Evaluating the hydrological performance of three global digital soil maps using SWAT+

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Soil & Water Assessment Tool SWAT

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SMART LAGOON

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INTRODUCTION

Scientifical Context

- ✓ Hydrological models are essential for understanding watershed dynamics and the impact of human activities on water resources.
- ✓ Soil data, which plays a crucial role in the hydrological cycle, is a necessary model input and global digital soil maps usually have coarse spatial resolutions, adding considerable uncertainty to hydrological models despite calibration efforts.
- ✓ A new digital soil maps with a finer resolution can help decision-makers address global challenges related to water resources and environmental issues through hydrological modelling.

Scientifical Context. DSOLMap flowchart

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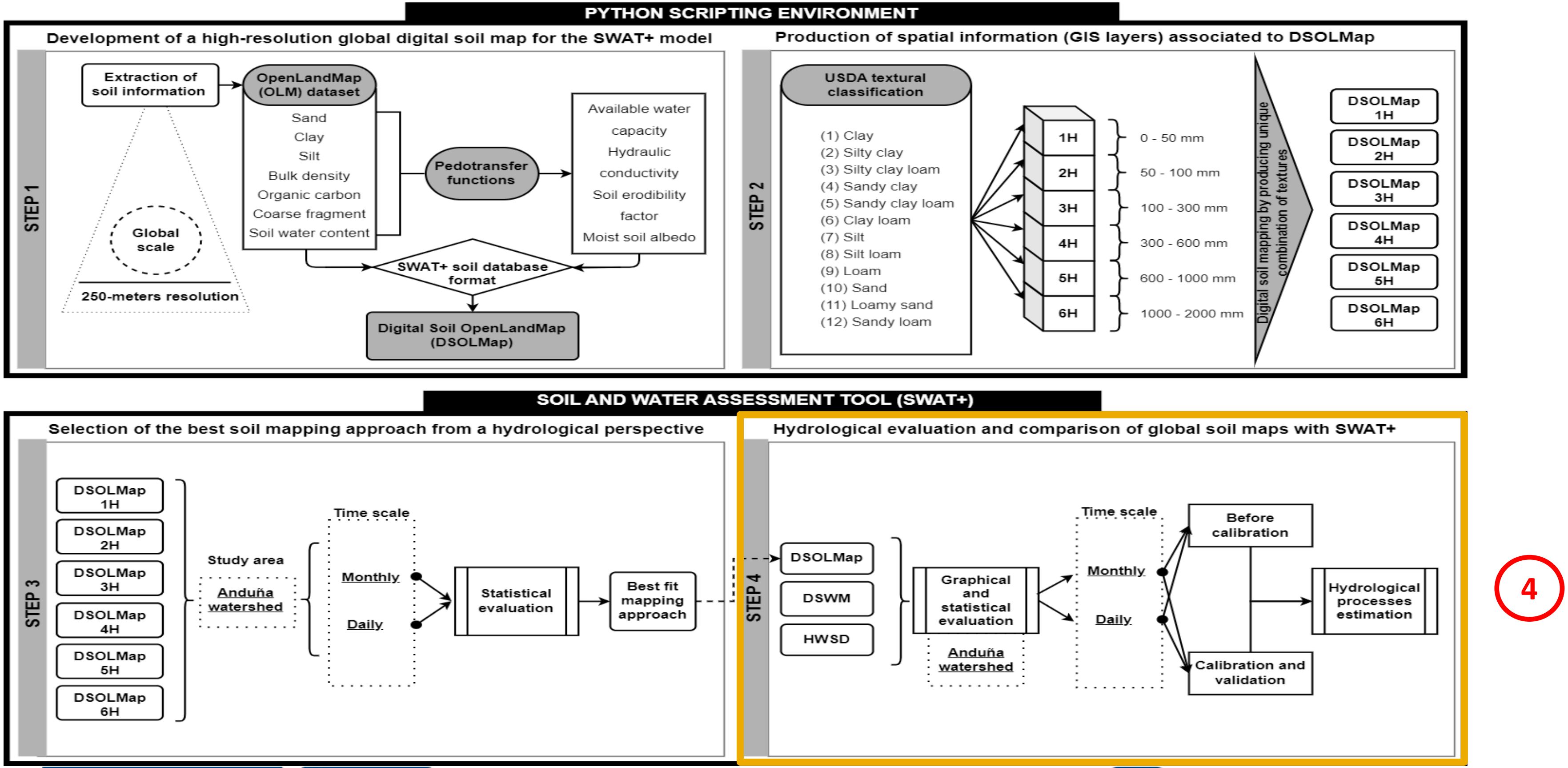
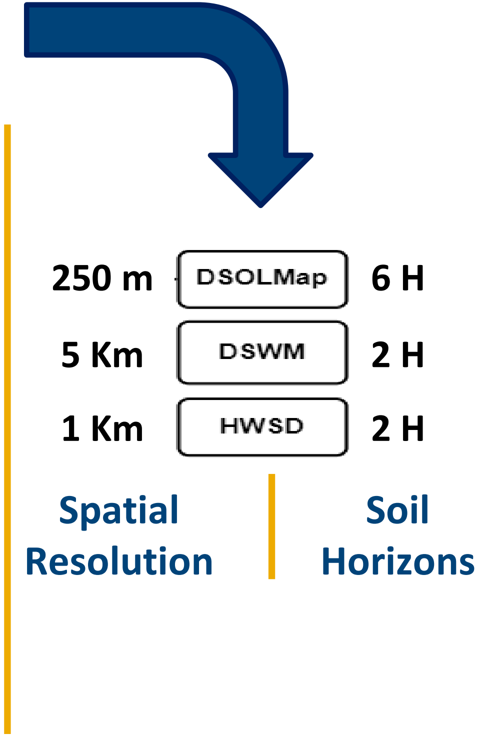


