SOLAR ENERGY AND THE *NEXUS* WATER, ENERGY AND FOOD: PETROLINA AND JUAZEIRO CASE STUDY

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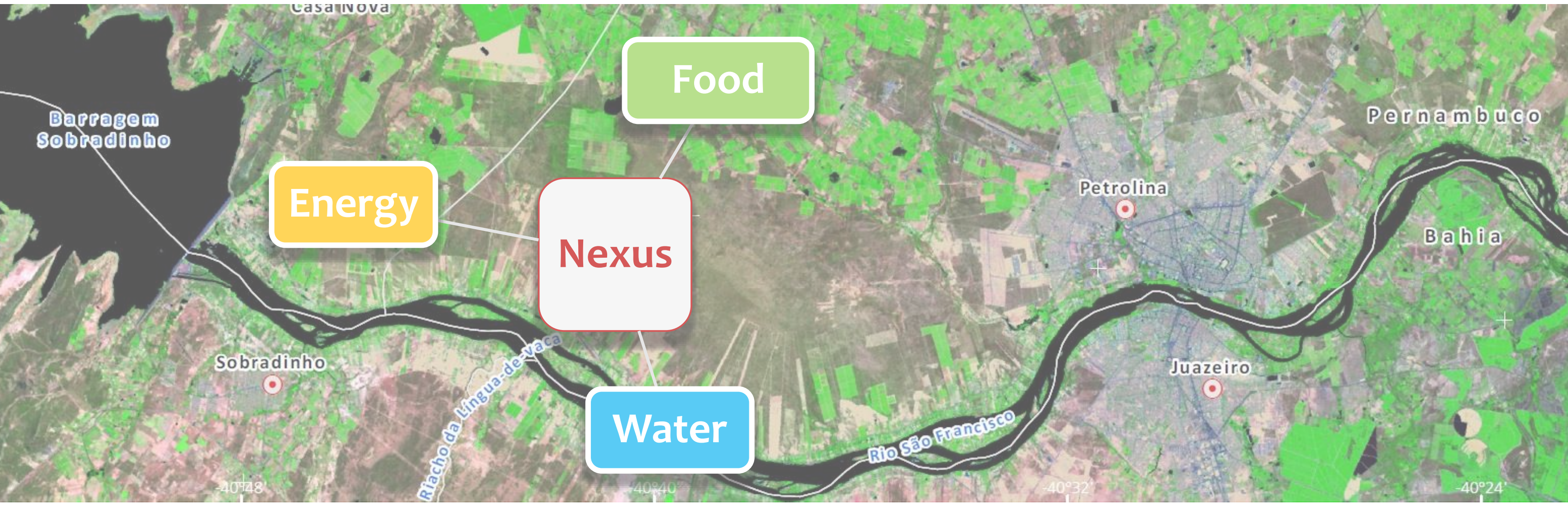
Abstract

Water, energy and food are essential resources for society. Their integrated management, based on synergies and trade-offs, is determinant to attend the demand in long-term. Petrolina and Juazeiro are cities in Brazilian semiarid where coexist: the Sobradinho hydropower (4,214 km^2 reservoir), and a fruit production center of 223 km^2, for Brazilian and international markets. Both activities depend on São Francisco River and Sobradinho reservoir. Although the water demand from Sobradinho Reservoir is intense – around 1 billion m^3, hydropower generation prevailed as a priority during the dry period 2012-2017. As the National Water Agency (ANA) maintained the reservoir outflow in rates above the inflow, the reservoir was led to its minimum levels. The water scarcity during these years caused conflicts as it reduced hydroelectricity generation while put in risk the fruit production. Since solar irradiation is abundant in this region, solar power plants represent a renewable energy source for the national grid. An increasing number of solar projects are being approved in national auctions of electric energy expansion. Moreover, a floating photovoltaic power plant is already being tested in the Sobradinho reservoir. Therefore, the research analyses scenarios of water management if floating solar panels had been adopted in complementarity to hydroelectricity from 2009-2018, when wet and dry periods occurred. The software Water Evaluation and Planning (WEAP) is used to model the scenarios. Results are represented in water, energy and food safety indicators to identify the strategies of integrated resource management to target SDGs 6, 7 and 12.

