Modelling the Effect of Riparian Vegetation Restoration on Sediment Transport in a Human-Impacted Brazilian Catchment

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Motivation

- 2010: Brazilian Parliament started initiative to revise the Brazilian Forest Act (BFA)
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  - Differentiation between conservation vs. reforestation requirements
  - Amnesty to small rural properties' (20–400 ha) reforestation debt (-58%)
    - 22% in riparian preservation areas (RPA)
- Riparian vegetation
  - Decreases speed runoff
  - Stabilizes river banks
  - Filters nutrients and pollutants
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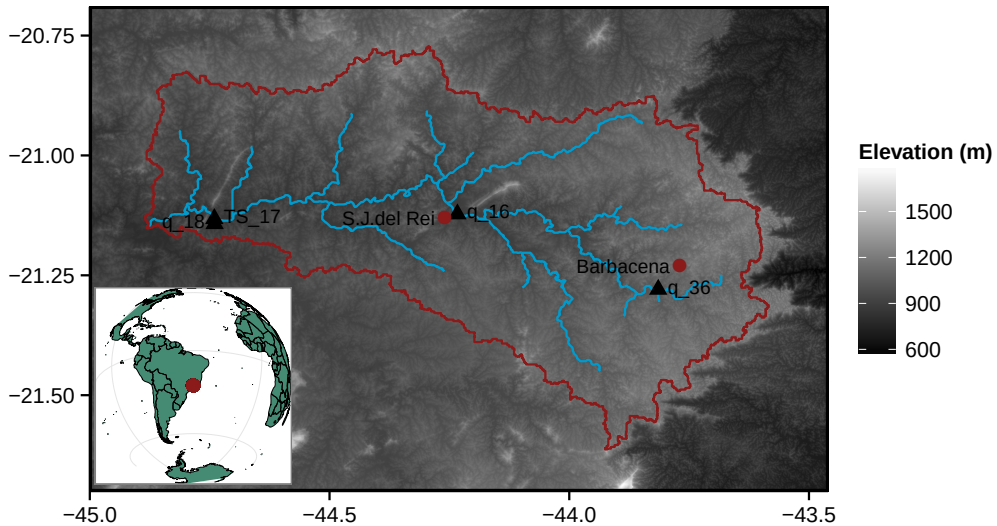
What are the consequences of riparian reforestation amnesty to water quality?

Study Site

- Rio das Mortes Catchment, MG, Brazil
- $\sim$6,500 km^2
- Typical human-impacted Brazilian catchment



