University of São Paulo
Institute of Astronomy, Geophysics and Atmospheric Sciences

Laboratório de Clima e Biosfera

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

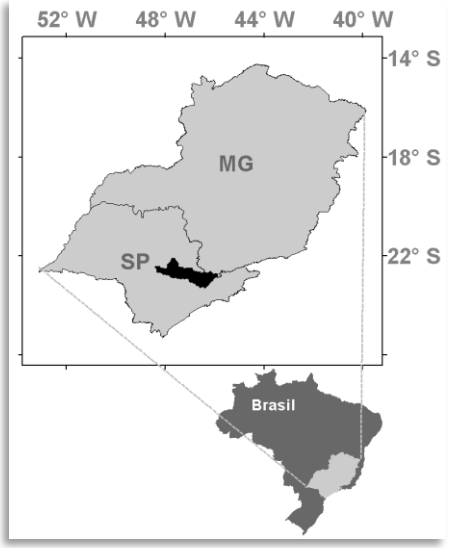
Jonathan Mota da Silva, Humberto Rocha, Sandra Saad,

Emilia Brasílio, Gré Lobo

2014 International SWAT Conference & Workshops – Pernambuco, Brazil

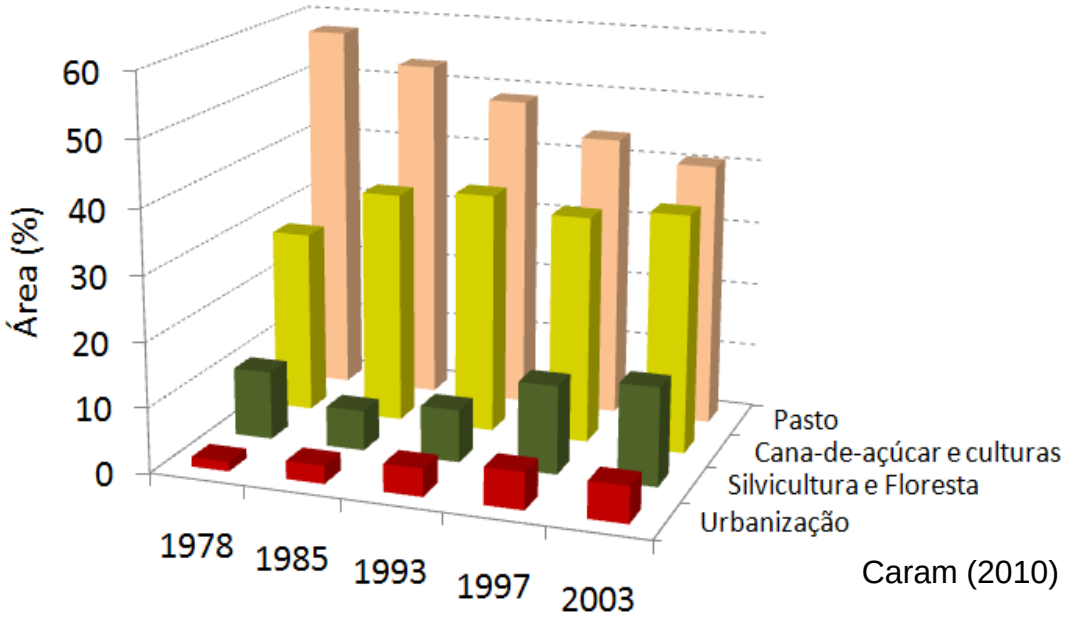
Porto de Galinhas (PE),
July 30 – 01 Aug, 2014

Introduction



Piracicaba River Basin

Land use change in Piracicaba River Basin



Caram (2010)

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

Flood in Atibaia City (2010)

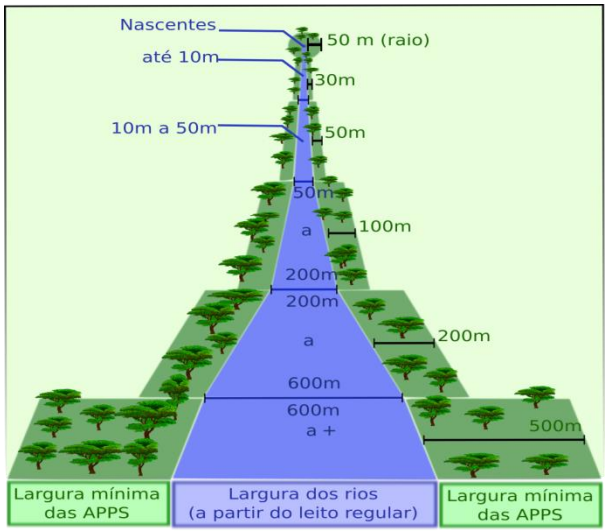
Water shortage in 2014

Introduction: How to coexist whith 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)

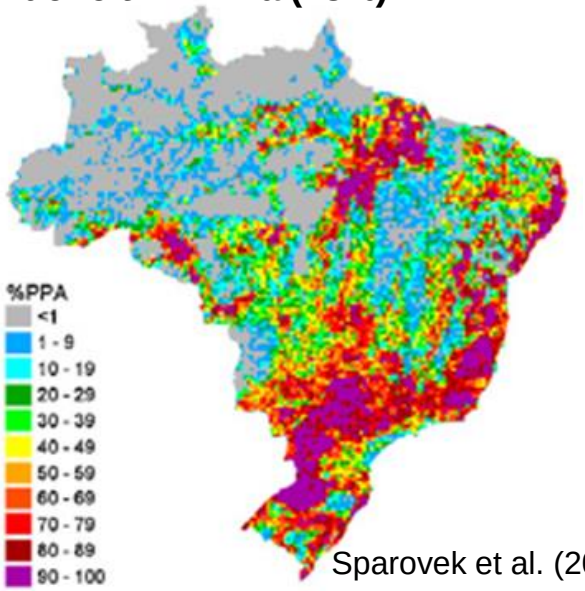
Limits of riparian PPAs



►The Forest Act Challenge

PPA's deficit

- **deficit: 44 Mha (43%)**



Sparovek et al. (2012)

Permanent Preservation Areas

►Riparian PPAs mantain:

