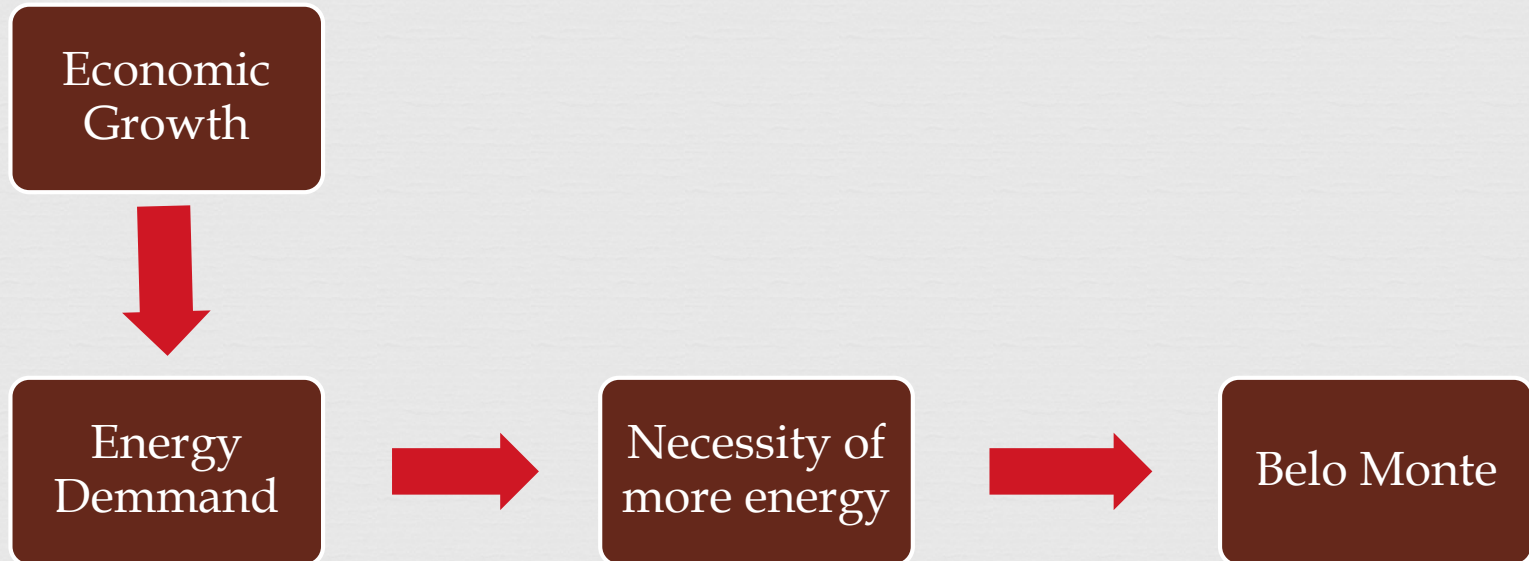


Impacts of Land Use Change on Southeast Amazon Basin Streamflow



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Celso Bandeira de Melo Ribeiro

Introduction



Modeling

Modelling



Advantages

Simulate
different
scenarios

Economy of
time and
money

Support to
decision
makers

Disadvantages

It is not 100%
accurate

Necessity of
data in
quantity and
quality

SWAT Model



Developed by:

- USDA Agricultural Research Service
- Texas A&M AgriLife Research

Global application:



SWAT Model



Input

- Digital Elevation Model - DEM
- Weather data
- Soils maps
- Soil use and occupation

Output

- Hydrology
- Sediments Transportation
- Plant growth
- Nitrogen Cycle
- Phosphorus Cycle

SWAT - CUP



☞ Software to Calibrate and Validate a model

☞ Time Optimizer:

- Identification of most sensitive parameters
- Identification of best values for each parameter

Objective



Calibrate a SWAT model for Xingu River sub basin using SWAT and SWAT-CUP and identify the influence of soil use changes on the flow of the main river.