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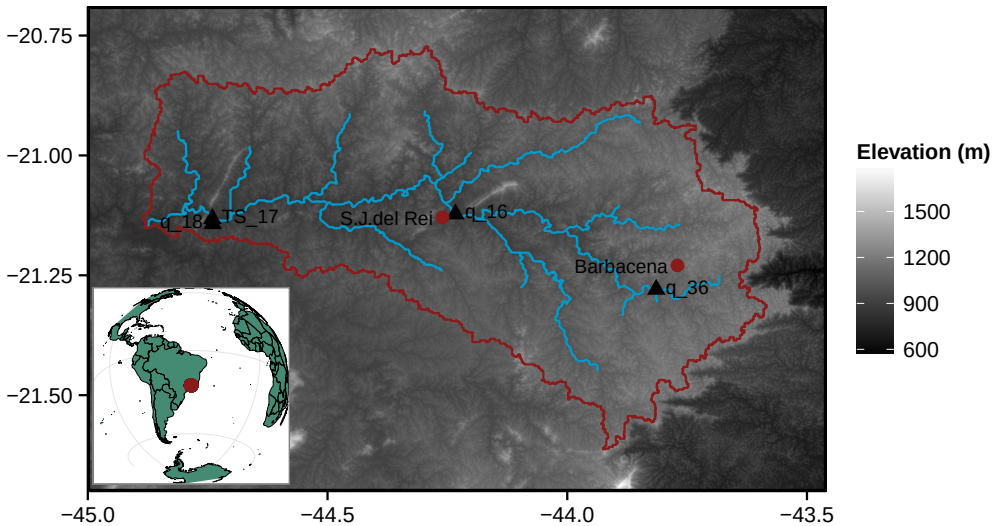
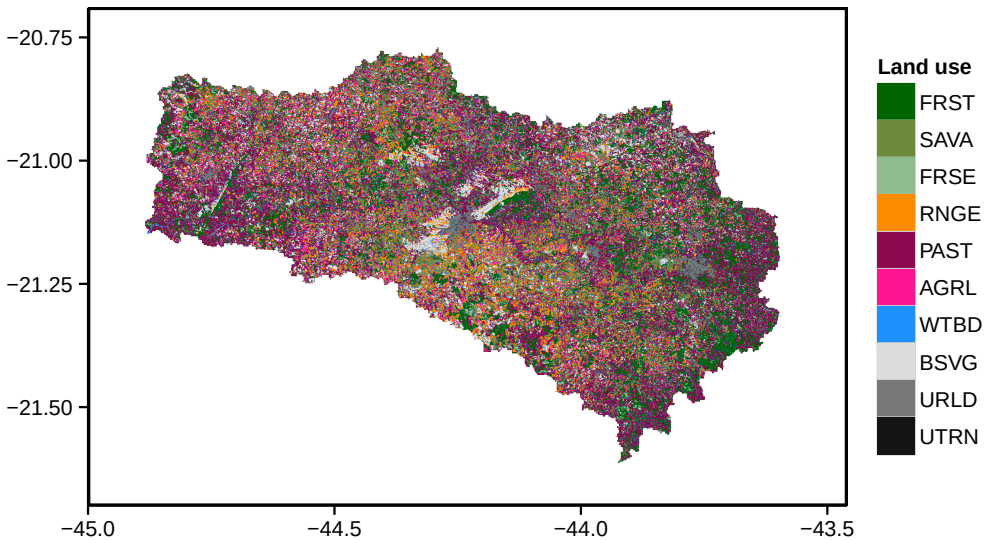


Land use	Area (%)
Atlantic Forest (FRST)	15.0
Cerrado Savannah (SAVA)	17.6
Pasture (PAST)	30.0
Crops (AGRL)	5.7
Other	31.7

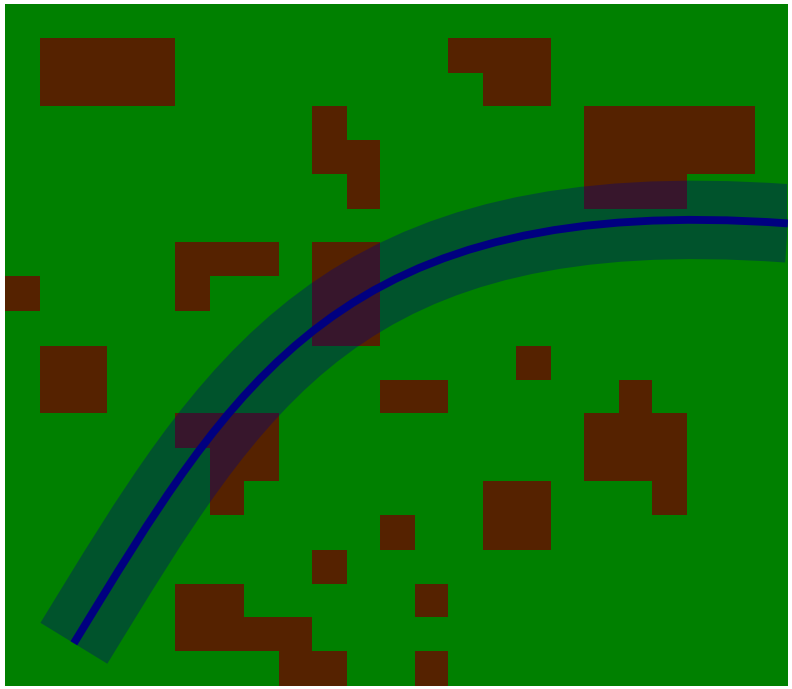


Methods

- Set up SWAT Model
  - DEM STRM (90 m)
  - Land use map (30 m; Silva-Junior et al., 2014)
  - FAO soil map (9 km)
  - 39 sub-catchments, 752 HRUs
- Calibration/Validation SWAT-CUP SUFI2
  - River discharge: 3 river gauges
  - Sediment concentration: 1 station
  - [3-montlhy sediment concentration $\rightarrow$ monthly sediment load series using Loadest (Runkel et al., 2004) via rloadest (Lorenz et al., 2013) in R]

