



The hydrological environmental services of Permanent Preservation Areas (PPA): a case study with numerical modeling in the Ribeirão das Posses watershed

Jonathan Mota da Silva, Humberto Rocha, Sandra Saad,
Emilia Brasília, Gré Lobo

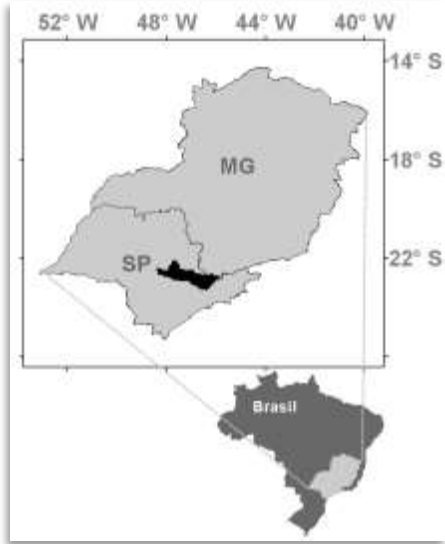


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Introduction

Piracicaba River Basin

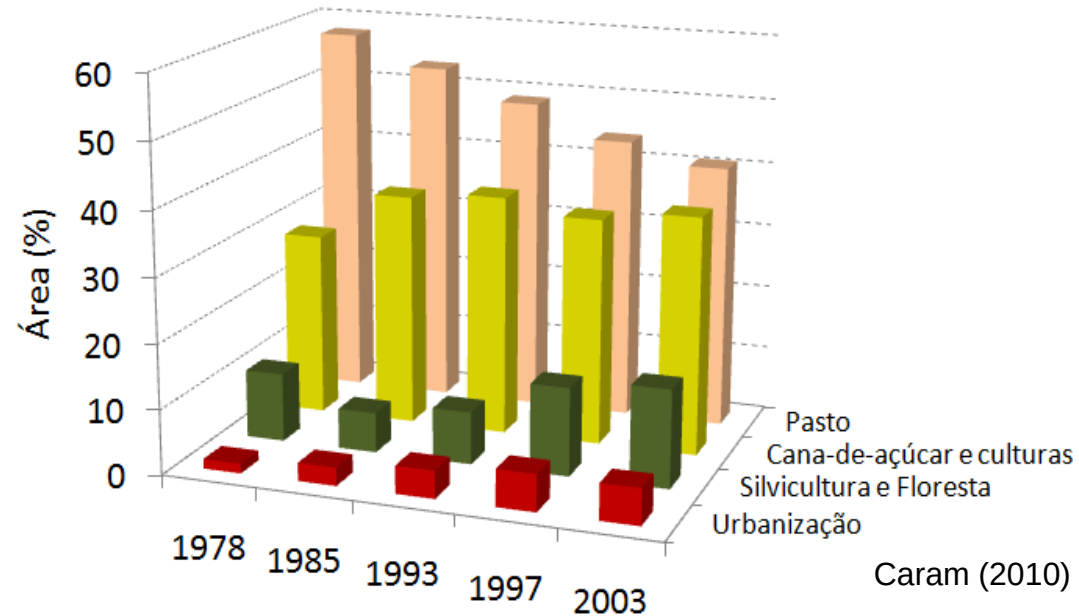


Main water producer of São Paulo metropolitan region (~50% do abastecimento)

Flood in Atibaia City (2010)



Land use change in Piracicaba River Basin



Water shortage in 2014



Introduction: How to coexist with land change pressure?

► With environmental conservation. In Brazil, it is helped by the Forest Act

- Legislation for the protection of natural vegetation, including the Permanent Protection Areas (PPA)

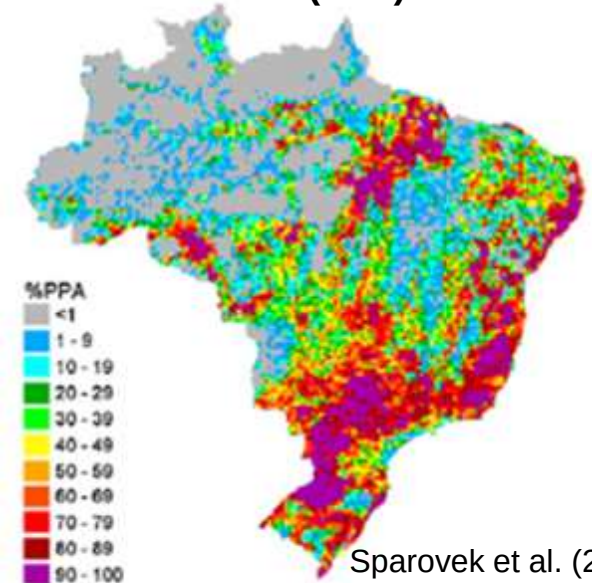
Limits of riparian PPAs



► The Forest Act Challenge

PPA's deficit

- deficit: 44 Mha (43%)



Sparovek et al. (2012)

Permanent Preservation Areas

► Riparian PPAs maintain:

- Streamflow regulation
- Encourage infiltration
- Reduce erosion

This set of benefits, among others, are the Hydrological Environmental Services (HES)

The effects of the extent of riparian vegetation vary from basin to basin. What are the effects of varying the extent of these ranges in HES?

Study area

► Ribeirão das Posses Watershed

Drainage area ~ 12 km²

Rural watershed – smallholder agriculture

Payments for Env. Services (PES) -

Conservador das Águas proj. (ANA ,TNC and Extrema (MG) City Hall)

► DEM

(source: ASTER resampled to 15 m)

Elevation ~ 950-1450 m

16% watershed with slope > 25°

► Hydroclimatology

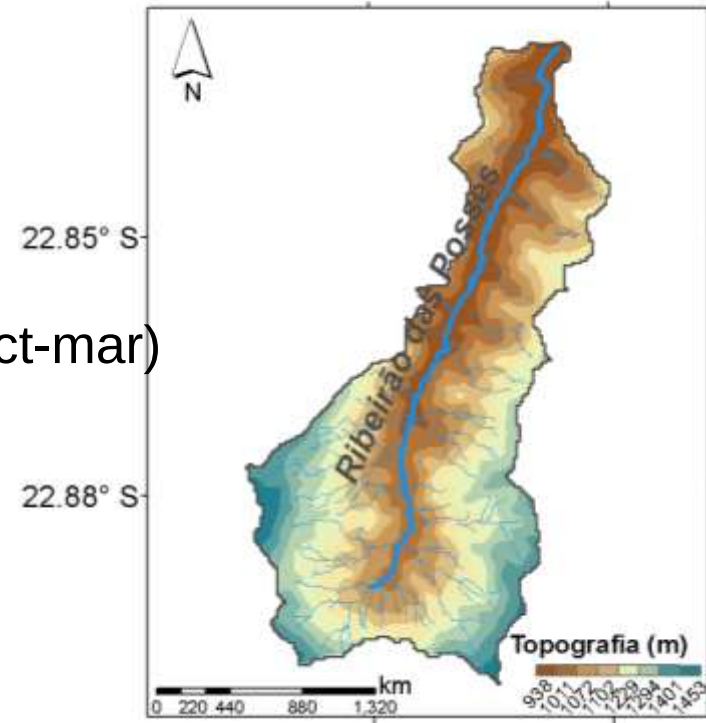
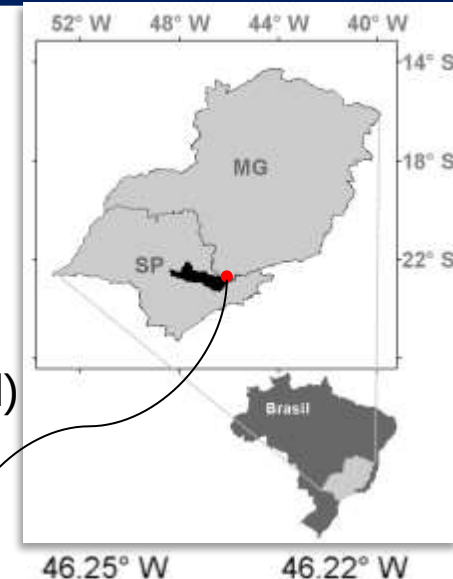
Annual rainfall: 1600 mm (highest occurrences oct-mar)

