Land use update function in SWAT – application in two macro watersheds in Brazil

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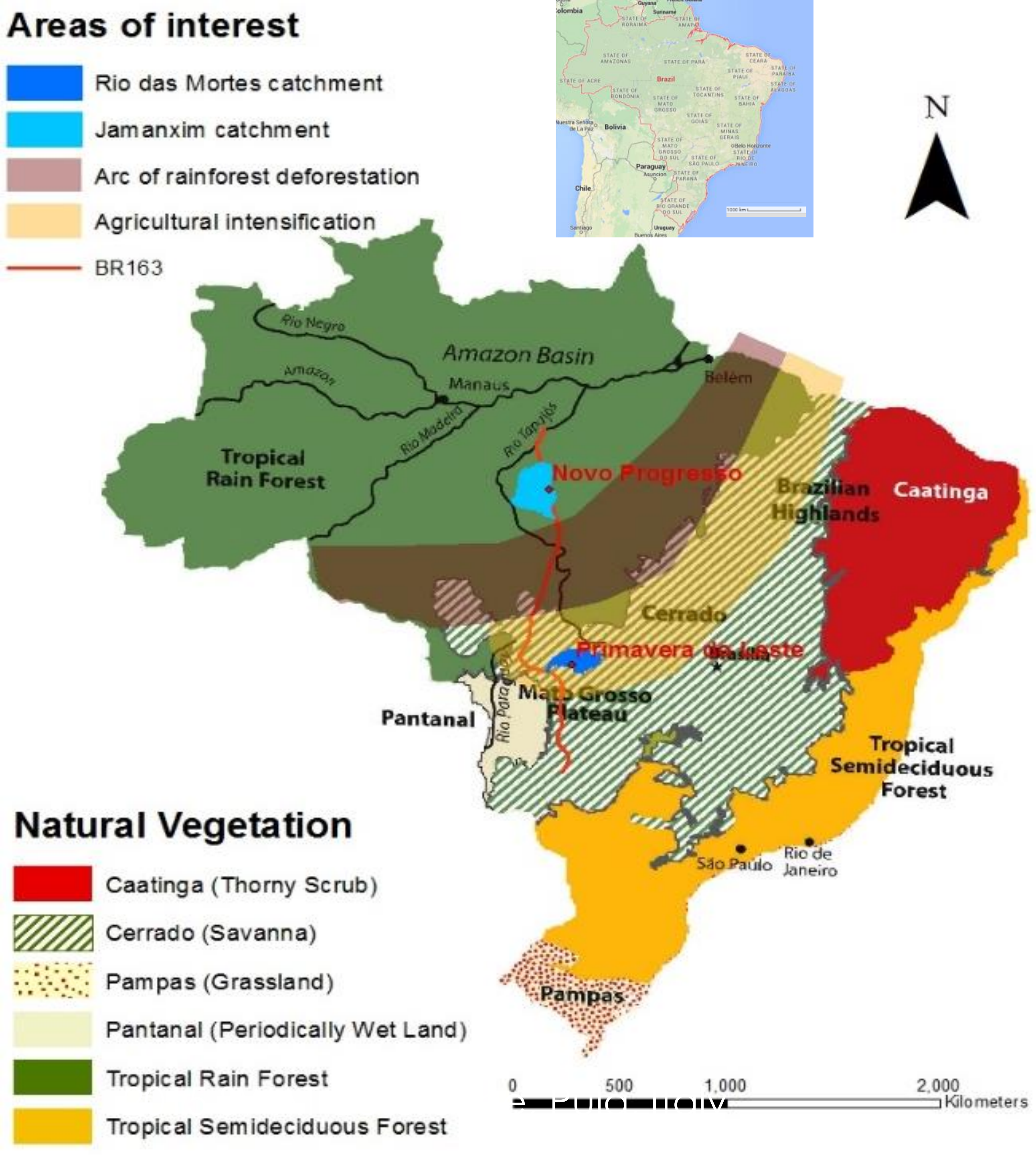

Research Area

Aim:

- Investigation of effects of land use change on stream flow
- Inclusion of land use change in the model calibration and validation

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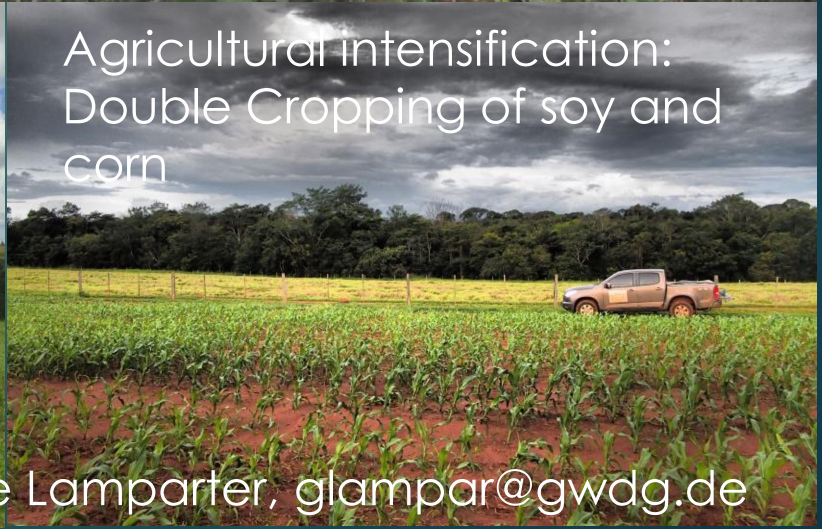
Land use change (Cerrado biome)



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Land Use Change (Amazonian rainforest biome)

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We learned (mainly from micro-catchment studies):

- Forest removal rises stream flow
- Forest removal reduces ET
- Agricultural land use rises soil bulk density
  - decreases infiltrtion capacity
  - increases surface runoff
  - decreases storage capacity…

BUT WHAT DOES IT DO ON MACRO CATCHMENT SCALE?

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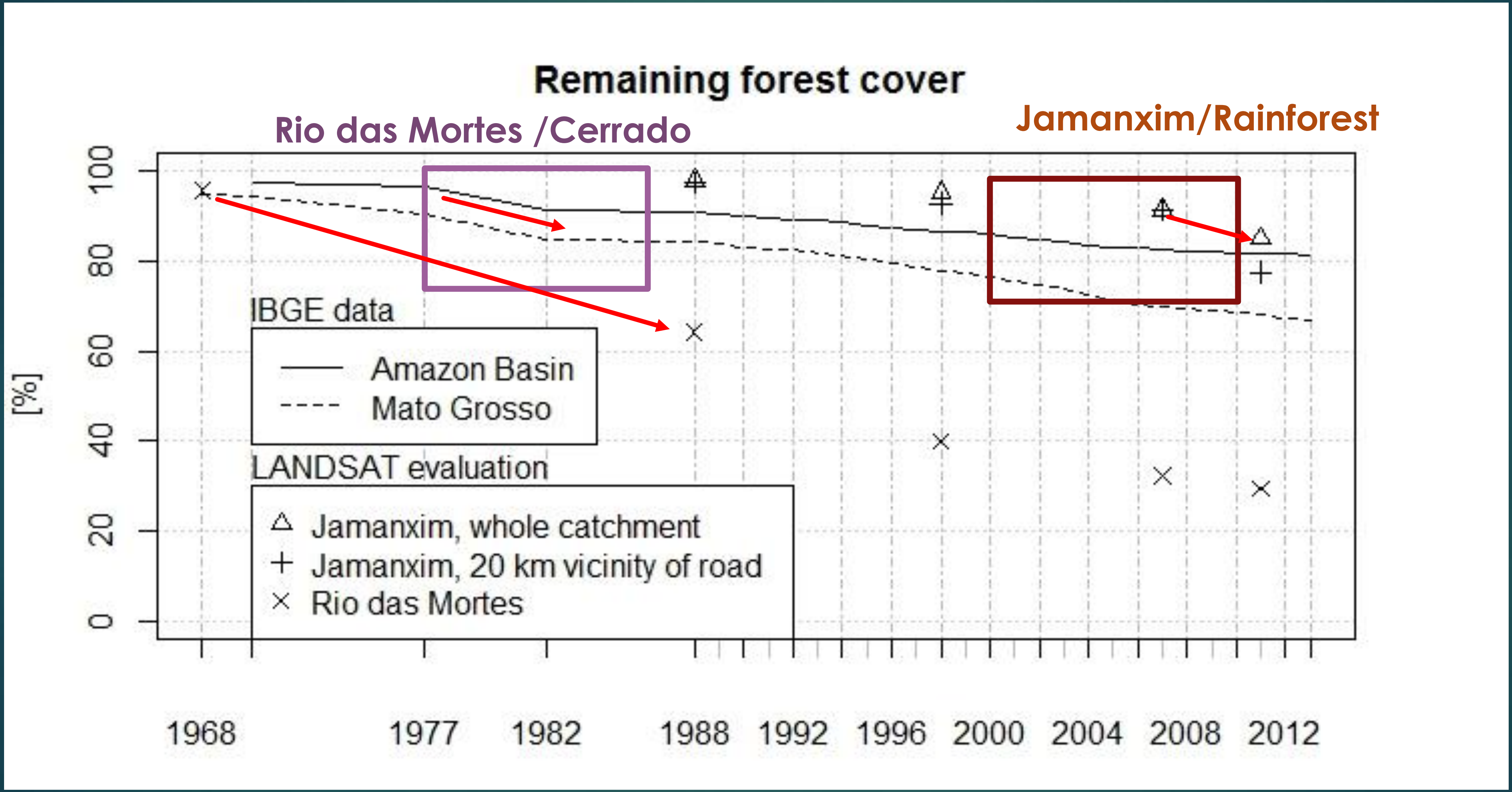
Historic land use change



