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The Water Footprint of Hydroelectricity in Santa Catarina State - Southern Brazil

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1. Introduction

Large hydropower plants are Brazil's main source of electricity, comprising approximately 70% of the installed capacity.

Santa Catarina State presents a similar pattern, where hydropower corresponds to 70.39% of the total installed capacity of 4,572.105 MW.

Due to the significant disparities in size and layout between hydroelectric facilities, there has been considerable debate over the method to be adopted in order to normalize their associated water consumption.

Mekonnen and Hoekstra (2012) proposed the **Water Footprint** concept as a general approach to standardize the allocation of water resources to human activities.

Our objective was to estimate the water footprint of hydroelectricity generation in the Santa Catarina State, Brazil.

2. Methods

The state of Santa Catarina is located within the geographic coordinates 25° 57'41" S to 29° 23'55" S and 48° 19'37" W to 53° 50'00" W, and comprehends an area of approximately **95,346 km²**. According to the Köppen classification, there are two predominant climate types in the state**: Cfa and Cfb**. The average annual rainfall is **1500 mm**.

Monthly energy output data series were available for nine hydropower stations according to the period each one was commissioned. Each power plant was allocated a weather time series from the nearest station, as illustrated in Figure 1.

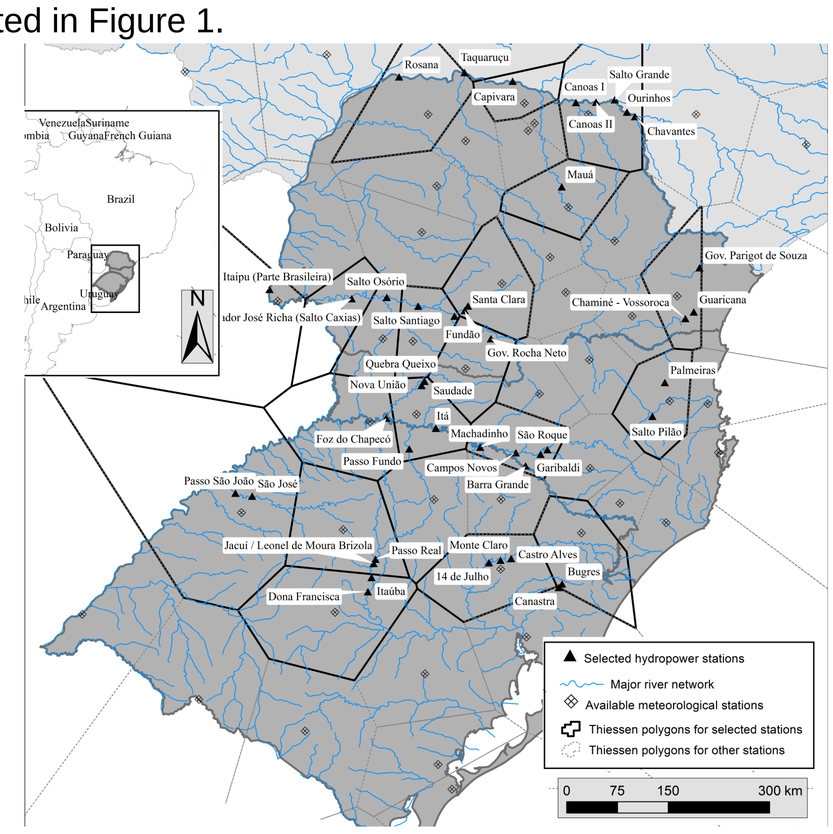

Figure 1. Southern Brazil, location of different Hydropower plants and Meteorological Staitions is indicated.

Water Footprint Estimation for Hydroelectricity

We adopted the water footprint formula for hydroelectricity proposed by Mekonnen and Hoekstra (2012) :

$$WF = \frac{WE}{EG}$$

where WF is the water footprint (m^3 GJ^{-1}), WE is the volume of evaporated water (m^3 $month^{-1}$) and EG is the electricity generated (GJ $month^{-1}$).

