AN AUTOMATED TOOL FOR COUPLING SWAT+ OUTPUTS WITH IAHRIS SOFTWARE TO ASSESS HYDROLOGIC ALTERATION IN RIVER SYSTEMS

Adrián López-Ballesteros, Javier Senent-Aparicio, Carolina Martínez, Anastasio Fernández-Yuste, Jaclyn Tech, Raghavan Srinivasan

WHAT WOULD BE THE PERFECT BIRTHDAY PRESENT FOR ME?

NEW PREPROCESSING TOOLS

NEW PROCESSING FEATURES

NEW POSTPROCESSING TOOLS

SWAT+
SOIL & WATER ASSESSMENT TOOL

+

HYDROLOGICAL MODEL

INDICATORS OF HYDROLOGIC ALTERATION IN RIVERS

IAHRIS SOFTWARE

Develop by:

- Polytechnic University of Madrid (UPM)
- Spanish Centre for Studies and Experimentation of Public Works (CEDEX)

Designed to:

- Characterize river flow regimes
- Quantify hydrologic alteration
  - 19 hydrological parameters
  - 21 - 25 Indicators of Hydrologic Alteration (IAHs)

Based on:

Natural flow regime paradigm

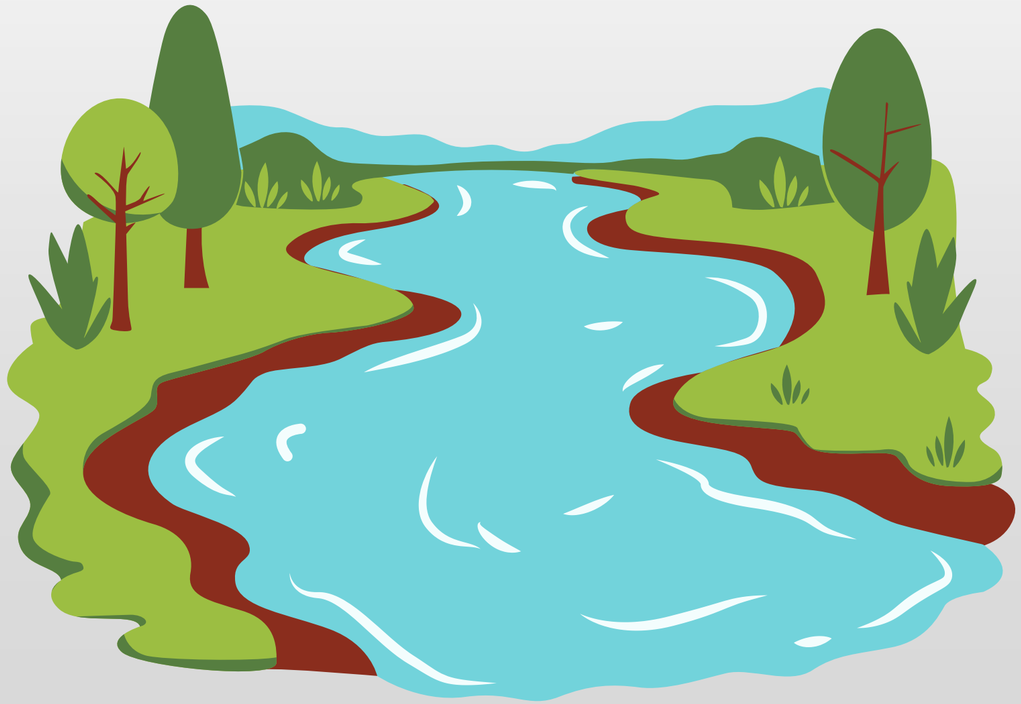
(Poff et al., 1997)

Natural flow = Reference condition for assessing the ecological status of river systems

Water Framework Directive (EC, 2000)

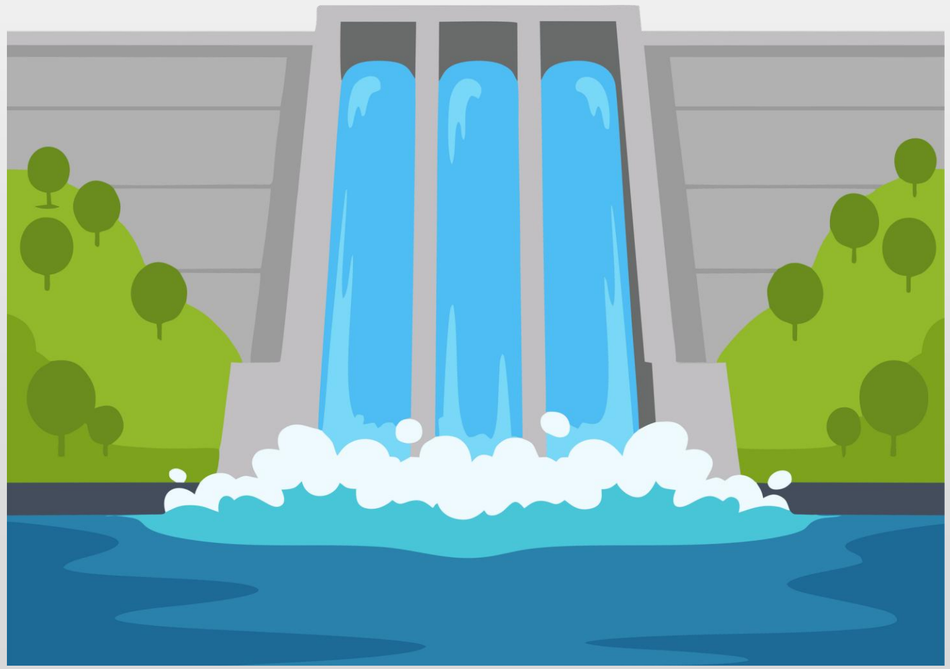
To do this:

NATURAL FLOW



VS

ALTERED FLOW



HYDROLOGICAL PARAMETERS

(HIGHEST ENVIRONMENTAL RELEVANCE)

Aspect	Hydrological parameter	Description
Habitual flow values	P1	Magnitude of monthly and annual flow contributions
	P2	Extreme variability
	P3	Seasonality of maximum and minimum flows
	P4	Habitual variability
Floods	P5	Magnitude of maximum floods
	P6	Magnitude of the bed-forming discharge
	P7	Magnitude of the connectivity discharge
	P8	Magnitude of habitual floods
	P9	Variability of maximum floods
	P10	Variability of habitual floods
	P11	Duration of floods
	P12	Seasonality of floods: one for each month
Droughts	P13	Magnitude of extreme droughts
	P14	Magnitude of habitual droughts
	P15	Variability of extreme droughts
	P16	Variability of habitual droughts
	P17	Duration of droughts
	P18	Number of days with zero flow: one for each
	P19	Seasonality of droughts: one for each month

ATTRIBUTES:

MAGNITUDE, VARIABILITY, FREQUENCY, DURATION, AND SEASONALITY

INDICATORS OF HYDROLOGIC ALTERATION (IAHS)

Aspect	Attribute	Indicator	Denomination
Habitual flow values	Magnitude	IAH1	Magnitude of annual flow contributions
		IAH2	Magnitude of monthly flow contributions
		M3*	Magnitude of monthly flow contributions:
	Variability	V1*	Variability of annual flow contributions
		V2*	Variability of monthly flow contributions
		V3*	Variability of monthly flow contributions:
		IAH3	Habitual variability
		IAH4	Extreme variability
	Seasonality	IAH5	Seasonality of maximum flows
		IAH6	Seasonality of minimum flows
Floods	Magnitude and frequency	IAH7	Magnitude of maximum floods
		IAH8	Magnitude of the channel-forming
		IAH9	Magnitude of the connectivity discharge
		IAH10	Magnitude of habitual floods
	Variability	IAH11	Variability of maximum floods
		IAH12	Variability of habitual floods
	Duration	IAH13	Duration of floods
	Seasonality	IAH14	Seasonality of floods: one for each month
Droughts	Magnitude and frequency	IAH15	Magnitude of extreme droughts
		IAH16	Magnitude of habitual droughts
	Variability	IAH17	Variability of extreme droughts
		IAH18	Variability of habitual droughts
	Duration	IAH19	Duration of droughts
		IAH20	Number of days with zero flow: one for
	Seasonality	IAH21	Seasonality of droughts: one for each

*** Additional IAH calculated only for non-coetaneous flow series.**

SWAT+IAHRIS TOOL

SWAT ÷ IAHRIS

https://github.com/AdrLBallesteros/SWATPlus-IAHRIS

Open-source software tool (Python)