- 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

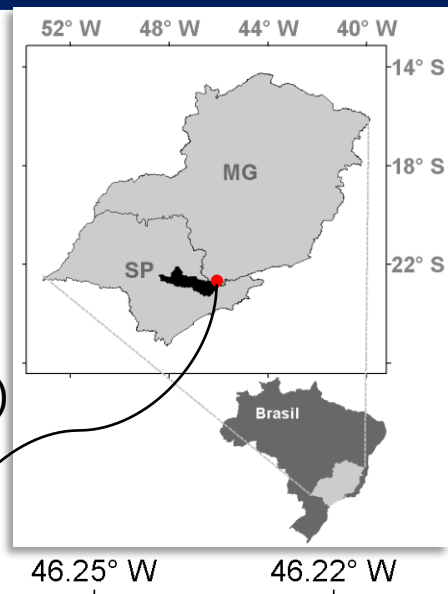
►Ribeirão das Posses Watershed

Drainage area ~ 12 km^2

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 whith slope > 25°

►Hidroclimatology

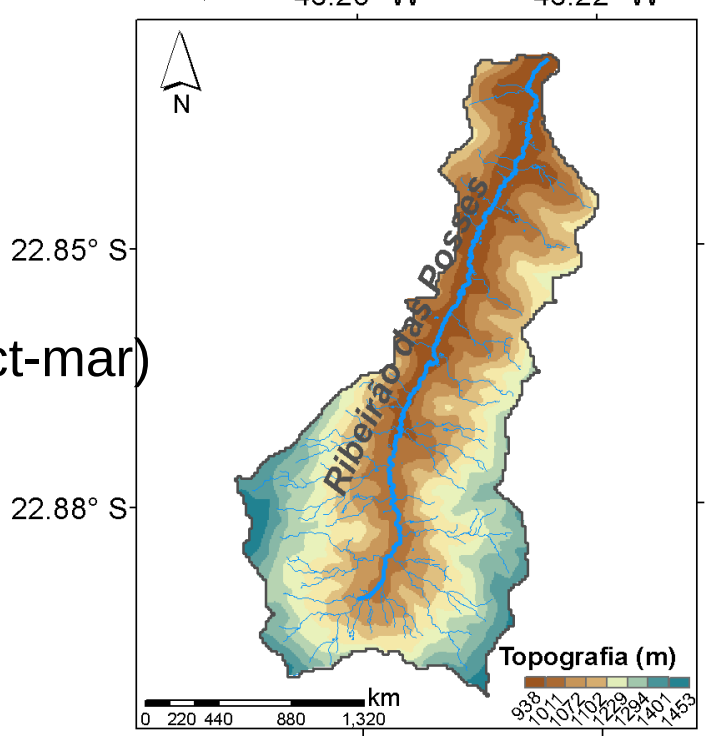
Annual rainfall:1600 mm (highest occurrences oct-mar)

Mean Streamflow: 250 litros s^{-1}

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

Mean Temperature: 14 °C (jun)

21°C (feb)

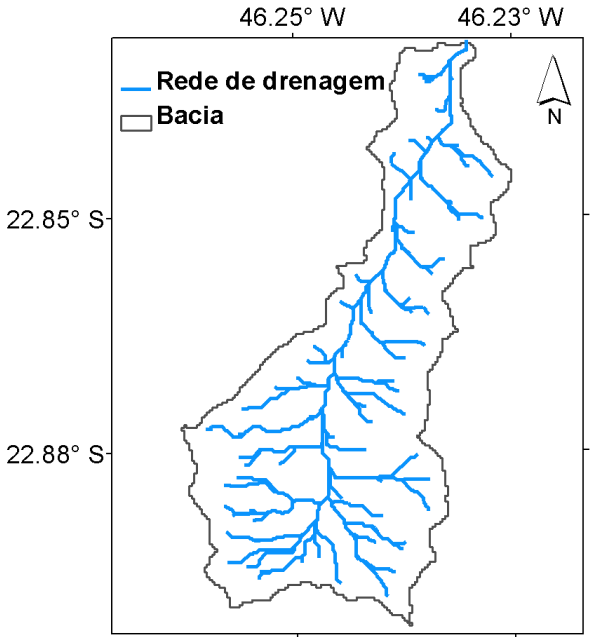


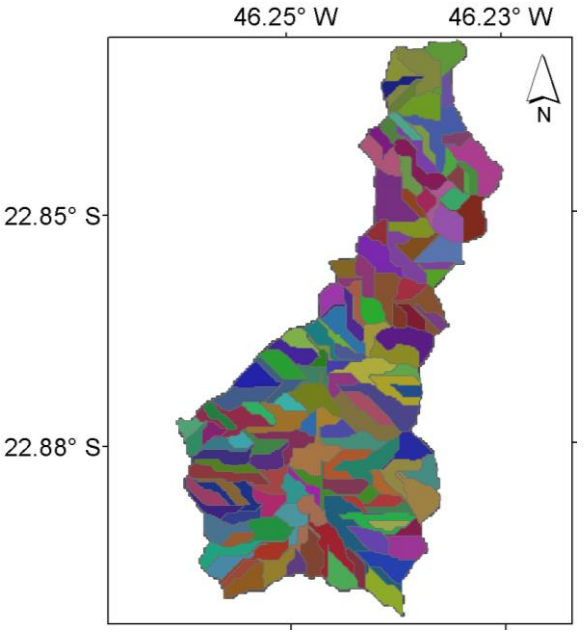
Input data

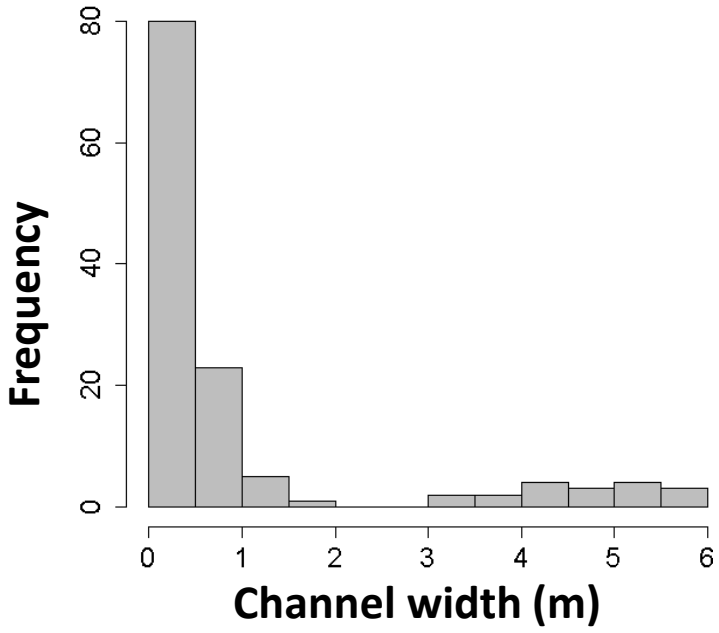
► Data from DEM
- rede de drenagem
- sub-bacias
- slope, channel width, channel depth, ...

► 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

► 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)

