Overcoming Data Limitations in Hydrologically Complex Basins: A Citizen Science and Low-Cost Sensor Approach for SWAT Model Calibration

International Soil and Water Assessment Tool (SWAT)

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Francisco J. Segura-Méndez*, Adrián López-Ballesteros, Mark Mulligan, Salvador Peña-Haro, Javier Senent-Aparicio.

**Postdoctoral researcher at the Catholic University of Murcia (UCAM). (Spain).*

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INTRODUCTION

General Context

- ✓ Ephemeral streams are over 50% of the global network. Flow ceases seasonally or due to human abstraction.
- ✓ In highly anthropized countries, such as Spain, the availability of daily scale data in natural regime becomes a complicated task, so that most of the times it is necessary to apply these models.
- ✓ Hydrological models such as SWAT become essential tools to simulate watershed dynamics, especially under such data-scarce conditions

SWAT+
SOIL & WATER ASSESSMENT TOOL

Environmental Challenges

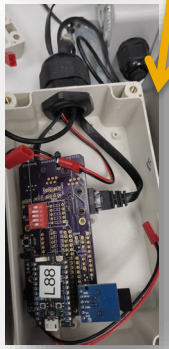
- ✓ Watershed drains into the ecologically sensitive **Mar Menor coastal lagoon**.
- ✓ Tourism, urban expansion and intensive agriculture result in sediment and nutrient runoff—especially during storms.

Modelling Challenges

- One of the main challenges in hydrological modelling particularly in highly managed Mediterranean basins is the lack of continuous, reliable datasets.
- In highly managed basins like those in the Mediterranean, the lack of continuous flow data complicates SWAT model calibration.
- Extreme events make this even harder, as they are short, intense, and often go unrecorded.

Emerging Opportunities

- ✓ Fortunately, new tools are now available to help close this data gap.
- ✓ Citizen science is increasingly adopted in hydrology. Mobile apps and DIY sensors provide viable alternatives.
- ✓ These tools are low-cost, scalable, and can be deployed in locations typically beyond the reach of traditional monitoring infrastructure.



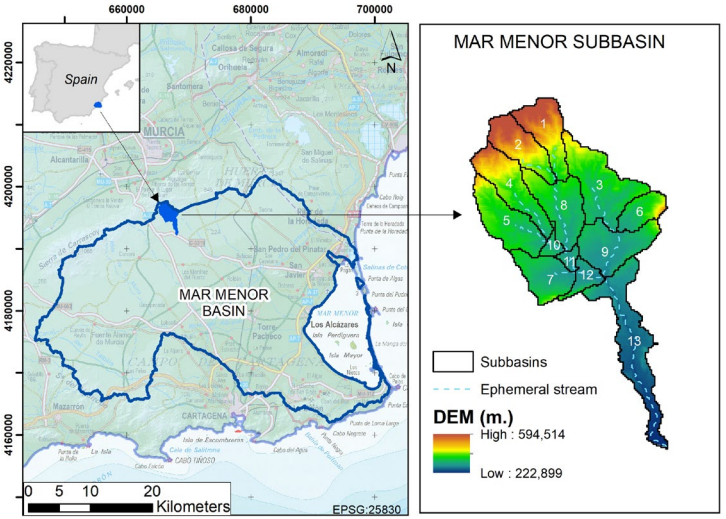
METHODOLOGY

Objectives

- ✓ Develop a cost-effective and replicable methodology for modelling ephemeral streams.
- ✓ Integrate citizen science and low-cost sensors to overcome data scarcity in semiarid watersheds.
- ✓ Calibrate and validate the SWAT model at a sub-hourly scale for improved simulation of storm events.
- ✓ Generate high-resolution hydrographs and rating curves for accurate flow estimation. (Test Swat Model).

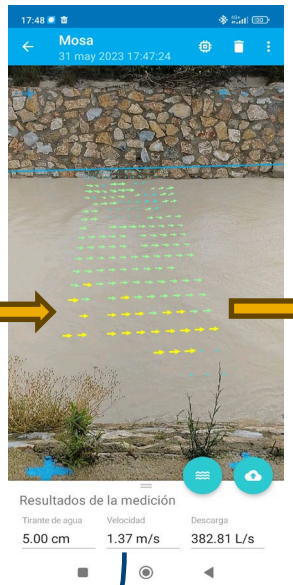
Watershed description: «Mosa»

- ✓ The study area is in southeast of Iberian Peninsula, in the Mar Menor basin. The watershed covers about 7.15 km^2.
- ✓ At the headwaters of the estuary basin, the altitude is around 560 m and at the mouth of the basin it is about 230 m.
- ✓ Semi-arid Mediterranean climate: tempered winters and warm summers with a maximum of 40ºC (August) and minimum of 10ºC (January).
- ✓ 330 mm/year of rainfall with an average temperature of 17°C.