SWAT+
SOIL & WATER ASSESSMENT TOOL

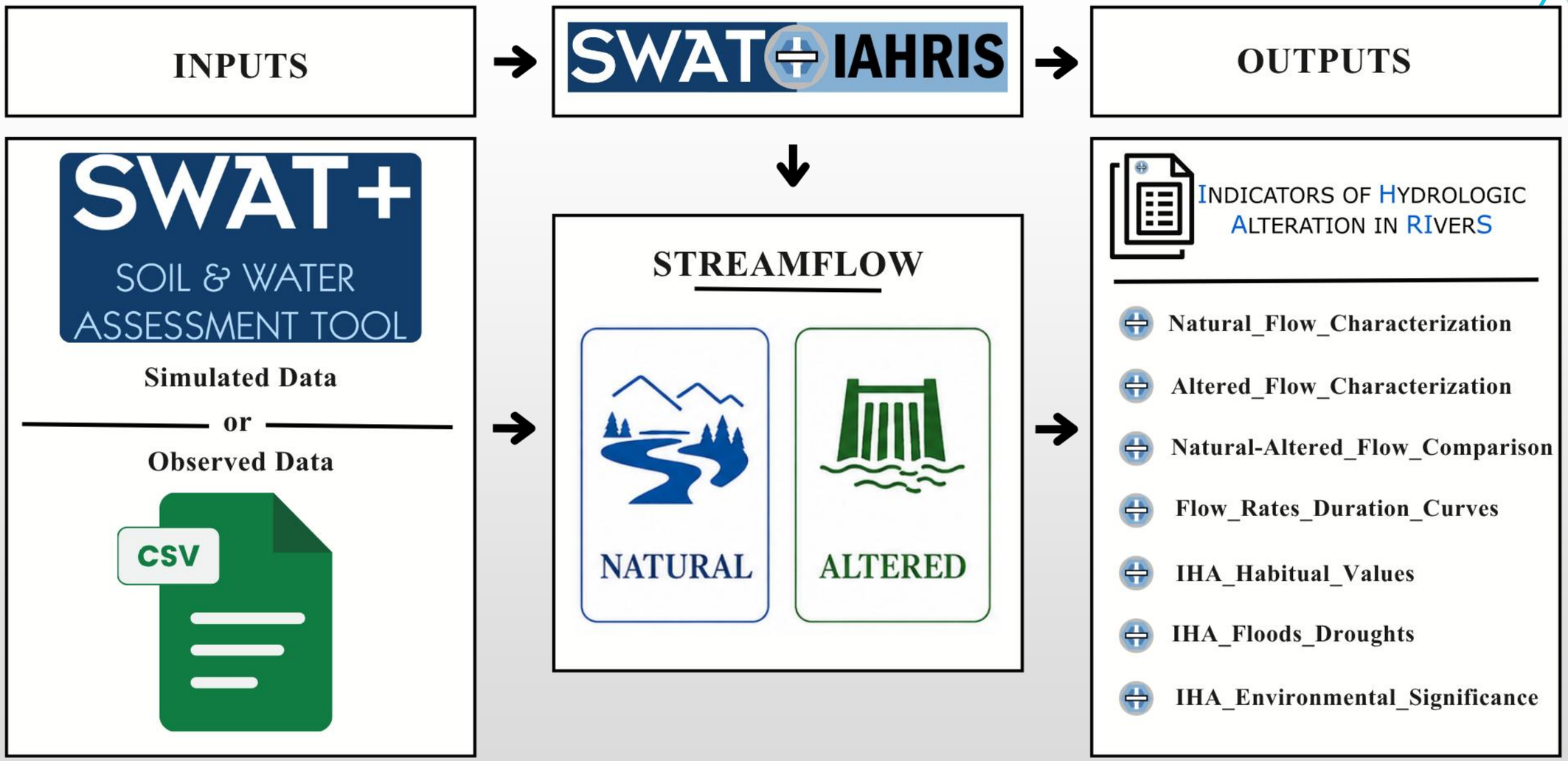
+

SWAT+ OUTPUT FILES (channel_sd_daily)