Metodology

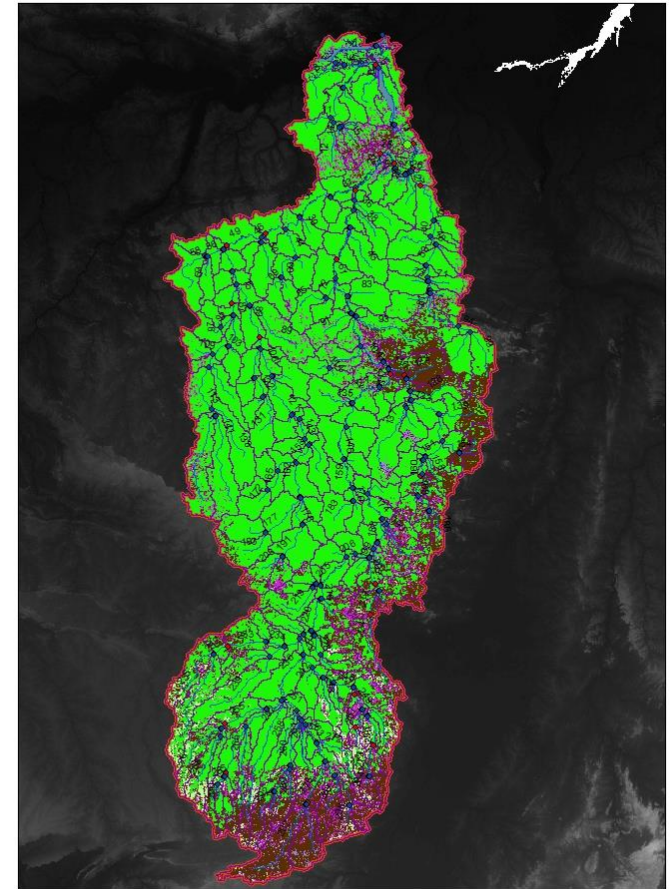
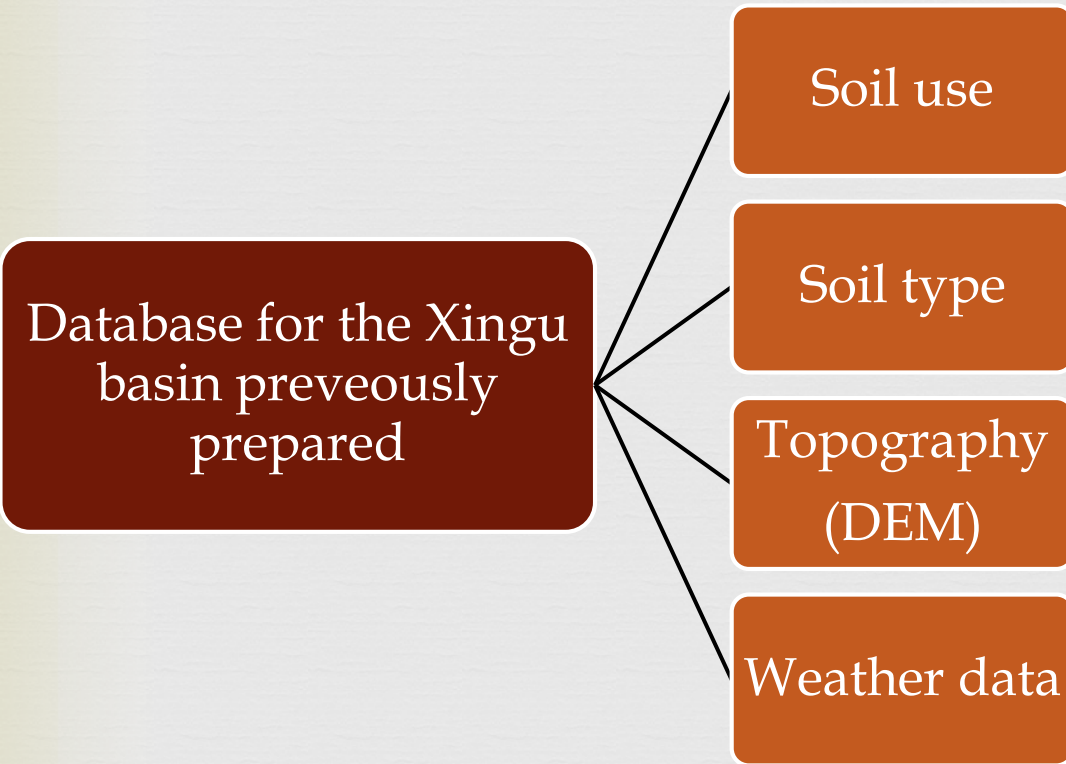
Study Area:

→ Xingu River Basin

→ Area = 509 000 km²

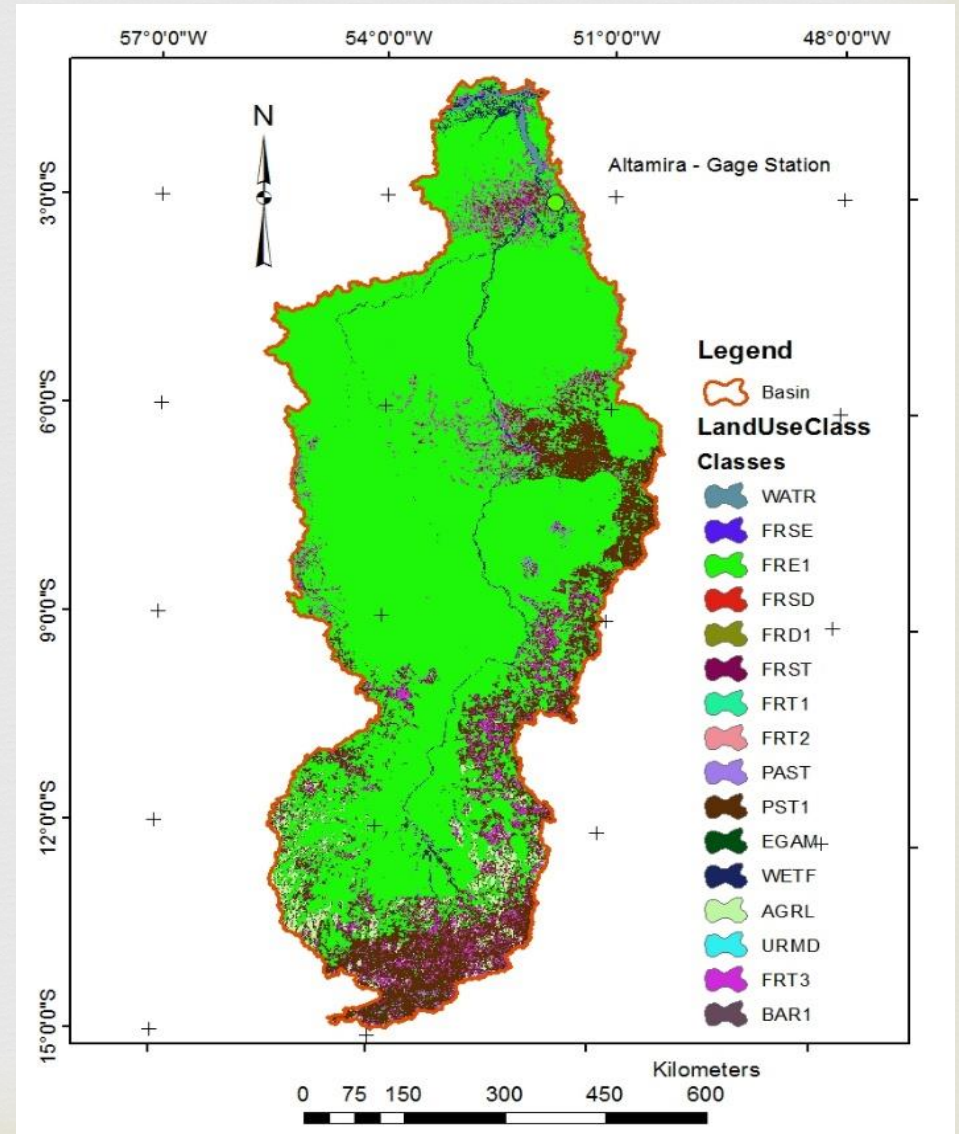


Metodology



Land Use

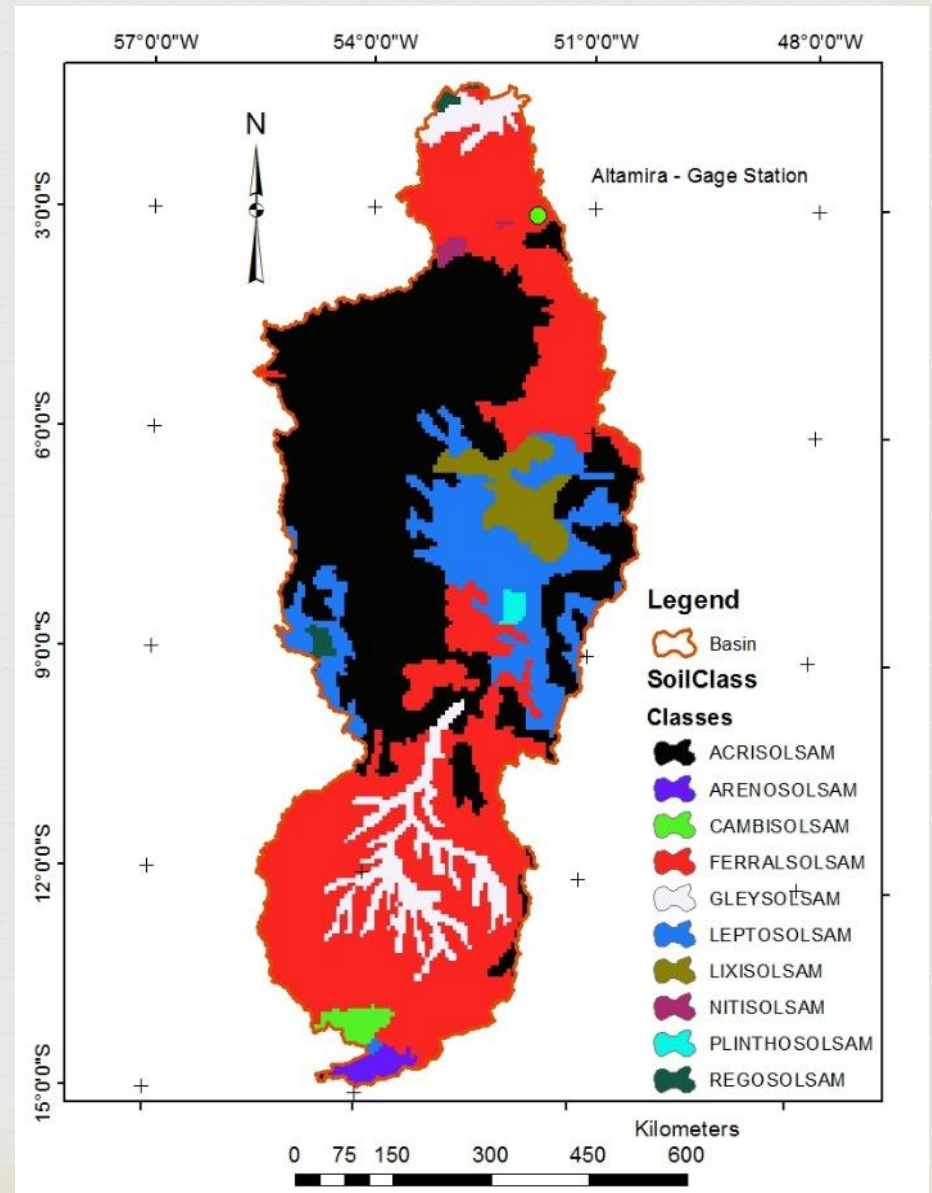
MODIS - MCD12Q1



Types of Soil

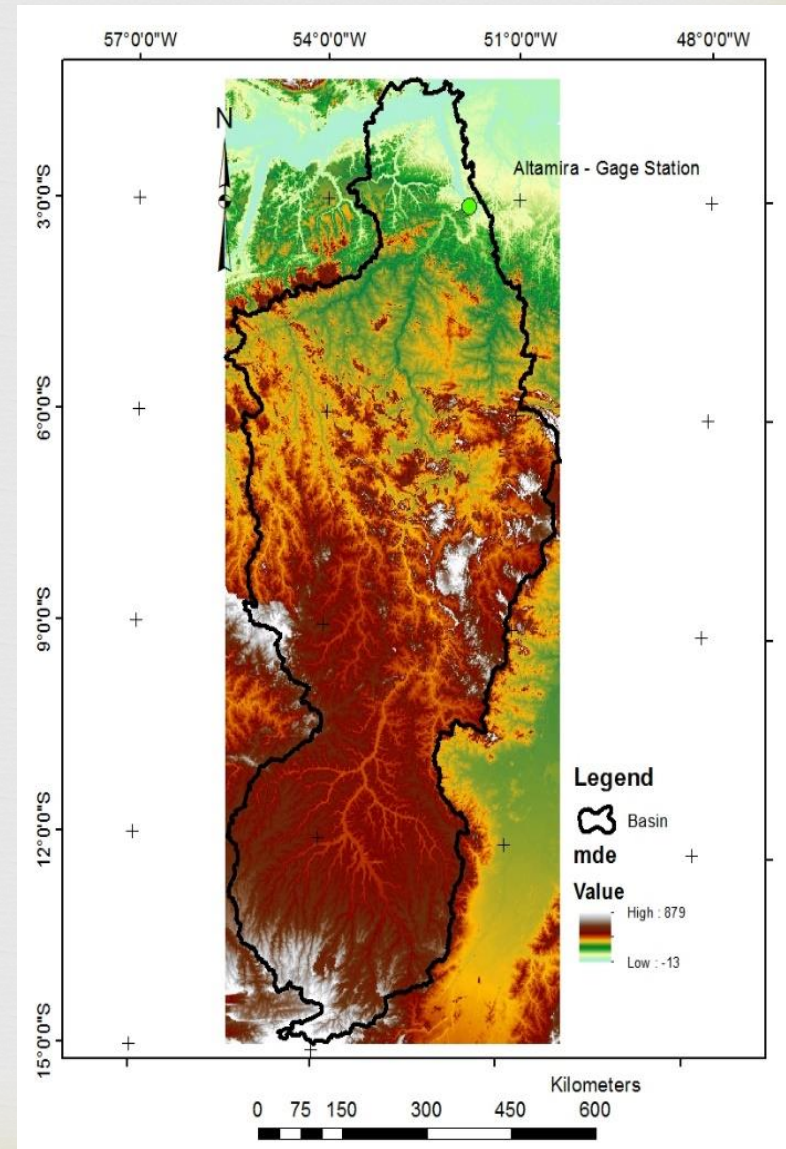
