Field Observations and Model Simulations of an Extreme Drought Event in the Southeast Brazil

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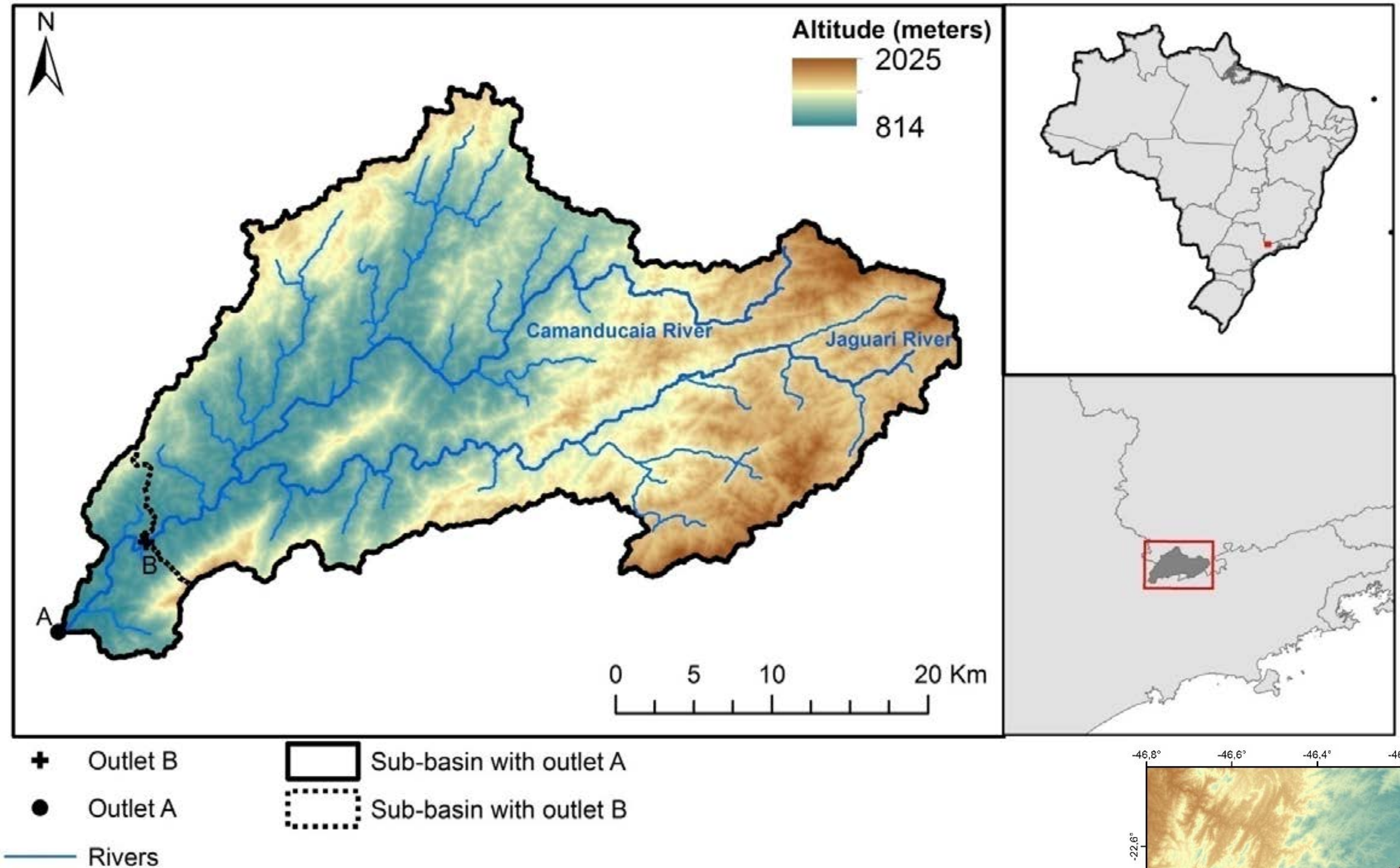
SWAT Soil & Water Assessment Tool

USP

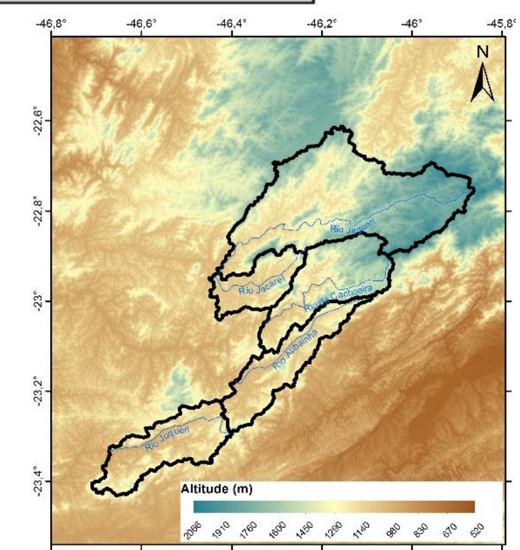
Warsaw, Poland

2017

Jaguari Sub-basin

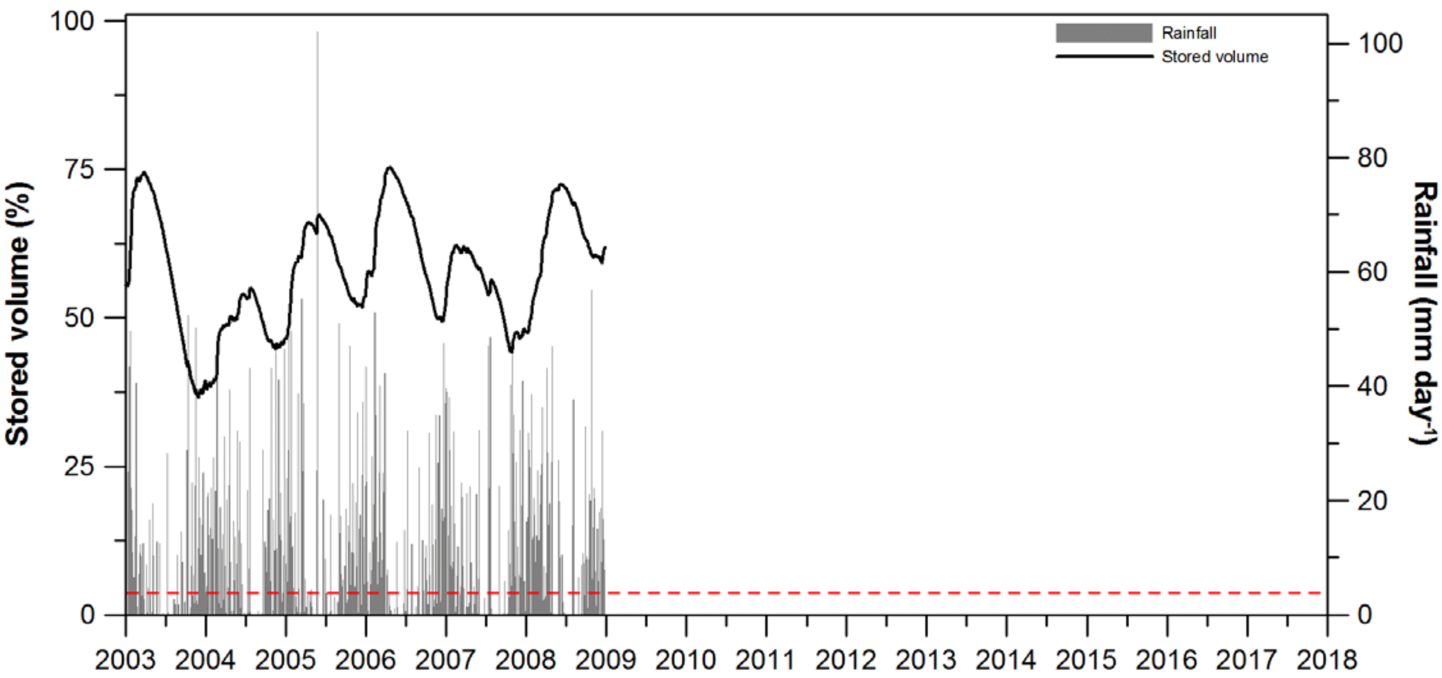


Drainage area: 968.6 km^2
Mean annual precipitation: 1592 mm y^{-1}
Mean anual discharge: 622 mm y^{-1} (~40% of precipitation)

