Natural Capital Accounting and Valuation of Ecosystem Services Project

National Forum – 16, 17, 18 Nov 2021

Results From the Matopiba Pilot Project

Hydrologic Responses from Land Use and Land Cover Changes

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United Nations

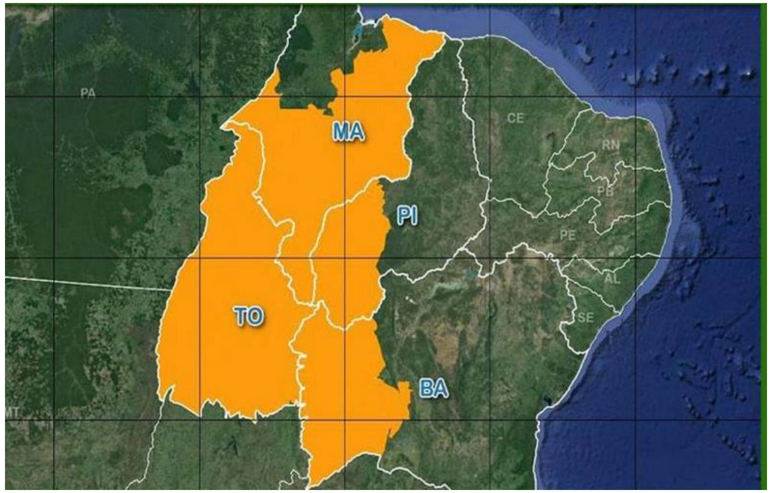
IBGE
Instituto Brasileiro de Geografia e Estatística

LAMPEGE
LABORATÓRIO DE MONITORAMENTO
E MODELAGEM PEDOGEOMORFOLÓGICA

Main Ideia

- Evaluate the effects of land use and land cover changes (LULCC) on the watershed water balance and on soil erosion in areas undergoing a rapid expansion of the mechanized agriculture in Brazil

- Focus: the MATOPIBA Region (NE Brazil)

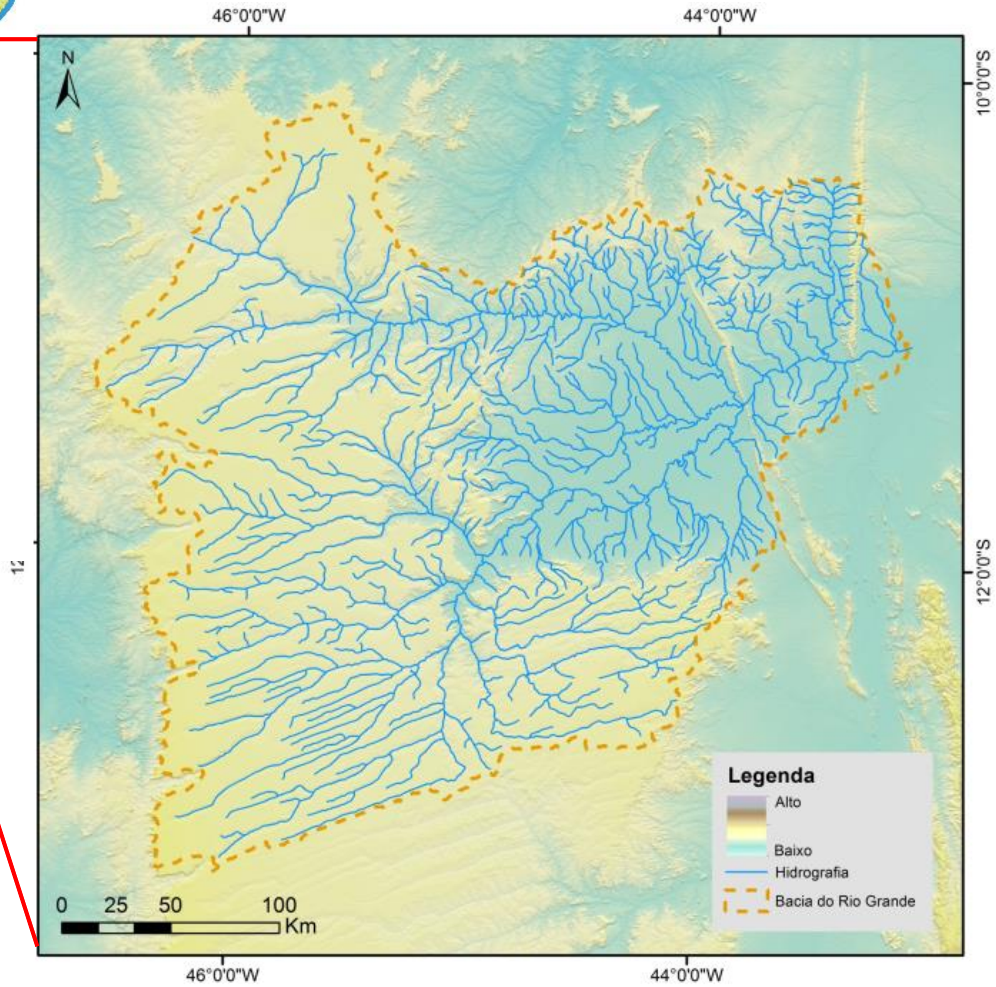


Experimental Basin

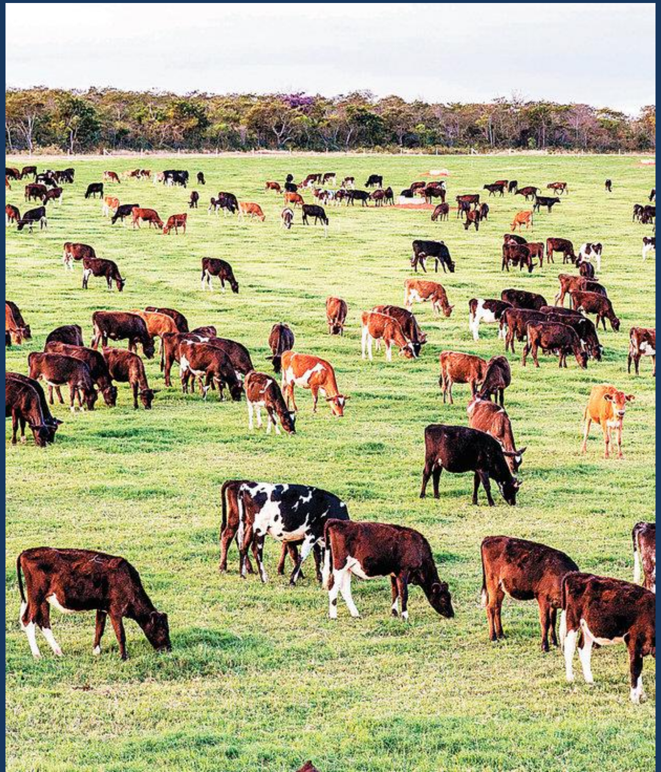
Grande river basin

(Western portion of Bahia State; ~76,000 km^2)

Land use and land cover map of Brazil – 2016. IBGE



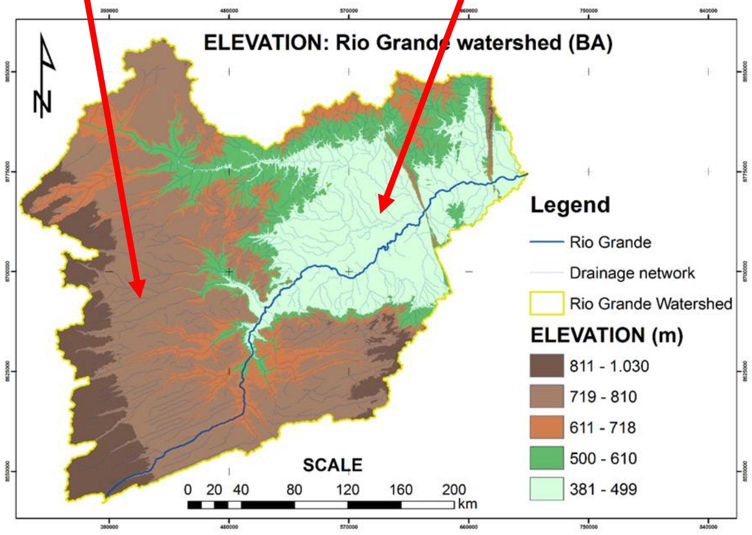
Barreiras - BA



best areas for
agriculture expansion → flat plateaus (sandstones)

High Plateaus

Lowlands



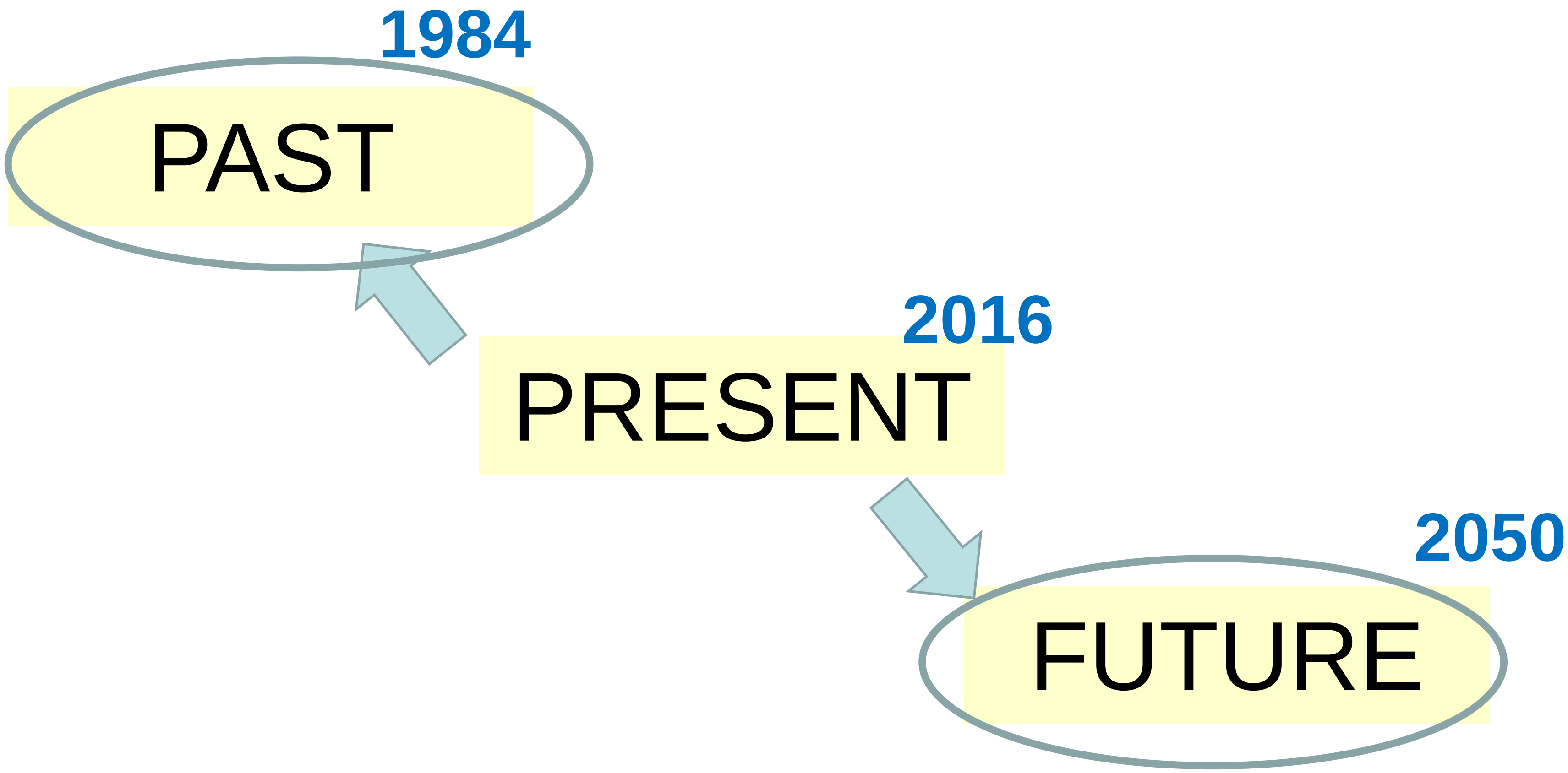
Defining Scenarios

MEETING LOCAL STAKEHOLDERS

FIELD MAPPING

(Geology, Topography, Soils, Land Use)