Scientifical Context. Objectives

- ✓ Hydrological modelling of the Anduña river basin based on three different soil scenarios (Digital Soil Open Land Map, Digital Soil World Map, and Harmonized World Soil Database) using SWAT+ model.
- ✓ Analyse the sensitivity of the parameters, calibrate and validate the three soil scenarios, on a monthly and daily scale, from a multi-objective calibration using SWATplus-CUP software.
- ✓ Evaluation of variations in hydrological processes for each of the digital soil maps studied.

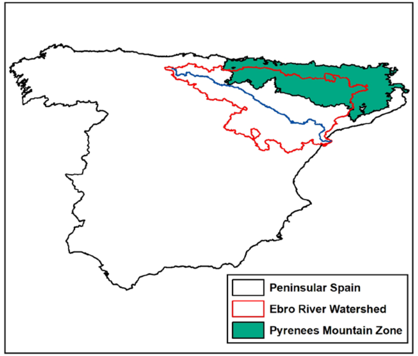


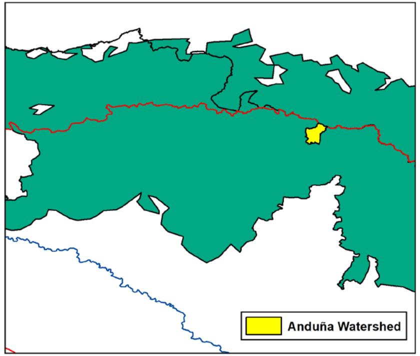
METHODOLOGY

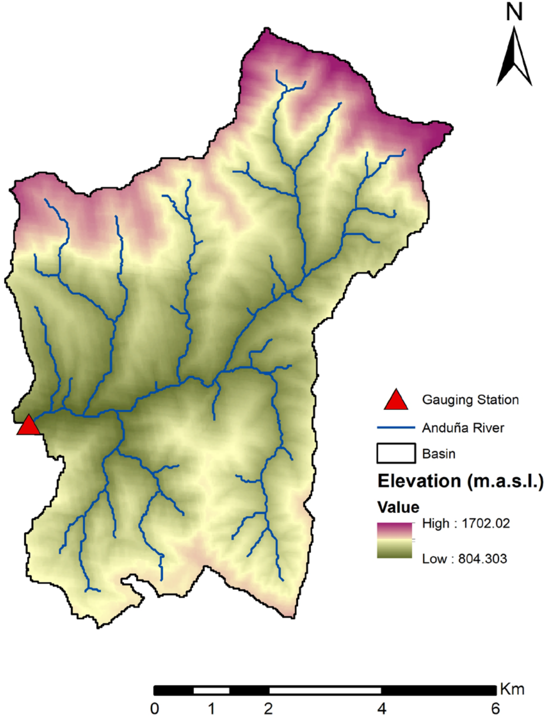
Watershed description

- The Anduña river watershed is an area of high natural value, which allows the comparison of the different soil maps without significant added uncertainties.
- The Pyrenees region is also one of the main sources of water resources for the Ebro River watershed, the largest Mediterranean basin in Spain (85,362 Km^2).

Anduña Watershed	
Area	47 km^2
Precipitation	1,740 mm/year
PET	750 mm/year
Discharge	1.49 m^3/s







SWAT+ Model. Data collection

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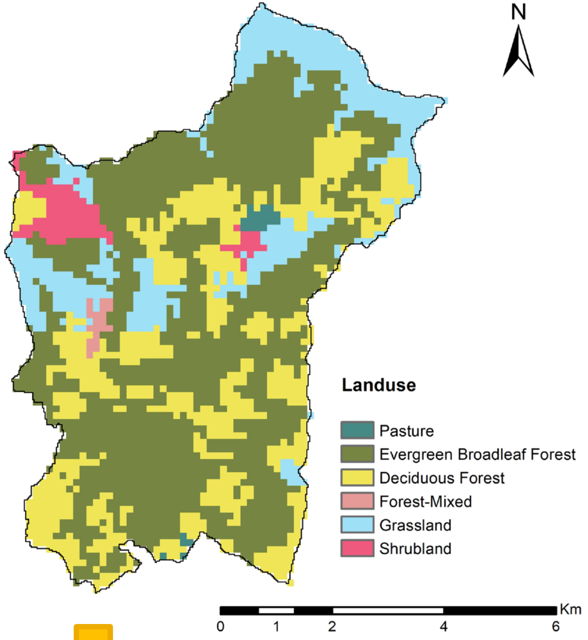
Input	Spatial Resolution	Source
Weather data	5 km x 5 km	Spanish National Meteorological Agency (AEMET)
DEM	25 m x 25 m	National Geographic Institute of Spain (IGN)
Land uses	100 m x 100 m	CORINE Land Cover 2018 (CLC)

- **Observed streamflow data** on monthly and daily scale were extracted from **CEDEX gauging station no. 9259** located at Izalzu for 1992 – 2018 period.



