Groundwater vs. surface water irrigation: A comparative analysis at multiple landscape scales

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Motivation

- Groundwater–surface water exchanges are not considered.
- Irrigation is treated as a constant demand, ignoring the highly variable climate of Uruguay.
- Return flows from irrigation are not recognised in the catchment water balances.
- The role of return flow enriching or diluting the concentration of nutrients need to be assed.

Water regulation

- Groundwater use is permitted if the well is at least 200 meters from the nearest existing well, with a fixed volume allocation

- Surface water use is permitted if flow exceeds monthly percentiles, typically 40% for reservoirs and 20% for direct intakes.

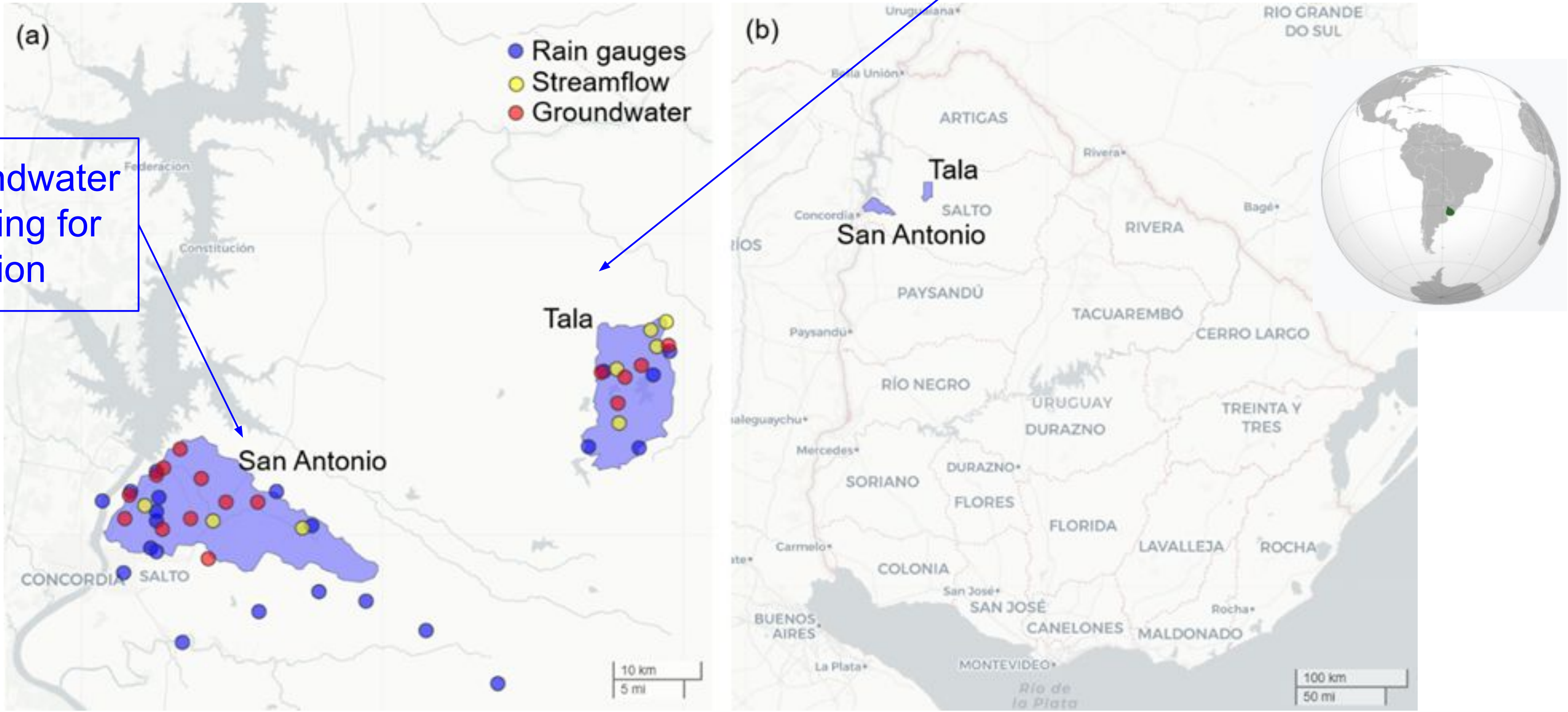
Objectives

- To identify differences in groundwater-fed and reservoir-fed irrigation systems.
- To estimate irrigation water use and assess its impacts on hydrology.
- To show opportunities to improve the representation of irrigation-related processes

Experimental Catchments: Two Case Studies

Water Releases from reservoirs for irrigation and environmental use

Groundwater pumping for irrigation



Methods

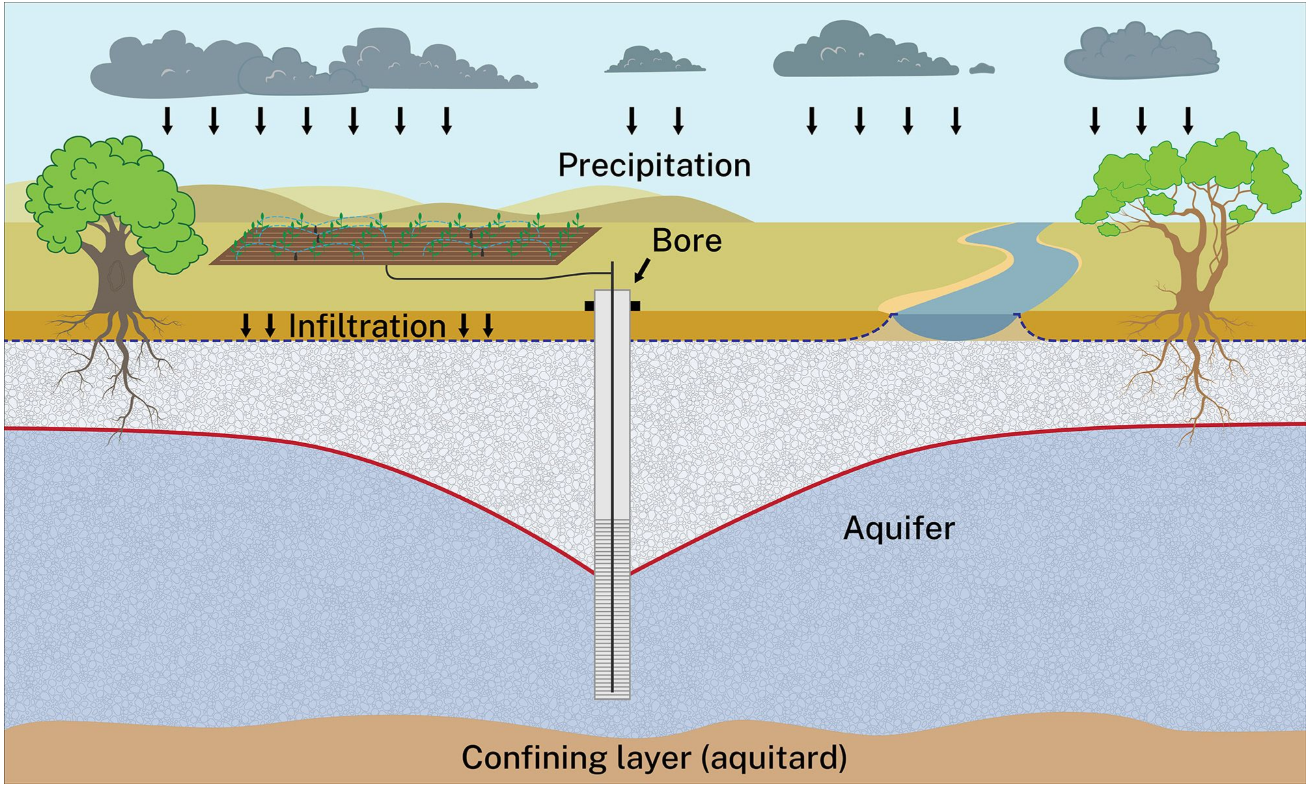
1. San Antonio catchment (groundwater-fed irrigation, 225 km2)