Hydrologic Modeling
Land Use Input Conditions



3 Scenarios

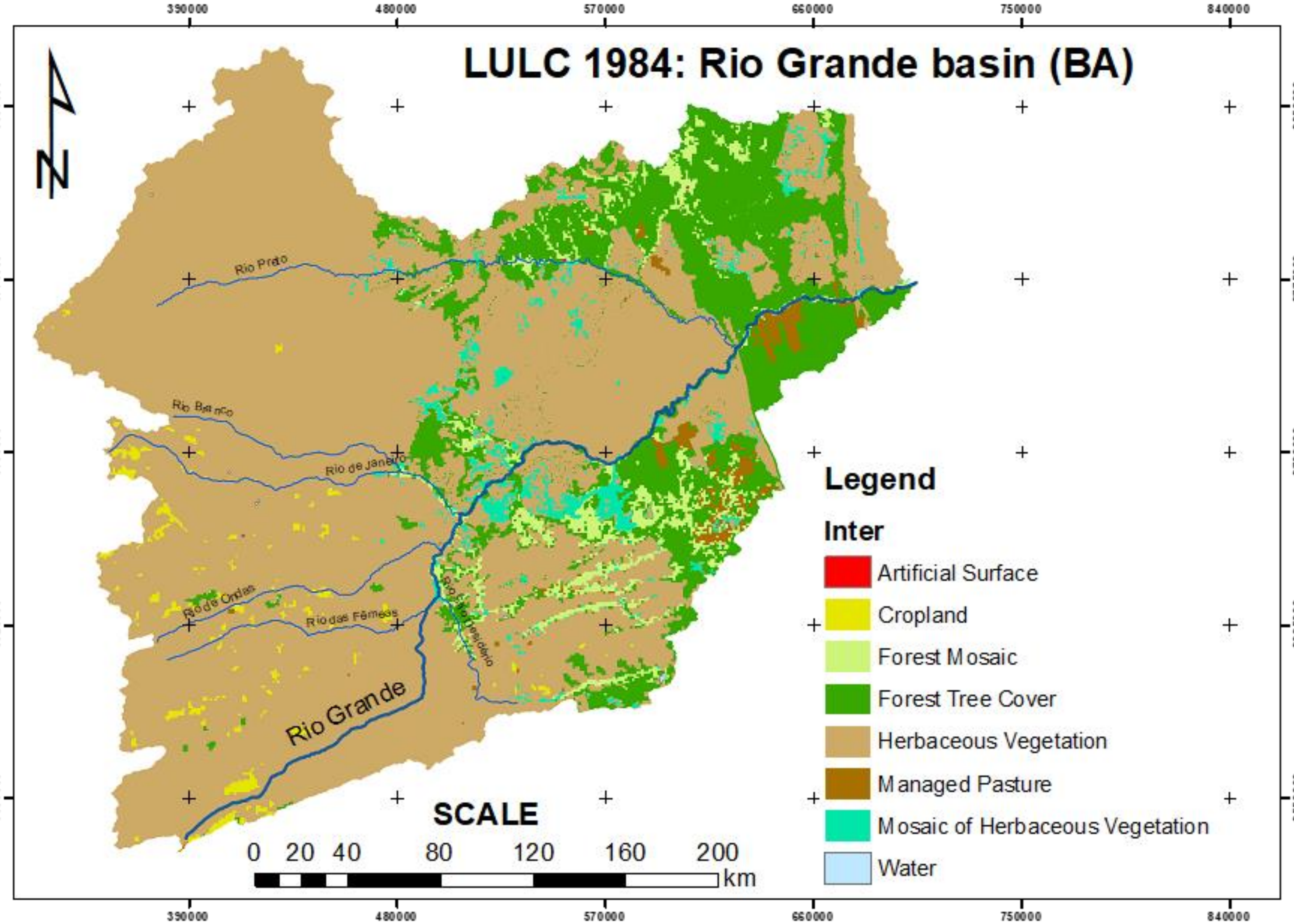
Scenarios	Description
LULC Previous Condition (1984)	Simulation of water balance and sediment production computed by LULC of 1984.
LULC Current Condition (2016)	Simulation of water balance and sediment production according to the current condition, computed by the LULC map (2016).
Agressive Devolopment	**A)** 100% of agricultural expansion over current arable areas (CAA), regardless of the climate changes **B)** 100% of agricultural expansion over current arable areas (CAA) taking into account the climate changes (changes in temperatures and precipitations).

Main Ecosystem Services Studied

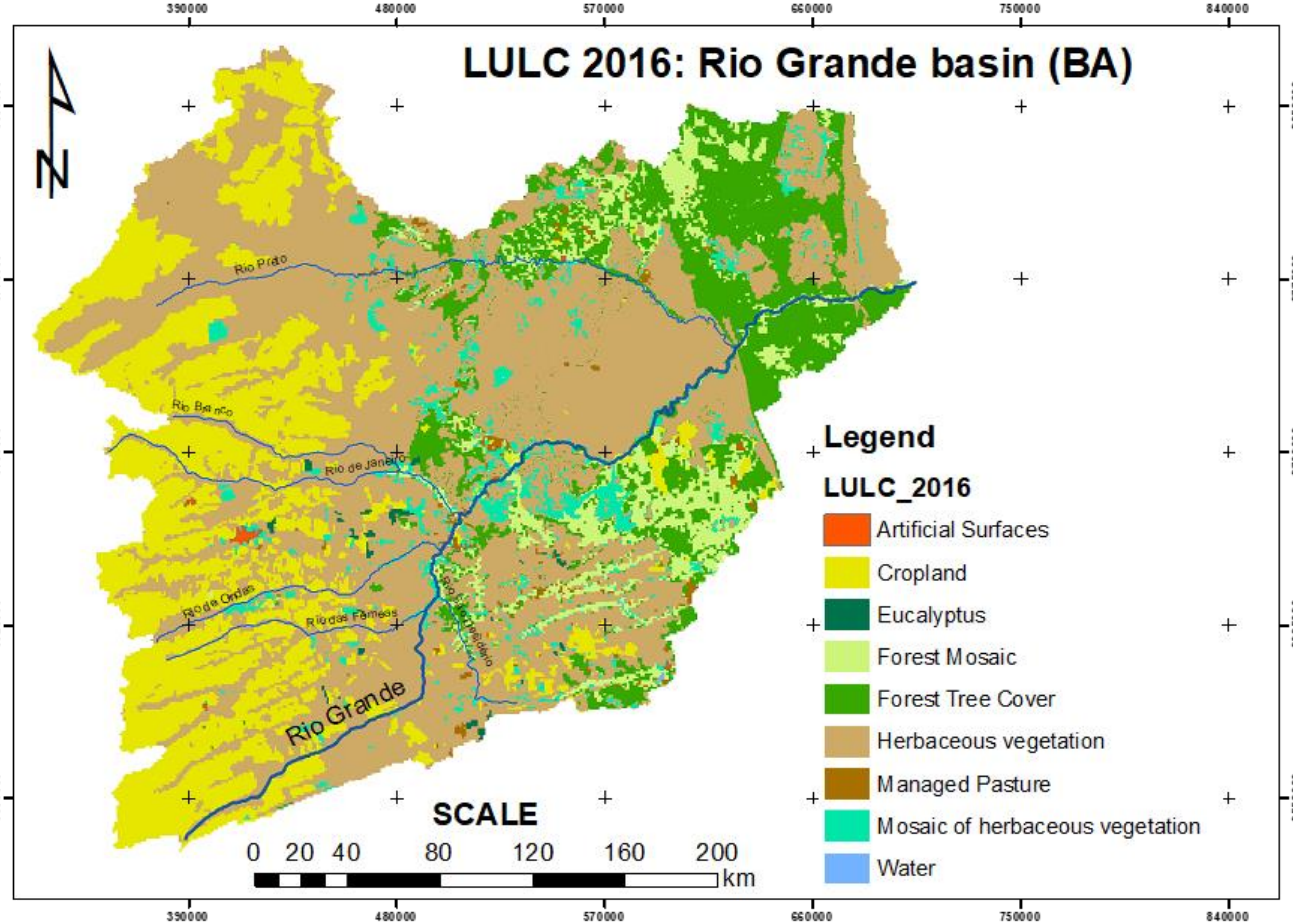
- Water supply
- Water flow regulation
- Rainfall pattern regulation
- Soil and sediment retention, especially in drainage basins characterized by a rapid replacement of natural vegetation by croplands and urban areas.