Mean Streamflow: 250 litros s⁻¹

(~ 1% of streamflow arriving at Resev. Jaguarí-Jacareí)

Mean Temperature: 14 °C (jun)

21°C (feb)



Input data

► Data from DEM

- rede de drenagem
- sub-bacias
- slope, channel width, channel depth, ...

► Land use

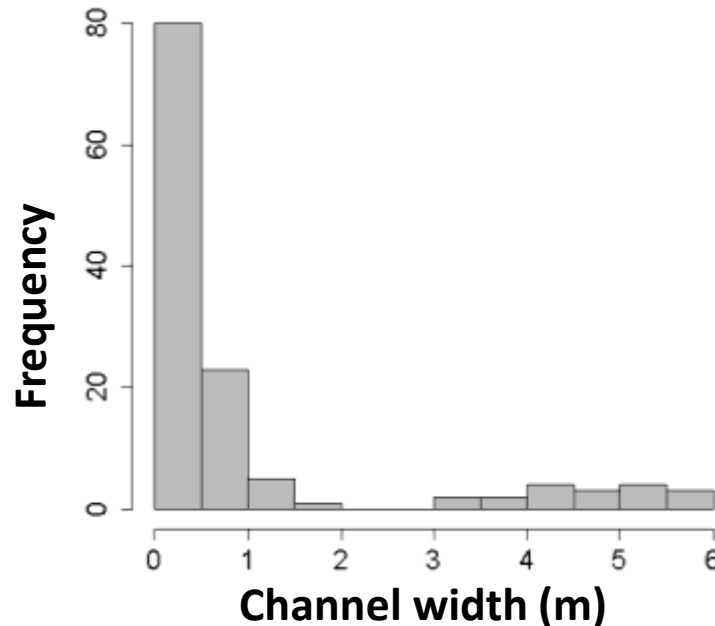
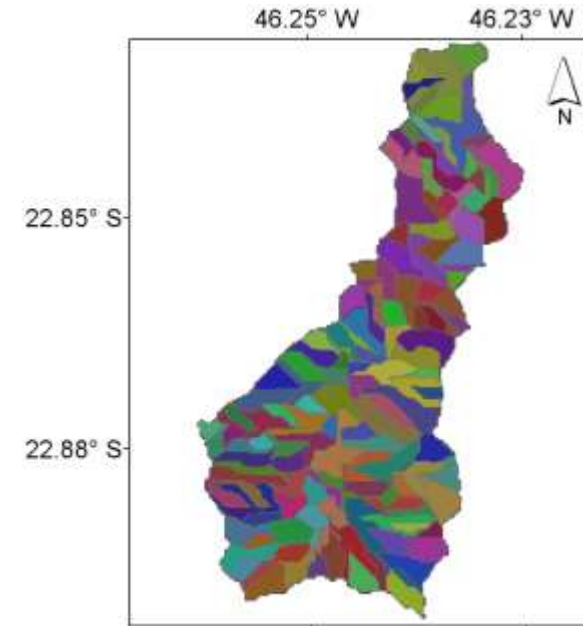
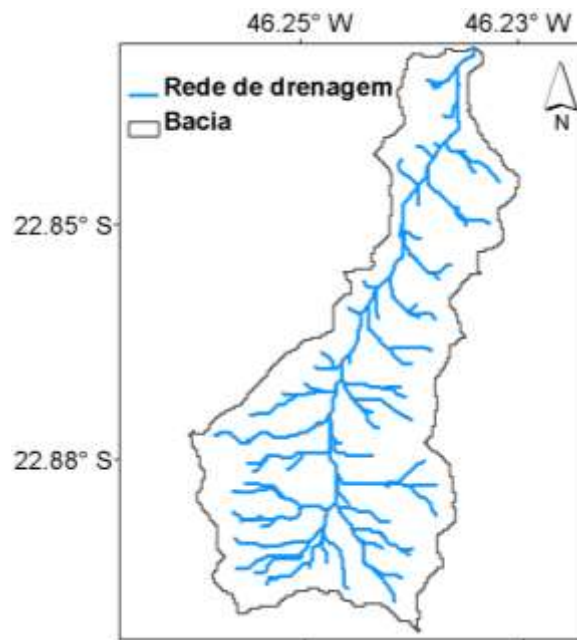
► Soil

- soil parameter:

- ✓ Saturated Hyd. Cond. (sol_k) – PTFs Saxton & Rawls (2006)
- ✓ Soil Properties – Soil Map
- ✓ Available Water Capacity (sol_awc) – Minasny & Hartemink (2011)

► Hidrometeorological

- Streamflow
- Rainfall
- Temp. Air, UR, Vel. Wind and Irrad. Solar
- Energy fluxes (H,LE), net radiation (Rn), ...



