD for Kafue Gorge L, 13 Billion USD for Kafue Gorge U and 16 USD Billion for Kariba dam. There was no difference in outcome between BAU Baseline and BAU Dry for all hydropower. Therefore, the BAU Wet profit differs from BAU Baseline and BAU dry. In the BAU Wet scenarios, it is expected to have more rainfall hence more generated runoff. If the runoff increases more water will be available for power generation. Due to wetter conditions (BAU Wet), it is expected the Profit to increase by 21% for Cahora Bassa, 26% for Kafue Gorge L, 20% for Kafue Gorge U and 33% for Kariba.

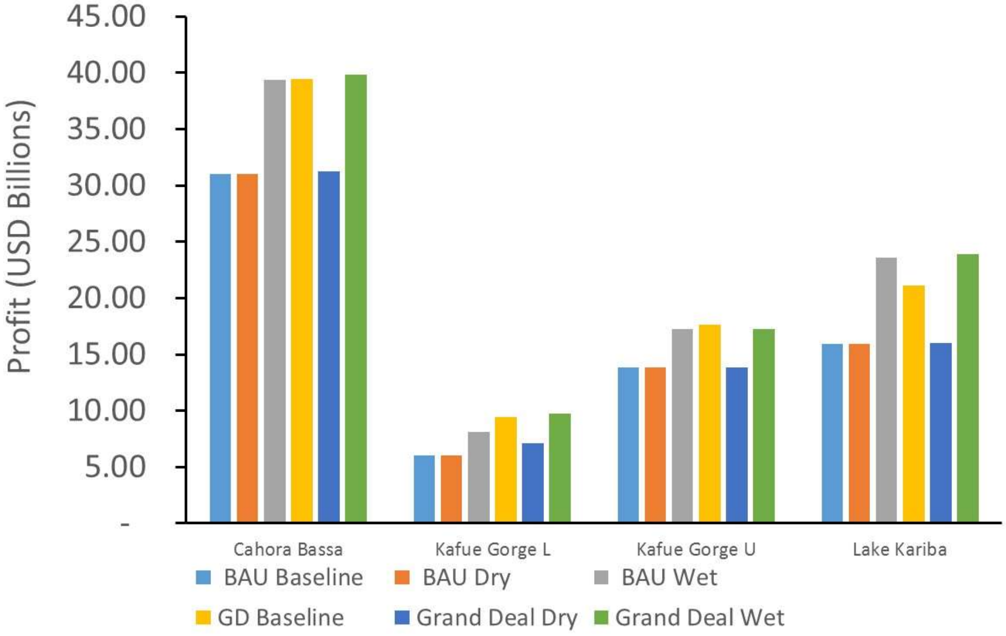

Figure 7. Hydropower Profit for different scenarios

Therefore, the Grand Deal (GD) baseline scenario showed a similar behaviour as BAU Wet scenario for Cahora Bassa and for other hydropower stations the behaviour were different. The GD Baseline showed a slightly Profit increase for both Kafue dams and a reduction compared to BAU Wet, BAU Dry and BAU Baseline. While for Kariba the GD Baseline scenario showed a decreases Profit under GD Baseline scenario. The GD baseline scenario showed a similar increase (21%) as was with BAU Wet scenario for Cahora Bassa, higher increase for Kafue Gorge (36.4%), 22% for Kafue Gorge U and a profit reduction (25%) for Kariba reservoir compared to BAU baseline.

GD Dry scenario shows a similar profit for all Hydropower stations compared to BAU Baseline Scenario (Less than 1% difference), except for Kafue Gorge L. Therefore, the GD Wet scenario shows an increase in profit in relation to the BAU Baseline scenario and similar to GD Baseline for all hydropower stations except for Kafue U. The difference was 22%, 38%, 19% and 34 for Cahora Bassa, Kafue Gorge L, Kafue Gorge U and Kariba respectively.

Overall the maximum profit is mainly dependent on the water availability in the Zambezi water course.

5 Conclusions

We studied the effects of climate change on Cahora Bassa, Kafue and Kariba hydropower. There was a combination of hydrological modelling with an electricity information to understand the relation between climate induced variations of water availability and profitability. Thus, it was possible to evaluate changes in inflow/outflow quantity and seasonality resulting from climate change from an electricity production perspective. Climate change leads to an alteration in seasonality that is beneficial to the electricity system under wet hydrological conditions, it is negatively impacted and aggravated under dry conditions. The model showed a good performance on simulating the river and dam behaviour under different climate scenarios. In general, the effect of hydrological conditions being wetter or drier has a big impact on the profitability of hydropower. The dryer condition is likely to reduce the profit, such that more than 50% of the time the turbine flow will be below the average turbine flow. With wetter conditions it is expected the profit to increase by 21% for Cahora Bassa, 26% for Kafue Gorge L, 20% for Kafue Gorge U and 33% for Kariba. Our findings in this paper provide important insights into the impact of climate change on SAPP and shows the importance of linking hydrological and socio-economic modelling. Though, a clear need for future research is given and should focus on water reuse, agricultural development and returns flows. Some uncertainty can be posed to the agriculture, basin development, population growth and future electricity policies.

For the studied dams, the wet scenario is the one that will give higher Profit for all hydropower stations. Thus, the linkage of global, regional, and site-specific impacts of climate change on the water-energy nexus provides many opportunities for future research.