Models Used

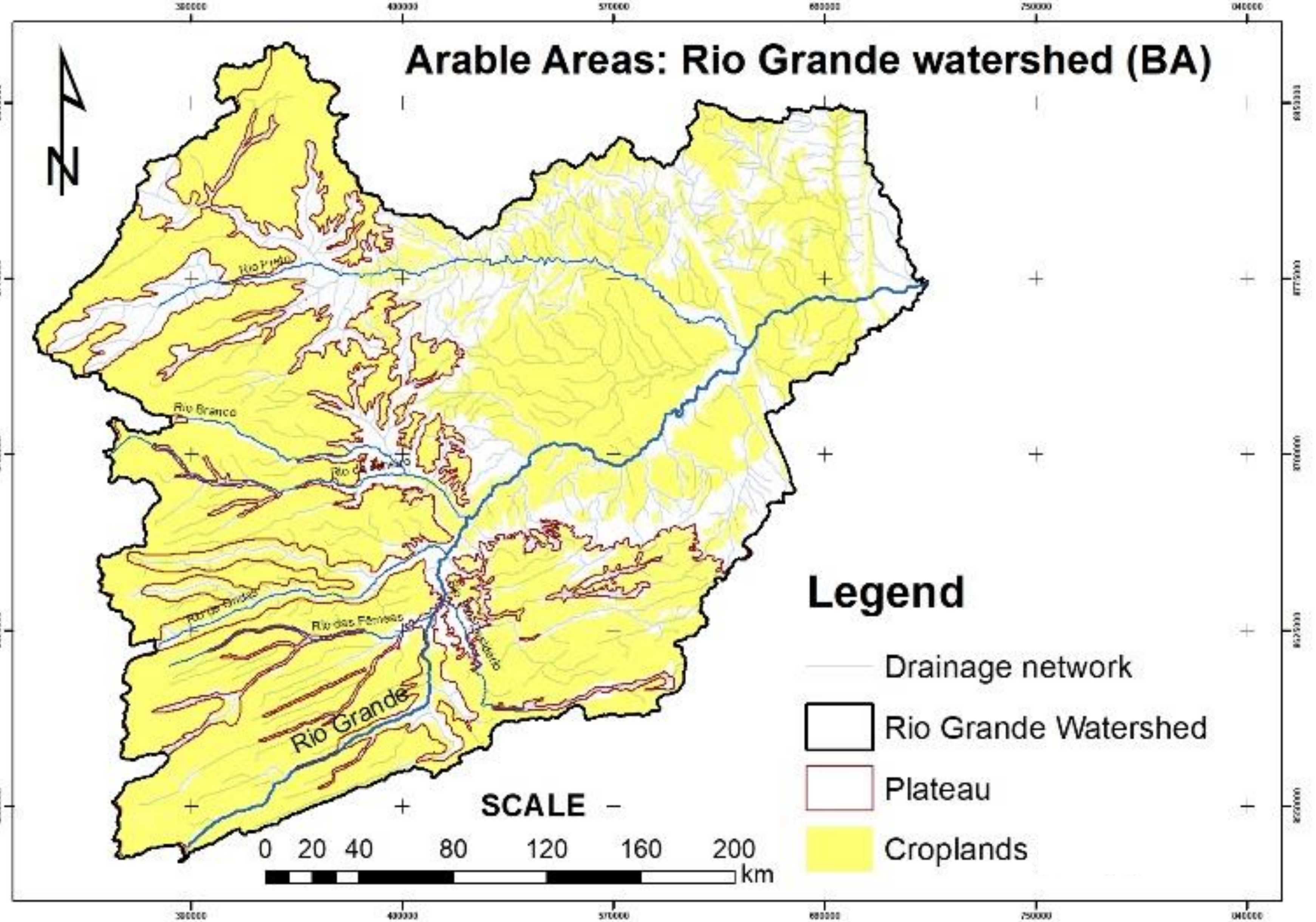
- SWAT
- InVEST
- ARIES



LULC 1984: Rio Grande basin (BA)
N
Rio Preto
Rio Branco
Rio de Janeiro
Rio de Ondas
Rio das Fêmeas
Rio Grande
Legend
Inter
Artificial Surface
Cropland
Forest Mosaic
Forest Tree Cover
Herbaceous Vegetation
Managed Pasture
Mosaic of Herbaceous Vegetation
Water
SCALE
0 20 40 80 120 160 200
km
390000
480000
570000
660000
750000
840000
8850000
8775000
8700000
8625000
8550000


LULC 2016: Rio Grande basin (BA)
N
Rio Preto
Rio Branco
Rio de Janeiro
Rio de Ondas
Rio das Fêmeas
Rio Grande
Legend
LULC_2016
Artificial Surfaces
Cropland
Eucalyptus
Forest Mosaic
Forest Tree Cover
Herbaceous vegetation
Managed Pasture
Mosaic of herbaceous vegetation
Water
SCALE
0 20 40 80 120 160 200
km
390000
480000
570000
660000
750000
840000
8850000
8775000
8700000
8625000
8550000

Aggressive Development Scenario



LULCC from 1984 to 2016

LULC	AREA				
	1984		2016		Relative Change
	km^2	%	km^2	%	%
Herbaceous Vegetation	58237.97	75.59	40441.22	51.67	-30.56
Cropland	812.32	1.05	18575.64	23.73	2186.74
Forest Tree Cover	12345.14	16.02	10199.39	13.03	-17.38
Forest Mosaic	2956.36	3.84	5269.83	6.73	78.25
Mosaic of Herbaceous Vegetation	1713.71	2.22	2899.08	3.70	69.17
Managed Pasture	940.14	1.22	555.86	0.71	-40.87
Artificial Surface	13.71	0.02	99.92	0.13	628.79
Water	24.50	0.03	24.72	0.03	0.89
Eucalyptus	0.00	0.00	204.84	0.26	
Total		100		100	

The results presented in Table 1 attest that in the Grande river basin, during the studied period from 1984 to 2016, it is not the Forest Tree Cover that is being replaced by croplands but, instead, the savannah/shrublands of the Herbaceous Vegetation

Hydrologic Modeling with SWAT: Implementation and Results

Implementing the SWAT model

Streamflow Calibration and Validation

- Calibration Procedures
- Validation Procedures
- Cross-Validation Procedures

Sediment Calibration and Validation

Model Results

Hydrologic Components of Water Flow Regulations

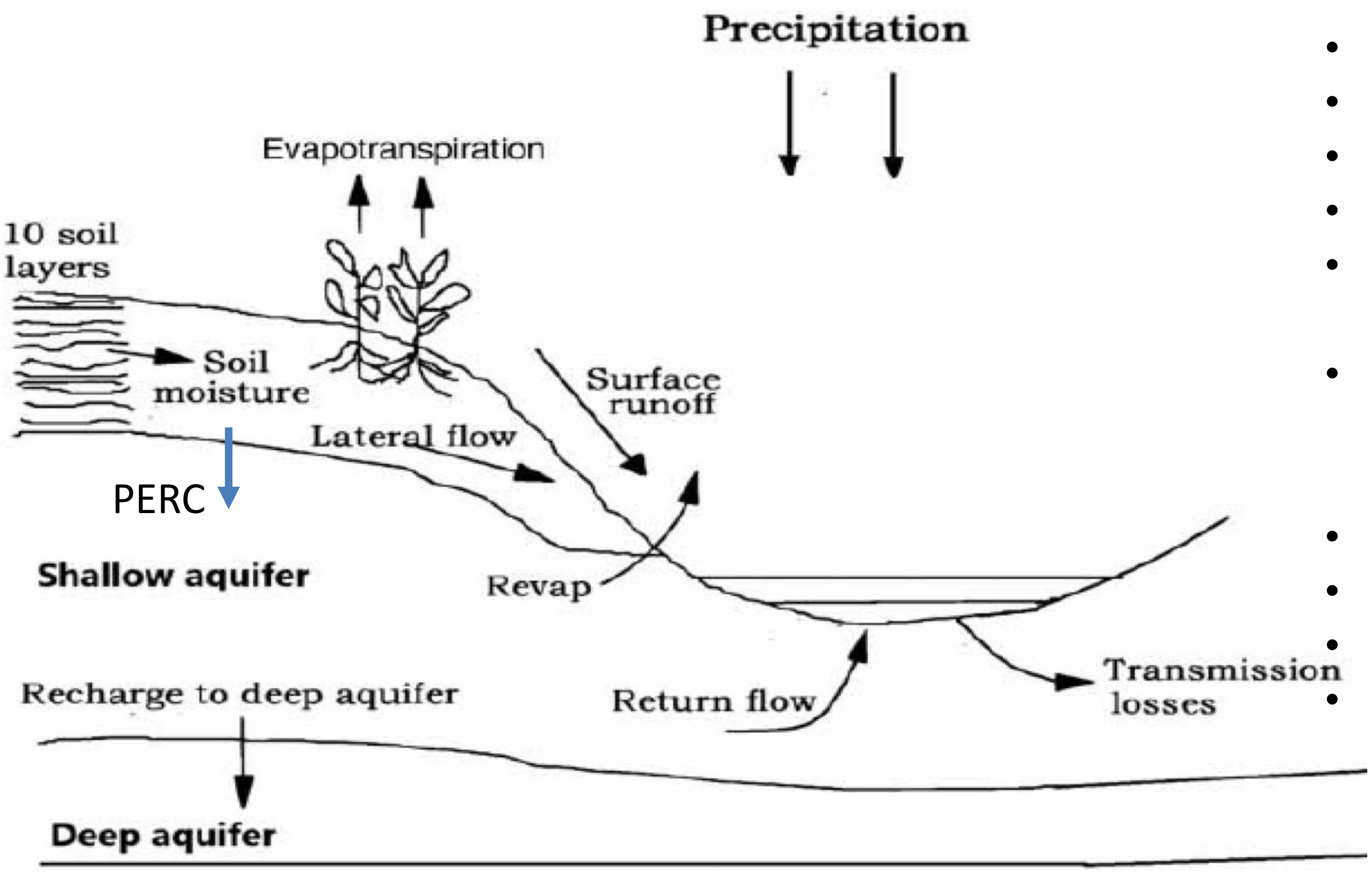
Hydrological Results for 2016

Hydrological Results for 1984

Hydrologic Changes from 1984 to 2016

Sediment Yield (1984 x 2016)

Main Hydrologic Components of the SWAT Models are (all expressed in mm)

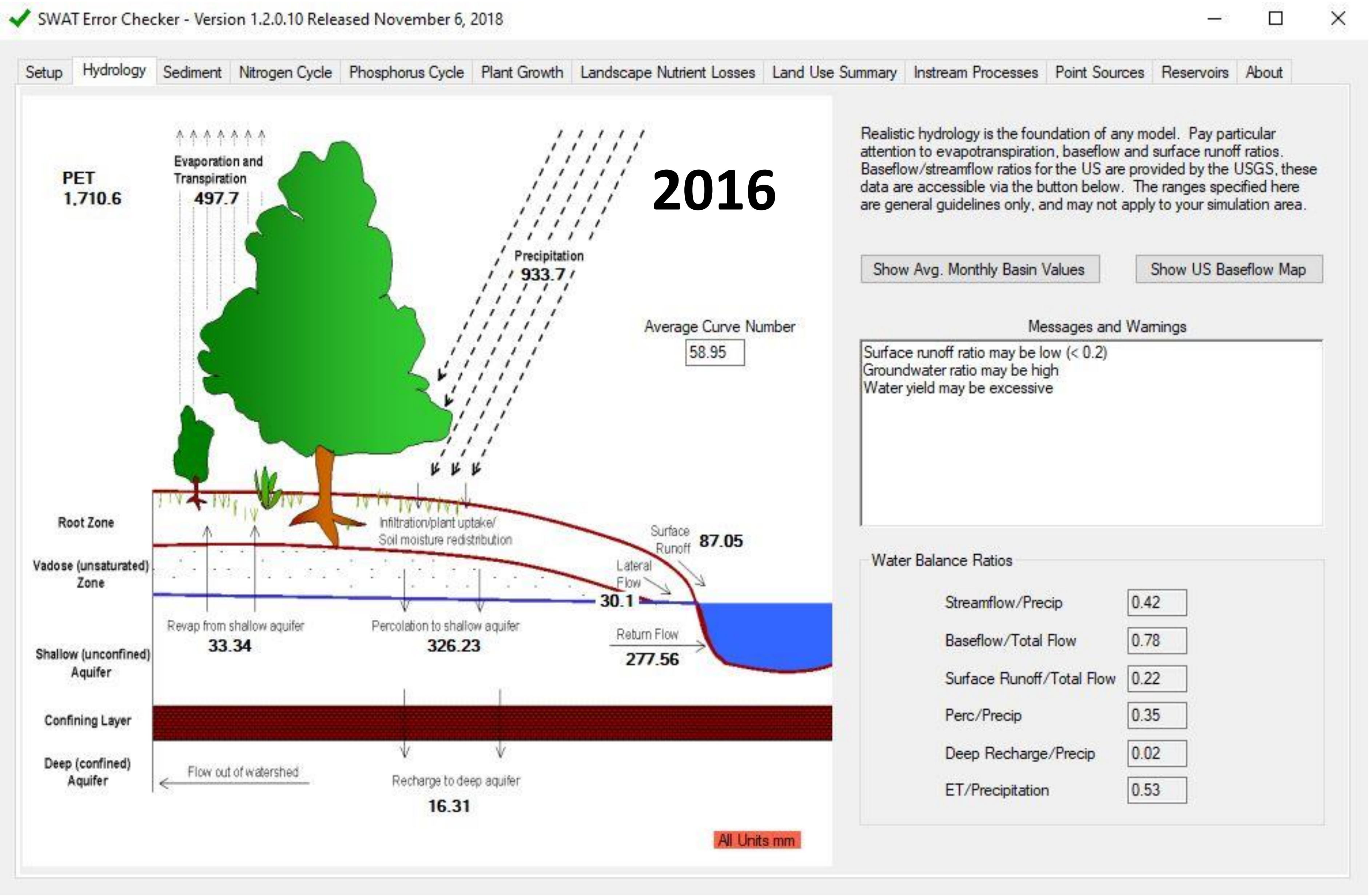


- **soil water content (SW)**
- **surface runoff (SURQ)**
- **lateral flow (LATQ)**
- **groundwater flow or return flow (GW_Q)**
- **baseflow**
  - SWAT consider baseflow = LATQ + GW_Q
- **water yield (WYLD)**
  - is the stream discharge at the HRUs and sub-basin scales;
  - WYLD = SURQ + LATQ + GWQ (Eq. 2);
- **percolation (PERC)**
- **groundwater recharge or deep recharge (GW_RCHG)**
- **evapotranspiration (ET)**
- **streamflow (FLOW_OUT)**
  - defined at the watershed scale (the whole drainage basin);
  - represents the stream discharge leaving the catchment outlet (m^3/s).