Future climate conditions semiarid



Energy → Water

Water → Conservation in hydrological cycle and supply

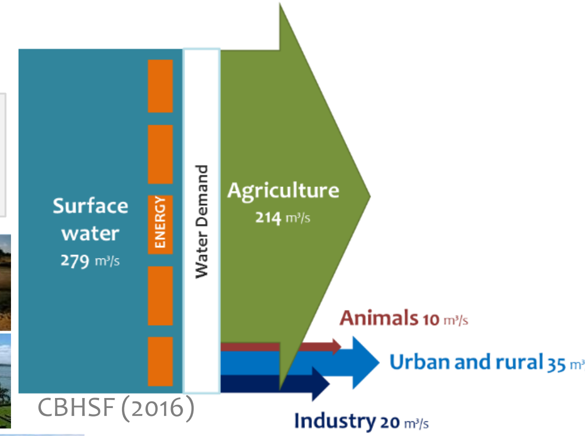
Water → Energy

Water → Food

Floating PV at Sobradinho Hydropower reservoir

CONCEPT

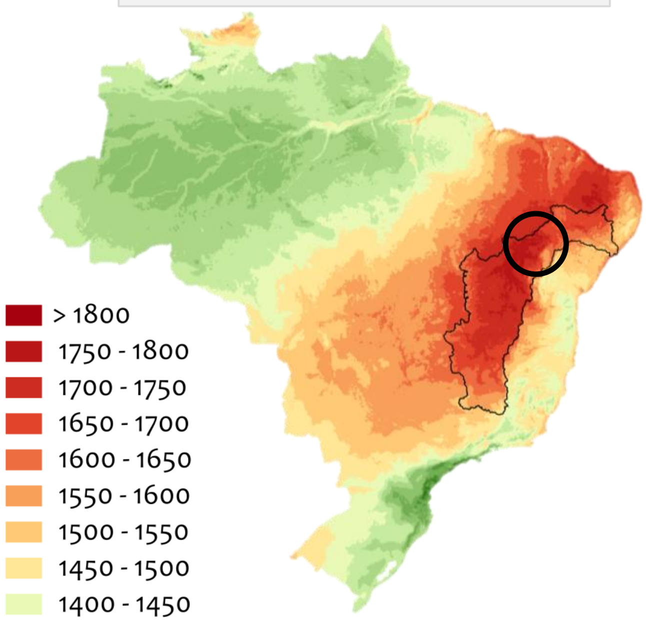
Water Demand SF basin (2010)



CBHSF (2016)

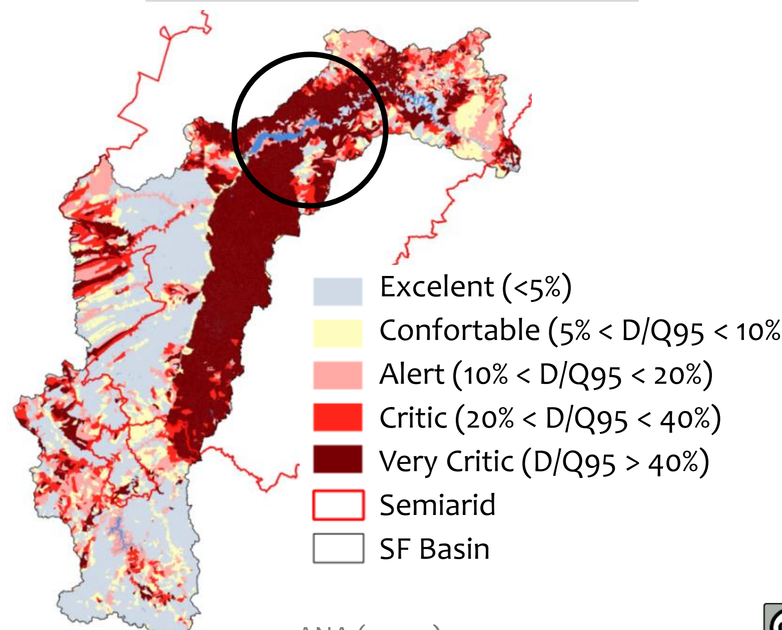
BASIN CONTEXT

PV potencial (kWh/kWp.ano)



Pereira et al. (2017)

