Escola Politécnica
Departamento de Engenharia Hidráulica e Ambiental

Universidade de São Paulo

PHD5036
Modelagem de Processos Hidrológicos

Aplicação RUBEM Hydrological
Bacia do Rio Ipojuca - PE

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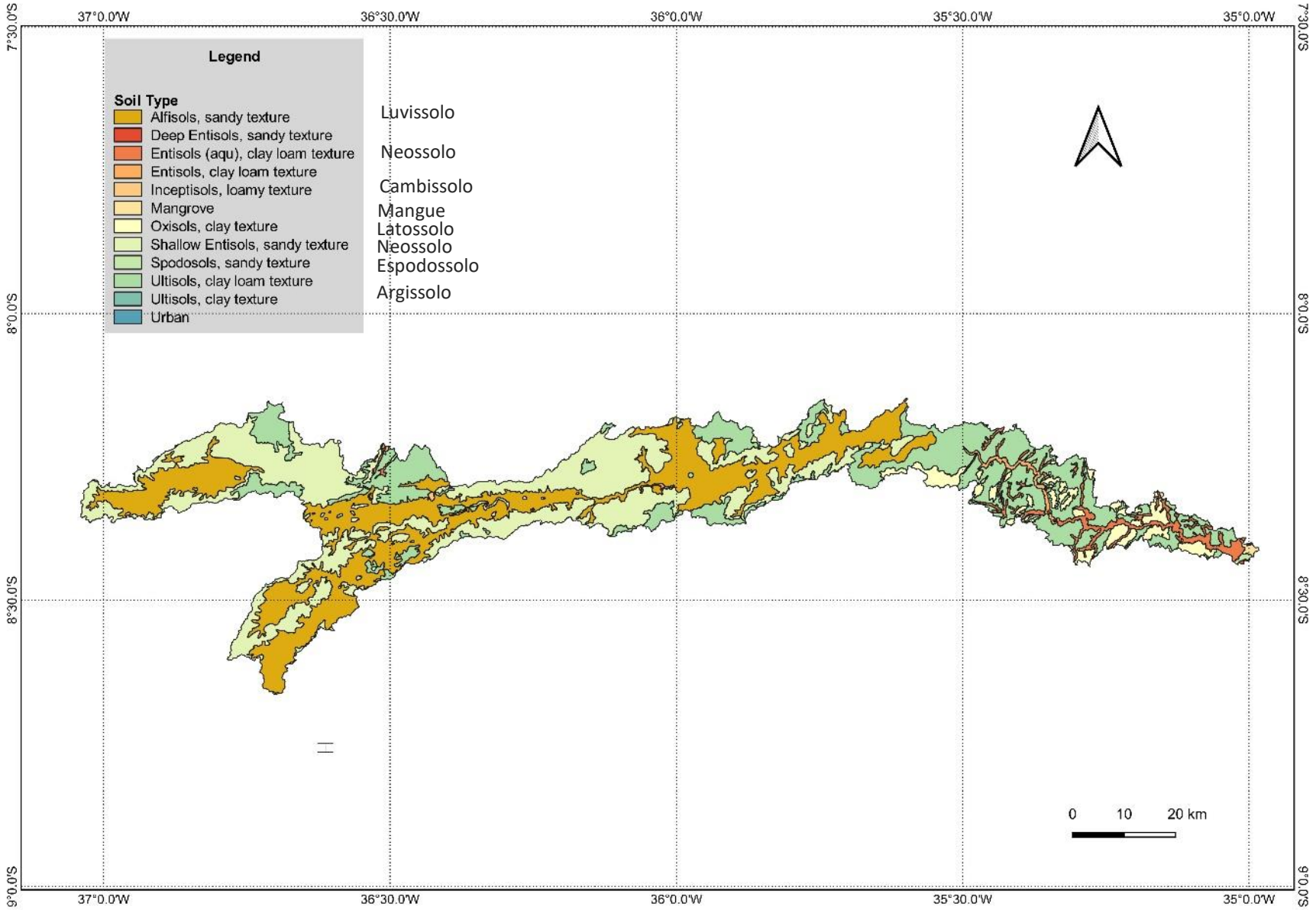
Laboratório de Sistemas de Suporte a Decisões
Recursos Hídricos e Meio Ambiente