ISRIC - World Soil Information

<http://www.isric.org/>



Digital Elevation Model - DEM

<http://hydrosheds.cr.usgs.gov/dataavail.php>

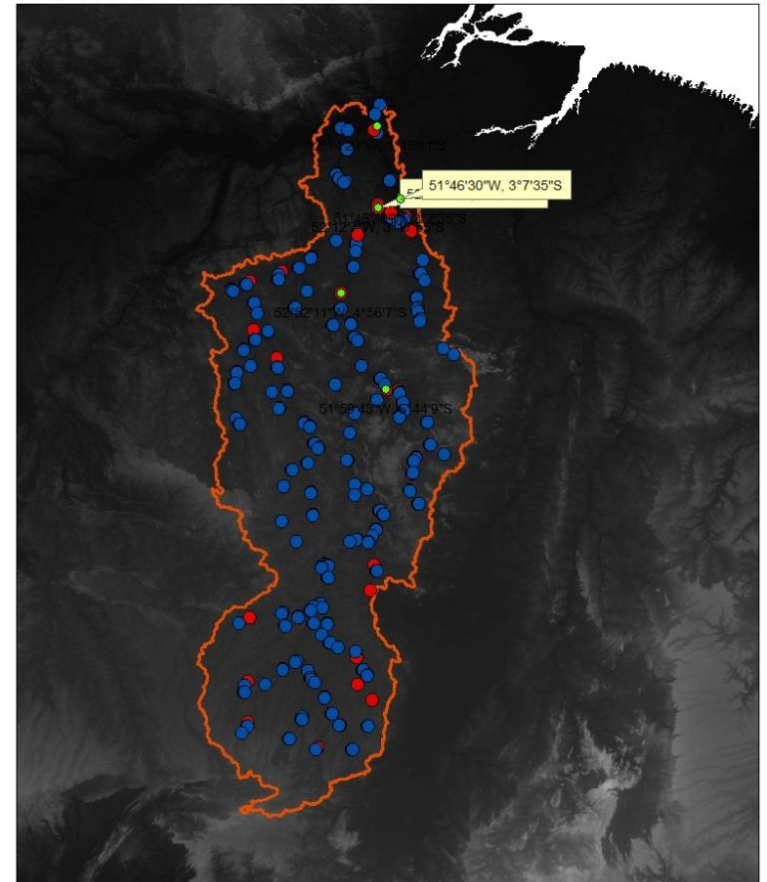


Weather Data

☞ Data from monitoring stations:

☞ INMET

☞ ANA



Use of monthly flows to calibrate the model



Inventory of monitoring stations
from National Water Agency -
ANA

Número	Código	Nome Est.	Tipo	Código Ric	Curso d'agua	Entidade	Lat	Long	Área	Início	Fim
1	2E+07	PASSAGEM BR-080	FDT	1.9E+07	RIO XINGÚ	ANA	-10 48 00	-53 07 00	136,937.00	10/1/1975	3/1/1984
2	2E+07	KOKRAIMORO	F	1.9E+07	RIO XINGÚ	ANA	-07 34 00	-52 40 00	197,705.00	2/1/1979	8/1/1983
3	2E+07	PORTO SEGURO	F	1.9E+07	RIO XINGÚ	ANA	-07 13 03	-52 35 13	202,000.00	11/1/1983	1/1/1987
4	2E+07	BOA SORTE	FDSQT	1.9E+07	RIO XINGÚ	ANA	-06 44 03	-51 59 43	206,863.00	1/1/1977	
5	2E+07	UHE SÃO FELIX	F	1.9E+07	RIO XINGÚ	ANA	-06 47 53	-52 00 03	208,715.00	1/1/1976	12/1/2005
6	2E+07	SÃO FELIX DO XINGU	FDQ	1.9E+07	RIO XINGÚ	ANA	-06 36 00	-52 03 00	250,626.00	2/1/1976	3/1/1998
7	2E+07	JOARI	F	1.9E+07	RIO XINGÚ	ANA	-06 34 00	-52 05 00	272,000.00	10/1/1981	12/1/1998
8	2E+07	UHE POMBAL	F	1.9E+07	RIO XINGÚ	ANA	-05 55 04	-52 35 27	262,681.00	1/1/1976	12/1/2005
9	2E+07	IPIXUNA	F	1.9E+07	RIO XINGÚ	ELETRONOR	-05 39 00	-51 40 00	276,000.00		
10	2E+07	SÃO JOSÉ X-6	F	1.9E+07	RIO XINGÚ	ANA	-05 47 00	-52 52 00	276,000.00	2/1/1979	11/1/1985
11	2E+07	BELO HORIZONTE	FDS	1.9E+07	RIO XINGÚ	ANA	-05 24 23	-52 54 07	277,265.00	1/1/1984	5/1/1998
12	2E+07	SÃO MIGUEL X-5	F	1.9E+07	RIO XINGÚ	ANA	-04 56 07	-52 52 11	286,871.00	3/1/1979	
13	2E+07	ILHA DA BOA VISTA - XIN-001	F	1.9E+07	RIO XINGÚ	ANA	-03 49 53	-52 35 15		7/1/2005	
14	2E+07	ARARAS	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 35 00	-52 26 00	444,417.00	11/1/1978	12/1/1989
15	2E+07	TABOCA	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 24 03	-51 58 28	446,952.00	11/1/2000	12/1/2001
16	2E+07	ILHA DO CANTEIRO - ME	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 24 14	-51 56 27	446,966.00	5/1/2001	7/1/2001
17	2E+07	EIXO ILHA DO CANTEIRO	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 24 33	-51 58 02	446,996.00	11/1/2000	7/1/2001
18	2E+07	BABAQUARA CONJ.1	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 22 00	-52 12 00	446,000.00	9/1/1978	8/1/1983
19	2E+07	BABAQUARA CONJ.2	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 22 00	-52 12 00	446,000.00	10/1/1978	11/1/1986
20	2E+07	BABAQUARA CONJ.3	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 22 00	-52 12 00	446,000.00	10/1/1978	9/1/1981
21	2E+07	BM 1	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 18 53	-52 02 18	446,636.00	1/1/2001	12/1/2001
22	2E+07	BM 2	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 14 07	-52 04 03	446,465.00	12/1/2000	12/1/2001
23	2E+07	BABAQUARA	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 17 00	-52 12 00	446,000.00	6/1/2001	10/1/2001
24	2E+07	UHE ALTAMIRA	F	1.9E+07	RIO XINGÚ	ANA	-03 17 55	-52 12 07	447,816.00	1/1/1976	12/1/2005
25	2E+07	ALTAMIRA	FDSQT	1.9E+07	RIO XINGÚ	ANA	-03 12 53	-52 12 44	446,203.00	1/1/1984	
26	2E+07	ALTAMIRA	F	1.9E+07	RIO XINGÚ	ANA	-03 12 00	-52 13 00	446,573.00		
27	2E+07	TIRA DÚVIDA	F	1.9E+07	RIO XINGÚ	ANA	-03 13 00	-52 13 00		1/1/1979	12/1/1981
28	2E+07	KOATYNEMA	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 16 00	-52 02 00	446,998.00	11/1/1978	12/1/1982
29	2E+07	EIXO ILHA DA SERRA	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 25 40	-51 57 28	447,070.00	3/1/2001	12/1/2001
30	2E+07	CANA VERDE I	FD	1.9E+07	RIO XINGÚ	ELETRONOR	-03 16 00	-51 58 00	447,000.00	11/1/2000	12/1/2001
31	2E+07	CANA VERDE 1A	FD	1.9E+07	RIO XINGÚ	ELETRONOR	-03 25 21	-51 57 29	447,064.00	5/1/2001	11/1/2001
32	2E+07	CANA VERDE II	F	1.9E+07	RIO XINGÚ	ANA	-03 23 43	-51 57 38	446,952.00	11/1/2000	
33	2E+07	MANGUEIRAS	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 26 48	-51 58 12	447,075.00	5/1/2001	12/1/2001
34	2E+07	ILHA DO NERIS	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 28 24	-51 58 17	447,086.00	12/1/2000	12/1/2001
35	2E+07	HEC I	FD	1.9E+07	RIO XINGÚ	ELETRONOR	-03 30 58	-51 58 15	448,720.00	12/1/2000	12/1/2001
36	2E+07	HEC II	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 29 47	-51 56 07	448,720.00	11/1/2000	10/1/2001
37	2E+07	JUSANTE BACAJÁ	FD	1.9E+07	RIO XINGÚ	ELETRONOR	-03 30 17	-51 42 43	470,000.00	5/1/2001	12/1/2001
38	2E+07	BARRA DO VENTO I	F	1.9E+07	RIO XINGÚ	ANA	-03 28 07	-51 40 28	472,500.00	6/1/2002	
39	2E+07	VERTEDOURO - COMPLEMENT	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 18 50	-51 43 53	477,000.00	1/1/2001	12/1/2001
40	2E+07	BELO MONTE	F	1.9E+07	RIO XINGÚ	ANA	-03 07 00	-51 42 00	479,417.00	11/1/1975	
41	2E+07	UHE BELO MONTE	F	1.9E+07	RIO XINGÚ	ANA	-03 07 33	-51 46 30	446,573.00	1/1/1976	12/1/2005
42	2E+07	VARADOURO	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 26 24	-51 54 03	447,075.00	5/1/2001	12/1/2001
43	2E+07	PIMENTAL	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 24 43	-51 54 50	447,064.00	11/1/2000	12/1/2001
44	2E+07	SERINGUEIRA	FD	1.9E+07	RIO XINGÚ	ELETRONOR	-03 25 08	-51 55 48	447,064.00	5/1/2001	12/1/2001
45	2E+07	CONTRA	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 25 03	-51 55 27	447,064.00	5/1/2001	12/1/2001
46	2E+07	POSTO DO LEO	F	1.9E+07	RIO XINGÚ	ELETRONOR	-03 26 12	-51 56 37	447,075.00	5/1/2001	12/1/2001
47	2E+07	BOCA DE SANTO ANTÔNIO I	FD	1.9E+07	RIO XINGÚ	ELETRONOR	-03 06 53	-51 46 00	478,816.00	12/1/2000	12/1/2001
48	2E+07	PORTO DE MOZ	F	1.9E+07	RIO XINGÚ	ANA	-01 45 14	-52 14 27	504,277.00	1/1/1928	5/1/1971
49	2E+07	PORTO DE MOZ	F	1.9E+07	RIO XINGÚ	ANA	-01 45 11	-52 14 24	504,277.00	3/1/1979	