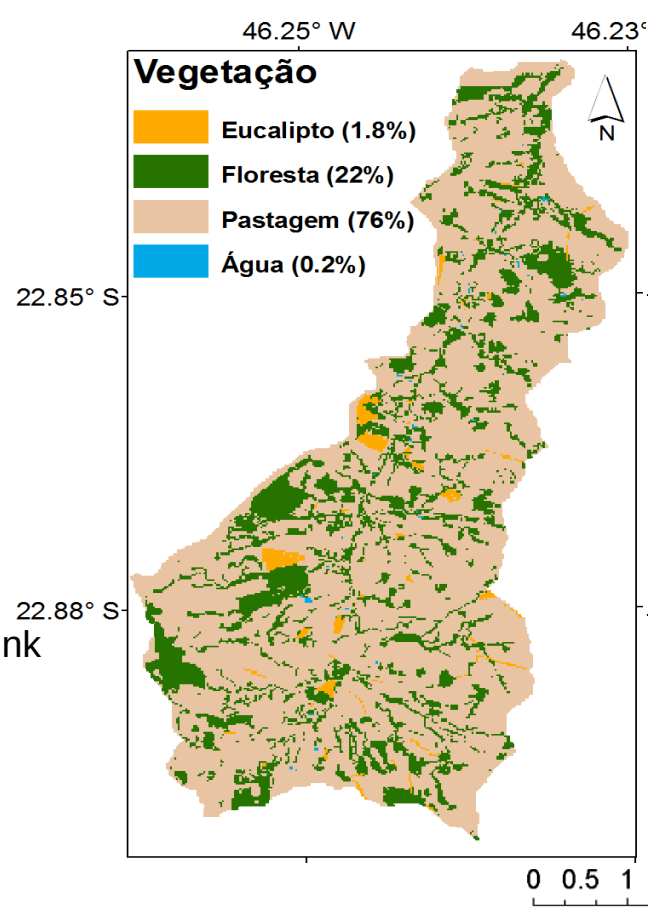
►Hidrometeorological

- Streamflow

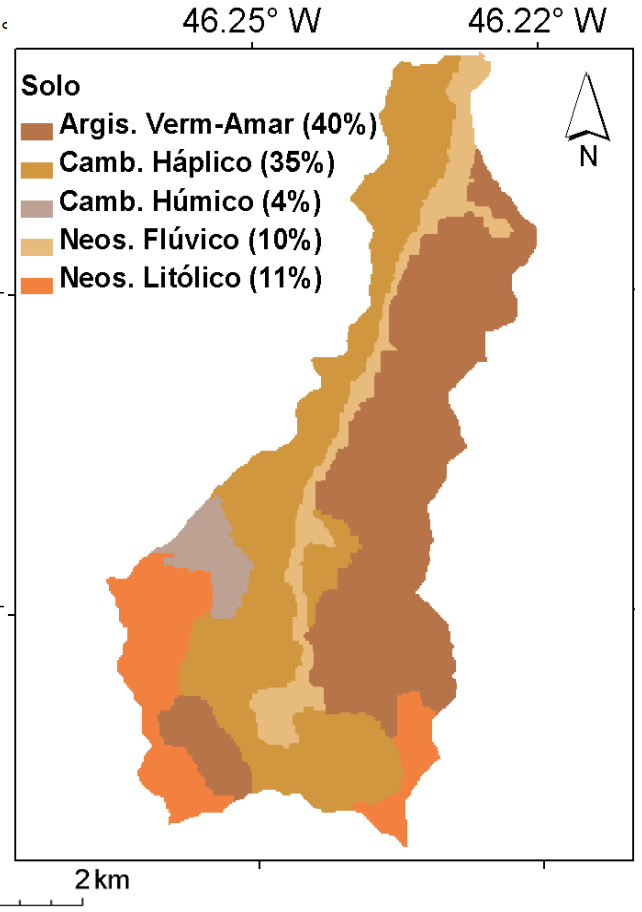
- Rainfall

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

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



Adapted form Azevedo (2008): 20 m resolution



Adapted Azevedo (2008) and Calheiros (2009): 1:5:10^4 scale

Input data

► **Land use**

► **Soil**

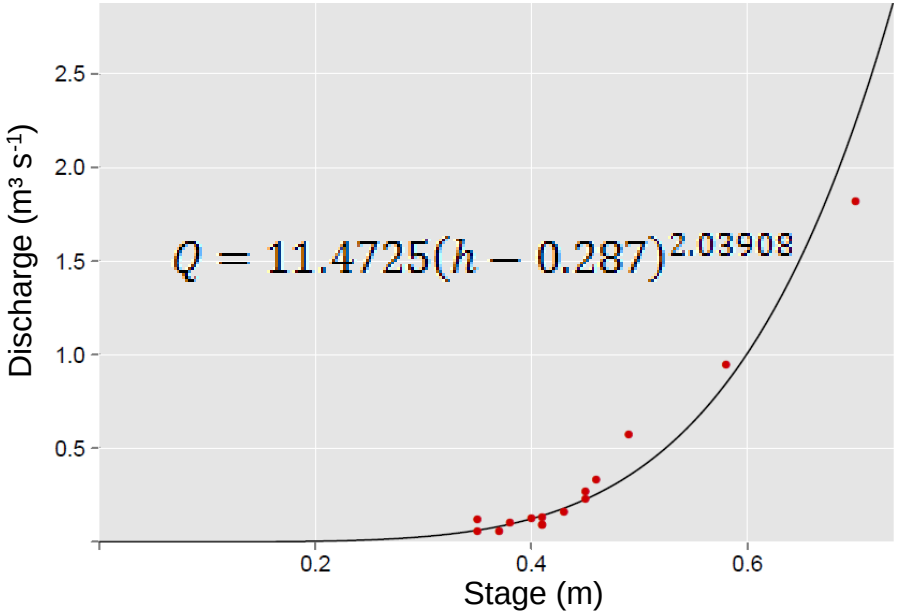
- **soil parameter:**

✓ Saturated Hyd. C
PTFs Saxton & R

✓ Soil Properties –

✓ Available Water C
(sol_awc) – Minas
(2011)

Stage-Discharge Rating Curve (Preliminary)



►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)