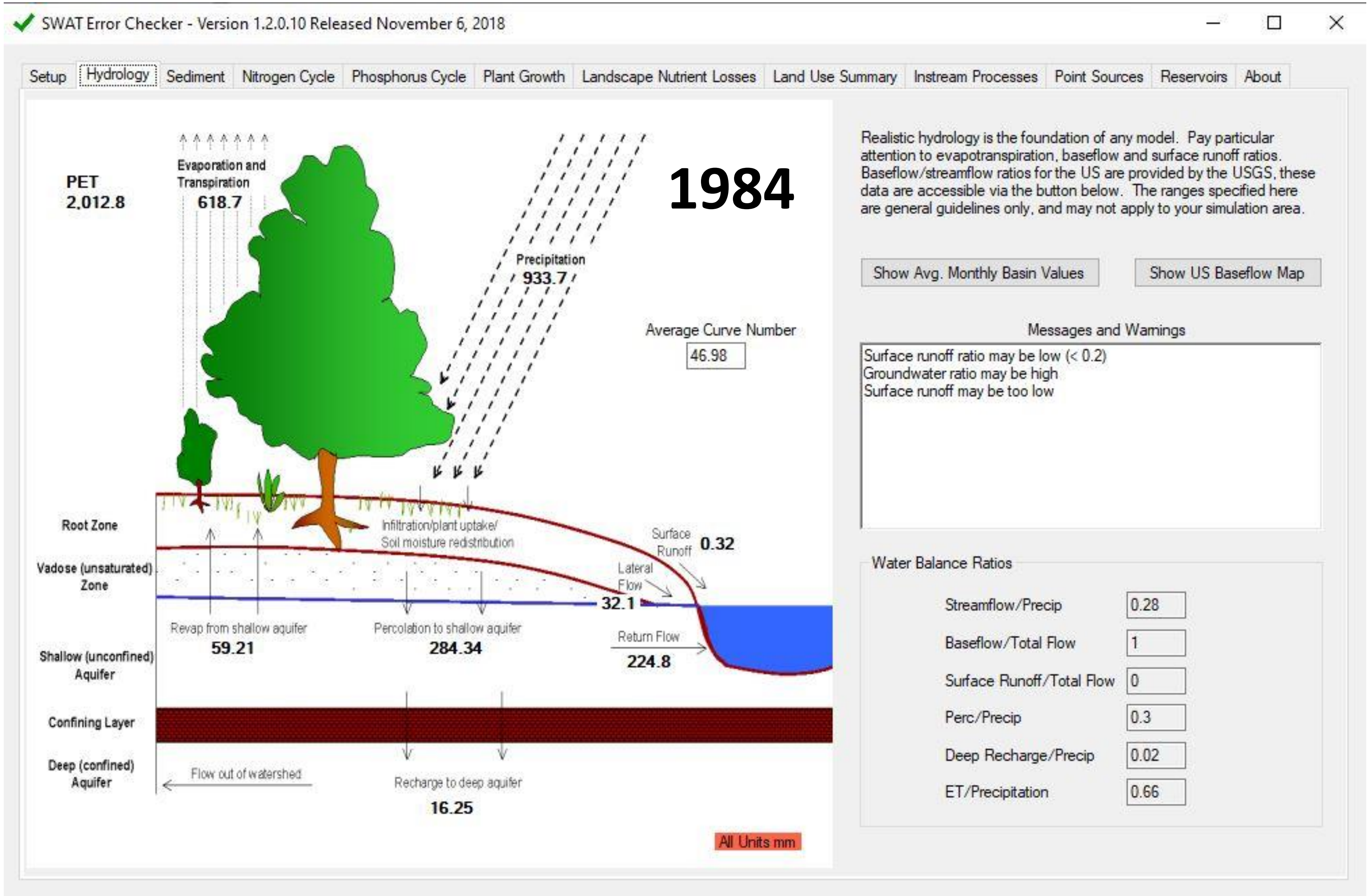
$$\mathrm{WYLD} = \mathrm{SURQ} + \mathrm{LATQ} + \mathrm{GW\_Q} = \mathrm{SURQ} + \mathrm{baseflow}$$

$$\mathrm{FLOW\_OUT} = \sum_{i=1}^{n} \mathrm{WYLD}$$

SWAT Model Output for 2016 – Global Annual Values



SWAT Model Output for 1984 – Global Annual Values



Hydrologic Changes – 1984 x 2016

Hydrologic Components (mm)	1984	2016	Relative Change (%)
Evapotranspiration	618.70	497.70	-19.56
Surface runoff	0.32	87.05	27103.13
Lateral flow	32.10	30.10	-6.23
Groundwater flow	224.80	277.56	23.47
Water yield	257.22	394.71	53.45
Baseflow	256.90	307.66	19.76
Percolation	284.34	326.23	14.73
Deep recharge	16.25	16.31	0.37
Revap	59.21	33.34	-43.69

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Main Results :
- Decrease in EVT
- Huge increase in surface runoff
- Increase in water yield
- Small increase in groundwater flow, baseflow and percolation

Results in Terms of Water Balance Ratios

(1984 x 2016)

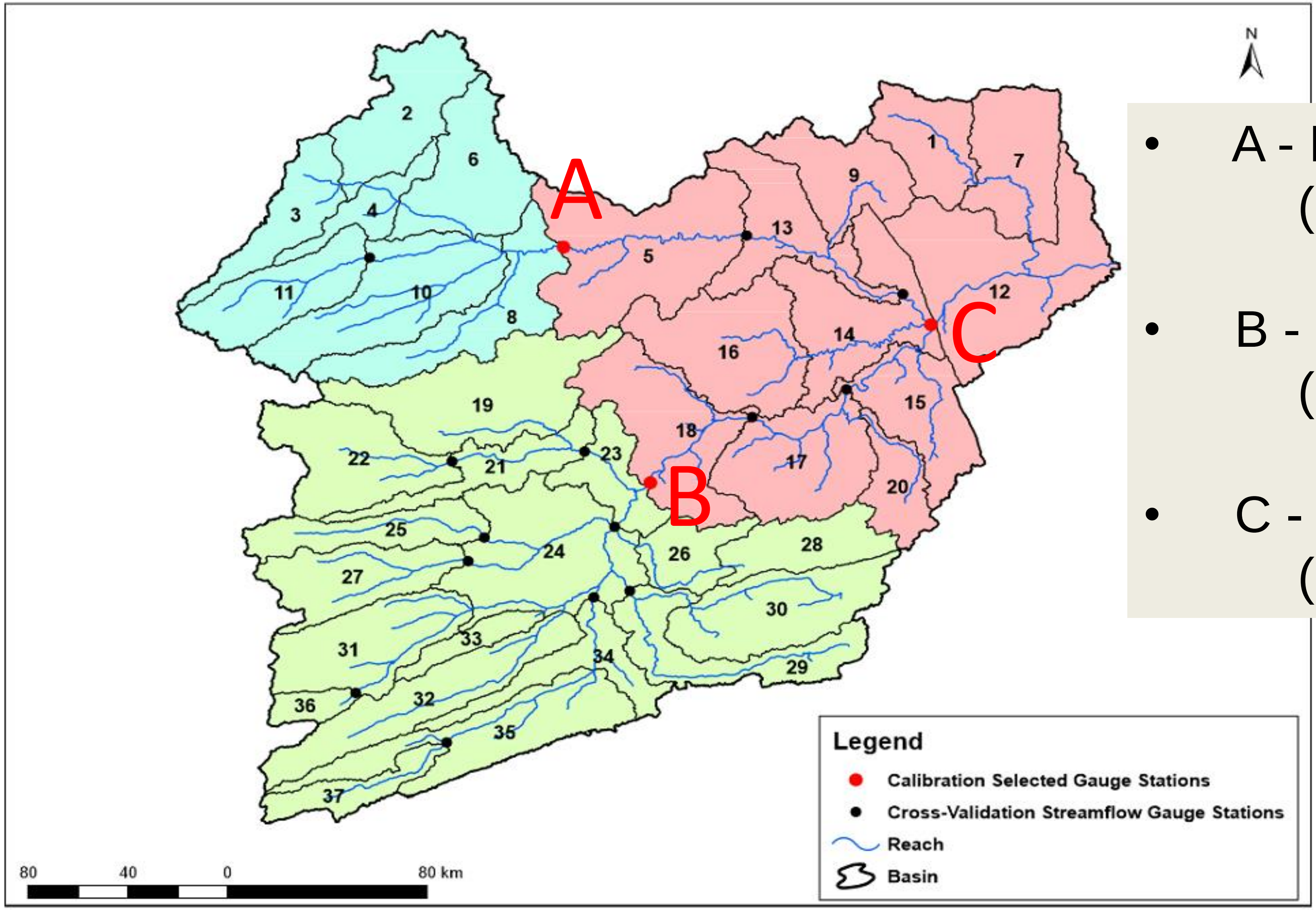
Water Balance Ratios	1984	2016	Relative Change (%)
ET/Precip	0.66	0.53	-19.70
Streamflow/Precip	0.28	0.42	50.00
Percolation/Precip	0.30	0.35	16.67
Deep Recharge/Precip	0.02	0.02	0.00
Baseflow/Total flow	1.00	0.78	-22.00
Surface runoff/Total flow	0.00	0.22	21900.00

Main Results :

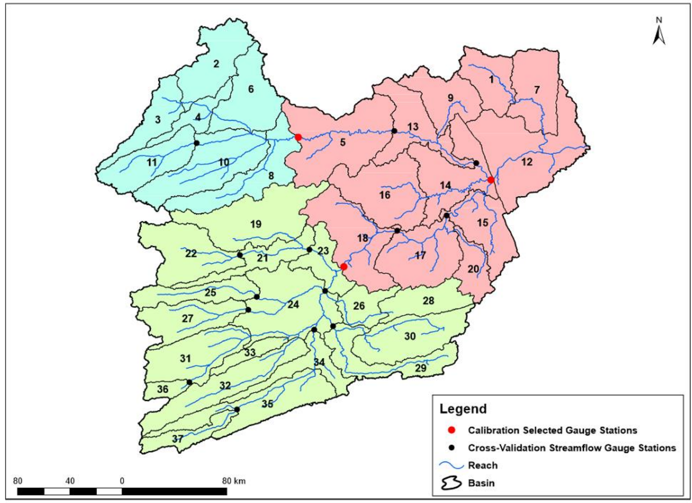
- Decrease in EVT
- Increase in streamflow (water yield)
- Decrease in the contribution of baseflow to the total flow (although baseflow has increased in absolute values – see previous table)
- Huge increase in the contribution of surface runoff to the total flow