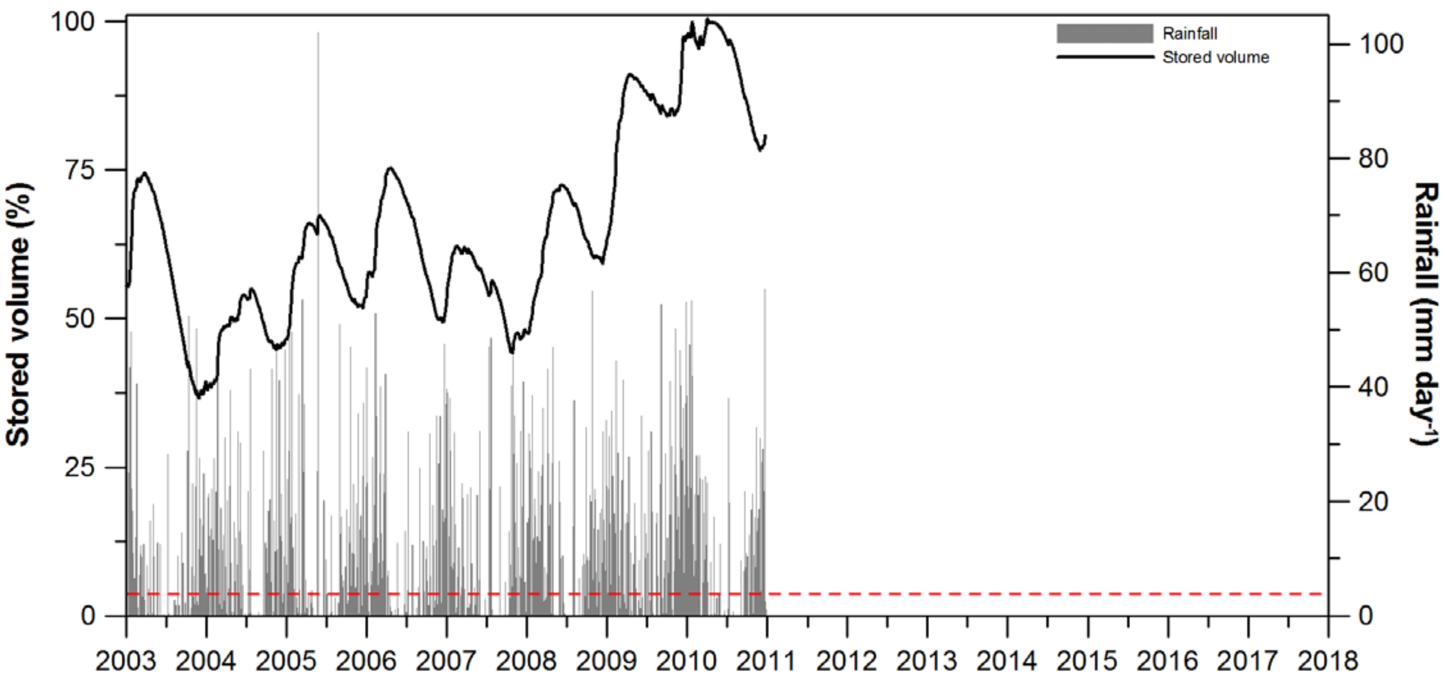


8.8 million people!!

Understading the crisis at Cantareira System



Understanding the crisis at Cantareira System




Bruno Azevedo/G1

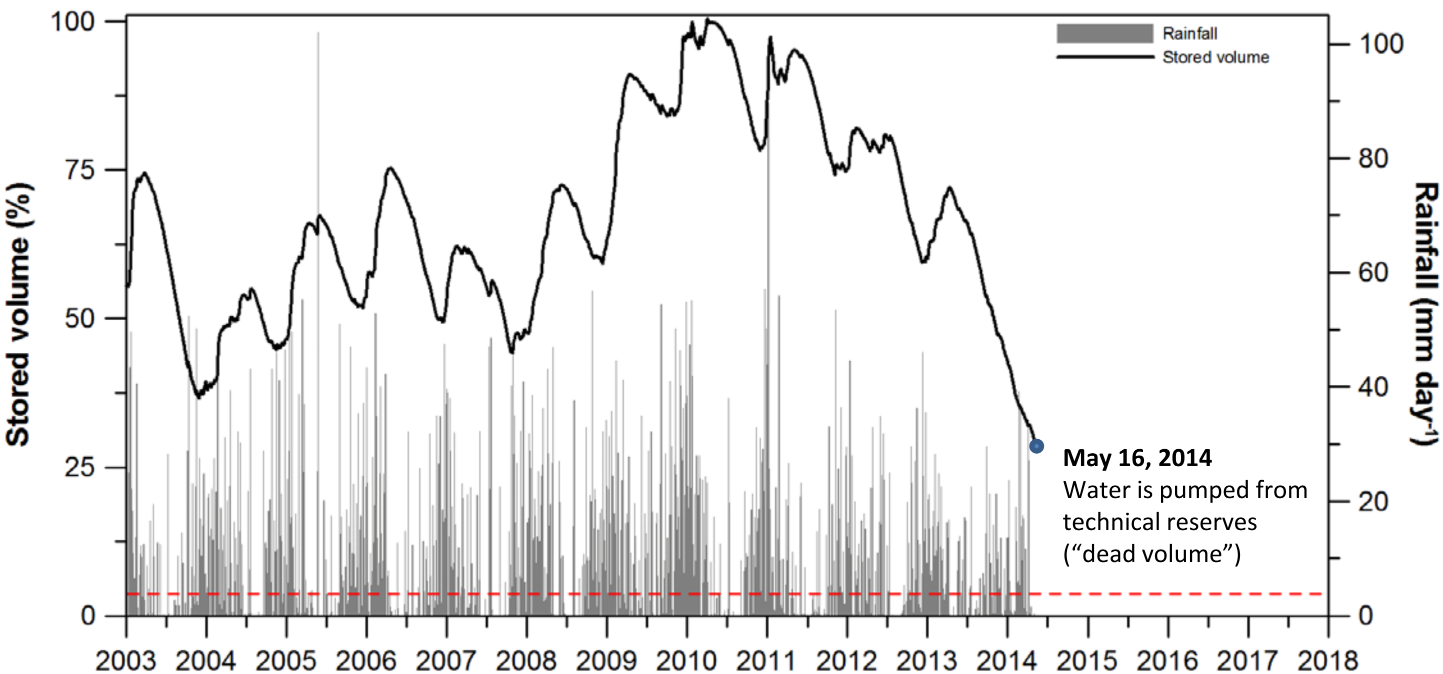

Nilson Cardin/Agência Estado


Isabela Leite/EPTV

ESTADÃO

Represas do Sistema Cantareira transbordam e ameaçam 12 cidades (Dams from Cantareira System flood and threaten 12 cities)

