

# Solar energy and the Water, Energy and Food Nexus in the Brazilian northeast - a case study

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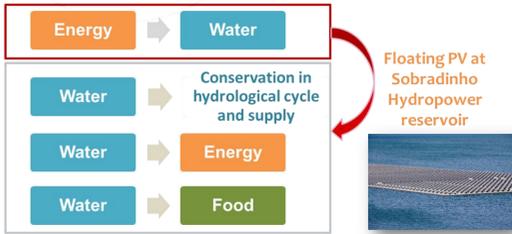
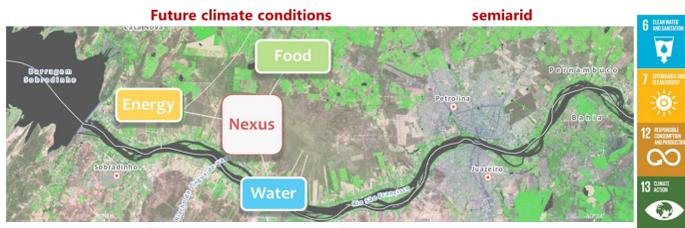
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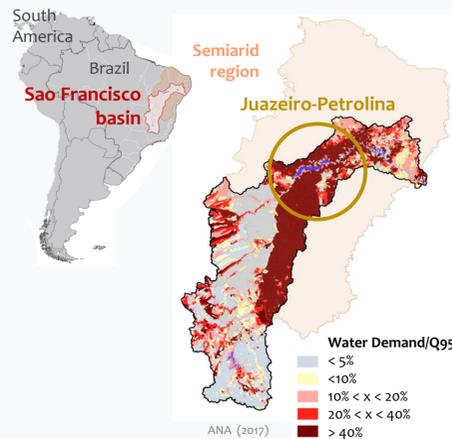
CONCEPT



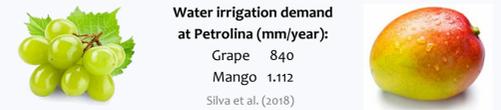
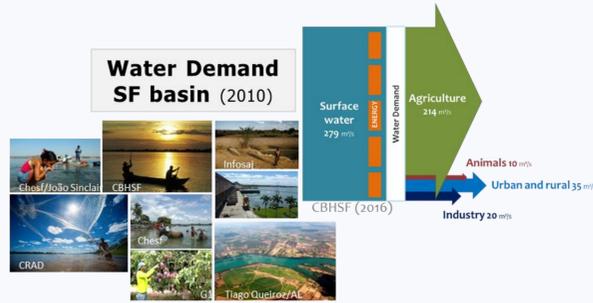
Water, energy and food are essential resources for society. Their integrated management, based on the synergies and trade-offs offered by Nexus concept, is determinant in resources conservation and to attend to the demand in the long-term. At Brazilian semiarid Northeast, coexist at Petrolina and Juazeiro cities: the Sobradinho hydropower plant (HPP), with a 4,214 km<sup>2</sup> flooded area reservoir, and a fruit production center of 223 km<sup>2</sup>, destined to Brazilian and international market. Both human activities depend on the water availability of São Francisco River and Sobradinho reservoir. Although the water demand for irrigation is intense - 348 million m<sup>3</sup> in 2016, hydropower generation prevailed as a priority during the extremely dry period from 2012 to 2017. As the Water Agency (ANA) maintained the reservoir outflow in rates above the inflow, Sobradinho reservoir run dry twice.

Solar irradiation is a main characteristic of semiarid. Thus, hybrid hydro-solar power generation show potential to minimize conflicts related to water access. In addition, national auctions of electric energy expansion have approved an increasing number of solar plants in this region. Moreover, a floating photovoltaic (PV) power plant is already being tested inside the Sobradinho reservoir. In this study, we analyzed scenarios of water management to improve the WEF Nexus at Sobradinho and target the SDGs 6, 7, 12, and 13. The software Water Evaluation And Planning (WEAP) was used to model the scenarios. The results are expressed in: saved water from evaporation, additional water available for multiple uses, and hydroelectricity generated. The dimensions of the PV system were also estimated for the most solar demanding scenario.