The basin was divided in 3 main hydrologic regions

(used for calibration/validation and check the spatial distribution of the hydrologic changes)



- A - Northern Upstream region (or Northern Plateau) [BLUE]
- B - Southern Upstream region (or Southern Plateau) [GREEN]
- C - Downstream region (or Lowlands) [PINK]



Hydrologic components measured at each one of the three hydrologic regions (1984 x 2016)

Northern Upstream (blue)

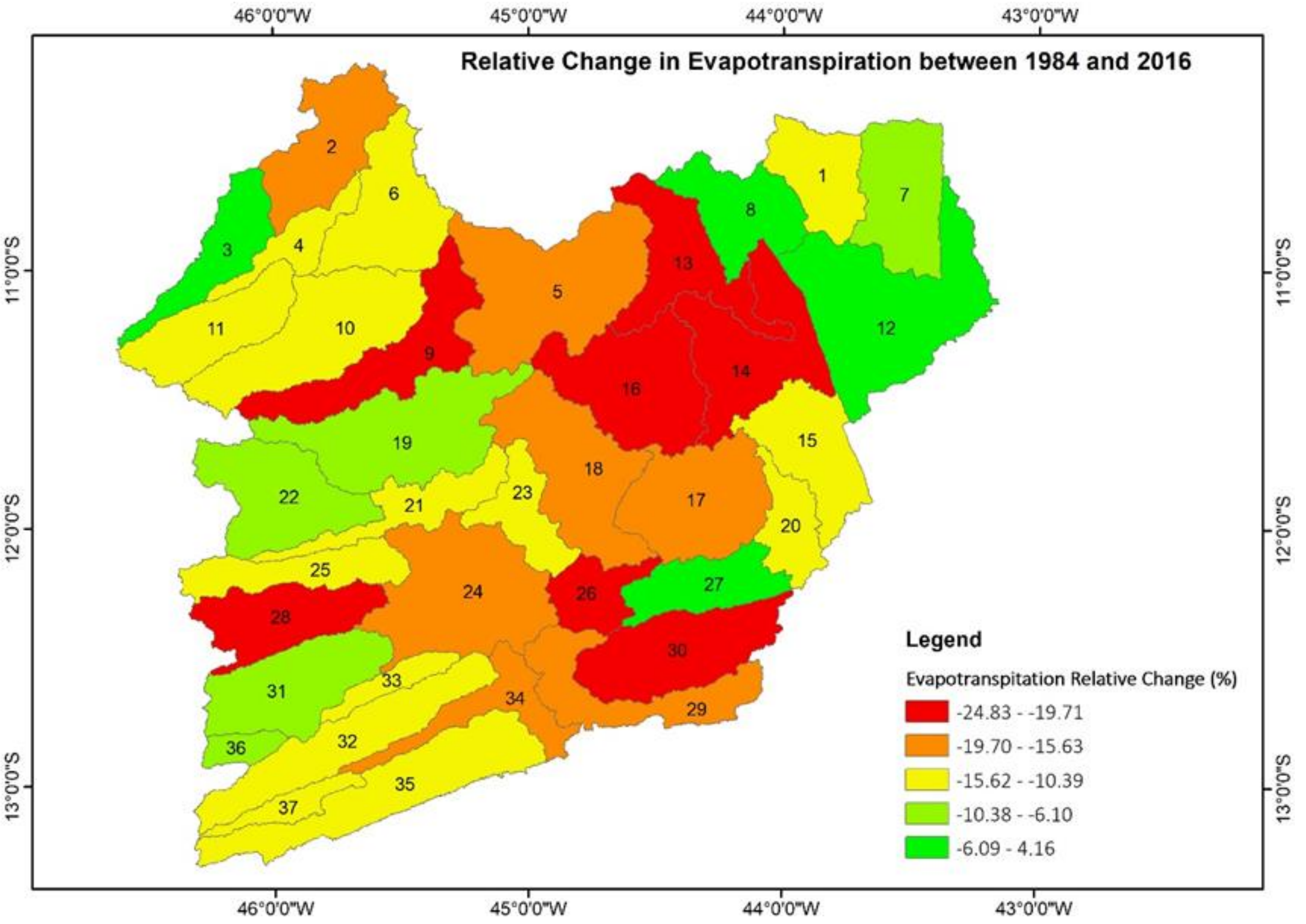
Southern Upstream (green)

Lowlands (pink)

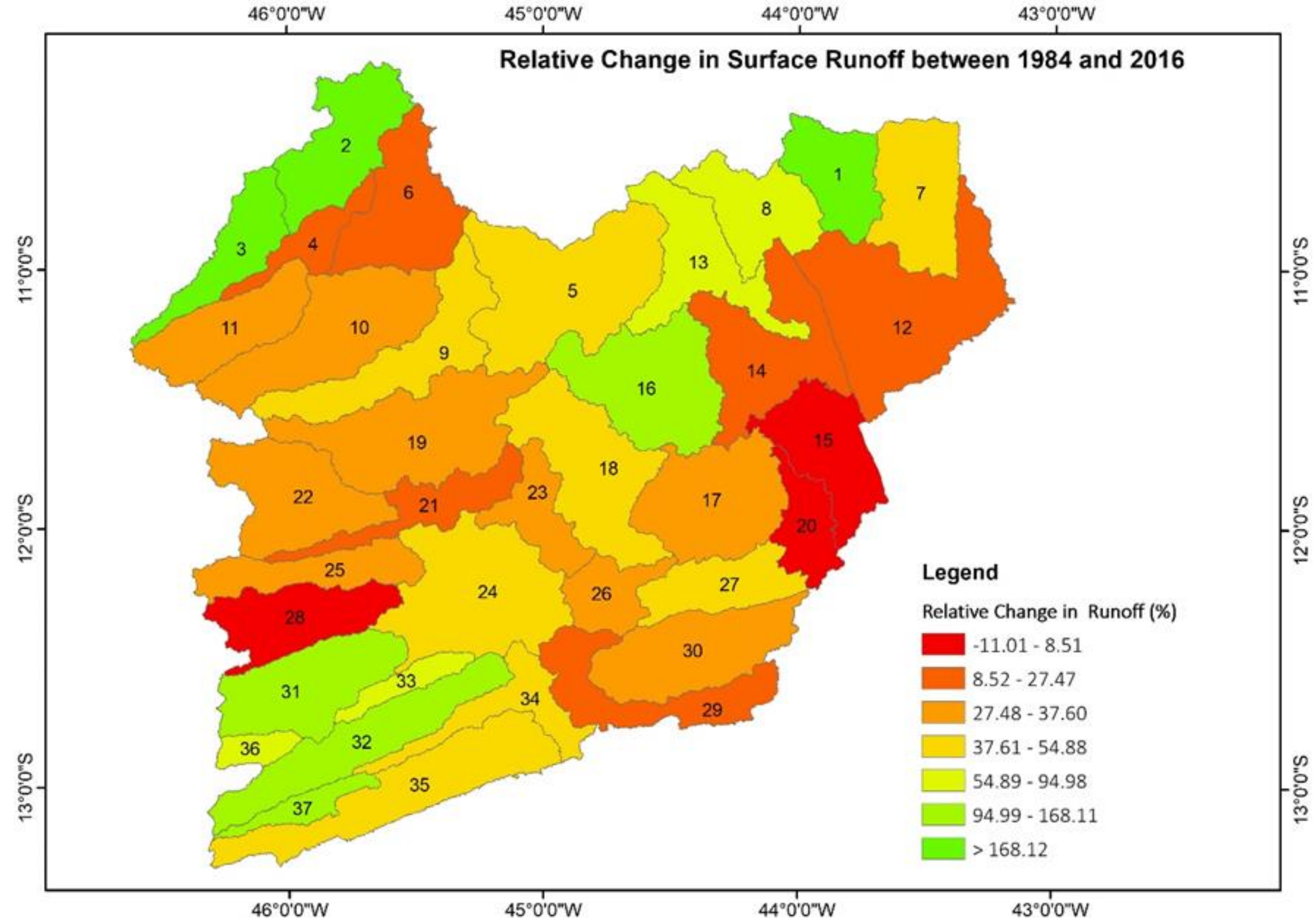
Scenario	1984			2016			Variação Relativa (%)		
Component (total sum)/ Section	North Upper Stream (8)	South Upper Stream (23)	Lowlands (14)	North Upper Stream (8)	South Upper Stream (23)	Lowlands (14)	North Upper Stream (8)	South Upper Stream (23)	Lowlands (14)
Evapotranspiration (mm)	8445.94	7455.95	8325.45	7867.01	5949.24	4778.66	-6.85	-20.21	-42.60
Percolation (mm)	3432.93	3747.50	3179.43	3806.85	4131.77	6123.32	10.89	10.25	92.59
Runoff (mm)	0.94	10.49	3.04	1052.83	1111.26	607.64	112142.32	10495.53	19907.84
Groundwater (mm)	3210.48	3463.38	1248.94	3200.78	3543.13	5335.08	-0.30	2.30	327.17
Water Yield (mm)	4175.31	4469.24	1893.83	5058.93	5647.72	6649.53	21.16	26.37	251.11
Lateral flow (mm)	865.31	815.24	371.90	614.20	782.28	399.48	-29.02	-4.04	7.42
Sediment Yield (ton/ha)	0.11	0.20	0.42	52.64	9.00	2.53	48642.59	4468.02	505.98

Diminuição da evapotranpiração
Aumento da percolação
Aumento enorme do runoff
Aumento de GW
Aumento de Water Yield
Diminuição do Lateral Flow (que no SWAT é contribuinte do baseflow – na realidade é contribuinte para o water yield)