- NATURAL FLOW
- ALTERED FLOW

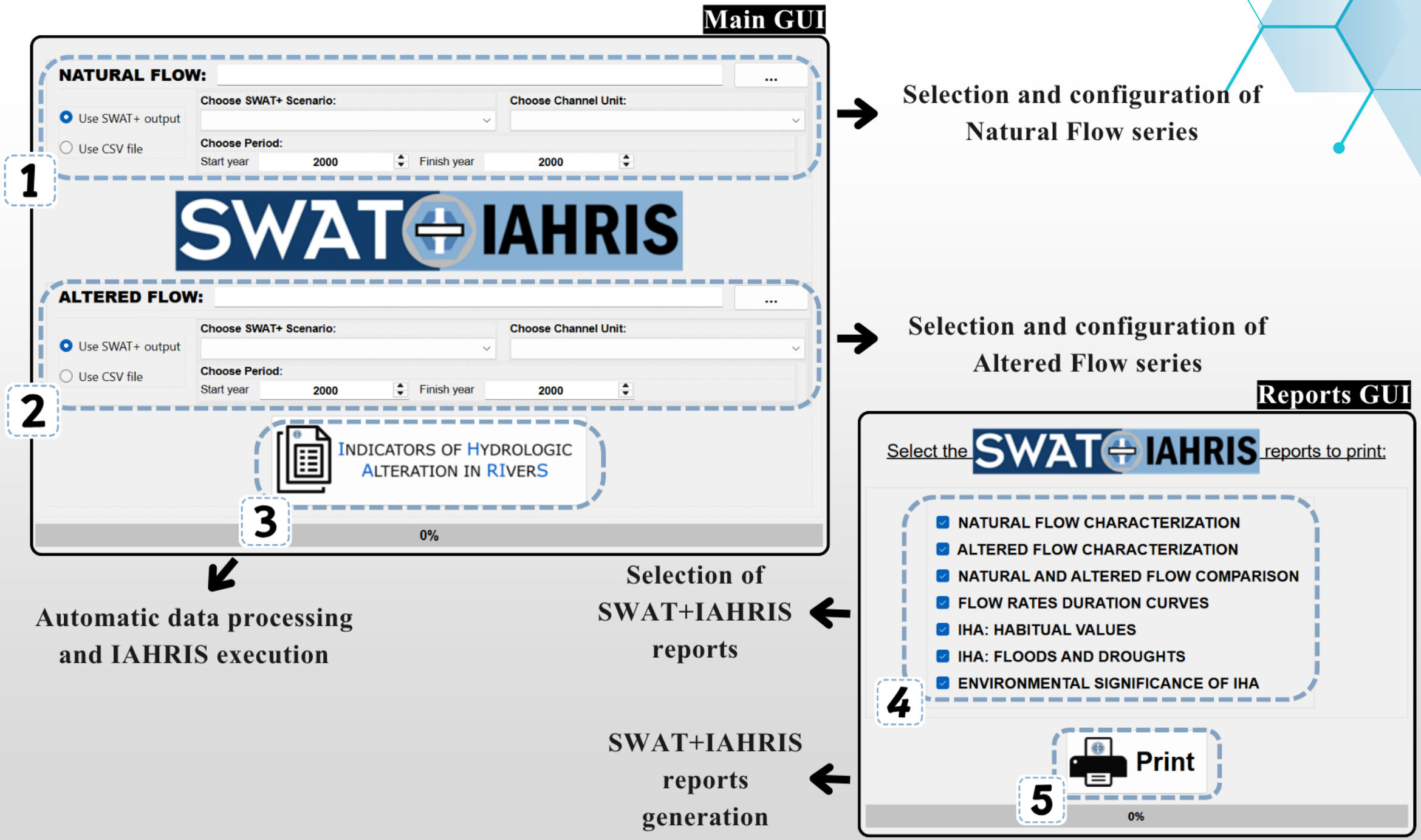
IAHRIS FRAMEWORK

SWAT+IAHRIS WORKFLOW



7 SWAT+IAHRIS Reports

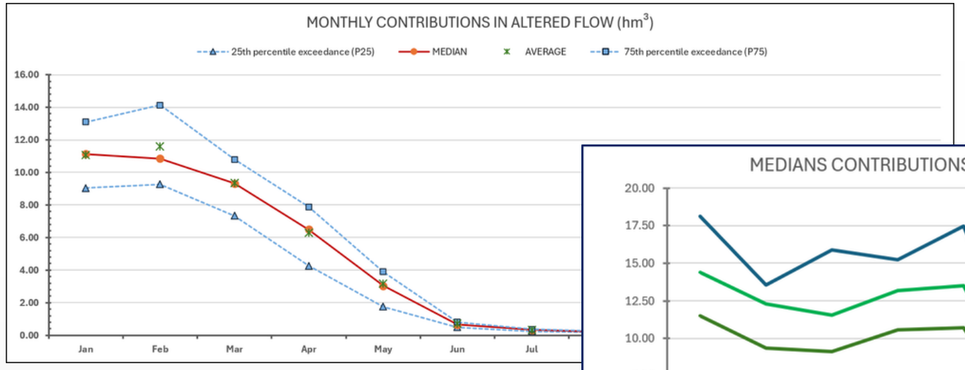
SWAT+IAHRIS GUI

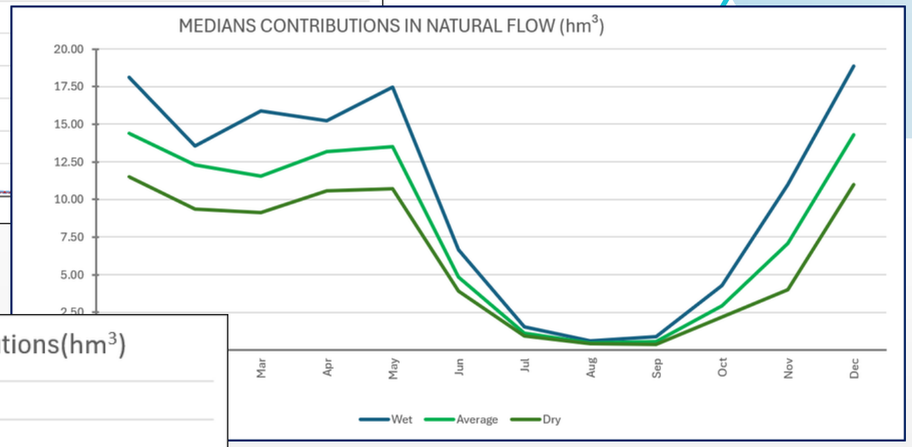

Main GUI
NATURAL FLOW:
...
Use SWAT+ output
Use CSV file
Choose SWAT+ Scenario:
Choose Channel Unit:
Choose Period:
Start year
2000
Finish year
2000
1
SWAT+ IAHRIS
ALTERED FLOW:
...
Use SWAT+ output
Use CSV file
Choose SWAT+ Scenario:
Choose Channel Unit:
Choose Period:
Start year
2000
Finish year
2000
2
INDICATORS OF HYDROLOGIC ALTERATION IN RIVERS
3
0%
Selection and configuration of Natural Flow series
Selection and configuration of Altered Flow series
Reports GUI
Select the SWAT+ IAHRIS reports to print:
NATURAL FLOW CHARACTERIZATION
ALTERED FLOW CHARACTERIZATION
NATURAL AND ALTERED FLOW COMPARISON
FLOW RATES DURATION CURVES
IHA: HABITUAL VALUES
IHA: FLOODS AND DROUGHTS
ENVIRONMENTAL SIGNIFICANCE OF IHA
4
Print
5
0%
Automatic data processing and IAHRIS execution
Selection of SWAT+IAHRIS reports
SWAT+IAHRIS reports generation

