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

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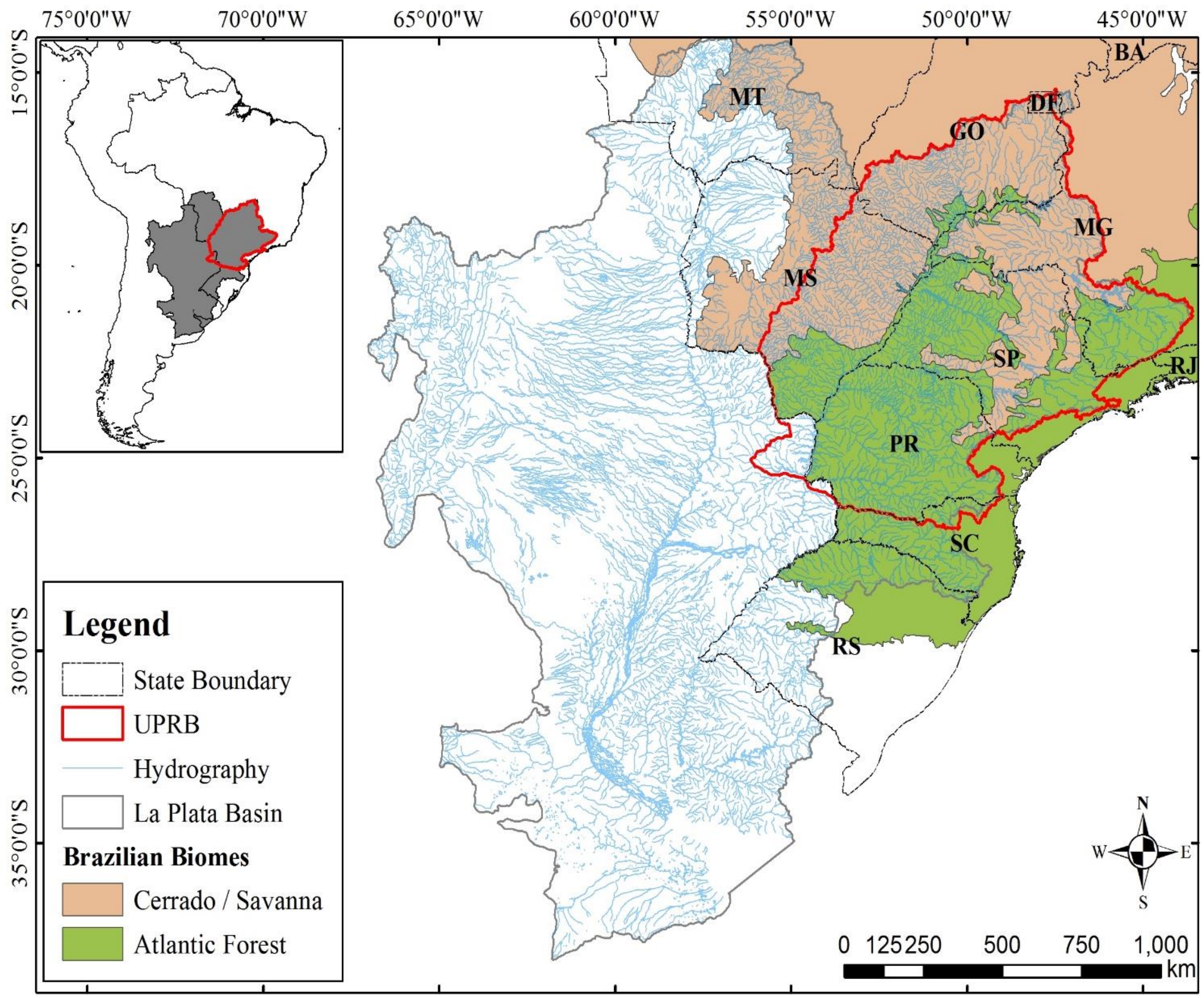
Sixth SWAT – SEA Conference

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.

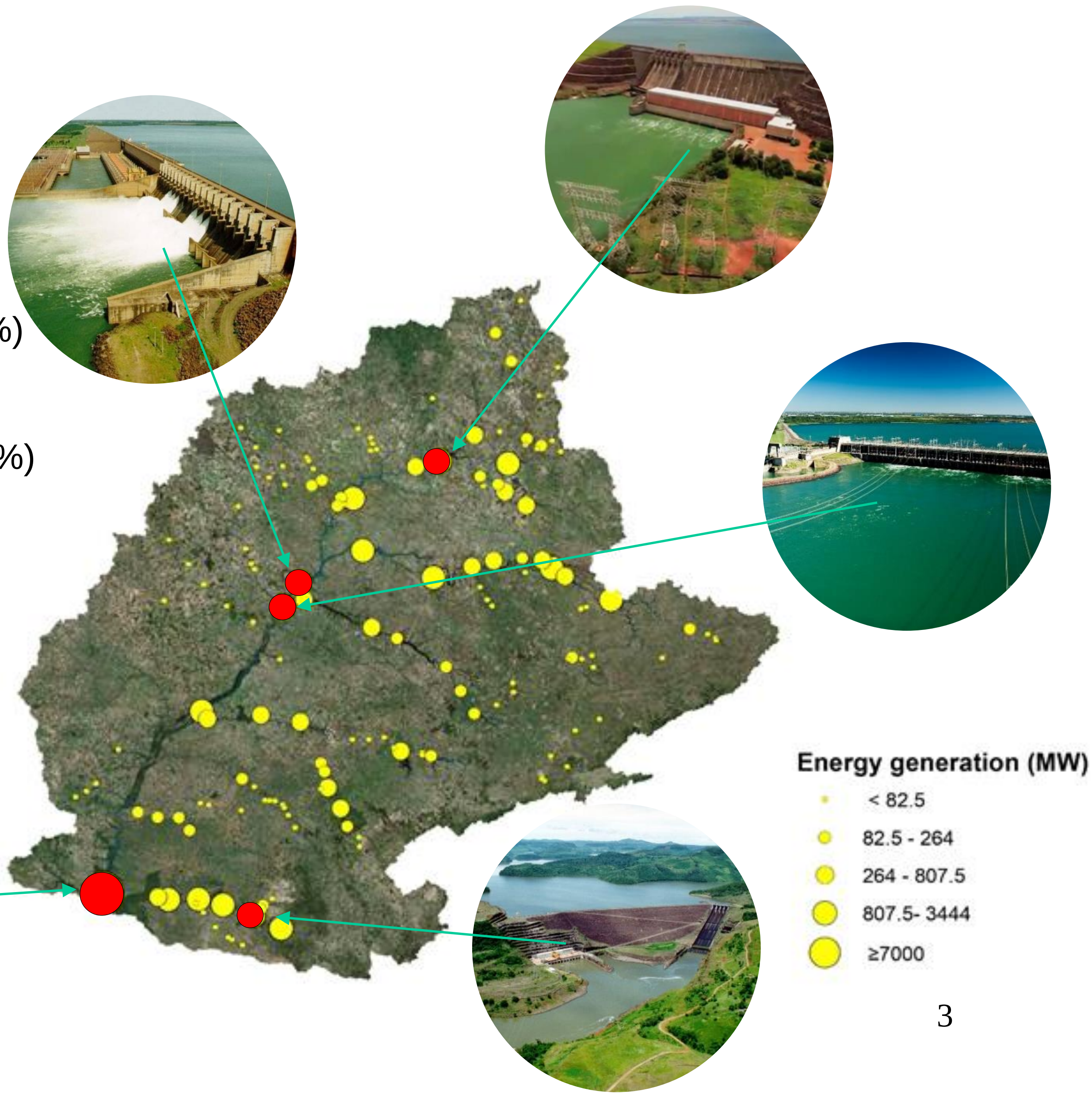
Importance of the Upper Paraná River Basin:

- 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%

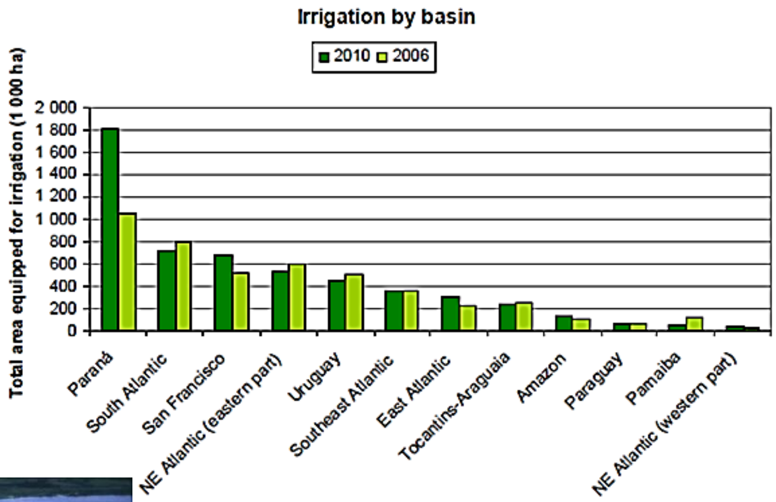
✓**National consumption:** 30%



Importance of the Upper Paraná River Basin:

- **Public and industrial supply**

- **Agriculture livestock development**

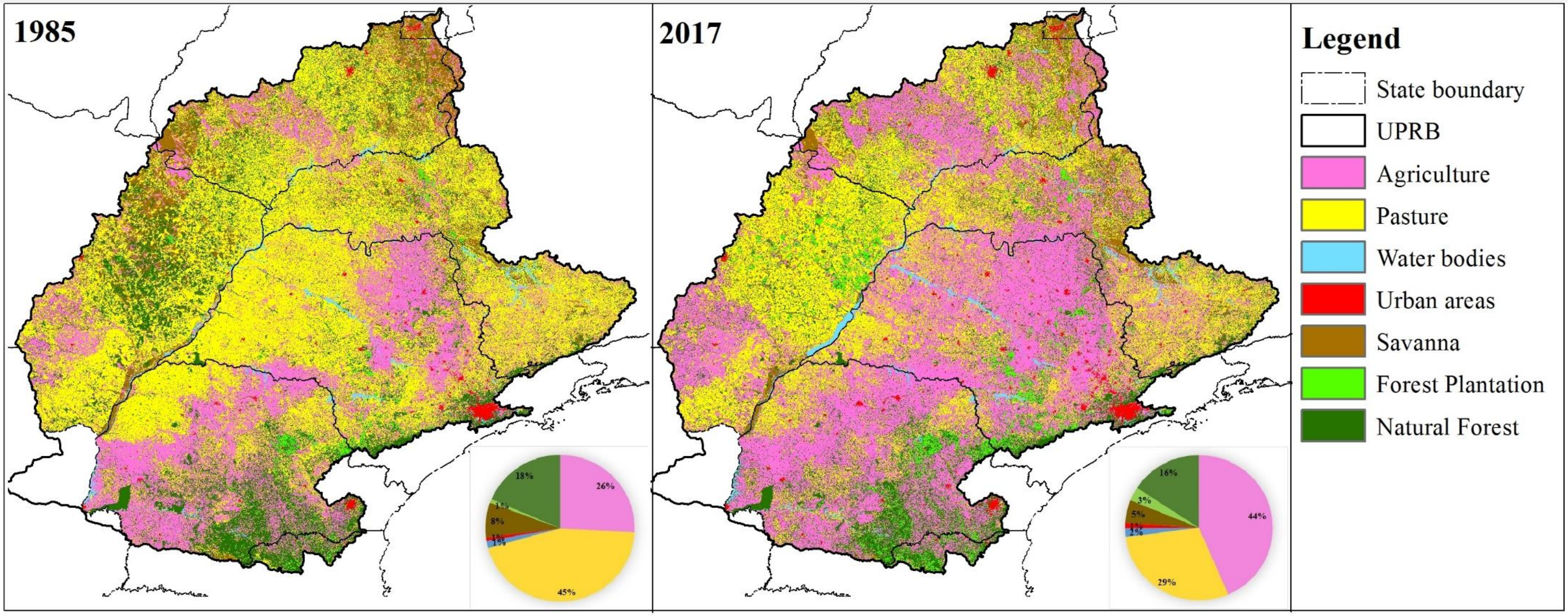


Source: FAO's global water information system - Land and Water Division

- **Water transportation**

Some features of UPRB

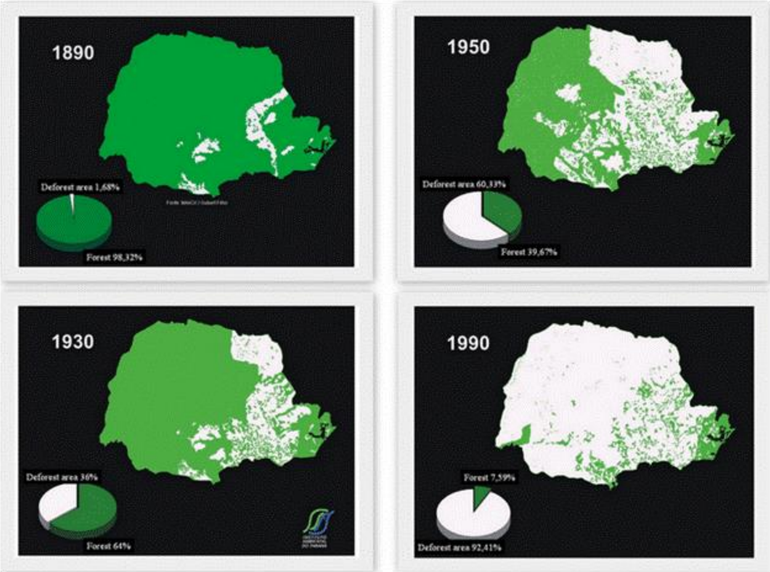
- In the last 30 years, natural areas have declined more than 40%, occupying now around 20% of the basin.
- Areas of agriculture and urban infrastructure grew respectively 63 and 62%.



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);



89% of the primitive forest (1.500.000 km^2) has been deforested

- **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).

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 Ortogonal Function - SON

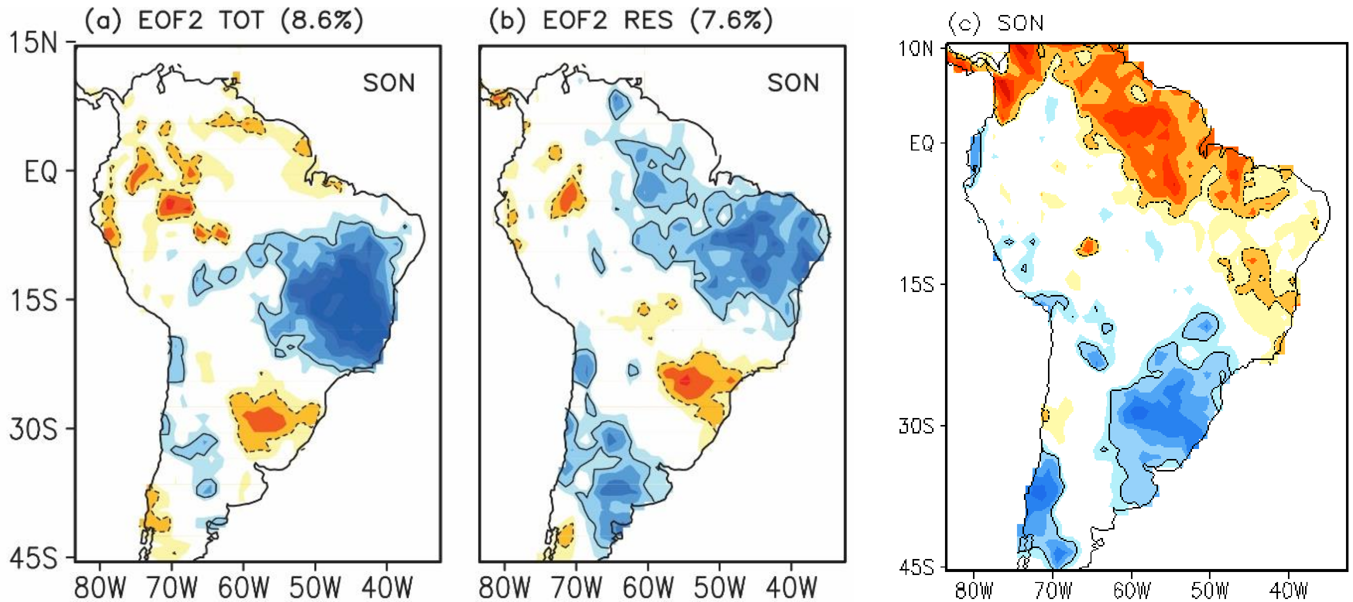


Figura 13: Modos de variabilidade interanual para a precipitação do trimestre de SON para o período 1970-2013: (a) EOF1 TOT; (b) EOF1 RES.

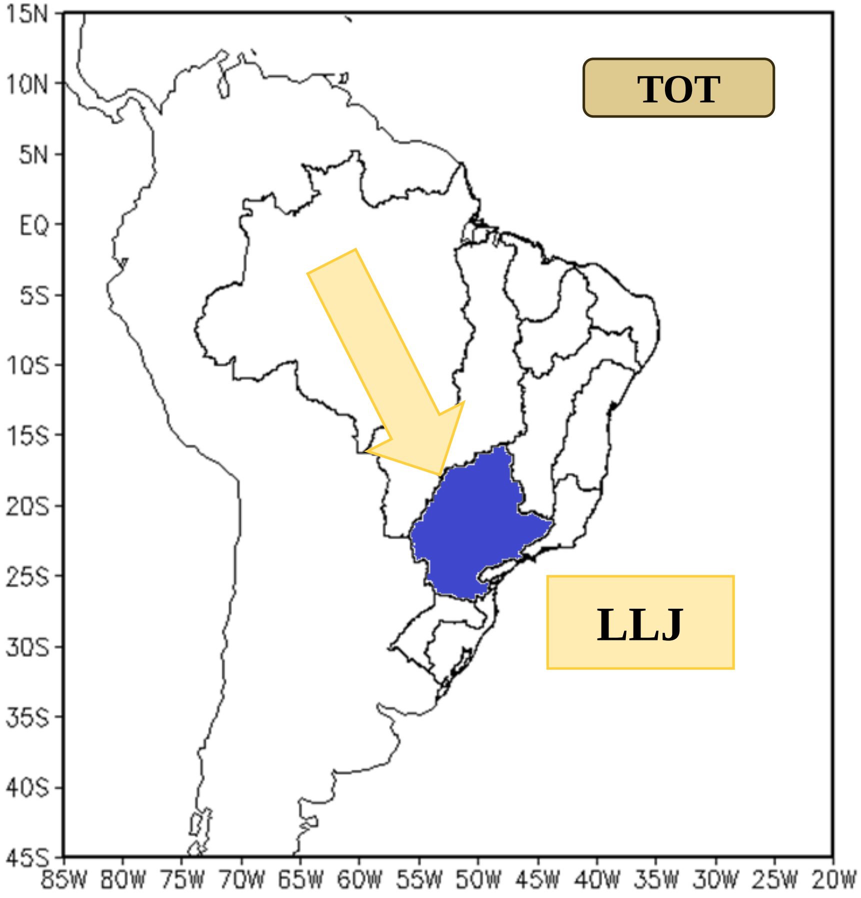
		CP2 TOT	r
SON	ININO 3.4	4,96%	-0,22
	CP2 RES	15,31%	0,39