Definition of weather stations according to the period of available data.

Weather Stations Used



Boa Sorte

Altamira

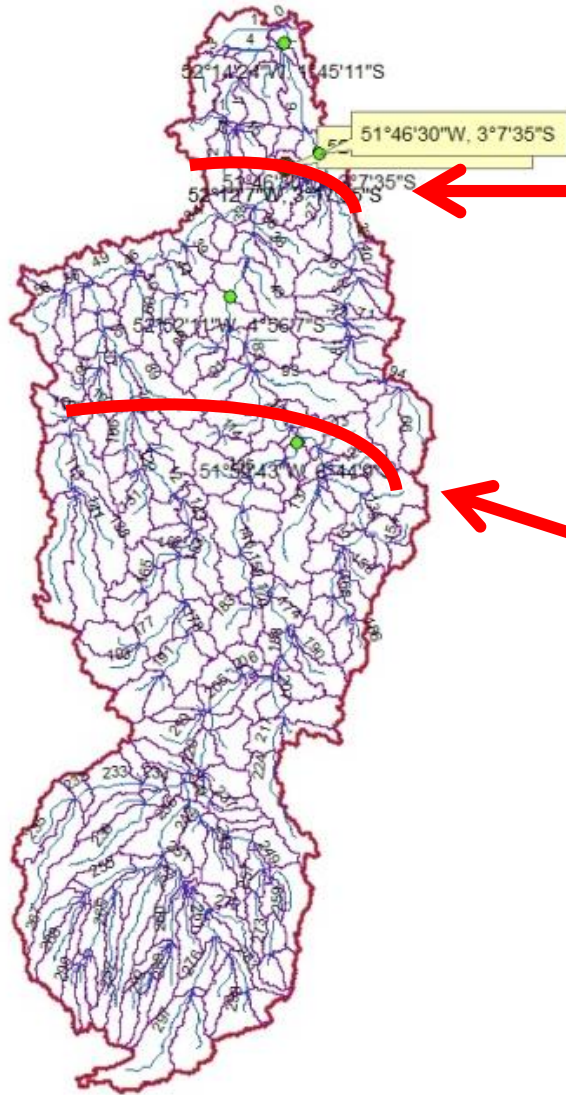
Code 18460000

Code 18850002

Period: January
1976 to
February 2009

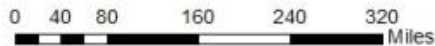
Período:
January 1971 to
January 2013

Bacia Hidrográfica do Rio Xingú



Calibration with
Altamira station

Calibration with Boa
Sorte station



SWAT - CUP



R²

- Coefficiente of determination
- 0 a 1

NSE

- Nash-Sutcliffe efficiency
- Relative magnitude data variance compared to the measured data variance

$$NSE = 1 - \frac{\sum_{i=1}^n (Y_{obs} - Y_{sim})^2}{\sum_{i=1}^n (Y_{obs} - Y_{mean})^2}$$