Understanding the crisis at Cantareira System



Jorge Araújo/Folha de São Paulo

theguardian

São Paulo faces a critical water shortage as the World Cup prepares to kick off

The Economist

Water in Brazil

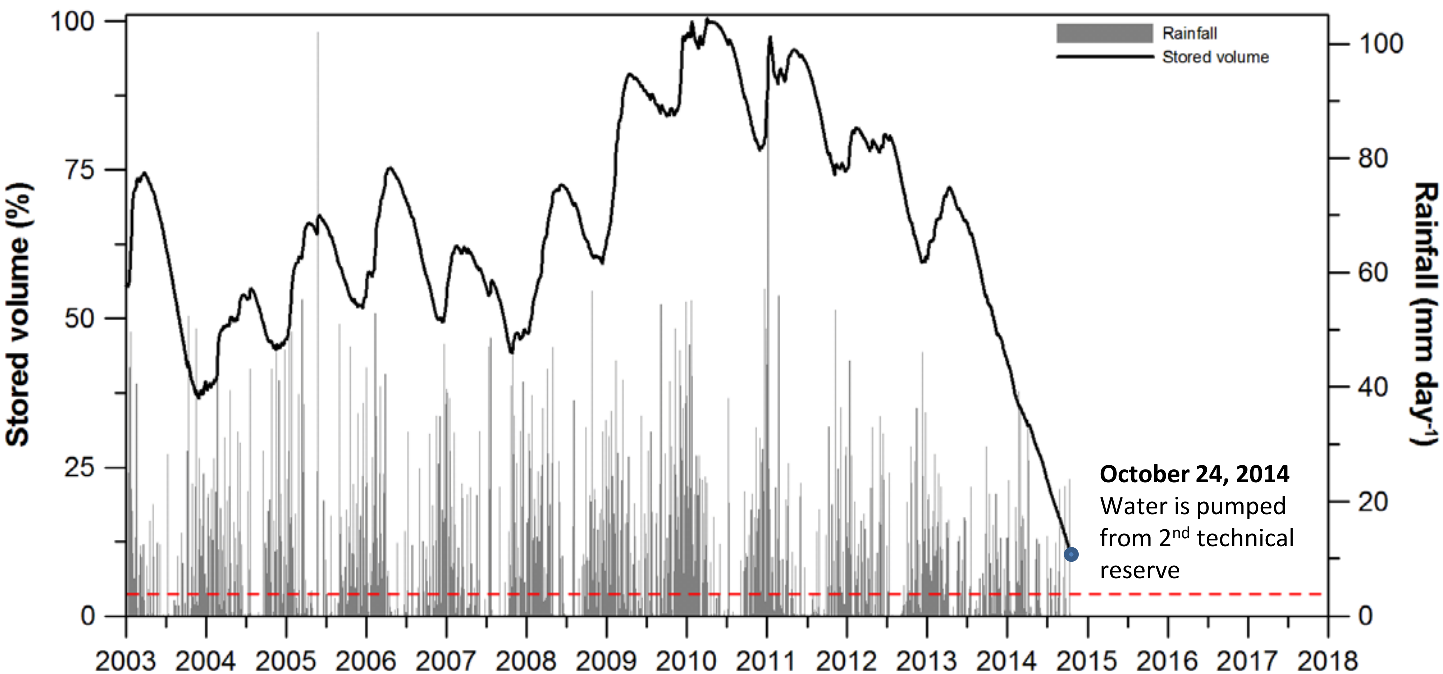
Nor any drop to drink

REUTERS

Brazil may face water shortages during World Cup, group says

Climate Center (2014)

Understanding the crisis at Cantareira System



Silas Basílio/TV Vanguarda

Dom Phillips/Washington Post

BBC

Brazil drought crisis deepens in Sao Paulo

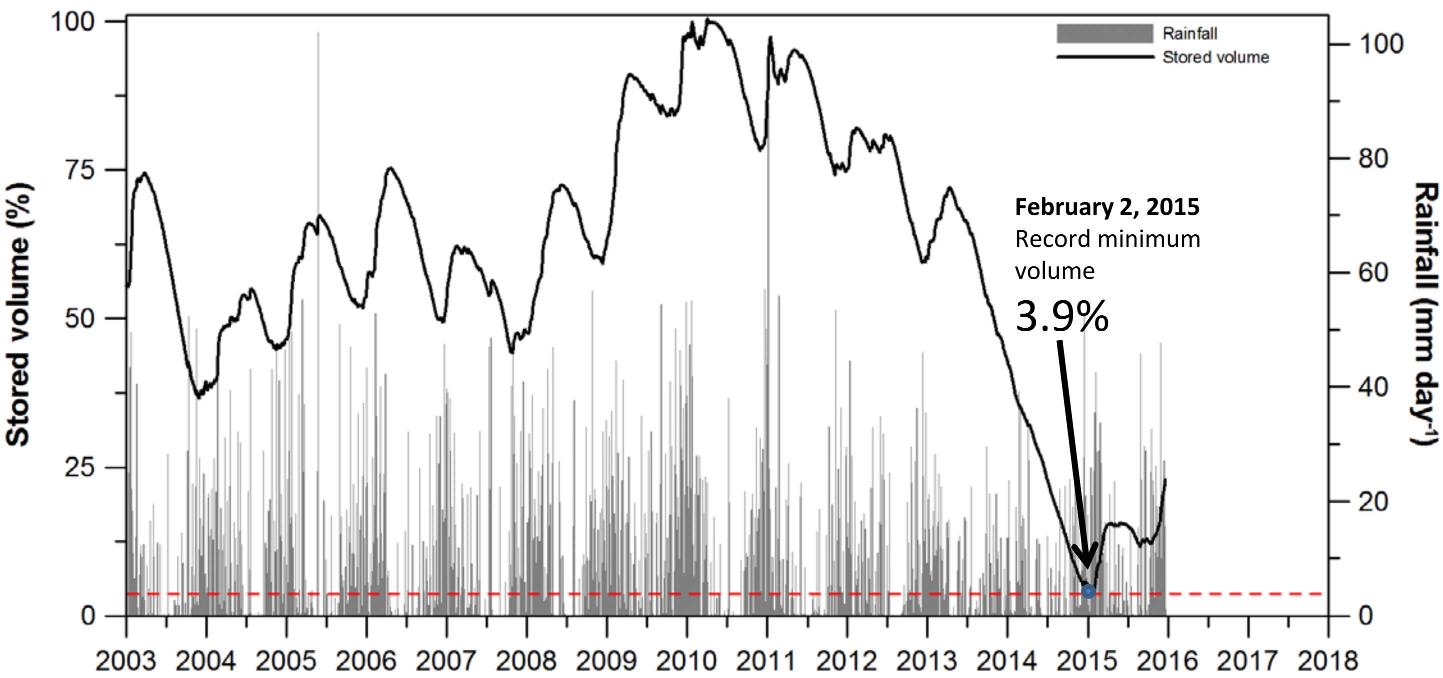
INDEPENDENT

Devastating pictures show São Paulo's worst drought in 80 years

theguardian

Brazil drought crisis leads to rationing and tensions

Understanding the crisis at Cantareira System



INDEPENDENT

Brazil water shortage: Sao Paulo devastated by its worst drought on record

The New York Times

Taps Start to Run Dry in Brazil's Largest City

The San Diego Union-Tribune

Rains during Carnival raise water level in Sao Paulo's biggest reservoir

February, 2015: a month of contrasts!

