The Belo Monte effect: how an enormous dam has already affected a rich Amazon ecosystem – and what the future might hold for it

Poster · October 2018

DOI: 10.13140/RG.2.2.27986.81609

Marcelo G. P. Camargo
University of São Paulo
4 PUBLICATIONS **5** CITATIONS

Victor Sacek
University of São Paulo
32 PUBLICATIONS **147** CITATIONS

Gyrlene Silva
University Federal of São Paulo, Brazil
20 PUBLICATIONS **185** CITATIONS

Dailson J Bertassoli
University of São Paulo
13 PUBLICATIONS **82** CITATIONS

The Belo Monte effect: how an enormous dam has already affected a rich Amazon ecosystem - and what the future might hold for it

Camargo MGP[1], Sacek V[2], Silva GAM[3], Alem VAT[1], Bertassoli DJ[1,4], Araujo KR[5], Sawakuchi HO[6], Sawakuchi AO[1]

[1]Institute of Geosciences - University of Sao Paulo; [2]Institute of Astronomy, Geophysics and Atmospheric Sciences - University of Sao Paulo; [3]Federal University of Sao Paulo; [4]Bremen University; [5]Federal University of Pará; [6]Umea University

2017/12470-2

São Paulo School of Advanced Methane Science
October 2018
Brazil

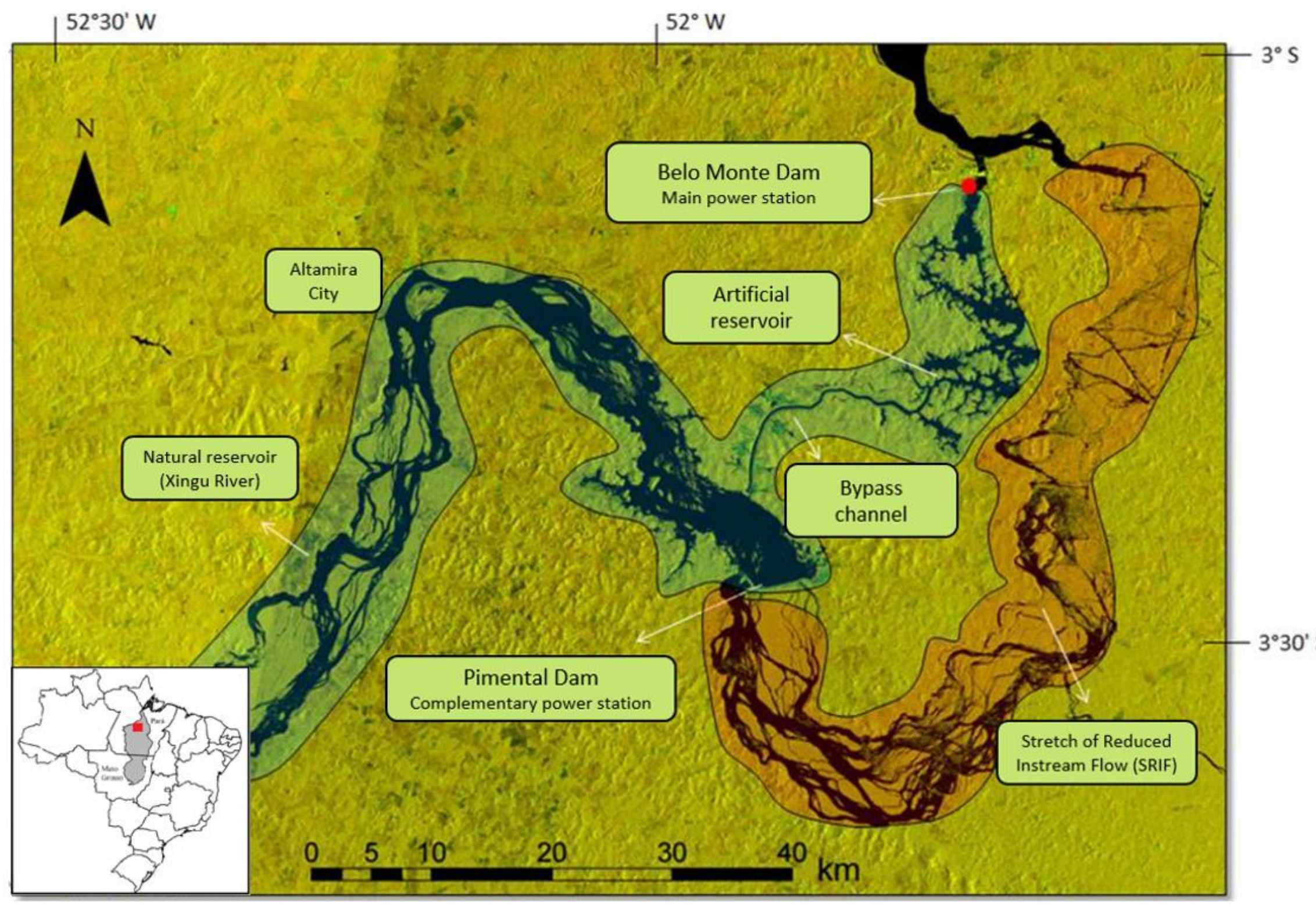
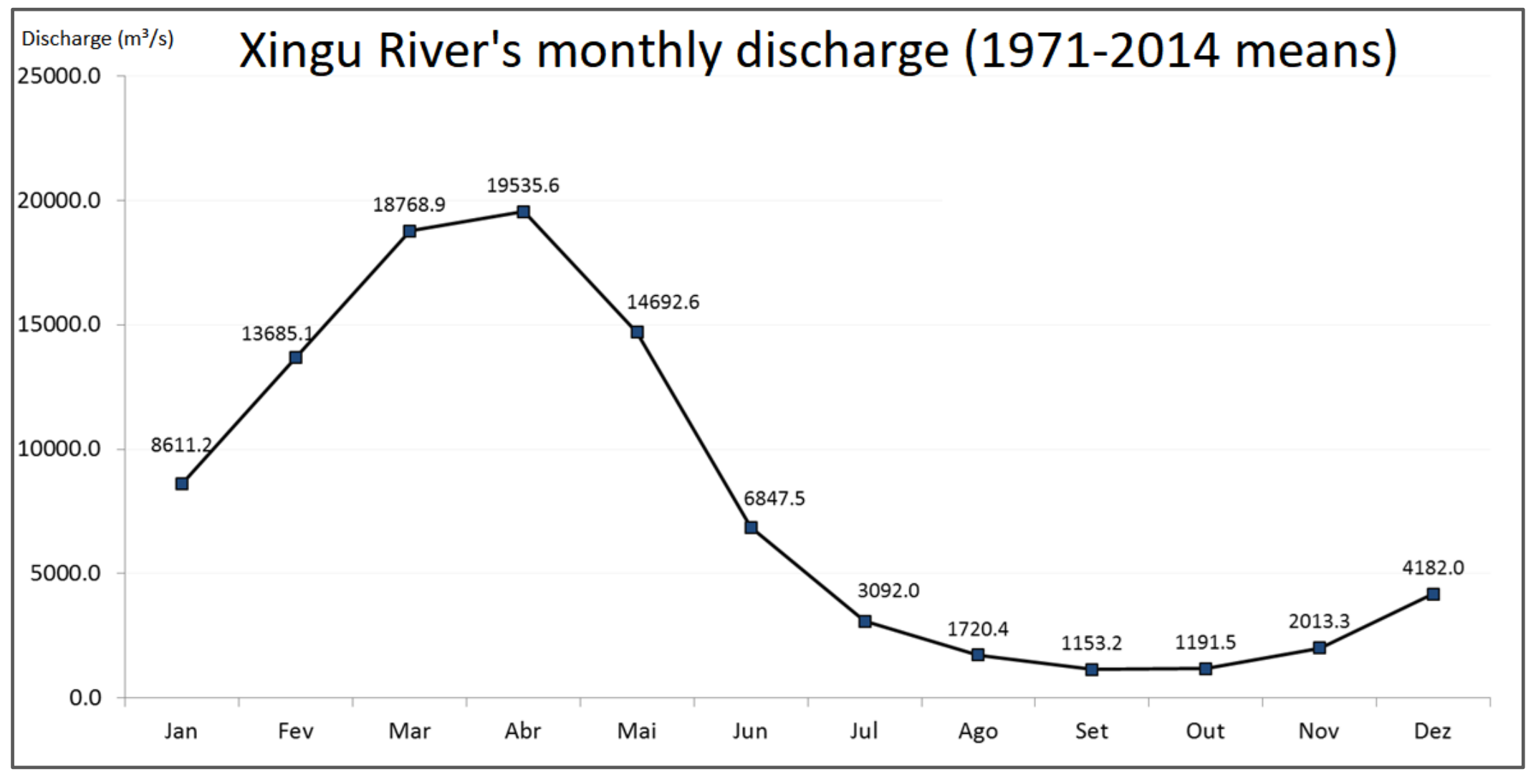


Figure 1. Radar image of Xingu River's Big Bend as of Jan/2016, with major features illustrated. Camargo et al. (in prep)

Context

The Belo Monte hydropower plant is located on the Brazilian portion of the Amazon rainforest, in the so-called "Big Bend" of the Xingu River (Fig. 1). Officially inaugurated in May 2016 and expected to be fully completed by 2019, the Belo Monte Dam is the largest entirely Brazilian hydroelectric power plant in terms of installed capacity, and the fourth one in the world.

Figure 2. Average monthly discharge measured in Altamira - PA. Camargo, 2016



However, of the 11.233 MW of installed capacity, the effective generation of energy will be 4.500MW, on average (Fig. 2). This happens due to the high seasonality of the Xingu River, whose discharge can change by up to 40 times between dry and wet seasons.