SWAT-CUP



PBIAS

- Tendency of simulated data to be larger or smaller than the observed values

$$\text{PBIAS} = \frac{\sum_{i=1}^n (Y_{obs} - Y_{sim}) * 100}{\sum_{i=1}^n (Y_{obs})}$$

Calibration



- ∞ The response of a model is related to the quality of input database. It is necessary to adjust parameters to improve model response
- ∞ The most sensitive parameters must be determined, through sensibility analysis.

Most Sensitives Parameters

Parameter	Description	Range of parameter	Best Value
CN2	Surface runoff	35 to 98	75.163
ESCO	Compensation of soil evaporation	0 to 1	0.2958
ALPHA_BF	Base flow	0 to 1	0.40416
RCHRG_DP	Deep aquifer percolation	0 to 1	0.5458
SLSUBBSN	Average length of lateral ramp	10 to 150	32.75
EPCO	Compensation for plant grown	0 to 1	0.85416
SURLAG	Surface runoff retardation coefficient	0.05 to 24	20.3078
CH_W2	Average width of main channel at top of bank	0 to 1000	287.5
CH_L2	Length of main channel	-0.05 to 500	160.383
CH_N2	Manning's roughness coefficient value for the main channel	-0.01 to 0.3	0.200

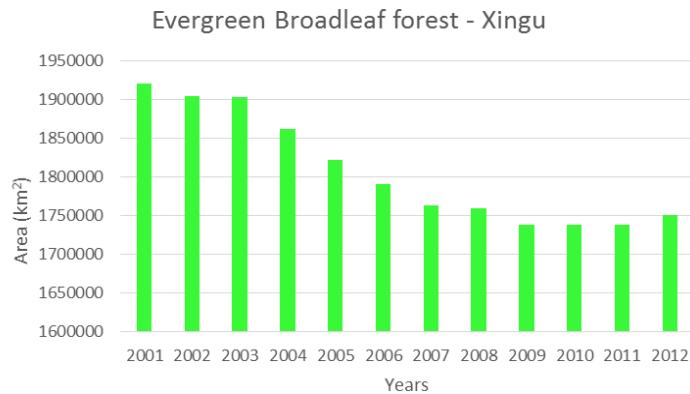
Results

PBIAS Evaluation				
Model	Value	Performance rating	Modeling Phase	Reference
SWAT	<10%	Very Good	Calibration and Validation	Van Liew et al. (2007)
SWAT	<10% to <15%	Good	Calibration and Validation	Van Liew et al. (2007)
SWAT	<15% to <25%	Satisfactory	Calibration and Validation	Van Liew et al. (2007)
SWAT	>25%	Unsatisfactory	Calibration and Validation	Van Liew et al. (2007)

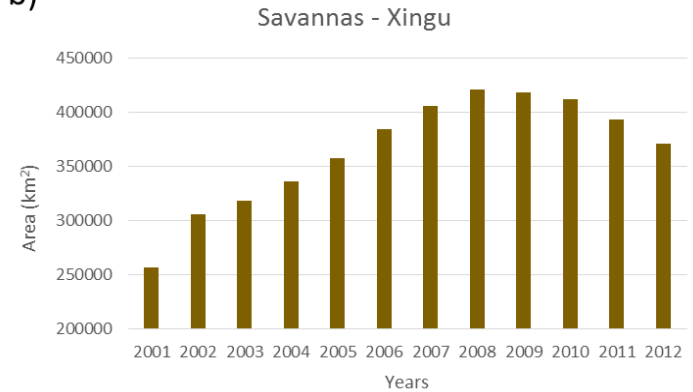
Land use Changes



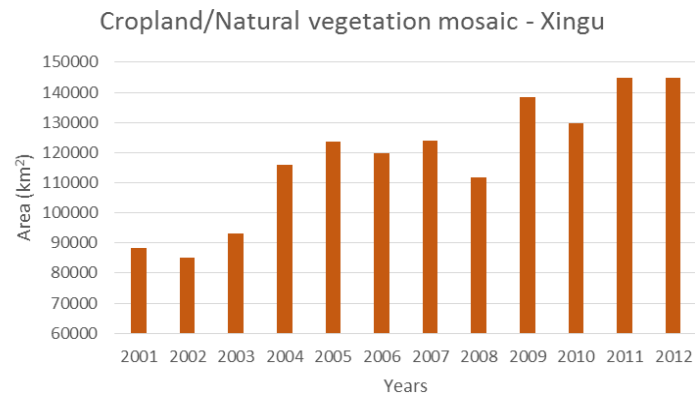
a)



b)