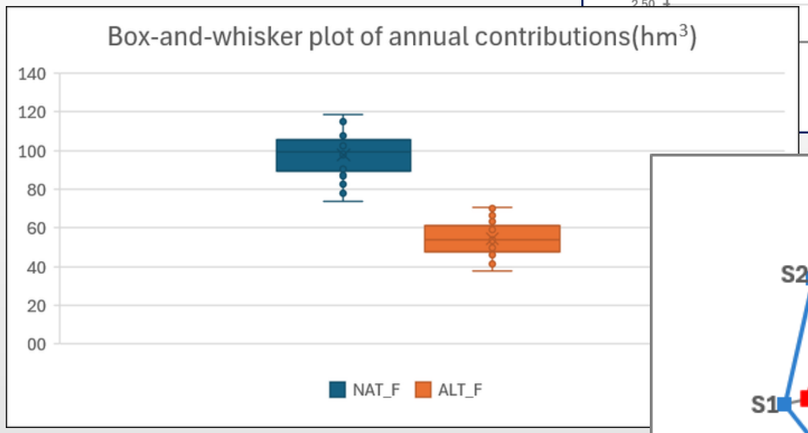
SWAT+IAHRIS OUTPUTS

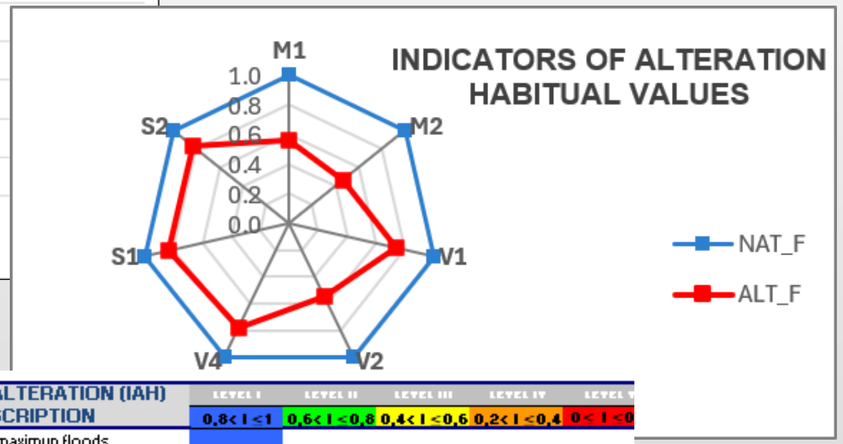
INDICATORS OF HYDROLOGIC ALTERATION IN RIVERS

- SWATPlus-IAHRIS_Altered_Flow_Characterization.xlsx
- SWATPlus-IAHRIS_Flow_Rates_Duration_Curves.xlsx
- SWATPlus-IAHRIS_IHA_Environmental_Significance.xlsx
- SWATPlus-IAHRIS_IHA_Floods_Droughts.xlsx
- SWATPlus-IAHRIS_IHA_Habitual_Values.xlsx
- SWATPlus-IAHRIS_Natural_Flow_Characterization.xlsx
- SWATPlus-IAHRIS_Natural-Altered_Flow_Comparison.xlsx









ASPECT		INDICATORS OF HYDROLOGIC ALTERATION (IAH) VALUE		CODE	DESCRIPTION	LEVEL I 0,8< I <1	LEVEL II 0,6< I <0,8	LEVEL III 0,4< I <0,6	LEVEL IV 0,2< I <0,4	LEVEL V 0< I <0
FLOODS	magnitude	0.80		IAH7	Magnitude of the maximun floods					
		0.92		IAH8	Magnitude of the effective discharge					
		0.26	"	IAH9	Frecuency of the connectivity discharge					
	variability	0.76		IAH10	Magnitude of the flushing flood					
		0.69	"	IAH11	Variability of the maximum floods					
		0.68	"	IAH12	Variability of the flushing floods					
	duration	0.28		IAH13	Floods duration					
	seasonality	0.72		IAH14	Floods seasonality					
DROUGHTS	magnitude	0.38		IAH15	Magnitude of the extreme droughts					
		0.38		IAH16	Magnitude of the habitual droughts					
	variability	0.63	"	IAH17	Variability of the extreme droughts					
		0.66	"	IAH18	Variability of the habitual droughts					
	duration	0.11	"	IAH19	Droughts duration					
		1.00		IAH20	Nº of days with null discharge					
	seasonality	0.58		IAH21	Droughts seasonality					

SWAT+IAHRIS LIMITATIONS AND FUTURE DEVELOPMENT

- **LIMITATIONS:**

1. Lots of reports, tables, plots, and information. → Not easy to digest...
2. Needs a daily streamflow series without gaps or missing values.
3. At least 15 years of flow records are required to generate the IAHRIS reports.

- **SOLUTIONS:**

1. An AI assistant that helps users understand the output reports.

2. Streamflow modelling with SWAT+
3. Streamflow modelling with SWAT+

SWAT+
SOIL & WATER ASSESSMENT TOOL

- **FUTURE DEVELOPMENT:**
  - Including environmental flow assessment routines.
  - Command-line version → Integration with HAWQS and other tools.