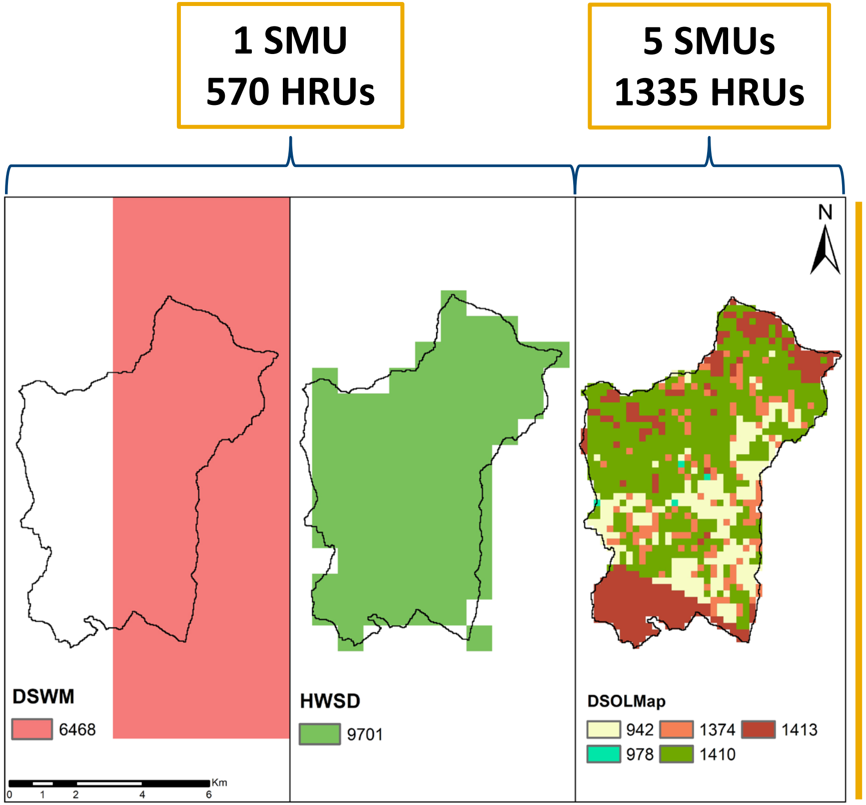
≈ 80% Forests

SWAT+ Model. Data collection

SOIL PROPERTIES	
Spatial Resolution	Data
5 km x 5 km	Digital Soil World Map (DSWM)
1 km x 1 km	Harmonized World Soil Database (HWSD)
250 m x 250 m	Digital Soil Open Land Map (DSOLMap)

- A higher number of soil map units (SMUs) leads to a higher number of HRUs in the watershed, causing the computational requirements to increase.

(Busico et al., 2020)



SWAT+ Model. Model Set-up

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- Climate data + Spatial data (variable)

3 different soil scenarios (1991-2018)

SWAT+ SOIL & WATER ASSESSMENT TOOL

- Slopes <8%, 8%–30%, and >30%
- No threshold to HRUs definition
- Hargreaves PET method

- Sensitivity analysis
- Model calibration

SWATplus-CUP

- SPE (SUFI-2) algorithm

- 1000 runs divided into 2 x 500 simulations

- Daily scale

- Multi-objective function (KGE, NSE, PBIAS and R^2)

Selected SWAT+ parameters and sensitivity analysis

Parameter	Description	P-value DSOLMap	P-value HWSD	P-value DSWM
BD().sol	Soil bulk density	<0.01	<0.01	<0.01
K().sol	Saturated hydraulic conductivity	<0.01	<0.01	<0.01
EPCO.hru	Plant uptake compensation factor	<0.01	<0.01	<0.01
CN2.hru	Initial SCS runoff curve number condition II	<0.01	<0.01	<0.01
AWC().sol	Available water capacity	0.01	<0.01	<0.01
SURLAG.bsn	Surface runoff lag coefficient	0.33	0.04	0.20
ALB().sol	Moist soil albedo of top soil horizon	0.34	0.26	0.60
ALPHA_BF.aqu	Alpha factor for groundwater recession curve	0.35	0.75	0.58
REVAP.aqu	Groundwater revap coefficient	0.59	0.78	0.42
ESCO.hru	Soil evaporation compensation factor	0.71	0.86	0.02
LAT_TTIME.hru	Lateral flow travel time	0.82	0.40	0.39