Calibration – Evapotranspiration of Ecosystems

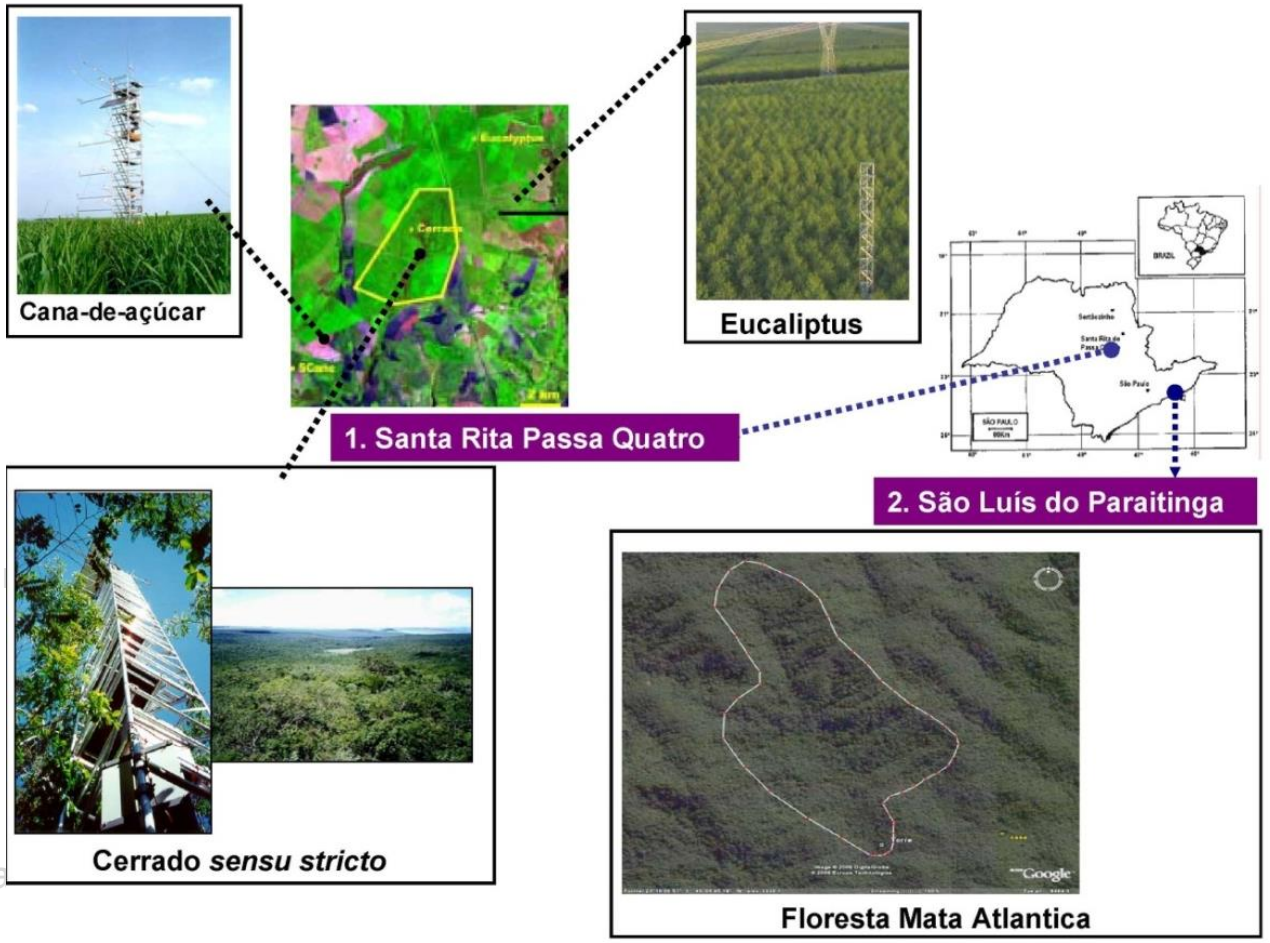
❑ **Flux towers (Eddy Covariance)**

► 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 & Hartemi (2011)

►Hidrometeorological
- Streamflow
- Rainfall
- -Temp. Air, UR, Vel. Wind and Irra Solar



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

Sources: Tatsch (2006), Bruno (2009), Rocha (2009), Cabral et al (2010, 2011), Freitas (2012), and preliminary data of the Projet 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

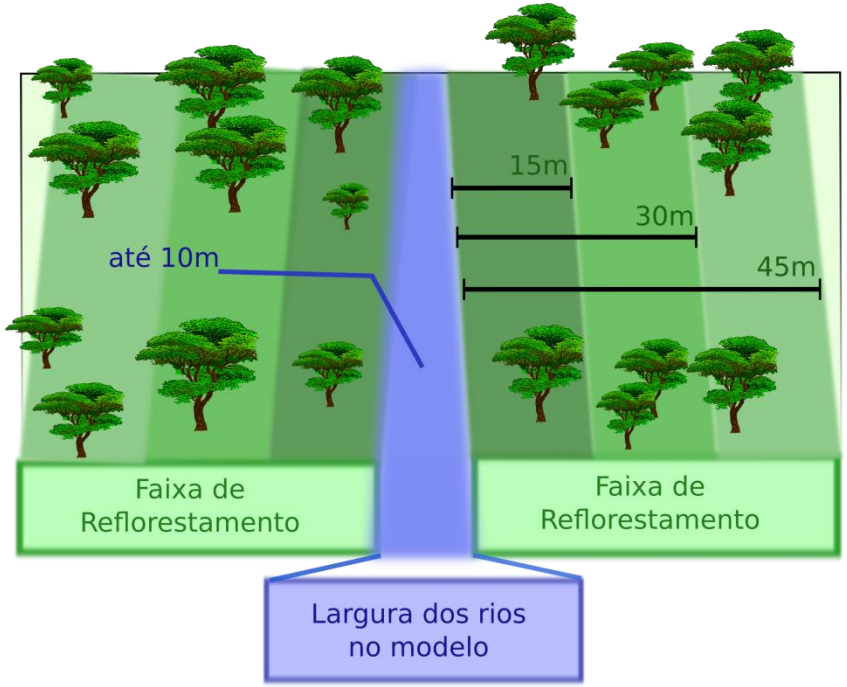
-Resolution
  - spatial (DEM, Land use and Soil): 15 m
  - temporal: daily

Reforestation Scenarios

►Experimental design

▪ **Riparian buffer**

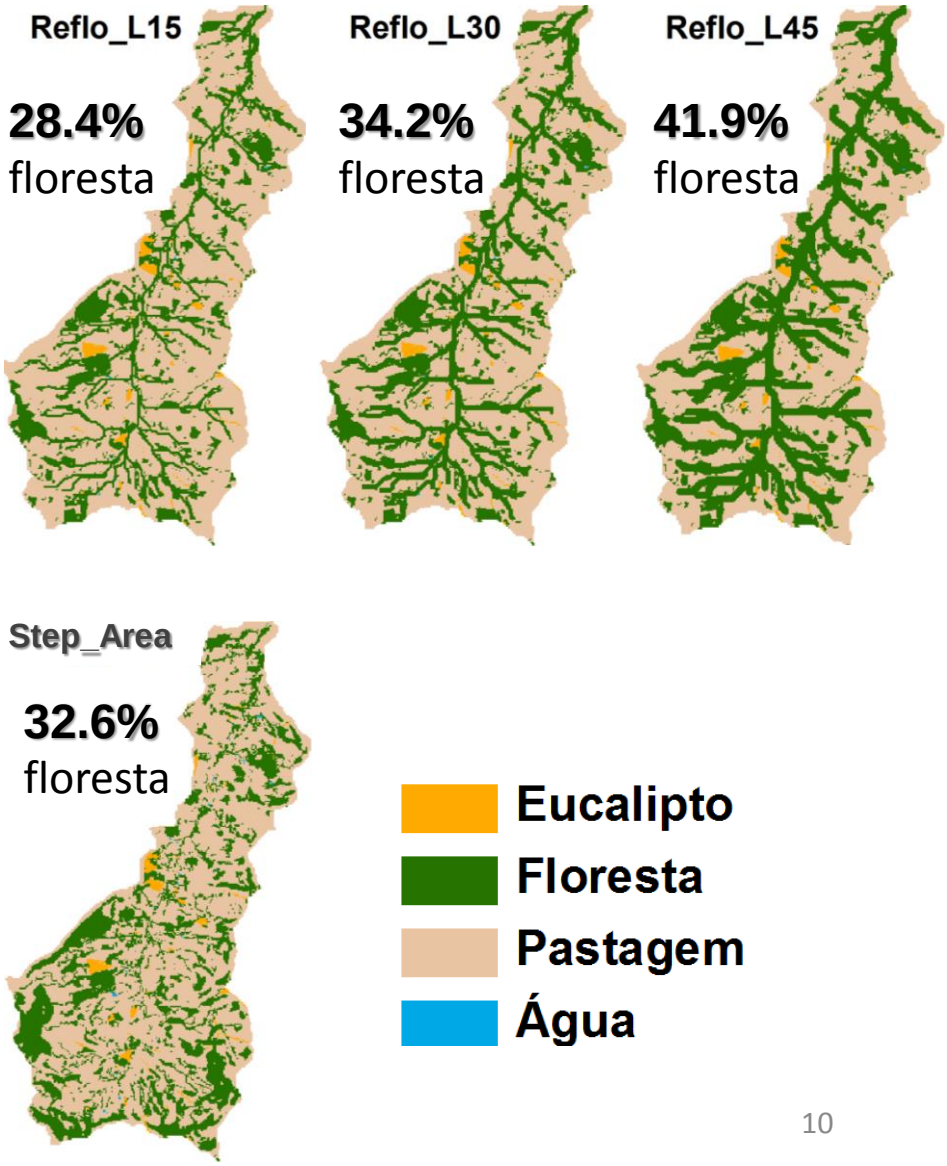
- 03 sizes buffer width:
• buffer width 15 m (Refl_L15)
• buffer width 30 m (Refl_L30)
• buffer width com 45 m (Refl_L45)