Solo

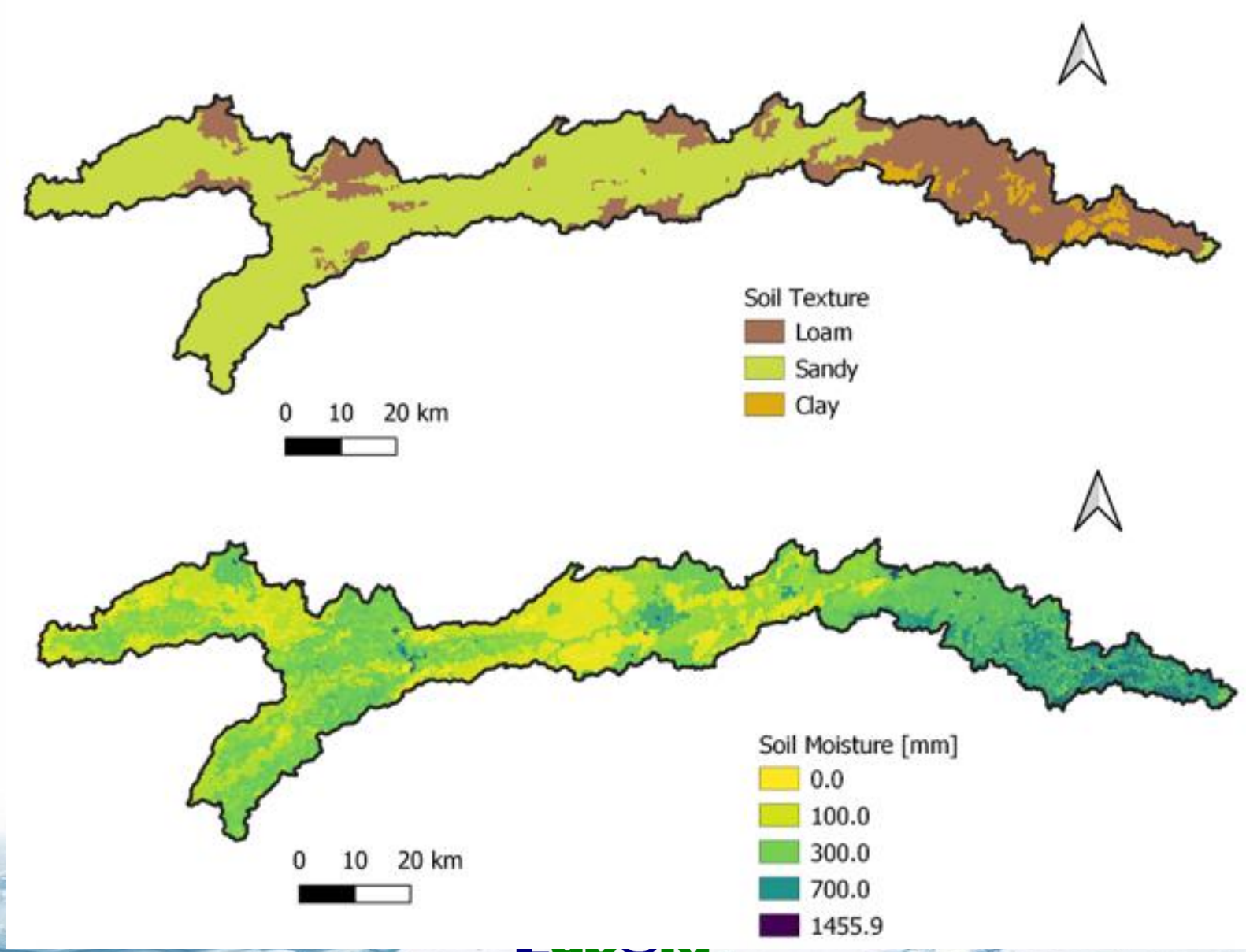

Legend
Soil Type
Alfisols, sandy texture
Deep Entisols, sandy texture
Entisols (aqu), clay loam texture
Entisols, clay loam texture
Inceptisols, loamy texture
Mangrove
Oxisols, clay texture
Shallow Entisols, sandy texture
Spodosols, sandy texture
Ultisols, clay loam texture
Ultisols, clay texture
Urban
Luvissolo
Neossolo
Cambissolo
Mangue
Latossolo
Neossolo
Espodossolo
Argissolo
37°0.0'W
36°30.0'W
36°0.0'W
35°30.0'W
35°0.0'W
7°30.0'S
8°0.0'S
8°30.0'S
9°0.0'S
0
10
20 km