Quantitative water balance



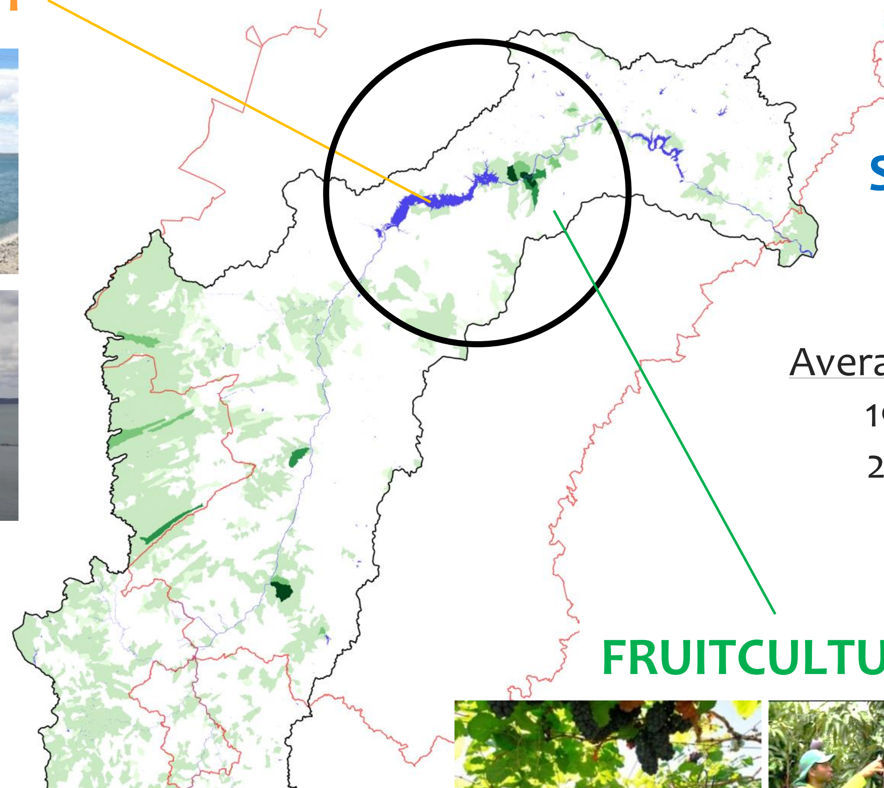
ANA (2017a)

SOBRADINHO HYDROPOWER PLANT

Reservoir capacity
34 billion m³
4,214 km²

CHESF (2019)

Petrolina-Juazeiro



Irrigation intensity (m³/s)

- 3.0-6.0
- 2.0-3.0
- 1.0-2.0
- 0.007-1.0
- 0.003-0.007

ANA (2017a)

SÃO FRANCISCO RIVER

2,863 km

Average inflow at Sobradinho
1999-2008: 1,883 m³/s
2009-2018: 1,369 m³/s

ONS (2019)