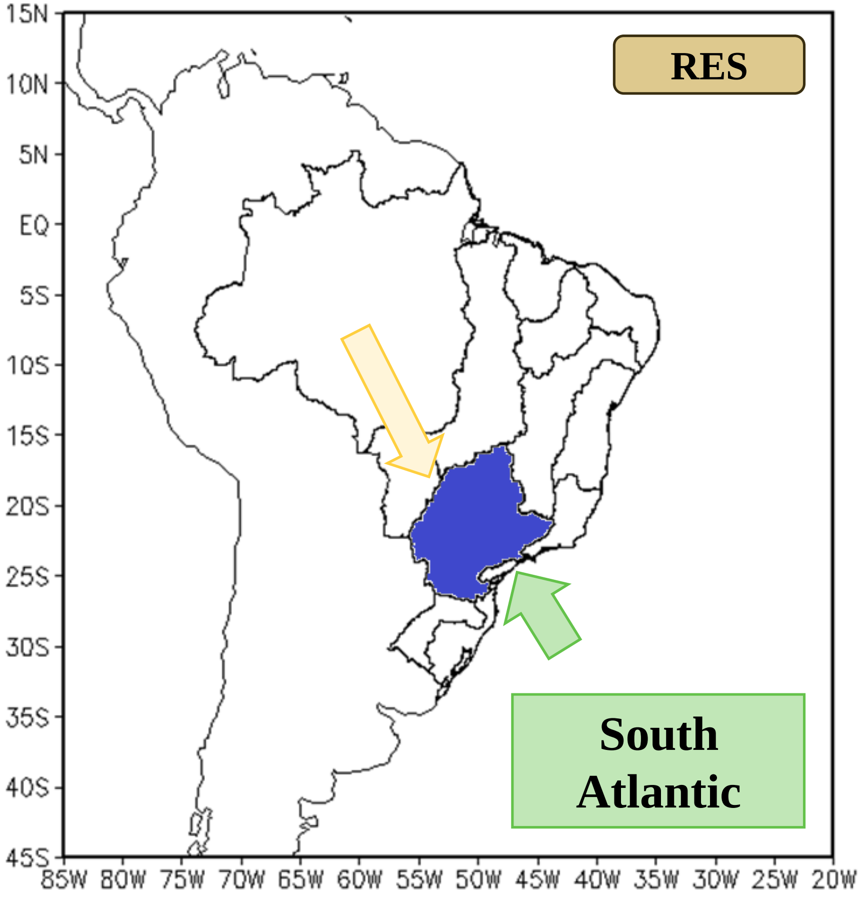
Percentage represents the portion of the variability explained by ENSO.
For EOF2 - ENOS explains only 5% of variability
Higher variability is explained by the non-ENSO component.

