Effects of climate change and land use on the hydrology of the Paraná River Basin - Brazil

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Sixth SWAT – SEA Conference
Siem Reap – Cambodia, October, 2019
The Upper Paraná River Basin:

- It is in the most anthropized biomes, Cerrado and Atlantic Forest;
- It has large food producing areas and important urban centers, becoming extremely important for the national economy;
- It has the largest energy production and the largest water demand;
- It has almost one third of the Brazilian population.
Importance of the Upper Paraná River Basin:

- Hydroelectric power generation:
  - Itaipu – 7,000 MW (17%)
  - Ilha Solteira – 3,444 MW (8.4%)
  - Itumbiara – 2,082 MW (5.1%)
  - Foz da Areia – 1,676 MW (4.1%)
  - Jupiá – 1,551 MW (3.8%)

✓ National production: 75%
✓ National consumption: 30%
Importance of the Upper Paraná River Basin:

- **Public and industrial supply**
- **Agriculture livestock development**
- **Water transportation**

Source: FAO’s global water information system - Land and Water Division
Some features of UPRB

- In the last 30 years, natural areas have declined more than 40%, occupying now around 20% of the basin.
- Areas of agriculture and urban infrastructure grew respectively 63 and 62%.
Some features of UPRB

- The basin has presented a **significant increase in their stream flows in the last decades** (e.g. Antico et al., 2015; Camilloni & Barros, 2003);

- This growth can be associated with increased rainfall and decreased evapotranspiration due to **land use changes** (e.g. Doyle & Barros, 2011);

- **Droughts extreme events** have been frequent in many areas of the world (e.g. Briffa et al., 2009; Dai et al., 2011) and can be related to **land use** (e.g. Ghaffari et al., 2010; Wang et al., 2012) or **climate change** (e.g. Beyene et al., 2010; Palmer et al., 2008).

89% of the primitive forest (1,500,000 km²) has been deforested.
## Related Issues

### Human activities
- Demographic growth.
- Demand for natural resources.
- Urbanization.
- Intensive Farming

### Hydrological budget
- Less water infiltration in the soil.
- Less evapotranspiration.
- Less moisture in the atmosphere.

### Energy budget
- Less energy used in photosynthesis.
- Lower latent heat flux and higher sensible heat flux.

### Rainfall availability
- Less rainy days.
- Extreme rainfall events.
- Natural disasters.
- Climate change.
Large and Synoptical Scales Variability
Empirical Orthogonal Function - SON

Figura 13: Modos de variabilidade interanual para a precipitação do trimestre de SON para o período 1970-2013: (a) EOF1 TOT; (b) EOF1 RES.

Percentage represents the portion of the variability explained by ENSO. For EOF2 - ENOS explains only 5% of variability. Higher variability is explained by the non-ENSO component.

<table>
<thead>
<tr>
<th></th>
<th>CP2 TOT</th>
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<tbody>
<tr>
<td>SON</td>
<td></td>
<td></td>
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<tr>
<td>ININO 3.4</td>
<td>4,96%</td>
<td>-0,22</td>
</tr>
<tr>
<td>CP2 RES</td>
<td>15,31%</td>
<td>0,39</td>
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</table>

Contributions from Itamara Souza
Composição dos Anos Extremos

Main Results

Larger Discharges

TTT

LLJ

RES

South Atlantic
Effects of Data Density
Study Area

- **Ivaí River Basin** – 36.589 km²
  - Data availability
  - No dams in the main stream

Contributions from Thais Fujita
Questions

- What are the implications of lower station density for the right bank?
- How compromised is the representation of precipitation variability?
- What is the minimum density required for hydrological studies?
Study Area

- Topography
- Soil classes
- Declivity
- Land Use

- 24 Sub-basins
- 5 fluviometric stations
- Calibration and Validation

SWAT
Soil & Water Assessment Tool
• “Novo Porto Taquara” Station:
  • 83% of the observed monthly flow behavior was captured by the model.
  • The Nash-Sutcliffe efficiency index for the simulation was 0.87 (Very Good).

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<tr>
<th>Flow</th>
<th>Observed</th>
<th>Simulated</th>
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<tr>
<td></td>
<td>717.88 m³/s</td>
<td>655.04 m³/s</td>
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</table>
Station density evaluation by flow response:

✓ Simulation quality increases with increasing rainfall density

RRMSE (Relative Root Mean Square Error - from zero to infinity, where zero indicates no error, and full similarity to the control run).
Station density evaluation by flow response:

- Tereza Cristina: 20 stations, 744 km²
- Ubá do Sul: 15 stations, 824 km²
- Vila Rica: 14 stations, 831 km²
- Porto Paraíso do Norte: 11 stations, 923 km²
- Novo Porto Taquara: 12 stations, 870 km²

**RRMSE vs Number of stations**
Land Use Identification Issues
Main Problem

Agreement between global land use products for HPRB (GLOBCOVER versus MODIS).