Methods

- Simulating riparian reforestation
  - Estimate % degradation of riparian protected area
  - More detailed river network



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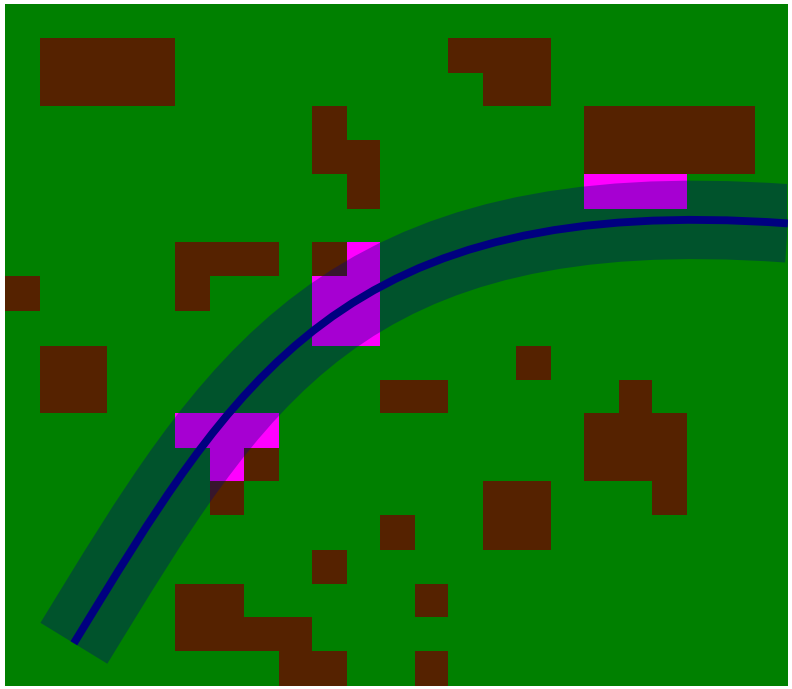

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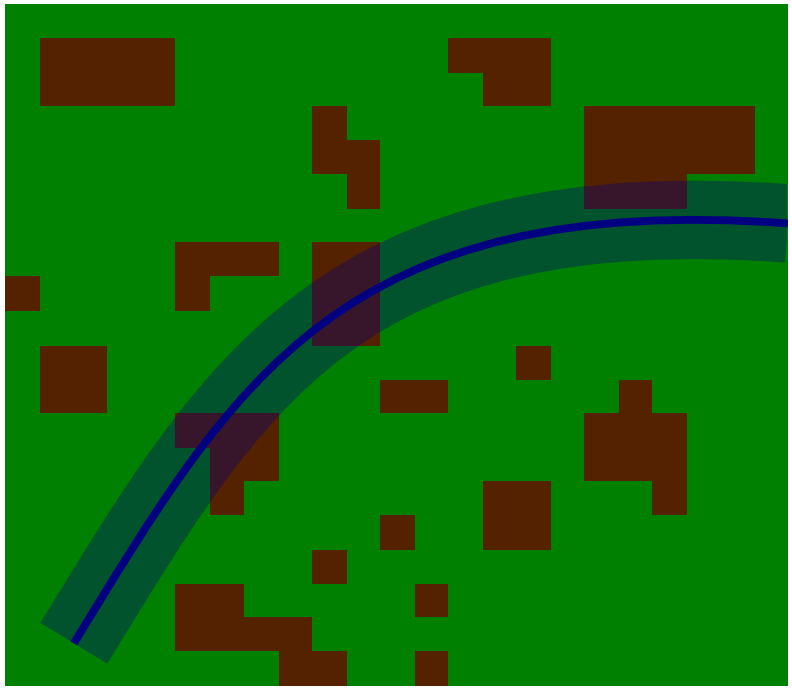
  - RPA $\times$ % degradation $=$ degradation m^2
  - Filter Strip function SWAT (HRU level)
  - $\textit{Filter Ratio} = \frac{\textit{Field Area}}{\textit{FS Area}}$