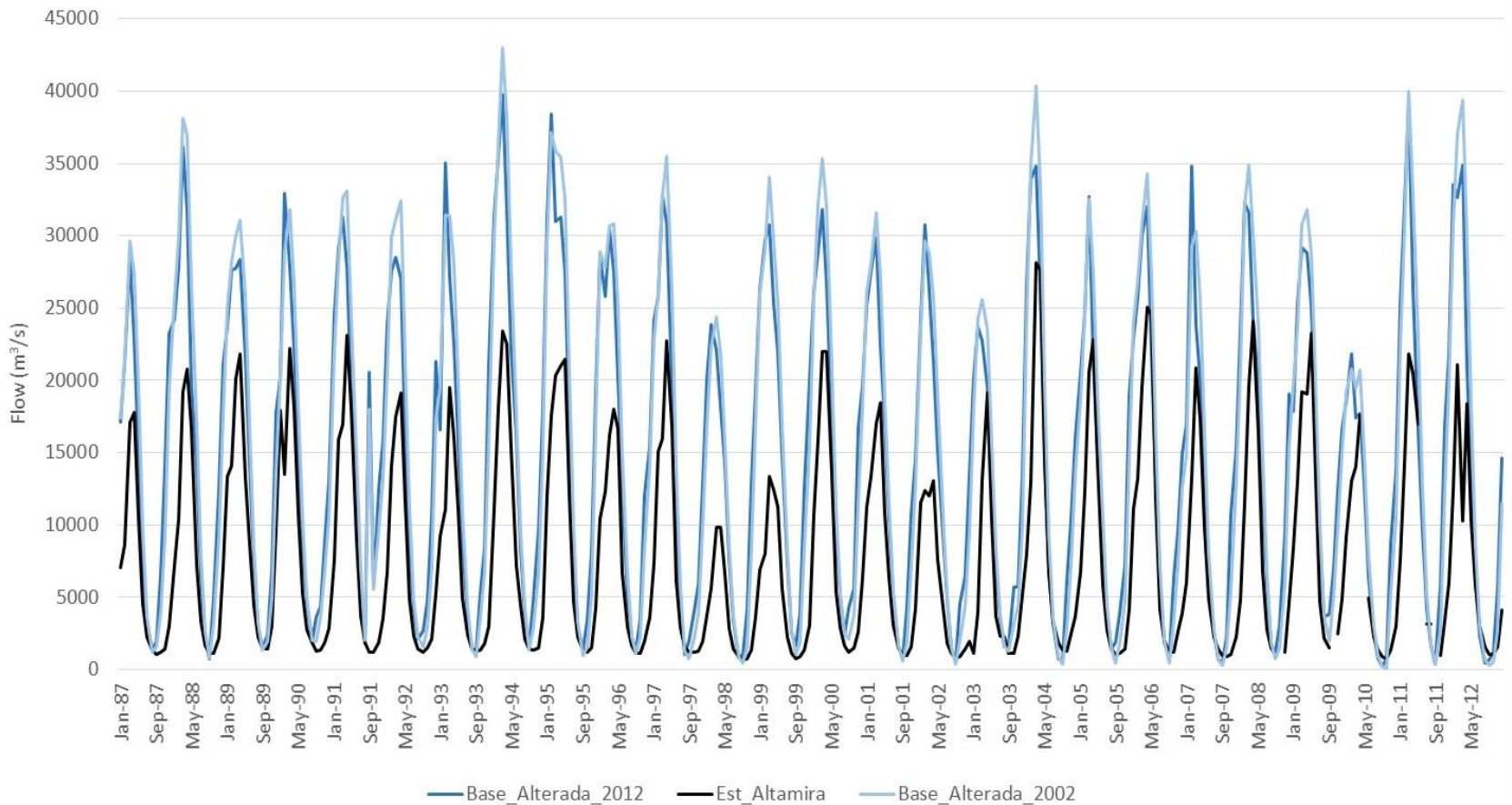
c)



Flow Simulation



Xingu - Gage Station Altamira X SWAT Flow Simulation



Conclusion



- ❧ Satisfactory results for calibration
- ❧ Streamflow results shows tiny variation from 2002 to 2012
- ❧ When properly calibrated and validated SWAT model is a very efficient tool to plan interventions and changes in the basins

Referências

Bibliográficas

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- ❧ NETO, A. R. *et al.* Simulação na Bacia Amazônica com Dados Limitados: Rio Madeira. *Revista brasileira de recursos hídricos*. Volume 13, n. 3. Jul/Set 2008, 47-58.
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- ❧ BRASIL, Lei nº 9433, de 8 de Janeiro de 1997. Institui a Política Nacional de Recursos Hídricos, cria o Sistema Nacional de Gerenciamento de recursos Hídricos, regulamenta o inciso XIX do art. 21 da Constituição Federal, e altera o art. 1º da Lei nº 7.990, de 28 de dezembro de 1989. *Diário oficial da República Federativa do Brasil*, Brasília, DF, 1997. Disponível em: <http://www.planalto.gov.br/ccivil_03/Leis/L9433.htm#art38vi> Acessado em: 11/06/2014.
- ❧ INPA, CARACTERÍSTICAS DA BACIA HIDROGRÁFICA DO RIO XINGU. Figura 7.2.4-1 Folha 2 de 2, 2014. Escala: 1:2.500.000. Disponível em: <http://philip.inpa.gov.br/publ_livres/Dossie/BM/DocsOf/EIA-09/Vol%2005/AAR%20MEIO%20BIOTICO/FIGURAS/figura_7_2_4_1_caract_bacia_xingu_folha_2.pdf> Acessado em: 11/06/2014.
- ❧ RIBEIRO, C. B. M. *et al.* Parametrization of physical and climatic characteristics in the Amazon basin for hydrological simulation with SWAT model. 2014 Internations SWAT Conference