Assessing Two Hydrological Models for Watersheds with Intensive Agriculture: A Focus on Hydrological Ecosystem Services modeling

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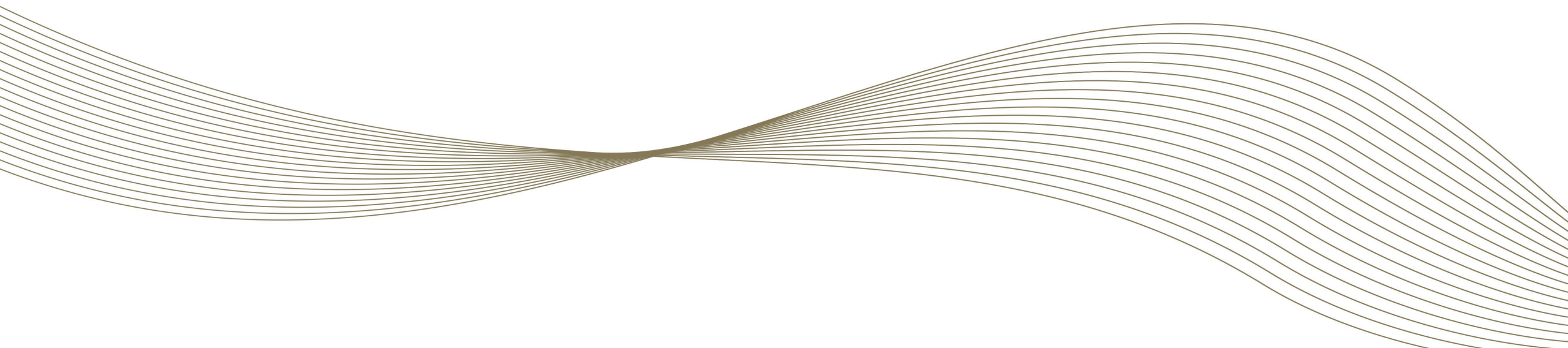


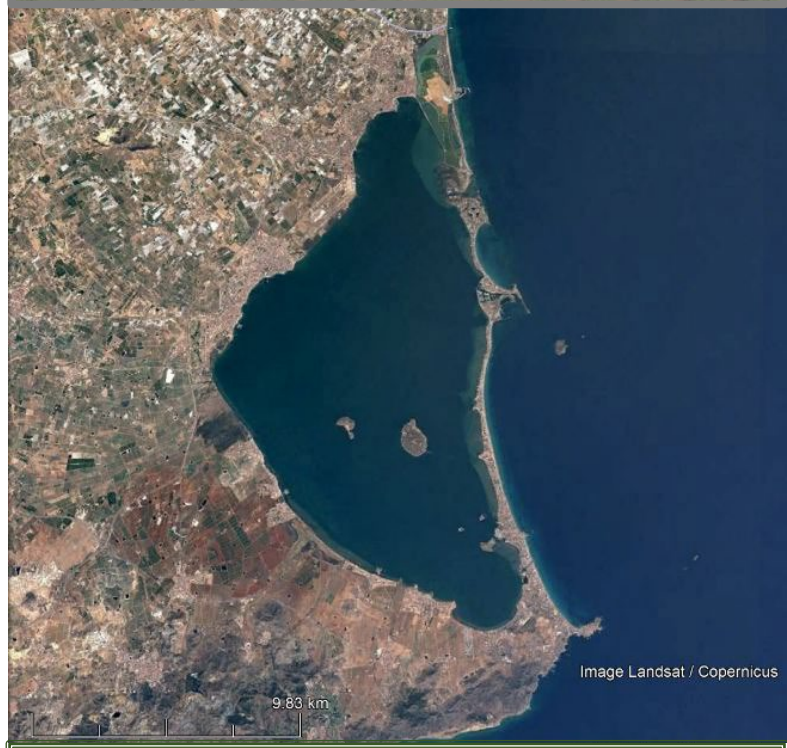
INTRODUCTION

Hydrological Ecosystem Services (HES): Vital for sustainable water resource management, especially in areas with intensive human activity.