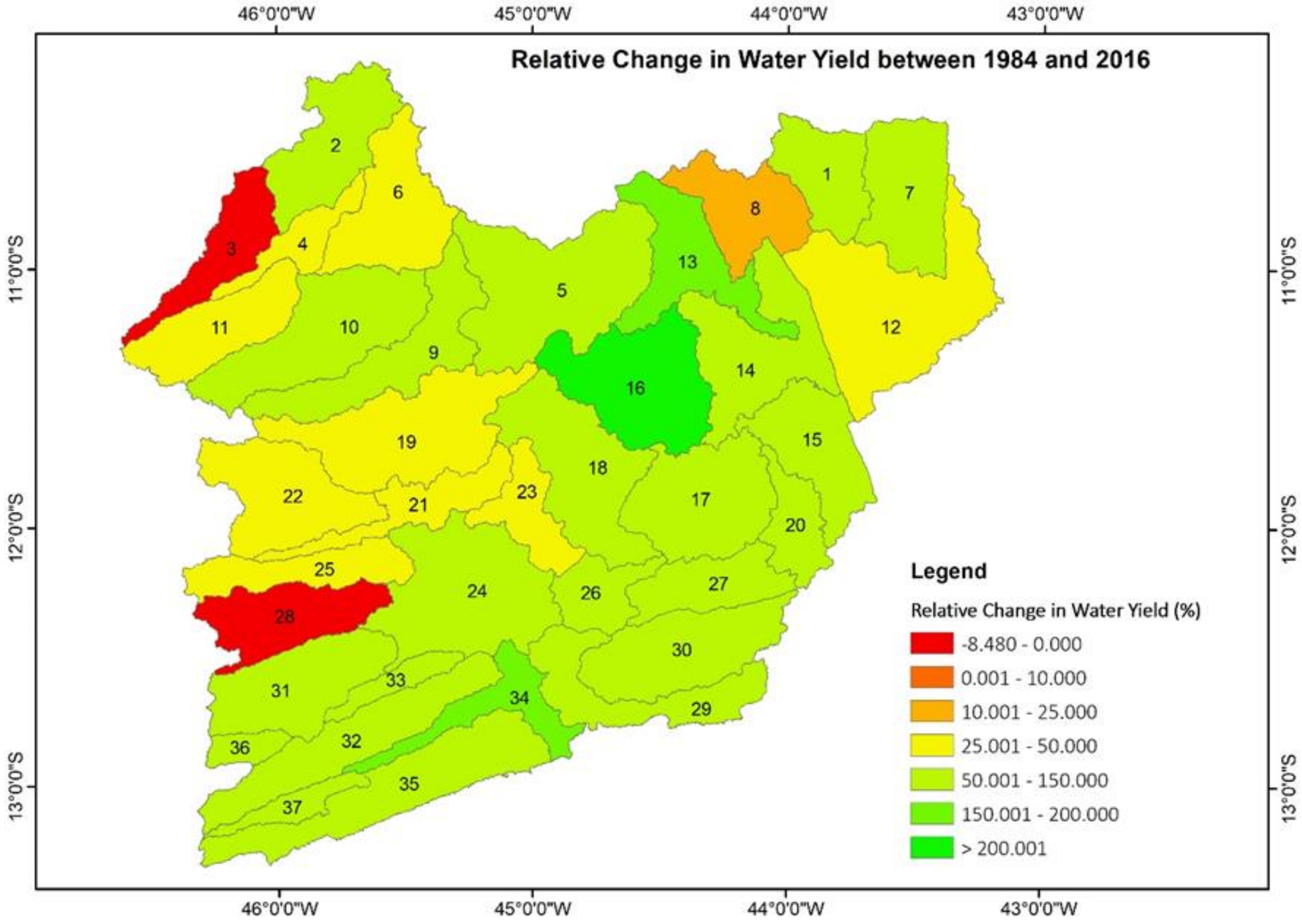
Relative changes in evapotranspiration inside the Grande river basin during the period 1984-2016.



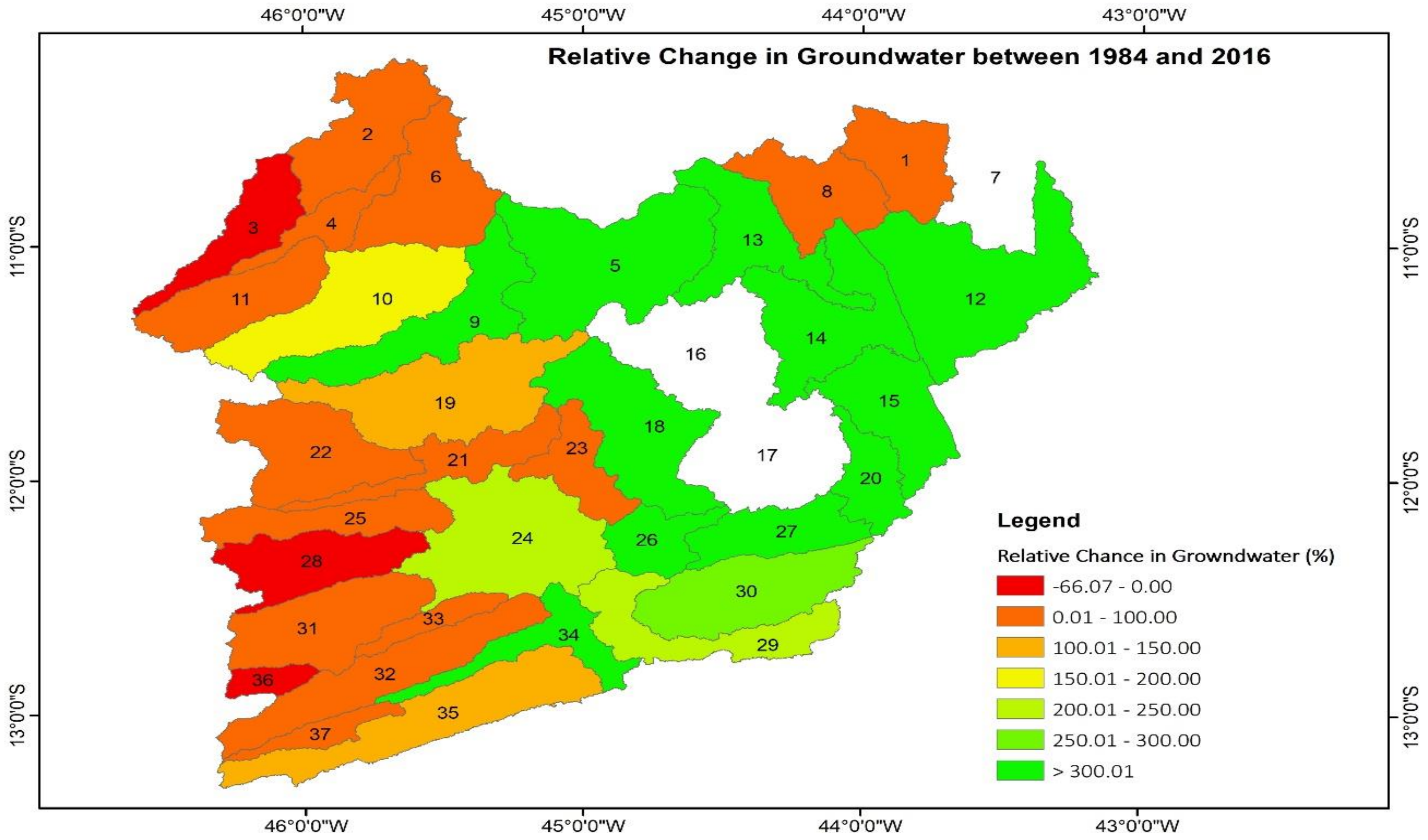
Relative changes in surface runoff inside the Grande river basin during the period 1984-2016.



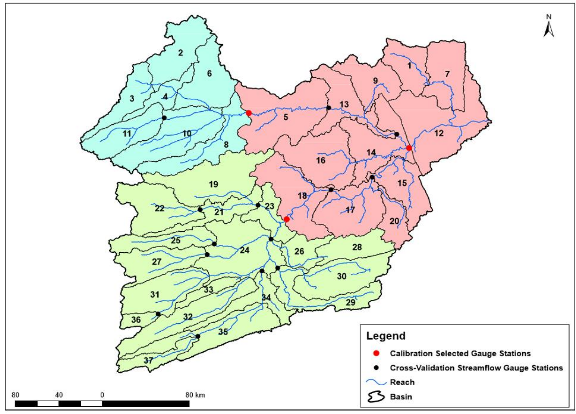
Relative changes in water yield inside the Grande river basin during the period 1984-2016.



Relative changes in groundwater flow inside the Grande river basin during the period 1984-2016.

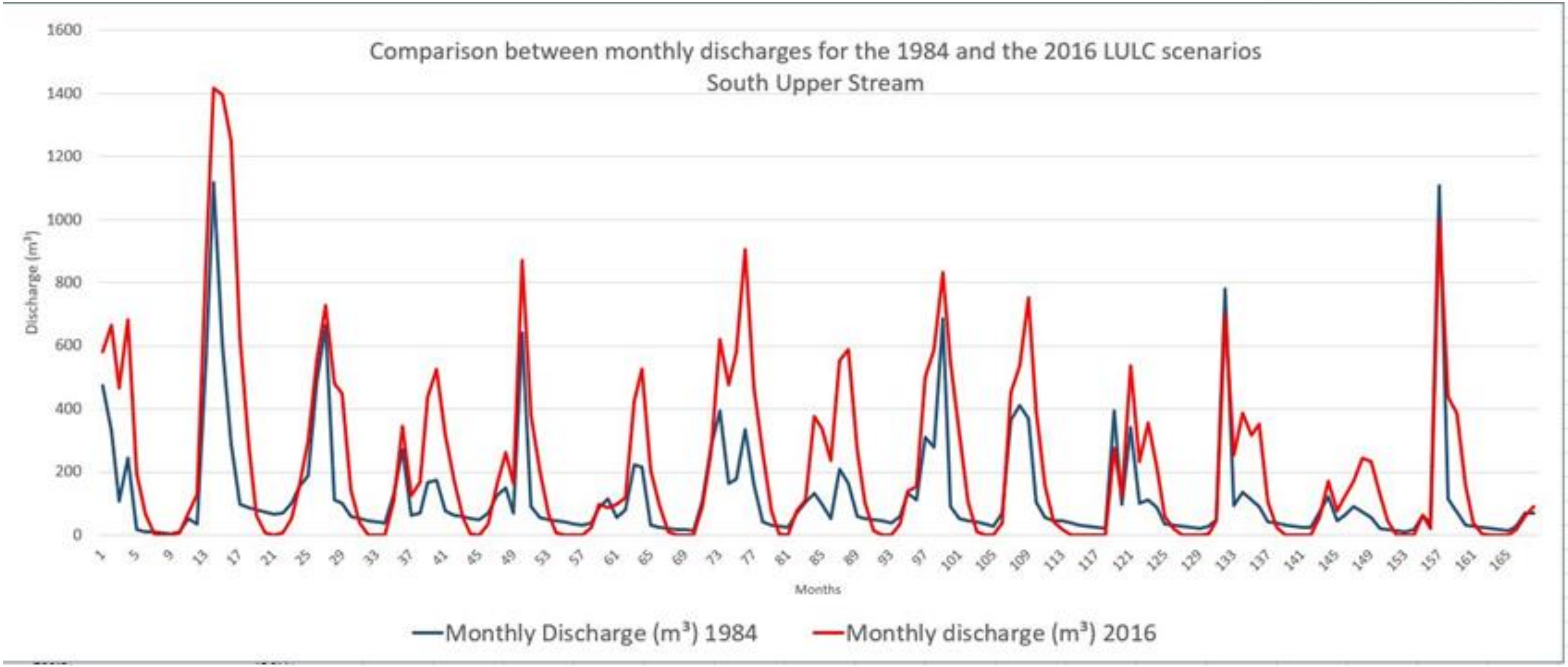


Water flow regulation

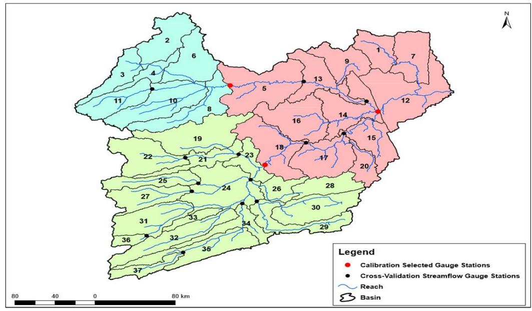


Maximum Flows (peak flows) x Minimum Flows (baseflow)

Southern Upstream (green)