Input data

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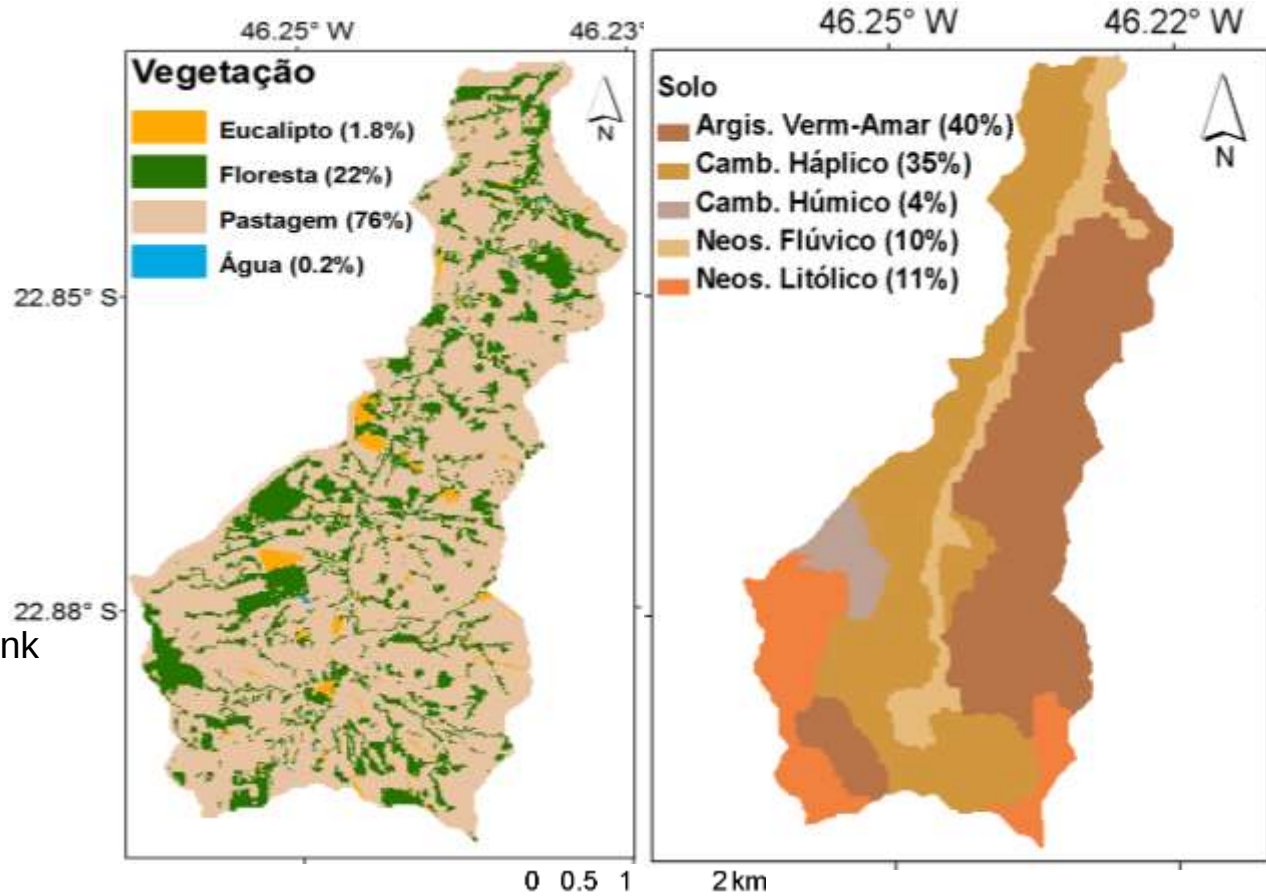
► Hidrometeorological

- Streamflow

- Rainfall

-Temp. Air, UR, Vel. Wind and Irrad. Solar

- Energy fluxes (H,LE), net radiation (Rn), ...



Adapted from Azevedo (2008):
20 m resolution

Adapted Azevedo (2008) and Calheiros
(2009): 1:5:10⁴ scale

Input data



► Land use

► Soil

- soil parameter:

- ✓ Saturated Hyd. Co
- PTFs Saxton & R
- ✓ Soil Properties –
- ✓ Available Water C
- (sol_awc) – Minas
- (2011)

► Hidrometeorological

- Streamflow

- Rainfall

-Temp. Air, UR, Vel. Wind and Irrad. Solar

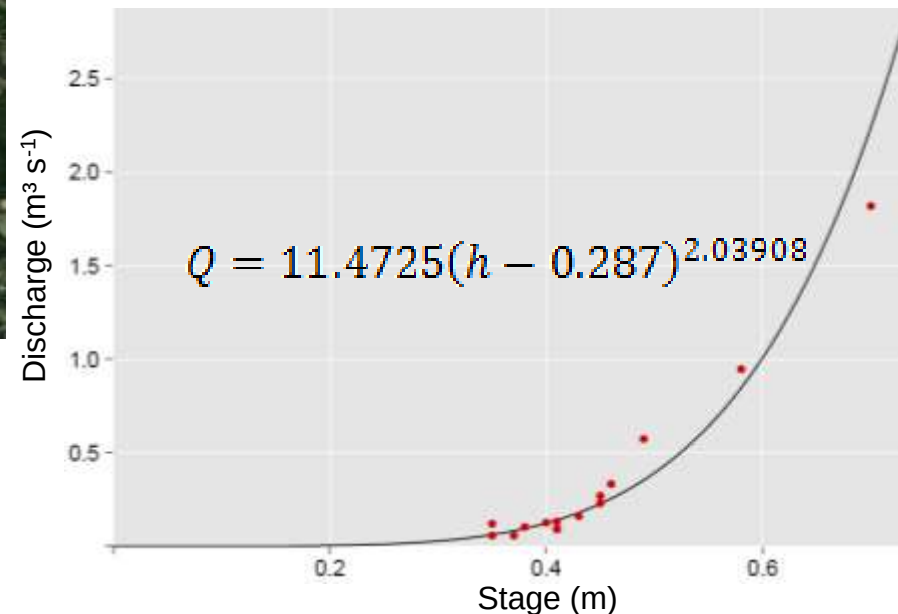
- Energy fluxes (H,LE), net radiation (Rn), ...

Daily Data

- Rainfall (source: ANA/CPRN)

-Temp. Air, RH, Vel. Wind e Irrad. Solar: Reanalysis (CFSR/NCEP/NOOA)

Stage-Discharge Rating Curve (Preliminary)



Calibration – Evapotranspiration of Ecosystems

► Data from DEM

- rede de drenagem
- sub-bacias
- slope, channel width, channel depth, ...

► Land use

► Soil

- soil parameter:

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► Hidrometeorological

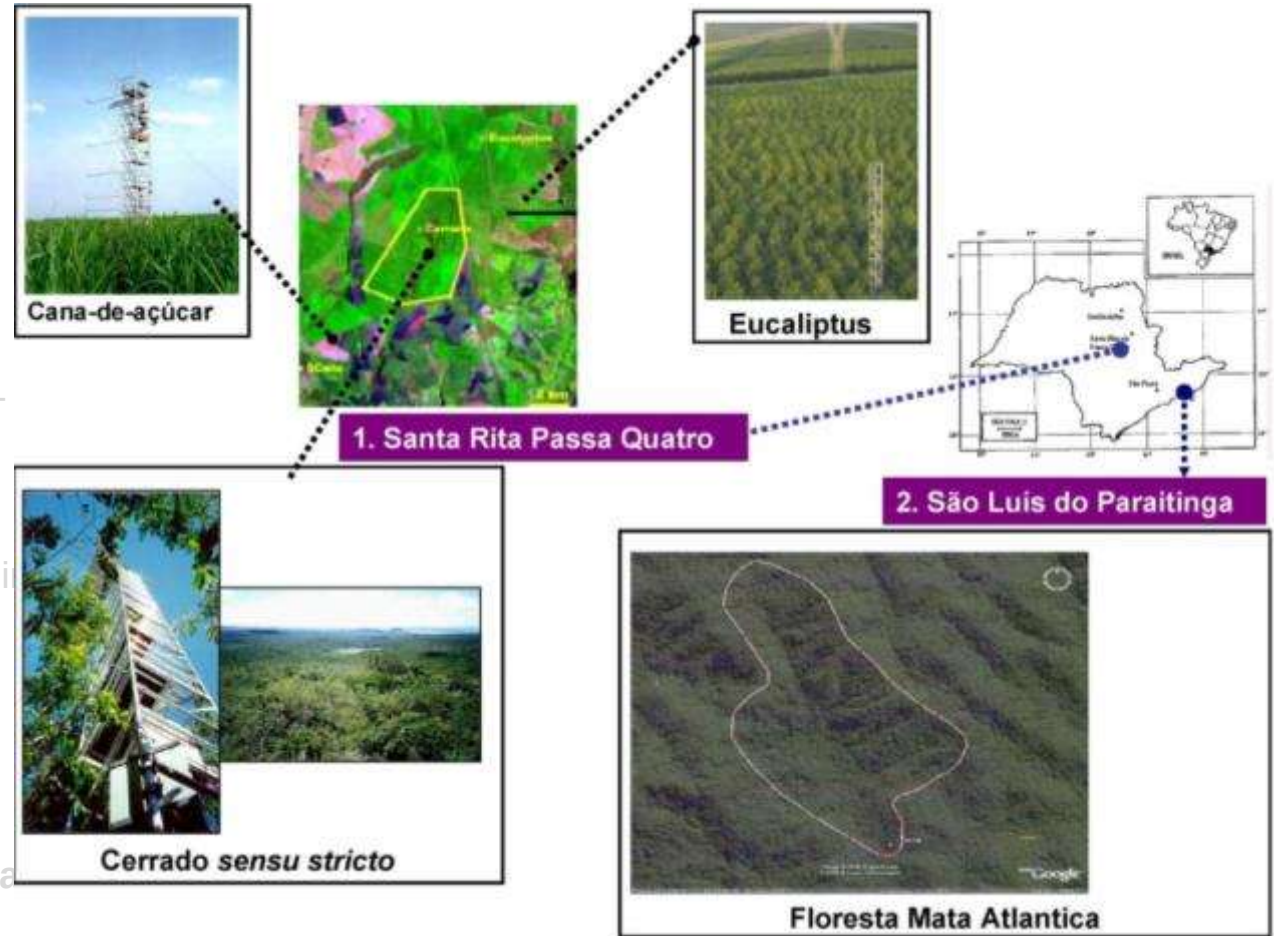
- Streamflow

- Rainfall

- Temp. Air, UR, Vel. Wind and Irra Solar

- Energy fluxes (H,LE), net radiation (Rn), ...

□ Flux towers (Eddy Covariance)



Sources: Tatsch (2006), Bruno (2009), Rocha (2009), Cabral et al (2010, 2011), Freitas (2012), and preliminary data of the Projeto Carbon Tracker and Water availability FAPESP (Program Global Climate Change)

Numerical experiment setup

► Calibration

- manual sensitivity analysis parameters: soil, groundwater, evapotranspiration
- manual calibration of evaporative fraction
- auto-calibration of streamflow using hydroPSO (Zambrano-Bigiarini & Rojas, 2013)

► Setup simulation

- Simulation period: **2006-2012**
 - warm up*: 5 years (2006-2010)
 - calibration: 2 years (2011-2012)
 - analysis*: **2011-2012**
- Resolution
 - spatial (DEM, Land use and Soil): 15 m
 - temporal: daily

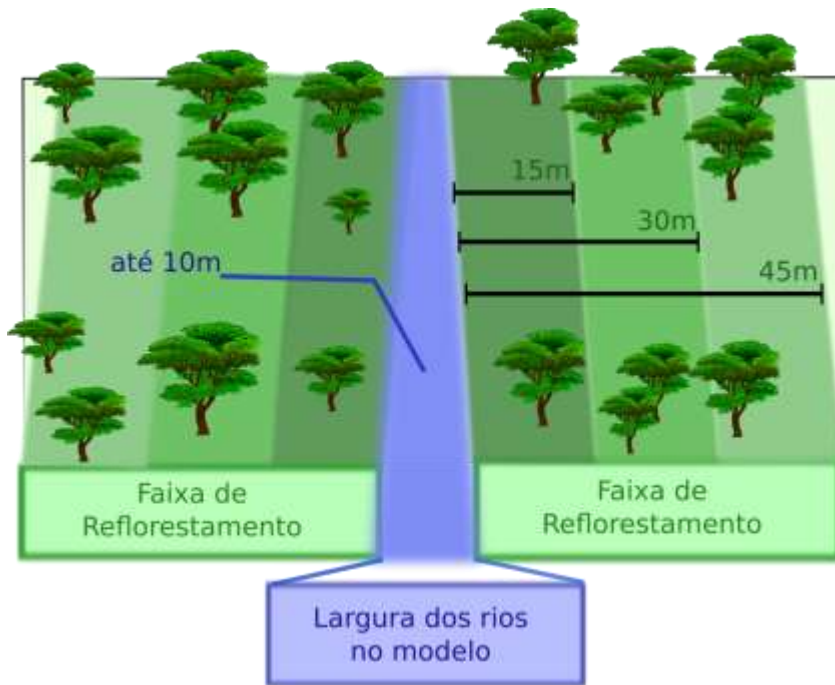
Reforestation Scenarios

► Experimental design

▪ Riparian buffer

- 03 sizes buffer width:

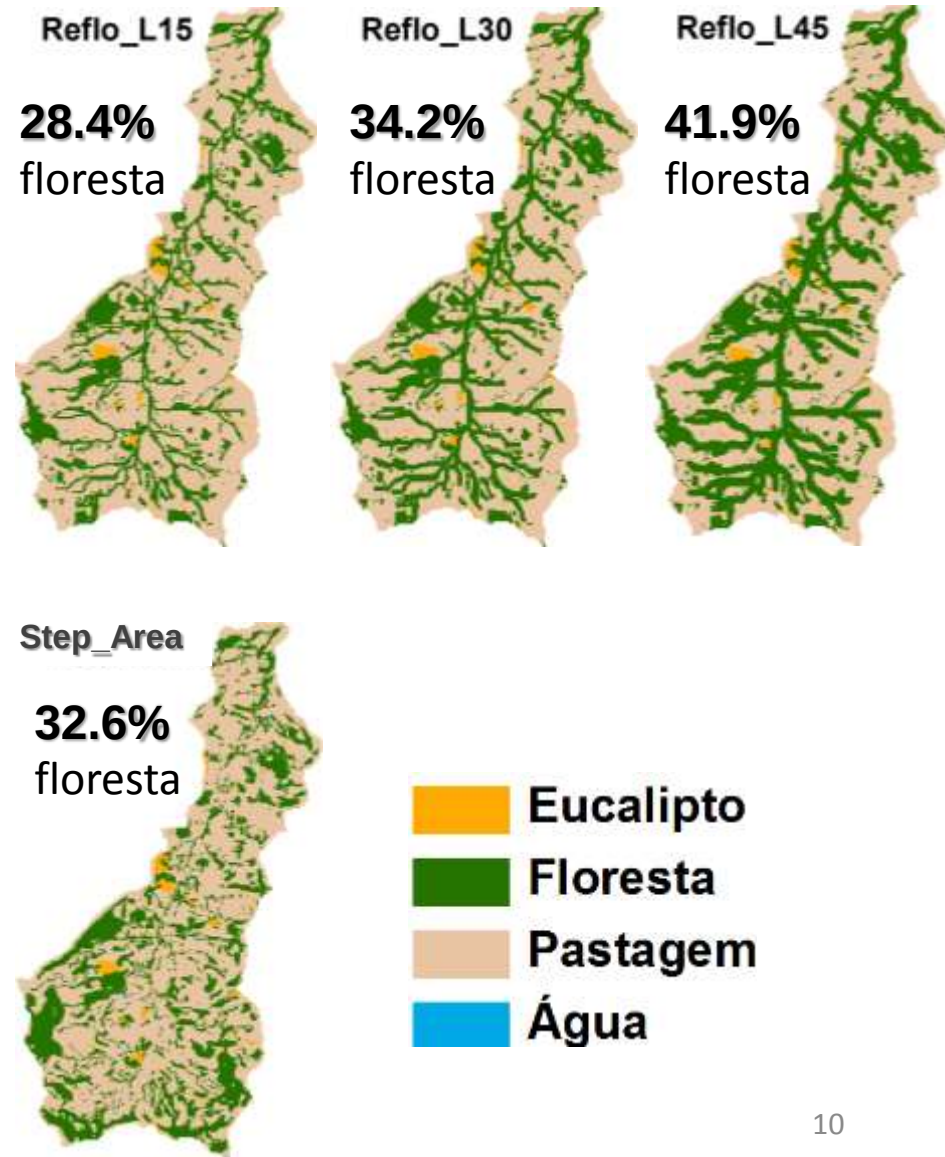
- buffer width 15 m (Refl_L15)
- buffer width 30 m (Refl_L30)
- buffer width com 45 m (Refl_L45)



▪ Step slope areas

- slope areas with slope $> 25^\circ$ (Step_area)

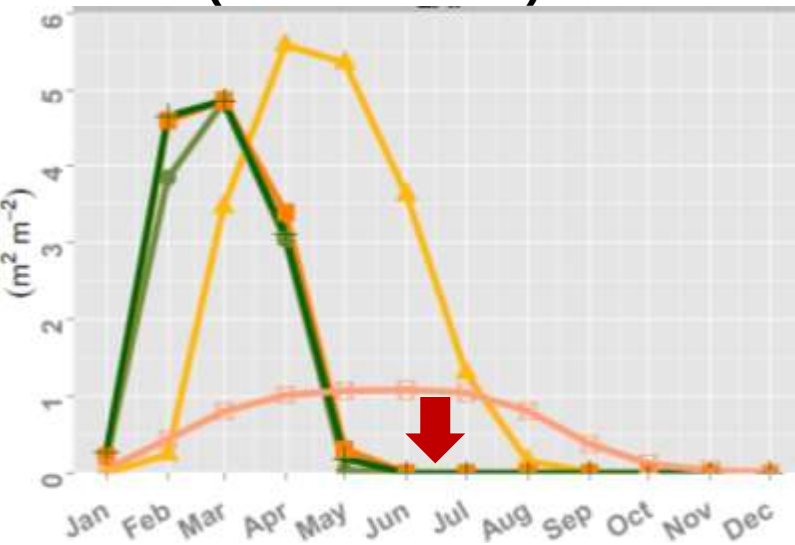
► Land use maps



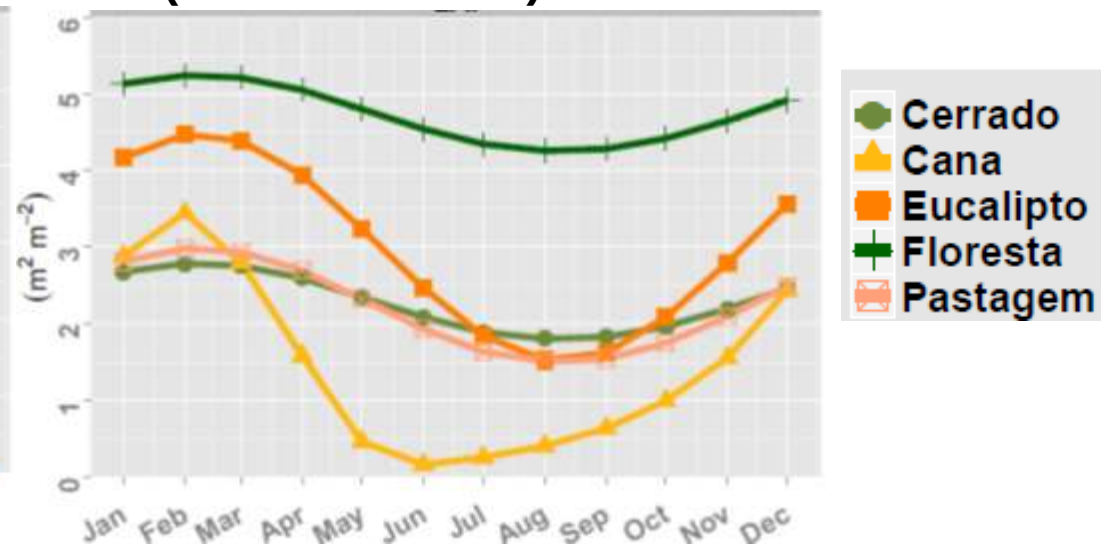
SWAT Vegetation parameters

► Modification – Seasonal LAI

(default SWAT)



(modified SWAT)



sources LAI:

Cerrado: Pivello e Varanda (2003)

Cana-de-açúcar :Cabral, et. al (2012)

Eucalipto: Maire (2011)

Floresta e pastagem: Von Randow et. al (2004)

► Vegetation parameters - ET manual calibration

Vegetação	gsi	canmx	chtmx	rdmx	esco	blai	alai _{min}
	(m s ⁻¹)					(m ² m ⁻²)	(m ² m ⁻²)
Cana-de-açúcar	0.0025	1.00	4.00	2.00	1.00	4.00	1.50
Cerrado	0.0035	1.60	10.00	6.00	1.00	3.50	1.8 0
Eucalipto	0.009	1.60	21.00	6.00	1.00	5.50	1.50
Floresta	0.005	1.80	30.00	6.00	1.00	6.00	4.50
Pastagem	0.003	0.70	1.20	1.50	0.98	3.00	1.50

Calibration of Evaporative Fraction (EF)