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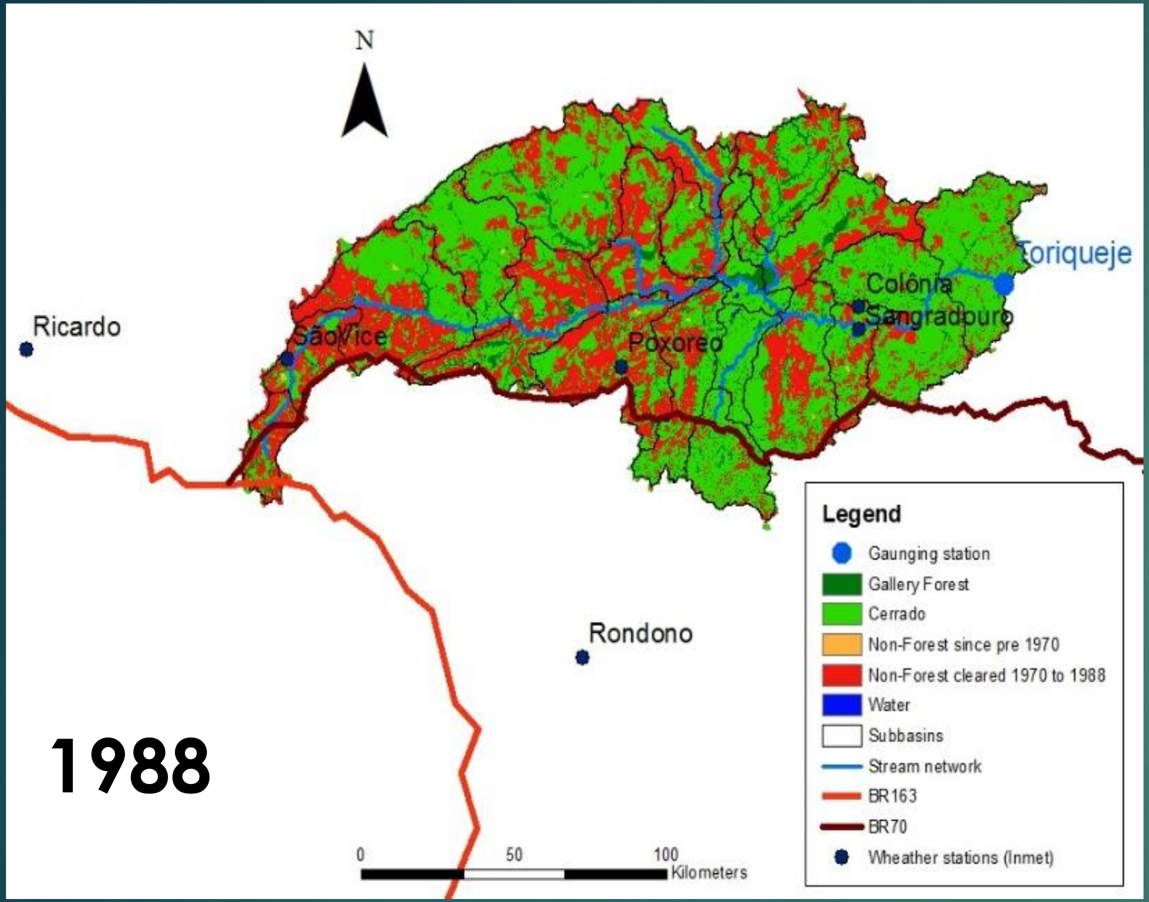
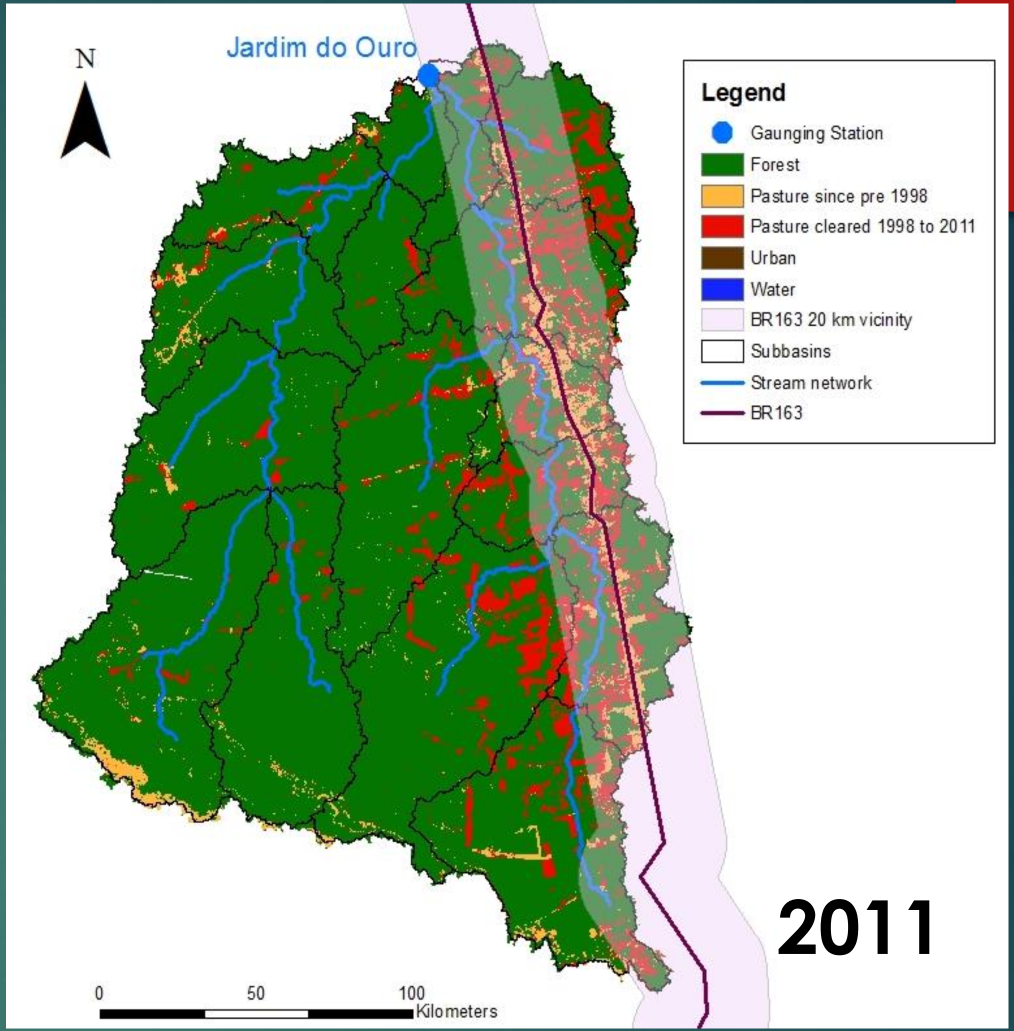
Study watersheds





Rio das Mortes, Mato Grosso
Cerrado Biome

Jamanxim, Para
Amazon rainforest Biome

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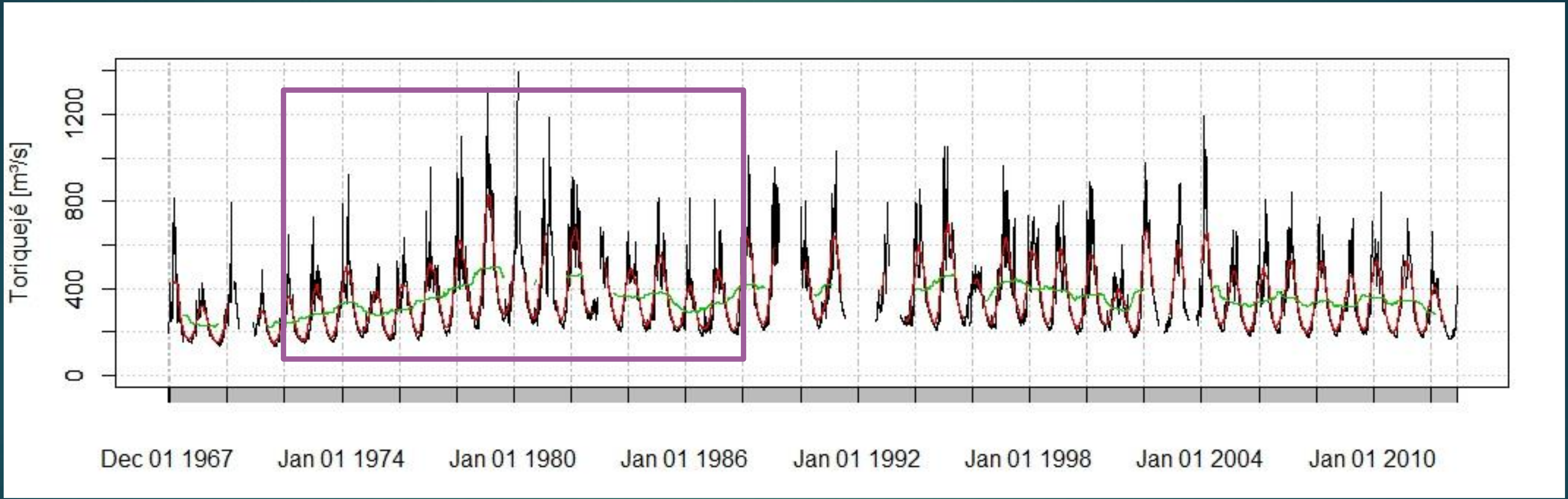
Historic discharge records for the Rio das Mortes catchment