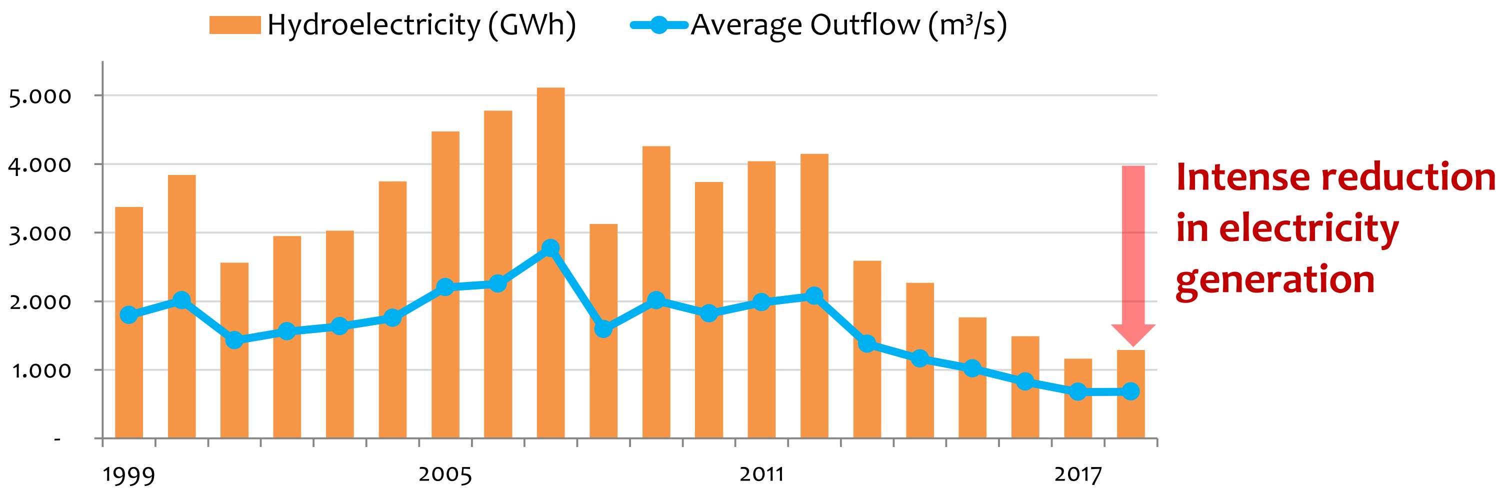
FRUITCULTURE

2018
1.853.687 ton
600 km²
456 million euros

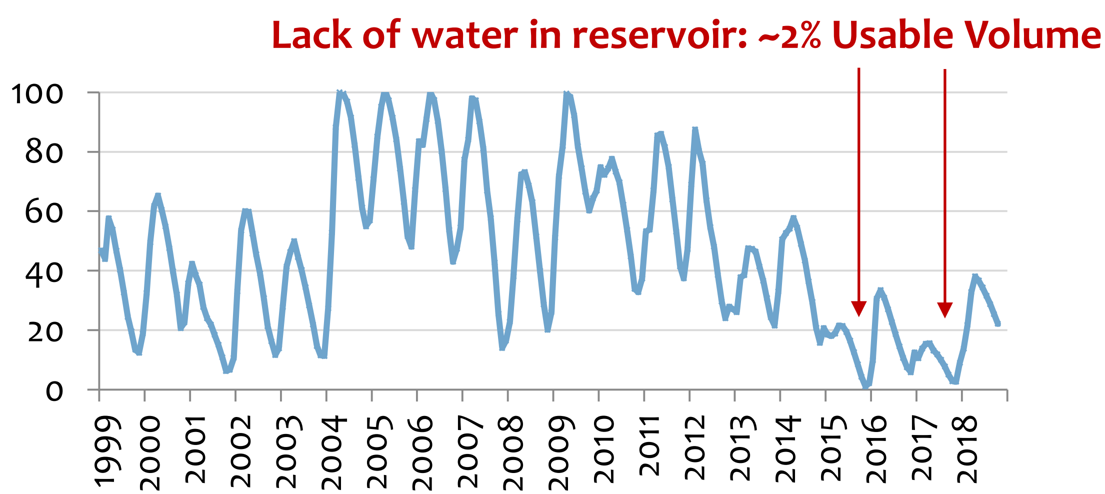
IBGE (2019)

CASE STUDY

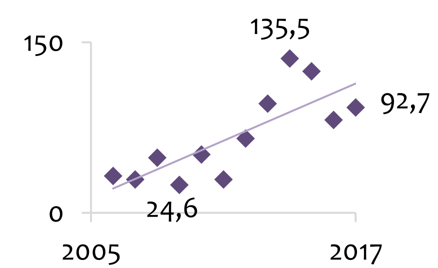
WATER and ENERGY during recent severe drought



ONS (2019)



ONS (2019)



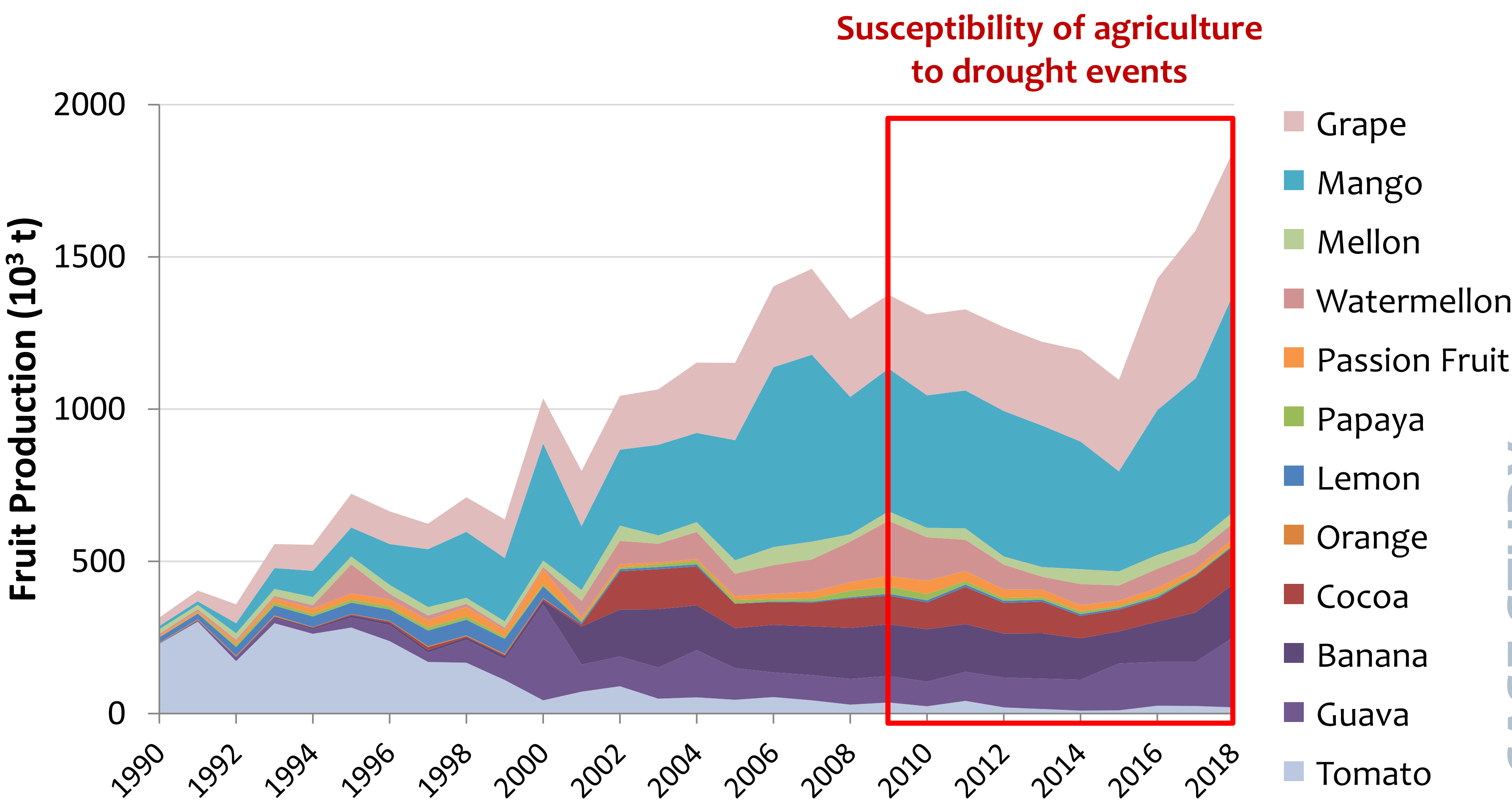
CO_2 emission factor of electricity from Brazilian grid