Características físico-hídricas das classes de solo

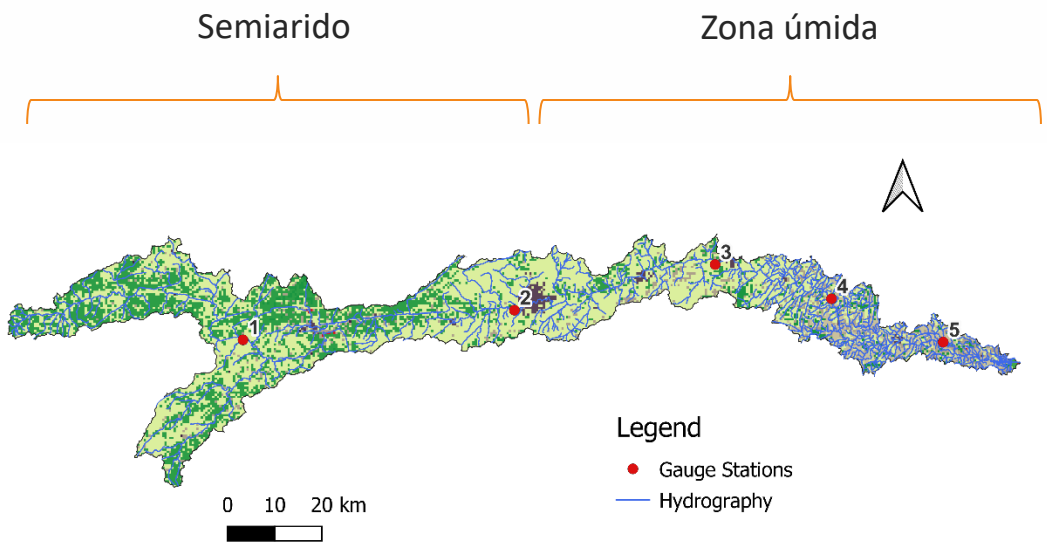
Soil classification[1]	K_R[2]	Dg[3]	Z_r[4]	θ_{SAT}[5]	θfc[6]	θw[7]
Ultisols, clay loam texture	153.16	1.54	150.39	0.46	0.26	0.19
Inceptisols, loamy	235.71	1.31	137.45	0.55	0.29	0.18
Spodosols, sandy	253.91	1.41	131.25	0.47	0.22	0.08
Entisols, clay loam	89.35	1.54	114.30	0.42	0.31	0.20
Oxisols, clay texture	237.27	1.25	200.81	0.58	0.36	0.27
Deep Entisols, sandy texture	367.88	1.59	200.00	0.33	0.08	0.03
Shallow Entisols, Sandy texture	367.88	1.59	60.00	0.33	0.08	0.03
Entisols, clay loam texture	153.16	1.46	120.00	0.43	0.28	0.22
Ultisols, clay texture	164.16	1.38	177.20	0.52	0.38	0.28
Alfisols, sandy texture	367.88	1.64	148.07	0.38	0.29	0.17
Mangrove	367.88	1.31	120.00	0.33	0.12	0.06
Ultisols, loamy texture	352.39	1.51	147.50	0.47	0.22	0.14
Inceptisols, clay texture	267.69	1.18	132.52	0.54	0.37	0.22
Oxisols, loamy texture	187.77	1.31	189.77	0.45	0.26	0.15
Histosols	89.35	1.54	50.00	0.42	0.31	0.20
Urban Area IRB	203.53	1.48	140.82	0.47	0.24	0.13
Urban Area UIB	252.48	1.22	166.67	0.56	0.37	0.24

[1]Relation between Brazilian Soil Classification and US soil taxonomy: Argissolos (Ultisols), Cambissolos (Inceptisols), Latossolos (Oxisols), Organossolos (Histosols), Neossolos (Entisols quartzipsamment), Espodossolos (Spodosols), Gleissolos (Entisols -Aqu-alf-and-ent-ept); [2]Hydraulic Conductivity [mm/month]; [3]Soil Bulk Density [g/cm^3]; [4]Root-zone Depth [cm]; [5]Saturated capacity water content [θ (cm^3/cm^3)]; [6]Wilting Point water content [θ (cm^3/cm^3)]; [7]Field capacity water content [θ (cm^3/cm^3)]

