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Modeling the Impacts of LULC and Climate Change on Runoff and Sediment Production for the Puyango-Tumbes Basin, Ecuador-Peru

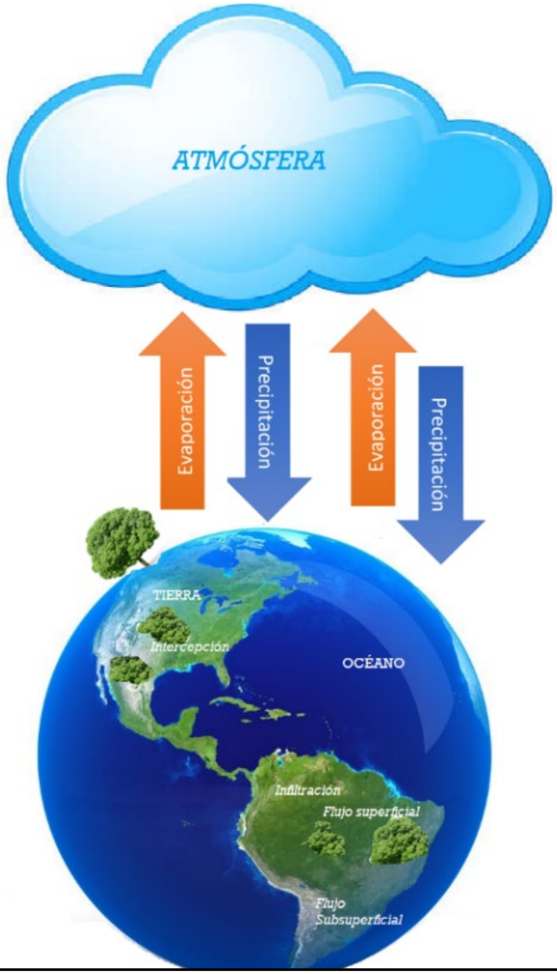
Robinson Peña Murillo* & Waldo Lavado-Casimiro

Universidad Técnica de Ambato, Ecuador
rf.pena@uta.edu.ec

Introduction

Climate change + human activities = streamflow and soil erosion
(*Dai et al., 2020*)

From 1800 to 2000, the human population increased from 1 billion to 6.5 billion, projected to reach 9 billion by 2050 → LULC
(*Zalasiewicz et al., 2011)*



Changes in LULC: deforestation and replacement of native vegetation with agriculture, urbanization, and other forms of land use. Spatial pattern of LULC → hydrological processes. Altered LULC = energy balance, ET, flow regimes.
(Bronstert et al., 2002)

Hydrological model (SWAT):
- Simulation of long-term hydrological variables.
- Assessment of hydrological response to LULC change.
- Determination of the impact of climate change on water resources.

(Abbaspour, 2015)

IPCC6 → Climate Change → CMIP6 → Predicting future climate conditions under changing scenarios (mitigation, adaptation, or impacts) → SSP
(Calvin et al., 2023)

Transboundary water resources: interactions between upstream and downstream countries.
(Nodoushan et al., 2021)

STUDY AREA

Puyango-Tumbes basin

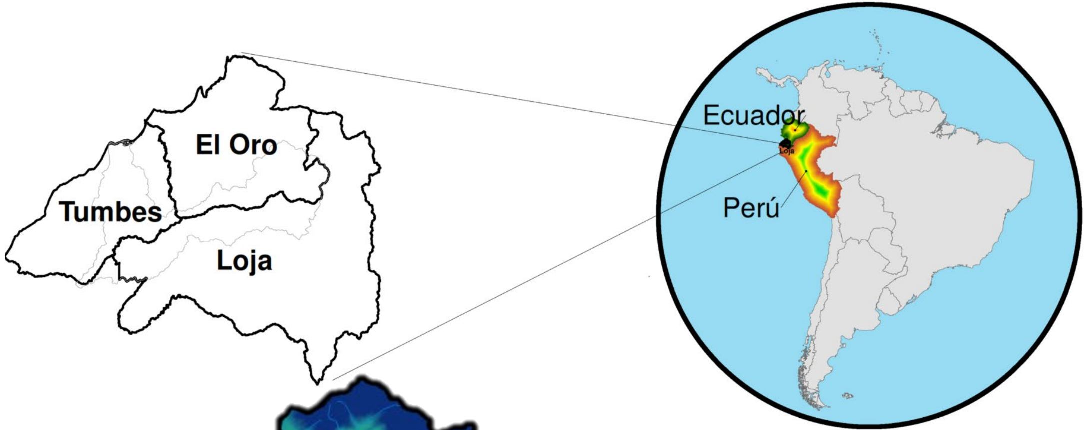
Area: 4 800 km^2 →prov. **El Oro** y **Loja** (60%) y Dep. **Tumbes** (40%).
Originates in Portovelo and flows through the → Cord. Chilla and Cerro Negro.
Río: 230 km *(Araoz, 2002).*

Fx → *B. upper:* **13 m³s⁻¹**, *B. Middle:* **82 m³s⁻¹**,*B. lower:* **103 m³s⁻¹**

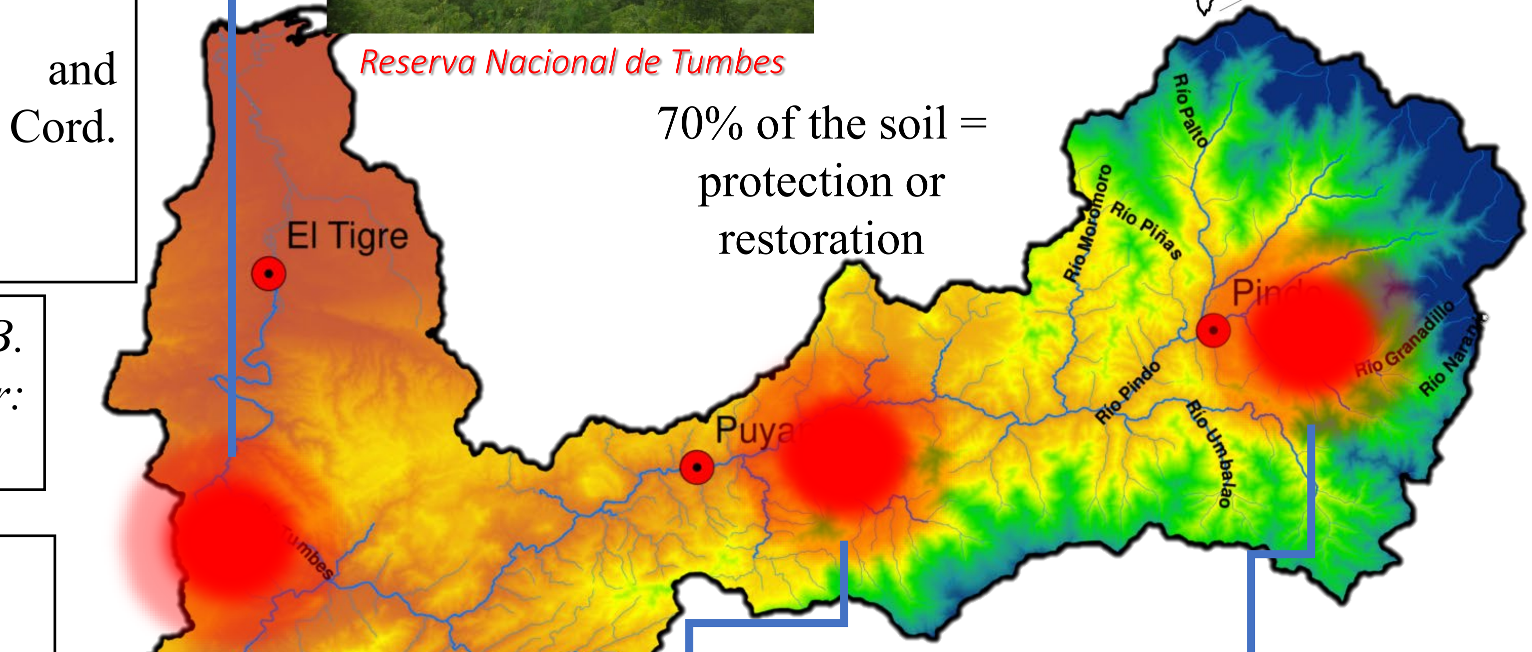
Geography: Coastal plain and mountainous region.

Climate: subtropical
P: 1 200 mm (100 mm – 2700 mm)
T°: lowlands: 24.5 °C mountanious: 22°C
(ATA et al., 2003).