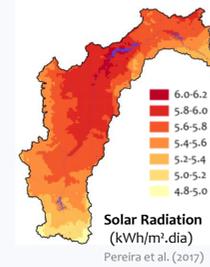
CONTEXT



**Multiple Uses of Water**  
~15 mi habitants that depends on São Francisco River to access water  
~1 mi hab at Juazeiro-Petrolina region:  
~40% depend economically on agriculture and pasture  
> 80% have income lower than US\$ 200  
IBGE (2019); CBHSF (2016)

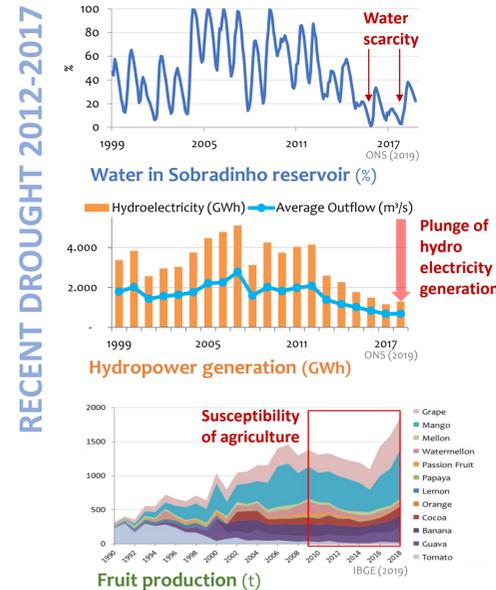
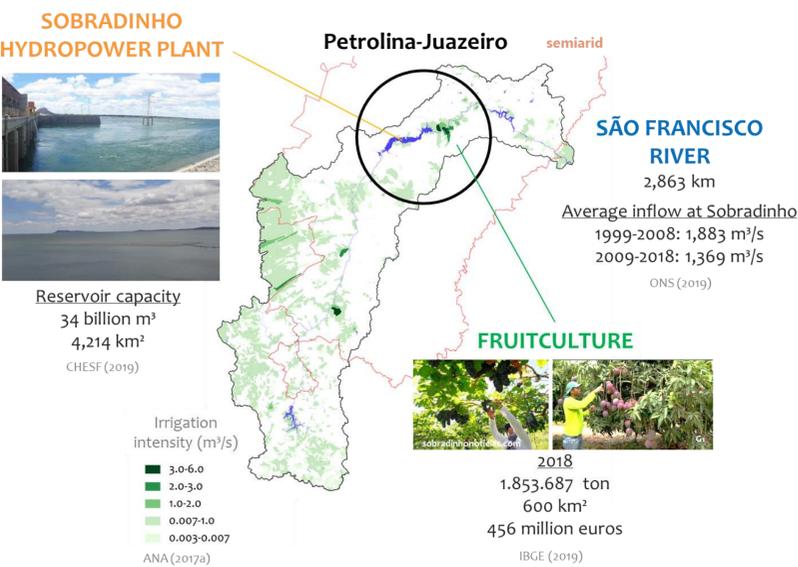


**Fruits are important products that depends on irrigation**  
Juazeiro-Petrolina produced 31% of Grape and 38% of Mango in Brazil in 2016 for internal market and exportation.  
IBGE (2019)



**Abundant energy source**  
Solar radiation is a plentiful resource at semi-arid region due to constant incidence and little cloud presence during the year.

CASE STUDY



**Threat to water security**  
Anomalous low rainfall 2012-2017  
< 50% of rain season pattern in some regions (Marengo et al., 2017)  
Sobradinho dam reached ~2% of its water capacity in December 2015 and November 2017 (ANA, 2018a).