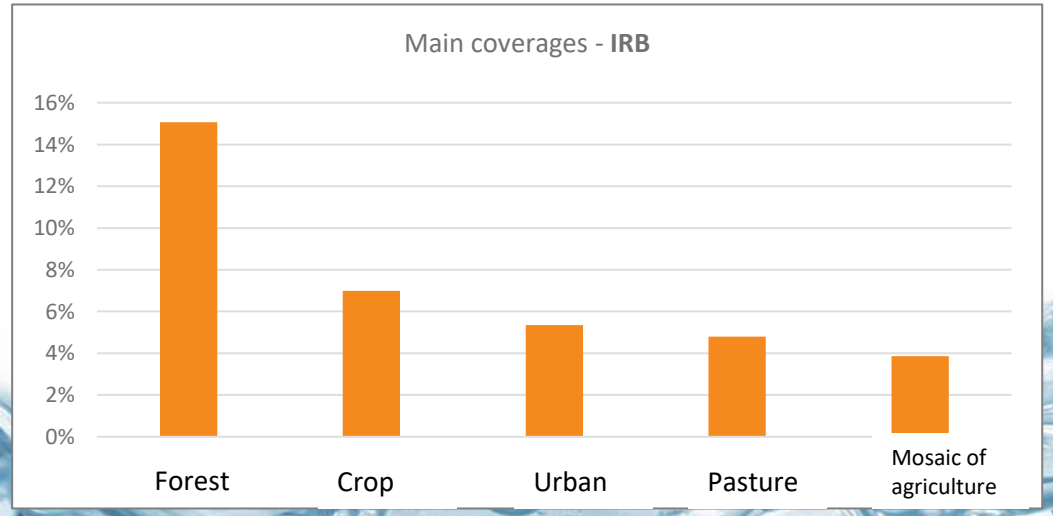
Textura e umidade do solo (abril/2008)



Cobertura na bacia e postos Flu



- A more significant number of coverages (16 classes)
- Natural forest closer to the coast and Savanna Formation in center region.
- Average pasture around 5% of the area between 1985-2018



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Frações de área na célula e rugosidade para cada cobertura

Coberturas MapBiomas coleção 4.0	Frações de área				Rugosidade
	av	as	ao	ai	Manning
Formação Florestal	1	-	-	-	0.16
Formação Savânica	1	-	-	-	0.2
Mangue	0.7	0.3	-	-	0.15
Floresta Plantada	1	-	-	-	0.16
Área Úmida Natural não Florestal	0.7	0.3	-	-	0.15
Formação Campestre	0.9	0.1	-	-	0.2
Apicum	0.7	0.3	-	-	0.15
Afloramento rochoso	0.2	0.3	-	0.5	0.045
Outra Formação Natural não Florestal	0.9	0.1	-	-	0.2
Pastagem	0.8	0.2	-	-	0.15
Agricultura	0.8	0.2	-	-	0.17
Cultura Anual e Perene	0.8	0.2	-	-	0.17
Cultura Semi-Perene	0.8	0.2	-	-	0.17
Mosaico de Agricultura e Pastagem	0.8	0.2	-	-	0.16
Praia e Duna	0.3	0.7	-	-	0.04
Infraestrutura Urbana	0.4	0.1	-	0.5	0.6
Mineração	-	1	-	-	0.045
Outra Área não Vegetada	0.4	0.1	-	0.5	0.6
Rio, Lago e Oceano	-	-	1	-	0.01
Aquicultura	-	-	1	-	0.15

Legenda: av - área vegetada / as - solo nu / ao - água / ai - impermeável

Dados de entrada para aplicação – Dataset input

- Spatial Resolution: 500m
- Temporal Resolution: monthly
- Period time: January/2000 - December/2018
- Available data: meteorological forcings (precipitation and evapotranspiration), hydrologic budget terms (evapotranspiration, runoff, soil moisture storage, and total storage) and maps of gridded parameters (land mask, soil layers, total storage capacity, and NDVI)
- https://labsid.poli.usp.br/softwares/rubem-hydrological/
  - Baixe os dados para um drive no computador (salve no HD)
  - Input: contém todos os dados .tif e .txt
  - output

Índices de performance para calibração

$$RMSE = \sqrt{\frac{\sum_1^N (Q_s - Q_o)^2}{N}}$$ Singh et al. (2005)

$$n_t = \frac{SD}{RMSE} - 1$$

Ritter et al. (2013)

$$NSE = 1 - \left(\frac{1}{n_t + 1}\right)^2$$

$$RB = \frac{\frac{1}{N} \cdot \sum_1^N (Q_s - Q_o)}{Q_o}$$ McCuen et al. (2006)