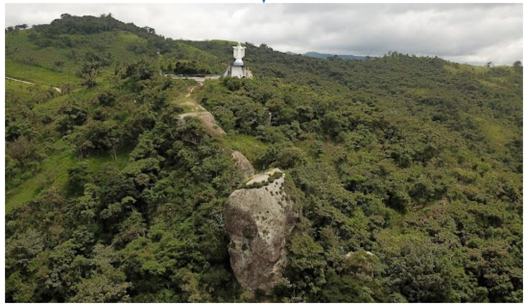
Reserva Nacional de Tumbes



70% of the soil = protection or restoration



Bosque del Puyango



Portovelo

Water demand: agricultural (67.79%), population (10.61 %), industrial (5.58%), aquculture (0.80%) y ecological (14.96%) *(MAP & GIS, 2018).*

Lower basin→ **El Niño** 1982–83 y 1997–98, **Niño Costero** 2017 *(SENAMHI, 2019).*

OBJECTIVES

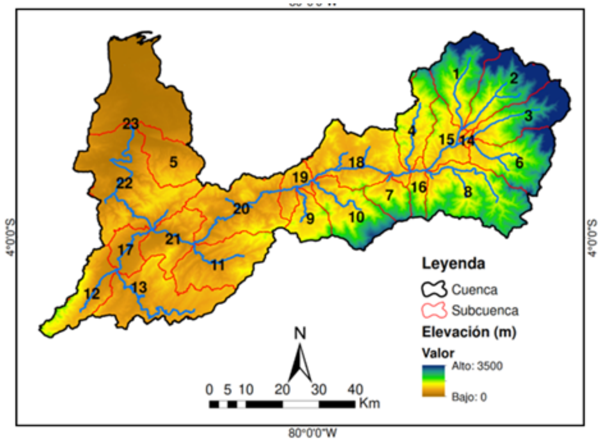
Evaluate the impact of LULC and climate change on streamflow and sediment in the Puyango–Tumbes basin.

1. Assess the SWAT hydrologic al model.
2. Evaluate the impact of LULC on streamflow.
3. Quantify the impact of CC and LULC on SSP →FP.

DATA

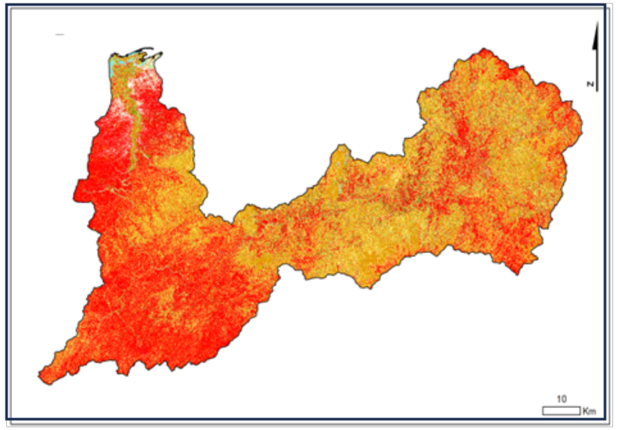
Digital elevation model (DEM)

STRM 30 M



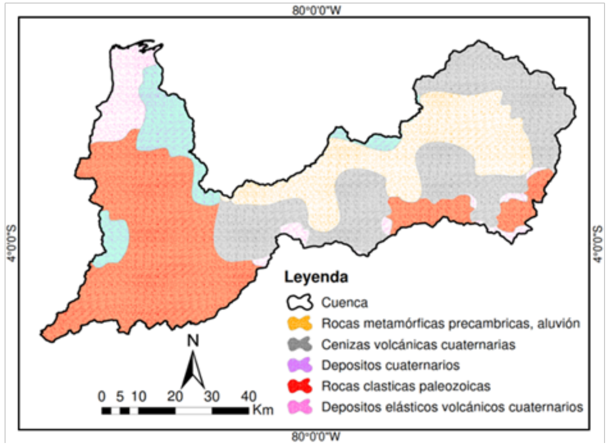
Land use and land cover (LULC)

MODIS (t1: 1985; t2: 1995; t3: 2005; t4: 2015)



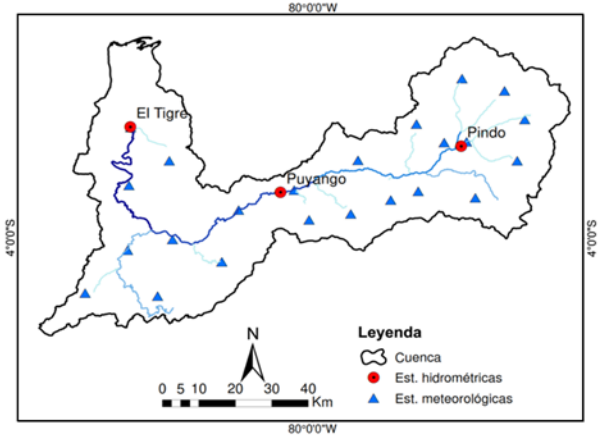
Soil type

HSWD 1km



Weather information

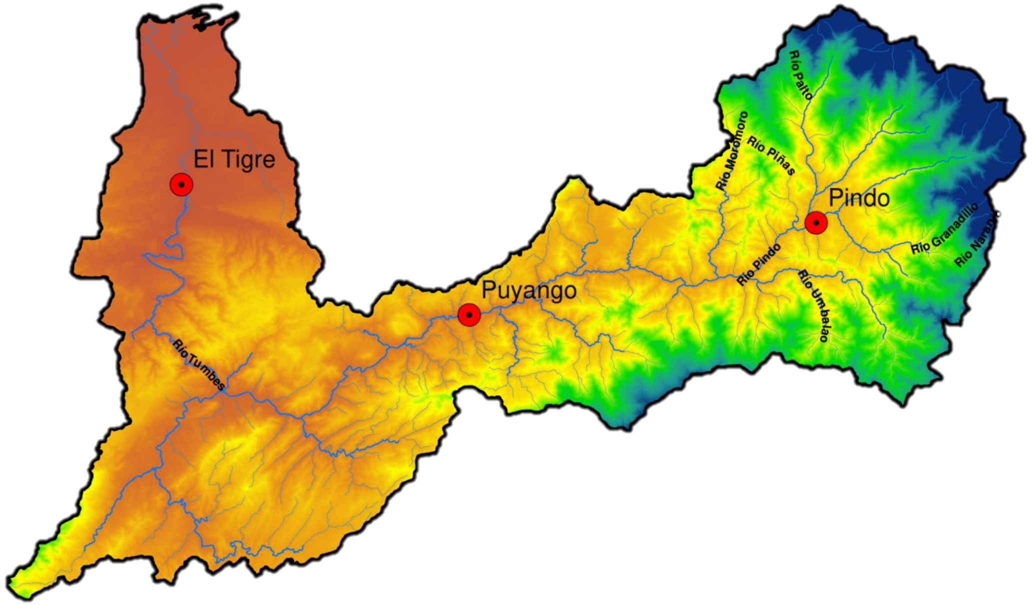
Pisco, Rain4PE



$$S_y = 0.602Q^{0.938}$$

S_y bottom sediments yields (t day^{-1}); Q: discharge (m^{3}s^{-1})

Goyburo (2017) → El Tigre



Discharge 1992-2015

Analysis Period (1985-2015)