Hidrograma	Jan	Fev	Mar	Abr	Mai	Jun	Jul	Ago	Set	Out	Nov	Dez
A	1100	1600	2500	4000	1800	1200	1000	900	750	700	800	900
B	1100	1600	4000	8000	4000	2000	1200	900	750	700	800	900

Also, there's a commitment of minimal water releasement to the Stretch of Reduced Instream Flow (SRIF), which follows a consensus hydrogram proposed by the government (table showed above). However, there's already an important water scarcity going on the SRIF, expected to increase as Belo Monte gets completed.

Motivation

Climate models oftenly project a severely reduced precipitation (and thus, water availability) over Eastern Amazon, especially the Xingu River Basin (Fig. 3). This might affect Belo Monte's already inefficient energy generation capacity in a negative way.

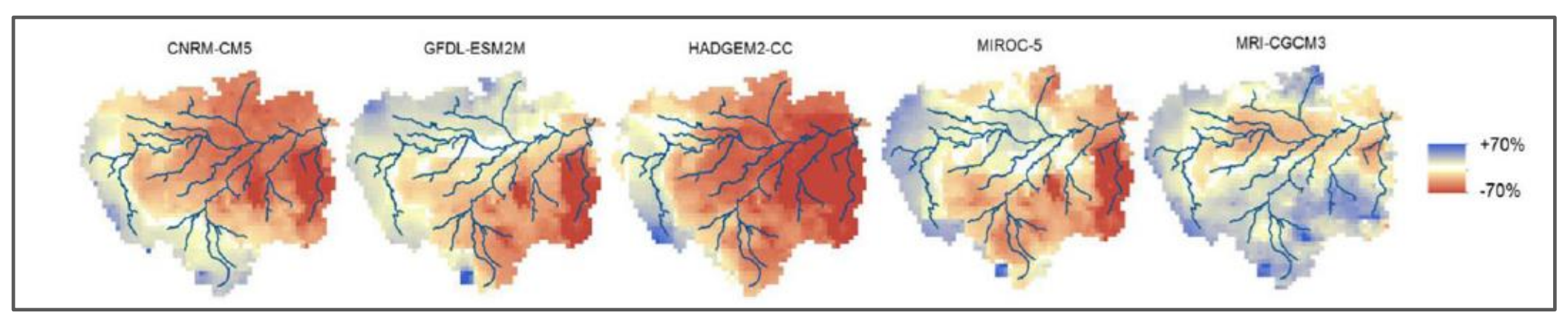


Figure 3. Local runoff anomalies projected by five GCM model runs for the period 2070-2099. Sorribas et al. (2016)

Methods

A hydrologic model (based on Sacek et al., 2014) was applied using topography (e.g. ETOPO1, SRTM) and precipitation data (Fig. 4). The model is initially tested with historical data (CHIRPS 1981-2015 rainfall and National Water Agency 1971-2014 measured discharges), proceeding to calibration and further input of future precipitation projections obtained from CMIP5 multi-model results (2018-2045).