▪ **Step slope areas**

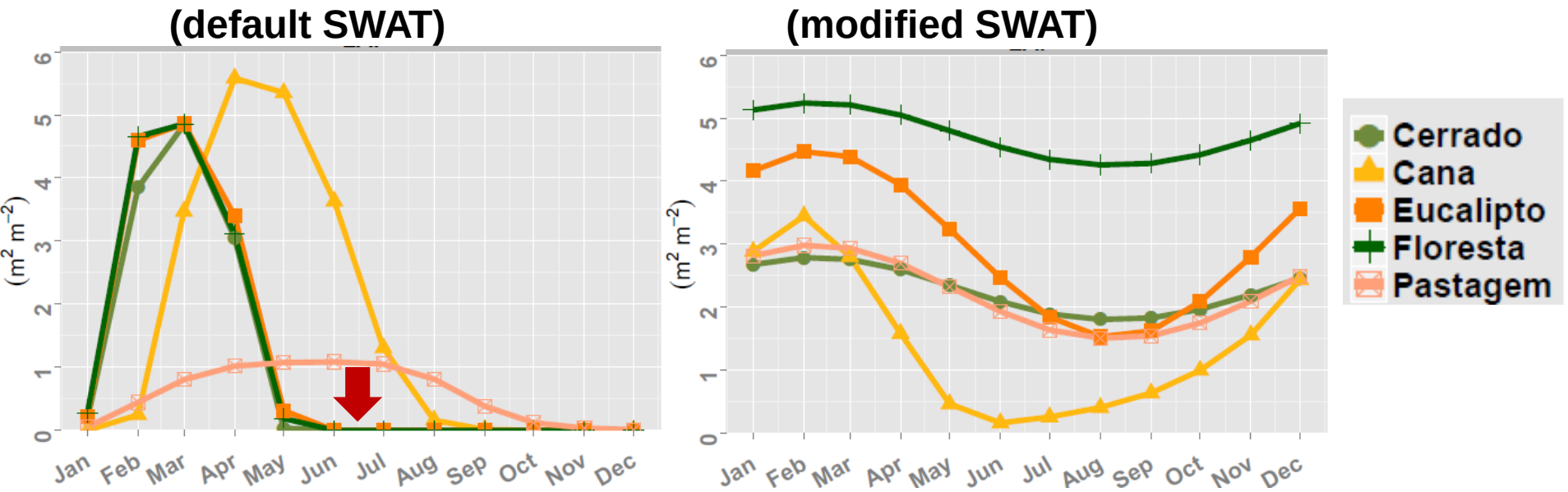
- slope areas with slope > 25° (Step_area)

►Land use maps



SWAT Vegetation parameters

►Modification – Seasonal LAI



sources LAI:
Cerrado: Pivello e Varanda (2003)
Cana-de-açucar :Cabral, et. al (2012)
Eucalipto: Maire (2011)
Floresta e pastagem:Von Randow et. al (2004)

►Vegetation parameters - ET manual calibration

Vegetação	gsi ($m\ s^{-1}$)	canmx (mm)	chtmx (m)	rdmx (m)	esco	blai (m2 m-2)	$alai_{min}$ ($m^2\ m^{-2}$)
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)

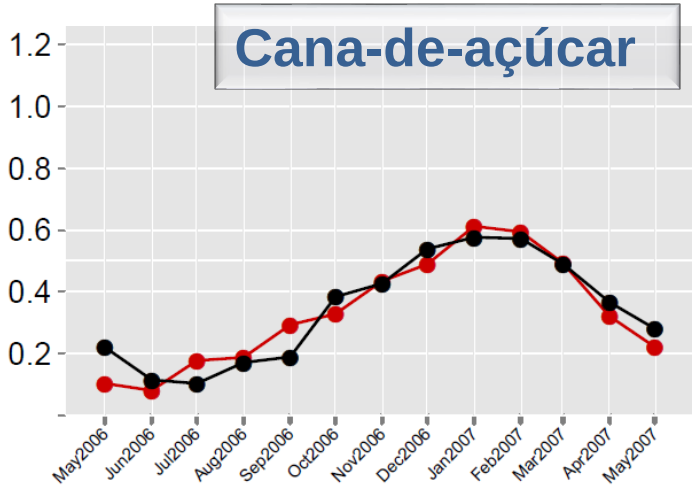
$$\overline{EF} = \frac{\overline{ET}}{\overline{Rn}}$$

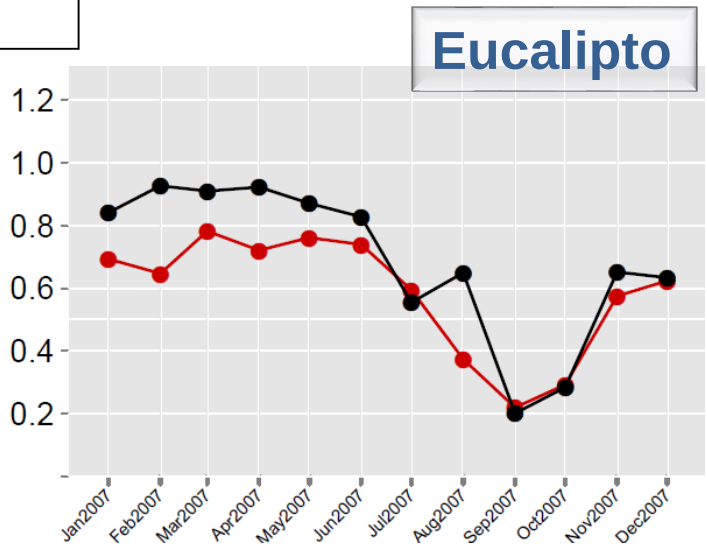
HRU mean of EF on Piracicaba River Basin for 3 types of land cover

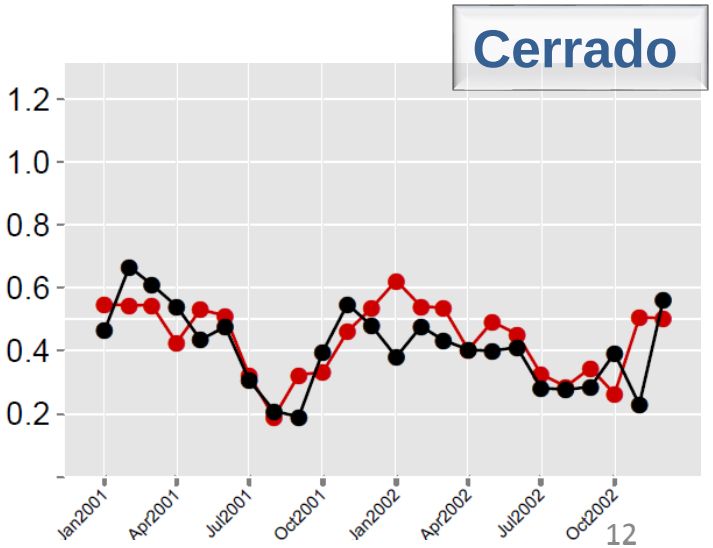
- Manual calibration of seasonal Evaporative Fraction (EF) trough adjustment of vegetation parameters