$$F(Q_s) = u \cdot F(Q_0)$$

$$F(Q_s) = \frac{i}{N_s}$$

$$F(Q_o) = \frac{i}{N_o}$$

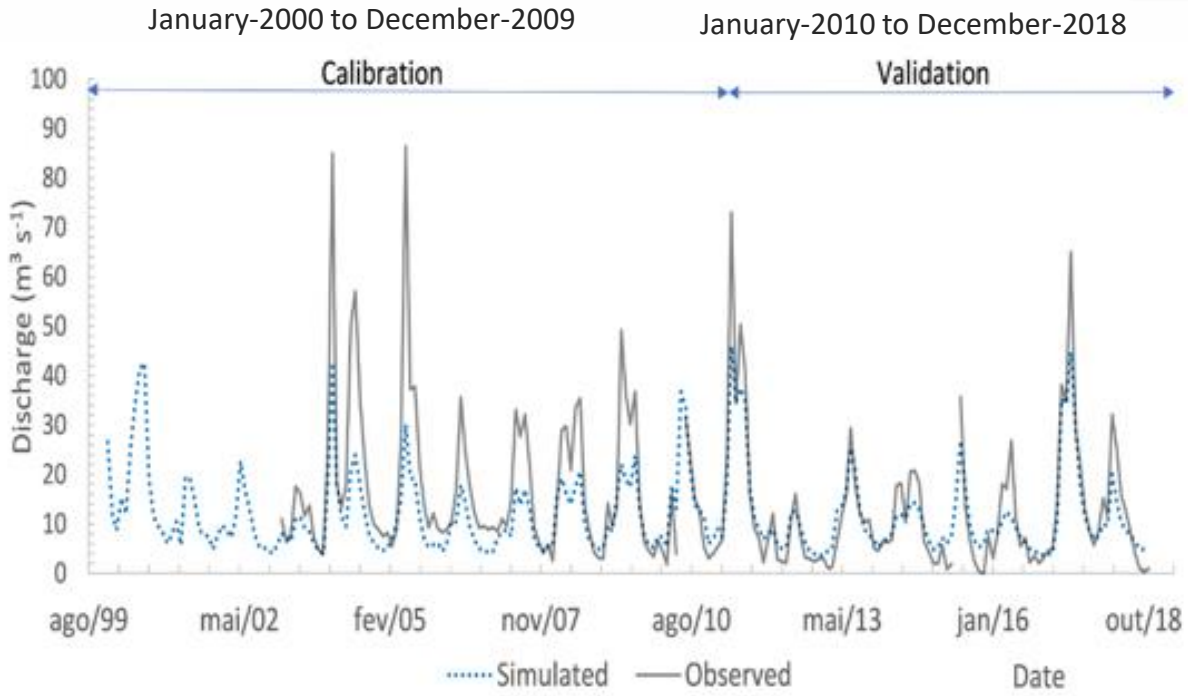
O'Brien et al. (2001)

Performance classification	RMSE	NSE	RB
Very good	$\geq \frac{SD}{3.2}$	≥ 0.9	≥ -0.12 to ≤ 0.12
Good	$\geq \frac{SD}{2.2}$ to $< \frac{SD}{3.2}$	0.8 to 0.9	≥ -0.18 to < -0.12 or ≥ 0.12 to < 0.18
Acceptable	$\geq \frac{SD}{1.2}$ to $< \frac{SD}{2.2}$	0.65 to 0.8	≥ -0.22 to < 0.18 or ≥ 0.18 to < 0.22
Unsatisfactory	$< \frac{SD}{1.2}$	< 0.65	≤ -0.22 or ≥ 0.22

$RMSE$ – Root Mean Square Error (-);
SD – standard deviation of observed data;
n_t – number of times that the observations variability is greater than the mean error;
NSE – Nash-Sutcliffe Efficiency (-);
RB – relative bias (-);
Q_o– observed discharge ($m^3\ s^{-1}$);
Q_s – simulated discharge ($m^3\ s^{-1}$);
N – sample size;
N_o – sample size of observed discharge;
N_s - sample size of simulated discharge;
$F(Q_o)$ – cumulative distribution function of the percentile of Q_o;
$F(Q_s)$ – cumulative distribution function of the percentile of Q_s

Parâmetros calibrados para a bacia do Rio Ipojuca

Parameter	Min	Calibrado	Max
Interception parameter (α)	1	4.415	10
Parameter related to soil moisture (b)	0.01	0.078	1
Land use factor weight (w1)	0.1	0.510	1
Soil factor weight (w2)	0.1	0.120	1
Slope factor weight (w3)	0.1	0.370	1
Regional Consecutive Dryness level (RCD)	0.01	5.375	10
Flow direction factor (f)	0.01	0.581	1
Baseflow recession coefficient (α_{gw})	0.01	0.922	1
Flow recession coefficient (x)	0.01	0.307	1