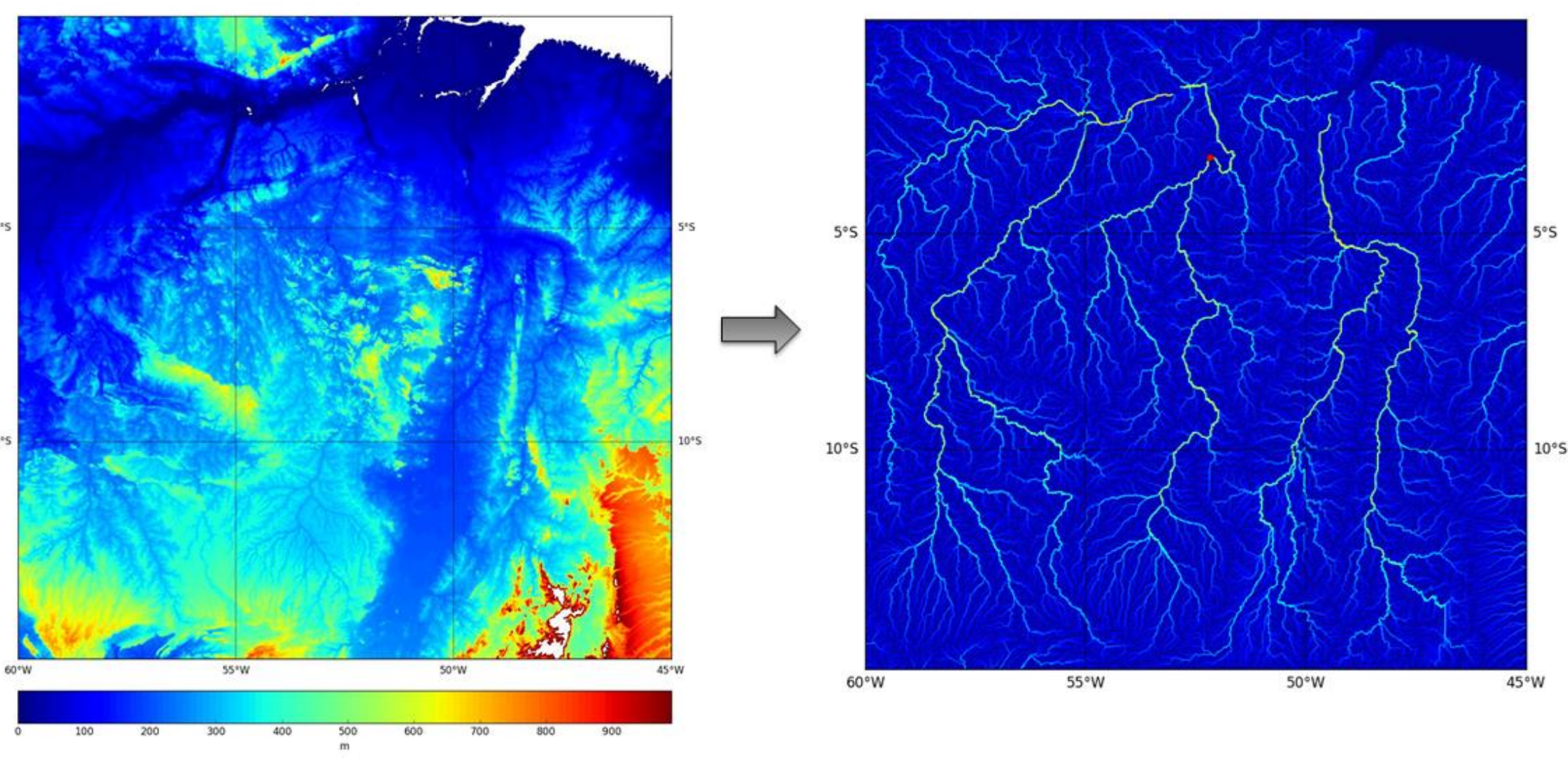
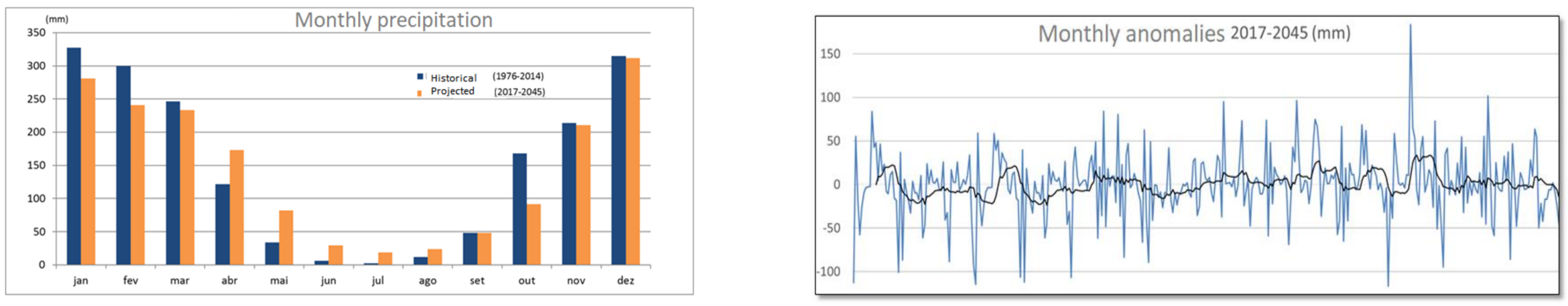


Figure 4. Drainage system simulation based on a Digital Elevation Model. Camargo, 2016