(kCO_2/MWh)

MCTIC (2018)

CASE STUDY

FRUIT during recent severe drought



IBGE (2019)

CASE STUDY

SCENARIOS

Objectives	WEF Security	Scenarios variation
Meet multiple uses of water - urban, rural, animals, industries	water security	guaranteed
Meet the water demand - Irrigation	food security	guaranteed
Generate electricity	energy security	Related to Outflow
Avoid Salt Wedge	environmental security	Above $800 m^3/s$
Minimize Evaporation	water security	Related to water storage in reservoir

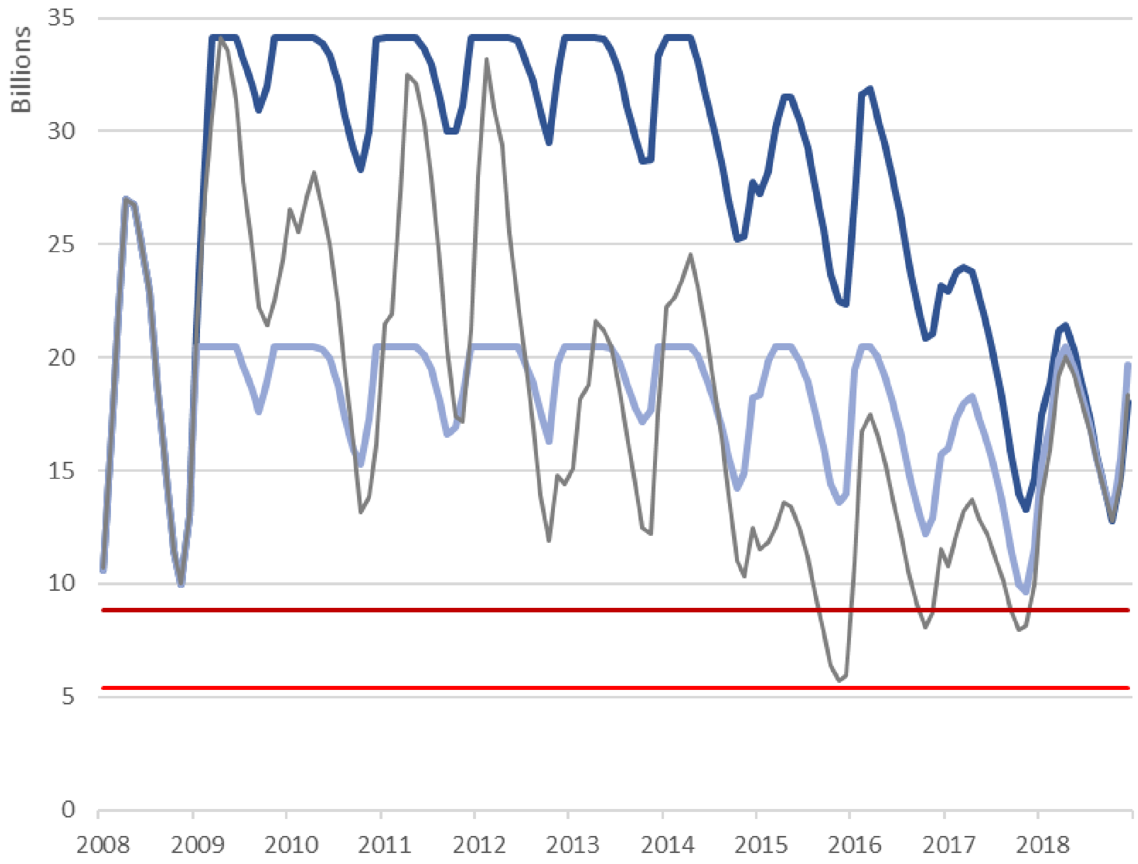
SCENARIOS

* Boundary conditions:

Maximum Storage Capacity in Reservoir (% [bi m³])	Minimum Flow Requirement at Mouth (m^3/s)		
	1,000	**900**	**800**
100% [34.1]			
90% [31.3]			
80% [28.4]			
70% [25.5]			
60% [22.6]			

* Other parameters were set for both scenarios:
  * Water Demand: observed data
  * Hydraulic Outflow from resevoirs: maximum flow
  * Nodes priority: equal distribution

Water Volume at Sobradinho Reservoir



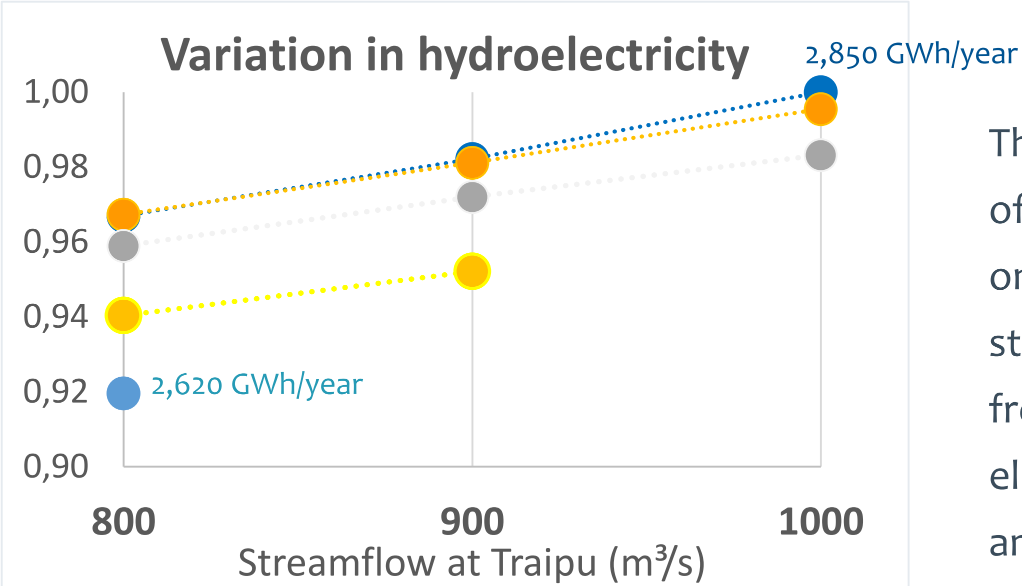
Maximum Storage Capacity **100%**

Minimum SF River Mouth **1,000** m³/s

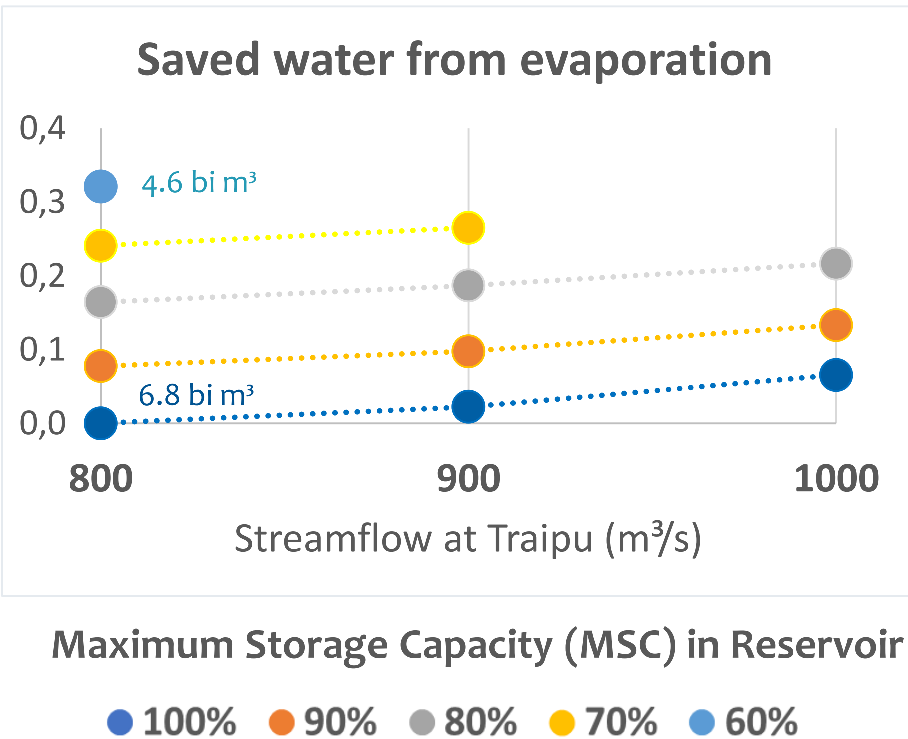
Maximum Storage Capacity **60%**

Minimum SF River Mouth **800** m³/s

RESULTS



The high water reserve and high streamflow of scenario MSC 100% + 1,000 m³/s generated, on average, 2,850 GWh/year. The water storage reduction affected energy starting from MSC 80%. The scenario with the lowest electricity generation obtained 92% the amount of the highest scenario.