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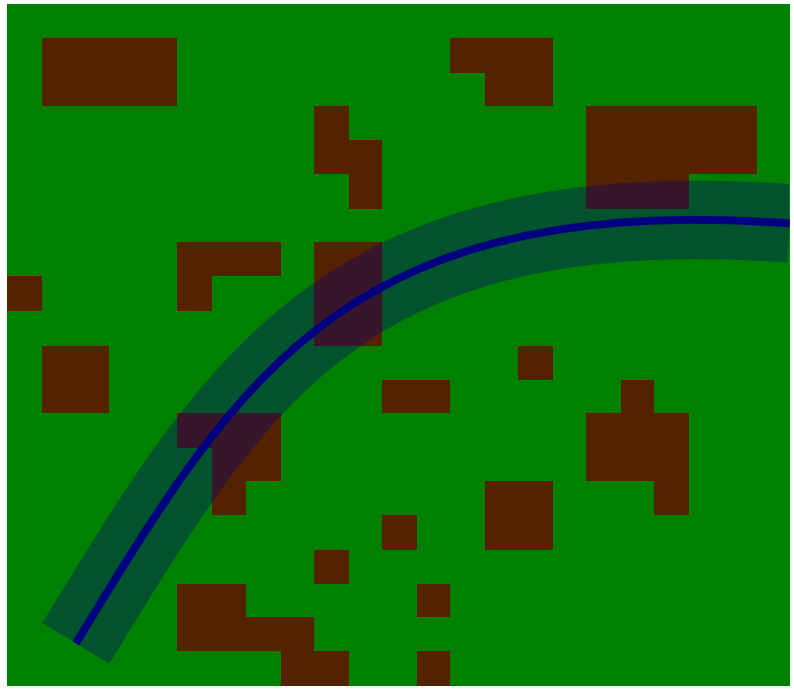
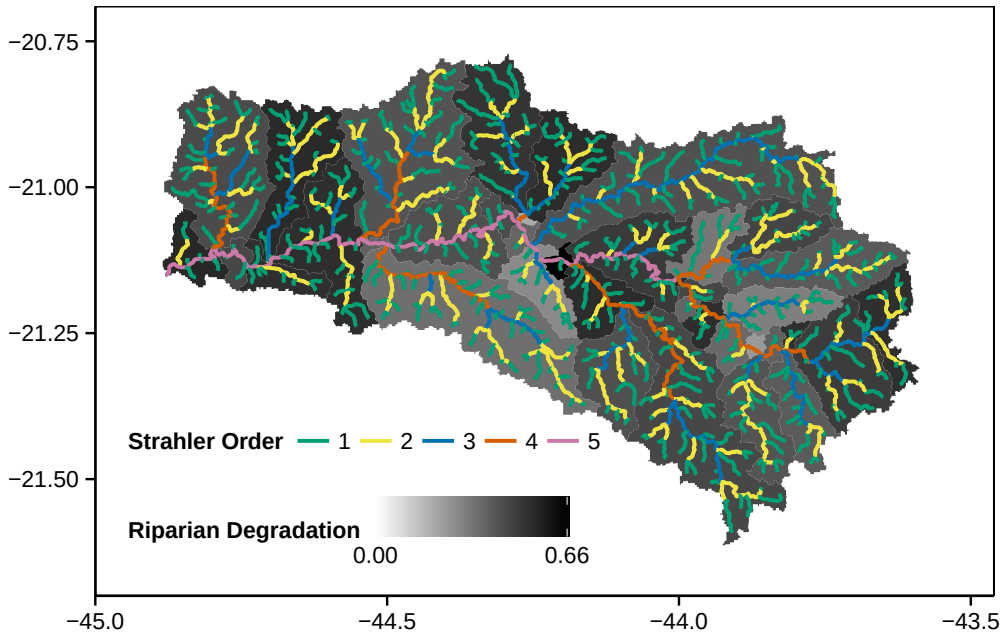
  - $Filter\ Ratio = \frac{Field\ \ Area}{FS\ \ Area}$
- Riparian reforestation scenarios
  - BFA: RPA according to channel width
    - channel $<$10 m $\rightarrow$ RPA 30 m
    - channel 10–50 m $\rightarrow$ RPA 50 m
  - 2$\times$BFA
  - Fixed width 5 m