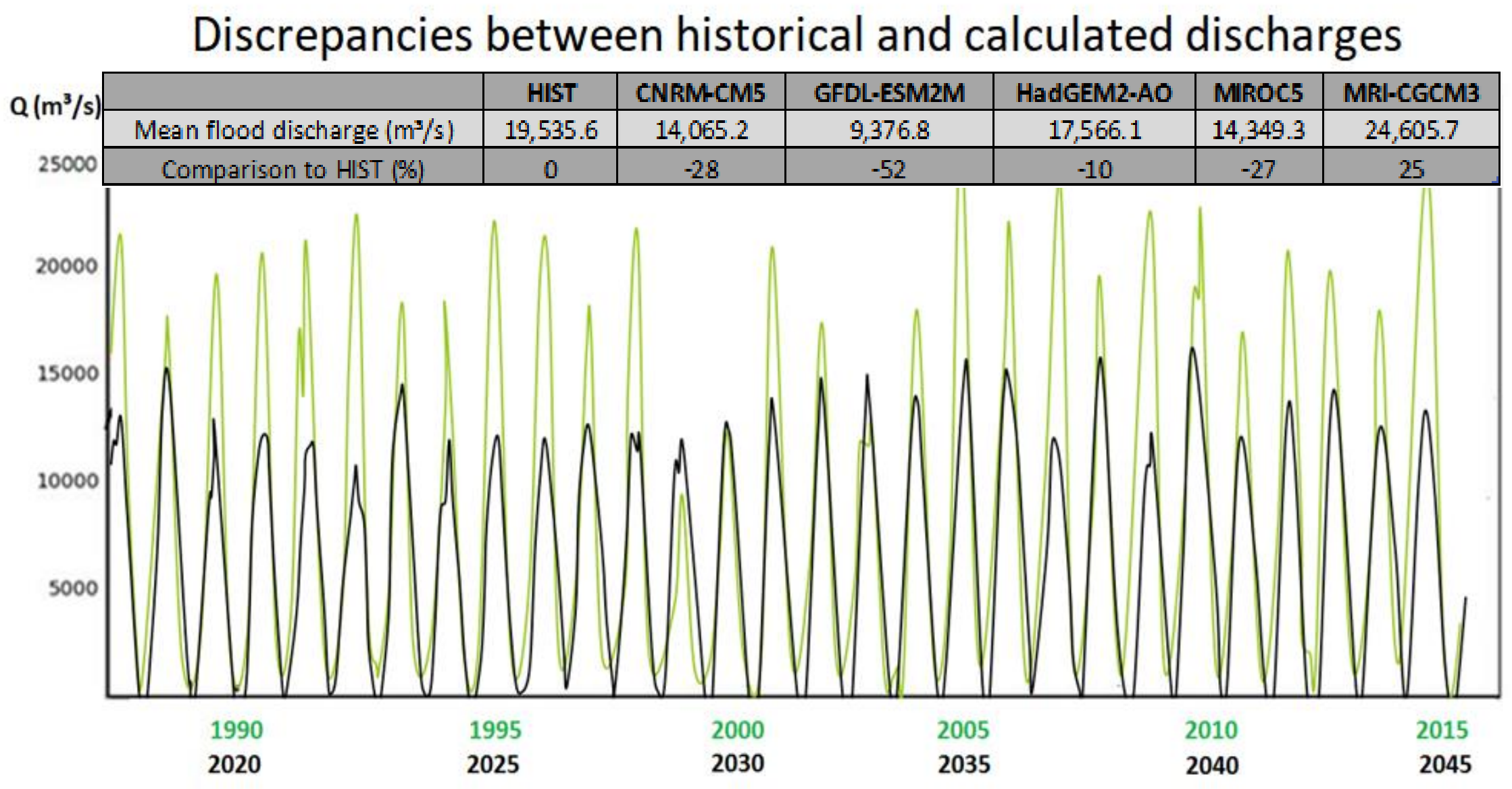
Results

Precipitation is projected to decrease by up to 20%, with significant negative anomalies happening sometimes in a short period of time (Figs. 5 and 6), which might lead to an overall drought over the watershed. Interestingly, the dry season is expected to have a small increment in rainfall, although it's not nearly as impactful as the decline during the wet season, when Belo Monte is supposed to produce all of its capacity.

Discharge simulations point out an average 28% decreasing on Xingu River's discharge by 2045 (Fig. 7), with a similar negative impact on Belo Monte's energy generation capacity, considering it's a run-of-the-river hydroelectric plant. Meanwhile, when adding the minimal commitment to the SRIF, even more total discharge is needed to fully operate Belo Monte, with estimations ranging from 20,000 to 25,000 m³ s^{-1} to supply both needs (Camargo et al., in prep).



Figures 5, 6. CMIP5 multi-model runs for 2017 to 2045, showing average monthly rainfall and future anomalies over Xingu River Basin. Camargo, 2016.



	HIST	CNRM-CM5	GFDL-ESM2M	HadGEM2-AO	MIROC5	MRI-CGCM3
Mean flood discharge (m³/s)	19,535.6	14,065.2	9,376.8	17,566.1	14,349.3	24,605.7
Comparison to HIST (%)	0	-28	-52	-10	-27	25

Figure 7. Comparison of discharge simulations for the Xingu River versus historical ones. Camargo et al. (in prep).

Pre- and post-reservoir GHG emissions

Context

Aiming to further expand our understanding of Belo Monte's impacts over the Xingu River basin, several field trips were conducted to the "Big Bend" and its surroundings from 2015 to 2017. The purpose of the trips was to measure CH4 and CO2 fluxes from soil and water, and collect soil and sediment to evaluate the potential production of these gasesl in order to understand how the establishment of a hydroelectric reservoir, which happened in 2016, could impact GHG dynamics over the area.

Methods

Fluxes were measured using floating and static chambers for water and soil, respectively (based on Sawakuchi, 2014), headspace concentrations from water samples and also incubation and soil flooding experiments on a multi-environment approach (Fig. 8). The samples were both analyzed on-field by cavity ring-down spectroscopy and at the laboratory by gas chromatography.