   SWAT+gwflow

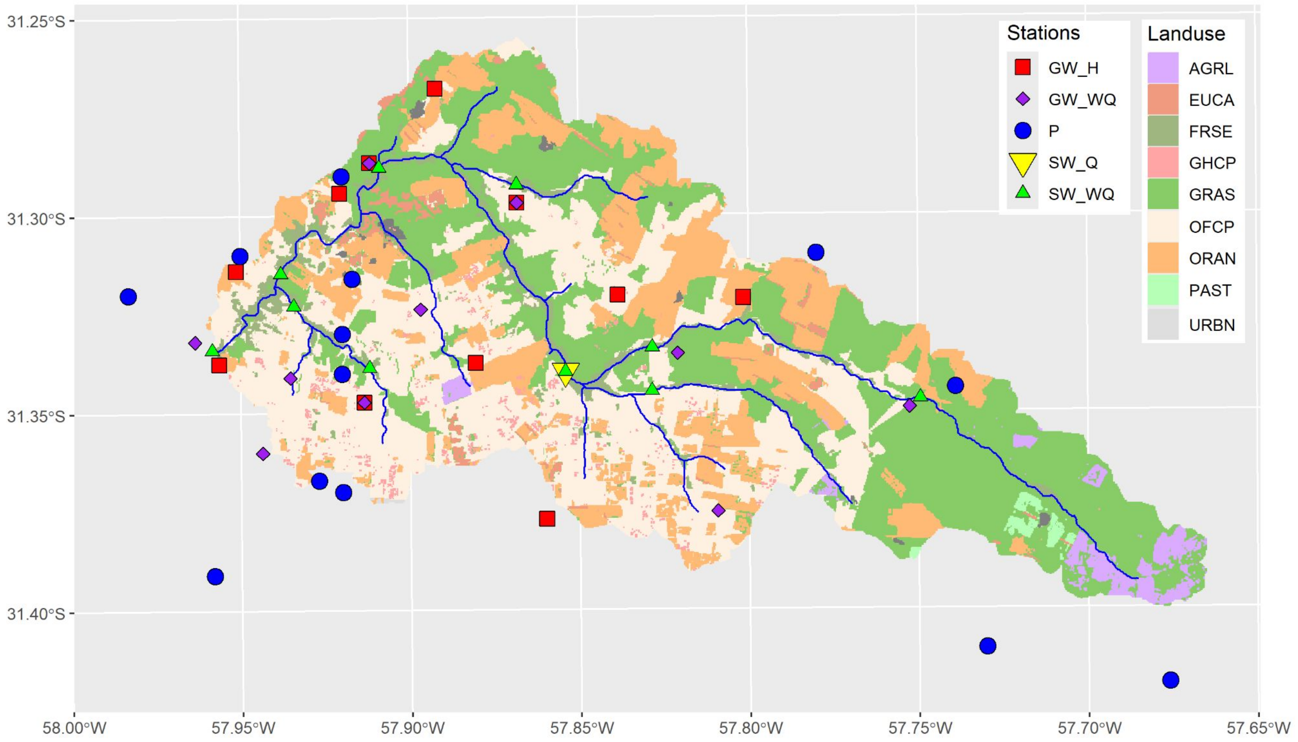
2. Tala catchment (reservoir-fed irrigation, 120 km2)

   SWAT2012

1. San Antonio



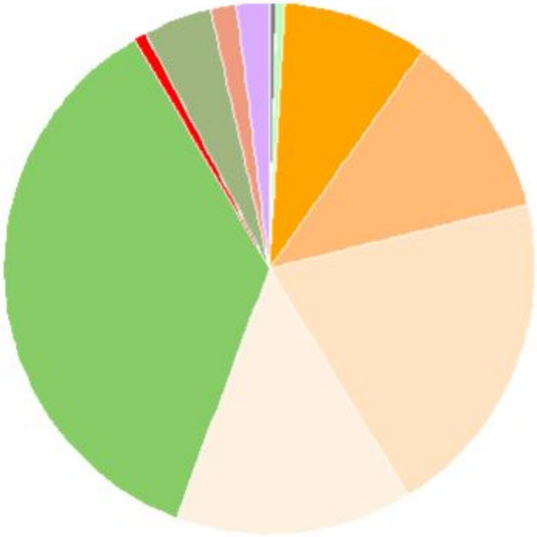
San Antonio (225 km2)

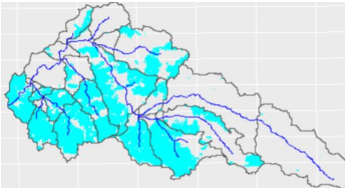


groundwater pumping for irrigation

Land and Water Use

Actual Land Use





LUSE	Area (km2)
AGRL	4.1
EUCA	3.3
FRSE	8.6
GHCP(irr)	1.7
GRAS	74.5
OFCP	30.0
OFCP(irr)	41.9
ORAN	23.7
ORAN(irr)	18.4
PAST	9.9
URBN	0.7