Guzha et al 2013 showed a clear trend
between the 70th and 80th of rising discharge

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Experimental setup

	Rio das Mortes (savanna)	Jamanxim (rainforest)
Calibration Period	1977-1981	2000-2004
Validation Period	1982-1986	2005-2009
LU-update % per annum in validation and calibration period; mean (min – max) for different subbsasins	2.4 (1.7-3.4) (Cerrado to Non-Forest)	0.6 (0-4) (Forest to pasture)
Test application without land use update	1977-1986 (LU from 1988)	2000-2009 (LU from 2011)

Carbiocial Story lines	Rio das Mortes	Jamanxim
Scenario trend 2030	3% natural, 23% pasture, 73% cropland	46% forest, 40% pasture, 13 cropland
Scenario sustainable 2030	3% natural, 12% pasture, 84% cropland	65% forest, 1% pasture, 34% cropland
Scenario intensification 2030	2% natural, 24% pasture, 73% cropland	30% forest, 57% pasture, 13% cropland

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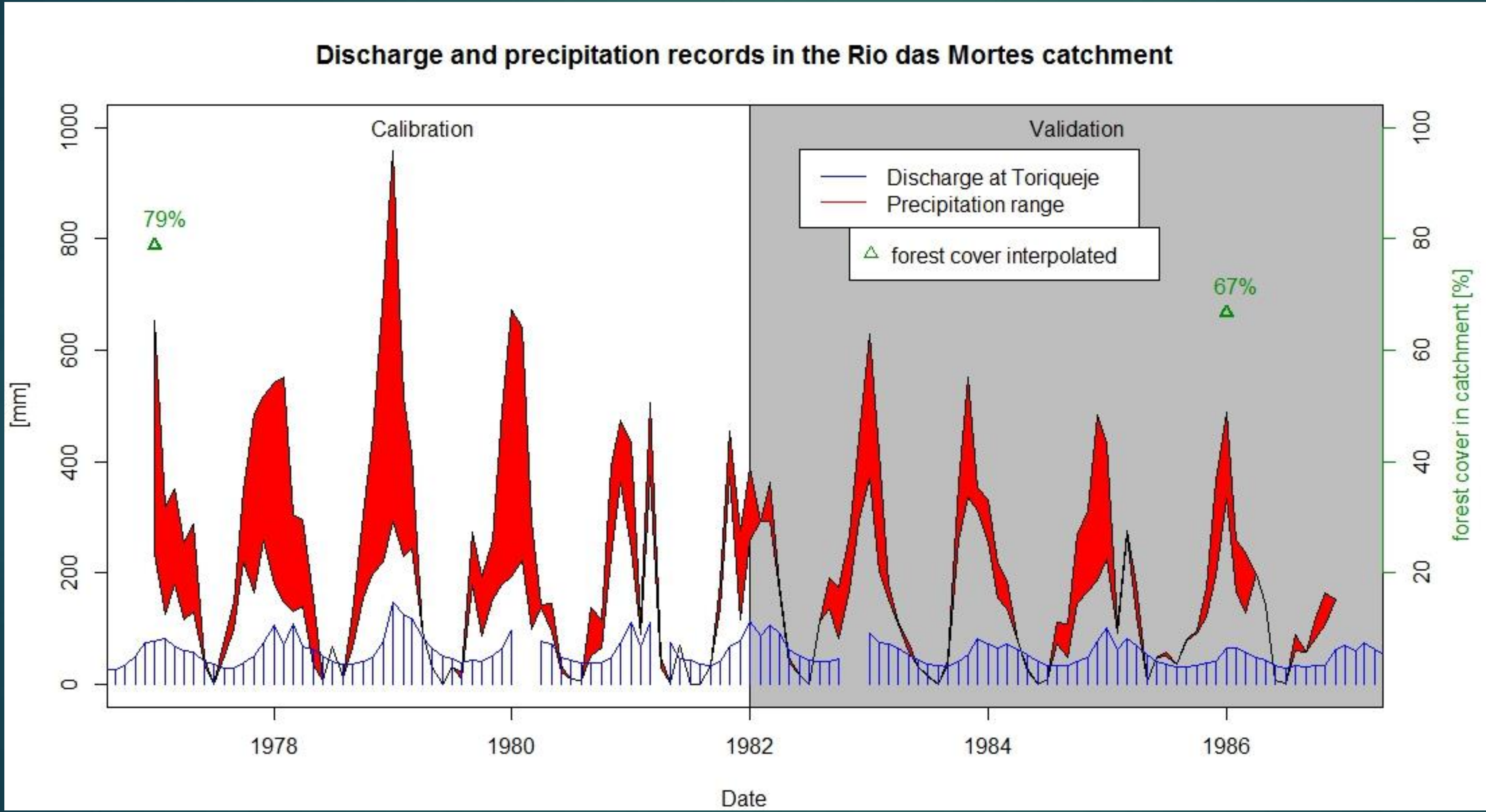
Calibration and Validation: Rio das Mortes(Cerrado savannah) watershed



- ANA discharge station
- INMET climate records from 6 weather stations
- 2.5% annual Cerrado deforestation (Landsat and reconstruction)

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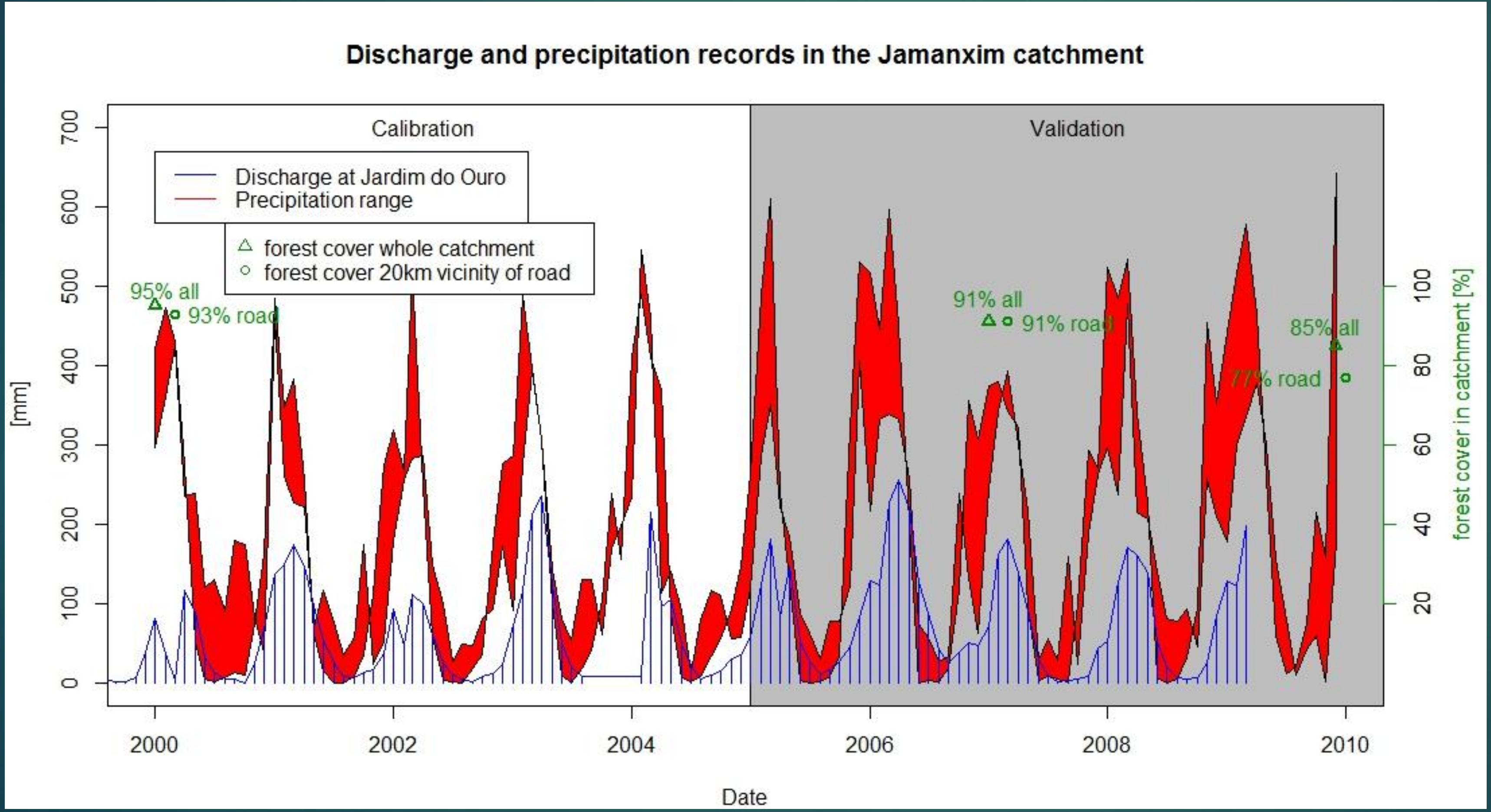
Calibration and Validation: Jamanxim (rainforest) watershed