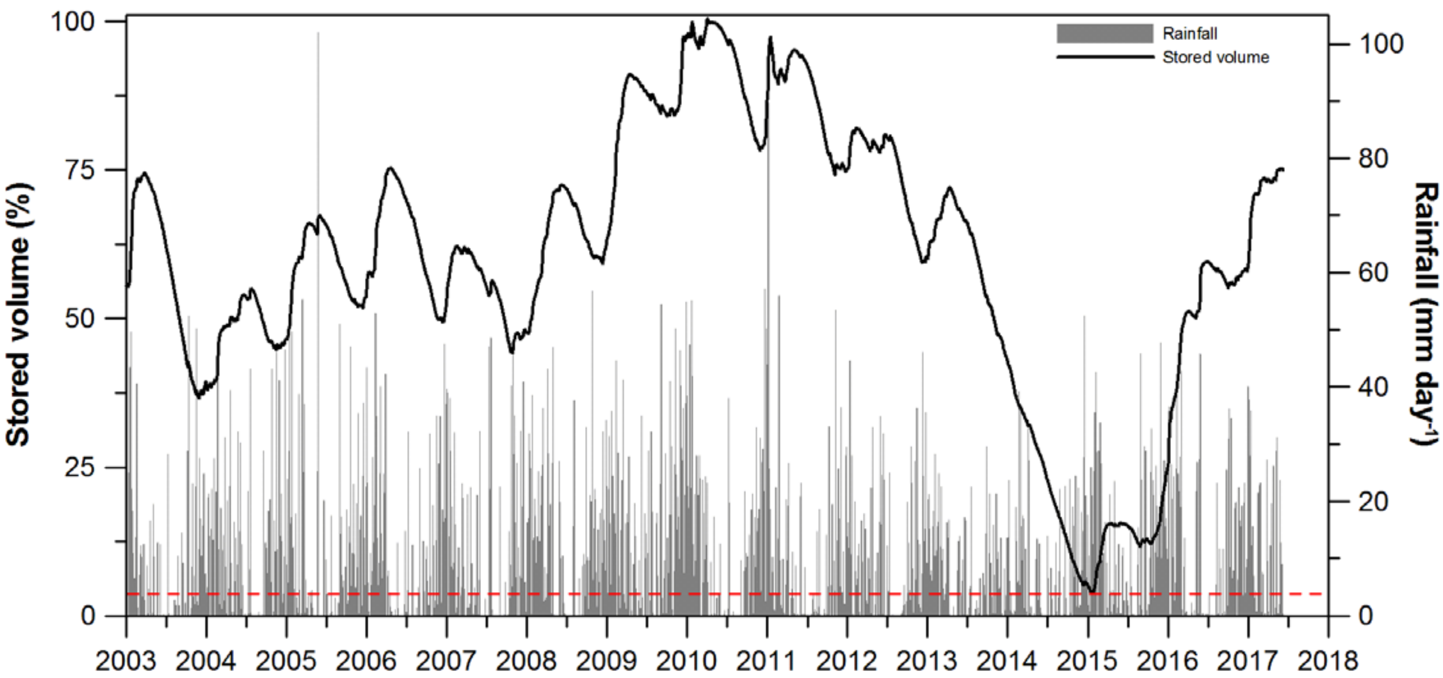
The Telegraph

Remains of former town re-emerge in Brazil's drought

ALJAZEERA

Drought-stricken Sao Paulo hit by floods

Understading the crisis at Cantareira System



REUTERS

Drought ends in Brazil's Sao Paulo but future still uncertain

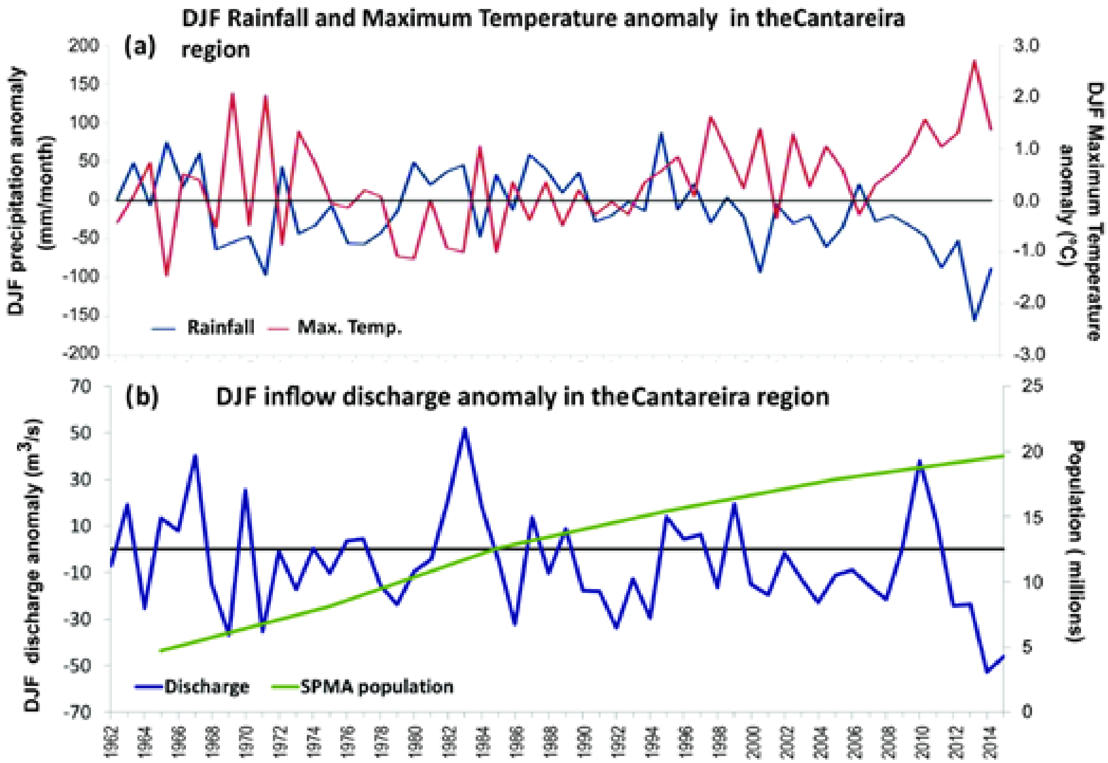
FOLHA DE S.PAULO

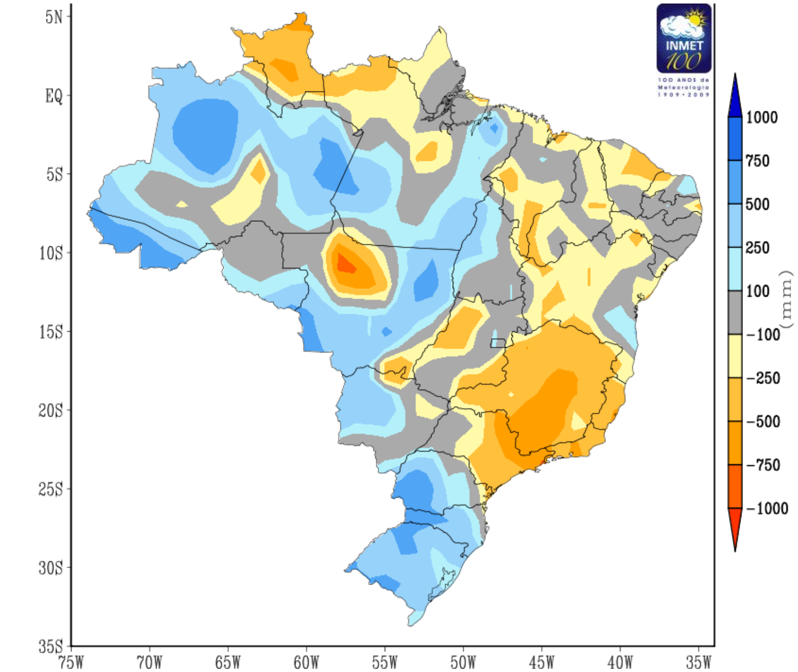
Após crise, 'turismo do Cantareira' celebra volta de água e de clientes

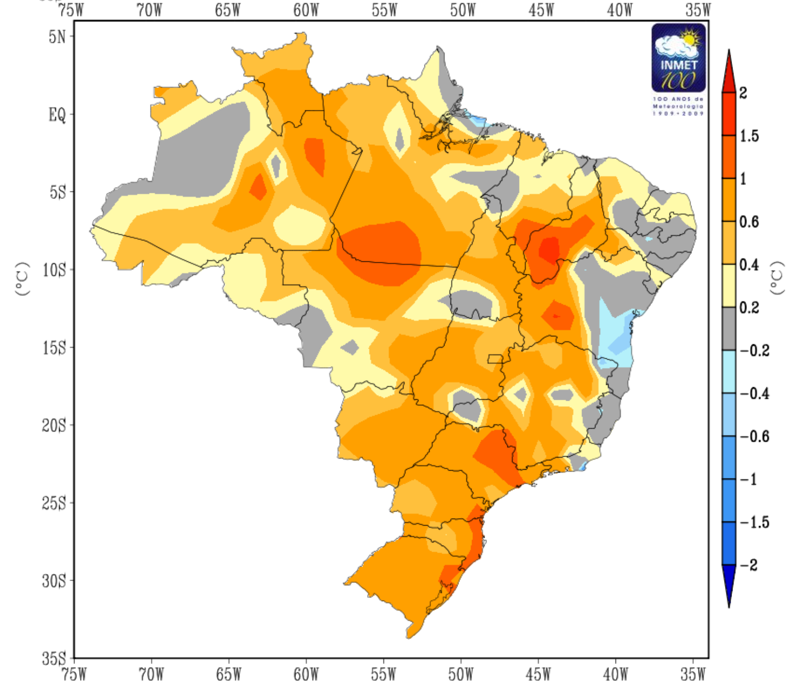
(After crisis, 'Cantareira tourism' celebrates the come back from water and clientes)