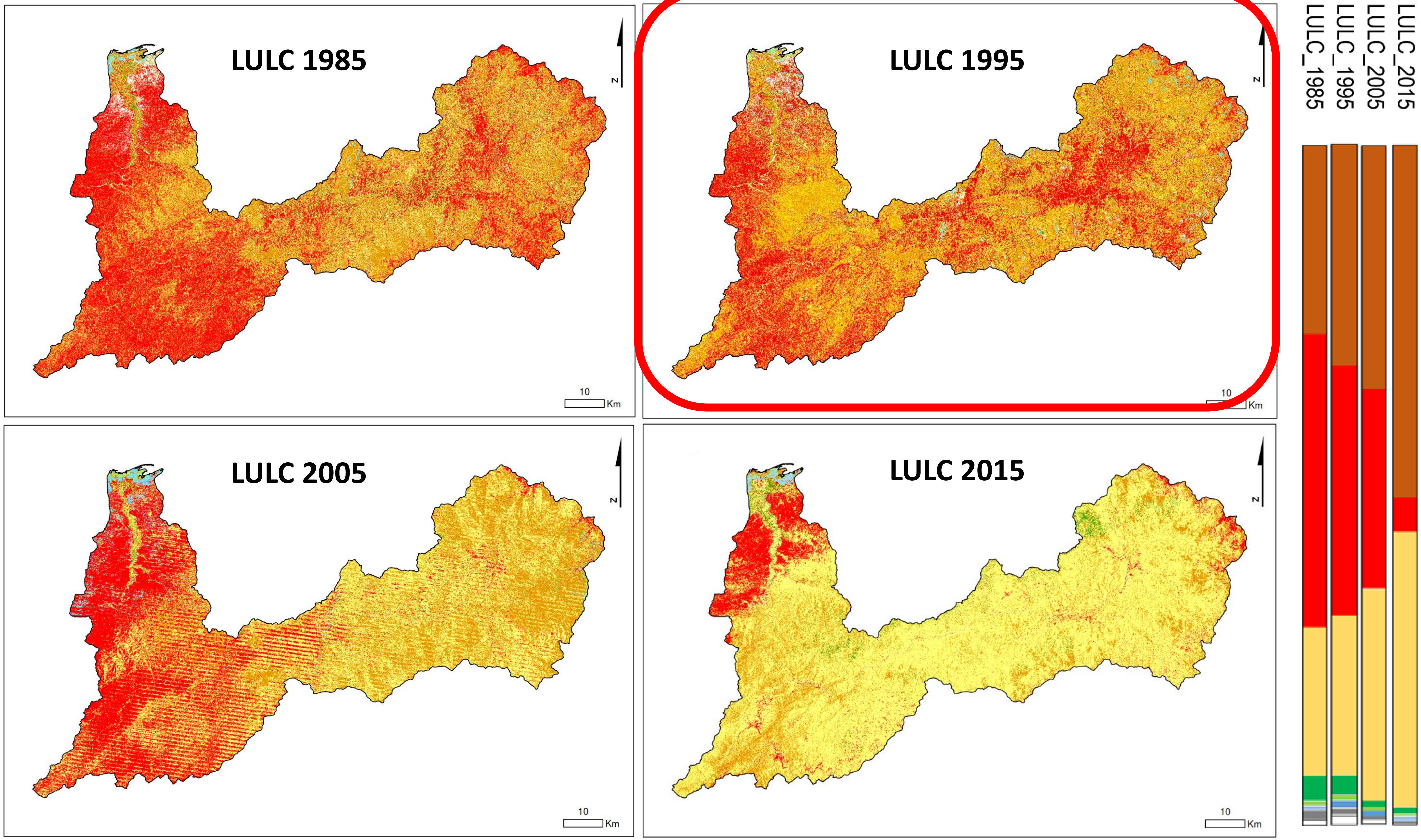
GCM models (24) → p5,p50 and p95

Pr, tmax, tmin; SSP245, SSP585

2035-2065/2070-2099 --> Bias correction

DATA

LAND USE AND LAND COVER CHANGE (LULC)



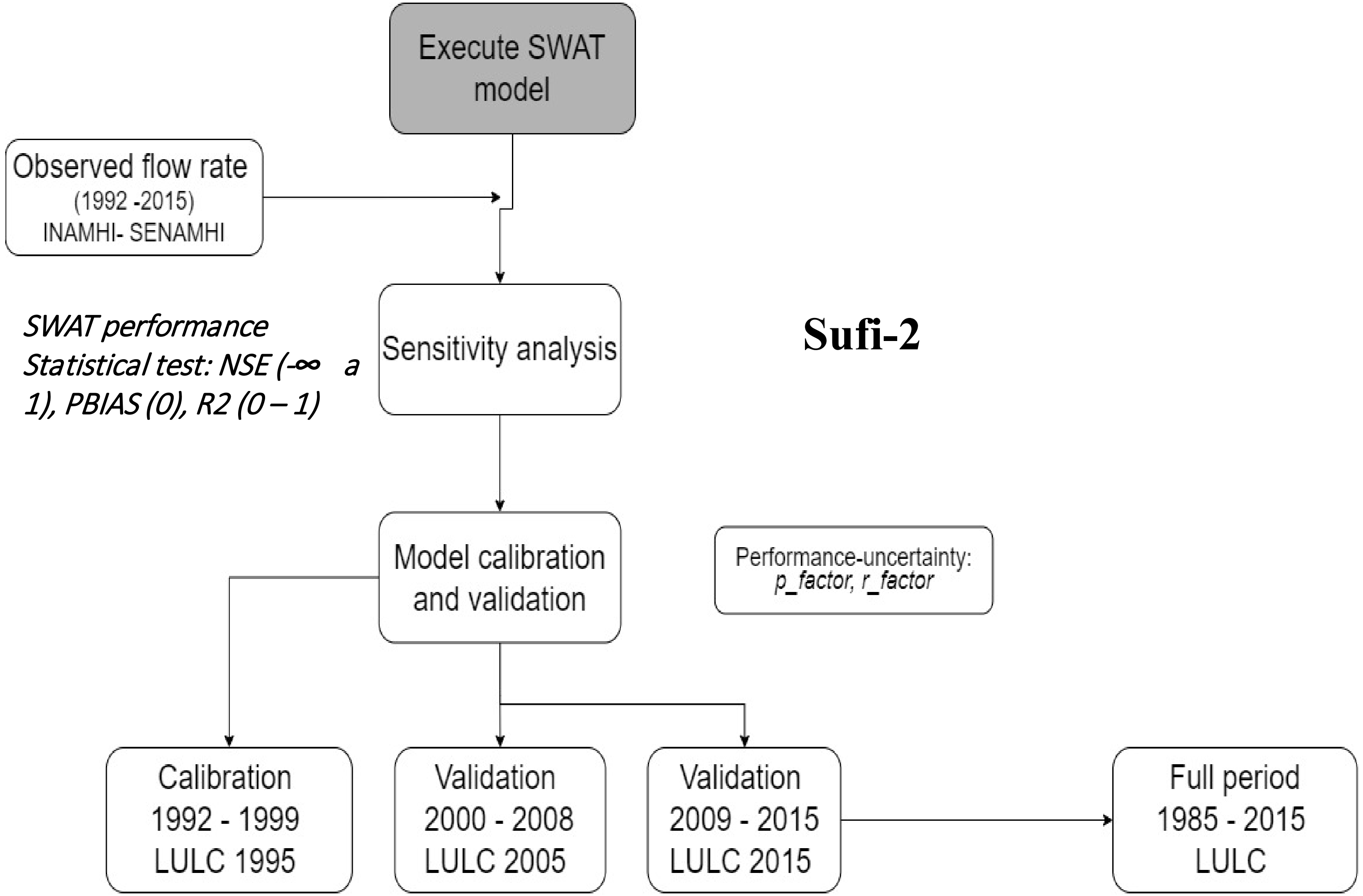
Forest (+25%)

Grasslands (+18%)

Sabanas (-38%)

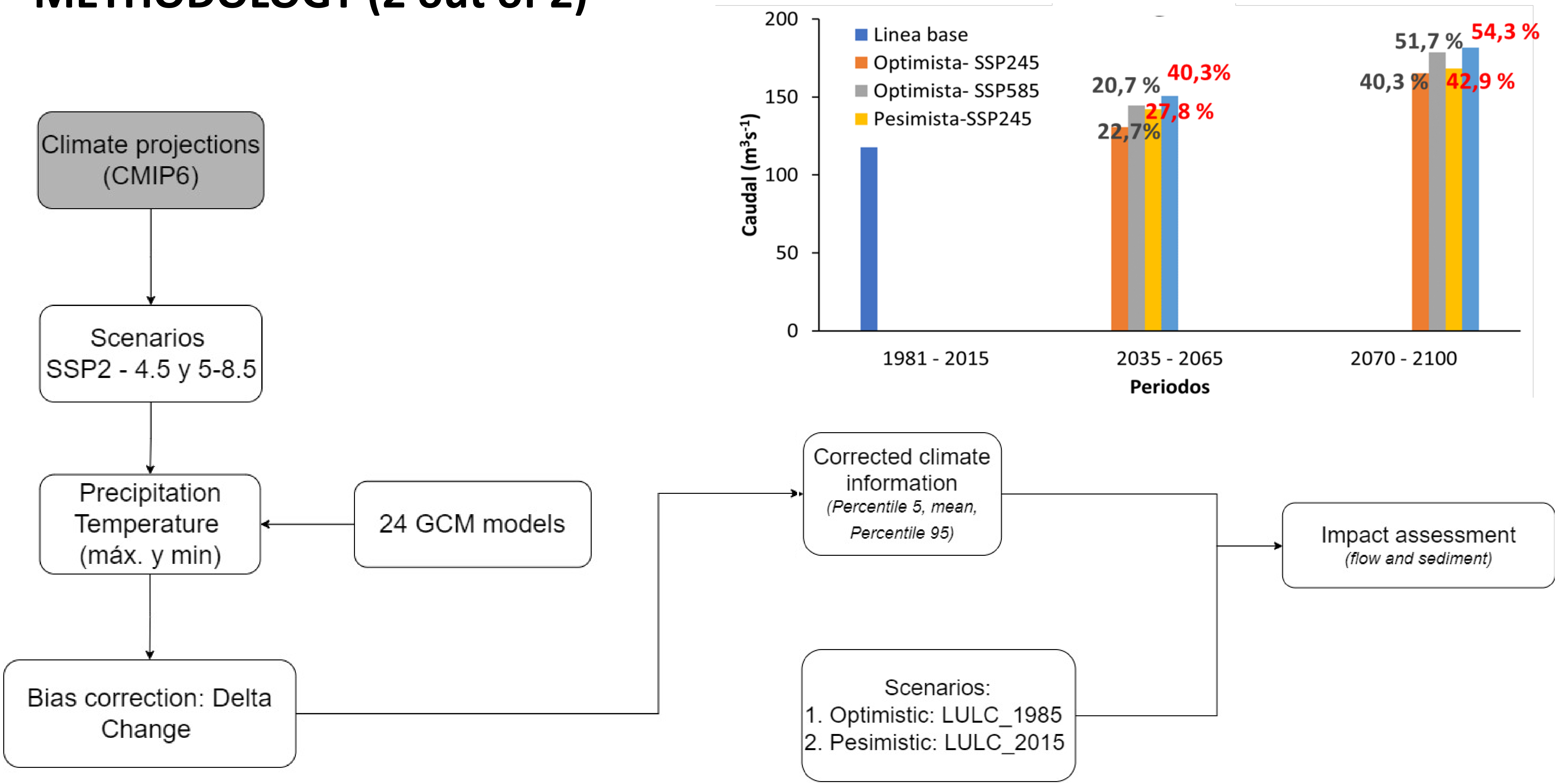
METHODOLOGY (1 out of 2)