The combination of MSC 100% + 800 m³/s resulted in the highest evaporation (6.8 bi m³). Savings from evaporation were achieved if we reduced MSC or increased the streamflow. Water savings reached 2.2 bi m³ (32% less evaporation) in scenario 60% MSC + 800 m³/s.

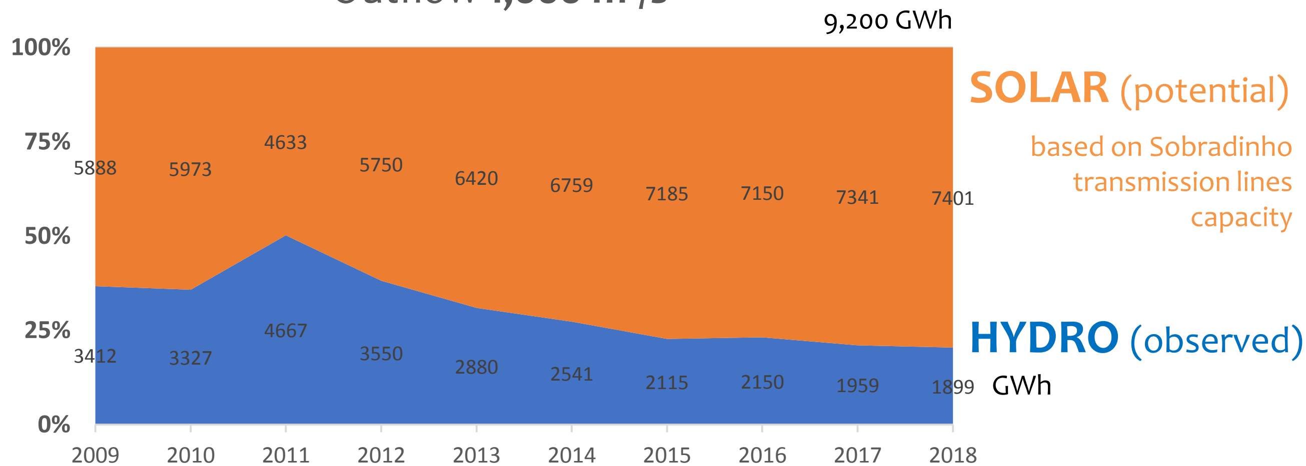
Potential amount for solar energy

The opportunity for hybrid solar-hydro energy at Sobradinho is intensified during severe drought events.

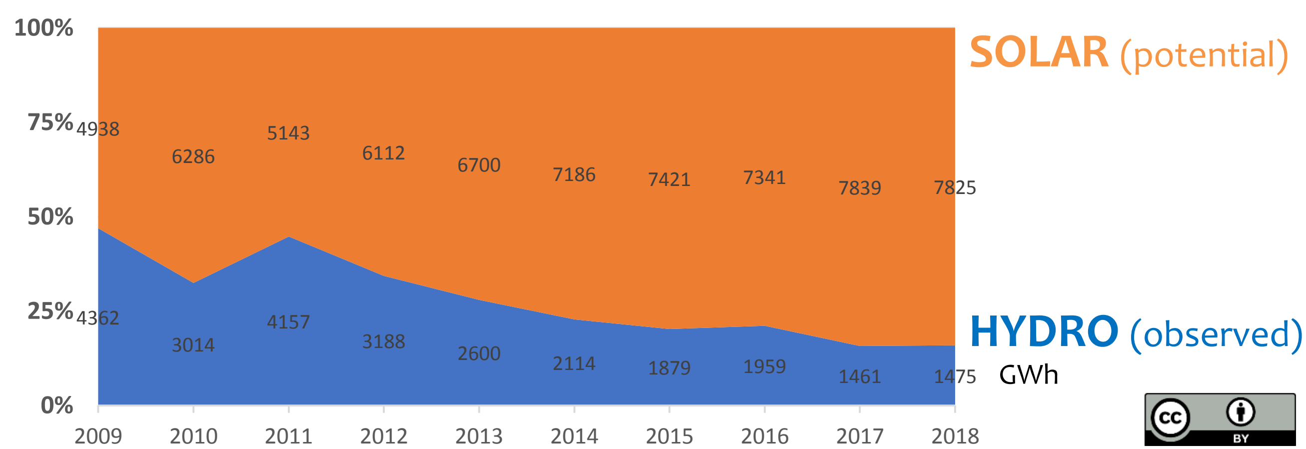
A floating solar power plant operating at Sobradinho takes advantage of the current grid connection infrastructure, underused in dry periods. In addition, adding solar to Sobradinho avoids investments in new transmission lines.