Warm-up 1991 | Calibration 1992-2004 | 2005-2018 Validation

RESULTS

Soil properties

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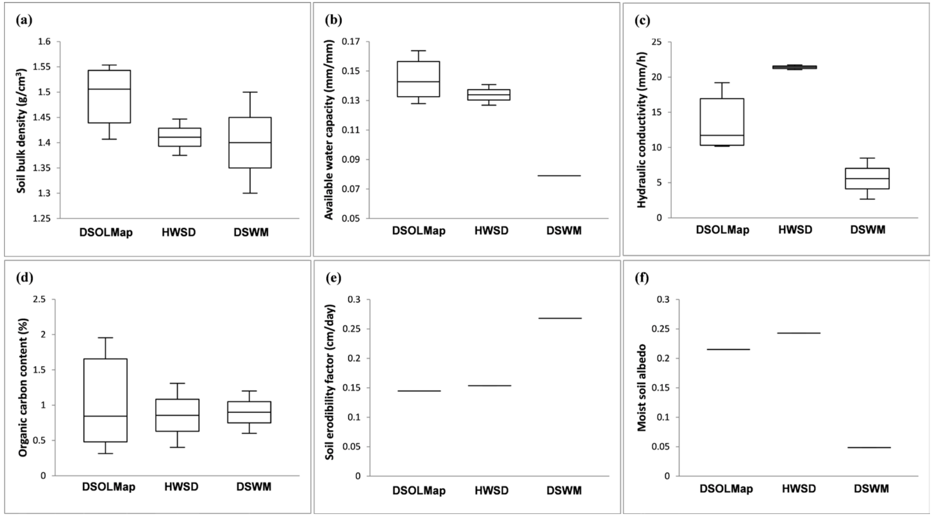
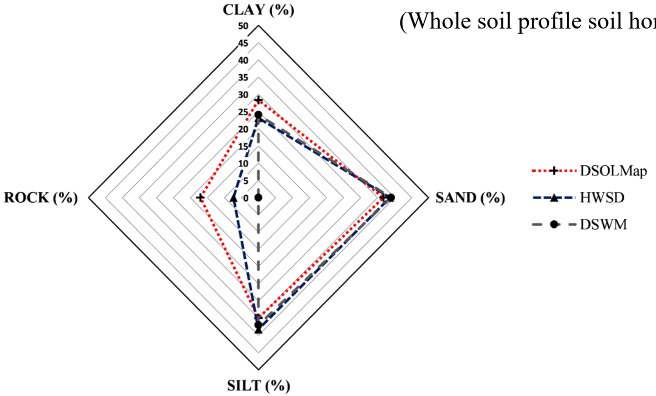
❖ **SWAT+ required soil input data**

Parameter	Description	Units
BD[1]	Soil bulk density	g/cm^3
AWC[1]	Available water capacity	mm/mm
K[1]	Saturated hydraulic conductivity	mm/hr
CBN[1]	Organic carbon content	% of soil weight
CLAY[1]	Clay fraction	% of soil weight
SILT[1]	Silt fraction	% of soil weight
SAND[1]	Sand fraction	% of soil weight
ROCK[1]	Coarse fragment content	% of total weight
ALB	Moist soil albedo of topsoil horizon	-
USLE_K	Soil erodibility factor of topsoil horizon	cm/day

[1]Values per soil horizon



(Whole soil profile soil horizons)



SWAT+ model calibration

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❖ **Selected SWAT+ parameters for streamflow calibration**

Parameter	Change type	Calibration Range	Best fitted values: DSOLMap	HWSD	DSWM
BD().sol	Percentage change	±20%	+14.27	-18.36	-14.84
K().sol	Percentage change	±20%	+14.085	+16.2	+19.32
EPCO.hru	Absolute change	0 – 1	0.92915	0.7745	0.9685
CN2.hru	Percentage change	±20%	+2.71	-19.88	+1.72
AWC().sol	Percentage change	±20%	-13.455	-16.04	-15.32