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APPENDIX 1: Modifications made in the WEAP

In the document we provided the result of simulation of Hydropower generation under different climate scenario. The Zambezi WEAP model was provided by ZAMCOM under non-disclosure agreement signed The model set-up and parameterization data was supplied by ZAMCOM under a non-disclosure agreement, following the signing of a MoU for promoting collaboration with the ACEWATER2 CoEs.

Population data

The population data was screened against the national statistics of the countries in the basin since the population data provided in the model sometimes did not match with those in statistics of the country. Table 1 gives the data provided by the model and the one by national statistics.

In case of Tete there was a need to estimate the population for the base year (2010). This was estimated based on the equation:

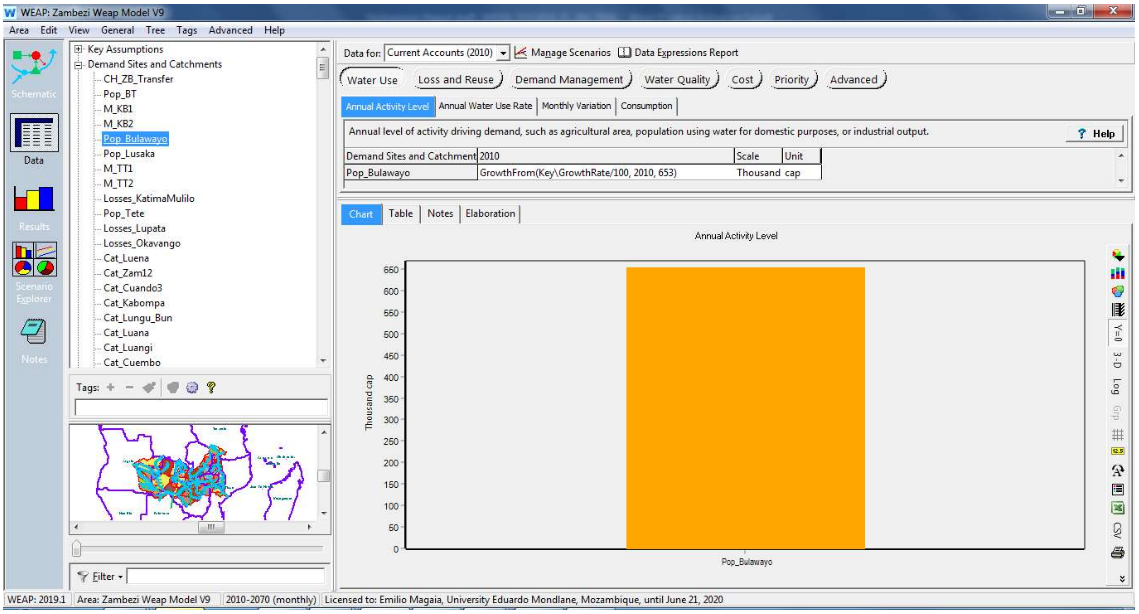
$$\boldsymbol{P_{future}} = \boldsymbol{P_{actual}} * (\mathbf{1} + \boldsymbol{K})^{\boldsymbol{t}}$$

Where: **P** is the population, **k** is the growth rate (4%) and **t** is the time (3 years). The 3 years' timeframe was used for Tete since the existing data is for 2007.

Tabela 1 Population data

Item	**Code in the model**	**Population in the Model**	**Population in the statistics**	**Source**
Population of Tete	Pop_Tete	2.954.000	2006720	(INE, 2007)
Population of Bulawayo	Pop_Bulawayo	1.560.800	653.337	(ZNSA, 2012)
Population of Lusaka	Pop_Lusaka	1.211.100	2.191.225	(NAR, 2012)

This data is important to estimate the amount of water demand from the watercourse under the TREE MENU. The tree menu is used to edit and navigate through the Tree which appears in the Data View. Options on this menu allow the user to add, rename, delete, move and organize branches. See "Editing the Tree" on WEAP USER GUIDE for more information. Many of these functions are also available by right-clicking on the Tree.



Data for: Current Accounts (2010)

Annual level of activity driving demand, such as agricultural area, population using water for domestic purposes, or industrial output.

Demand Sites and Catchment	2010	Scale	Unit
Pop_Bulawayo	GrowthFrom(Key\GrowthRate/100, 2010, 653)	Thousand	cap

WEAP: 2019.1 | Area: Zambezi Weap Model V9 | 2010-2070 (monthly) | Licensed to: Emilio Magaia, University Eduardo Mondlane, Mozambique, until June 21, 2020

Figure 1. Example of population node in WEAP

WATER USE

The water use in the model is driven by Annual activity. The annual activity is driving water demand such as in agricultural area, population using water for domestic purposes or industrial. In order to comply with this input, changes were done under TREE MENU in the water use in the Population node. We changed the population size according to the 2010 census for Tete, Bulawayo and Lusaka mainly.

LOSS AND REUSE

The provided model did not give any provision for some loss of water to the system. In the TREE MENU under the demand site and Catchment is possible to assign some percentage as Loss and Reuse. This is stated in the model as

"Loss within demand site or demands that are otherwise unaccounted for, resulting in an increase in supply requirement. Supply requirement = Demand/ (1-Loss rate)"

In this regard a value of 5% was assumed as a monthly value for all 3 demanding sites stated above.