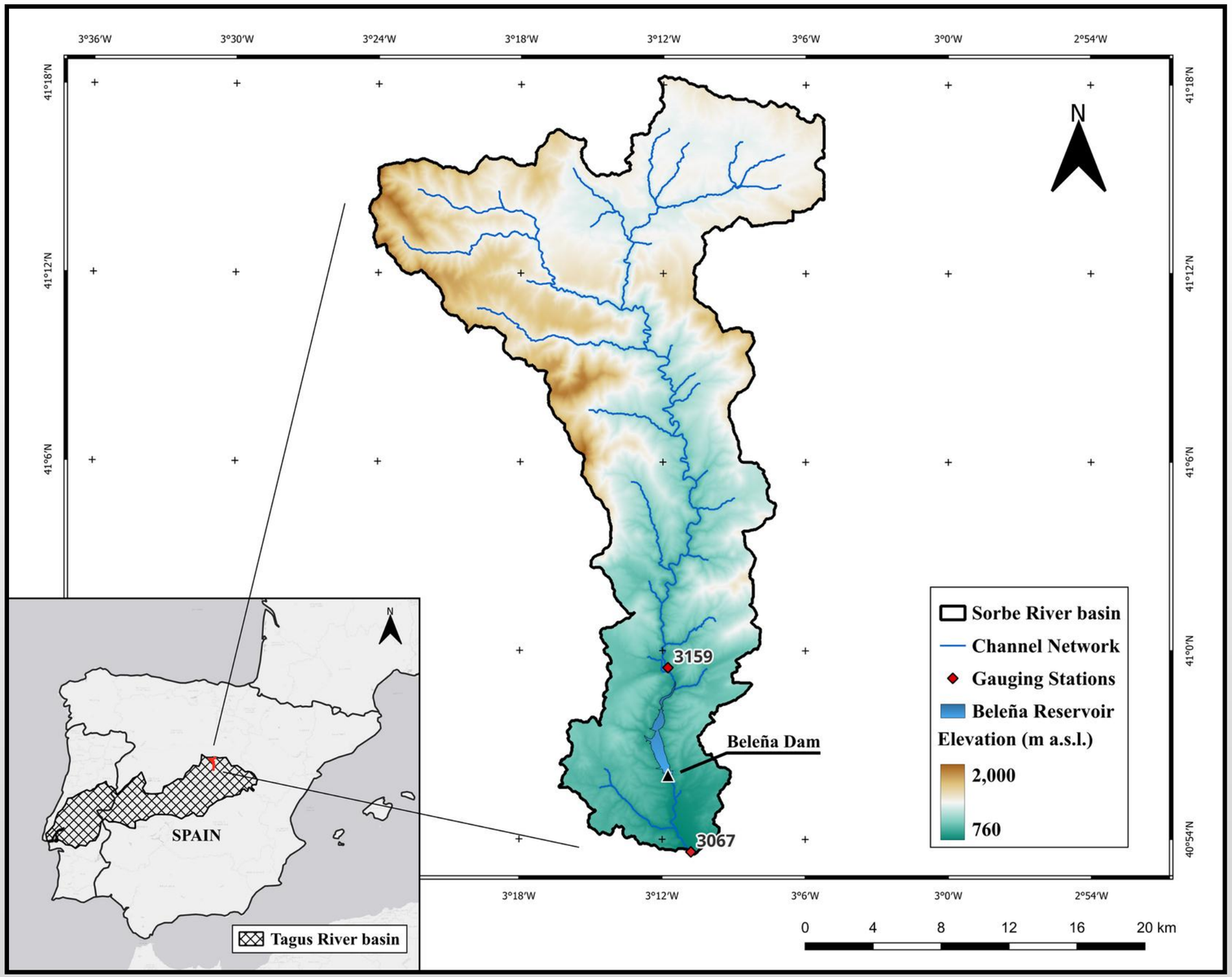
SWAT+IAHRIS APPLICATION EXAMPLES

1. Dam-induced impact

2. Climate change impact

STUDY AREA

Sorbe River basin



Area: 520 km²

Reservoir: Beleña Dam

Mean elevation: 1307 m a.s.l.

PCP: 734 mm

ETP: 1013 mm

LULC: Forest and pasture areas

- **SWAT+ Inputs**:

(López-Ballesteros et al., 2024)