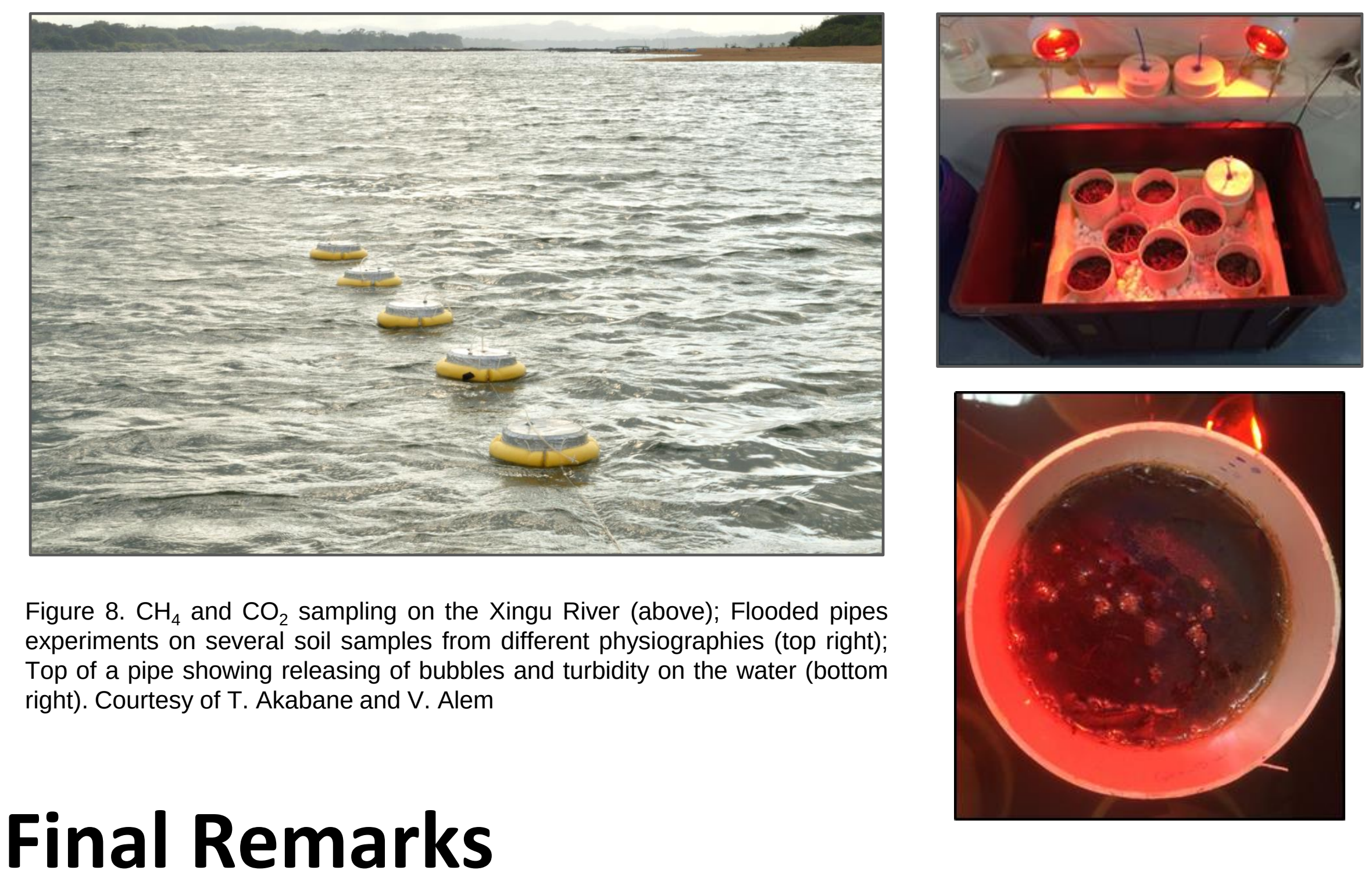


Figure 8. CH_4 and CO_2 sampling on the Xingu River (above); Flooded pipes experiments on several soil samples from different physiographies (top right); Top of a pipe showing releasing of bubbles and turbidity on the water (bottom right). Courtesy of T. Akabane and V. Alem

Results

Our results (Fig. 9) show a significant change in CH_4 emissions after the reservoir establishment, with an average CH_4 flux from the river to the atmosphere varying from 2 mmol m^{-2} d^{-1} to 11 mmol m^{-2} d^{-1}. We also found that there's a high variability in post-reservoir emissions, which suggests an important zoning in reservoir emissions, as well as a short residence time in the water column, evidenced by stable fluxes by the channel, and higher fluxes on flooded areas.