- ANA discharge records
- CFSR Global weather (no INMET records in the whole watershed) –
- 0.6% annual rainforest deforestation (LANDSAT images)

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catchment	Rio das Mortes	Jamanxim
Area [km²]	17,556	37,403
Dominant natural vegetation	Cerrado and Gallery Forest	Rainforest
Dominant soils types	Latosolo, Neosolo	Latosolo, Argisolo
Main period of deforestation	1975-1990	2000-2010
Current degree of deforestation	~70%	~26%
No of subbasins in the model (min-max [km²])	20 (260-1500)	17 (890-4500)
No of HRUs	240	135
Thresholds	2% LU, 5% soil, 5% slope	2% LU, 5% soil, 5% slope
Climate *	Aw after Köppen Tropical wet and dry with 4-5 months dry season	Am after Köppen Tropical monsoon climate with 3 months dry season
Annual rainfall [mm] *	Primavera d. Leste: 1784	Novo Progresso: 2232
Mean temperature [°C] *	Primavera d. Leste: 22.0	Novo Progresso: 25.8
Mean slope [%]	2.9	12.9
Fraction of slope: 0-2 | 2-5 | 5-max [%]	40.6 | 47.0 | 12.4	16.2 | 53.6 | 30.2

* ("Climate-Data.org" 2015)

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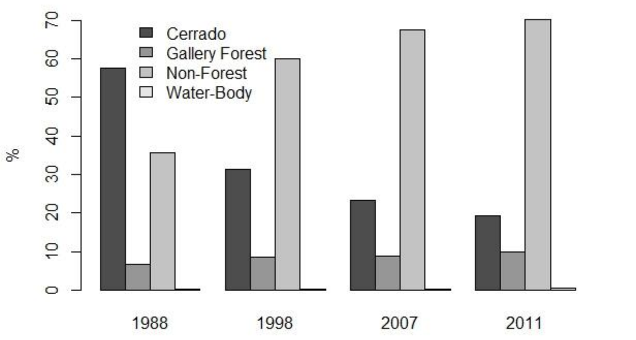
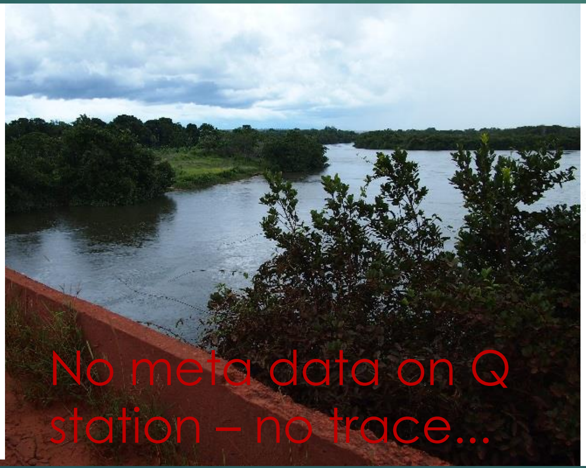
Challenges:

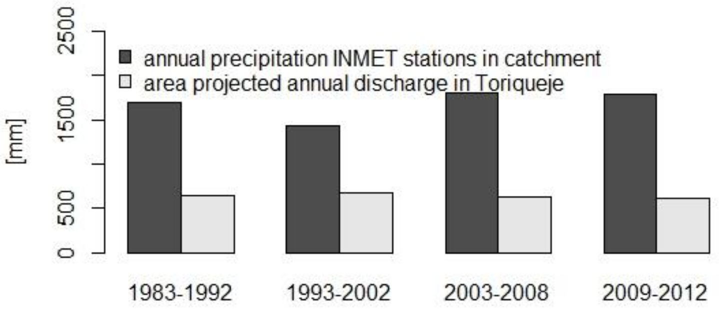
- Data aquisition
  - Historical land use distribution/classification
  - Climate records
  - Discharge records
- Parametrisation
  - Evergreen vegetation
    - Cerrado Savanna
    - Rainforest
  - Soils
  - Management

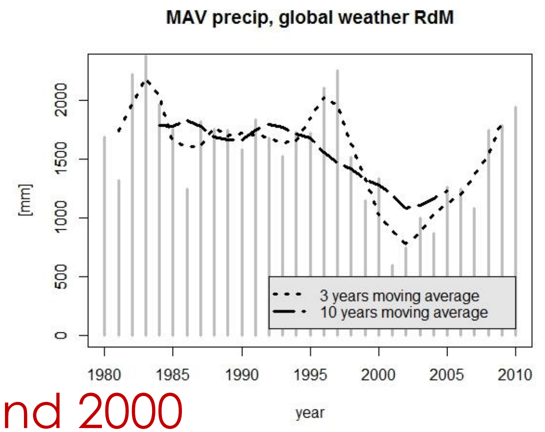


LUC Rio das Mortes



No meta data on Q station – no trace...





Missmatch of Q and P around 2000

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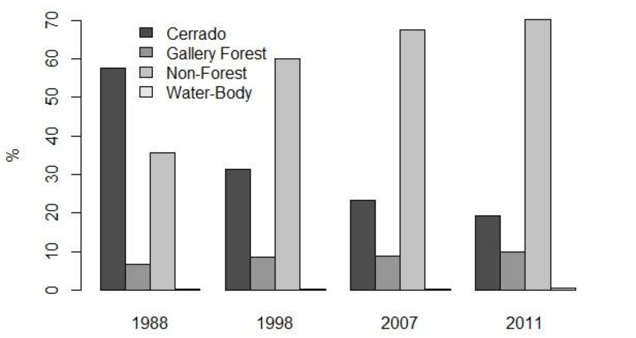
Challenges:

- Data aquisition
  - Historical land use distribution/classification
  - Climate records
  - Discharge records

Landsat versus statistical information

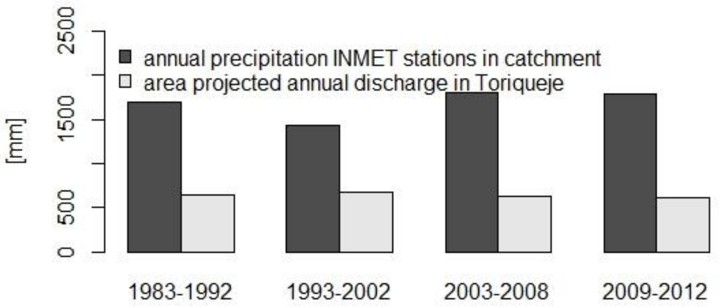
Sparse and records with gaps – „mismatch Q and P“

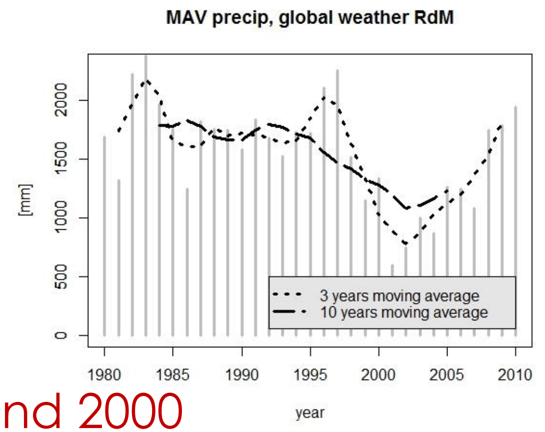
Limited additional information (e.g. Rating curve), Weak defined cross-section



LUC Rio das Mortes

No meta data on Q station – no trace...