Theoretical Water Requirements

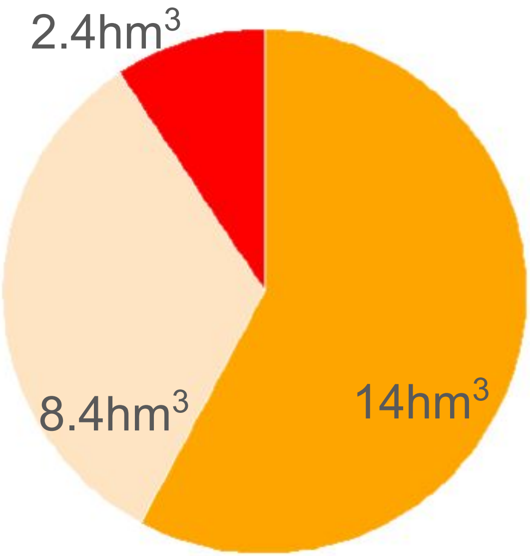


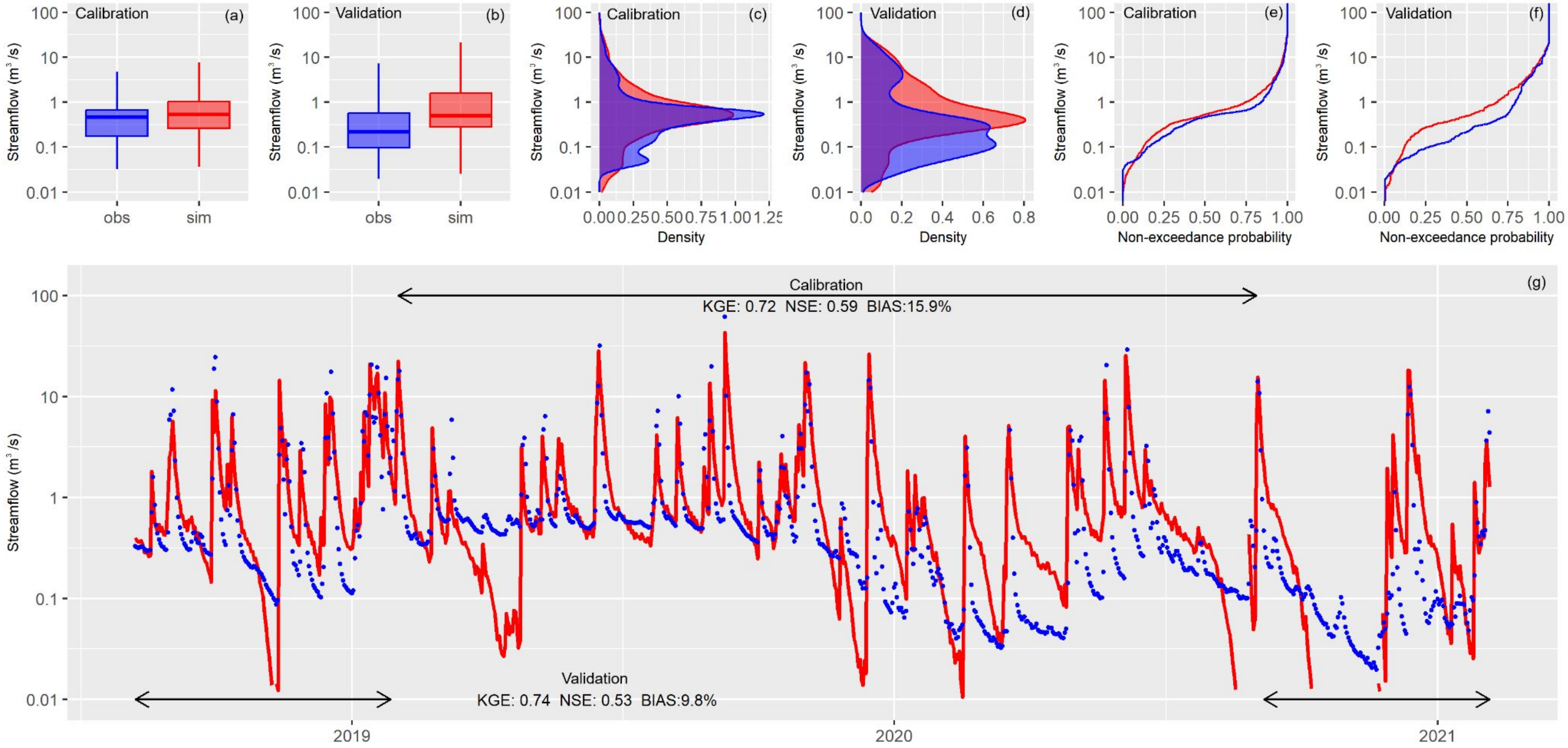
Table 1. Calibration parameter for the 1st phase (total streamflow).

Parameter	Description	File	Range	Type of Change	Best Fit
cn	Curve number compensation factor for soil group A, B, C and D [-]	cntable.lum	0.9–1.1	multiplicative	0.937
soil_k	Saturated hydraulic conductivity of soil	soil.sol	0.7–1.3	multiplicative	1.07
dp	Depth of the soil profile		0.7–1.3	multiplicative	1.08
epco	Plant uptake compensation factor	hydrology.hyd	0.01–1	substitutive	0.92
esco	Soil evaporation compensation factor		0.01–1	substitutive	0.103
perco	Percolation coefficient		0–1	substitutive	0.568
latq_co	Lateral flow coefficient		0.01–0.99	substitutive	0.265
surq_lag	Surface runoff lag coefficient	parameter.bsn	1–24	substitutive	2.03

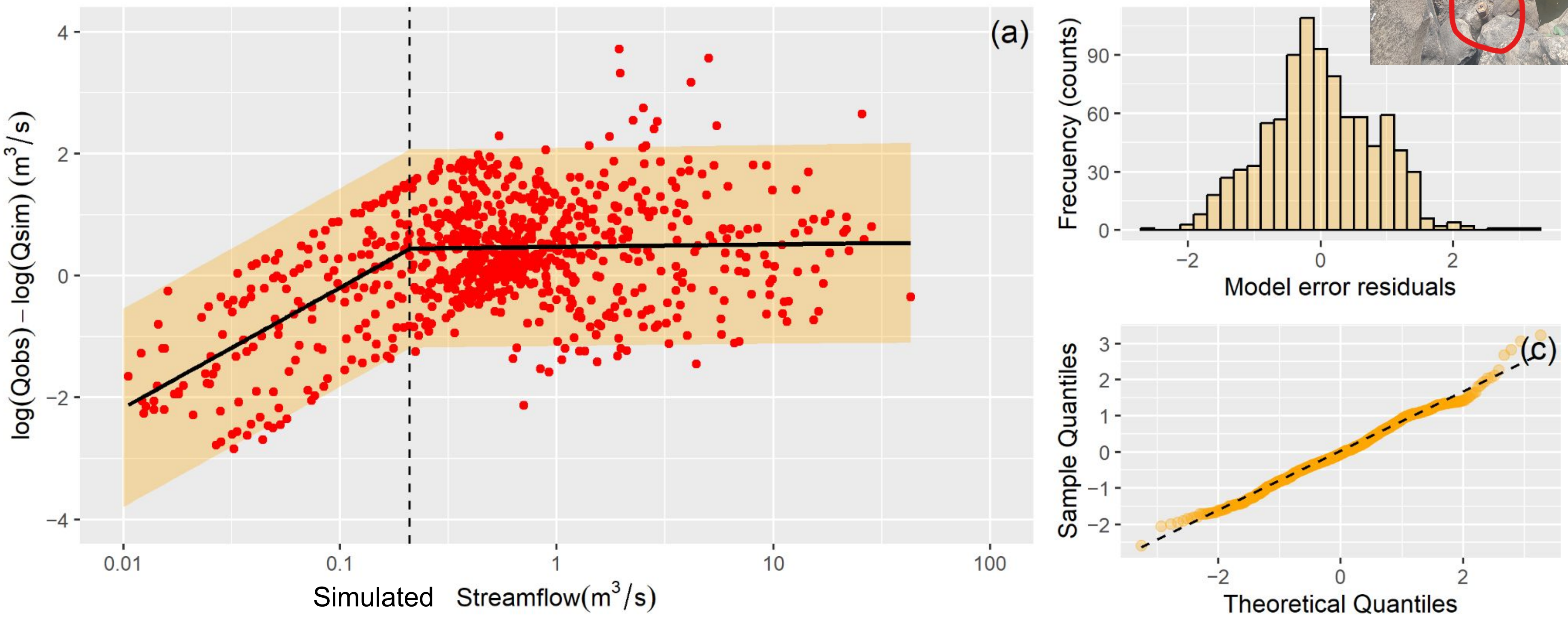
Table 2. Calibration parameters of 2nd phase (groundwater + baseflow).

Parameter	Description	File	Range	Type of Change	Best Fit
specific yield	Usable water released from an aquifer per unit volume when drained by gravity [-]	gwflow.input	0.2–0.35	substitutive	0.35
aquhydracond	Aquifer hydraulic conductivity factor [-]	gwflow.input	0.5–1.95	multiplicative	1.63
sbedhydracond	Stream bed hydraulic conductivity [m/d]	gwflow.input	0.1–50	substitutive	1.48
sbedthick	Stream bed thickness [m]	gwflow.input	0.5–2	substitutive	1.94
w_stress_oran	Water stress for irrigated citriculture [-]	lum.dtl	0.5–1	substitutive	0.51
w_stress_ofcp	Water stress for open field horticulture [-]	lum.dtl	0.5–1	substitutive	0.85
w_stress_ghcp	Water stress for greenhouse horticulture [-]	lum.dtl	0.5–1	substitutive	0.57