Modeling HES remains a challenge due to differences in model complexity and data requirements:

- SWAT+: High accuracy and detail, steep learning curve.
- InVEST: User-friendly, less detailed framework.

Watershed Challenges: Some watersheds, like the Mar Menor, are harder to model due to data scarcity or intense agricultural activity.



INTRODUCTION

OBJETIVES:

1. Compare high-data-demand models with low-data-demand models.

- Water supply
- Water purification
- InVEST model
- SWAT+ model
- Period: 2003-2023

2. Improve InVEST simulations by integrating it with SWAT+.

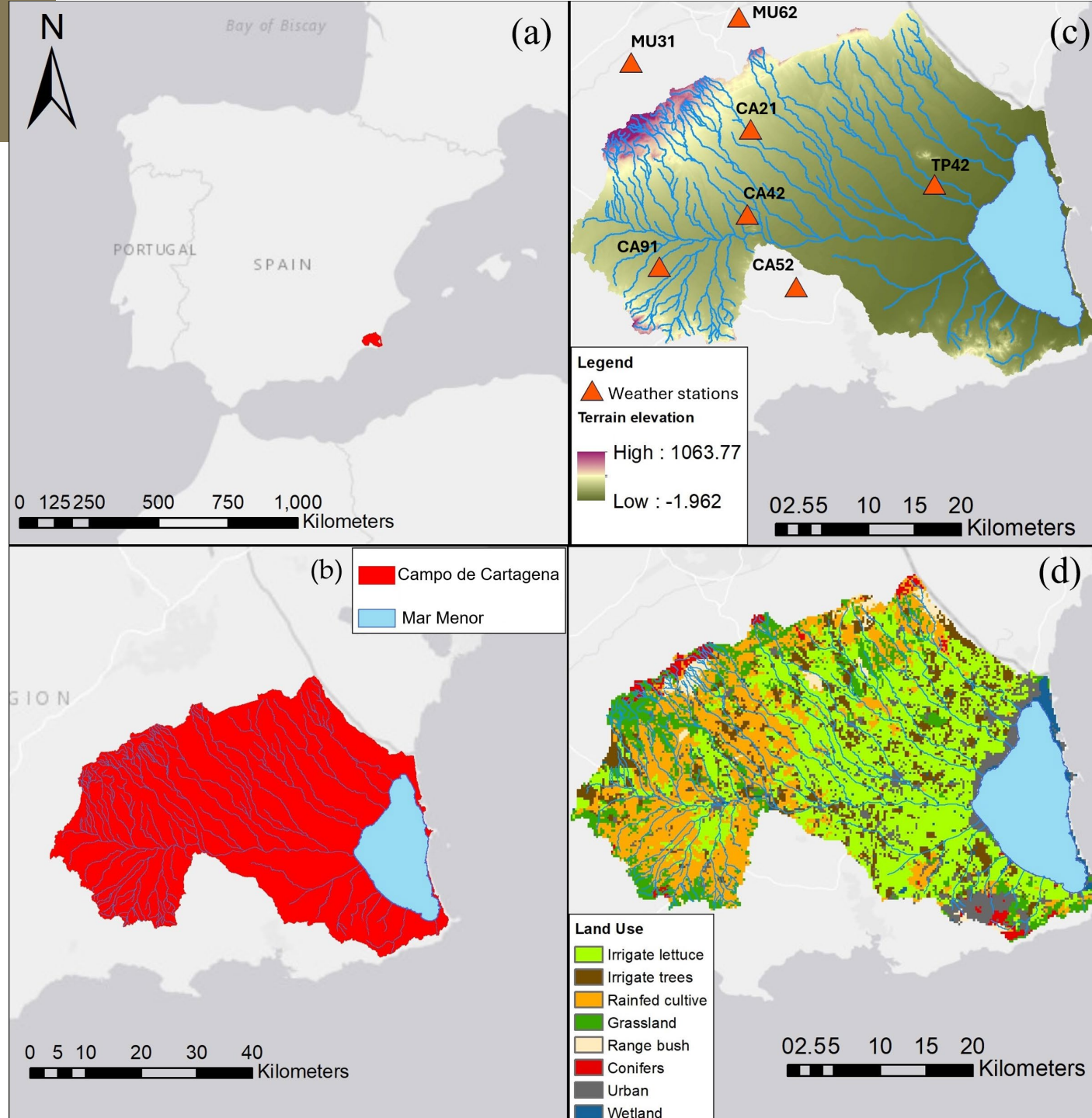
STUDY AREA: Mar Menor

MAR MENOR

- Hipersaline coastal lagoon
- Average depth: 4.4m
- Max. Depth: 7m
- Surface: 135km2
- La Manga: 20km long sand bar