The Complementary Relationship and the WREVAP algorithm

To estimate evaporation from reservoirs we used the WREVAP (McMahon et al, 2013a,b) which implements CRLE algorithm (Morton, 1986). Input data are site characteristics (latitude, elevation and average annual rainfall) and monthly time series of air temperature, humidity and daily sunshine hours). Average depth and salinity are also required.

3. Results and Discussion

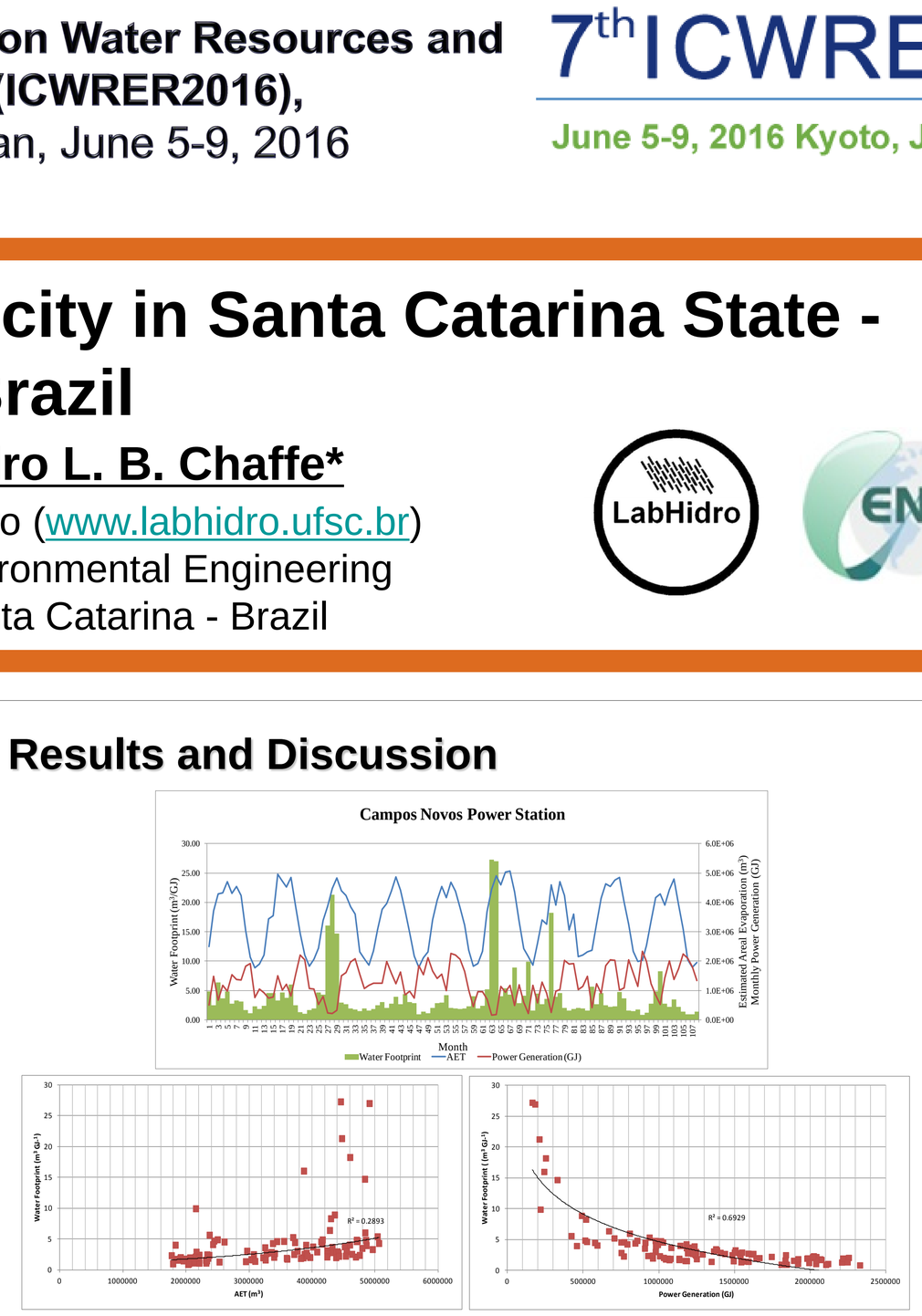

Figure 2. Water Footprint estimation for the case of Campos Novos Power Plant. Monthly variation of estimated Areal Evaporation, Power Generation and Water Footprint (top panel). Relation of Water Footprint to Areal Evaporation and to Power Generation (bottom panel).