Contributions from Itamara Souza

Main Results

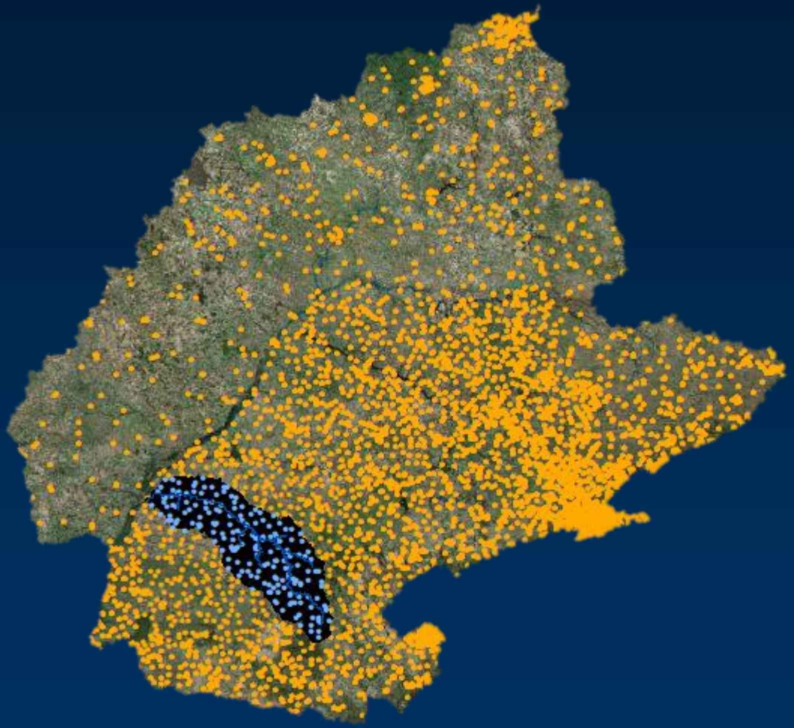
Larger Discharges





Effects of Data Density

Study Area



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

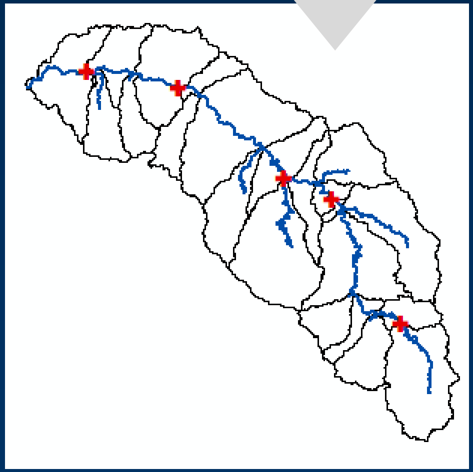
Contributions from Thais Fujita

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 | Dceclivity | Land Use

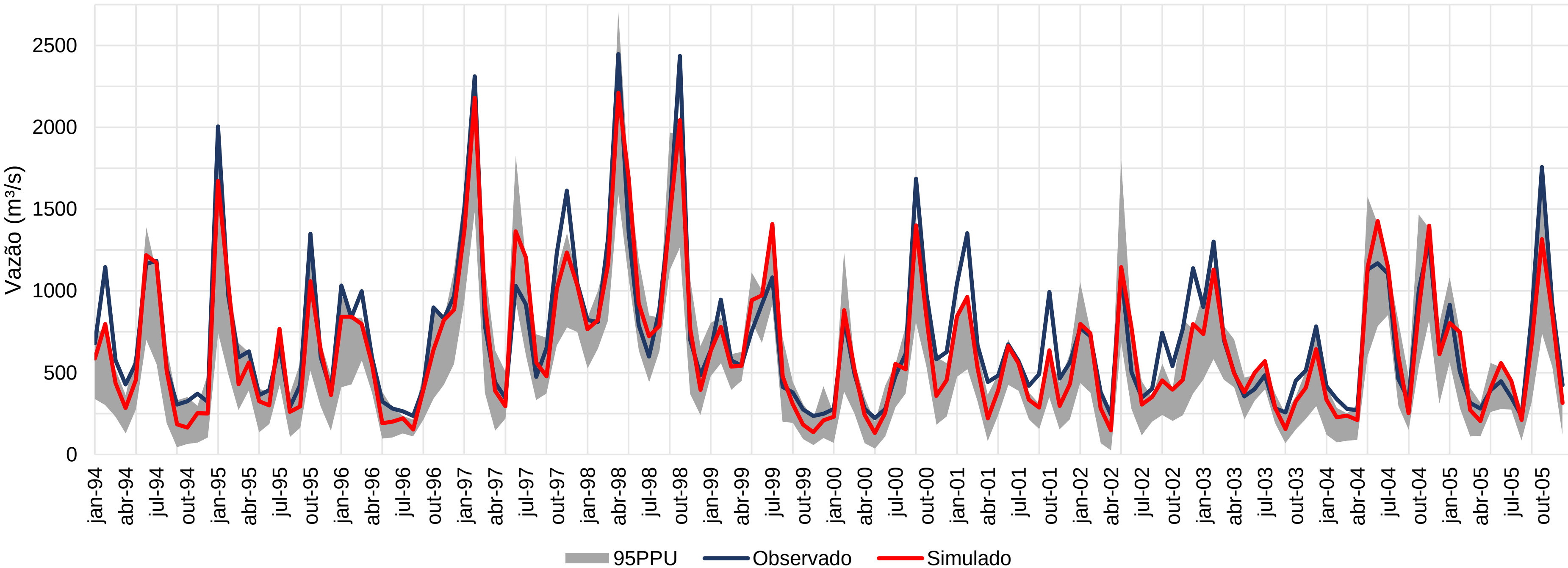


SWAT
Soil & Water Assessment Tool

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

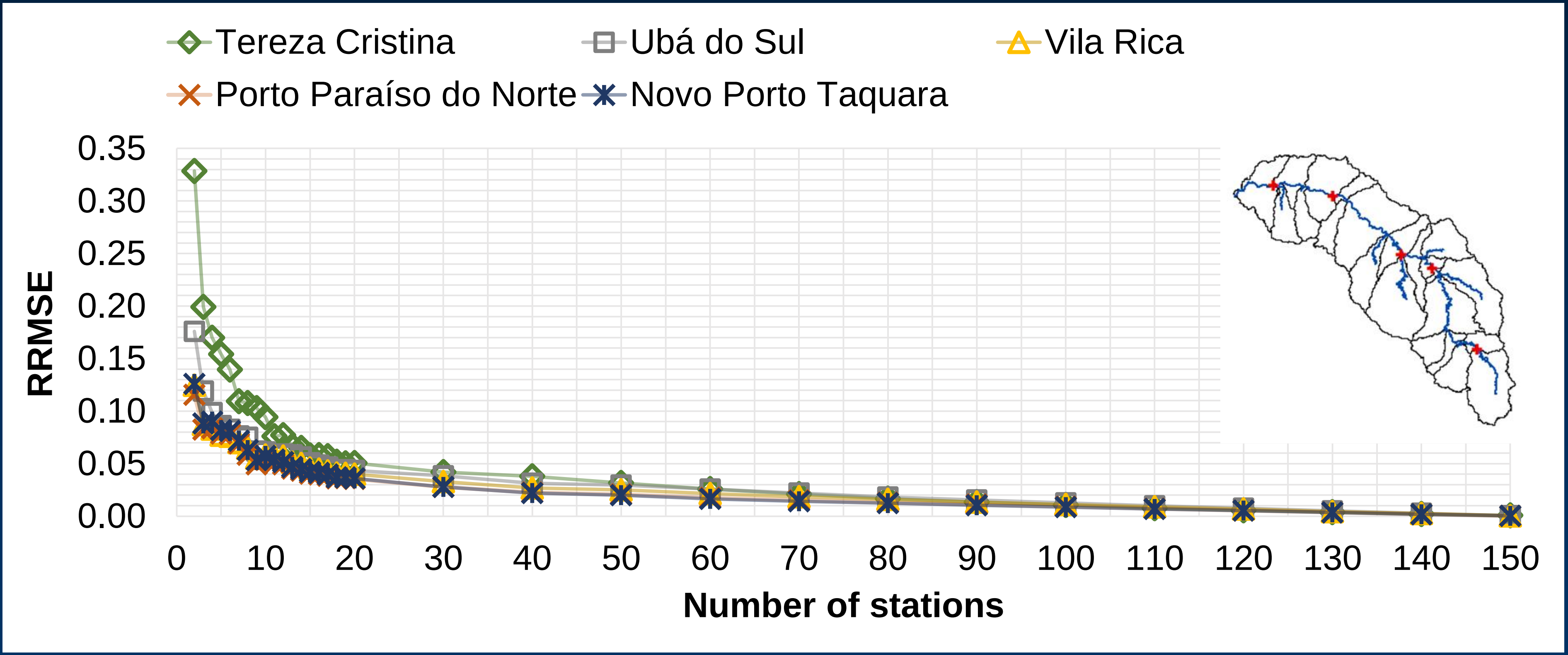
- **“Novo Porto Taquara” Station:**
  - 83% of the observed monthly flow behavior was captured by the model.
  - The Nash-Sutcliffe efficiency index for the simulation was 0.87 (Very Good).

Flow	
Observed	Simulated
717,88 m³/s	655,04 m³/s



Station density evaluation by flow response:

- ✓ Simulation quality increases with increasing rainfall density

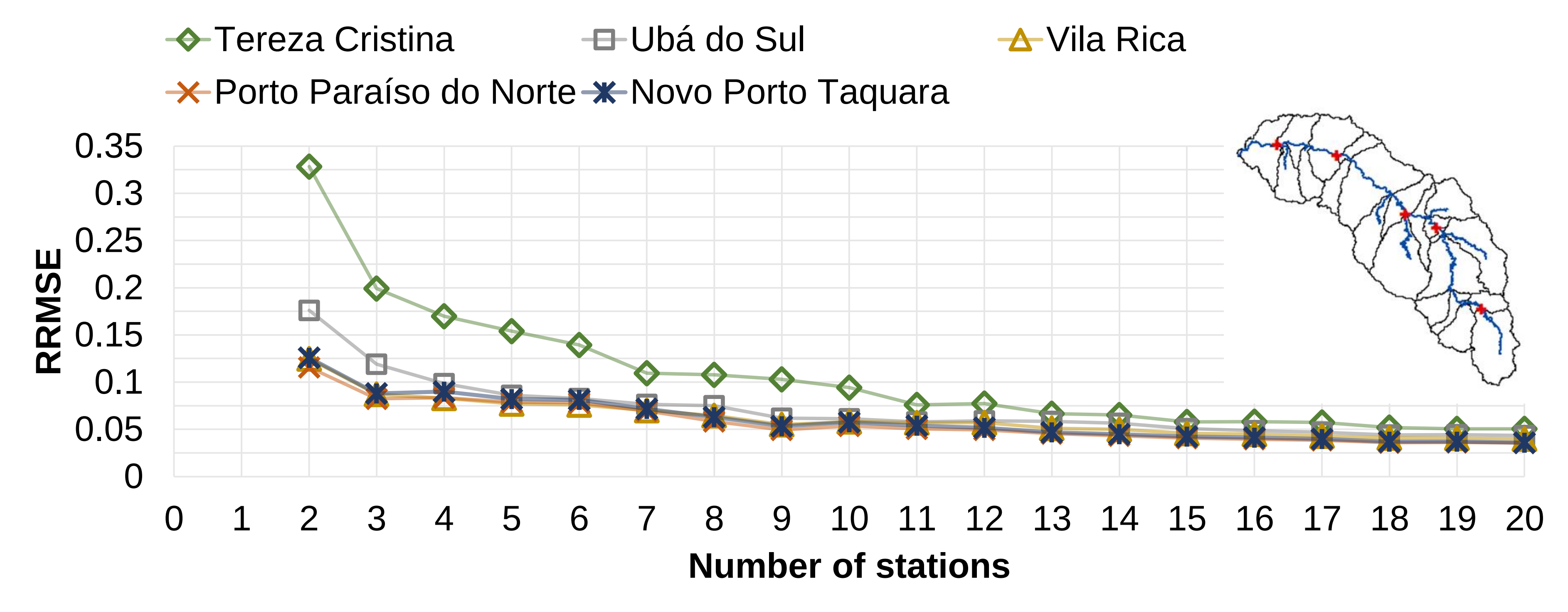


RRMSE (Relative Root Mean Square Error - from zero to infinity, where zero indicates no error, and full similarity to the control run).

Soil & Water Assessment Tool

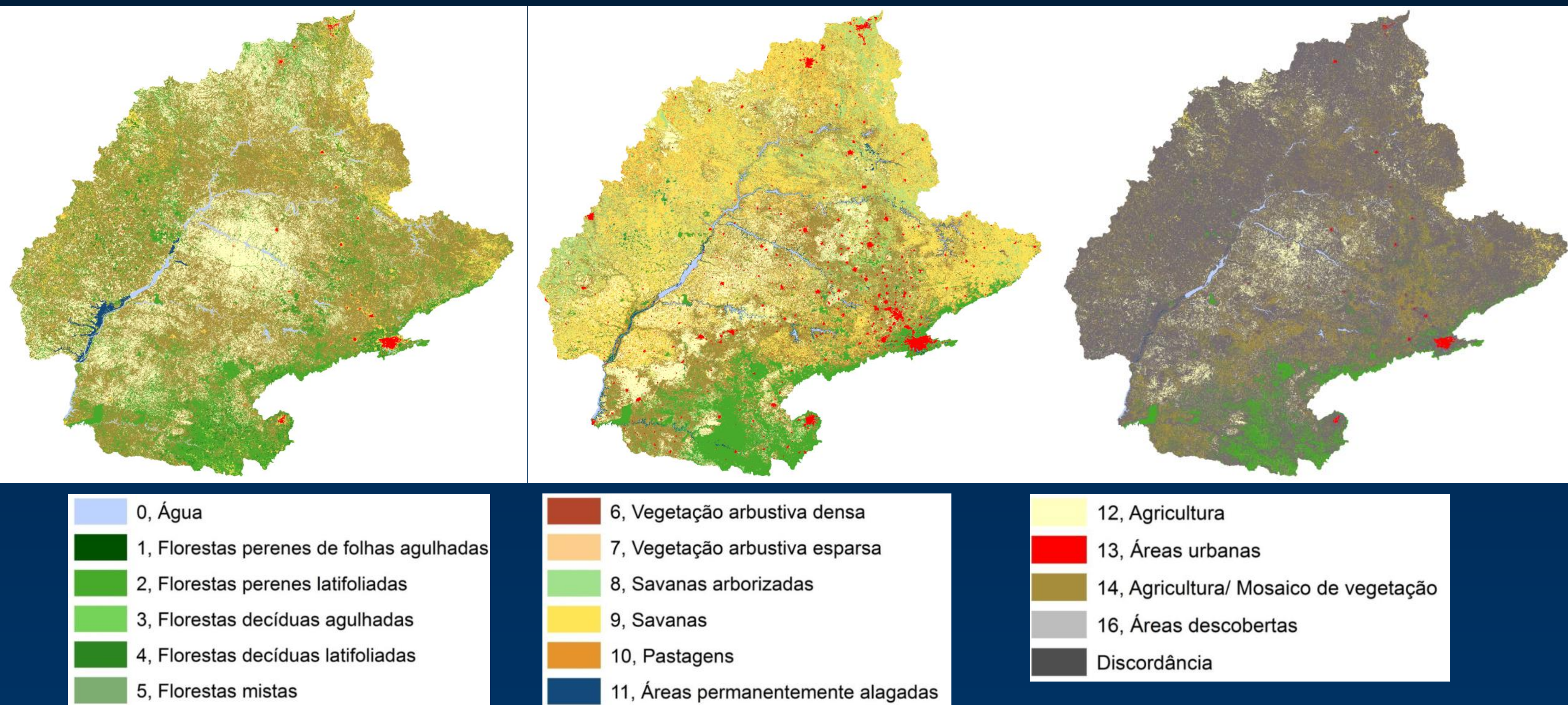
Station density evaluation by flow response:

20	15	14	11	12
744 km²	824 km²	831 km²	923 km²	870 km²



Land Use Identification Issues

Main Problem

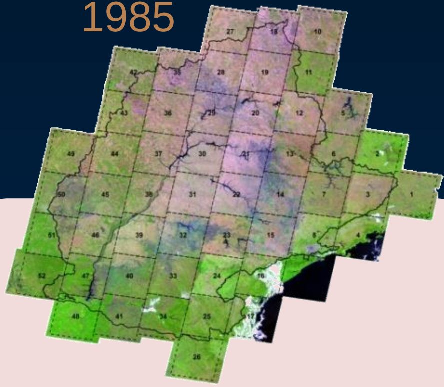


Agreement between global land use products for HPRB (GLOBCOVER versus MODIS).