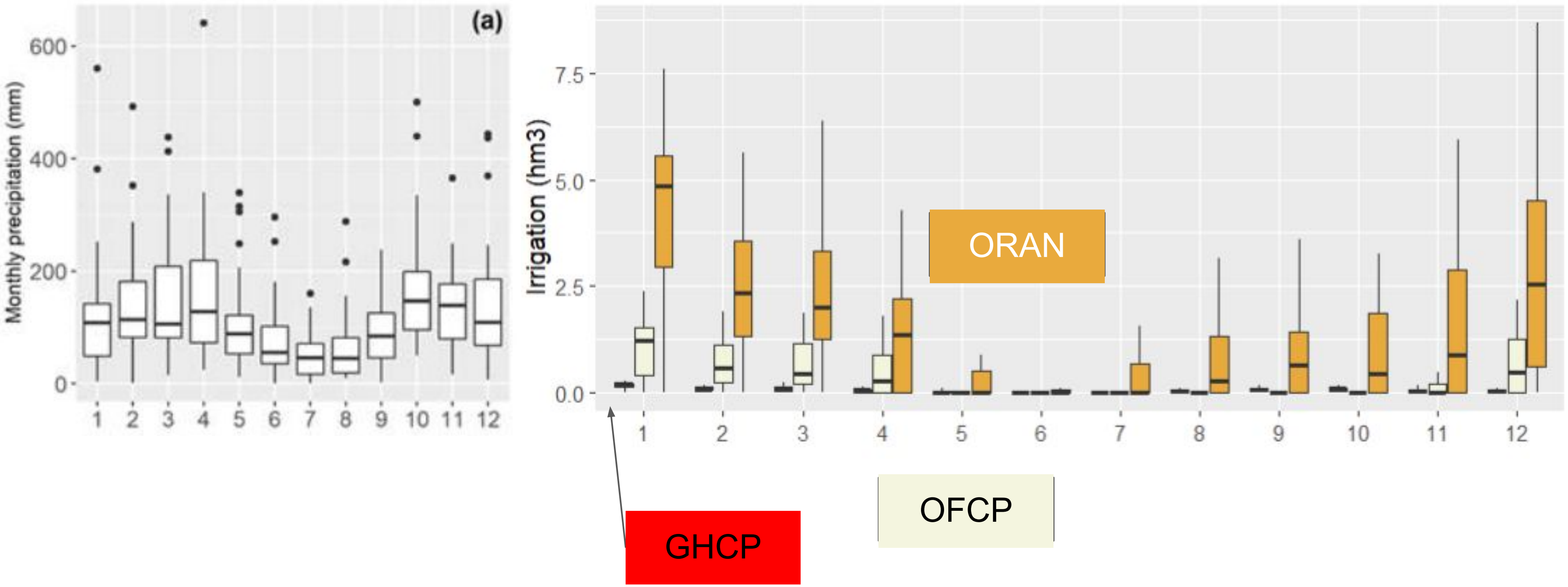
Calibration/validation



Streamflow Log Residuals ~ Simulated Streamflow

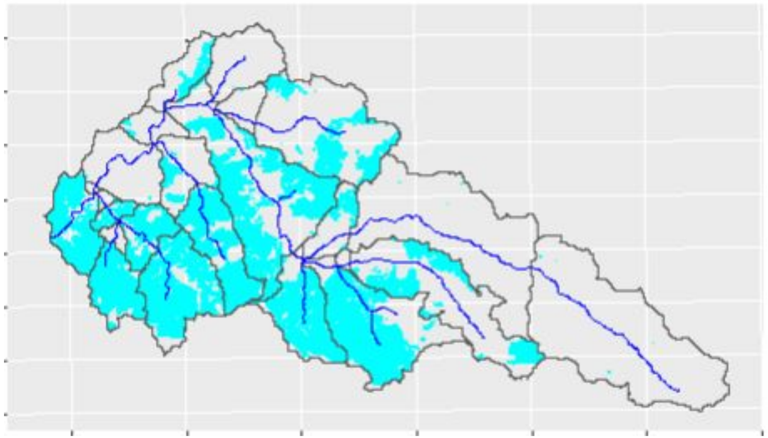


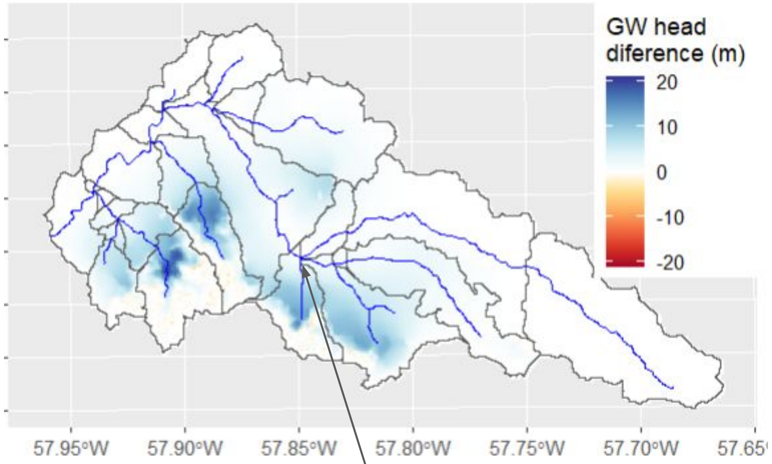
Water use (simulated)