	Parameter	Descripción de parámetros
Groundwater	ALPHA_BF	Baseflow alpha factor (days)
	GW_DELAY	Groundwater delay time
	GWQMN	Threshold depth of water in shallow aquifer required for return flow to occur (mm)
Time of concentration	SLSUBBSN	Average slope length (m)
Soil	SOL_AWC	Available water capacity of soil layer
Runoff	SURLAG	Runoff delay time



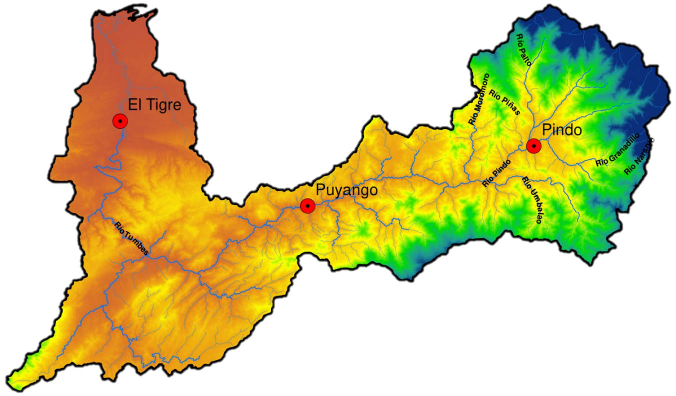
16 parameters --> 6
LULC 1995
Full period 1985-2015

METHODOLOGY (2 out of 2)

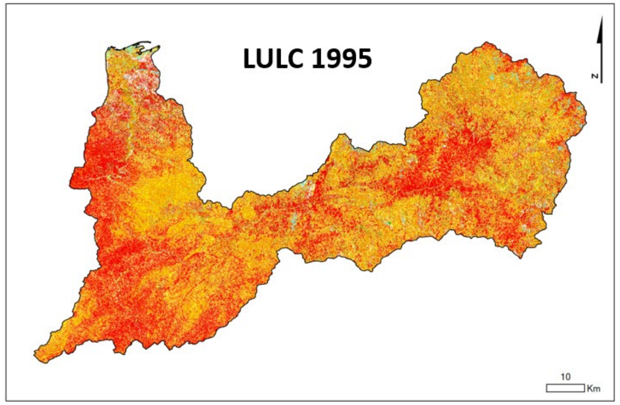


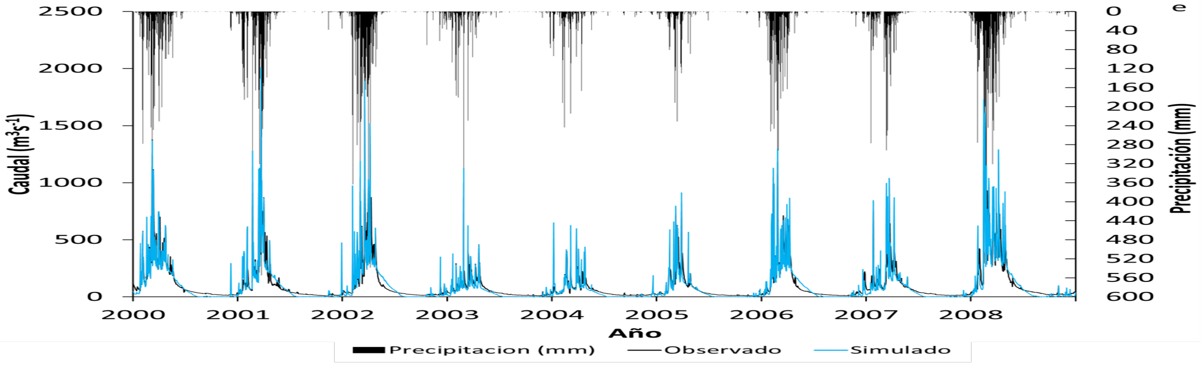
RESULTS

Model calibration and validation



Correlation			Pindo			Puyango			El Tigre		
Estadísticos	**LULC**	**Data**	**Sn_C (1992-1997)**	**C (1992-1997)**	**V (1998-1999)**	**Sn_C (1992-1997)**	**C (1992-1997)**	**V (1998-1999)**	**Sn_C (1992-1997)**	**C (1992-1997)**	**V (1998-1999)**
R^2	1995	1992-1999	0,9	0,89	0,78	0,78	0,89	0,78	0,78	0,87	0,79
NSE			0,38	0,77	0,69	0,68	0,77	0,69	0,46	0,82	0,69
PBIAS			-22,3	-12,4	-15,6	-19,2	-14,5	-17,3	-16,4	-8,2	-14,5
			Sn_C (2000-2006)	**C (2000-2006)**	**V (2007-2008)**	**Sn_C (2000-2006)**	**C (2000-2006)**	**V (2007-2008)**	**Sn_C (2000-2006)**	**C (2000-2006)**	**V (2007-2008)**