Avener Prado/Folha de São Paulo

2014 anomalies





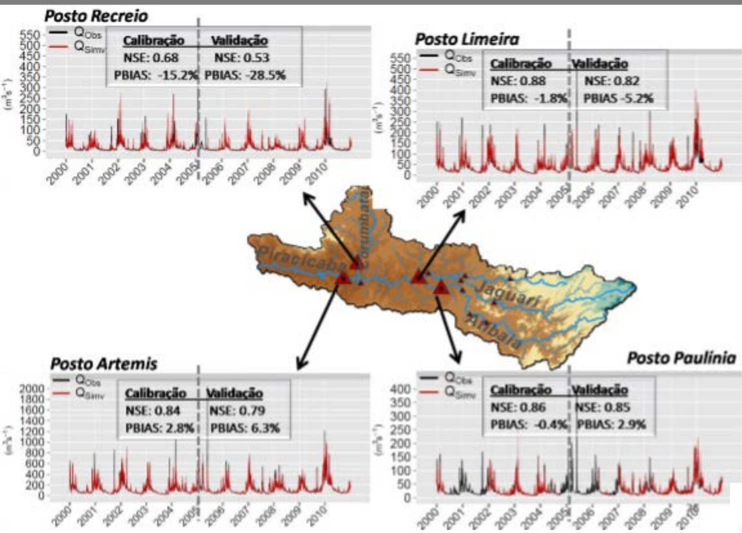


- Nobre *et al.* (2015) estimated a negative anomaly of ≈150 mm in DJF along with a positive anomaly of ≈3°C in temperature for Cantareira region;

- Demand increased 4 times since 1962.

Nobre et al, 2015. Some Characteristics and Impacts of the Drought and Water Crisis in Southeastern Brazil during 2014 and 2015. Journal of Water Resource and Protection, 2016, 8, 252-262

Previous Studies

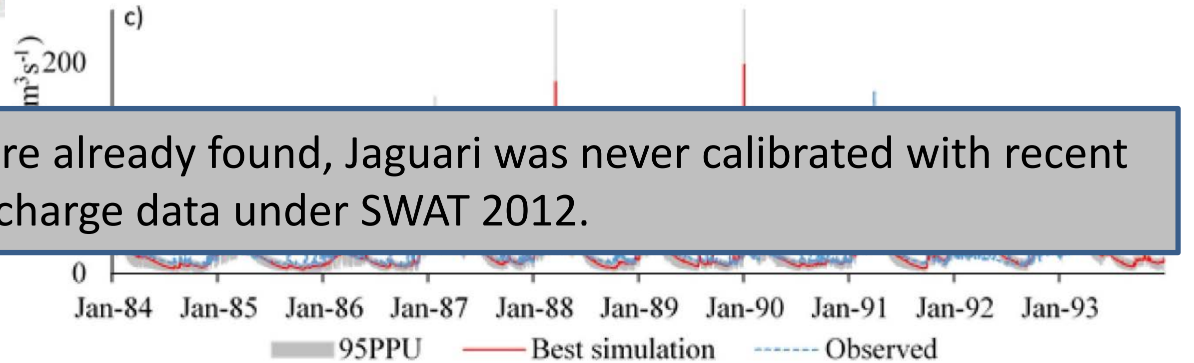


- Mota da Silva (2014) used SWAT 2005 to estimate the streamflow in several outlets from Piracicaba basin;
- Model was calibrated via hydroPSO (Zambrano-Bigiarini and Rojas, 2013) and presented satisfatory results;
- Cantareira System is part of Piracicaba, comprising the East portion of the basin.

PhD Thesis, USP, 2014

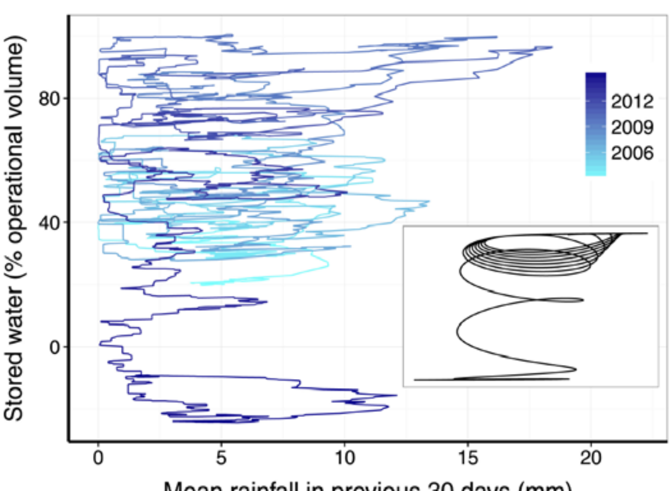
- Pontes *et al.* (2016) used

basin discharge from 1974-1994.



Pontes et al, 2016. Hydrological Modeling of Tributaries of Cantareira System, Southeast Brazil, with the Swat Model. Eng. Agríc. vol.36 no.6 Jaboticabal Oct./Dec. 2016

- Although satisfatory results were already found, Jaguari was never calibrated with recent discharge data under SWAT 2012.



- Coutinho *et al.* (2015) proposed a mathematical model controlling the volume of stored water.

- Regime changes depend on rainfall but also on the volume: higher the volume, more water from rainfall will flow to the reservoir. Low volume: rainfall supplies initially the dry soil.

Coutinho et al, 2015. Catastrophic Regime Shift in Water Reservoirs and São Paulo Water Supply Crisis. PLoS ONE 10(9): e0138278. doi:10.1371/journal.pone.0138278

Goals

- Assess the impacts of the 2014 drought on water fluxes over Jaguari sub-basin using a hydrological model (SWAT 2012), during 2012-2016 period;