Methodological Framework

- ✓ Our methodology integrates three components:
- Citizen engagement with mobile app for discharge data (DischargeApp).
- Real-time level monitoring via low-cost FreeStation sensors. Flow->BARATIN.
- Modelling using a sub-hourly calibrated SWAT model.



DischargeApp

SWAT model calibrated

Soil & Water Assessment Tool SWAT

Citizen Science: DischargeApp

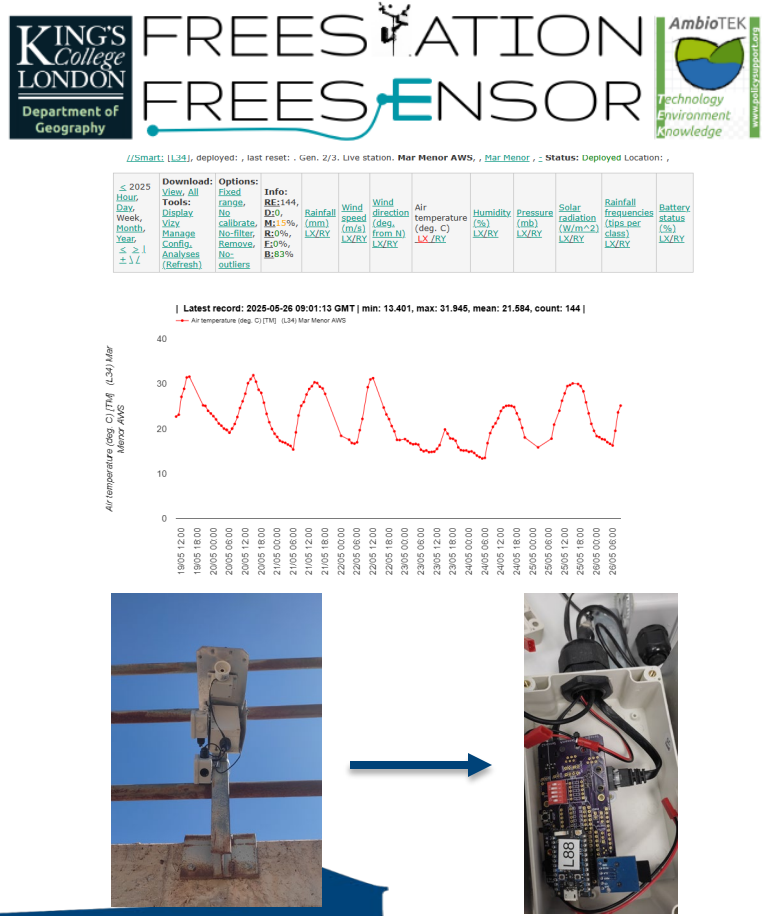
- ✓ A non-intrusive optical flow measurement system, utilizing Particle Image Velocimetry (PIV) via an Android mobile application DApp.
- ✓ Trained users: local agencies, NGOs, and engaged citizens.
- ✓ Videos captured during storm events used for discharge estimation.

DischargeApp_demo

https://play.google.com/store/apps/details?id=ch.photrack.discharge&pcampaignid=web_share

Low-Cost Sensor Deployment (FreeStation)

- ✓ FreeStation is an open-source (DIY) environmental monitoring system built with open-source components and tools. Costs less than 3% of commercial equivalents. Easily replicable, modular, and real-time data transmission enabled.
- ✓ The station continuously records water level, temperature, humidity, and atmospheric pressure data every 10 minutes