Missmatch of Q and P around 2000

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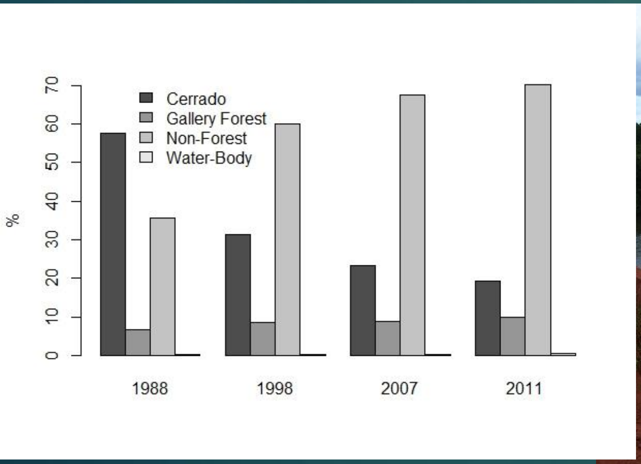
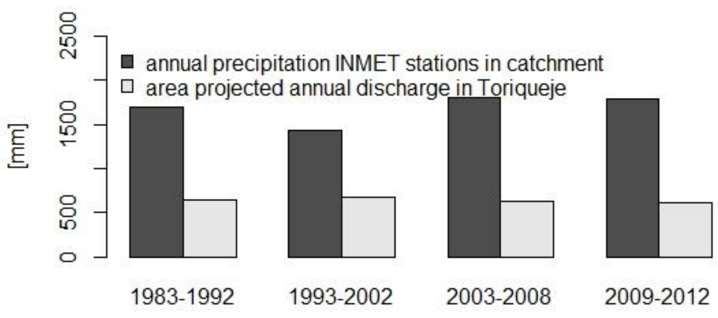
Challenges:

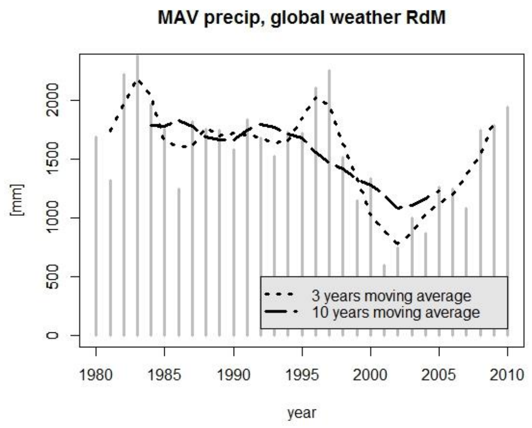
- Parametrisation
  - Evergreen vegetation
    - Cerrado Savanna
    - Rainforest
  - Soils
  - Management

Vegetation:
- **Dormancy**
- **Limited literature on Cerrado savanna / active mechanisms to deal with water stress**

Soil:
- **„old" map with Brazilian classification**
- **Sparse profile data for soil type parametrisation**
- **Limited own data from micro-watershed studies**







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Calibration Vegetation and Soil dependent

parameter	description	Land use dependent	Soil class dependent
GW_delay [days]	Groundwater delay		x
GW_revap	Groundwater revaporation		x
Sol_K [mm h^{-1}]	Soil hydraulic conductivity	x	x
CN2	Curve Number	x	x

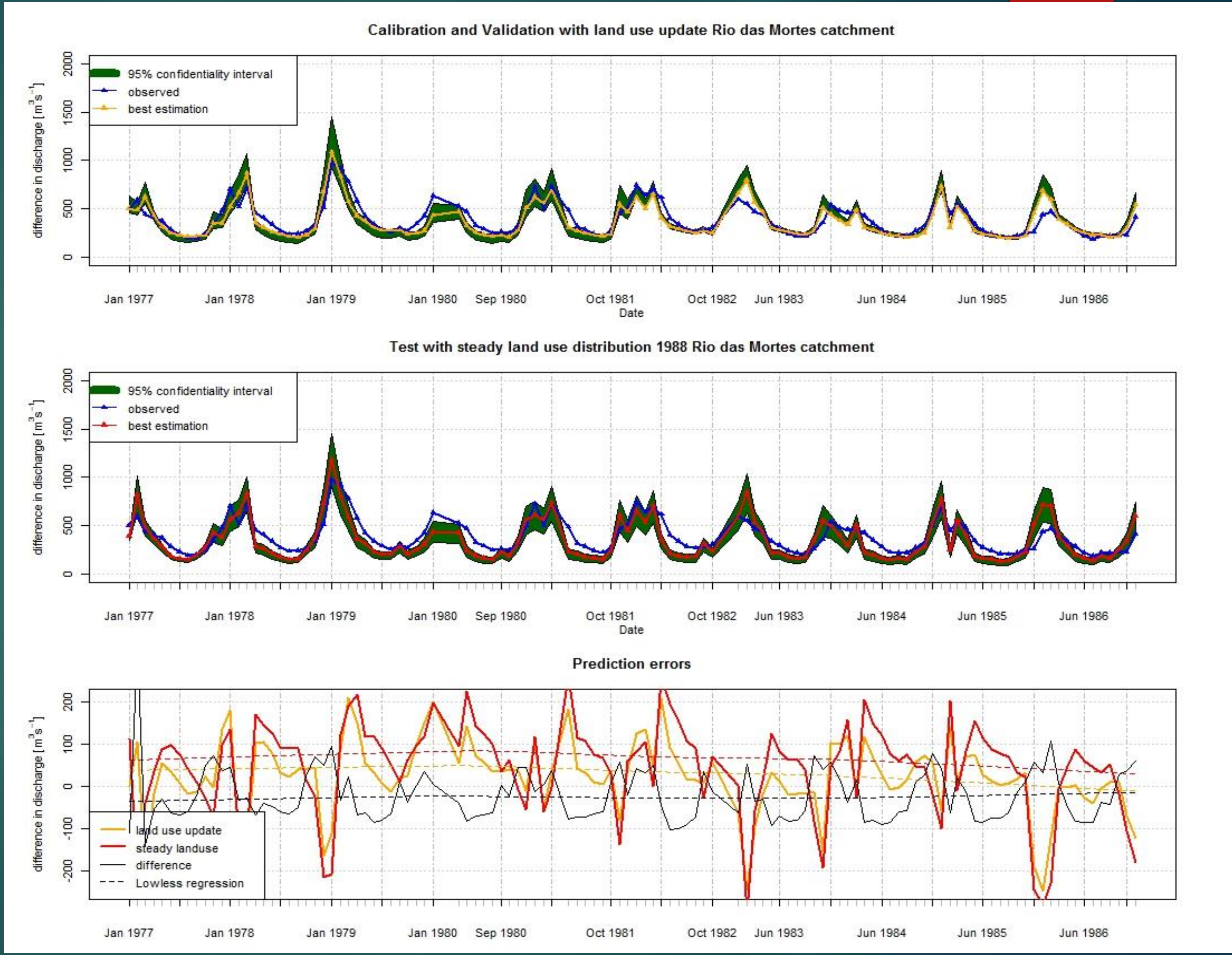
- Matrix of parameter calibration dependent on vegetation and soil
- Automatic calibration with SWAT-CUP SUFI-2
- Calibration: 2 iterations with each 1500 runs

Plus other parameters: such as GW_DELAY, Alpha BF etc...

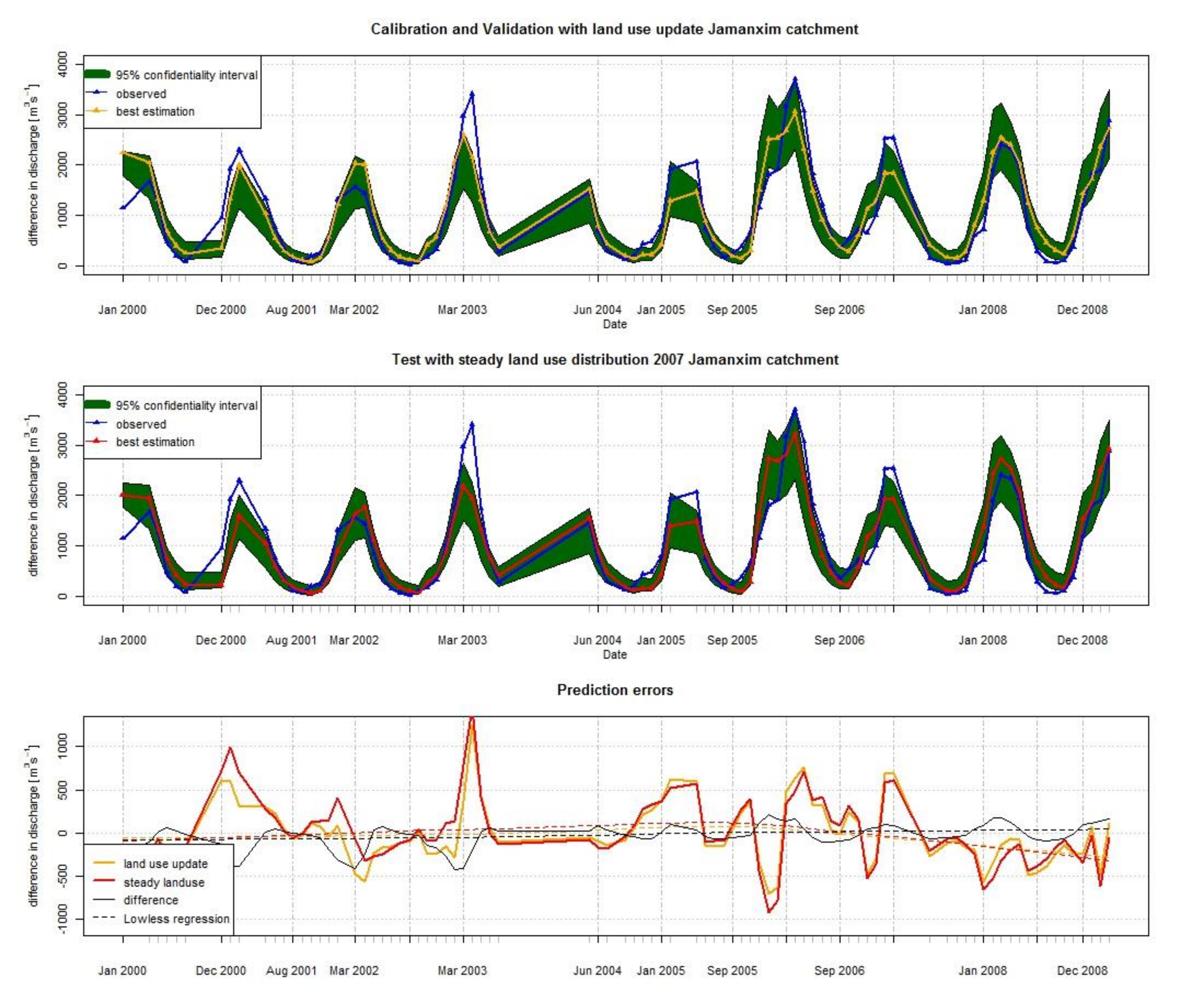
Calibration Validation and Test results:

	Rio das Mortes	Jamanxim
Calibration	NSE: 0.68	NSE: 0.80
Validation: land use update	NSE: 0.63	NSE: 0.85
Test: steady land use	NSE: 0.48	NSE: 0.81

Rio das Mortes Calibration, Validation and Test



Jamanxim: Calibration, Validation and Test



CONCLUSION:

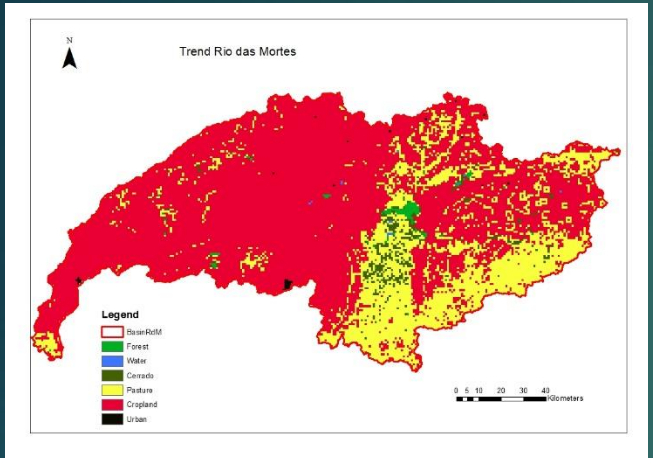
- Especially in periods with rapid and fundamental land use change even simple land use update improves model performance (effect is more pronounced for Rio das Mortes catchment)

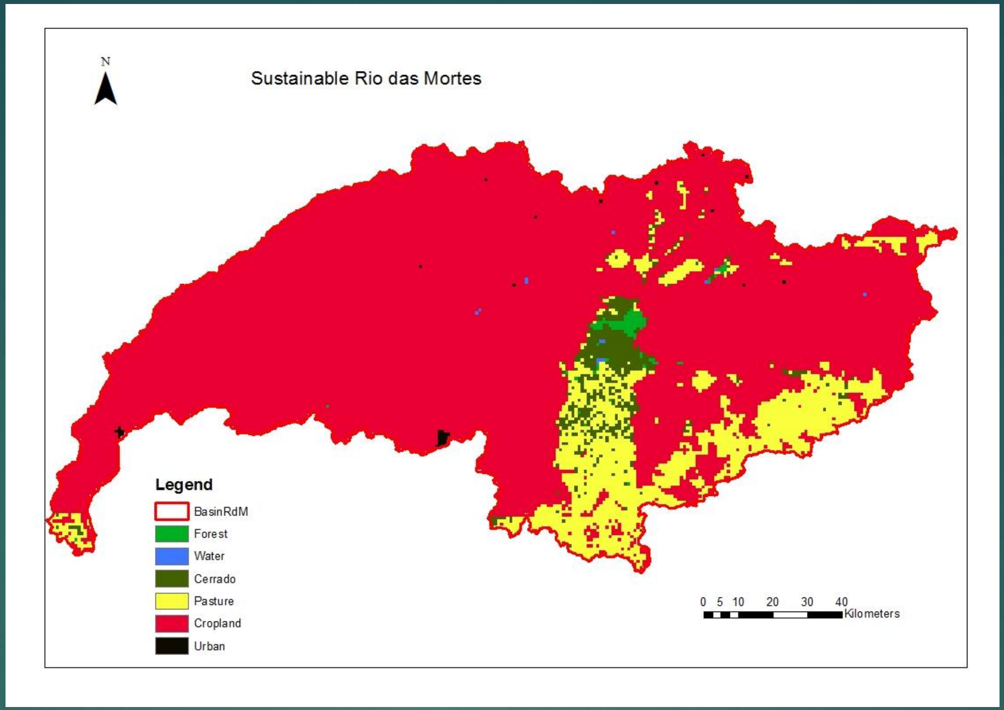
FURTHER WORK:

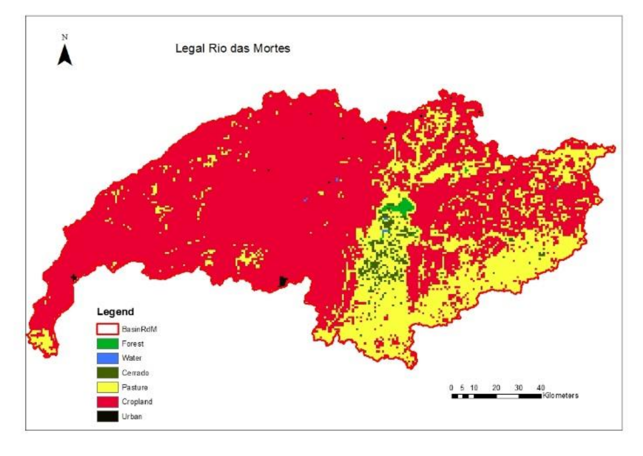
- Quantification of the „improvement“
- Investitgation of seasonality in runoff
- Did we get it right for the right reasons? More investigation into the water balance components (soft data)
- Climate feedback in the rainforest
- Scenarios (Storylines and Management)

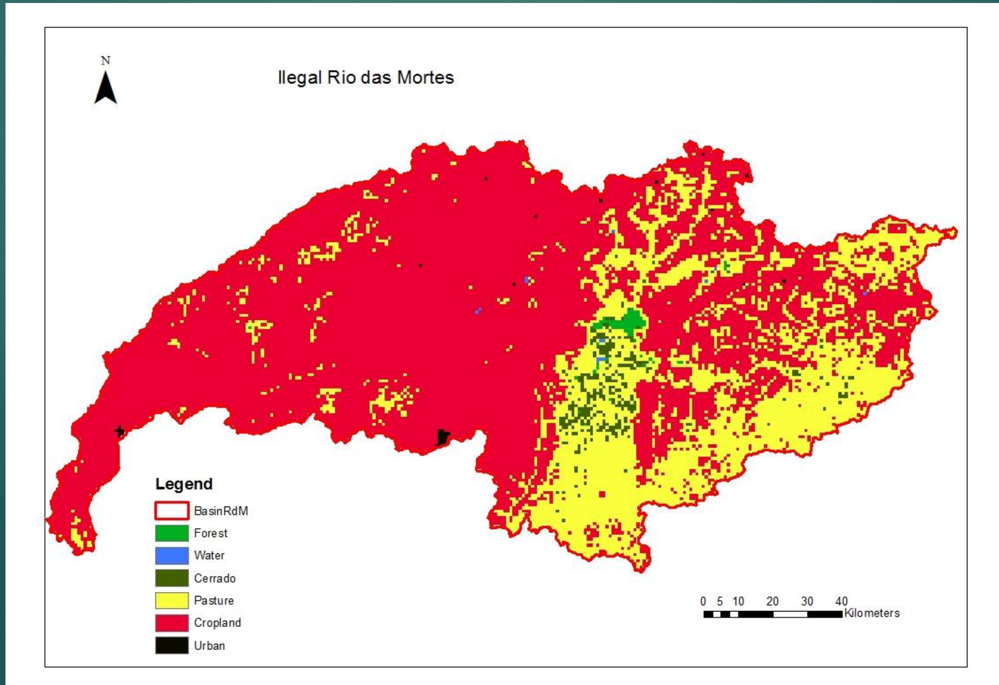
Any questions?