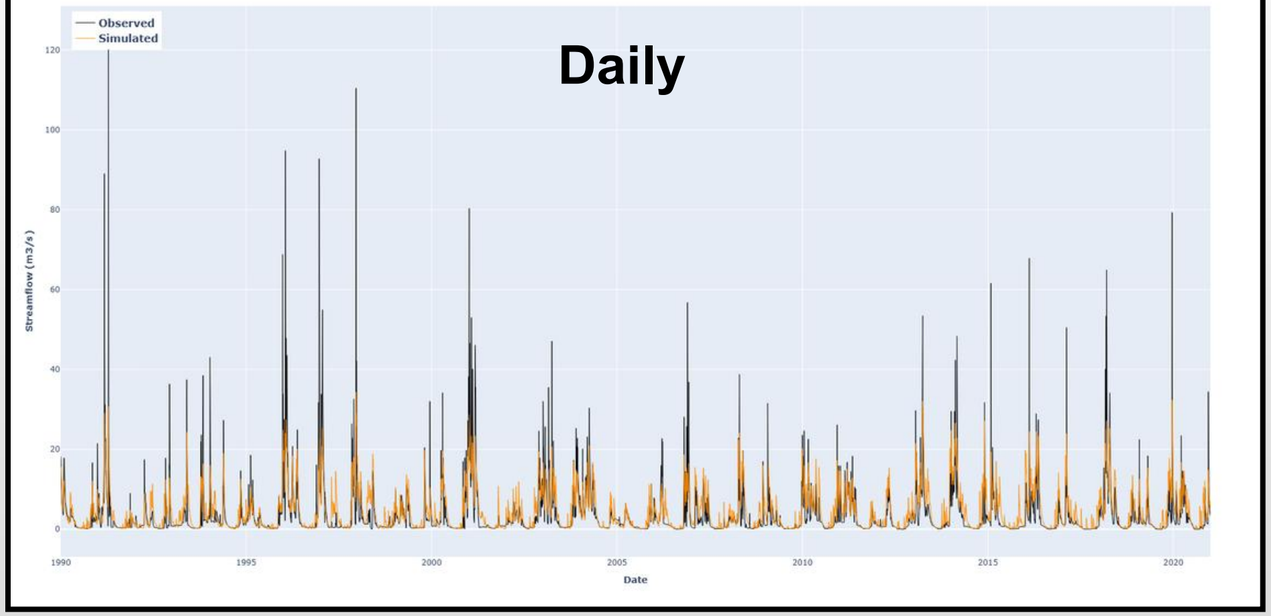
Parameter	Definition	Change type	Range	Final value
esco.hru	Soil evaporation compensation factor	Replace	0-1	73
epco.hru	Plant uptake compensation factor	Replace	0-1	63
cn2.hru	SCS curve number	Percent	±20%	−18.57
awc.sol	Available water capacity of the soil layer (mm/mm)	Percent	±25%	−0.92
perco.hru	Percolation coefficient	Replace	0-1	66
latq_co.hru	Lateral flow coefficient	Replace	0-1	50
cn3_swf.hru	Soil water factor for CN3	Replace	0-1	69
z.sol	Depth from soil surface to bottom of layer (mm)	Percent	±25%	1.931
k.sol	Saturated hydraulic conductivity (mm/hr)	Percent	±25%	488
bd.sol	Moist bulk density (g/cm3)	Percent	±25%	−20.63
ovn.hru	Overland flow Manning's n value	Percent	±20%	−14.86
lat_ttime.hru	Lateral flow travel time (days)	Replace	0.5-180	341
alpha.aqu	Groundwater recession constant (1/days)	Replace	0-1	2
sp_yld.aqu	Specific yield of the aquifer (m3/m3)	Replace	0.01-0.5	13
surlag.bsn	Surface runoff lag coefficient	Replace	0.05-24	1.087
chn.rte	Main channel Manning's n value	Replace	0.01-0.3	19
revap_co.aqu	Groundwater revap coefficient	Replace	0.02-0.2	13
revap_min.aqu	Threshold depth from surface to water table for revap to occur (m)	Replace	0-20	771
flo_min.aqu	Threshold depth from surface to water table for groundwater flow to occur (m)	Replace	0-20	572

(1987-2020)

Warm-Up: 3 years

SWAT+ Toolbox

Version 3.2



NSE: 0.58

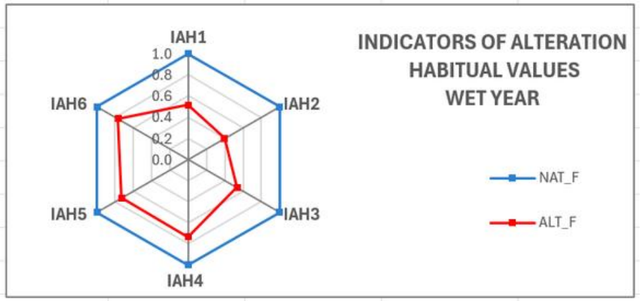
Sánchez-Gómez, A., Bieger, K., Schürz, C., Rodríguez-Castellanos, J.M., Molina-Navarro, E., 2025. Multi-spatial and multi-criteria calibration to guarantee a robust SWAT+ hydrological model in a large and heterogeneous catchment. Catena 261, 109508.