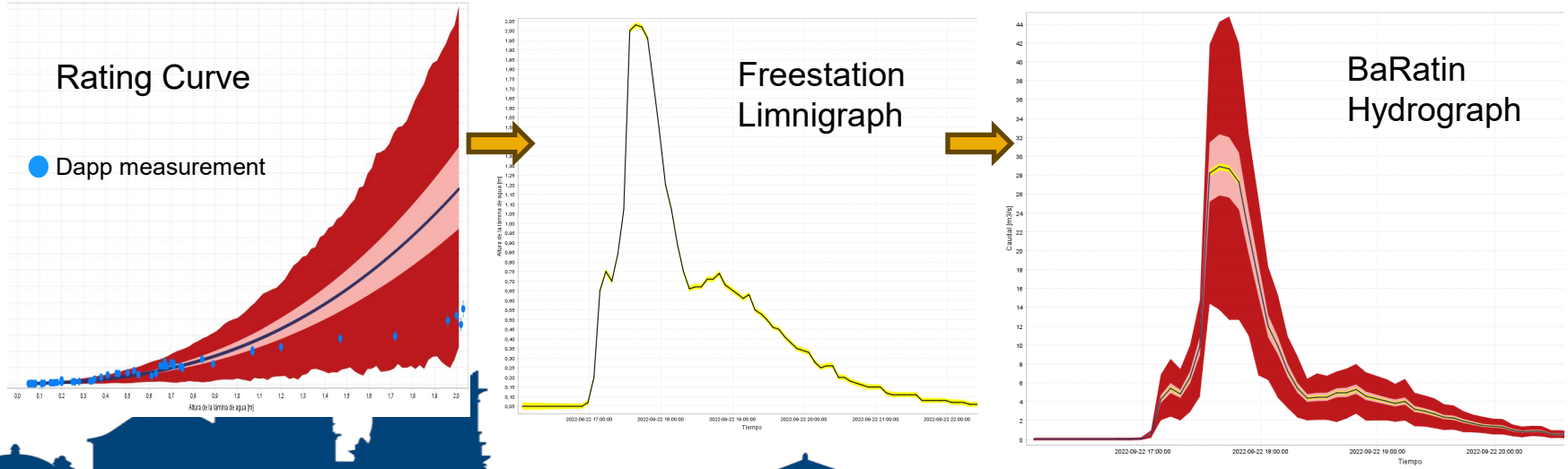


Rating Curve Calibration (BaRatin)

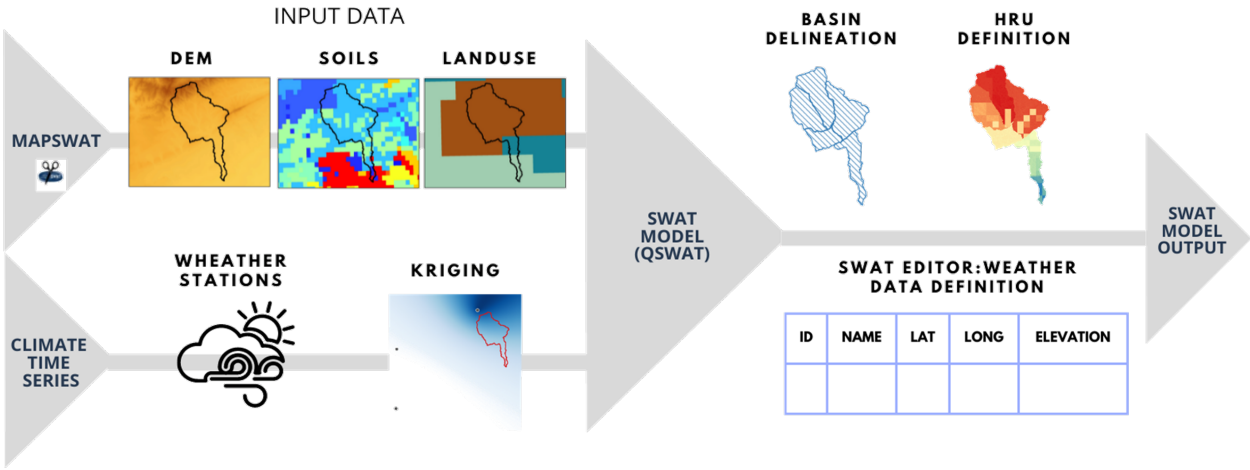
- ✓ Applied BaRatin Bayesian method to calibrate the stage–discharge relationship (Ratin Curve).
- ✓ Incorporated hydraulic knowledge and uncertainty analysis.
- ✓ Final curve: Q = a(h – b)^c with posterior credibility intervals.