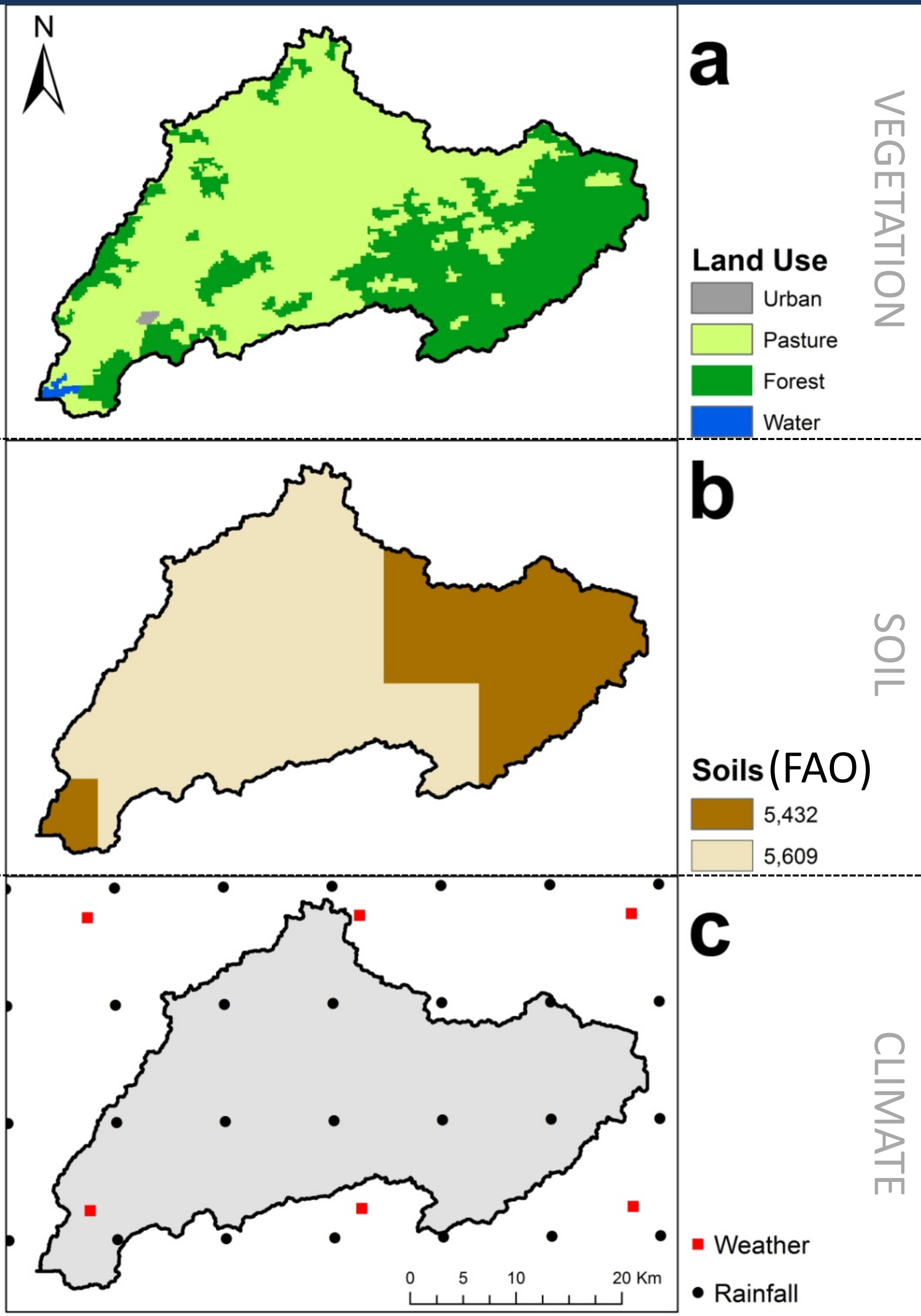
- Investigate how long term climate perturbations such as happened in 2014 might modify surface water balance.

SWAT Setup

- IBGE (2015) Land Use Shapefile;
- Mosaic and agriculture classes were reclassified into the dominant patch and pasture, respectively;
- Forest and pasture parameters were set according to Mota da Silva (2014).

- Batjes (2012) global soil map;
- SOL_K estimated via pedotransfer functions from Saxton & Raws (2006);
- Other parameters used according to Mota da Silva (2014).

- Weather (max and min temperatures, relative humidity, solar radiation and wind speed) taken from CFSv2 analysis (Saha *et al.*, 2014);
- Rainfall was estimated via SABESP, ANA, DAEE, IAC, INMET and CEMADEN gauges;
- Data was interpolated via IDW method.



SWAT-CUP Calibration

- PSO calibration proccess;
- 3 iteractions of 50 simulations;

$P < 0.0005$

Parameter	Description	Units	Range
GW_DELAY	Delay time for aquifer recharge	days	0, 500
ALPHA_BF	Baseglow recession constant	days	0, 1
REVAPMN	Threshold depth of water in the shallow aquifer for “revap” to occur	mmH_2O	0, 10
GW_REVAP	Groundwater “revap” coefficient	(-)	0.1, 0.5
RCHRG_DP	Deep aquifer percolation factor	(-)	0, 1
LAT_TTIME	Lateral flow travel time	days	1, 10
CH_S(1)	Average slope of tributary channels	m/m	0.001, 0.055
CH_N(1)	Manning's “n” value for the tributary channels	(-)	0.025, 0.035
SLSUBBN	Average slope length	m	8, 123
OV_N	Manning’s “n” value for overland flow	(-)	0.17, 0.4
SOL_AWC(1)	Available water capacity	$mmH_2O\ mm_{soil}^{-1}$	0.01, 0.3
SOL_K(1)	Saturated hydraulic conductivity	$mm\ h^{-1}$	0.5, 300
CH_S(2)	Average slope of main channel along the channel length	m/m	0.001, 0.055
CH_N(2)	Manning's “n” value for the main channel	(-)	0.025, 0.060
CH_K(2)	Effective hydraulic conductivity in main channel alluvium	$mm\ h^{-1}$	0, 180
ESCO	Soil evaporation compensation coeficient	(-)	0.8, 1

First Experiments

- Climate perturbations on daily max and min temperatures and/or rainfall;
- Same parameters of calibrated control (CTL) simulation;
- Other variables remains the same.