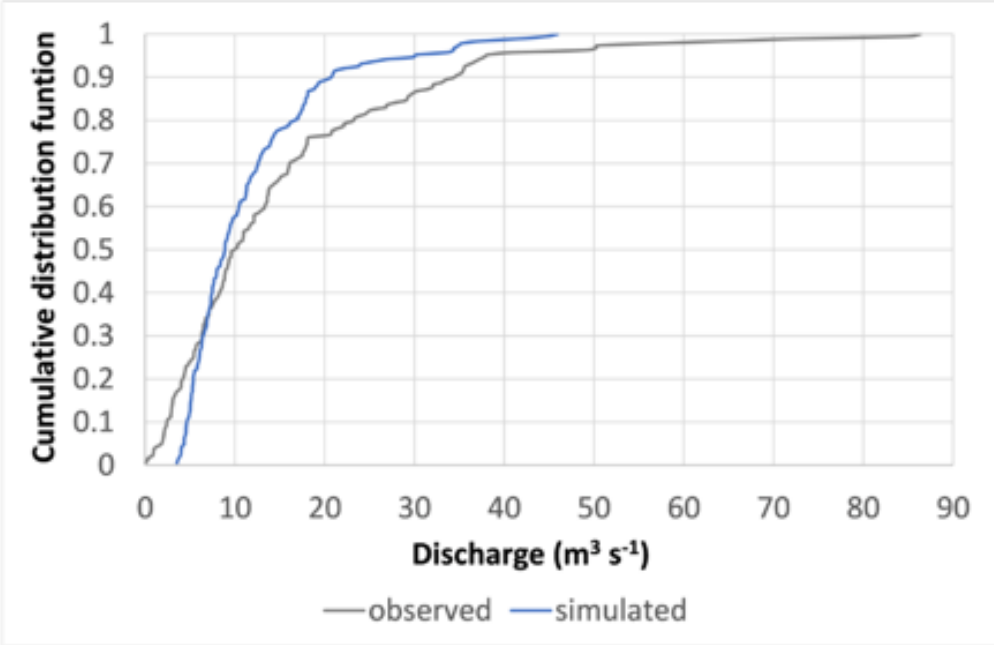


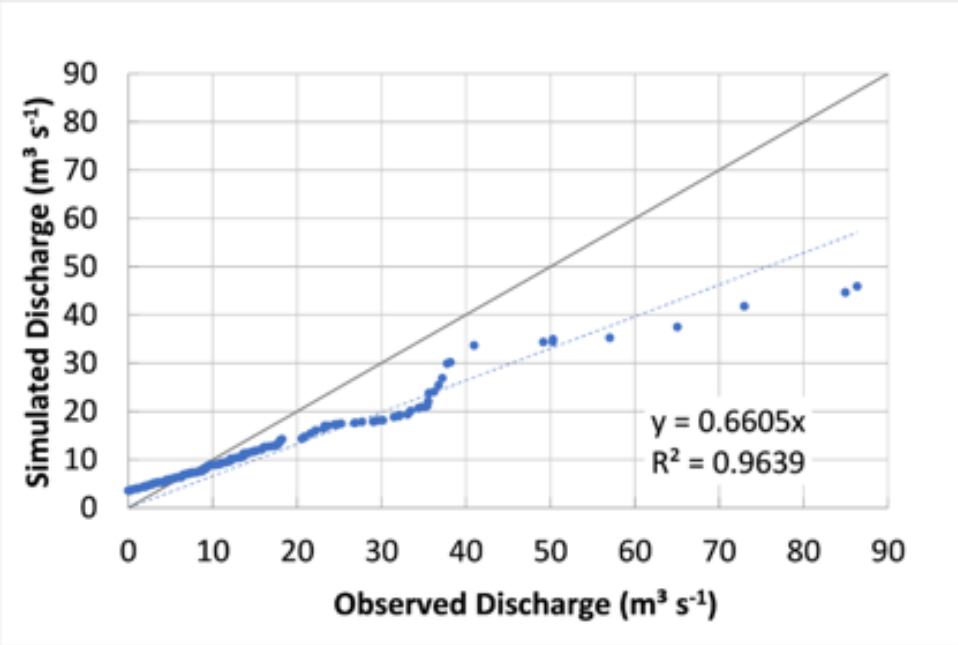
Area	Calibration Period					Validation Period				
(km²)	N	SD	RMSE	NSE	RB	N	SD	RMSE	NSE	RB
672	58	3.357	3.078	0.159	0.315	80	0.194	1.528	−61.2	12.71
2000	100	6.517	4.225	0.58	0.781	104	3.316	1.123	**0,885**	2.041
2650	105	7.145	5.355	0.438	0.818	68	6.712	**6.258**	0.131	1.03
2960	117	11.285	6.847	0.632	**0.01**	104	9.328	5.057	0.706	0.342
3310	82	16.144	12.32	0.417	−0.397	105	9.070	5.355	0.652	**0.007**

Legend: black number = Unsatisfactory; black underlined number = Acceptable; bold number = Good; bold underlined number = Very good; N - sample size; SD – standard deviation.