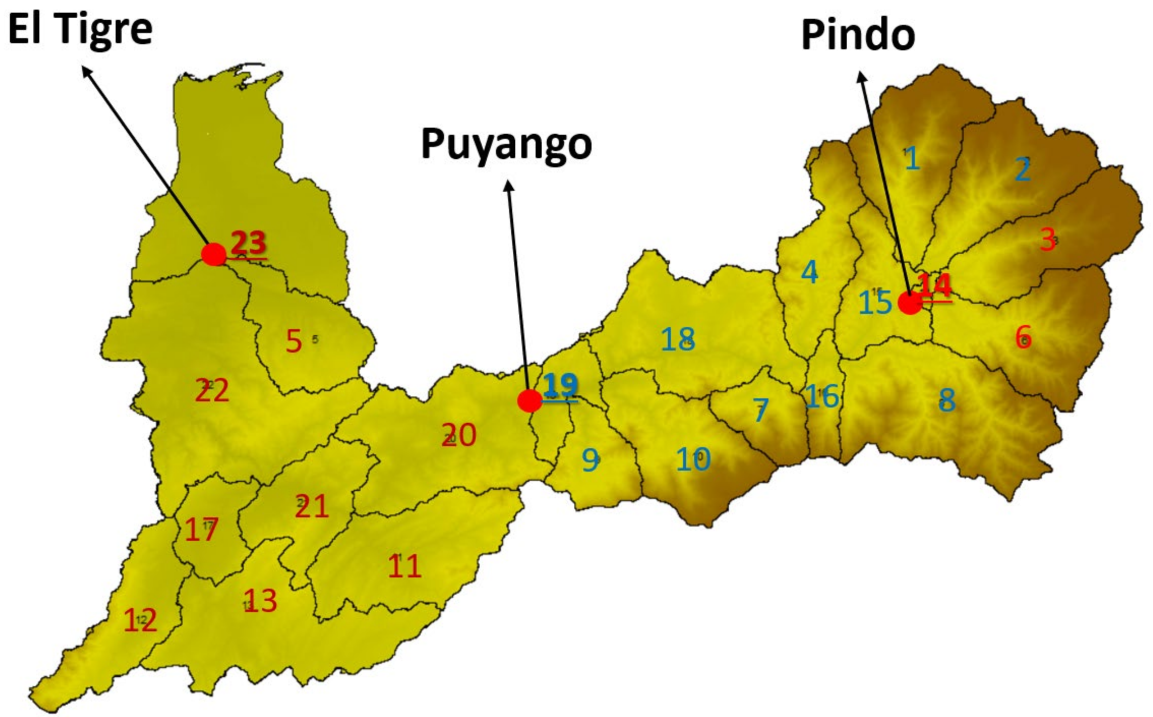


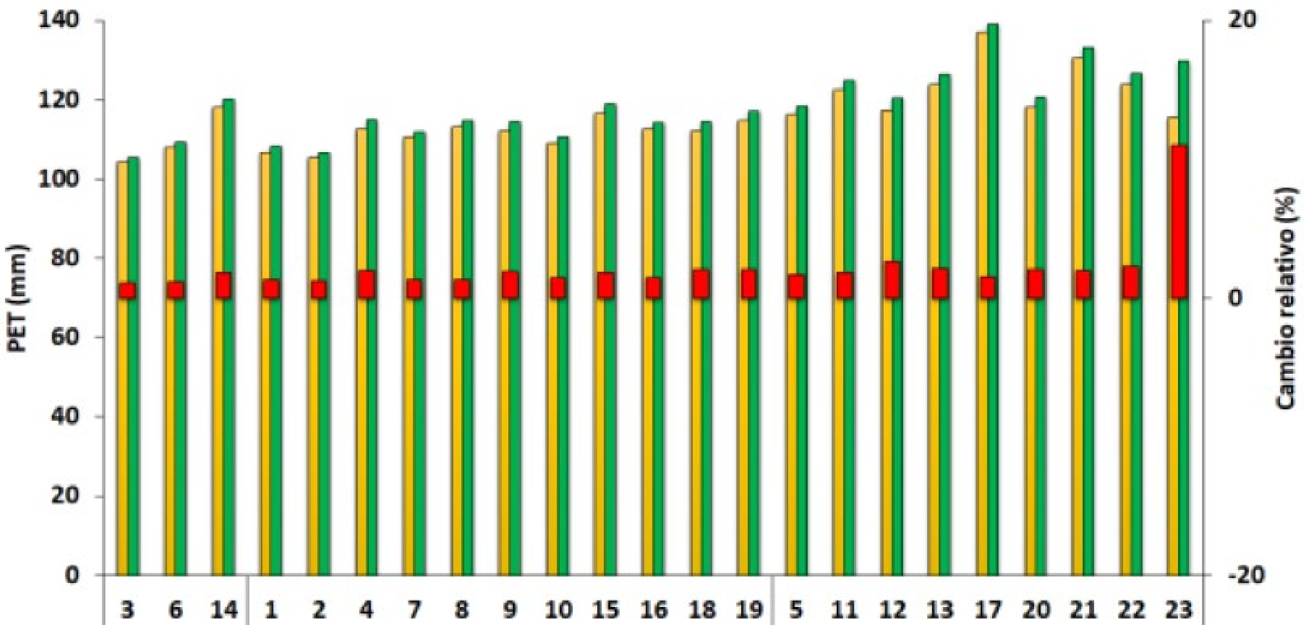
Sn_C: sin calibrar; C: calibración; V validación

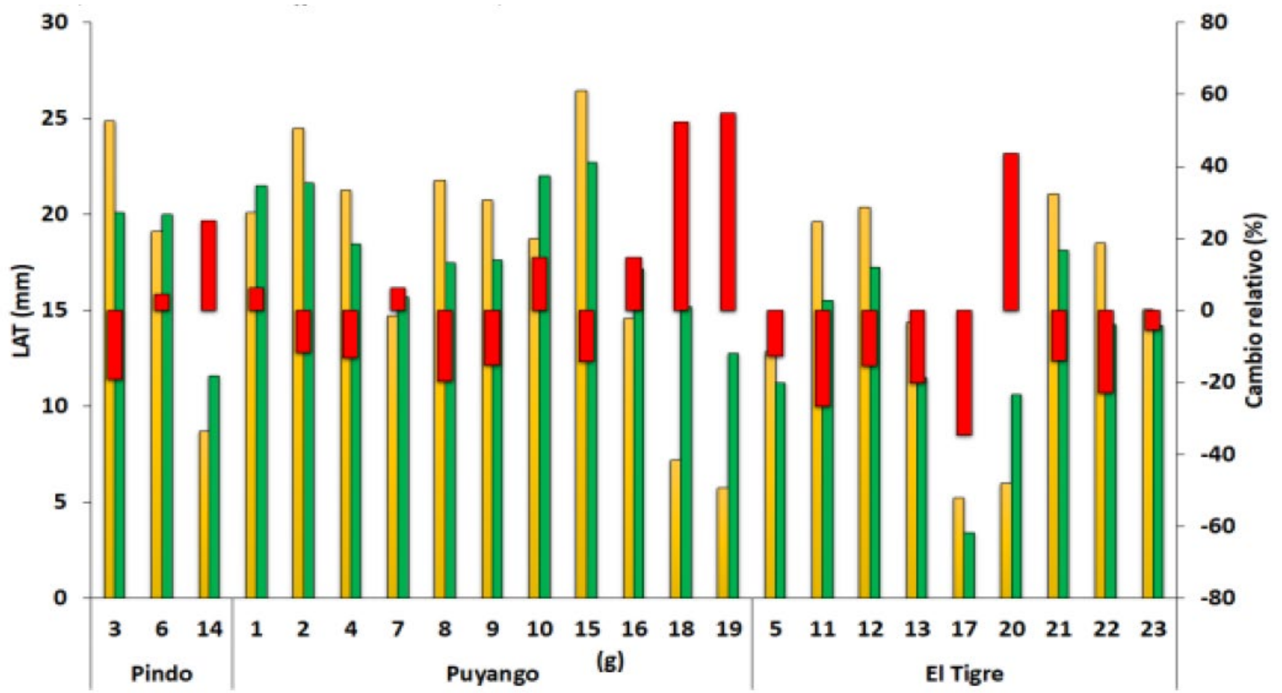
Performance Rating	RSR	NSE	PBIAS (%) Streamflow	PBIAS (%) Sediment	PBIAS (%) N, P
Very good	0.00 ≤ RSR ≤ 0.50	0.75 < NSE ≤ 1.00	PBIAS < ±10	PBIAS < ±15	PBIAS< ±25
Good	0.50 < RSR ≤ 0.60	0.65 < NSE ≤ 0.75	±10 ≤ PBIAS < ±15	±15 ≤ PBIAS < ±30	±25 ≤ PBIAS < ±40
Satisfactory	0.60 < RSR ≤ 0.70	0.50 < NSE ≤ 0.65	±15 ≤ PBIAS < ±25	±30 ≤ PBIAS < ±55	±40 ≤ PBIAS < ±70
Unsatisfactory	RSR > 0.70	NSE ≤ 0.50	PBIAS ≥ ±25	PBIAS ≥ ±55	PBIAS ≥ ±70

Nash-Sutcliffe efficiency (NSE), percent bias (PBIAS), and ratio of the root mean square error to the standard deviation of measured data (RSR)