i

Temperature based

T + 1°C

T + 2°C

T + 3°C

ii

Rainfall based

P - 10%

P - 20%

P - 40%

iii

Joint perturbation

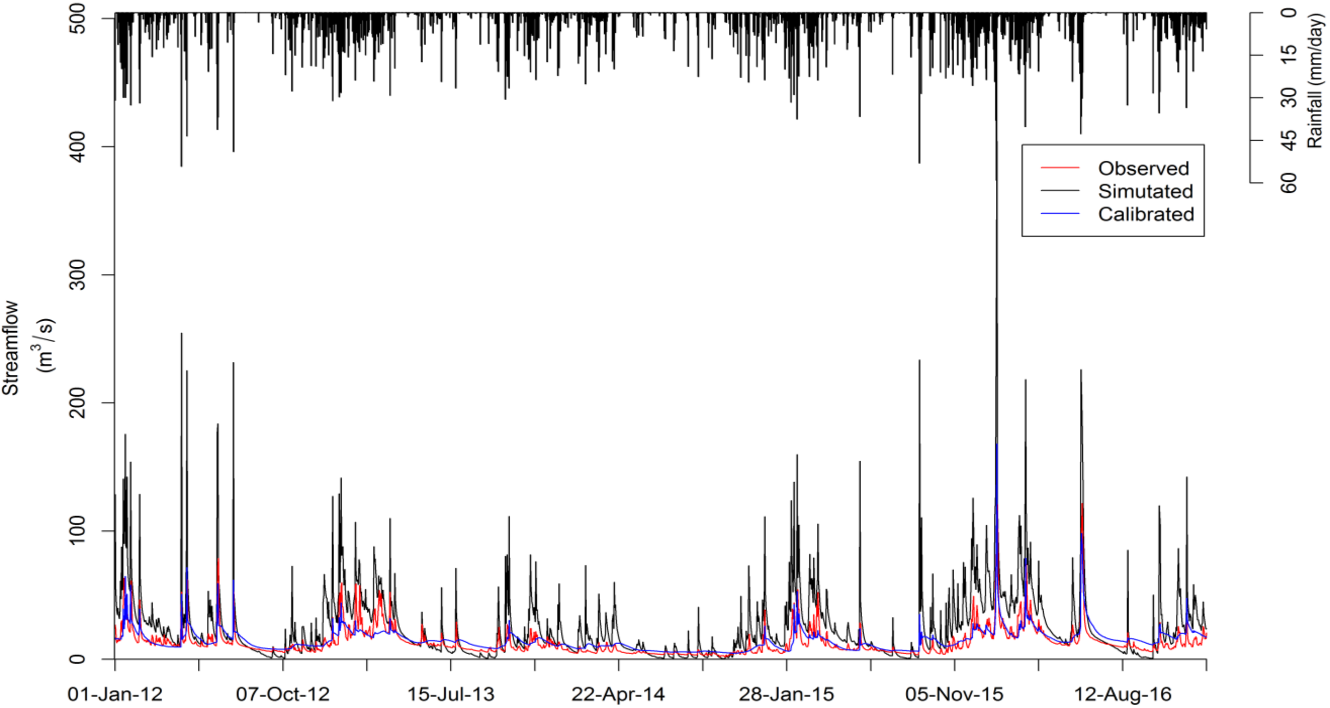
T + 1°C, P - 10%

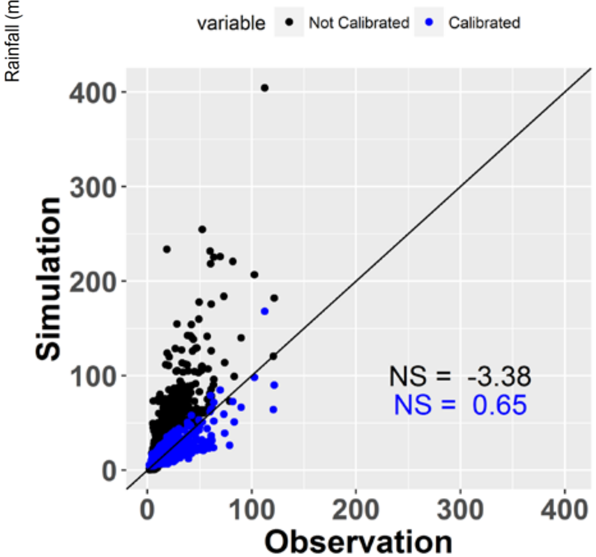
T + 2°C, P - 20%

T + 3°C, P - 40%

Results

✓ Calibrated streamflow reduced the peaks that were iniatilly quite overestimated, and better represented the base flow.

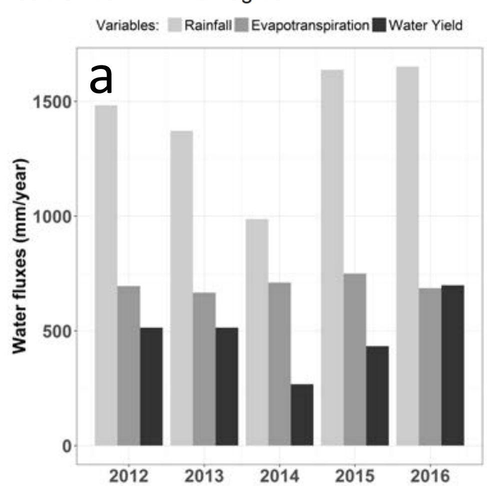


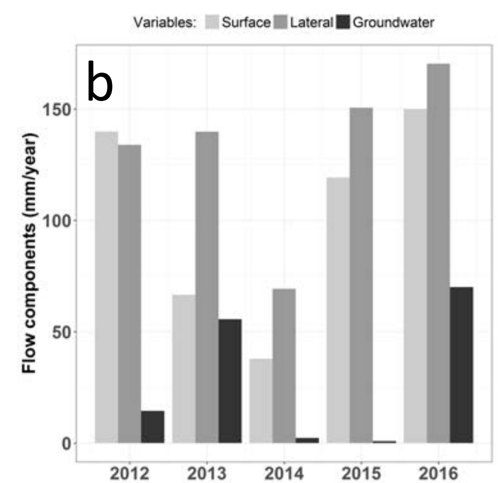


✓ Drought effects on water fluxes:

a) Increase in annual evapotranspiration, and a more pronounced decrease in water yield;

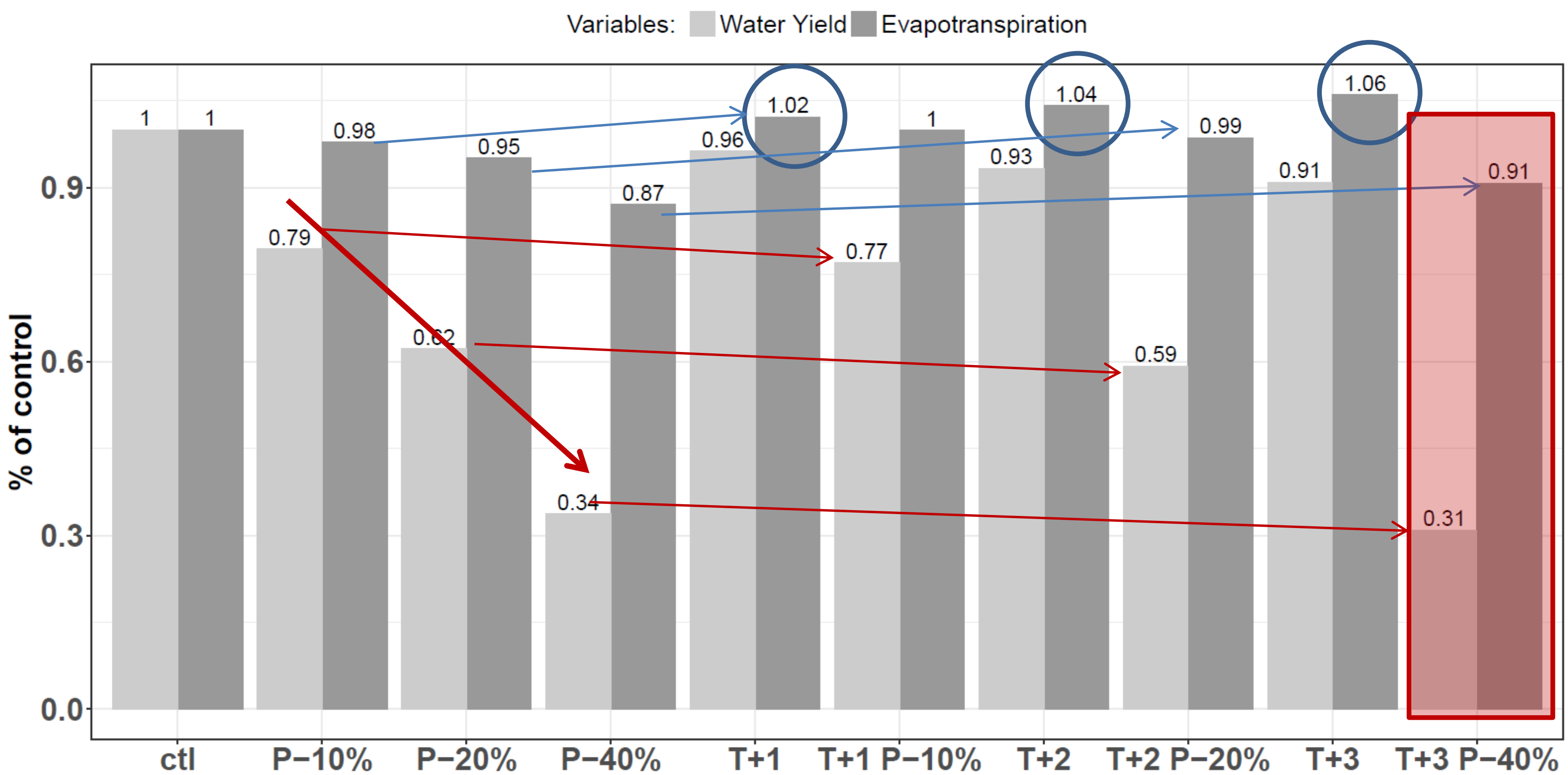
b) All components decreased in 2014. Groundwater fluxes were more affected.