Results

Riparian Degradation

- RPA width given the Strahler order (Boëchat et al., 2013)
  - 1^{st}–3^{rd} order $\rightarrow$ 30 m RPA
  - 4^{th}–5^{th} order $\rightarrow$ 50 m RPA
- RPA = 200 km^2, 3% of catchment area (6,500 km^2)
- Riparian degradation 48% (20–65% per sub-catchment)
- Whole catchment degradation 35.7%



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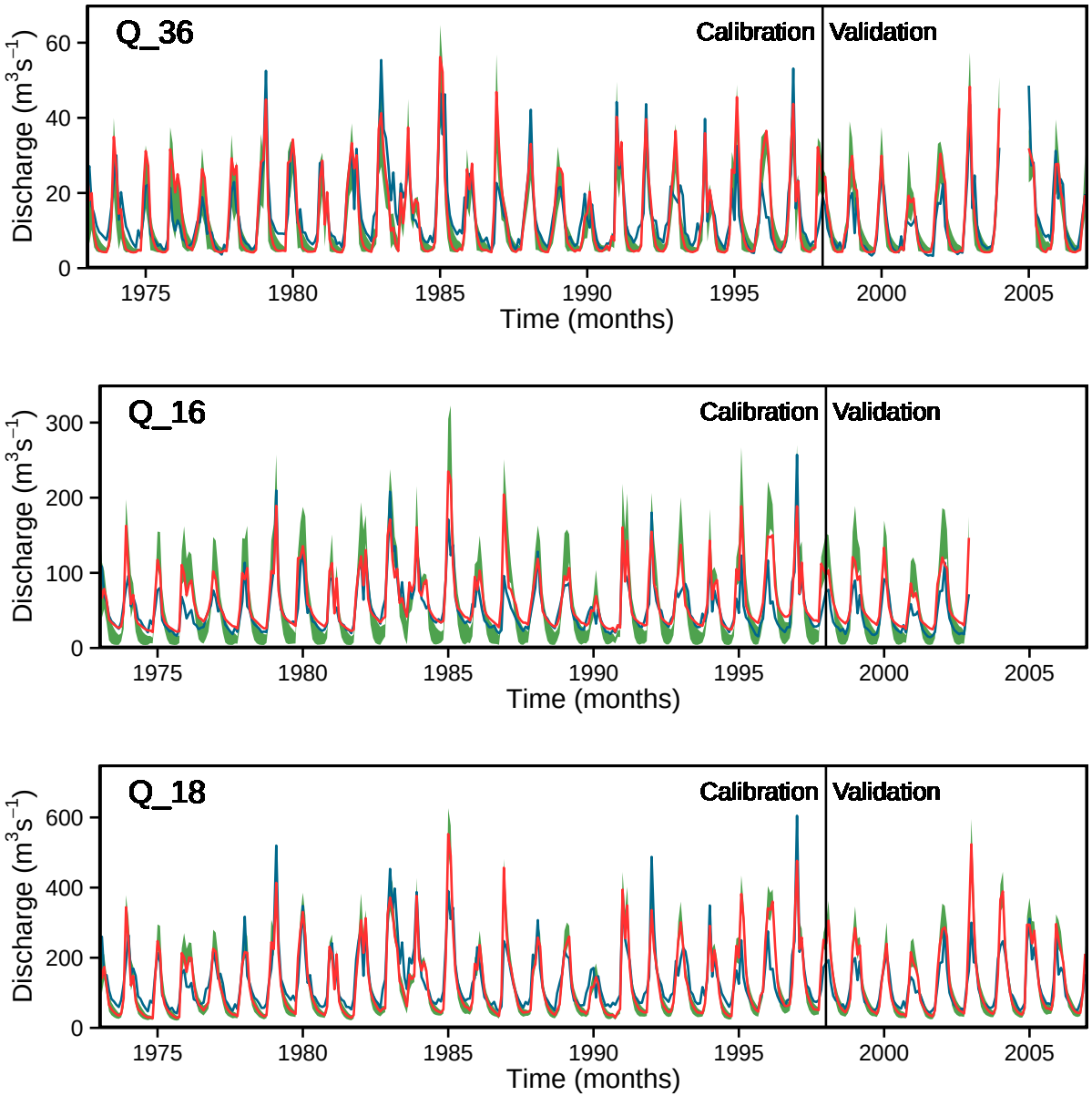
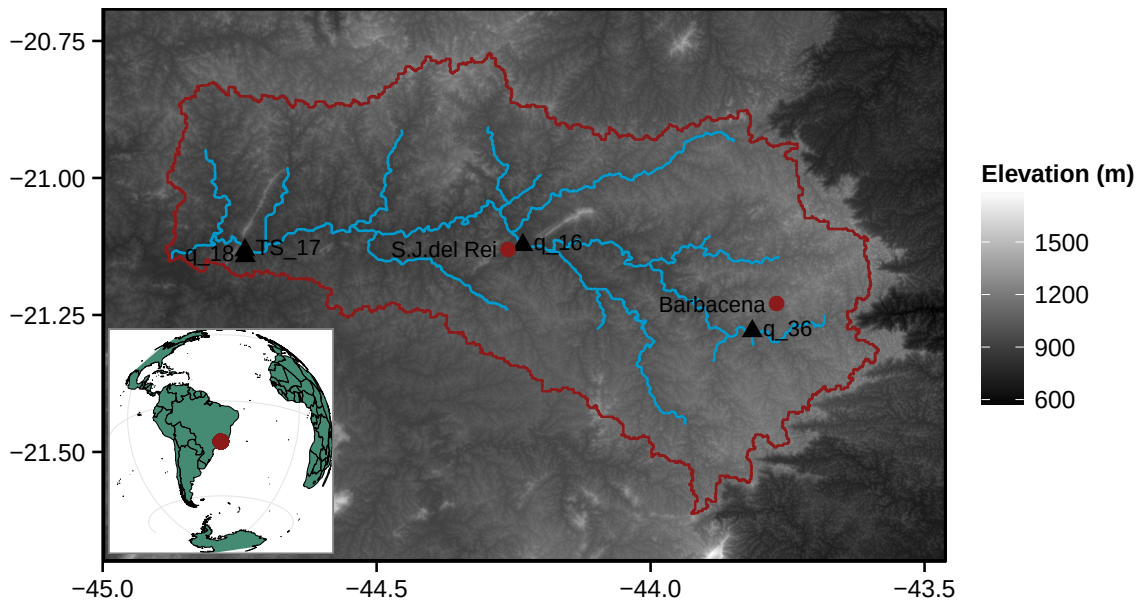
Model Calibration and Validation: River Discharge