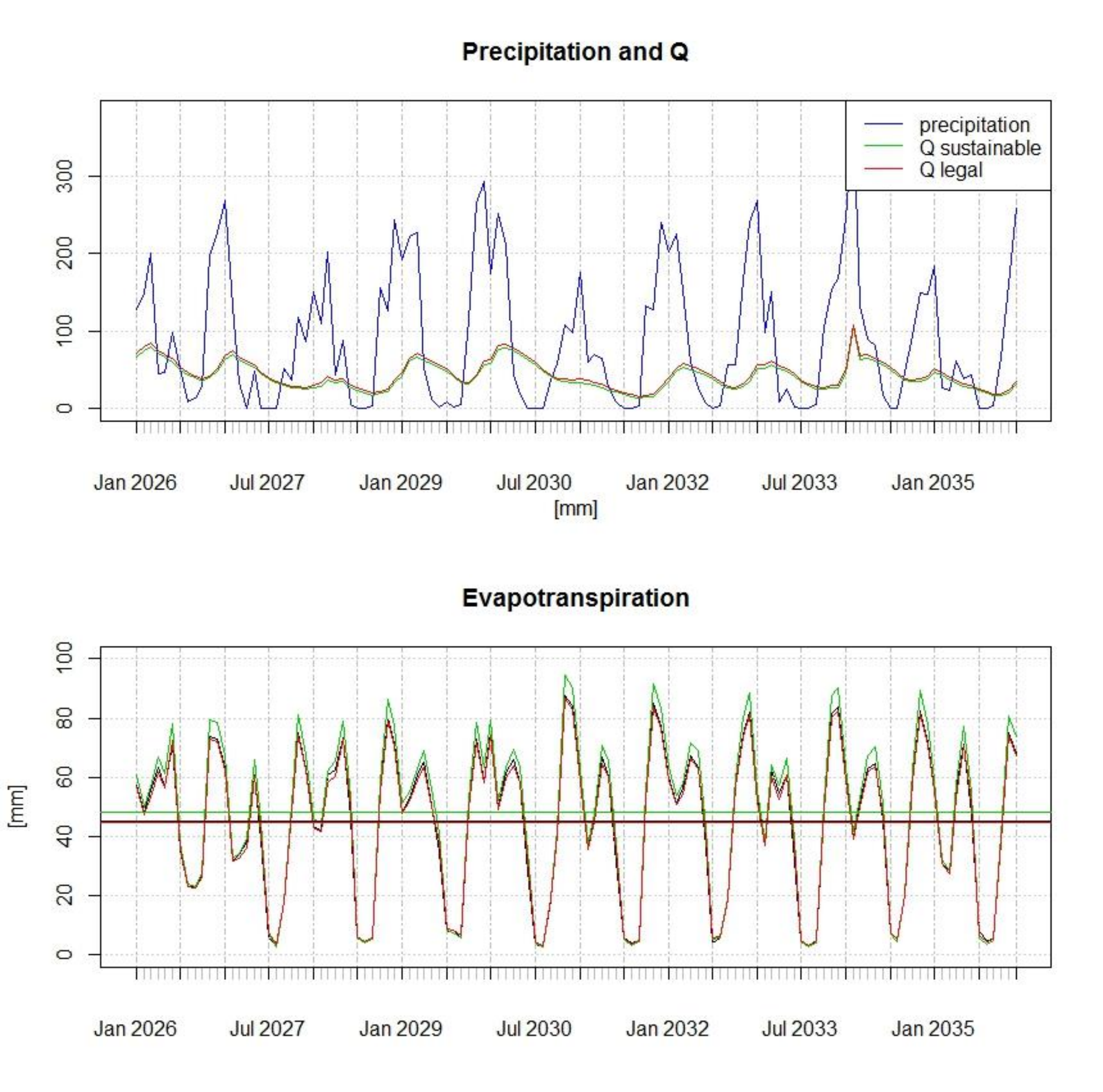
Scenarios 2030 Rio das Mortes










Precipitation and Q
precipitation
Q sustainable
Q legal
0
100
200
300
Jan 2026
Jul 2027
Jan 2029
Jul 2030
Jan 2032
Jul 2033
Jan 2035
[mm]
Evapotranspiration
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Jul 2027
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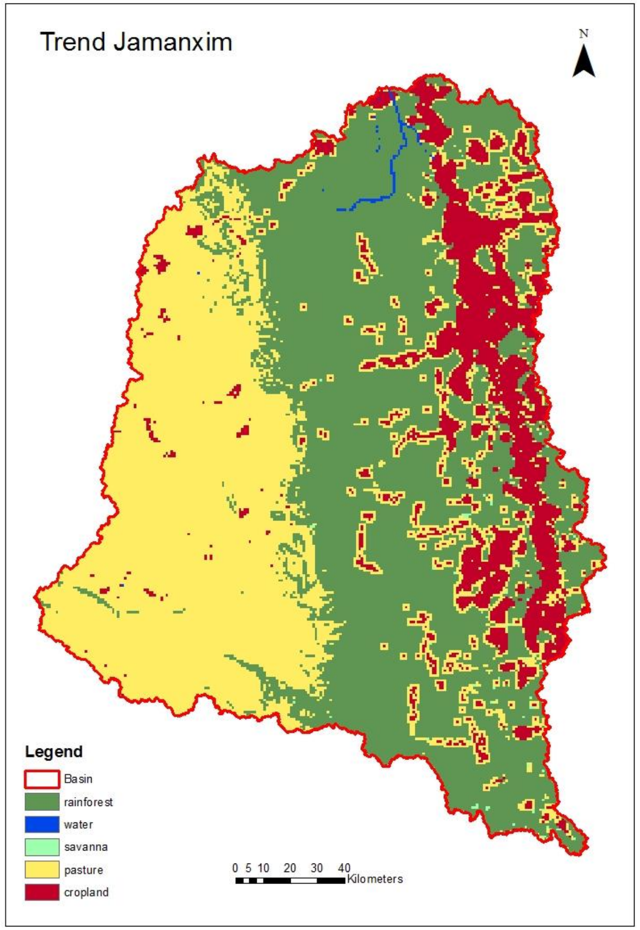
Jul 2030
Jan 2032
Jul 2033
Jan 2035


Trend Jamanxim
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Basin
rainforest
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savanna
pasture
cropland
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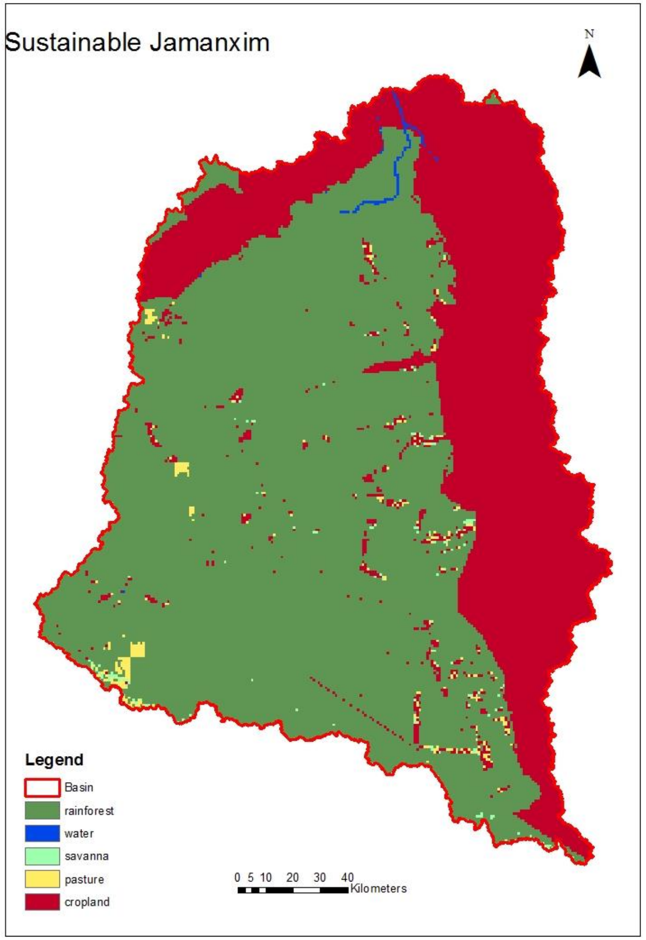
Kilometers