RESULTS





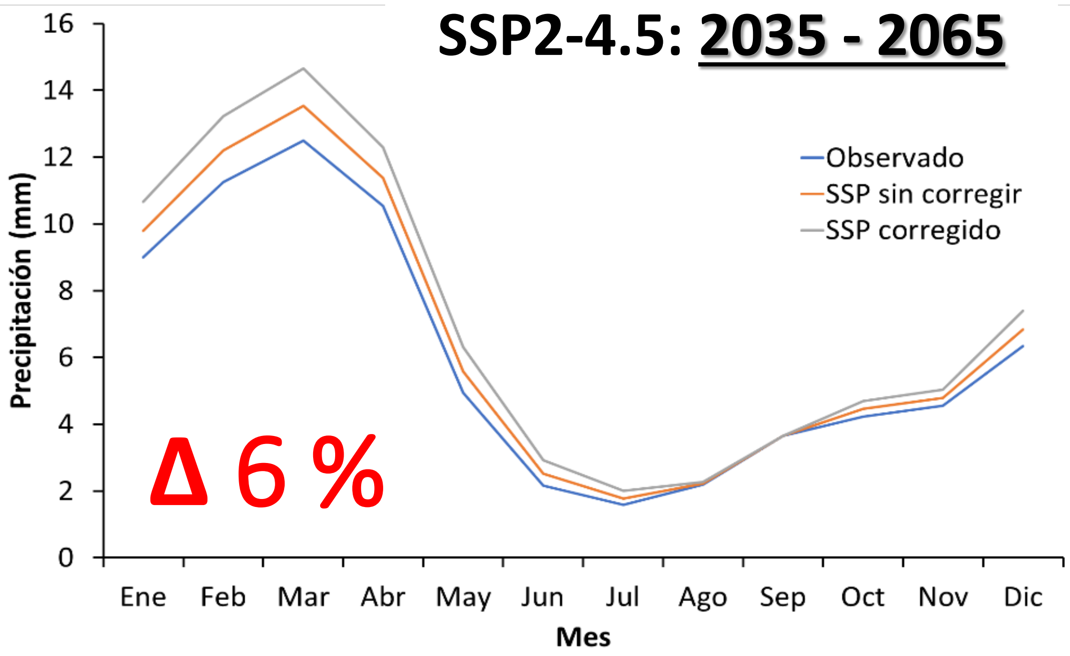


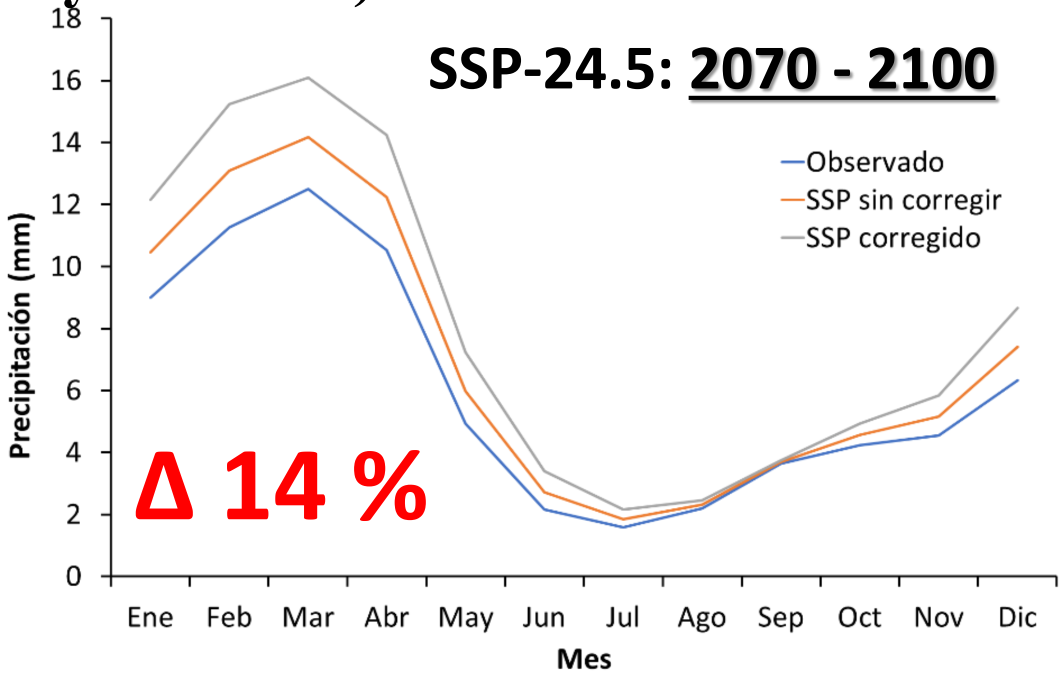
PET: potential evapotranspiration;
LAT_Q: lateral flow;

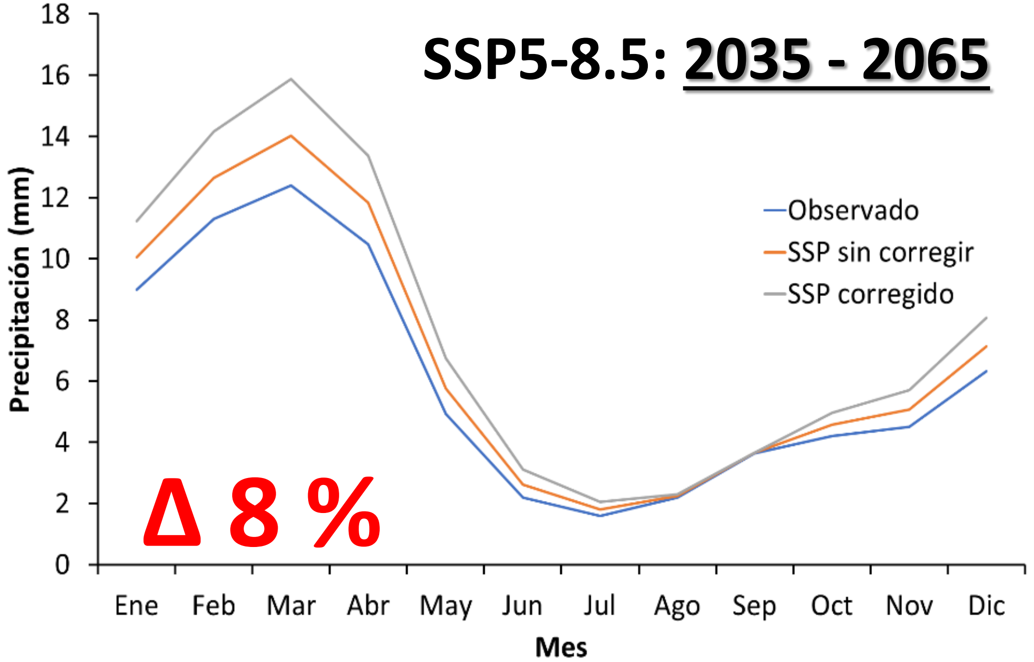
LULC 1985
LULC 2015
Cambio Relativo

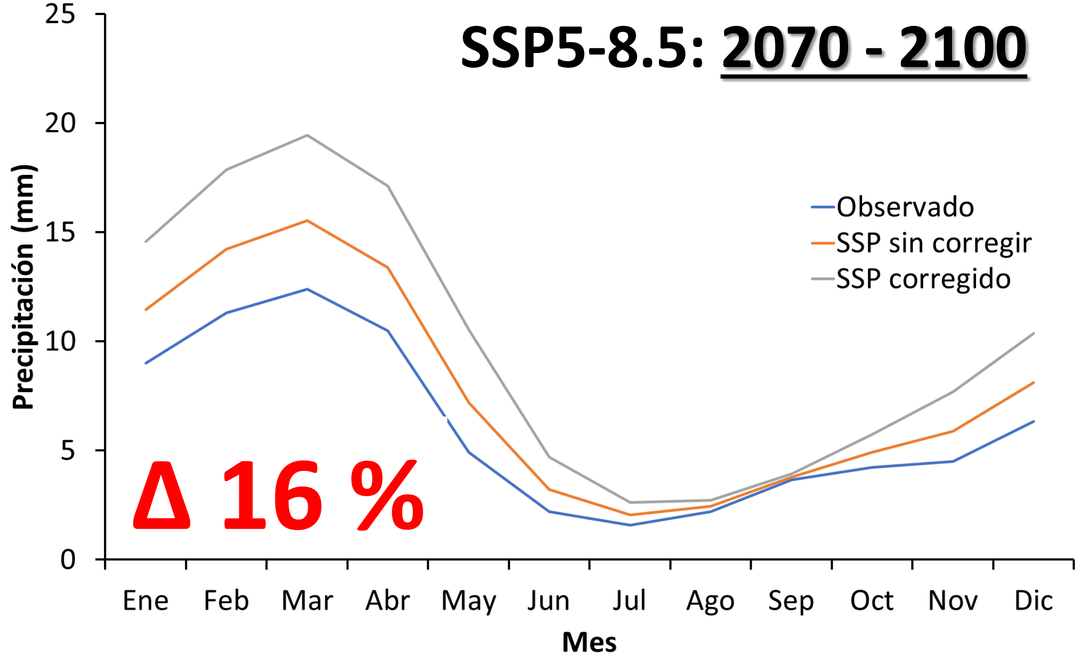
RESULTS → Basin –scale precipitation (SSP2-4.5 y SSP5-8.5)