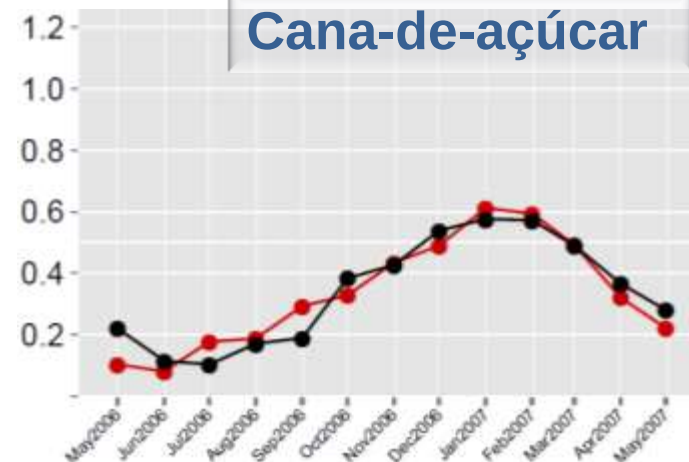
HRU mean of EF on Piracicaba River Basin
for 3 types of land cover

$$\overline{EF} = \frac{\overline{ET}}{\overline{Rn}}$$

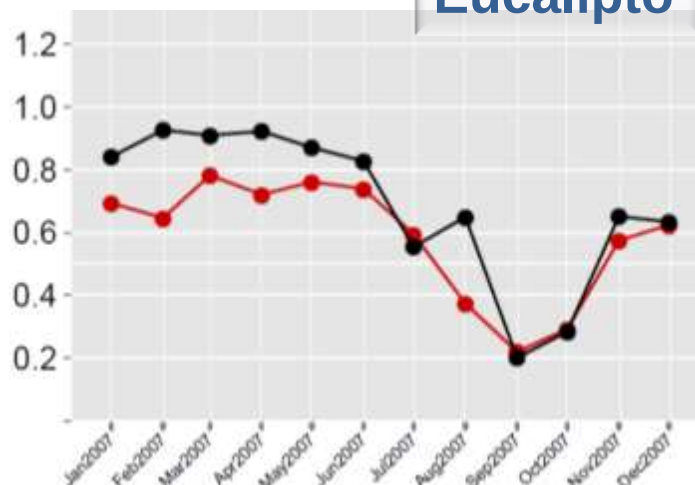
- Manual calibration of seasonal Evaporative Fraction (EF) through adjustment of vegetation parameters