Transition from Irrigation to Rainfed Agriculture

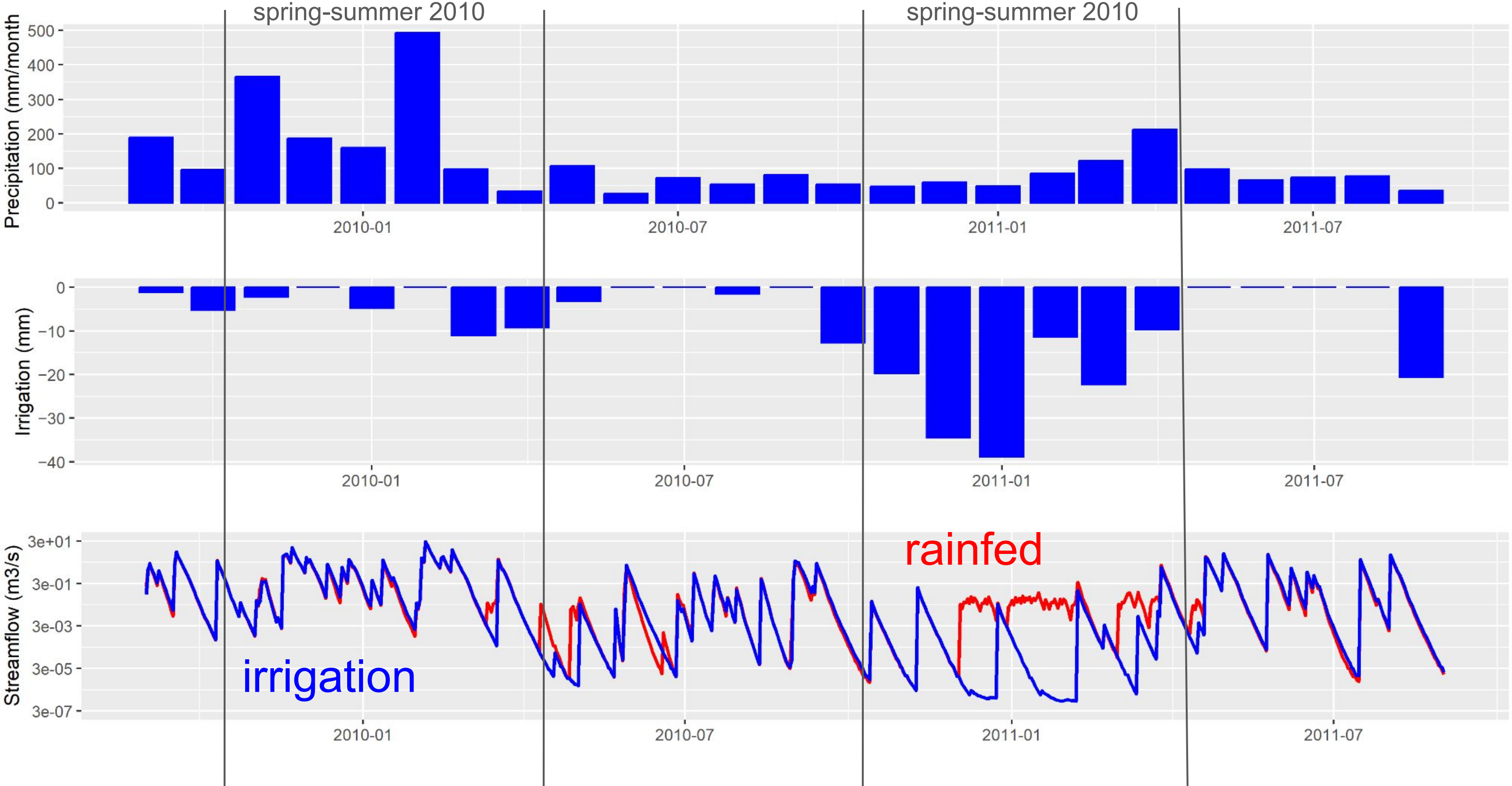
Irrigated crops





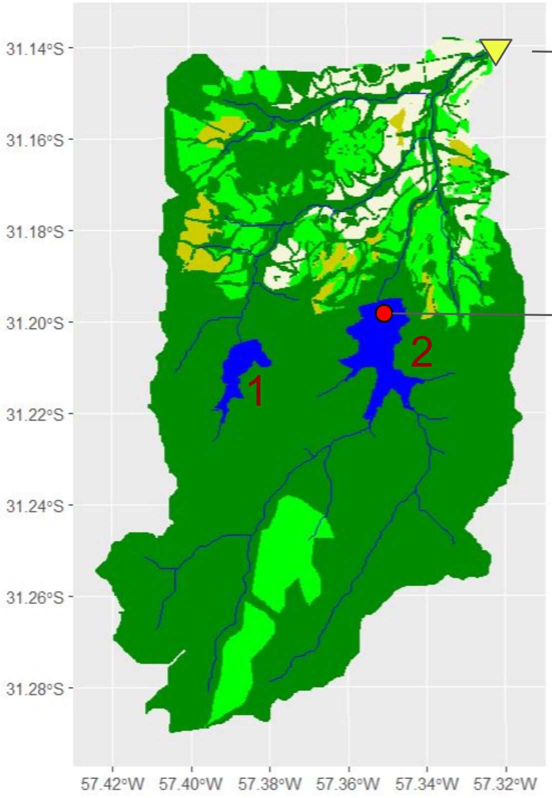
keep this location in mind for the next slide

Effect on Surface Water



2. Tala

Tala basin (120 km2)



Streamflow station

Reservoir water level volume

LANDUSE

- 2MAIZE/1SOYB-CRCR
- GRAS
- RICE/2PAST
- SOYB/2PAST
- WATR

Releases from reservoirs for irrigation and environmental use

Gauging at the streamflow station

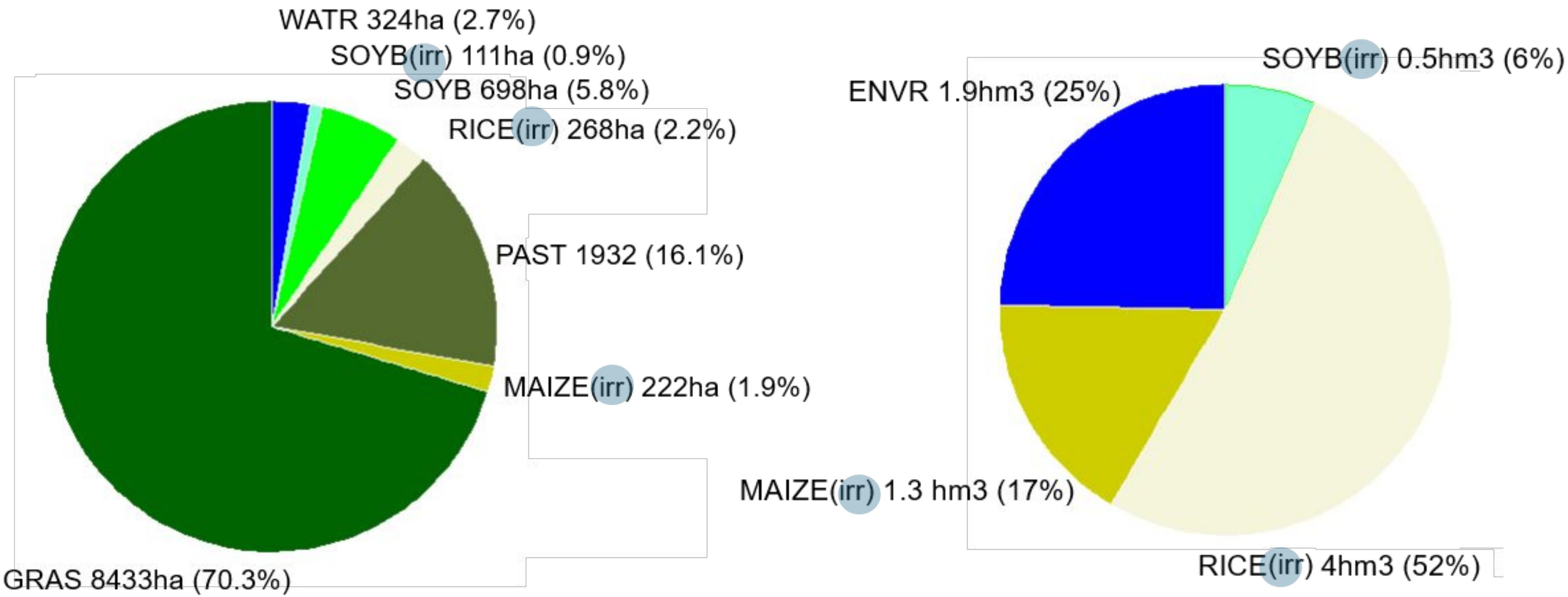
Land and Water Use

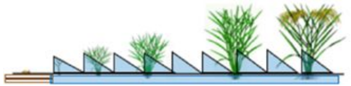
Water storage

Reservoir 1: 3.8 hm^3

Reservoir 2: 12.0 hm^3

Total storage: 15.8 hm^3

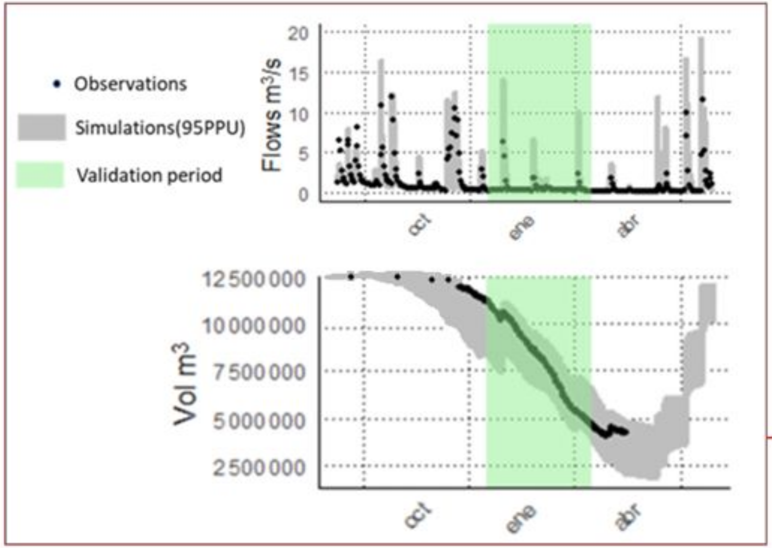




Calibration Parameters

Proceso	Parámetro	Descripción	archivo	tipo de cambio
Flujo de escorrentía	CN2	Número de Curva	mgt	pctchg
	SLSUBBSN	Lonitud media de la pendiente (m)	hru	pctchg
	OV_N	Coeficiente de manning para superficie	hru	pctchg
	ESCO	Factor de compensación de la evaporación del suelo	hru	absval
	SOL_AWC	Capacidad de agua disponible	sol	pctchg
	EPCO	Factor de compesación de la planta	hru	absval
	CH_K2	Conductividad hidraulica fondo de canales	rte	pctchg
	SOL_K	Conductividad hidraulica saturada (mm/h)	sol	pctchg
Flujo Base	GW_DELAY	Tiempo de demora del agua subterranea (días)	gw	absval
	ALPHA_BF	Constante de reseción del flujo base (1/días)	gw	absval
	GWQMN	Umbral de profundidad de agua en el acuífero poco profundo necesario para que se produzca el flujo de retorno(mm)	gw	absval
	GW_REVAP	Coeficiente "revap" de agua en el suelo	gw	absval
	REVAPMN	Umbral de percolación (mm)	gw	absval
	RCHRG_DP	Factor de percolación de acuifero profundo	gw	absval
	ALPHA_BF_D	Constante de reseción de acuífero profundo (1/días)	gw	absval
Embalse	RES_K	Conductividad fondo de embalse	res	pctchg
	RES_RR	Caudal posible de vertido de embalse	res	absval