https://zenodo.org/records/7463233

BaRatinAGE



SWAT Model Setup



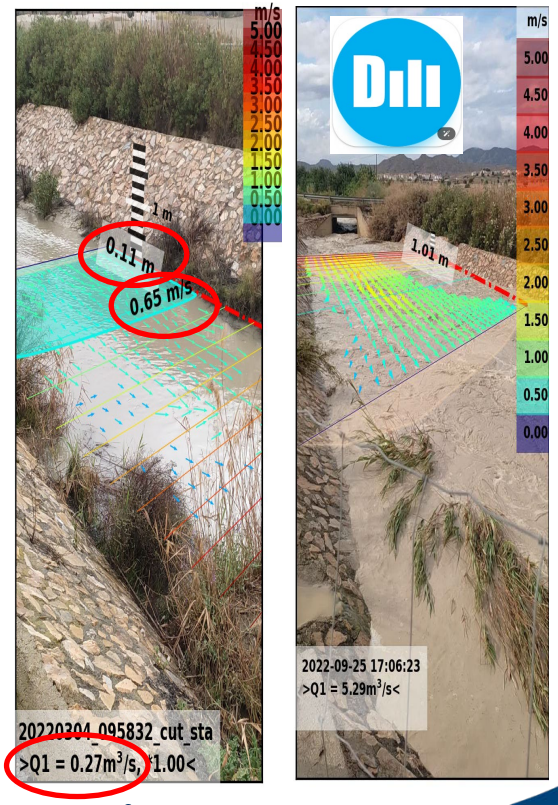
Data	Description	Source
DEM	25 m x 25 m resolution map	Spanish National Geographic Institute (IGN)
Land use map	Vector database	Map of Crops and uses by Spanish Ministry of Agriculture
Soil map	250 m x 250 m resolution map	Digital Soil Open Land Map (DSOLMap)
Climate data	Daily meteorological stations: CA21, CA42, CA52, CA91, MU31, MU62, TP42.	IMIDA (Murcian Institute for Agricultural and Environmentla Research)

RESULTS

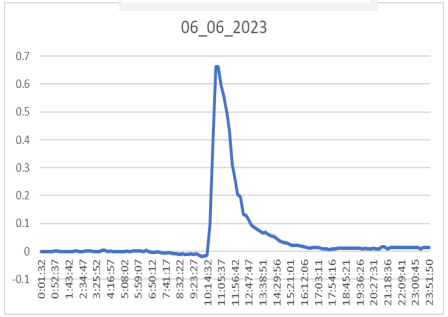
Monitoring Results

- ✓ Active citizen involvement led to robust data collection with **Dapp**.
- ✓ Implemented functionality to derive rating curves (Baratin) from **Freestation** water level sensor data.
- ✓ Overcame traditional limitations in ephemeral stream monitoring.

Dapp



FREESTATION



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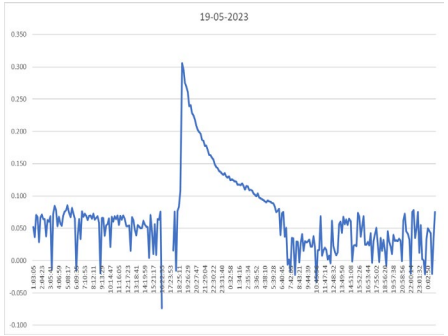


SWAT Model Calibration (monthly)