Results

Model Calibration and Validation: River Discharge

Variable	Period	p-factor	r-factor	R^2	NS	bR^2	Pbias
Q_36	Calib.	0.49	0.76	0.70	0.57	0.68	−3.7
	Valid.	0.59	0.78	0.77	0.59	0.69	11.5
Q_16	Calib.	0.41	0.94	0.72	0.56	0.65	15.8
	Valid.	0.57	1.28	0.82	0.12	0.60	41.2
Q_18	Calib.	0.29	0.52	0.75	0.66	0.72	−6.2
	Valid.	0.41	0.68	0.86	0.44	0.72	13.0



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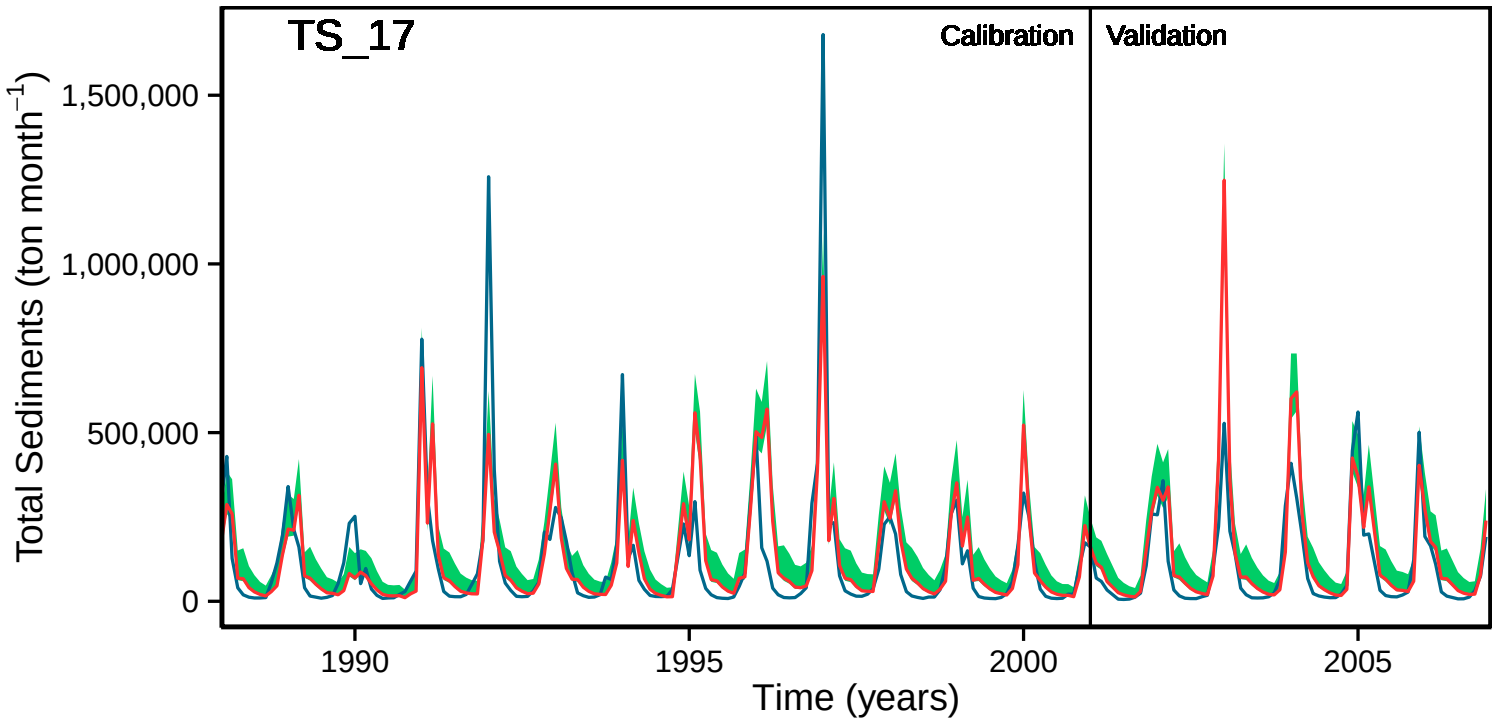
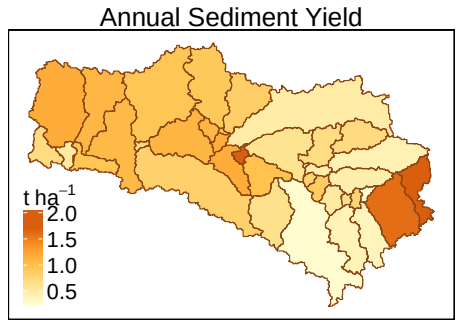


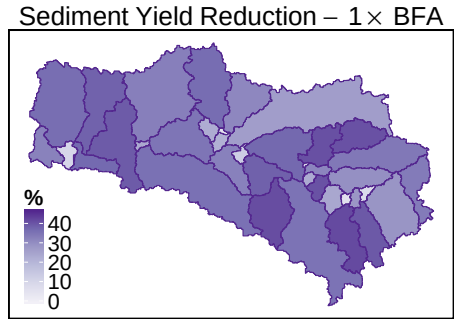
Variable	Period	p-factor	r-factor	R^2	NS	bR^2	Pbias
TS_17	Calib.	0.24	0.39	0.63	0.62	0.43	2.8
	Valid.	0.28	0.69	0.73	0.37	0.59	35.6

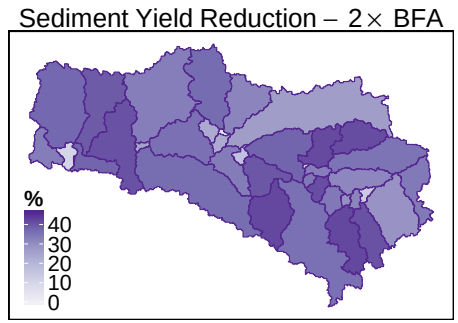
Results

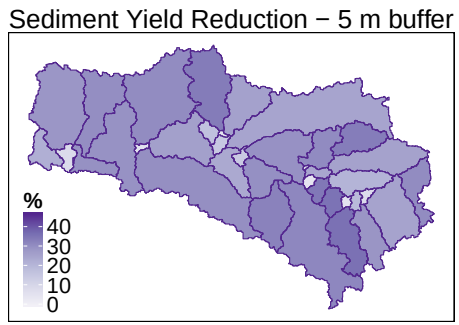
Sediment Yield and Sediment Yield Reduction