SSP2-4.5
2.8-4.3 °C
SSP5-8.5
3.7-7.4 °C

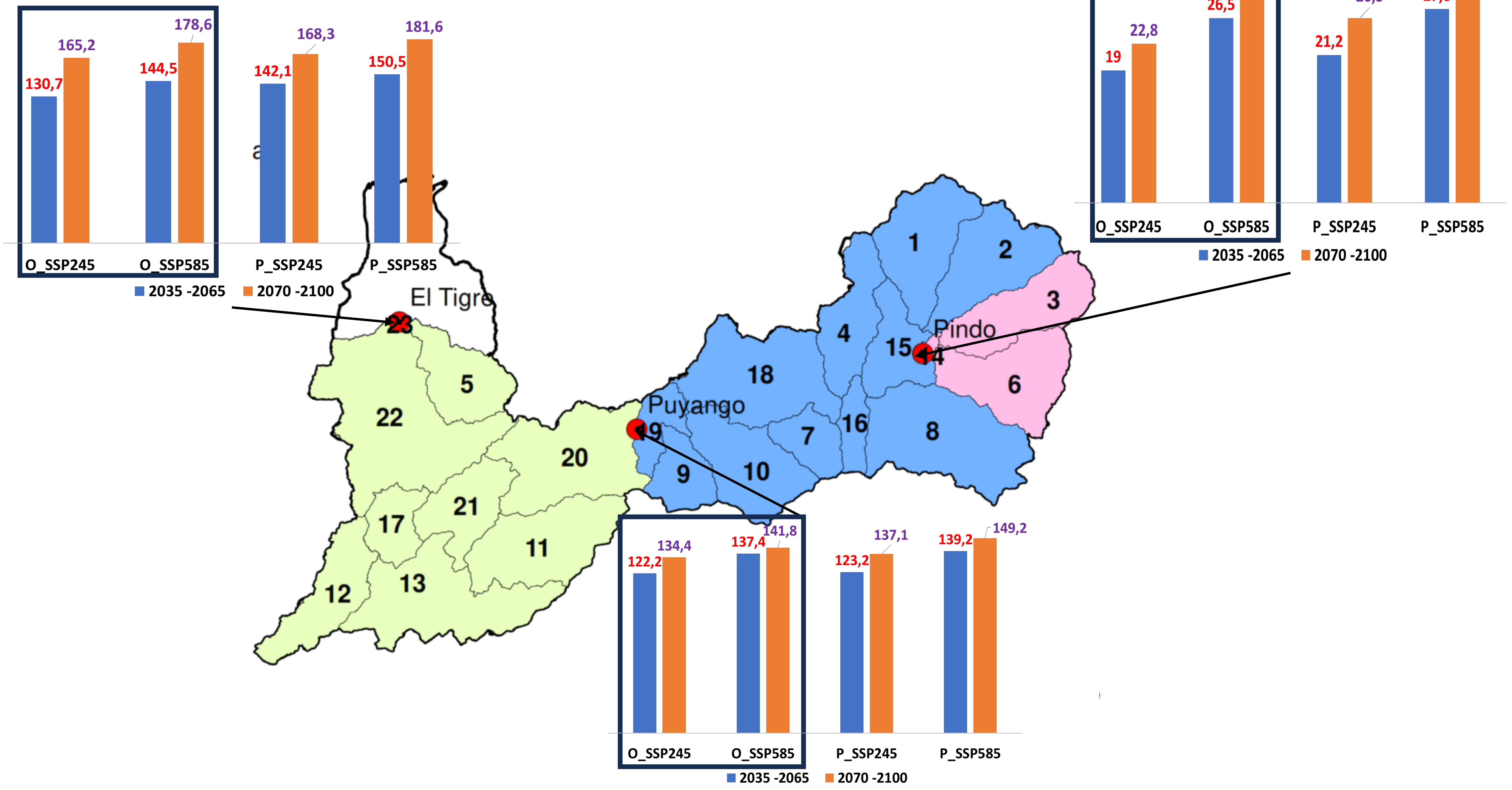








Caudal


130,7
165,2
144,5
178,6
142,1
168,3
150,5
181,6
O_SSP245
O_SSP585
P_SSP245
P_SSP585
2035 -2065
2070 -2100
19
22,8
26,5
29,6
21,2
26,5
27,8
30,8
O_SSP245
O_SSP585
P_SSP245
P_SSP585
2035 -2065
2070 -2100
122,2
134,4
137,4
141,8
123,2
137,1
139,2
149,2
O_SSP245
O_SSP585
P_SSP245
P_SSP585
2035 -2065
2070 -2100
El Tigre
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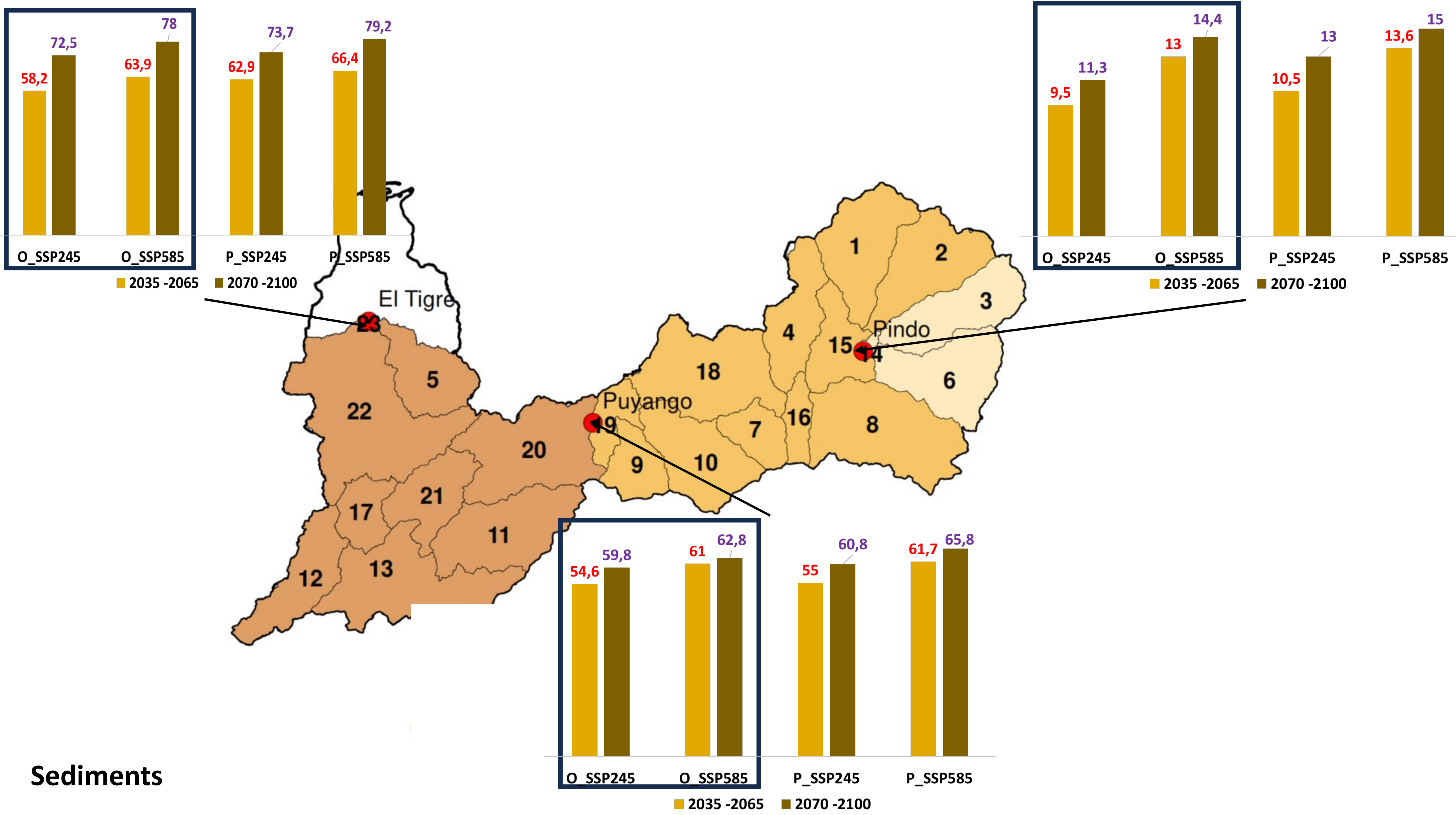

58,2
72,5
63,9
78
62,9
73,7
66,4
79,2
O_SSP245
O_SSP585
P_SSP245
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2035 -2065
2070 -2100
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62,8
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60,8
61,7
65,8
O_SSP245
O_SSP585
P_SSP245
P_SSP585
2035 -2065
2070 -2100