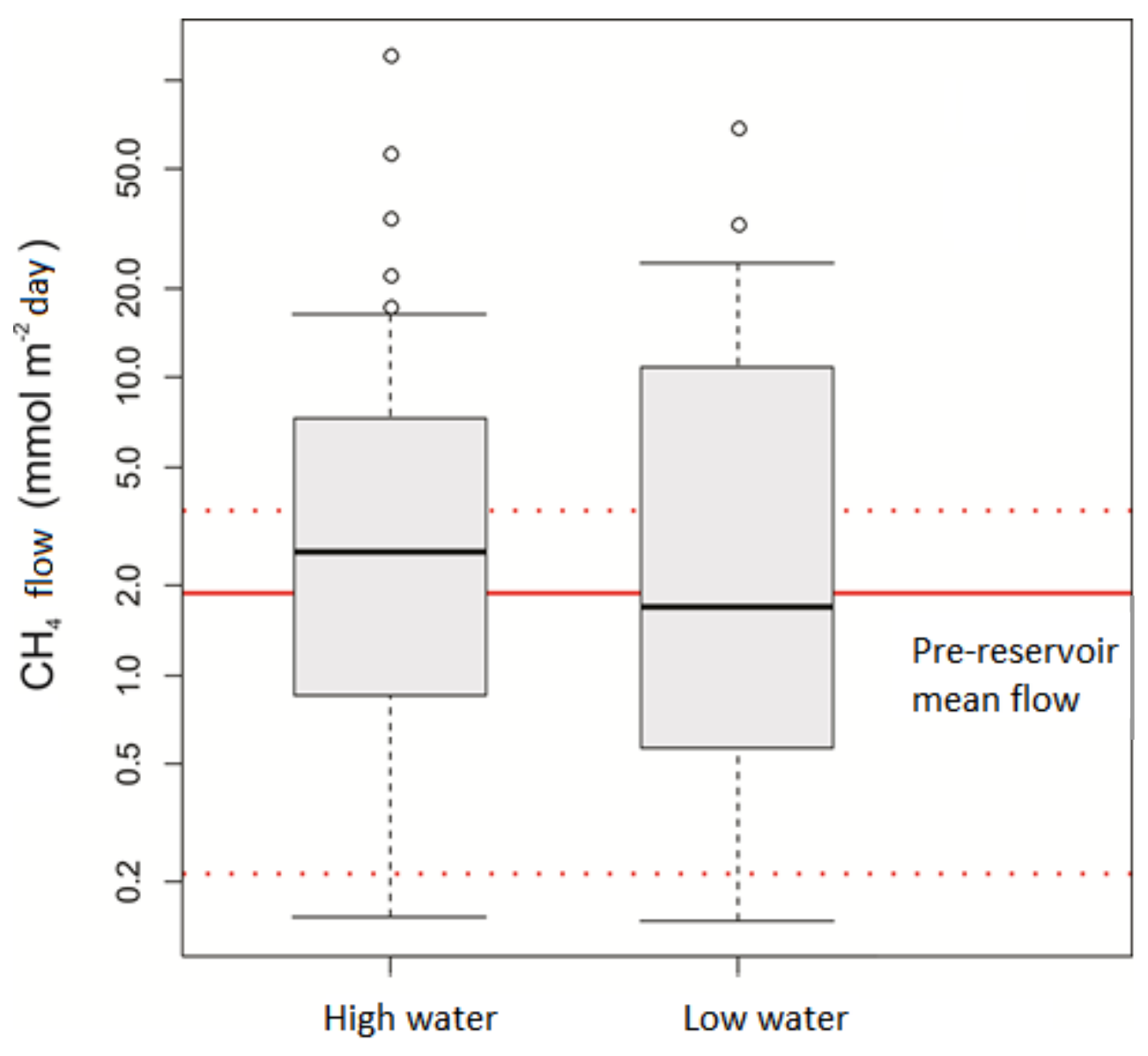
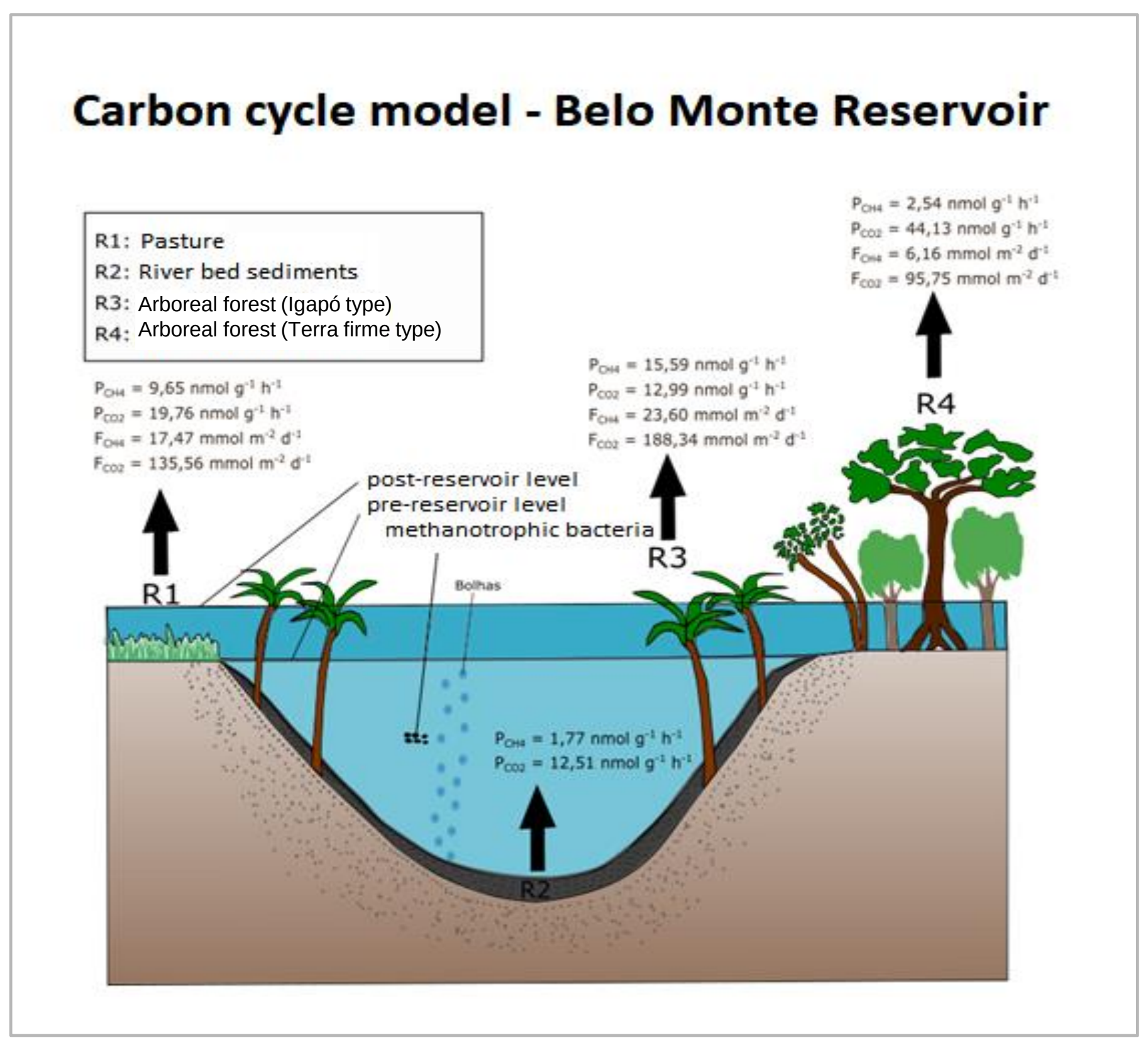