- Annual sediment yield 0.819 t ha^{-1}







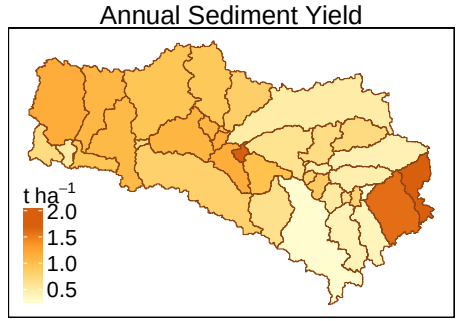


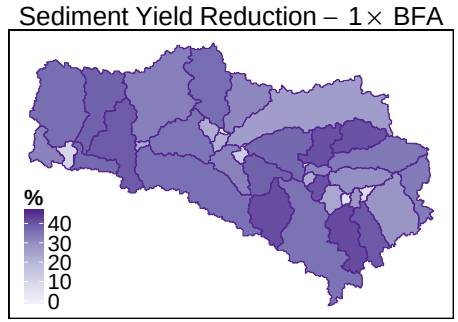
Results

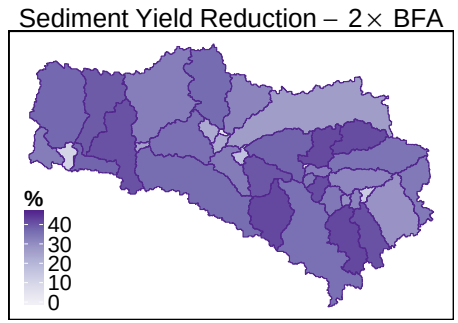
Sediment Yield and Sediment Yield Reduction

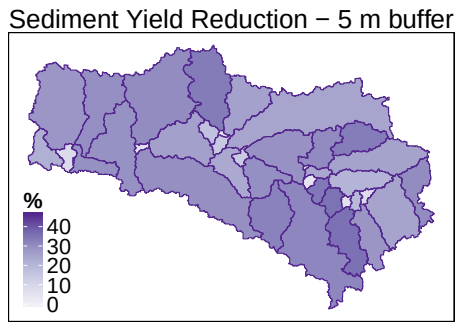
- Annual sediment yield 0.819 t ha^{-1}
- Sediment reduction with riparian restoration

BFA	34.0%
2×BFA	34.8%
5 m	28.0%









Conclusions

- Simulated reforestation of riparian vegetation pointed to a high sediment yield reduction, even by thin a riparian buffer corridor.
- Reforestation amnesty by BFA wastes opportunity of highly effective water quality improvement ($-\frac{1}{3}$ sediment export to streams).
- Suggested reforestation by homogeneous 5 m riparian corridor, despite sounding positive, does not account for possible deforestation of present riparian vegetation if the protection area is reduced

Acknowledgements

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Thank you for your time!

References

Boëchat, I., A. de Paiva, S. Hille, and B. Gücker. 2013. Land-use effects on river habitat quality and sediment granulometry along a 4th-order tropical river [Efeitos do uso do solo sobre a qualidade de habitat e a granulometria do sedimento ao longo de um rio tropical de 4a ordem]. Revista Ambiente e Água **8**:54–64.

Lorenz, L., R. Runkel, and L. De Cicco, 2013. rloadest: River Load Estimation.

Runkel, R. L., C. G. Crawford, and T. A. Cohn, 2004. Load Estimator (LOADEST): A FORTRAN Program for Estimating Constituent Loads in Streams and Rivers. *in* U.S. Geological Survey Techniques and Methods Book 4. United States Geological Survey.

Silva-Junior, E. F., T. P. Moulton, I. G. Boëchat, and B. Gücker. 2014. Leaf decomposition and ecosystem metabolism as functional indicators of land use impacts on tropical streams. Ecological Indicators **36**:195 – 204.