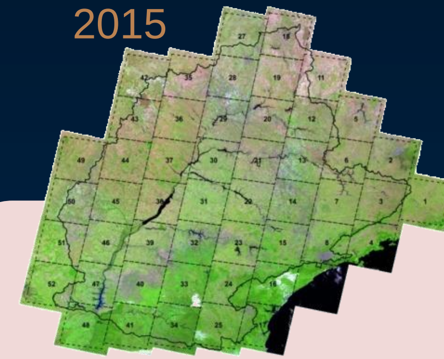
Contributions from Anderson Rudke

Database

1985

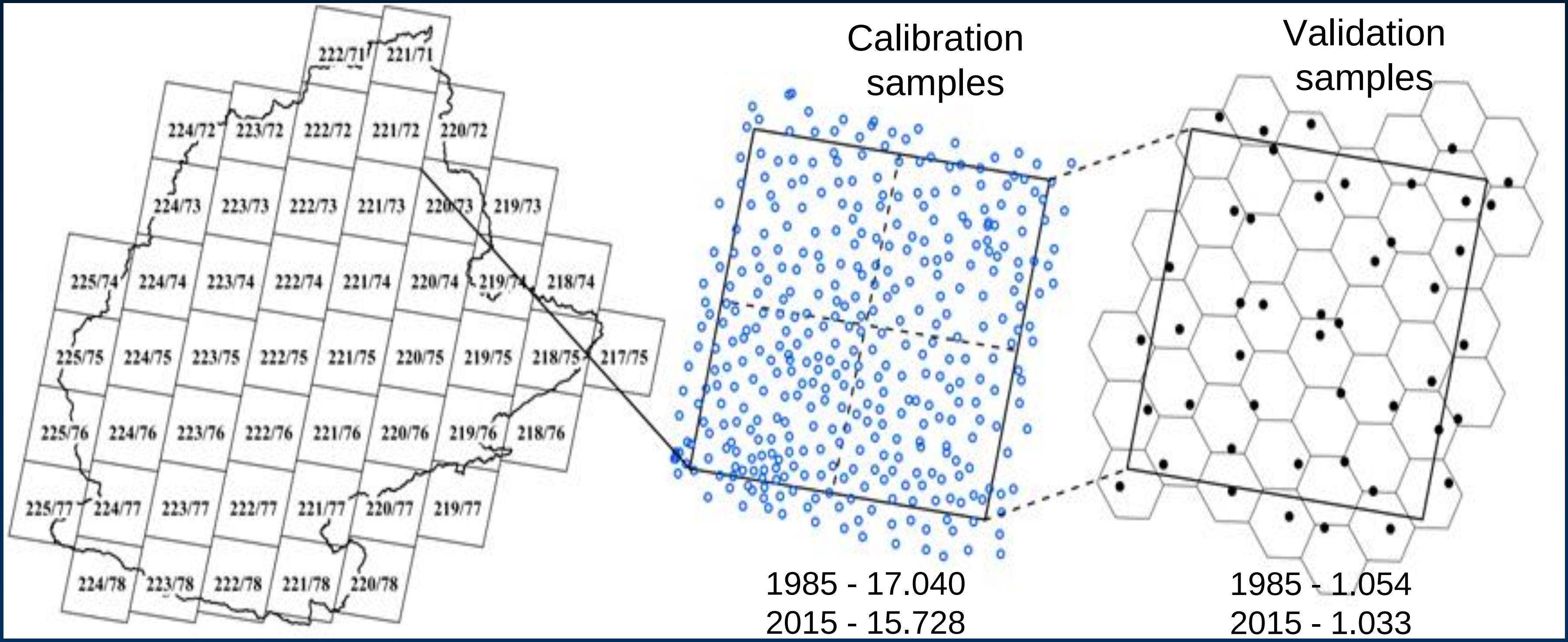


2015

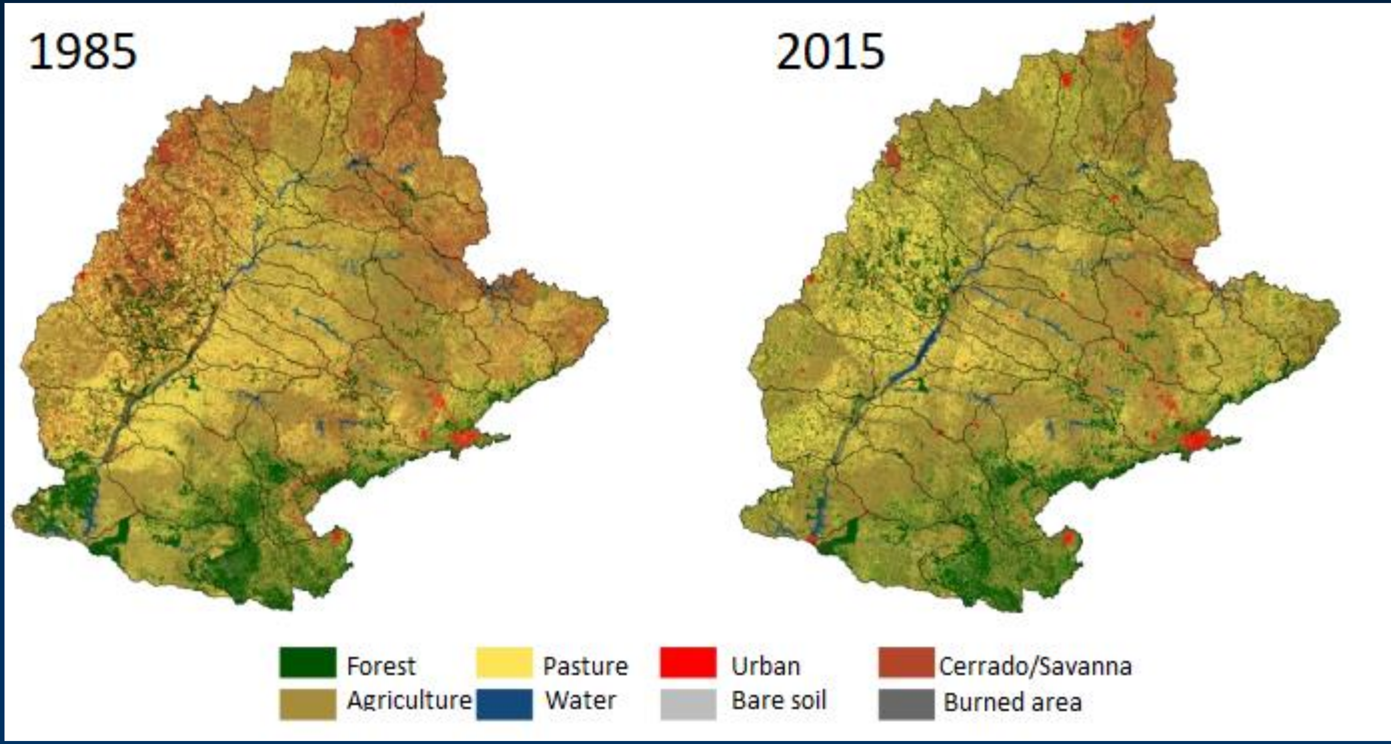


1985		2015
Landsat 5	- Satellite -	Landsat 8
30 m	- Spatial resolution	30 m
52 (170x183km)	- Nº of scenes -	50 (185x185km)