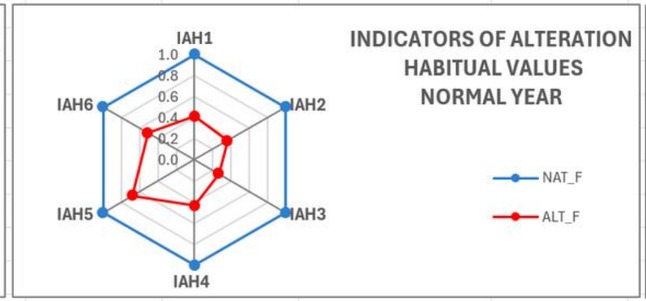
RESULTS

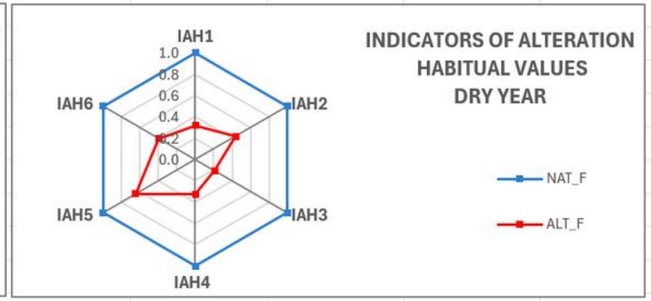
1. Dam-induced impact

NATURAL FLOW → **SWAT+ > channel_sd_daily > flo_out (cha58)**

ALTERED FLOW → **Gauging station 3067 (downstream Beleña dam)**







INDICATORS OF GLOBAL ALTERATION (IAG)			LEVEL I	LEVEL II	LEVEL III	LEVEL IV	LEVEL V
ASPECT	VALUE	CODE	0,64< I ≤1	0,36< I ≤0,64	0,16< I ≤0,36	0,04< I ≤0,16	0≤ I ≤0,04
WET YEAR	0.37	$IAG_{H\ WET\ YEAR}$					
NORMAL YEAR	0.19	$IAG_{H\ NORMAL\ YEAR}$					
DRY YEAR	0.15	$IAG_{H\ DRY\ YEAR}$					

Significant dam-induced alteration with strong reduction and redistribution of habitual flows, mainly in dry years.

2. Climate change impact

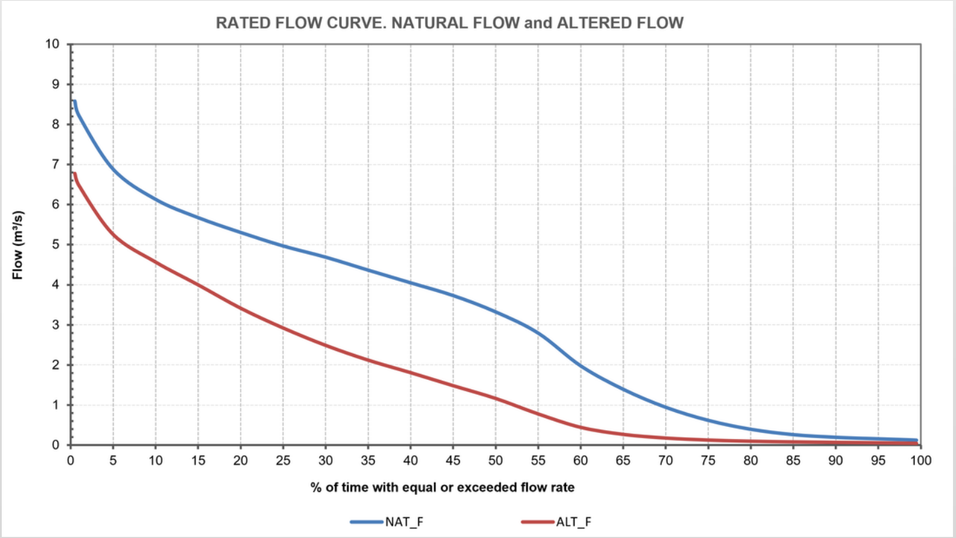
SWAT+ > channel_sd_daily > flo_out (cha58)

NATURAL FLOW → **Historical (1990-2010) > 11 ensembled GCMs**

ALTERED FLOW → **Far-Future (2080-2100) > 11 ensembled GCMs > SSP5-8.5**

AEMET AR6

(IPCC Sixth Assessment Report)



A significant reduction in water availability and an intensification of drought conditions. The greatest reduction is seen for low flows, suggesting that climate change will affect the baseflow conditions.

CONCLUSIONS

SWAT+ IAHRIS

Automates the post-processing of SWAT+ daily streamflow for hydrologic alteration assessment using the IAHRIS framework.

Provides an efficient and user-friendly bridge between these two tools.

Supports researchers in assessing the impacts of flow regulation, climate change, and other pressures on river flow regimes.

SUMMARY

Current Tools and Accessories

PREPROCESSING:

- QSWAT+
- MapSWAT
- SWATprepR
- WaterWebTools - ERA5 dataset
- W3S – Weather Web Service*

PROCESSING:

- SWAT+Editor
- SWAT+gwflow
- SWAT+MODFLOW
- Decision Tables
- Water Allocation
- Subdaily*

POSTPROCESSING:

- SWAT+Toolbox
- SWATplus-CUP
- R-SWAT
- pySWATplus
- SWATrunR / SWATfarmR / SWATdoctR / SWATtunR
- SWAT+IAHRIS

* Not working...

WE ALL ARE SWAT

KEEP RESEARCHING.
KEEP DEVELOPING NEW TOOLS.
AND LET'S PLAY.

alopbal@upv.es @AdrLBallesteros

THANK YOU!