SWAT HRU mean

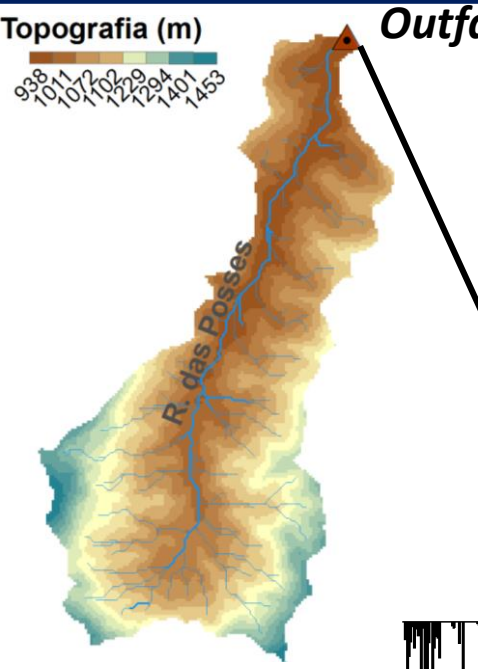
observed

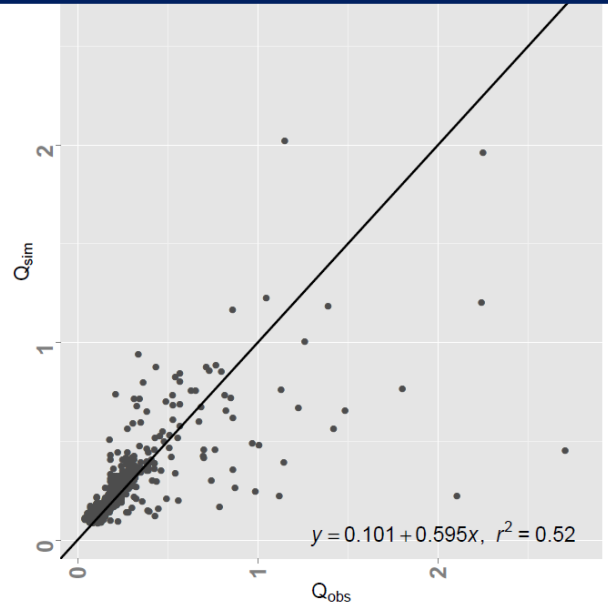


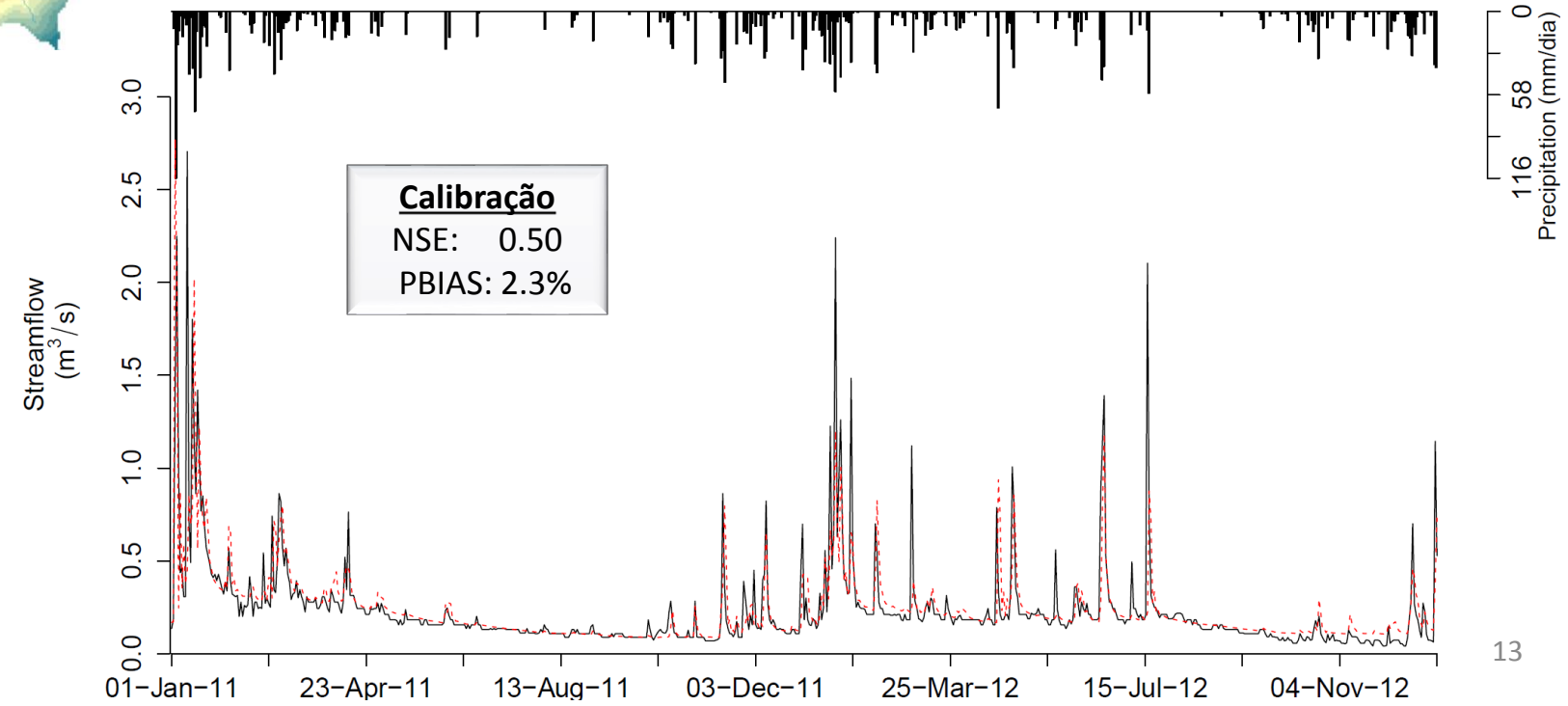




Results: Calibration streamflow (daily)