SWATplus-CUP

SWAT+ SOIL & WATER ASSESSMENT TOOL

Hard Calibration

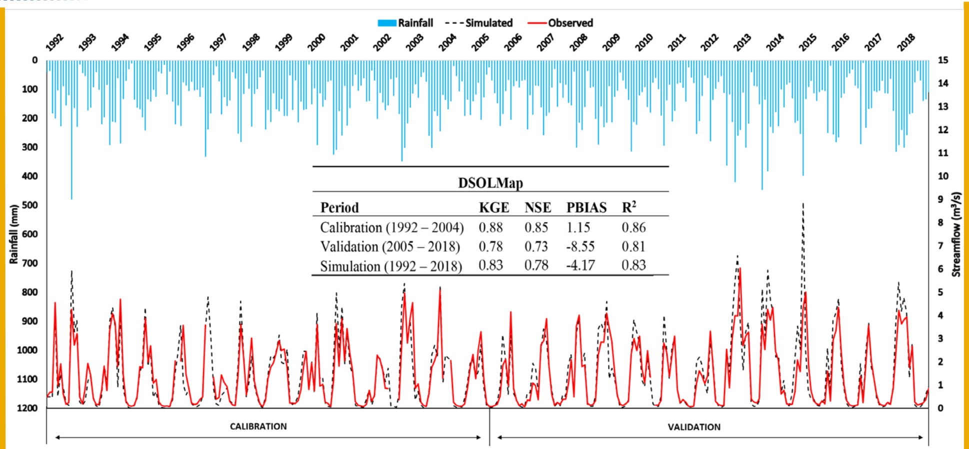
❖ **Daily and monthly statistical indices before calibration**

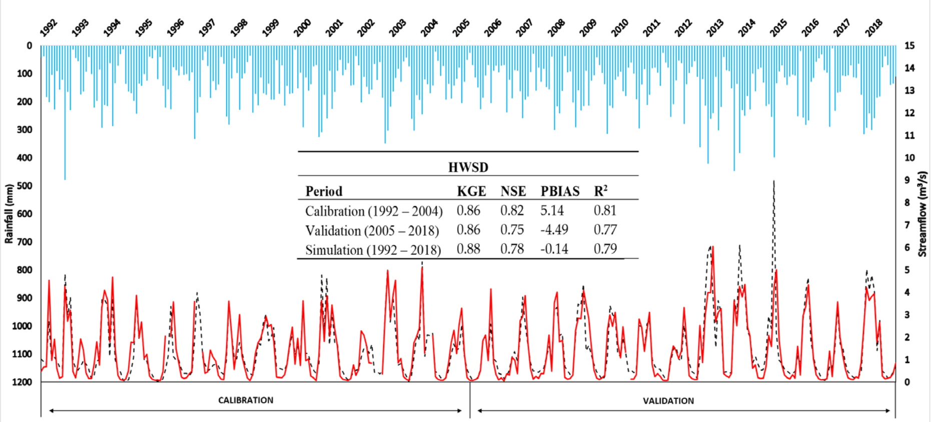
Scenario	Daily KGE	Daily NSE	Daily PBIAS	Daily R^2	Monthly KGE	Monthly NSE	Monthly PBIAS	Monthly R^2
DSOLMap	0.53	-0.02	-0.27	0.41	0.87	0.78	-0.86	0.81
HWSD	0.43	-0.23	-3.5	0.41	0.83	0.74	-4.14	0.79
DSWM	0.27	-0.66	-1.95	0.36	0.76	0.65	-2.68	0.75