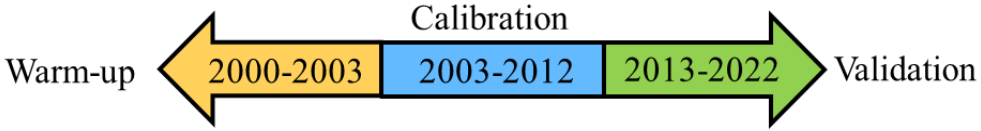
✓ **Monthly AET GLEAM 3.7b**

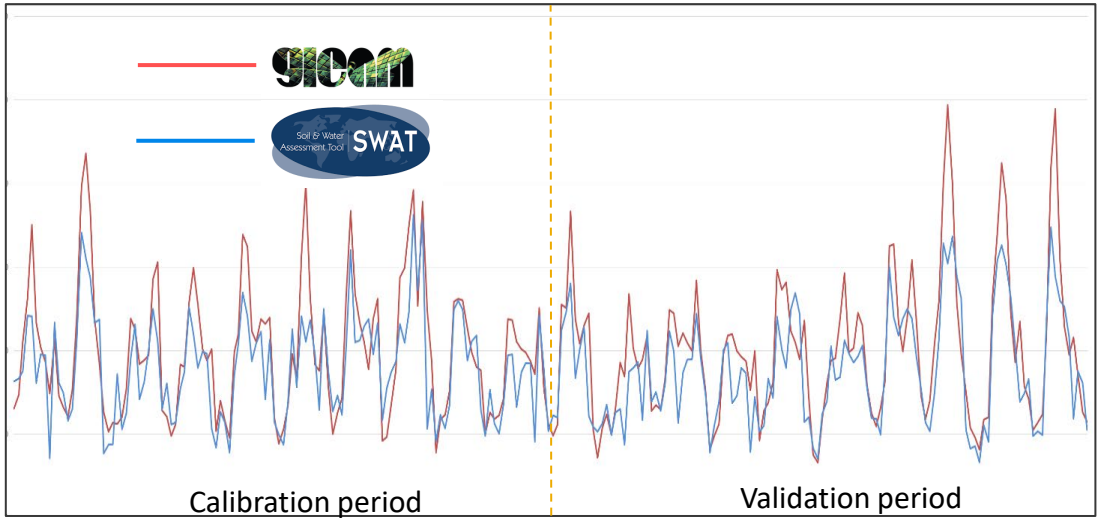
- Calibration

NSE= 0.64
PBIAS = 10.57 %
KGE = 0.71
R^2 = 0.72

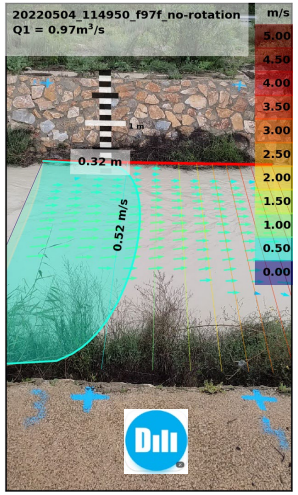
✓ Validation

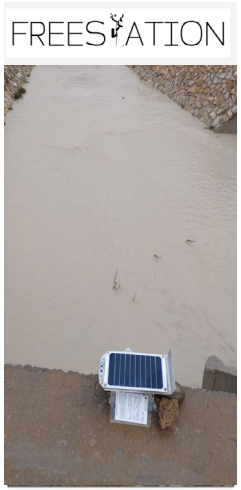
NSE = 0.64
PBIAS = 13 %
KGE = 0.70
R2 = 0.73