The combination of these energy sources rises the share of renewable electricity in the Brazilian grid.

Maximum Storage Capacity **100%**;
Outflow **1,000 m³/s**



Maximum Storage Capacity **60%**;
Outflow **800 m³/s**



Solar system dimensions

Scenarios	Energy (GWh/year)	Area (m^2)	km x km	% Sobradinho lake (usable water area)
MSC 100% + Outflow 1000 m^3/s	7.401	55.455.377	7,4	4,4%
MSC 60% + Outflow 800 m^3/s	7.839	58.742.114	7,7	4,7%

Input Data	Value	Unit
Capacity factor	0,195	
PV pannel power	250	Wp
PV pannel area	1.6	M^2
Row spacing ratio	2	

PV occupation at Sobradinho

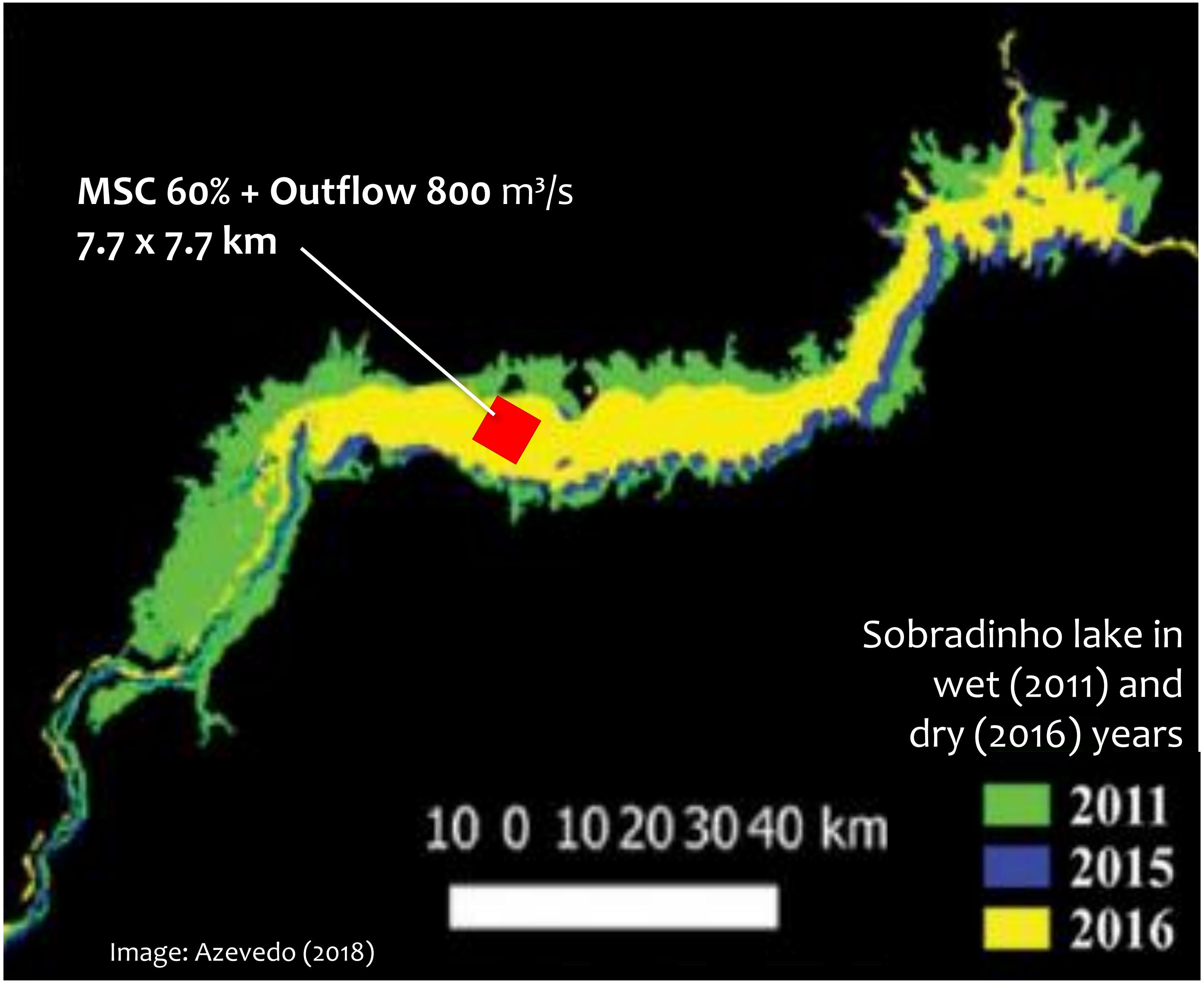


Image: Azevedo (2018)

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Thank you!

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