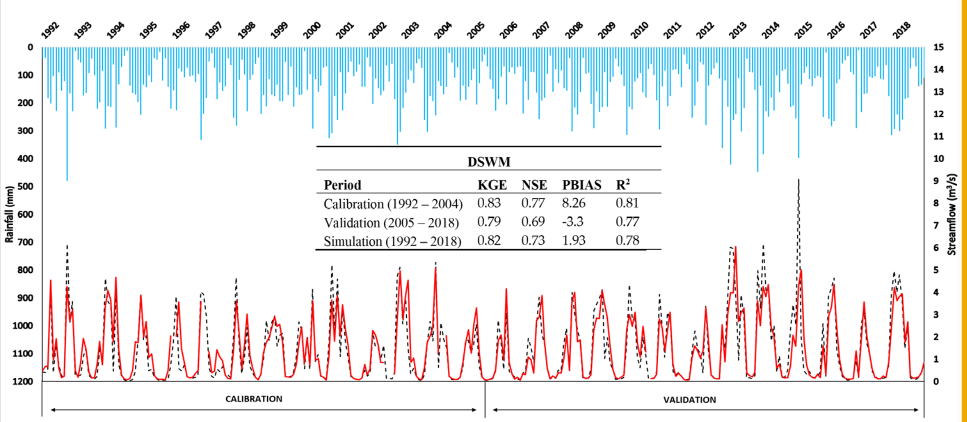
Hydrological performance

- **Daily performance indicator values of DSOLMap, HWSD and DSWM**

	DSOLMap				HWSD				DSWM			
Period	KGE	NSE	PBIAS	R^2	KGE	NSE	PBIAS	R^2	KGE	NSE	PBIAS	R^2
Calibration (1992–2004)	0.77	0.54	1.75	0.60	0.61	0.20	6.22	0.38	0.41	-0.32	8.98	0.34
Validation (2005–2018)	0.69	0.41	-8.33	0.57	0.54	0.02	-4.45	0.41	0.29	-0.59	-3.13	0.35
Simulation (1992–2018)	0.74	0.46	-3.60	0.58	0.58	0.09	0.56	0.39	0.34	-0.5	2.56	0.34







Hydrological processes evaluation

❖ **Average annual values of the estimated hydrological processes in the Anduña watershed for DSOLMap, HWSD and DSWM scenarios**

Hydrological process (mm/year)	**Before calibration (1992–2018)**			**After calibration and validation (1992–2018)**		
	DSOLMap	**HWSD**	**DSWM**	**DSOLMap**	**HWSD**	**DSWM**
Precipitation	1,737	1,737	1,737	1,737	1,737	1,737
Potential evapotranspiration	835	835	835	835	835	835
Actual evapotranspiration	756	713	723	752	748	779
Surface runoff	542	620	817	325	435	754
Base flow	403	356	128	635	516	152
Soil water content	378	255	256	221	335	339

SWAT+ SOIL & WATER ASSESSMENT TOOL

SWAT+ Check

CONCLUSIONS

Conclusions

- Using soil maps with finer ***spatial resolution*** and more detailed ***soil profiles***, such as DSOLMap, in hydrological modelling lead to a better representation of daily hydrological responses.
- After ***calibration***, only the DSOLMap reached satisfactory daily streamflow predictions with a ***minimal variation range*** of the SWAT+ parameters.
- For the Anduña watershed, the ***hydrological process estimations*** were aligned between the DSOLMap and the HWSD but not with those of DSWM.

THANKS FOR YOUR ATTENTION

Digital Soil Open Land Map (DSOLMap)

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DSOLMap, a novel high-resolution global digital soil property map for the SWAT + model: Development and hydrological evaluation

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ABSTRACT

This research paper addresses the ongoing challenge of developing fine-resolution global digital soil property maps for hydrological modelling applications. Hydrological models are essential for understanding watershed dynamics and the impact of human activities on water resources. Soil data, which plays a crucial role in the hydrological cycle, is a requisite model input. Global digital soil property maps usually have coarse spatial resolutions, adding considerable uncertainty to hydrological models despite calibration efforts. To address this issue, a new global digital soil property map with 250 m spatial resolution, known as Digital Soil Open Land Map (DSOLMap), was developed and evaluated in this study. The DSOLMap has a finer spatial resolution than existing global soil maps and a more detailed soil profile divided into six soil horizons. This new high-resolution global digital soil property map was tailored to the SWAT + model format. SWAT + is the latest released version of the Soil and Water Assessment Tool (SWAT), one of the most comprehensive hydrological models, and is widely used worldwide. A hydrological evaluation was conducted with the DSOLMap and its results were compared to two other global soil databases using the SWAT + model in a basin located in the north of Spain. The findings showed that using more detailed, finer-resolution soil data, such as those that the DSOLMap offers, improved the hydrological performance of the SWAT + model on a daily scale before and after calibration and validation procedures. The DSOLMap represents a global step forward in hydrological modelling, notably for regions with scarce or unavailable soil information. This new digital soil property map can help decision-makers address global challenges related to water resources and environmental issues through hydrological modelling.