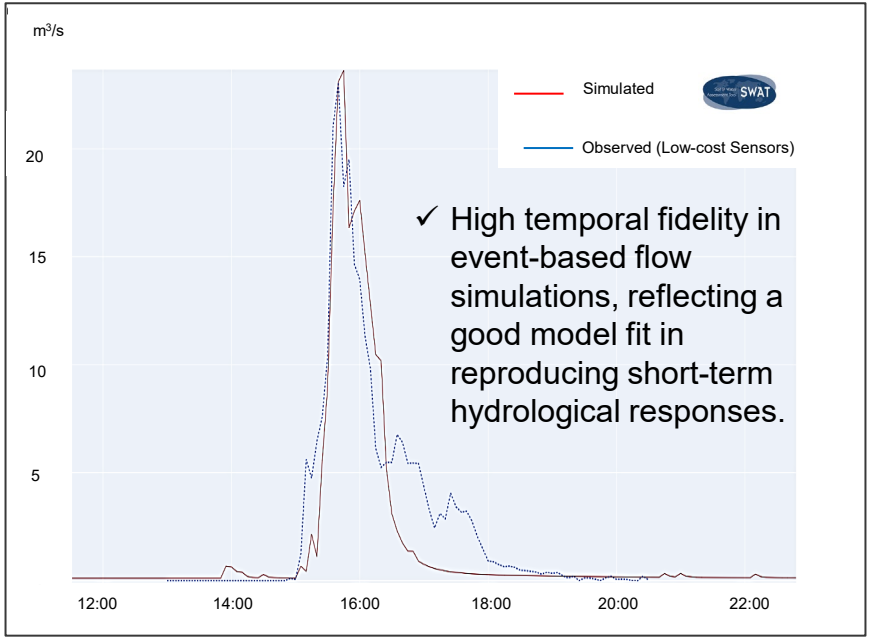
SWAT Model Sub-hourly calibration





CALIBRATION

IN SITU MONITORING SISTEM HYDROGRAPH



Subdaily (5-minutes) FLOWOUT MOSA Test Performance

$R^2 = 0.85$, PBIAS = 18.88%, NSE = 0.82 and KGE = 0.79

SWAT Model Calibration

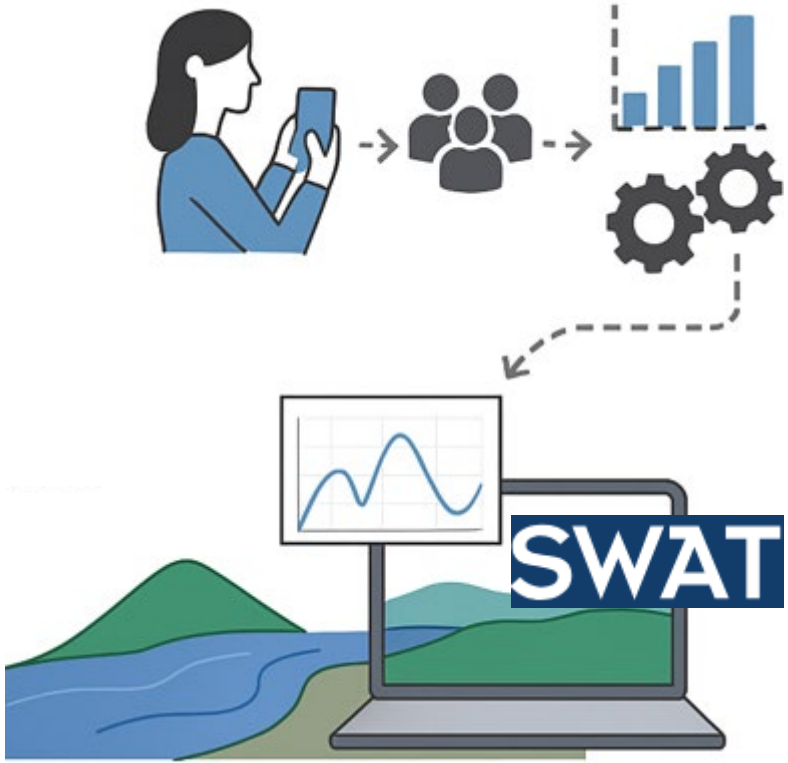
SWAT parameters selected for the AET and subdaily flow manual calibration.

Parameter	Description	Default value	Calibrated value
CN2.mgt	Initial SCS runoff curve number for moisture condition II	-	-5%
ESCO.hru	Soil evaporation compensation factor	0.95	0.8
EPCO.hru	Plant uptake compensation factor	1	0.2
SOL_AWC.sol	Soil available water content (mm/mm)	-	-10%
RCHRG_DP.gw	Deep aquifer percolation fraction	0.05	0.4
LAT_TIME.hru	Lateral flow travel time (days)	0	2

CONCLUSIONS

Scientific Contributions

- ✓ Novel integration of participatory monitoring with sub-hourly modelling (SWAT).
- ✓ Enhanced accuracy in hydrological response prediction.
- ✓ Method applicable to data-scarce and anthropized watersheds globally.



Future Perspectives

- ✓ Evaluate land use change, BMPs, and climate change scenarios.
- ✓ Extend methodology to other Mediterranean and arid regions.
- ✓ Inform adaptive watershed management and policy design.
- ✓ Incorporate real-time SWAT+ simulations for operational watershed forecasting.

Conclusions

- ✓ **Citizen science (Discharge App) and low-cost sensors (Freestation)** effectively bridge data gaps in ephemeral stream monitoring.
- ✓ Long-term deployment of **FreeStation sensors** can enhance early warning systems and flood risk assessments.
- ✓ **Sub-hourly SWAT** calibration is feasible and yields robust hydrological simulations.
- ✓ The approach is **scalable and transferable** to other data-scarce and anthropized basins.
- ✓ The methodology supports evidence-based watershed management and policy design.

THANKS FOR YOUR ATTENTION

Contact:

fjsegura@ucam.edu