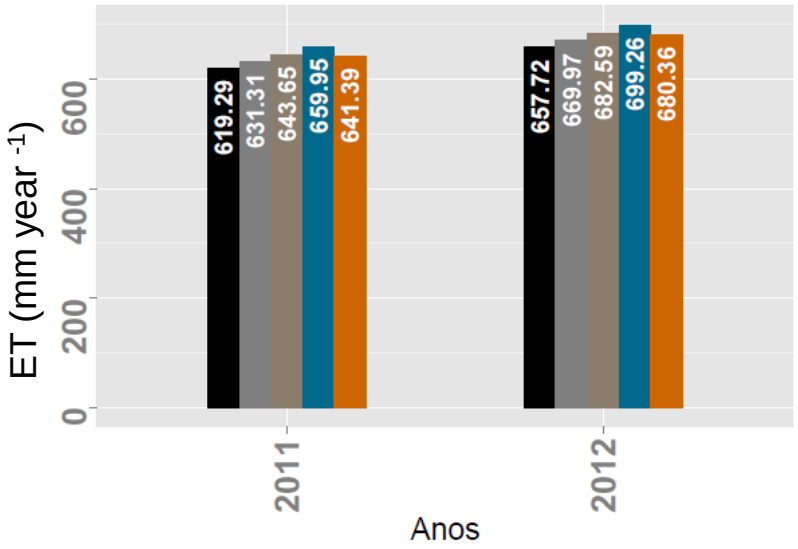


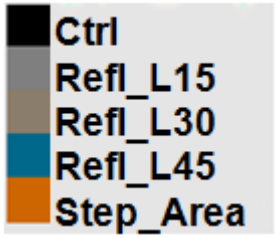




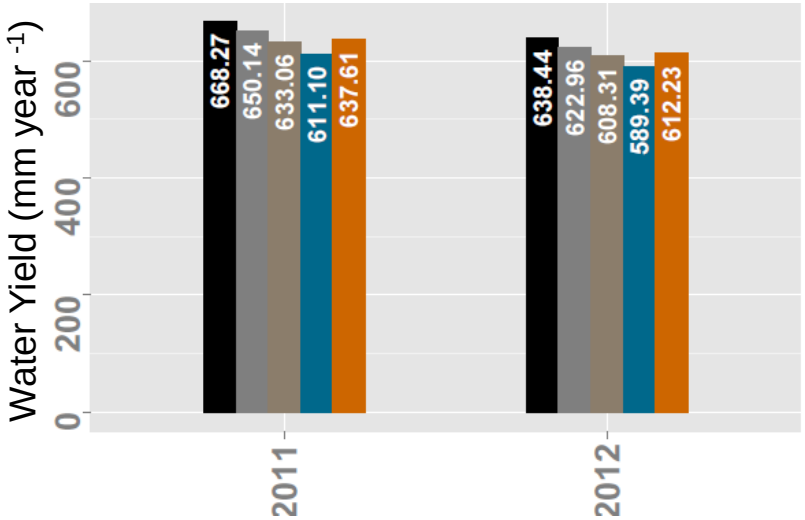
Results – AVE ANNUAL - Ribeirão das Posses Watershed

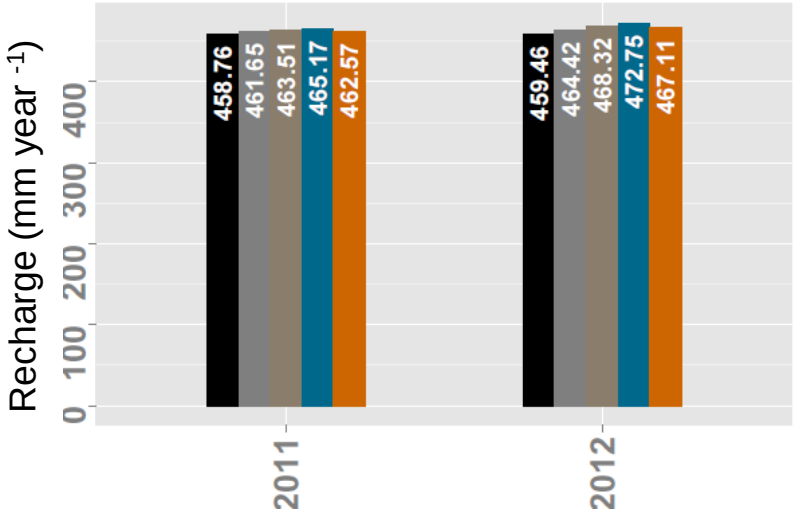
►Evapotranspiration, Water Yield and Total AQ. Recharge