Calibration and Validation samples



New Land Use files

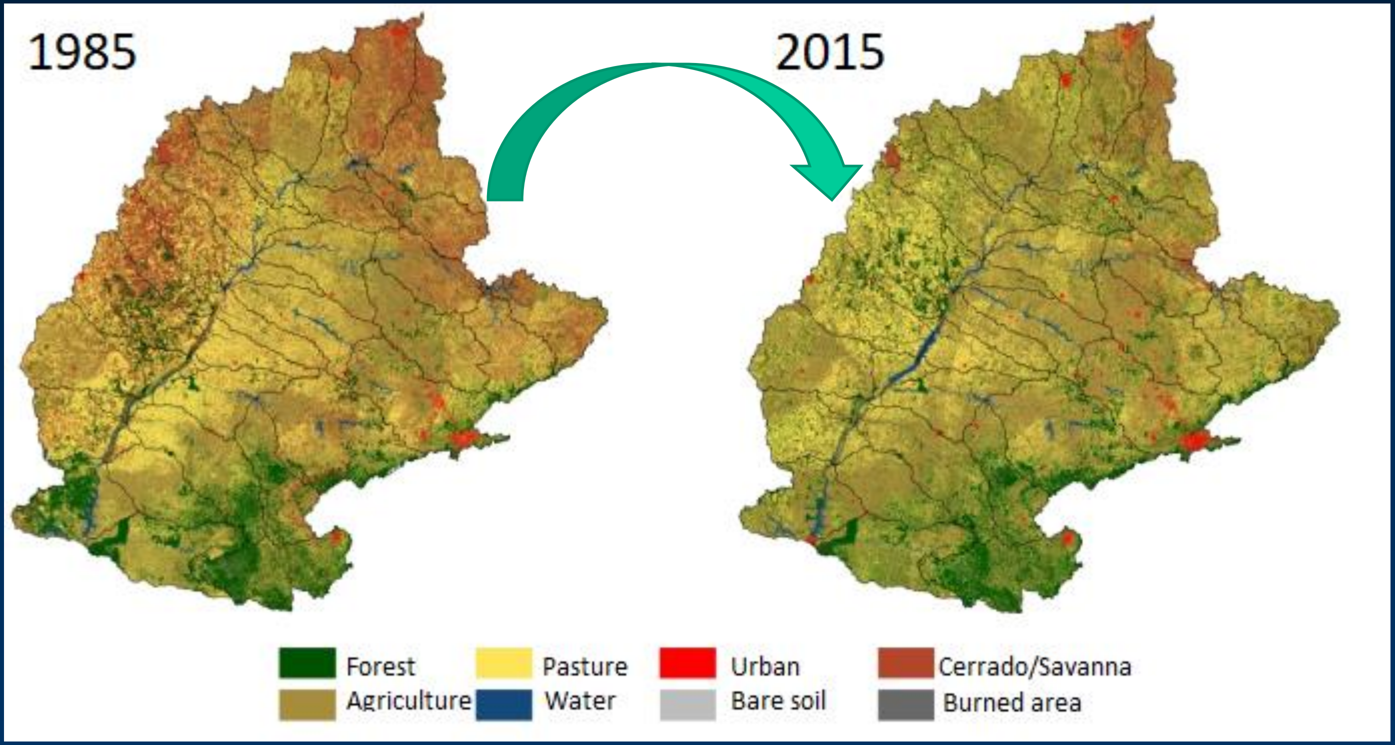


Classification accuracy

- 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%

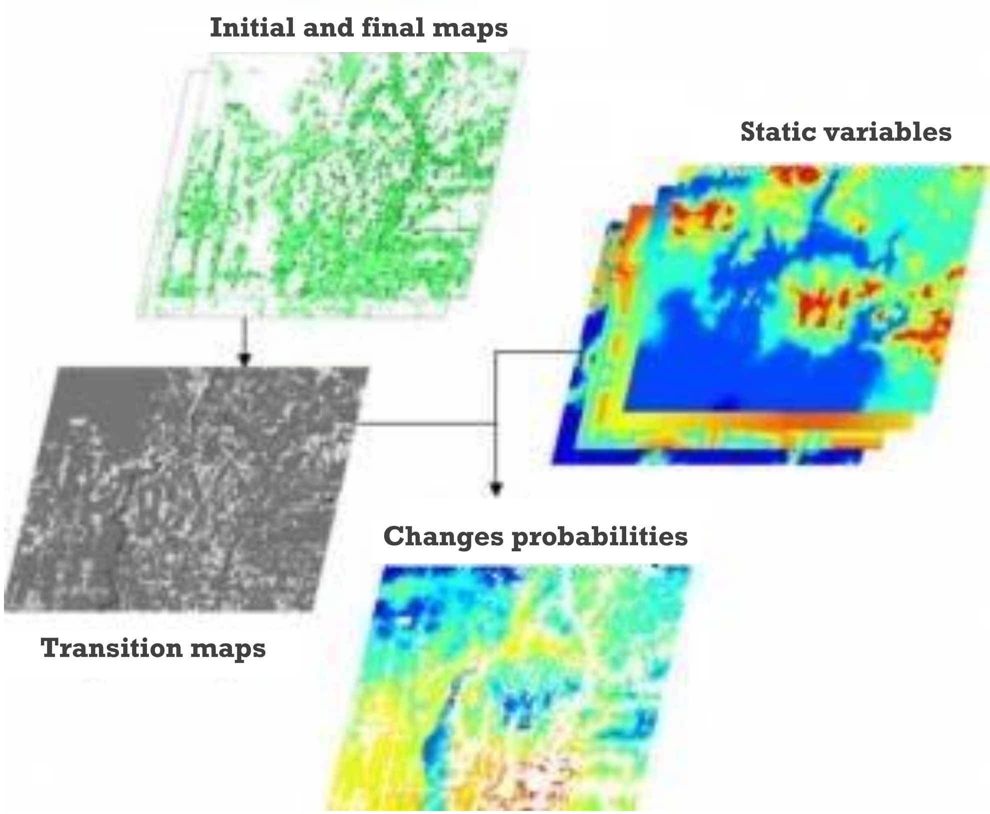
Land Use Variability and Changes

How to integrate the models considering LUCL Evolution?



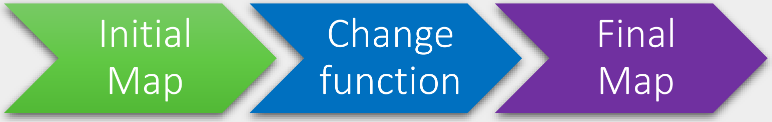
Contributions from Carolyne Machado

The Solution: Spatial Dynamic Modeling

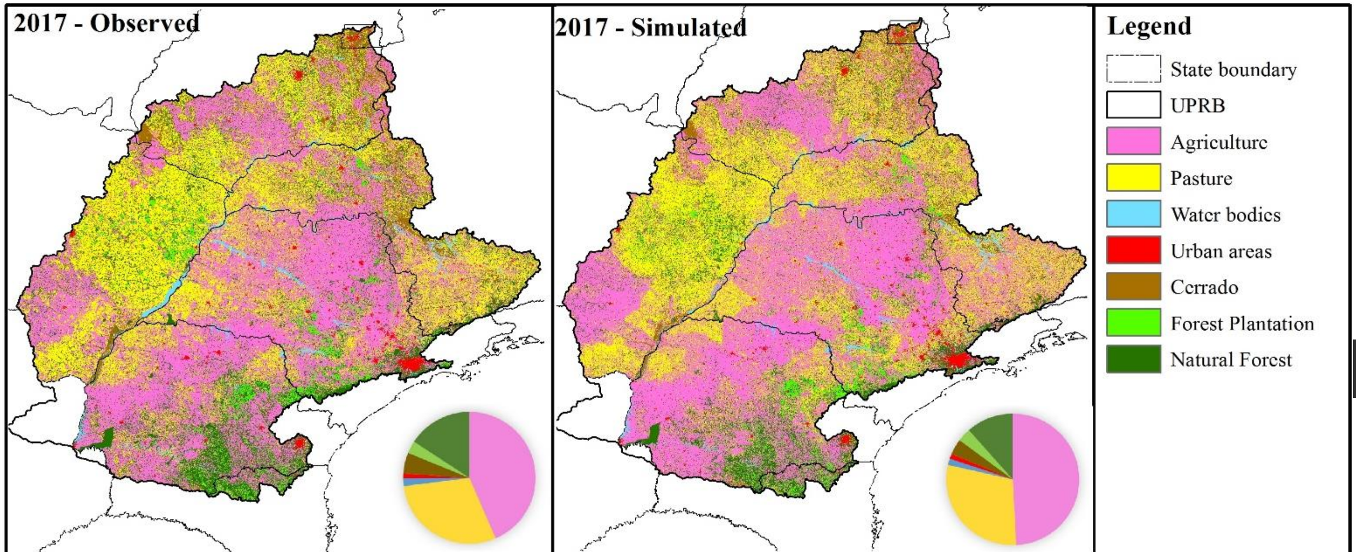


- Population;
- GDP;
- Roads;
- Agriculture.