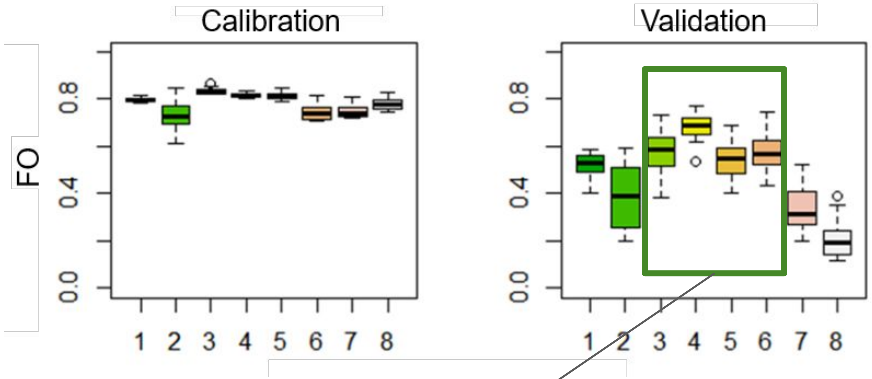
Calibration: 3 month moving window



Periodos de calibración	Periodo de datos observado de caudales									
1	Agosto	Septiembre	Octubre	Noviembre	Diciembre	Enero	Febrero	Marzo	Abril	Mayo
2	Agosto	Septiembre	Octubre	Noviembre	Diciembre	Enero	Febrero	Marzo	Abril	Mayo
3	Agosto	Septiembre	Octubre	Noviembre	Diciembre	Enero	Febrero	Marzo	Abril	Mayo
4	Agosto	Septiembre	Octubre	Noviembre	Diciembre	Enero	Febrero	Marzo	Abril	Mayo
5	Agosto	Septiembre	Octubre	Noviembre	Diciembre	Enero	Febrero	Marzo	Abril	Mayo
6	Agosto	Septiembre	Octubre	Noviembre	Diciembre	Enero	Febrero	Marzo	Abril	Mayo
7	Agosto	Septiembre	Octubre	Noviembre	Diciembre	Enero	Febrero	Marzo	Abril	Mayo
8	Agosto	Septiembre	Octubre	Noviembre	Diciembre	Enero	Febrero	Marzo	Abril	Mayo
Referencias	Calibración	Validación								

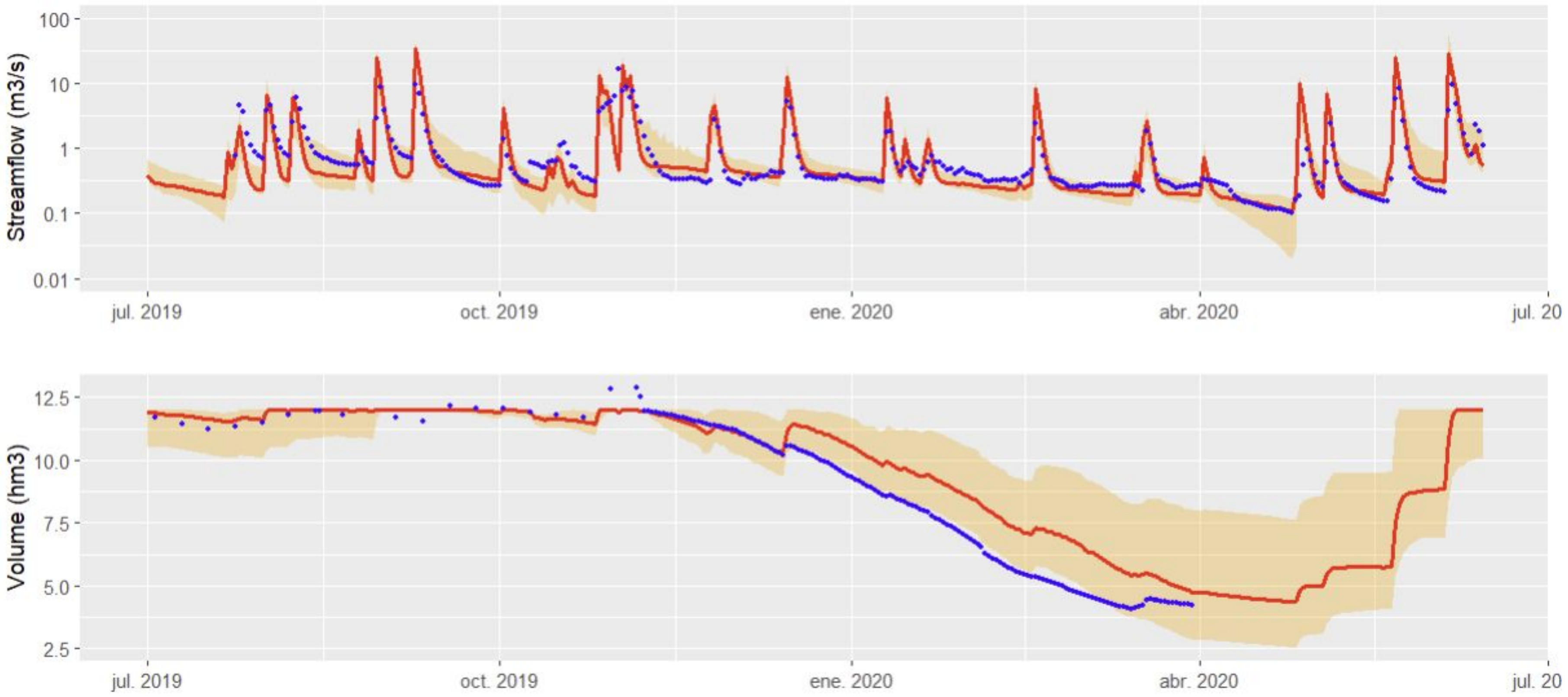
$$KGE = 1 - \left((r-1)^2 + \left(\frac{\sigma_{sim}}{\sigma_{obs}} - 1 \right)^2 + \left(\frac{\mu_{sim}}{\mu_{obs}} - 1 \right)^2 \right)^{0.5}$$