Parâmetros calibrados para a bacia do Rio Ipojuca

Permanência e regressão assíncronas

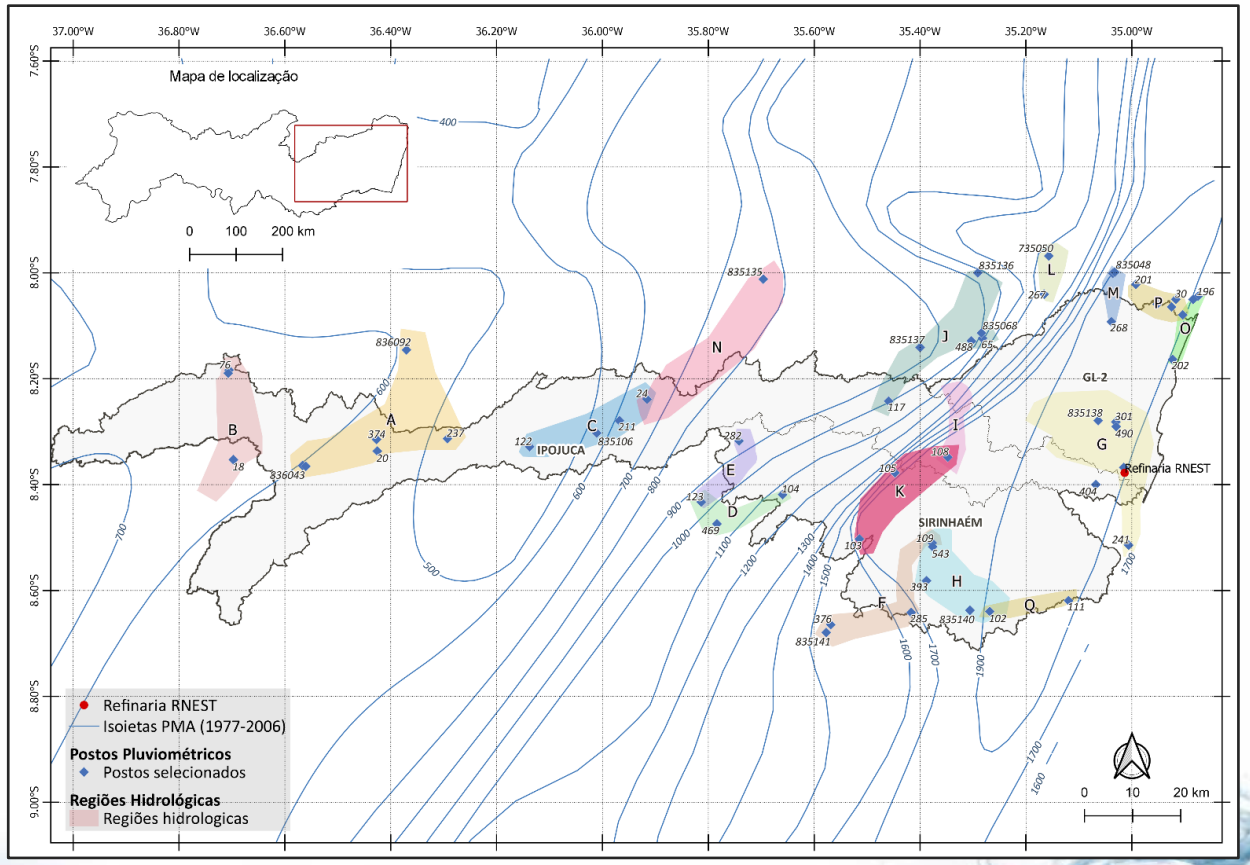


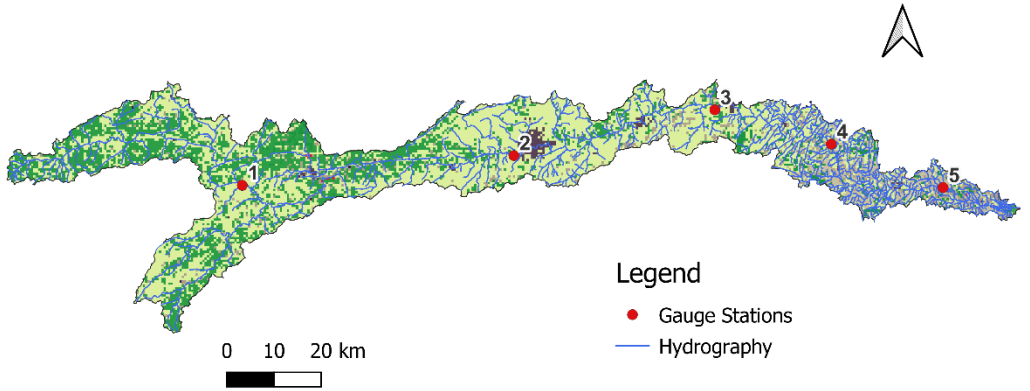


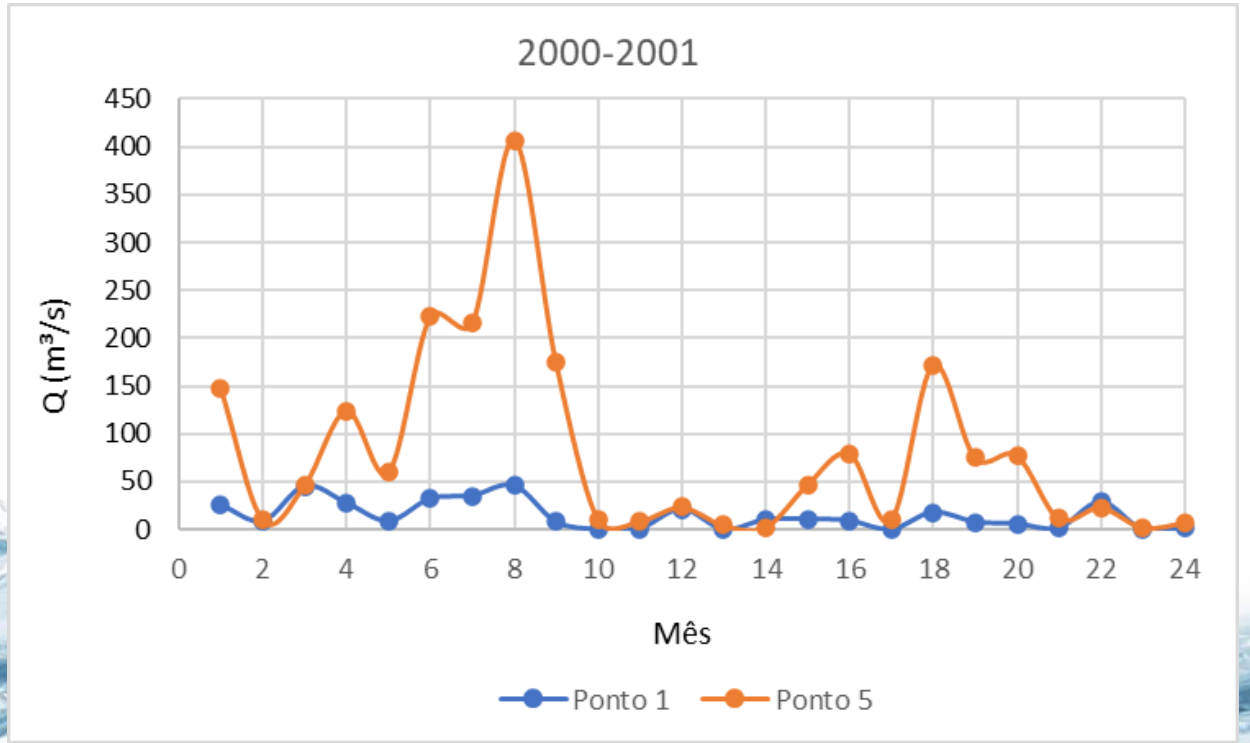
- O modelo não reproduziu satisfatoriamente as vazões mais altas
- O modelo subestimou as vazões média em 23,5% no período úmido e em 9,3% no período seco

Resultados para os anos 2000 - 2001

Mapa de Isoietas e regiões pluviométricas homogêneas







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Exercício

ANÁLISE DOS RESULTADOS DA APLICAÇÃO DO MODELO RUBEM NA BACIA DO RIO IPOJUCA

Méllo Júnior et al. (2022) and Suplementary Archive

Rode o modelo, consulte o artigo e verifique:

1. A influência dos parâmetros do modelo nas vazões estimadas
2. As heterogeneidades de solo e de uso e ocupação no escoamento

Referências

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