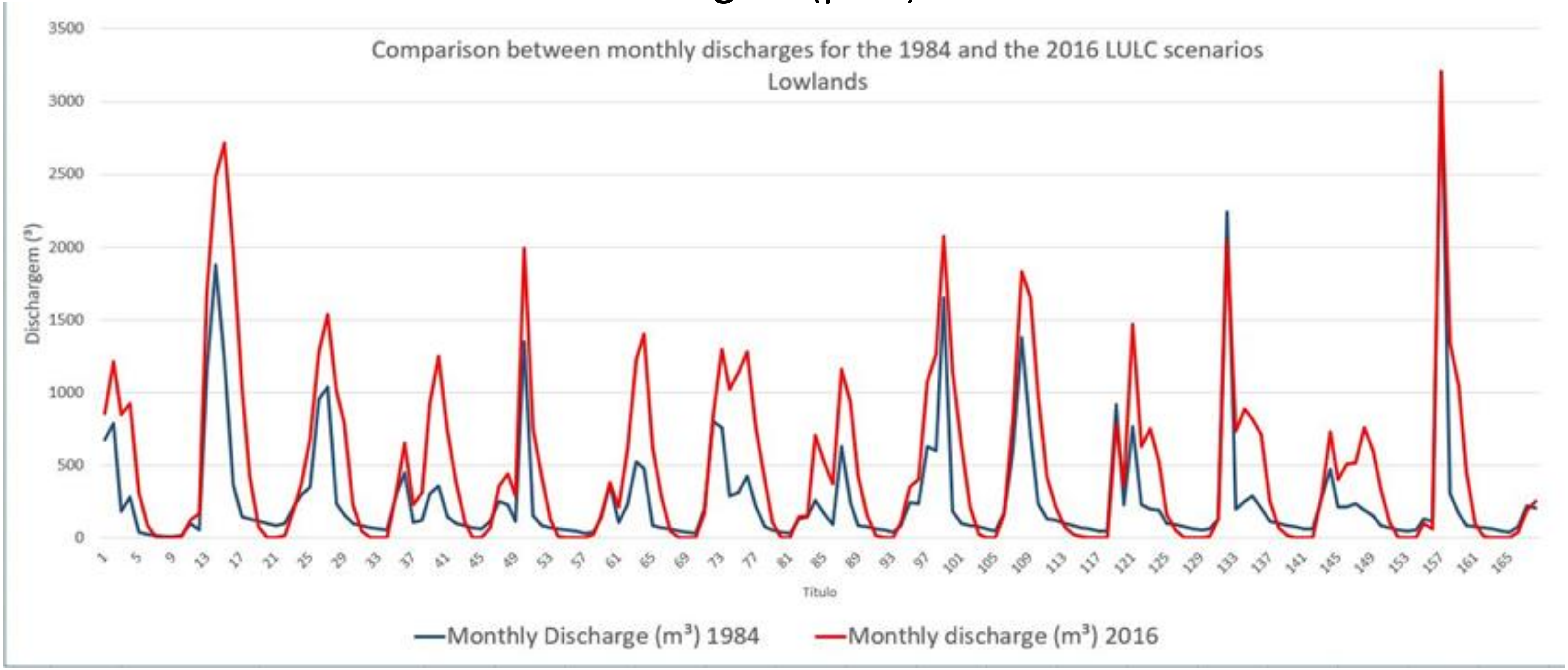


Water flow regulation



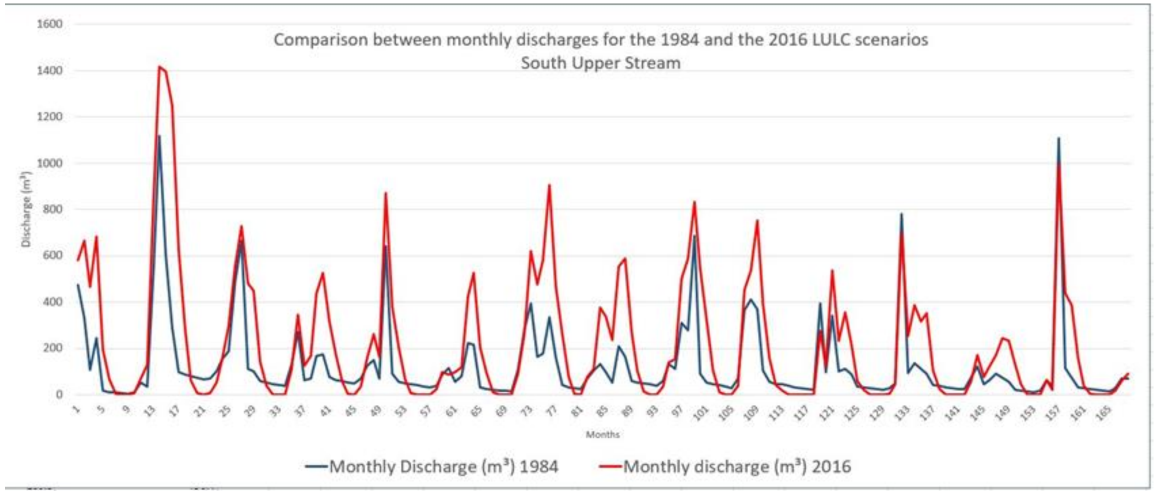
Maximum Flows (peak flows) x Minimum Flows (baseflow)

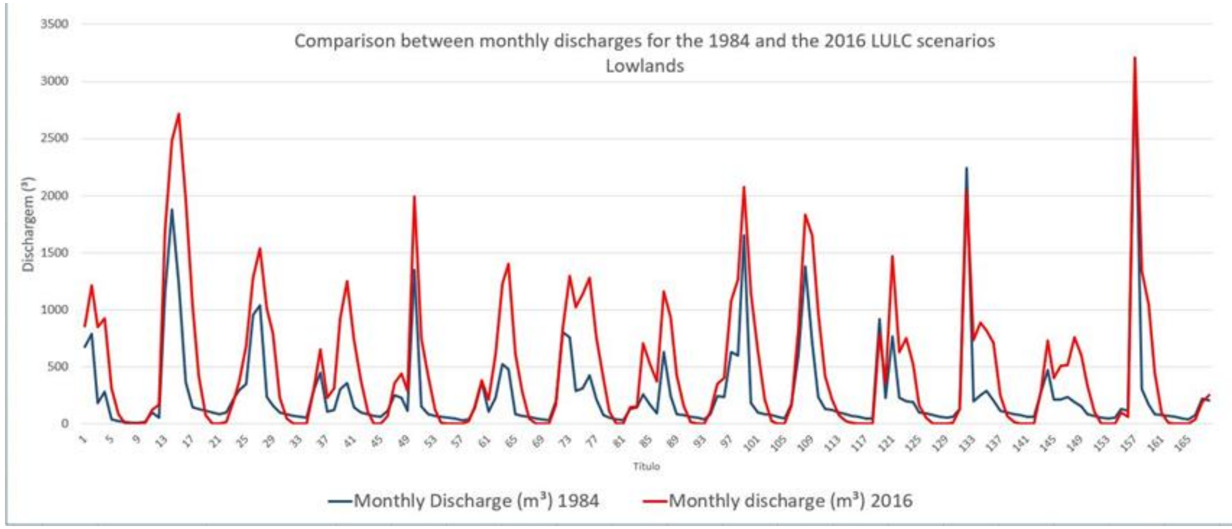
Downstream Region (pink)



Observa-se (visualmente) que a resposta da descarga fluvial na bacia ficou mais rápida (flashy)

1984 (blue) x 2016 (red)





- vazões máximas (peak flows) aumentam
- vazões mínimas (baseflows) diminuem

Quantificação dessa mudança na resposta hidrológica
“The R-B Flashiness Index”

A metric to quantify the frequency and rapidity of short term changes in stream flow (ex. due to LULCC) in response to storm events (for both peak and baseflow)

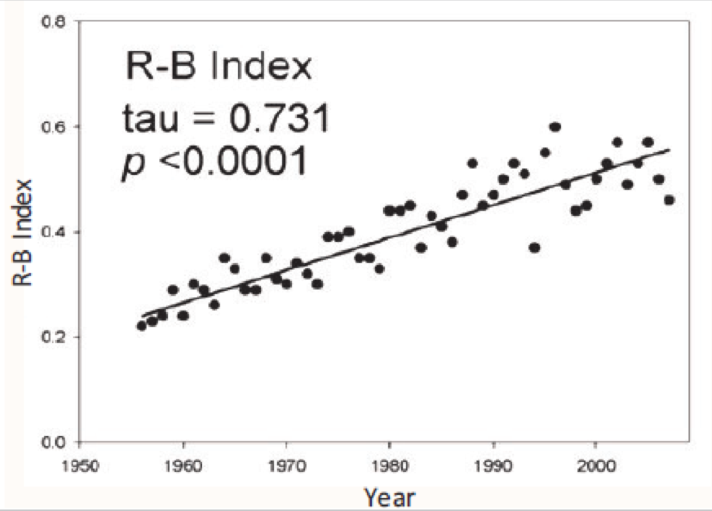


Figure 5. Time series plot showing the trend in flashiness for an urbanizing watershed in the state of Washington (DeGasperi et. al., 2009). The R-B Index had the highest Mann-Kendall tau value of any hydrologic metrics evaluated, suggesting it was a sensitive indicator of change.

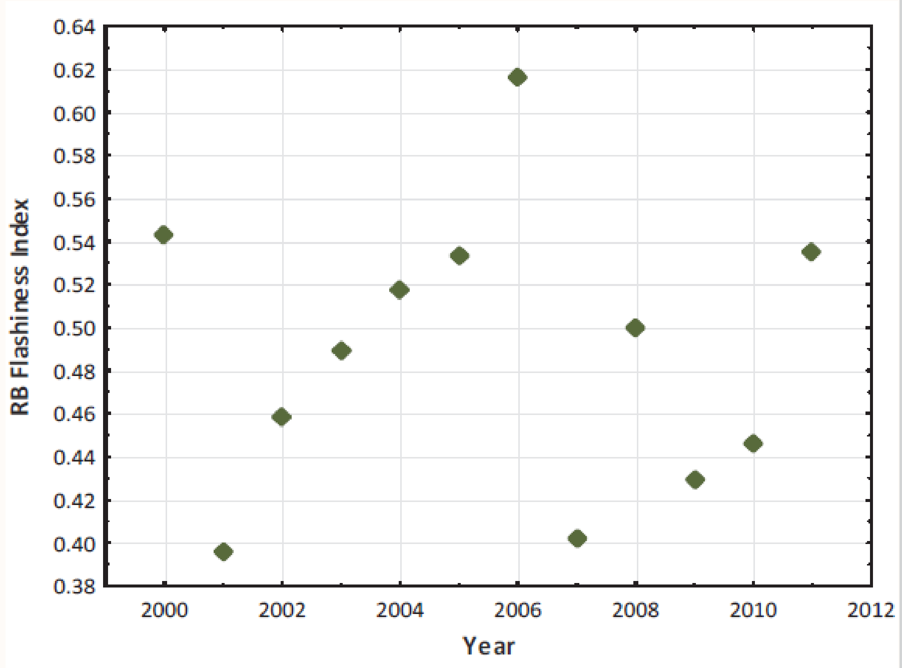
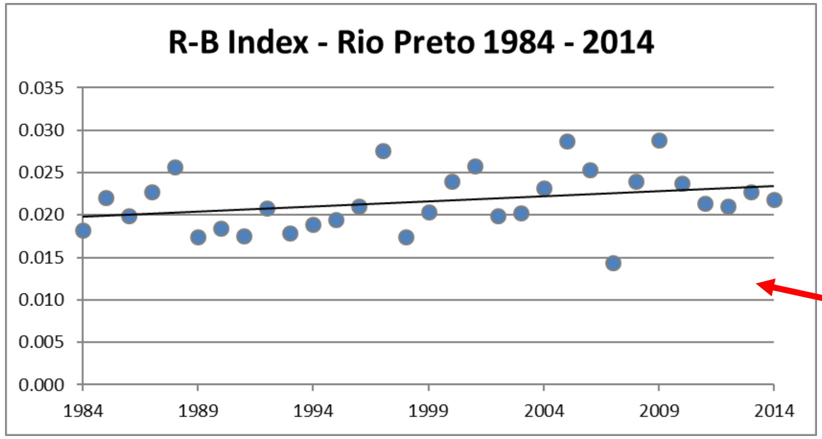
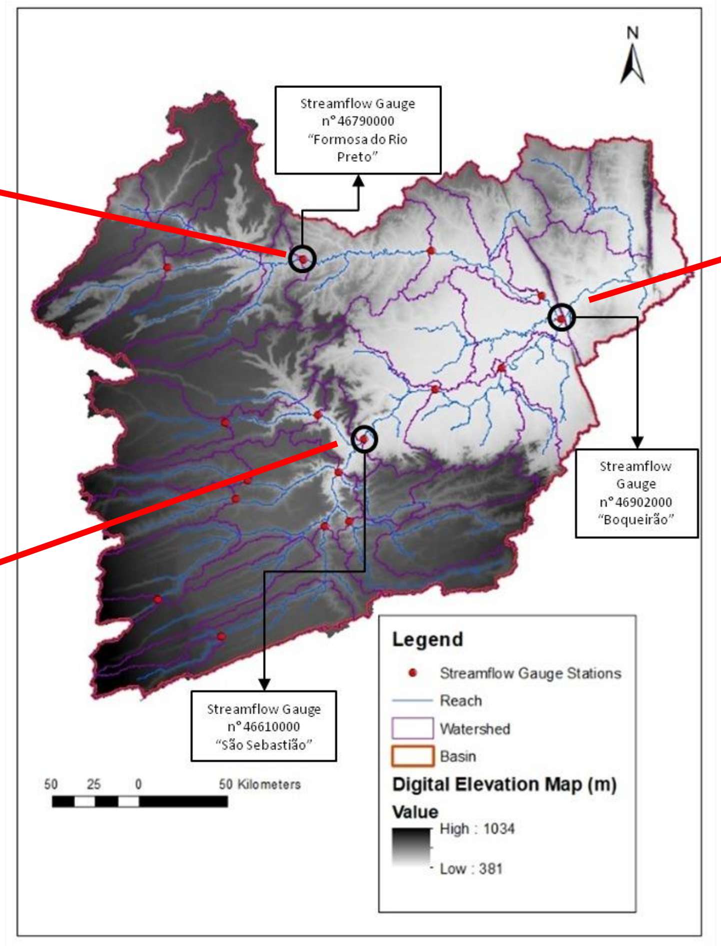