— SWAT HRU mean
— observed

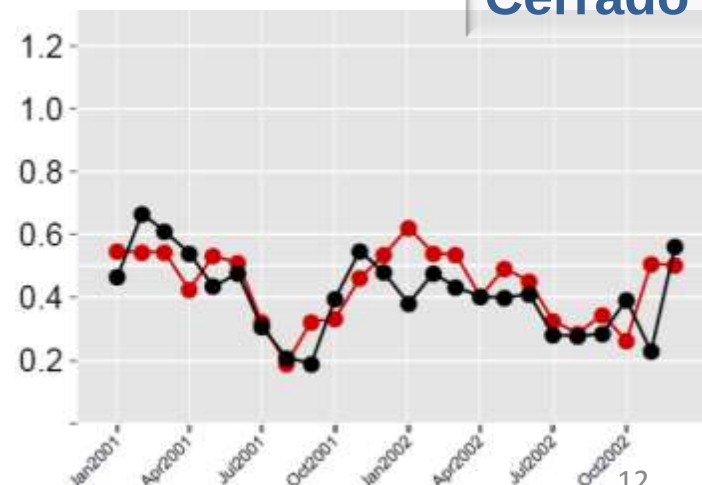
Cana-de-açúcar



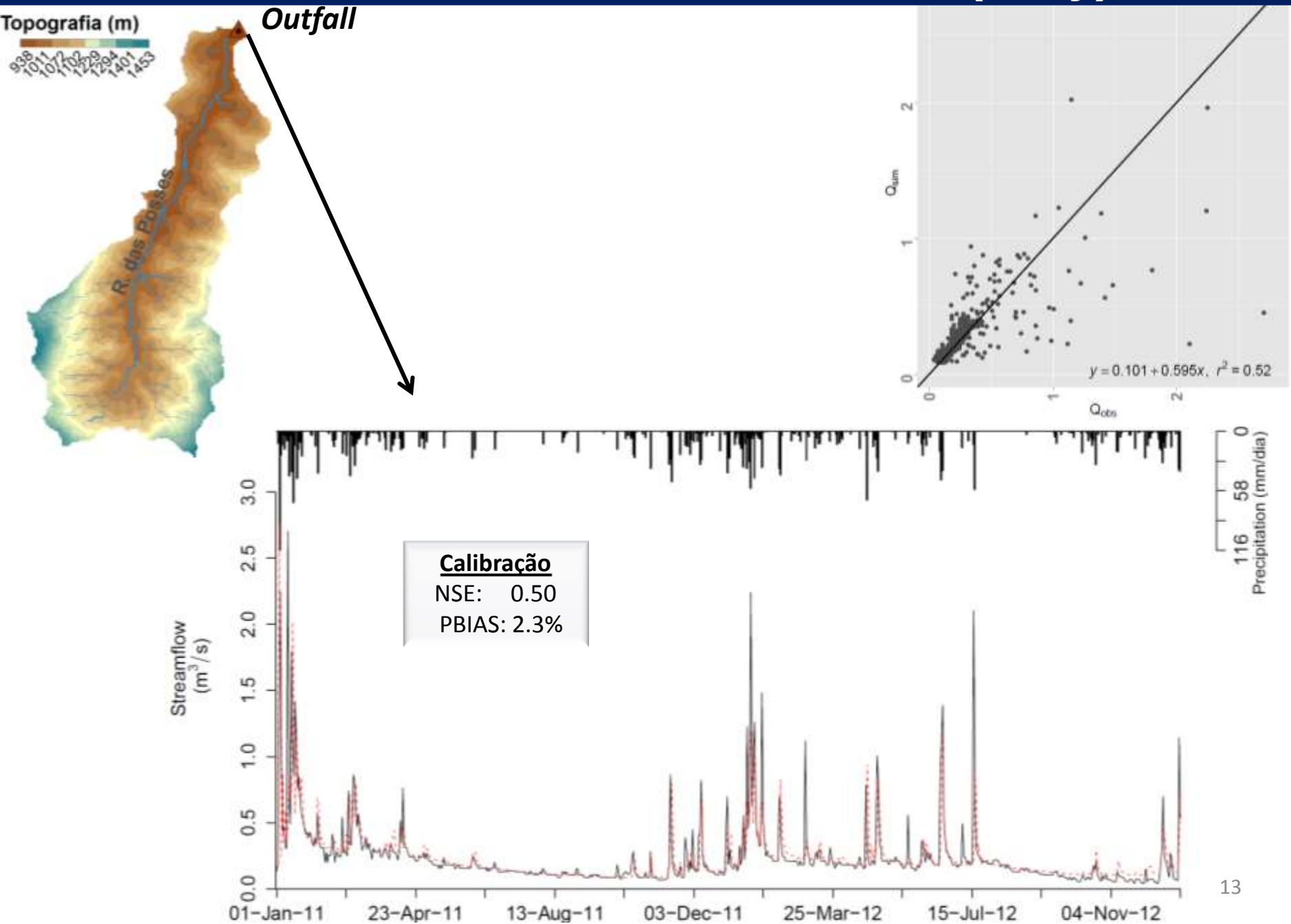
Eucalipto



Cerrado

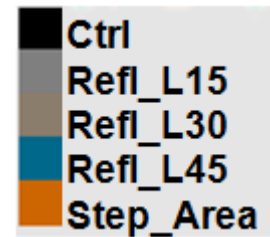
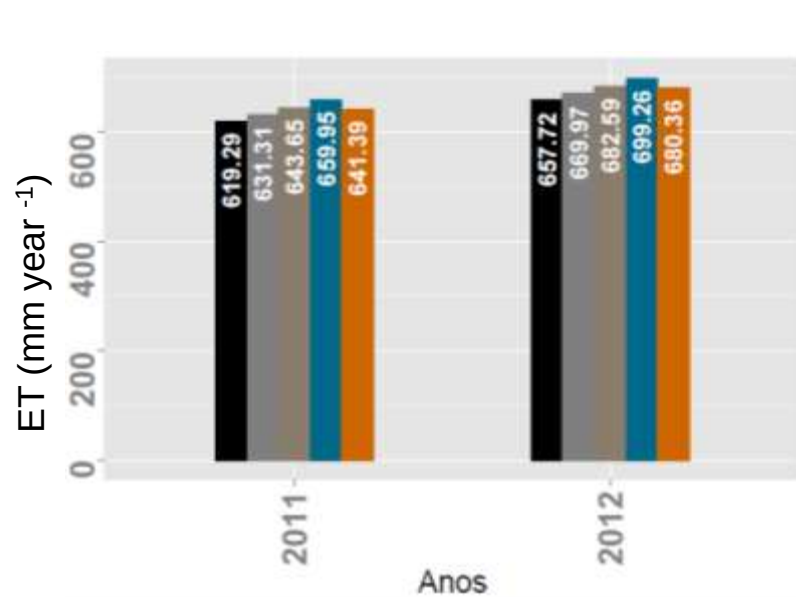


Results: Calibration streamflow (daily)

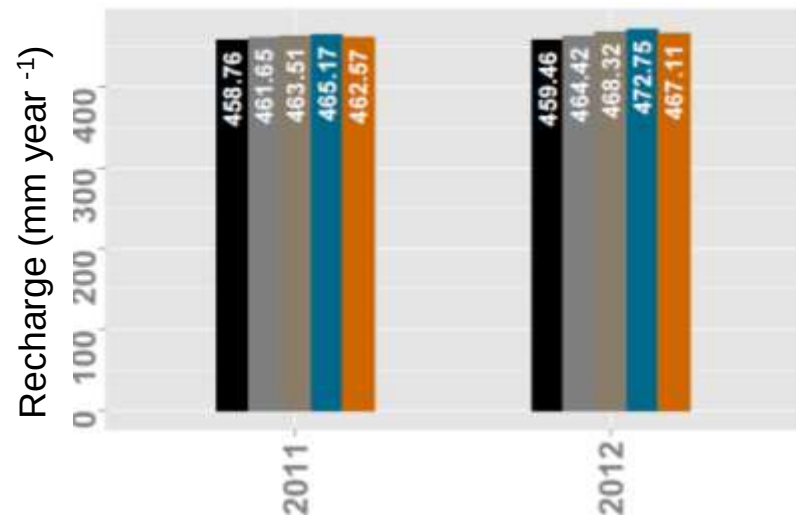
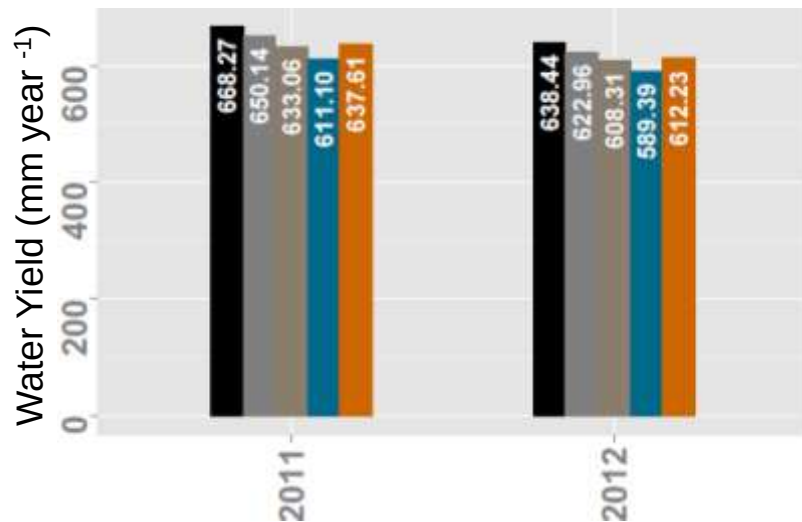


Results – AVE ANNUAL - Ribeirão das Poses Watershed

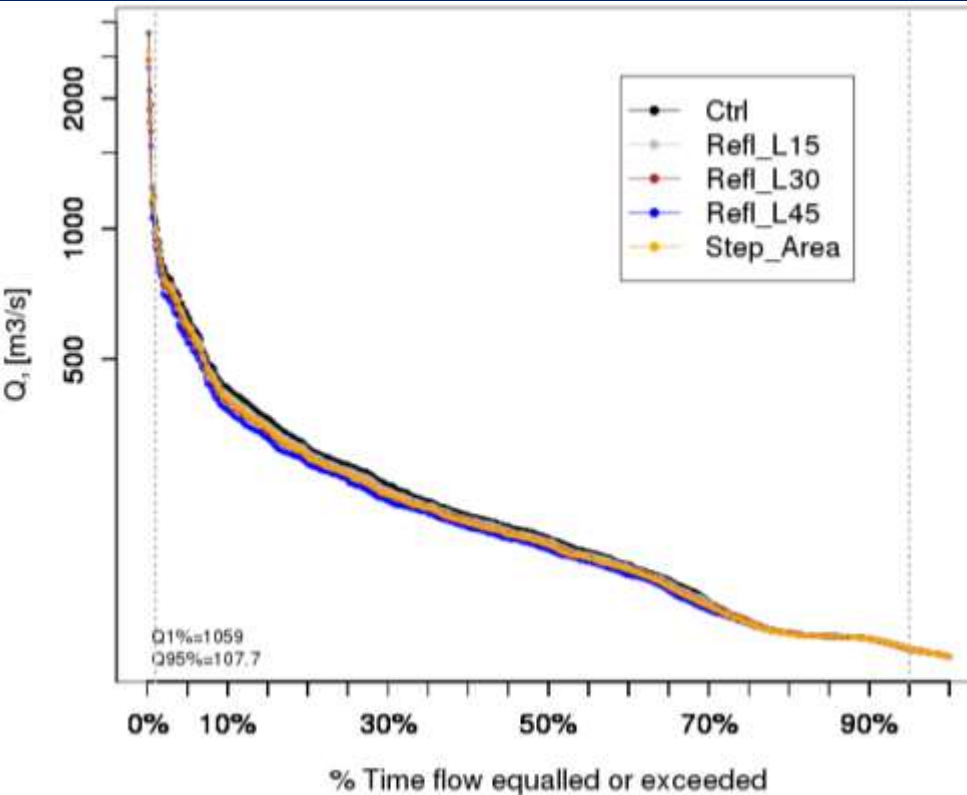
► Evapotranspiration, Water Yield and Total AQ. Recharge