Sustainable Jamanxim
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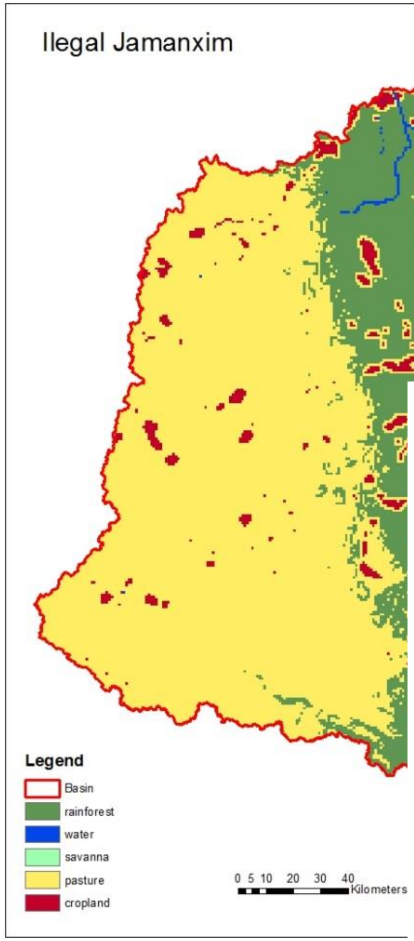
0 5 10 20 30 40
Kilometers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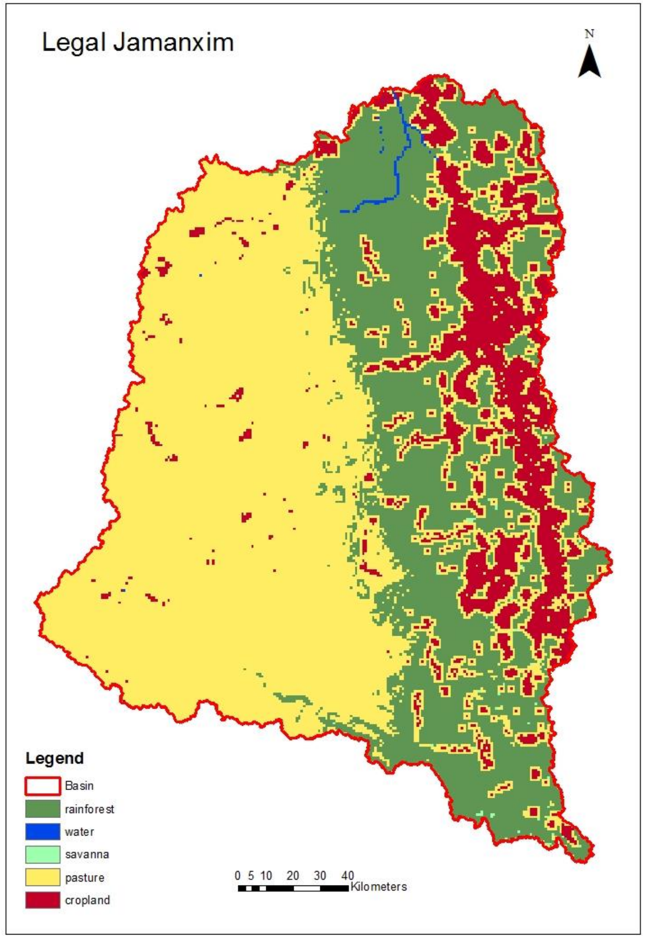
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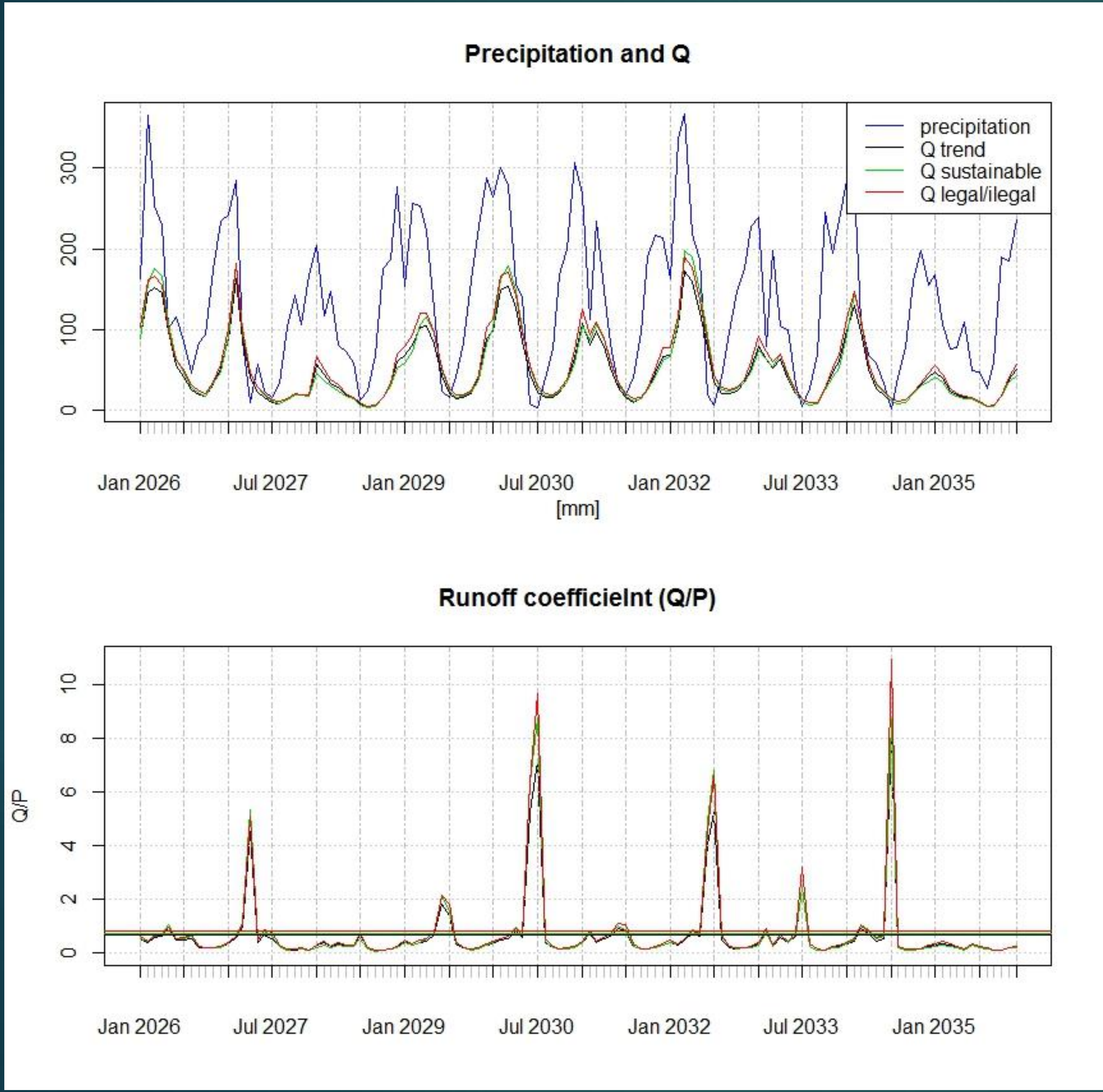
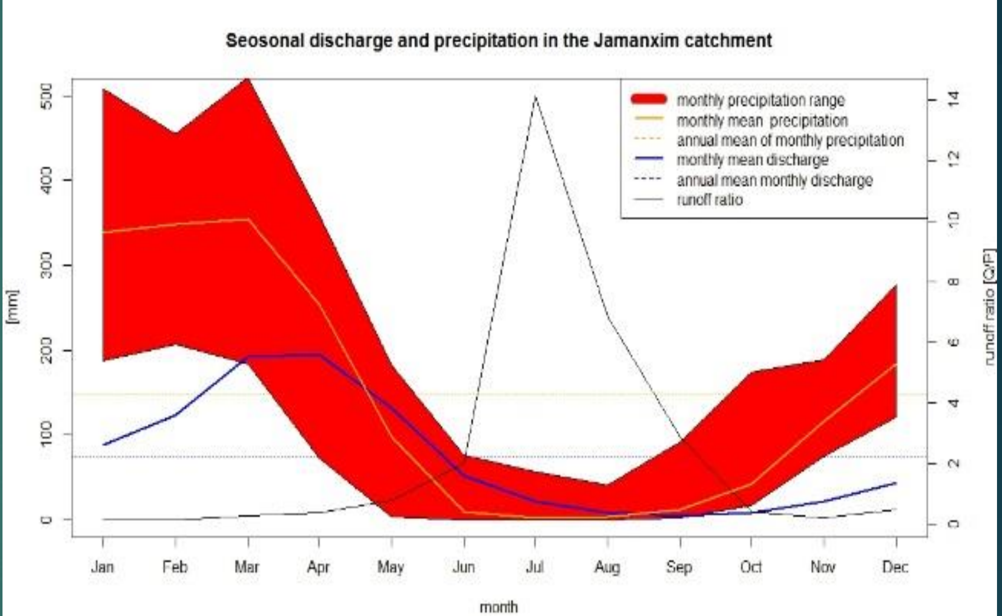
0 5 10 20 30 40
Kilometers


Precipitation and Q
precipitation
Q trend
Q sustainable
Q legal/ilegal
0
100
200
300
Jan 2026
Jul 2027
Jan 2029
Jul 2030
Jan 2032
Jul 2033
Jan 2035
[mm]
Runoff coefficielnt (Q/P)
Q/P
0
2
4
6
8
10
Jan 2026
Jul 2027
Jan 2029
Jul 2030
Jan 2032
Jul 2033
Jan 2035


Seosonal discharge and precipitation in the Jamanxim catchment
monthly precipitation range
monthly mean precipitation
annual mean of monthly precipitation
monthly mean discharge
annual mean monthly discharge
runoff ratio
[mm]
0
100
200
300
400
500
runoff ratio [Q/P]
0
2
4
6
8
10
12
14
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
month

Jamanxim: Changes in Q are mainly changes in ET