Figure 9. CH_4 fluxes before and after the establishment of Belo Monte reservoir. Bertassoli et al. (in prep), modified.

Figure 10. CH_4 and CO_2 production (P) and emissions (F) from four physiographies found at Xingu River's Big Bend. Alem et al. (in prep), modified.



For CO_2, measurements from both years showed a similar pattern - an expected variation between wet and dry seasons (during which negative fluxes happen), with flooded areas showing a pattern similar to the wet season channel emissions.

Our incubation, flooded pipes and artificial water column experiments showed that most of the production on soils happen at the first 10 centimeters of depth. Also, some physiographies have had greater productions and fluxes than others, with igapó forest ranked no. 1 (Fig. 10).

Some results point out a natural flux at the reservoir that's up to 5,000 times higher than the ones measured by Sawakuchi et al. (2014), before the reservoir formation.

Headspace experiments to measure CH_4 concentration of the flooded pipes' water columns had peaks followed by dips, suggesting that since most of the methane is produced in shallower environments, it's more easily released to the water column and thus, to the atmosphere.

Final Remarks

➔ Preliminary results suggest a decreasing trend in surface water availability, with a 20-30% lower discharge in 2050 when compared to historical data.

➔ These results have concerning implications not only on the economic sphere, impacted by Belo Monte's future energy generation, which might decline in a similar proportion, but also over socio-environmental aspects, such as an increase in water conflicts and intensification of impacts over aquatic and floodplain ecosystems. Additionally, our GHG analyses suggested that, in fact, the establishment of a hydroelectric reservoir can increase the amounts of methane and CO_2 released to the atmosphere in extreme proportions, crippling one of the most defended arguments in favor of hydroelectricity.

➔ When future discharge and water availability simulations are added to the GHG equation, the expected lowering of Xingu River's and its reservoir's water level might amplify the sheer amount of GHG released to the atmosphere, since the flooded organic matter will still sit at the bottom of the reservoir at the same time methane oxidation might reduce with an eventual decrease of the water column.

➔ Both results also put into question the real cost-benefit of the project, considering the many issues it has already faced since its planning and construction. At the same time, our results might help open up the discussion of new energy policies for Brazil, with greater energy security, efficiency and sustainability.

References: Camargo, M.G.P. (2016) *Undergraduate monography* // Sawakuchi, H.O.; et al. (2014) *Global Change Biology* 20-9 // Sorribas, M., et al. (2016) *Climatic Change* // Camargo, M.G.P et al.; Bertassoli, D.J. et al.; Alem, V.A.T. et al. (in prep)