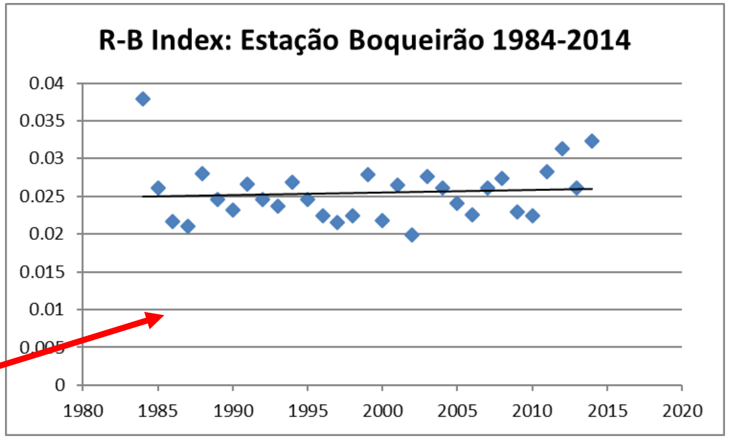
Figure 1. Dry Creek annual Richards-Baker Flashiness Index. Each data point represents the annual flashiness of Dry Creek, measured at the Vernon St. gauge in Roseville. Between 2000 and 2011, there was no consistent trend in flashiness in the watershed.

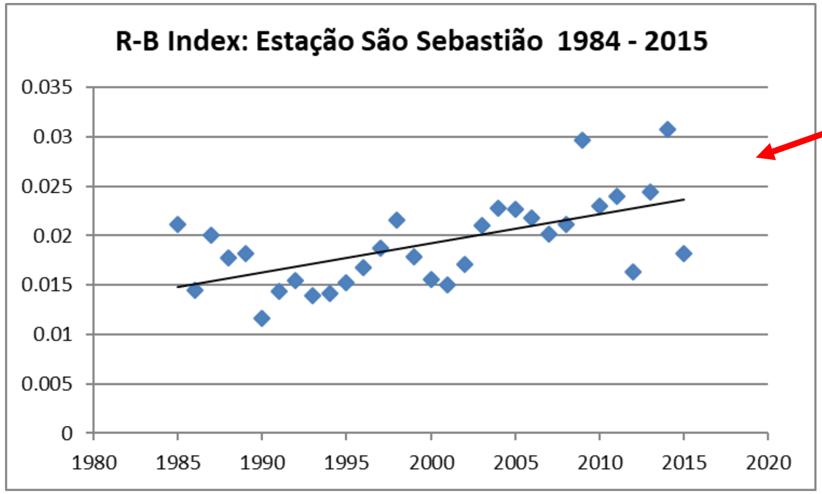
Applying the Flashiness Index to the Grande River Basin

(1984-2014 Period)



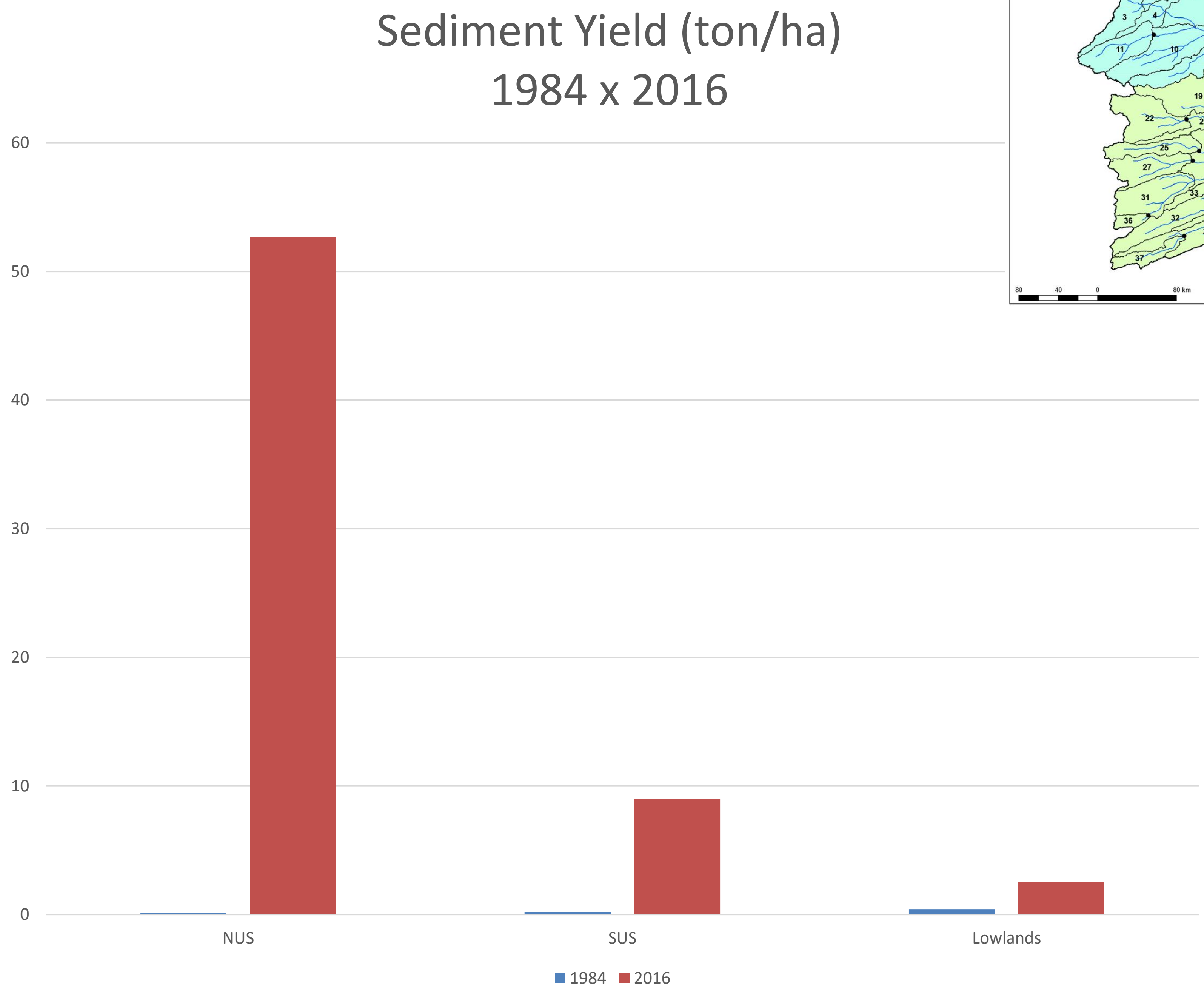


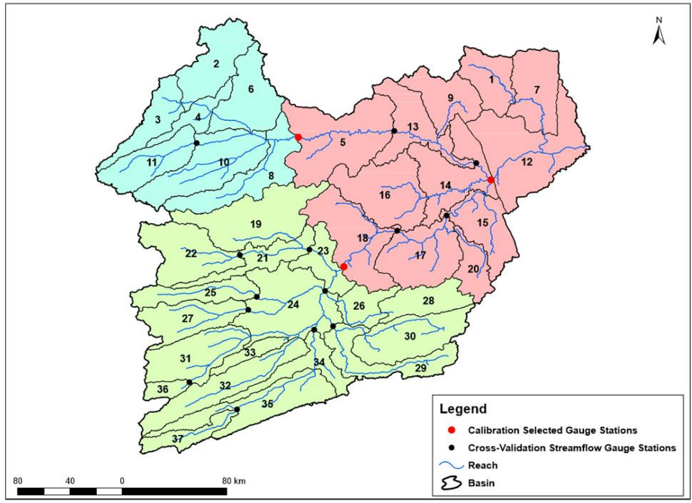




Sediment Yield – SWAT Model

Scenario	1984 (tons)			2016 (tons)			Relative Change (%)		
Component (total sum)/ Section	North Upper Stream (8)	South Upper Stream (23)	Lowlands (14)	North Upper Stream (8)	South Upper Stream (23)	Lowlands (14)	North Upper Stream (8)	South Upper Stream (23)	Lowlands (14)
Sediment Yield (ton)	1.86E+04	3.91E+05	1.15E+06	2.80E+07	3.11E+07	5.77E+07	1.50E+05	7.84E+03	4.93E+03
Sediment Yield (ton/ha)	0.11	0.20	0.42	52.64	9.00	2.53	48642.59	4468.02	505.98





NUS – blue
SUS – green
Lowlands - pink

Main Conclusions

- The Grande river basin presented important hydrologic changes from 1984 to 2016
  - Decrease in EVT
  - Huge increase in surface runoff
  - Increase in water yield
  - Decrease in the contribution of baseflow to the total flow (although baseflow has increased in absolute values – see previous table)
- The hydrologic response became more flashy in the upper portions (where LULCC took place)
  - Increase in peak flow
  - Decrease in baseflow
- Major increase in sediment yield in the upper portions (where LULCC took place)
  - Relative changes are more important here than absolute values (calibration for sediments was impossible)

Team 2020-2021

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