$$FO = 0.2 * KGE_{res} + 0.8 * KGE_{reach}$$

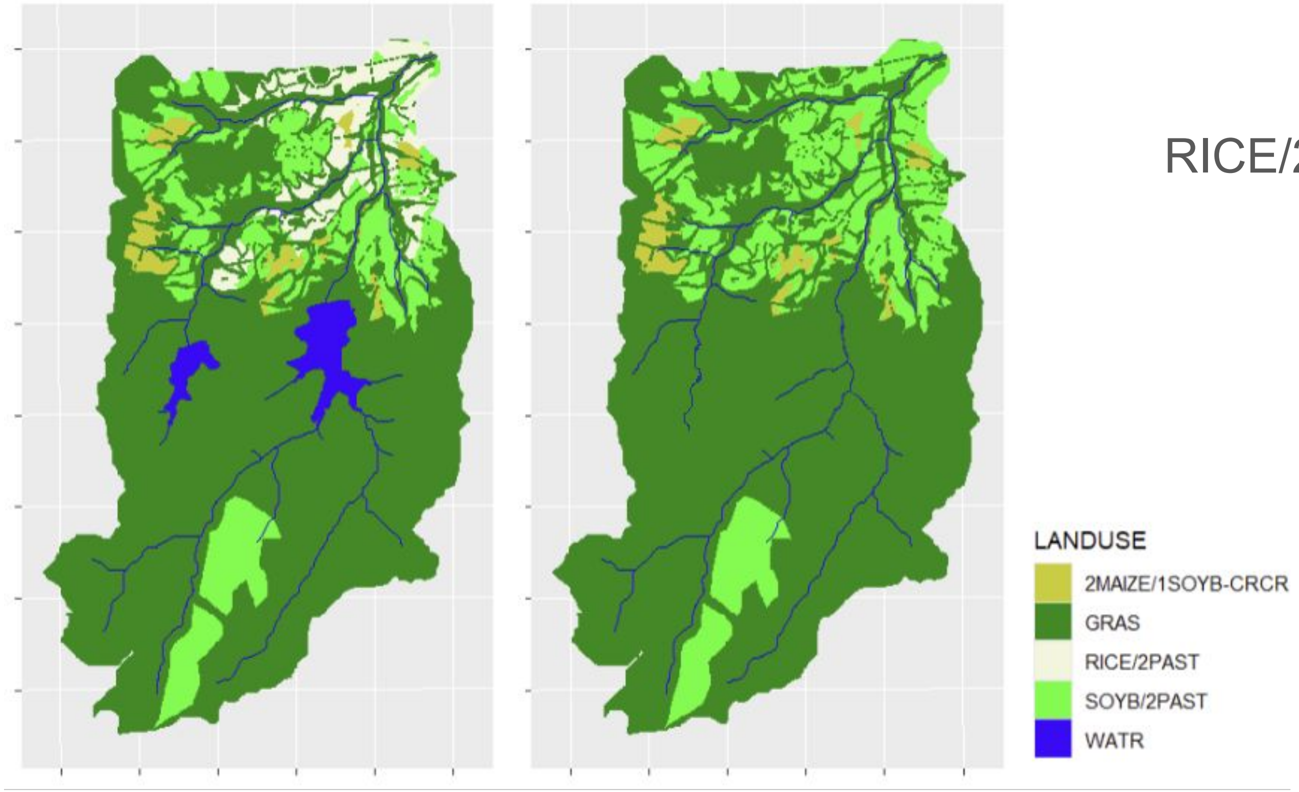


Best validation period: October to March

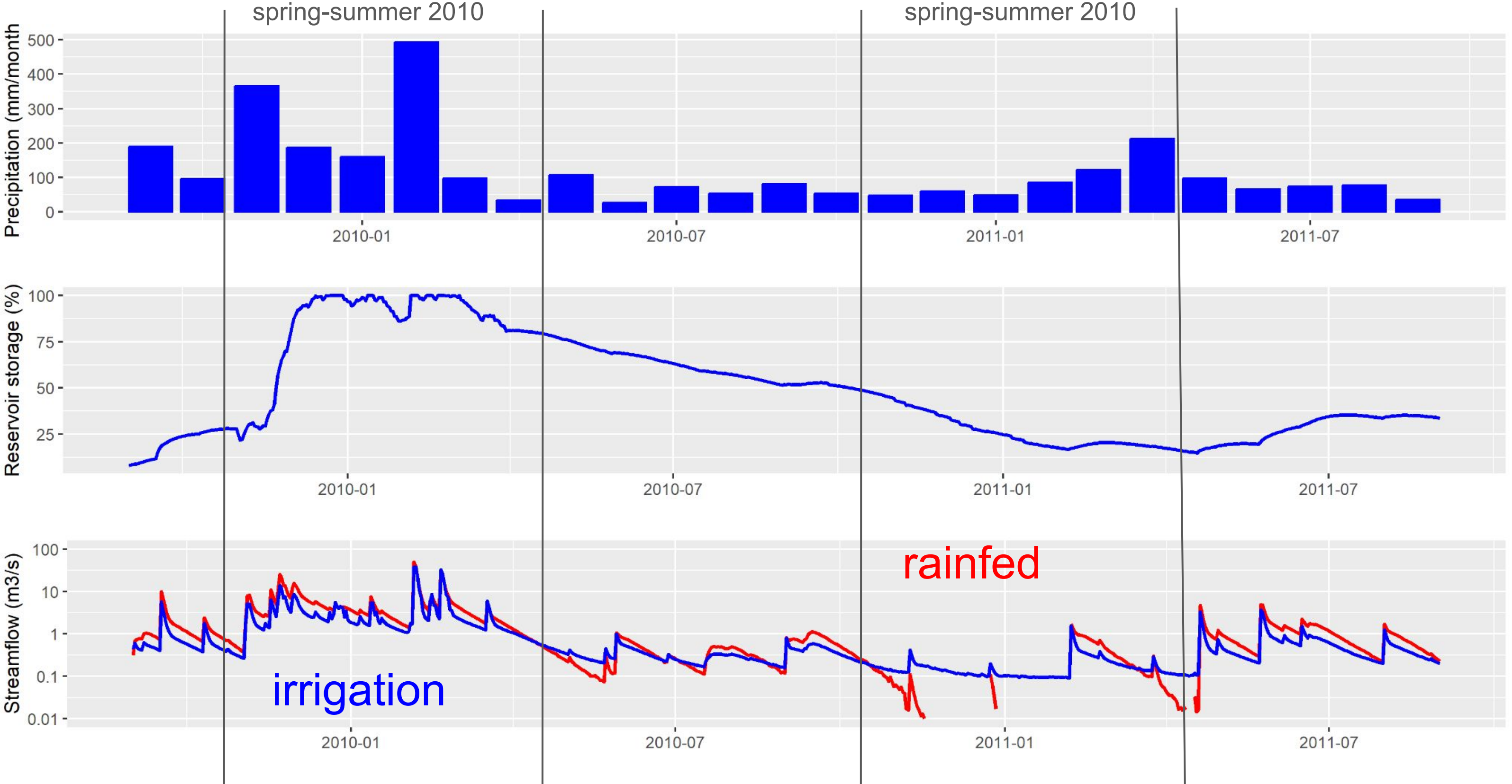
Overall performance



Transition from Irrigation to Rainfed Agriculture

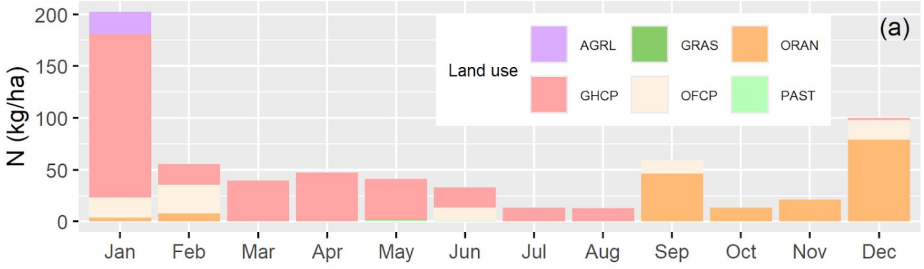


RICE/2PAST -> SOYB/PAST

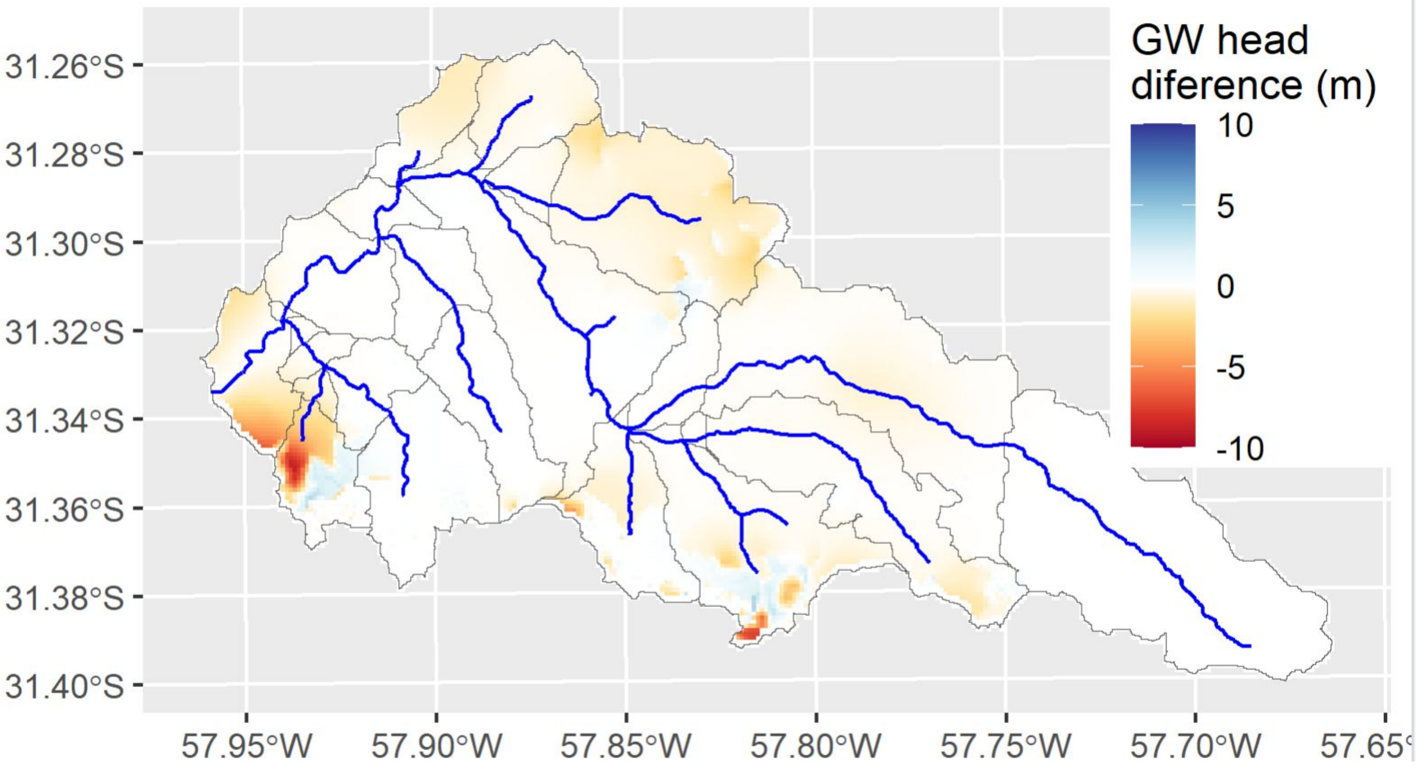

spring-summer 2010
spring-summer 2010
Precipitation (mm/month)
500
400
300
200
100
0
2010-01
2010-07
2011-01
2011-07
Reservoir storage (%)
100
75
50
25
2010-01
2010-07
2011-01
2011-07
Streamflow (m3/s)
100
10
1
0.1
0.01
rainfed
irrigation
2010-01
2010-07
2011-01
2011-07

3. Opportunities

Greenhouses



Boundary conditions (constant head vs no flow)



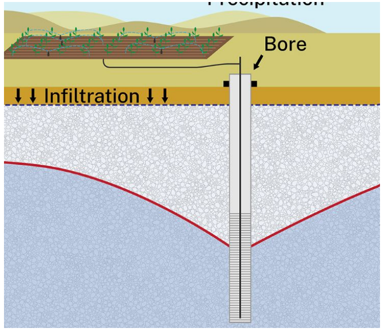