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

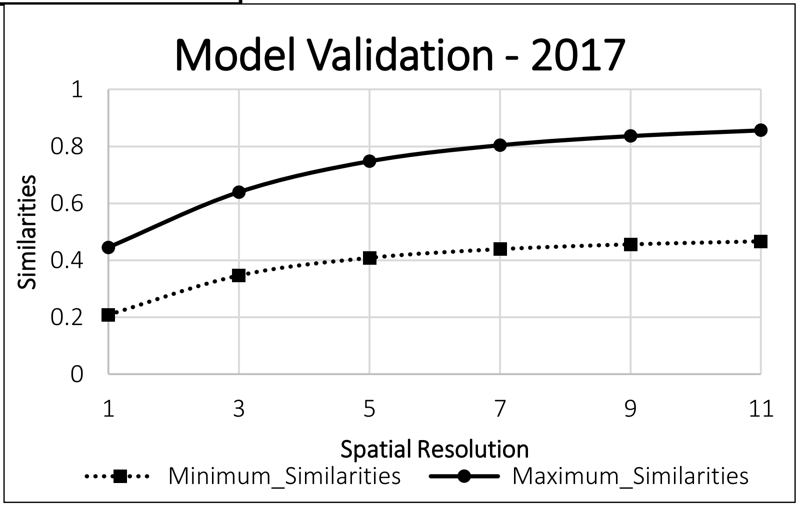


Model Validation

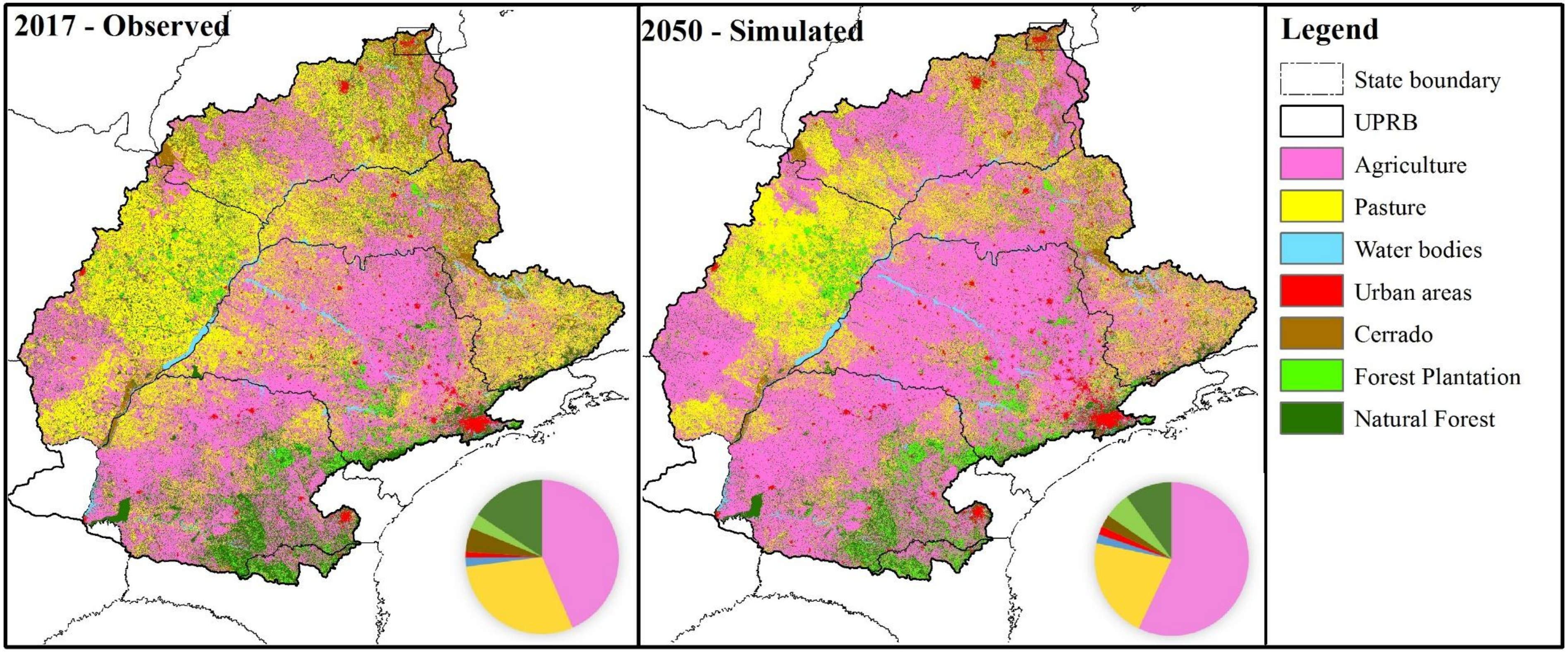


Global accuracy → 57.7 %

		Simulated							
		Agric.	Past.	Water	Urban	Cerra.	P. For.	N. For.	Total O.
Observed	Agric.	**30.64**	8.96	0.09	0.28	0.68	0.86	2.01	**43.52**
	Past.	11.04	**15.26**	0.04	0.09	0.87	0.76	1.41	**29.46**
	Water	0.26	0.12	**1.36**	0.00	0.05	0.00	0.09	**1.89**
	Urban	0.21	0.15	0.00	**0.79**	0.02	0.00	0.03	**1.20**
	Cerra.	1.41	1.46	0.02	0.02	**1.71**	0.11	0.39	**5.11**
	P. For.	0.77	0.83	0.00	0.00	0.09	**0.87**	0.51	**3.06**
	N. For.	4.86	2.60	0.02	0.05	0.46	0.70	**7.08**	**15.76**
Total S.		**49.19**	**29.37**	**1.54**	**1.23**	**3.86**	**3.30**	**11.51**	**100.00**



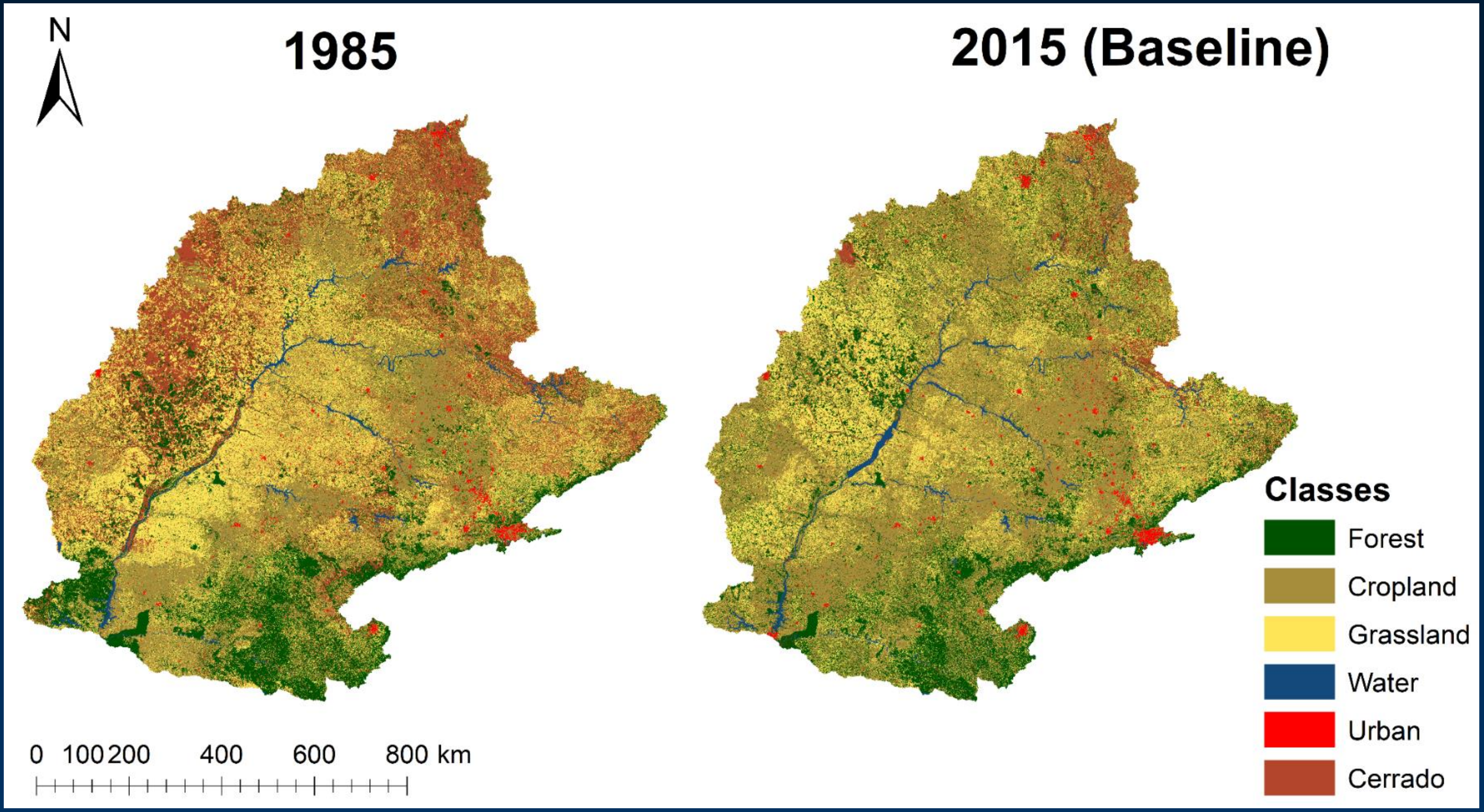
Preliminary Results



<u>Next steps</u>→ Create scenarios of LULC for BRAMS (Brazilian developments on the Regional Atmospheric Modelling System)