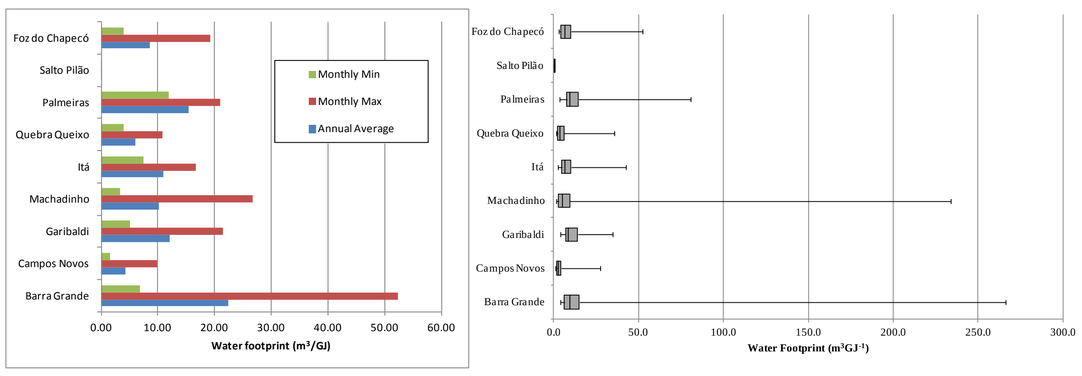

Figure 3. Water Footprint of the major hydropower plants in Santa Catarina State.

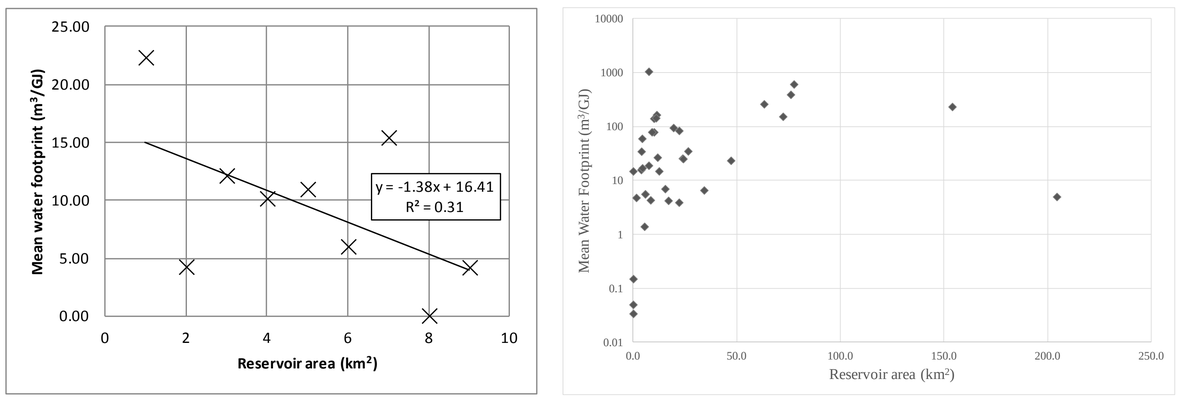

Figure 4. Water footprint relation to reservoir area when considering only Santa Catarina State major reservoirs (left figure) and when considering major reservoirs of the entire Southern Brazilian Region (right figure).

4. Conclusions

Significant variation in monthly evaporation and power output values – and, hence, of the water footprint – provides support for adopting a monthly time step for such estimates.

Despite the considerably large range of mean water footprint estimates between facilities, such values were generally low in comparison to those reported for power plants in other locations, and particularly in other regions of Brazil.

This study was limited by lack of data availability regarding reservoir properties and electricity generation of smaller facilities..

Aknowledgements

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