Contributions from Anderson Rudke
Database

1985
Landsat 5
30 m
52 (170x183km)

- Satellite -
- Spatial resolution
- Nº of scenes -

2015
Landsat 8
30 m
50 (185x185km)
Calibration and Validation samples

Calibration samples
1985 - 17.040
2015 - 15.728

Validation samples
1985 - 1.054
2015 - 1.033
New Land Use files

Classification accuracy

- **1985**
  - Kappa index: 0.53
  - Global accuracy: 63%
  - Accuracy by class:
    - Forest: 71%
    - Agriculture: 75%
    - Pasture: 54%

- **2015**
  - Índice Kappa: 0.70
  - Global accuracy: 78%
  - Accuracy by class:
    - Forest: 82%
    - Agriculture: 88%
    - Pasture: 71%
Land Use Variability and Changes
How to integrate the models considering LUCL Evolution?

Contributions from Carolyne Machado
The Solution: Spatial Dynamic Modeling

- Modeling platform developed by UFMG.
- Represents spatiotemporal dynamics of landscape phenomena.
- Probabilistic Stochastic Empirical Model.

The Solution: Spatial Dynamic Modeling

- Population;
- GDP;
- Roads;
- Agriculture.
Model Validation

Global accuracy → 57.7 %

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<th>Simulated</th>
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<td>15.26</td>
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<td>0.09</td>
<td>0.87</td>
<td>0.76</td>
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<td>0.12</td>
<td>1.36</td>
<td>0.00</td>
<td>0.05</td>
<td>0.00</td>
<td>0.09</td>
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<td>0.15</td>
<td>0.00</td>
<td>0.79</td>
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<td>0.00</td>
<td>0.03</td>
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<td>1.41</td>
<td>1.46</td>
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<td>0.02</td>
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<td>P. For.</td>
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<tr>
<td>Total S.</td>
<td>49.19</td>
<td>29.37</td>
<td>1.54</td>
<td>1.23</td>
<td>3.86</td>
<td>3.30</td>
<td>11.51</td>
<td>100.00</td>
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Model Validation - 2017

Spatial Resolution

Minimum_Similarities

Maximum_Similarities
Next steps → Create scenarios of LULC for BRAMS (Brazilian developments on the Regional Atmospheric Modelling System)
Hydrologic impacts of land use change in the UPRB
Contributions from Sameh Rafee

Percentage change in discharge for the year 2015 with respect to year 1985 at the final outlet of the basin

Paraná River
mean = 1.2; 4.2; -2.2
Green water flow (Evapotranspiration)

1985

2015

Change

Wet season (mm)
- < 350
- 350 – 400
- 400 – 450
- 450 – 500
- 500 – 550
- 550 – 600
- 600 – 650
- 650 – 700
- 700 – 750
- > 750

Wet season (mm)
- < 350
- 350 – 400
- 400 – 450
- 450 – 500
- 500 – 550
- 550 – 600
- 600 – 650
- 650 – 700
- 700 – 750
- > 750

%< 20
-20 – -10
-10 – 0
0 – 10
10 – 20
> 20

Dry season (mm)
- < 350
- 350 – 400
- 400 – 450
- 450 – 500
- 500 – 550
- 550 – 600
- 600 – 650
- 650 – 700
- 700 – 750
- > 750

Dry season (mm)
- < 350
- 350 – 400
- 400 – 450
- 450 – 500
- 500 – 550
- 550 – 600
- 600 – 650
- 650 – 700
- 700 – 750
- > 750

%< 20
-20 – -10
-10 – 0
0 – 10
10 – 20
> 20

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Conclusions

- ENSO plays a minor role over the precipitation regime of the UPRB;
- Synoptic and local scale phenomena together with Land Use changes are probably the main responsible features;
- Density of stations are fundamental features for a correct calibration/validation of hydrological models;
- Land use files largely available need to be improved in order to provide the correct hydrology of the interest region;
- Land use changes between 1985 and 2015 affected increases (decreases) in the wet (dry) season discharge up to 7% (-6%) at the final outlet of the basin
- Future land use changes may have potential impacts on the main economic activities developed in the basin such as hydropower generation, agricultural, and livestock, which means …
if the future looks something like this …

… we need to be prepared
Thank you

www.master.iag.usp.br/parana/index.html

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