Buffer width 45 m	Step slope areas
ET → + 6%	ET → + 3%
Water Yield → - 8%	Water Yield → - 4%
Recharge → + 2%	Recharge → + 1%

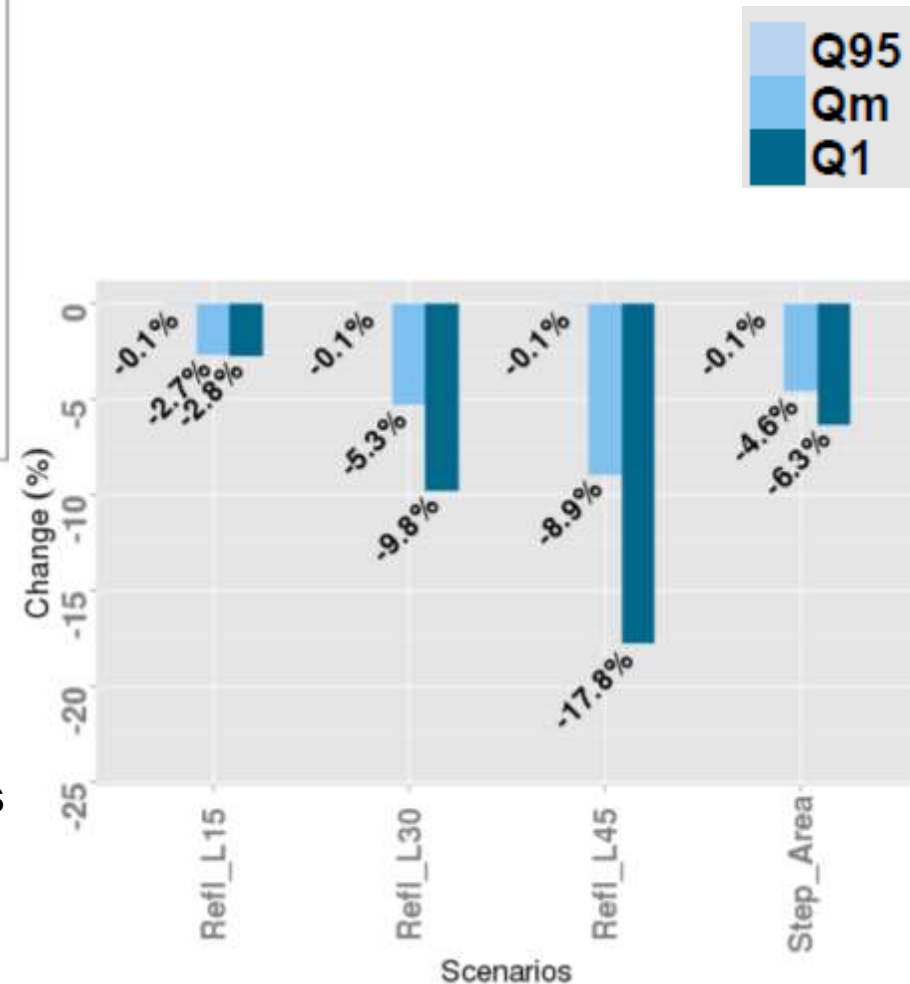


Results - Percentage change (%): Q_m , $Q_{1\%}$ and $Q_{95\%}$



► Hydrological environmental services

- slight reduction in the minimum streamflows
- significant reduction in maximum streamflows



Conclusions

► Ave Annual

- Evapotranspiration:
increased ~ **4.5%** with reforestation.
- Water Yield:
reduced ~ **6%**. Especially runoff superficial that reduced the maximum streamflow.
- Recharge:
increased ~ **1.5%** → increased base flow.

► Extreme streamflow

- Reduced floods events ~ 18% and did not adversely affect the streamflow during low-flow periods.

► Limitations of estimates

- parameter uncertainty
- HRU: not explicitly represents the location vegetation and are not hydraulically connected

□ Areas of permanent preservation (riparian reforestation and in steep areas) promoters are predominantly favorable hydrological environmental services in Brazil

Next Steps



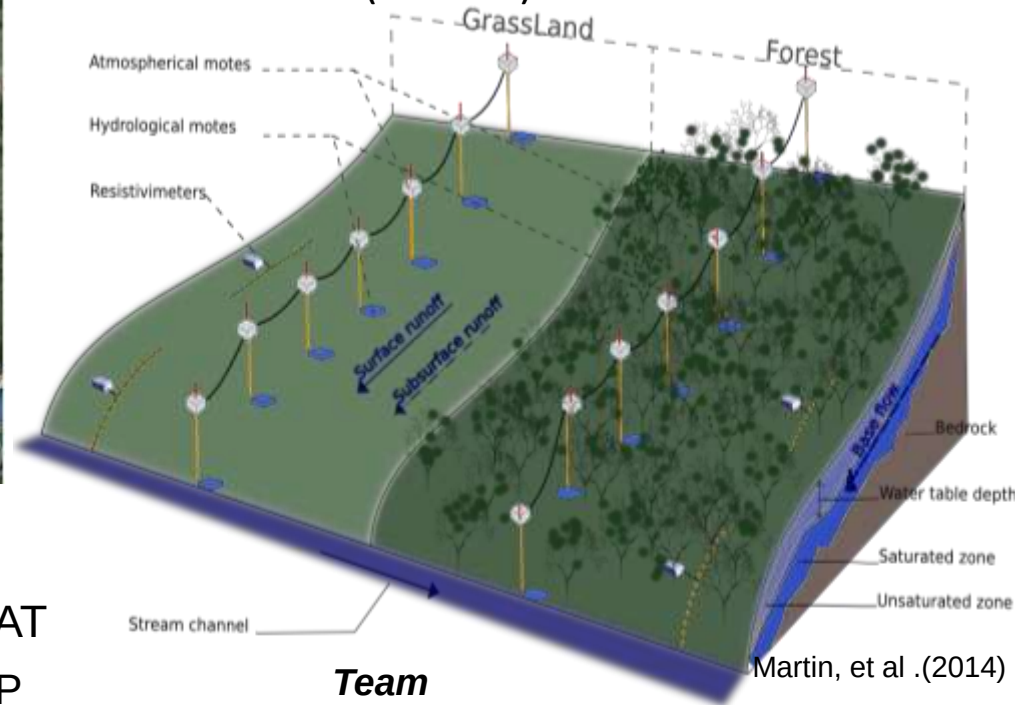
► Versions: SWAT-VSA / grid-based SWAT
obtain scenarios consist of combinations APP
and BMPs that optimize hydrological
environmental services

► Measurements (Hillslopes)

Evapotranspiration

Soil moisture

Project GEOSSENSORES & ECOFOR (FAPESP)



Team

- Prof. Humberto Rocha (Leader)
- Prof. Tomas Domingues
- Prof. Ricardo Hallak
- Helber Freitas, PhD
- Jonathan Mota, PhD
- Nilson Neres, Eng.
- Eduardo Lopes, Tecn.
- Emilia Brasilio, Meteorologist
- Thomas Martin, PhD Student
- Raianny Leite, PhD Student