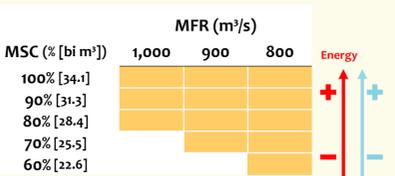
**Threat to energy security**  
Thermoelectric plants were powered on to meet the demand. Consequently, the CO<sub>2</sub> emissions factor of Brazilian electricity considerably fluctuated from 24 (2009) to 135 kCO<sub>2</sub>/MWh (2014) (MCTIC 2018)

**Threat to food security**  
Juazeiro and Petrolina produce fruits in a region with high water deficit and critical water use balance. Desertification is in course (INDE, 2018)

SCENARIOS

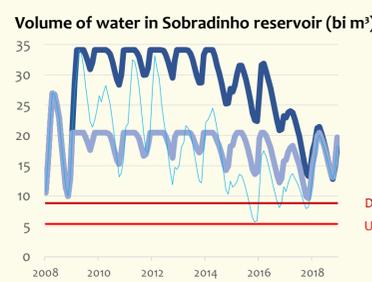
| WEF Security | Objectives  | Scenarios variation   |
|--------------|---|---|
| Water        | Meet multiple uses: urban, rural, animals, industries | Guarantee   |
| Water        | Minimize evaporation                                  | Function of maximum storage capacity (MSC) in reservoir       |
| Food         | Meet demand for irrigation                            | Guarantee   |
| Energy       | Meet electric transmission lines capacity             | Function of reservoir outflow + solar PV system               |
| Ecological   | Avoid salt wedge                                      | Set the minimum flow requirement at mouth (MFR) above 800m³/s |

**Boundary conditions**  
MSC - Maximum Storage Capacity in Sobradinho Reservoir  
MFR - Minimum Flow Requirement at Mouth

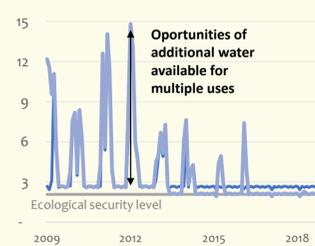


**Parameters set for both scenarios:**  
- Water Demand: observed data  
- Hydraulic Outflow from reservoirs: maximum flow  
- Nodes priority: equal distribution

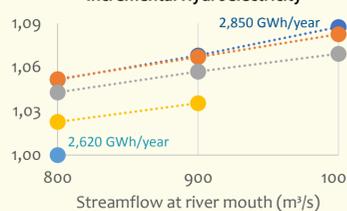
PRELIMINARY RESULTS



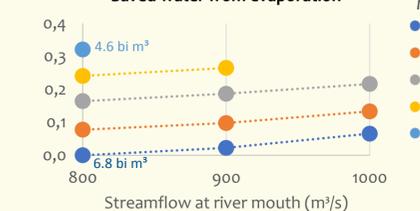
Streamflow at Mouth (bi m³)



Incremental Hydroelectricity



Saved water from evaporation

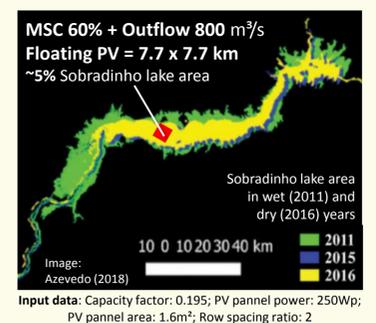


The high water reserve and high streamflow of scenario MSC 100% + 1,000 m<sup>3</sup>/s resulted in the highest evaporation (6.8 bi m<sup>3</sup>). Savings from evaporation were achieved by reducing MSC (more effective) or increasing the streamflow. Water savings reached 2.2 bi m<sup>3</sup> (32% less evaporation) in scenario 60% MSC + 800 m<sup>3</sup>/s.

The combination of MSC 100% + 800 m<sup>3</sup>/s resulted in the highest evaporation (6.8 bi m<sup>3</sup>). Savings from evaporation were achieved by reducing MSC (more effective) or increasing the streamflow. Water savings reached 2.2 bi m<sup>3</sup> (32% less evaporation) in scenario 60% MSC + 800 m<sup>3</sup>/s.

CONCLUSION

- The opportunity for hybrid solar-hydro energy was intensified during drought events.
- Solar power rises the share of renewable electricity in the Brazilian grid and reduces the CO<sub>2</sub> emission factor of the electricity.
- Floating PV system operating at Sobradinho reservoir avoids new investments because it takes advantage of the current infrastructure to feed the national electric grid, underused during dry periods.



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