Hydrologic impacts of land use change in the UPRB

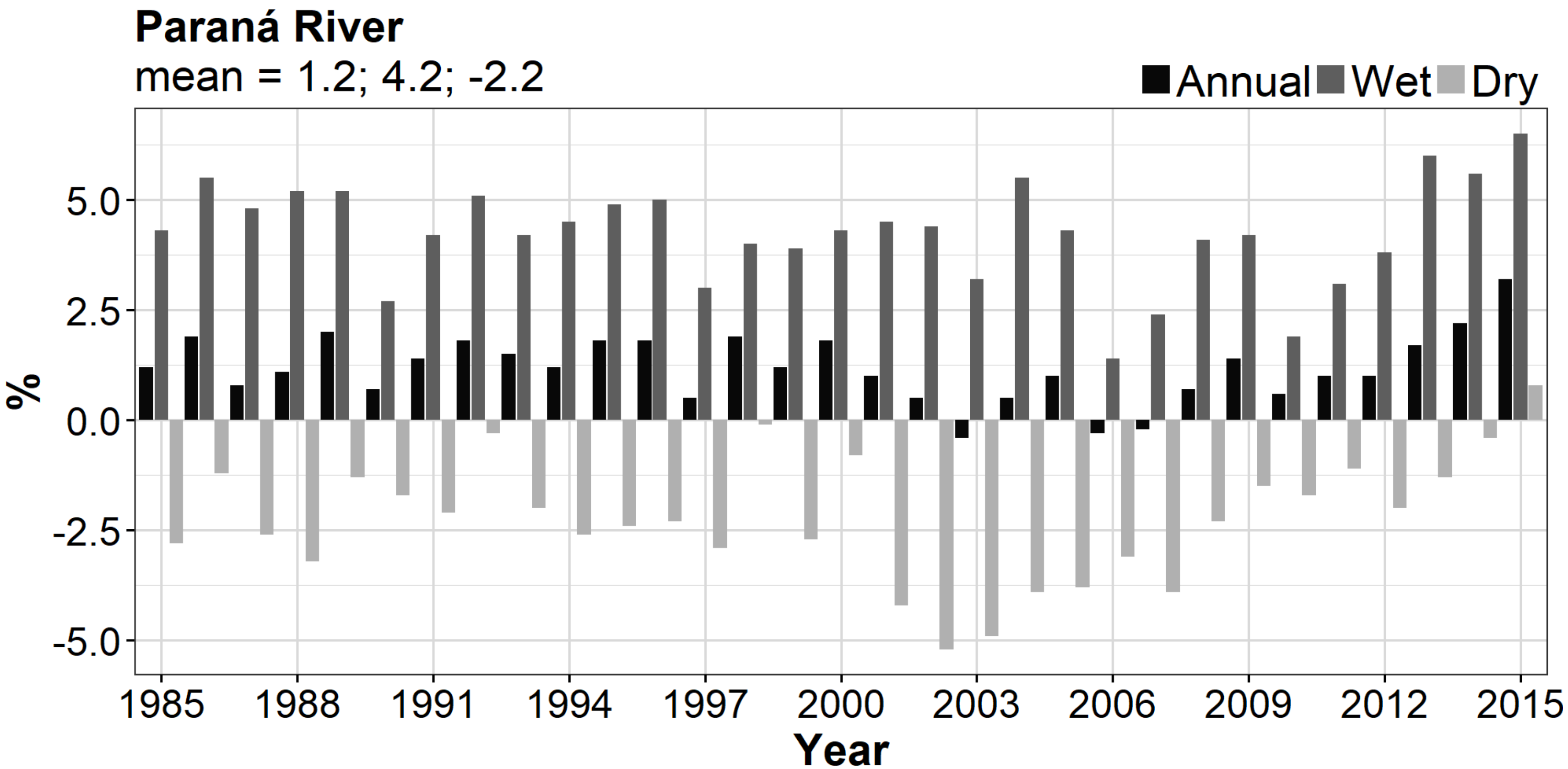
Scenarios



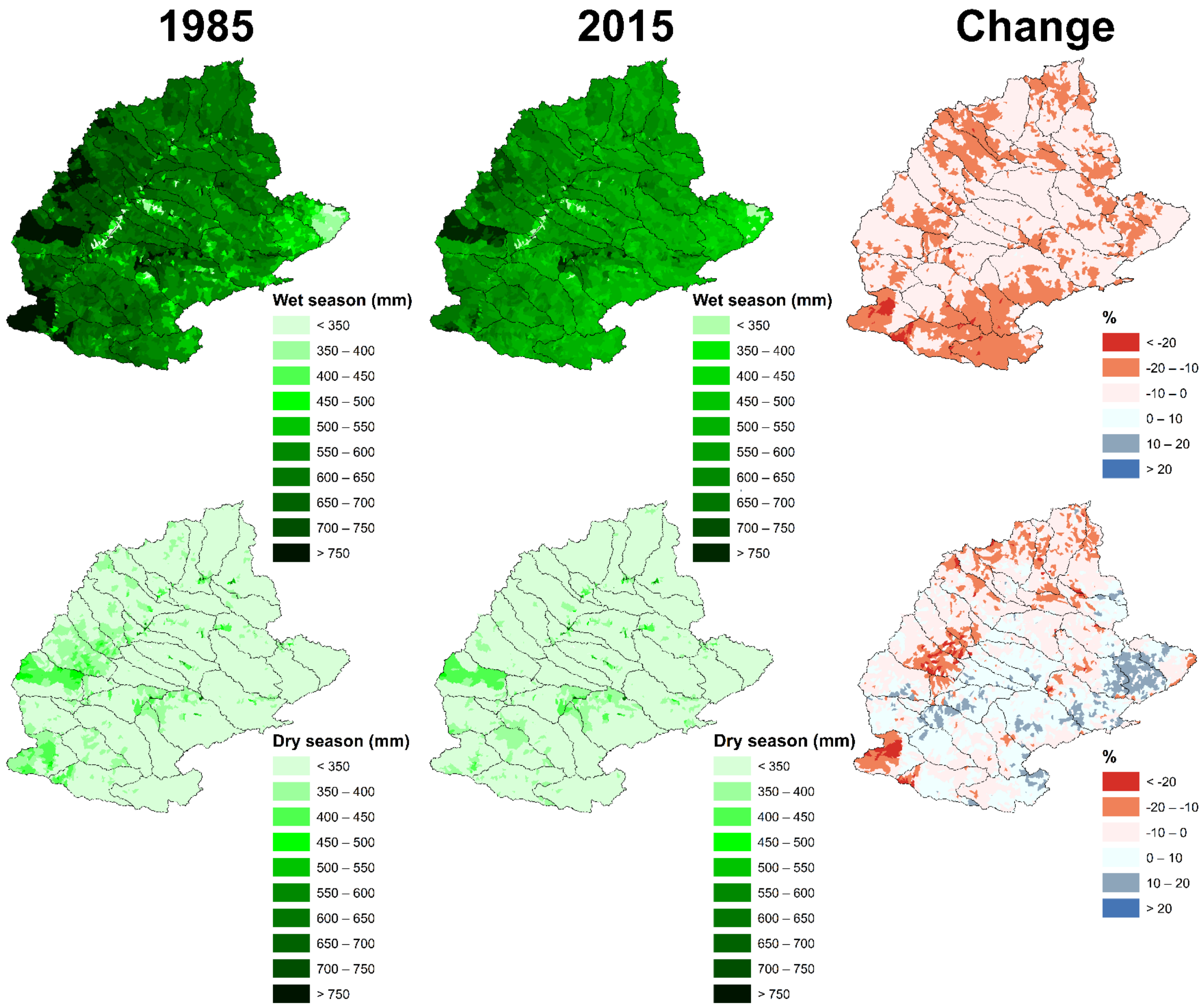
Contributions from Sameh Rafee

Source: Rudke (2018).

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



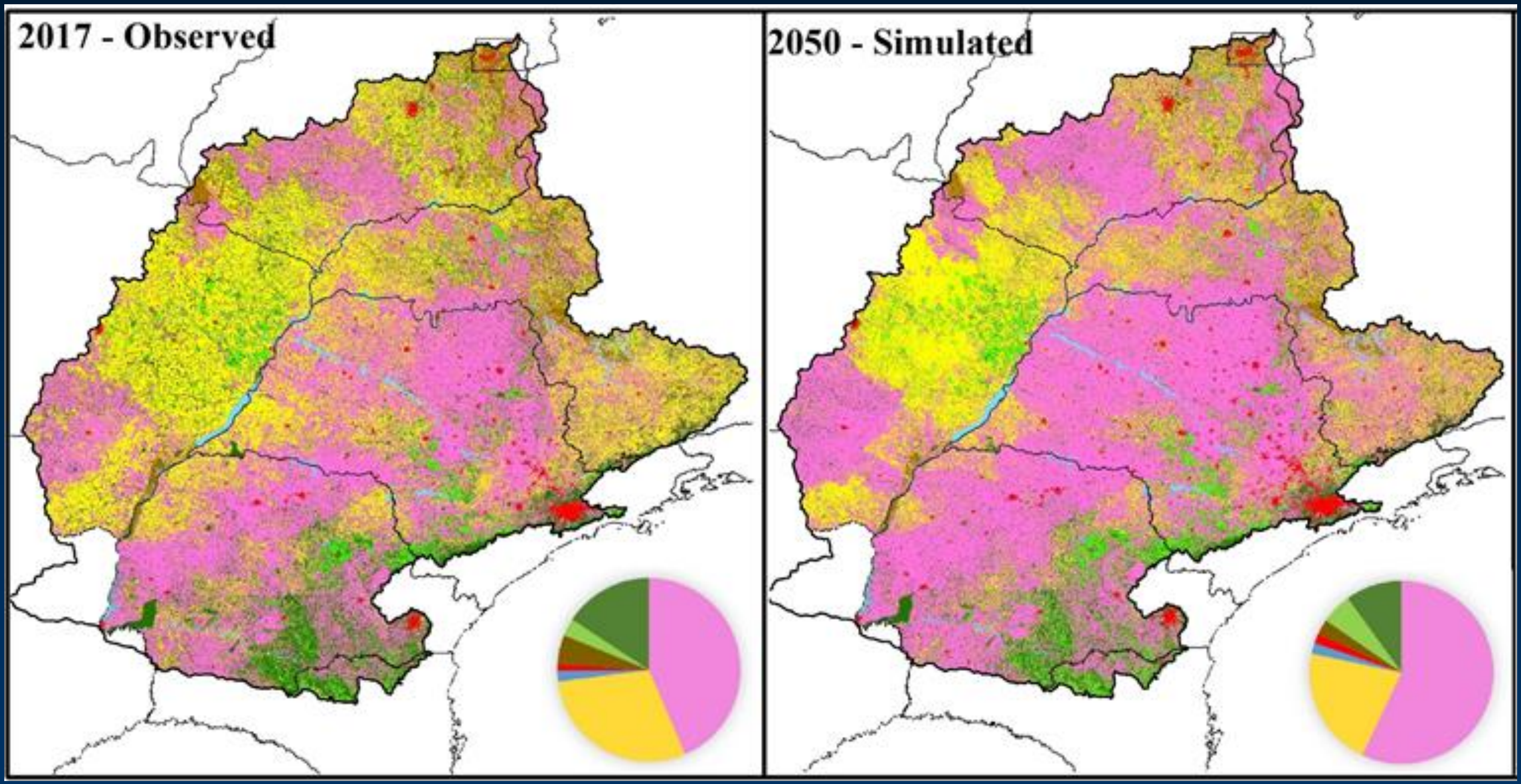
Green water flow
(Evapotranspiration)



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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