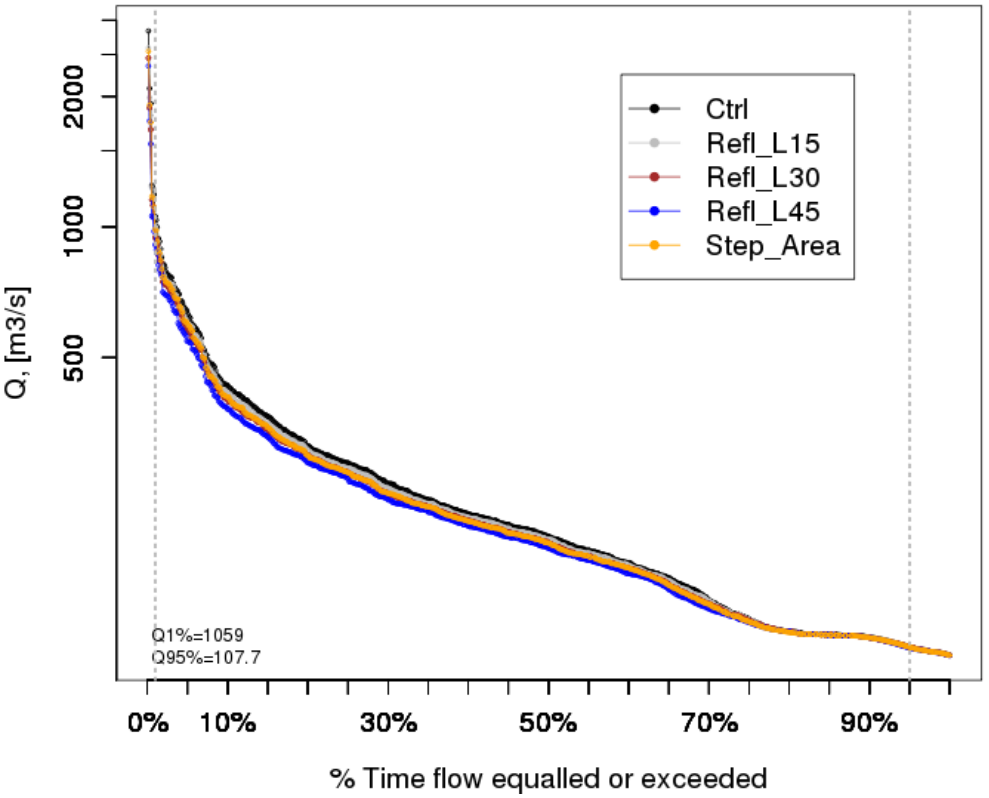


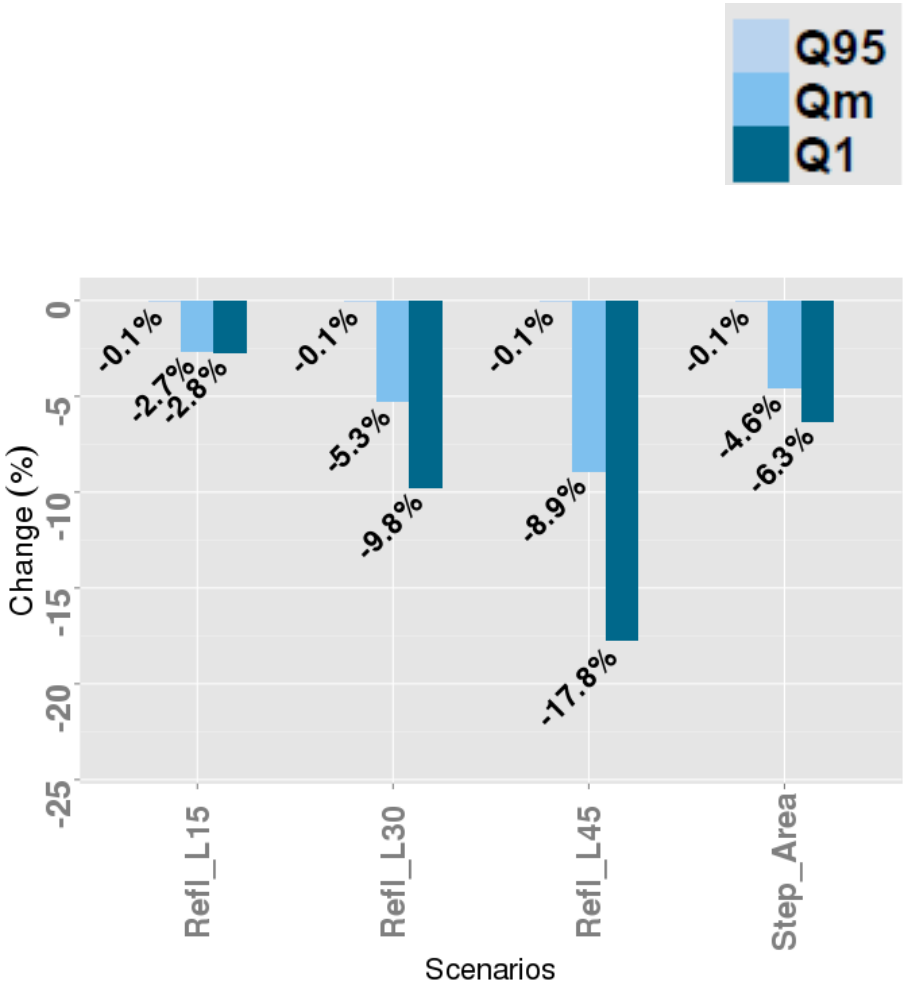
Buffer width 45 m	Step slope areas
ET → + 6%	ET → + 3%
Water Yield → - 8%	Water Yield → - 4%
Recharge → + 2%	Recharge → + 1%





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





►Hydrological environmental services

- sligth reduction in the minum streamflows
- significant reduction in maximum streamflows

Conclusions

► Ave Annual

— Evapotranspiration:
increased **~ 4.5%** with reflorestation.

— Water Yield:

redced **~ 6%**. Especially runoff supperficial that reduced the maximum streamflow.

— Recharge:

increased **~ 1.5%** → increased base flow.

► Extreme streamflow

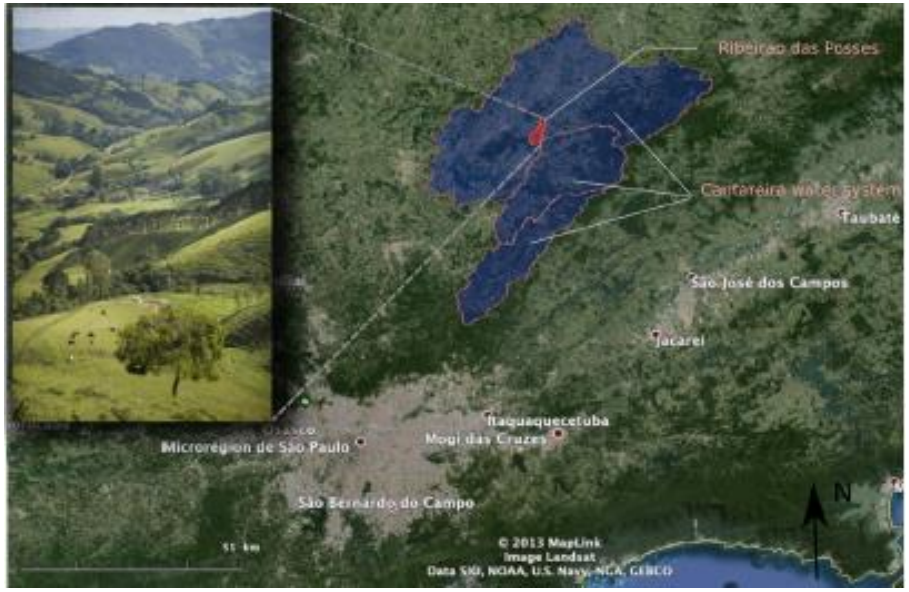
— Reduced floos events ~ 18% and did not adversely affect the streamflow during low-flow periods.

► Limitations of estimates

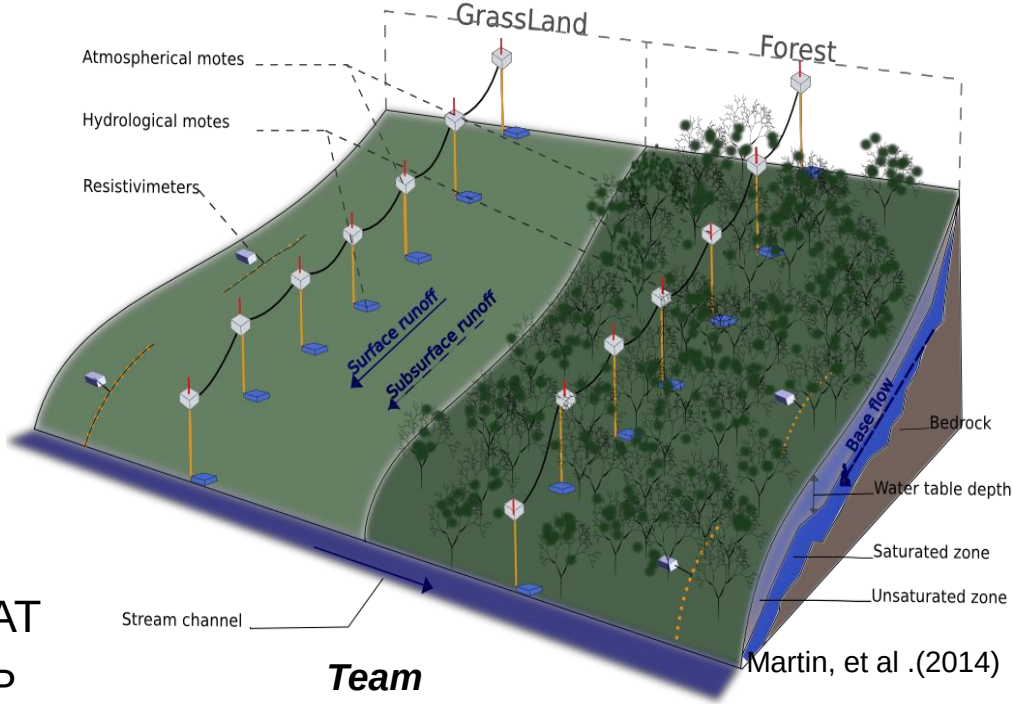
— parameter uncertainty
— HRU: not explicity represents the location vegetation and are not hydraulically connected

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

Next Steps



Project GEOSENSORES & ECOFOR (FAPESP)



Martin, et al .(2014)

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

► Measurements (Hillslopes)

Evapotranspiration

Soil moisture

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 Stundant*
- *Raianny Leite, PhD Stundant*