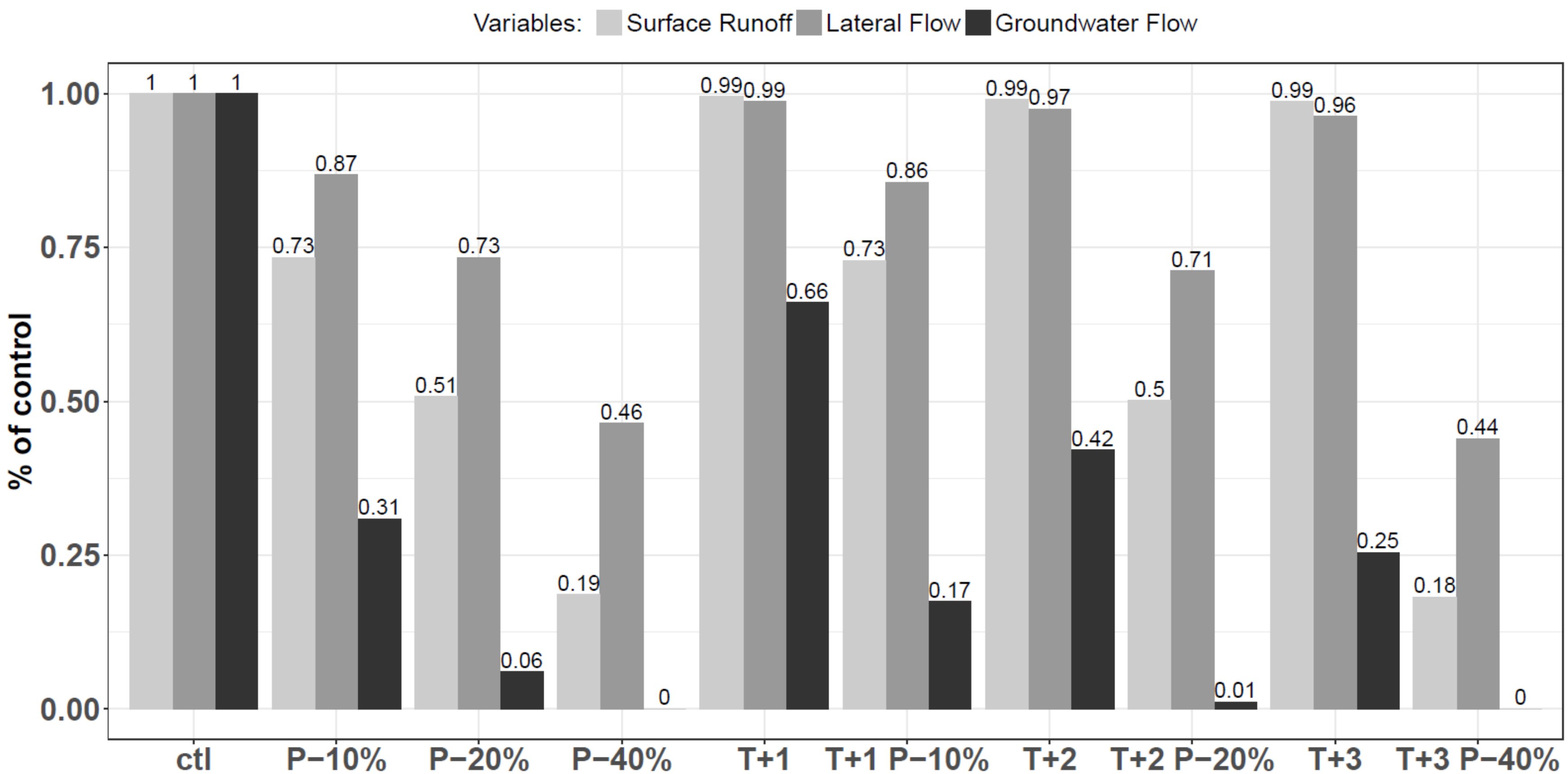
Results

✓ Evapotranspiration progressevely increases under hotter conditions;
✓ Water yield decreases under all conditions, especially on drier conditions;
✓ Joint perturbations of rainfall and temperature progressevely intensified the deplection in water yield, and softened the decrease in evapotranspiration comparing to only rainfall perturbations;
✓ The most extreme perturbations are similar to DJF/2014 anomalies. Results show a 69% decrease in water field and 9% decrease in evapotranspiration.

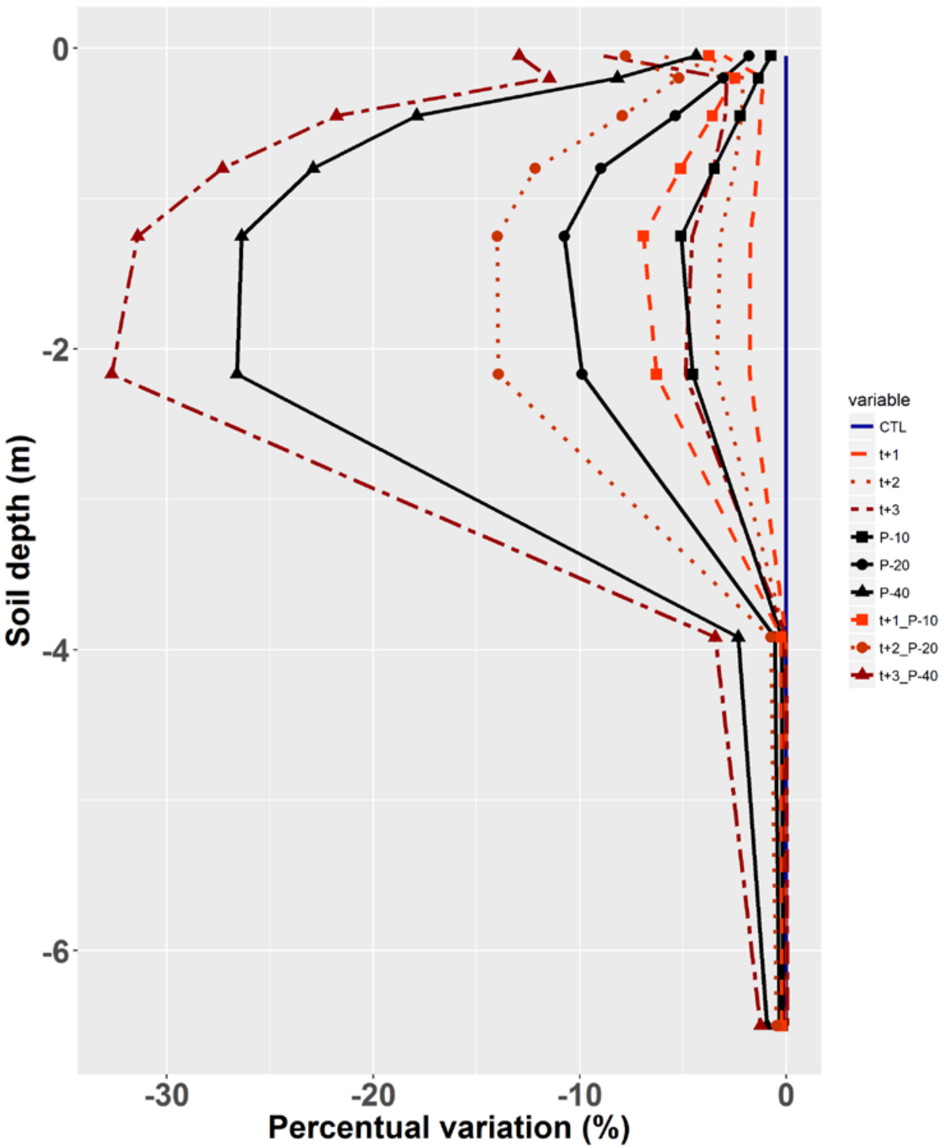


Results

✓ Increasing temperature has minor effects on surface and lateral flows but effectively decreases groundwater flow;
✓ All flows rapidly decrease under progressevely drier conditions, specially groundwater and surface flows;
✓ No groundwater flow was generated under P– 40% conditions.



Results



- Drying of the soil mainly on 0-4 m depth is linked to max root zone depth;
- Experiments increasing temperature present decrease in water stored close to the surface: soil evaporation effect;
- Below 4 meters, stored water has small variation, even for the most extreme case.

Final Remarks

- Model setup and calibration were able to simulate discharge in a good way (NS = 0.65);
- Drought reduced streamflow ≈60%, while evapotranspiration variation was much smaller;
- Groundwater flow was the most sensitive term for all experiments;
- Although climate perturbations were held for 5 years period, results weren't much worse than 2014 for discharge: water stored in a deep soil must be "easing" the impacts. On the other hand, evapotranspiration never increases under long drier conditions;
- More realistic scenarios should be applied in order to estimate impacts, controlling the duration and intensity of droughts.

Next Steps

- Flux tower measurements being held in Ribeirão das Posses basin, it will be used as reference for evapotranspiration in calibration process;
- Add second outlet in SWAT-CUP calibration;
- Validation process
- New scenarios.

Thank you!
Questions?

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