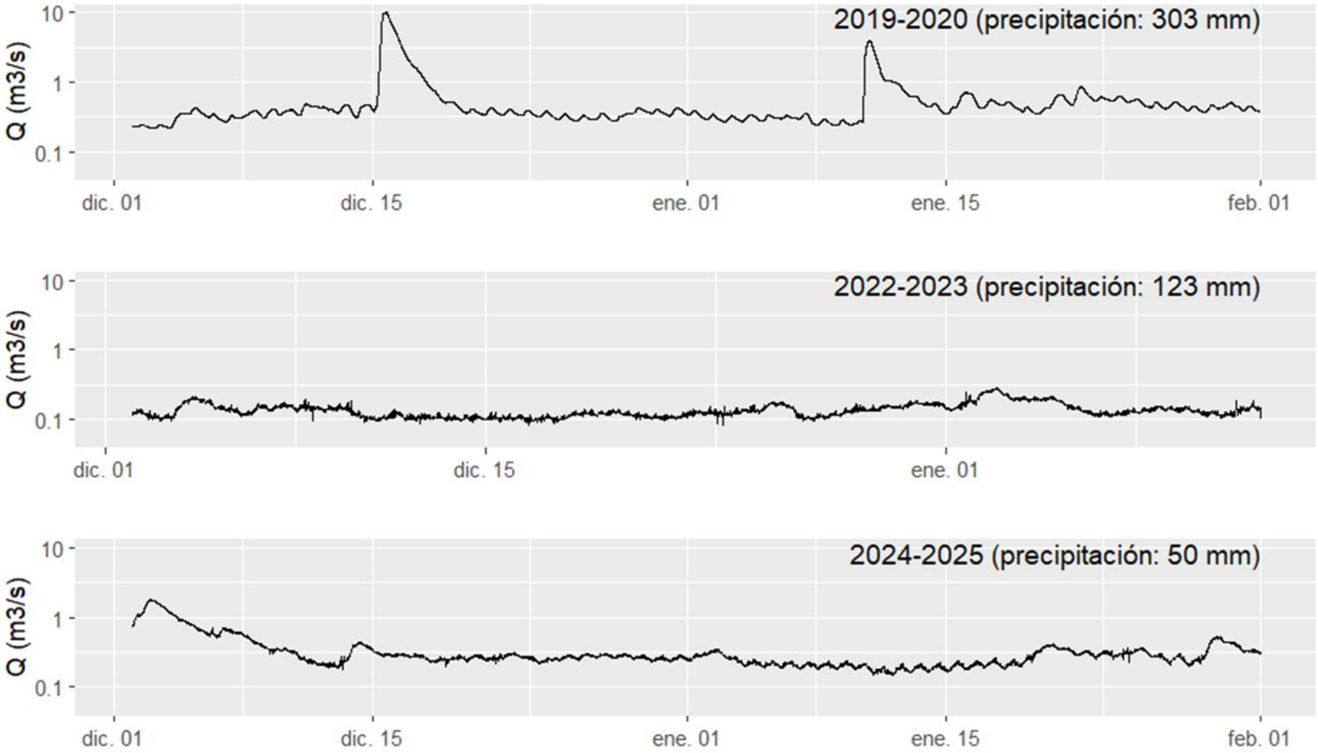
Photo: Gonzalo Medina

Over bund flow and/or bund failure (paddy rice - Tala)

Over bund flow and/or bund failure

Paddy rice – Uruguay – continuous flooding (southeast part of the country)
Photo: Federico Campos

Streamflow behavior for Dec-Jan in 3 different years (Tala)



Summary

- The SWAT model was implemented in two catchments with reasonable performance, despite limited availability of input data.
- The model proved useful for improving understanding of crop water use dynamics.
- The simulations highlight the strong influence of rainfall variability in triggering irrigation demand.
- Both catchments offers opportunities to test new approaches within SWAT.