Sediments

Station	Process	Base *	SSP 2–4.5		SSP 5–8.5	
		1981–2015	2035–2065	2070–2100	2035–2065	2070–2100
EL TIGRE Optimistic	Precipitation (mm)	2479	2638	2980	2829	3634
	Discharge ($m^3 s^{-1}$)	117,7	130,7 **20,7%**	165,2 **40,3%**	144,5 **22,7%**	178,6 **51,7%**
	Sediments (t $year^{-1}$)	52,7	58,2 **10,3%**	72,5 **37,4%**	63,9 **21,1%**	78,0 **47,8%**
Pesimistic	Discharge ($m^3 s^{-1}$)	95,9	142,1 **27,8%**	168,3 **42,9%**	150,5 **40,3%**	181,6 **54,3%**
	Sediments (t $año^{-1}$)	43,5	62,9 ***19,3%***	73,7 ***39,8%***	66,4 ***25,9%***	79,2 ***50,2%***

CONCLUSIONS

Impact LULC

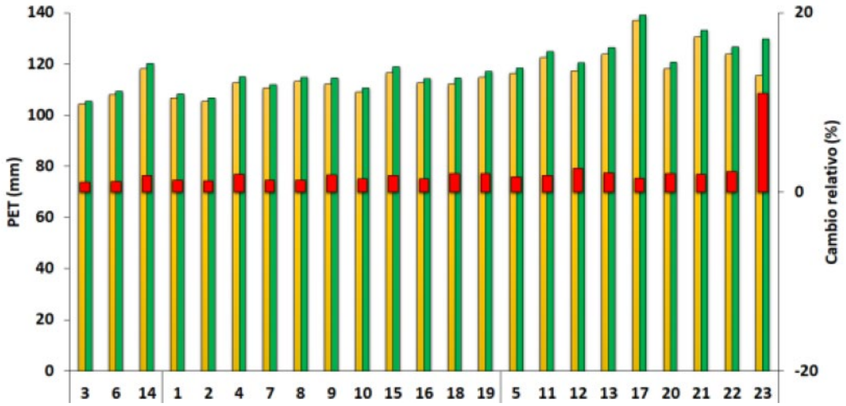
Increased pastures
(18,32 %)

Reduction of savannas
(38,27 %)

LULC
1985 vs 2015

Increased
- PET: 2,14 %
- SURQ: 33,32 %

Decrease
- PERC: 29,19 %
- GW_Q: 33,00 %



CONCLUSIONS

Flow and sediments → SSP5–8.5

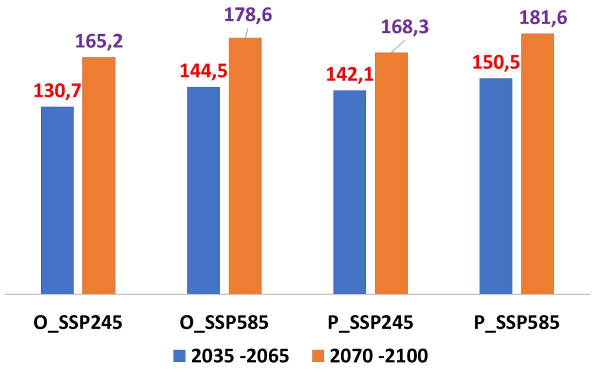
Increase → precipitations and temperatures

> Pessimistic scenarios
- SSP5–8.5
- SSP2–4.5

Sediments generation

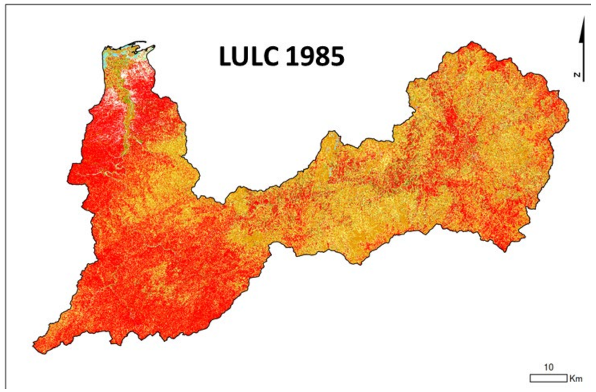
< Optimistic scenarios
- SSP5–8.5
- SSP2–4.5

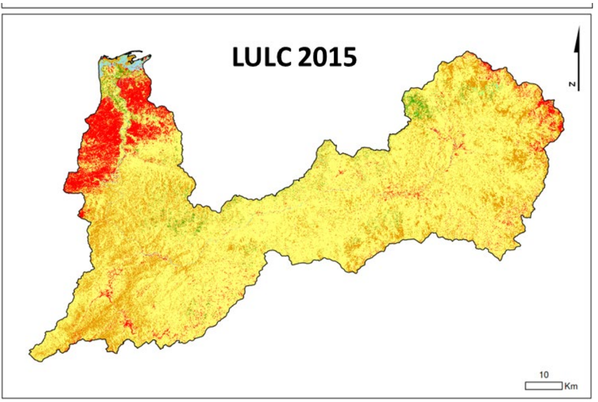
Future

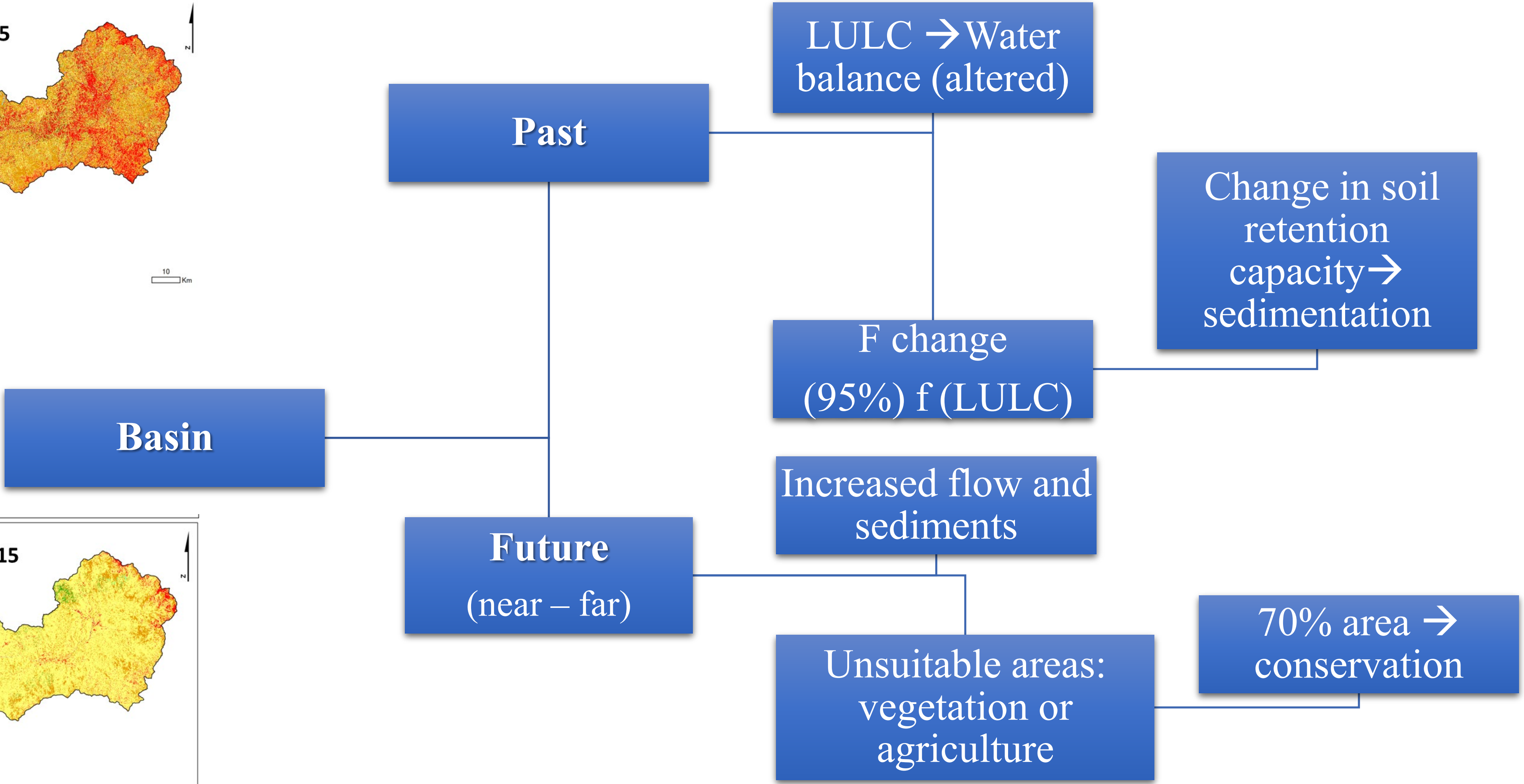


CONCLUSIONS

Hydrological processes uncertainty
Lack of monitoring







Climate change > LULC change

Thanks

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