CAMPO DE CARTAGENA

- Area: 1600 km2
- Higly anthropized
- Intesive agriculture (mostly irrigated)
- Stacionary rivers



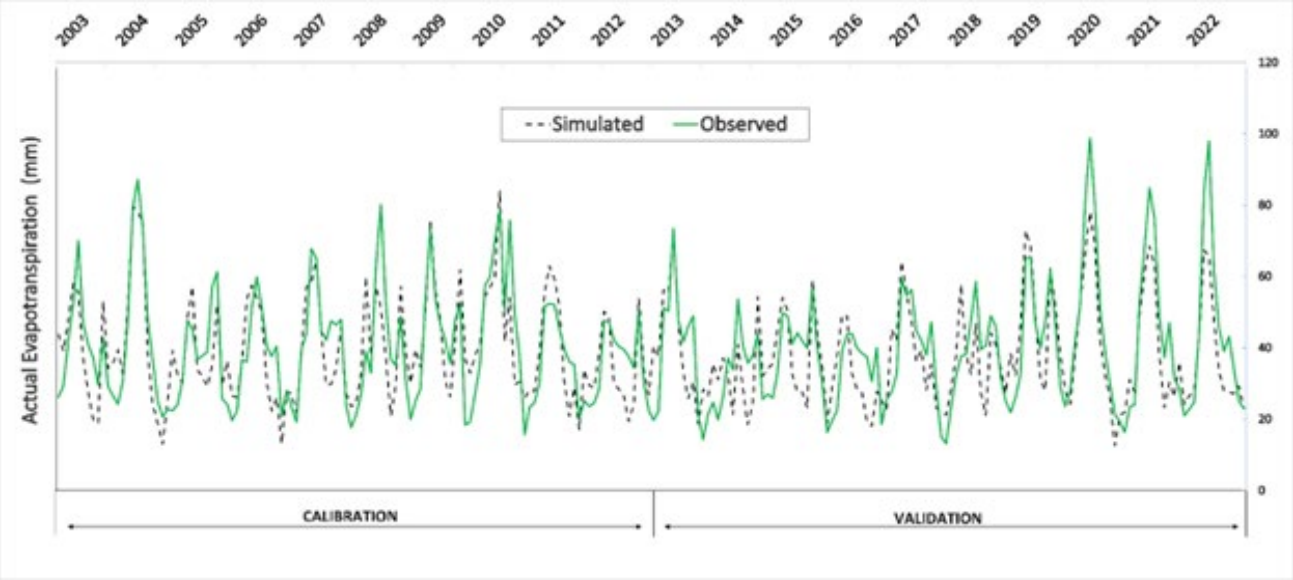
METHODOLOGY: InVEST models' inputs

ES	Model	Source	Inputs
Water supply	InVEST	IMIDA	Precipitation, Evapotranspiration, Z parameter
		DSOLMap	Plant Available Water Content
		Spanish Government	Land Use / Land Cover
		SWAT+	Watersheds
	InVEST - SWAT+	DSOLMap	Plant Available Water Content
		Spanish Government	Land Use / Land Cover
		SWAT+	Pcp, ET, Irrigation, Z parameter, Watersheds
Water purification	InVEST	IMIDA	Precipitation, Nutrient Runoff
		MDTG25 IGN	Digital Elevation Model
		Spanish Government	Land Use / Land Cover, Nutrient Loads
		SWAT+	Watersheds
	InVEST - SWAT+	MDTG25 IGN	Digital Elevation Model
		Spanish Government	Land Use / Land Cover
		SWAT+	Pcp, Nutrient Runoff and Loads, Watersheds

METHODOLOGY: Inputs of the SWAT+ model

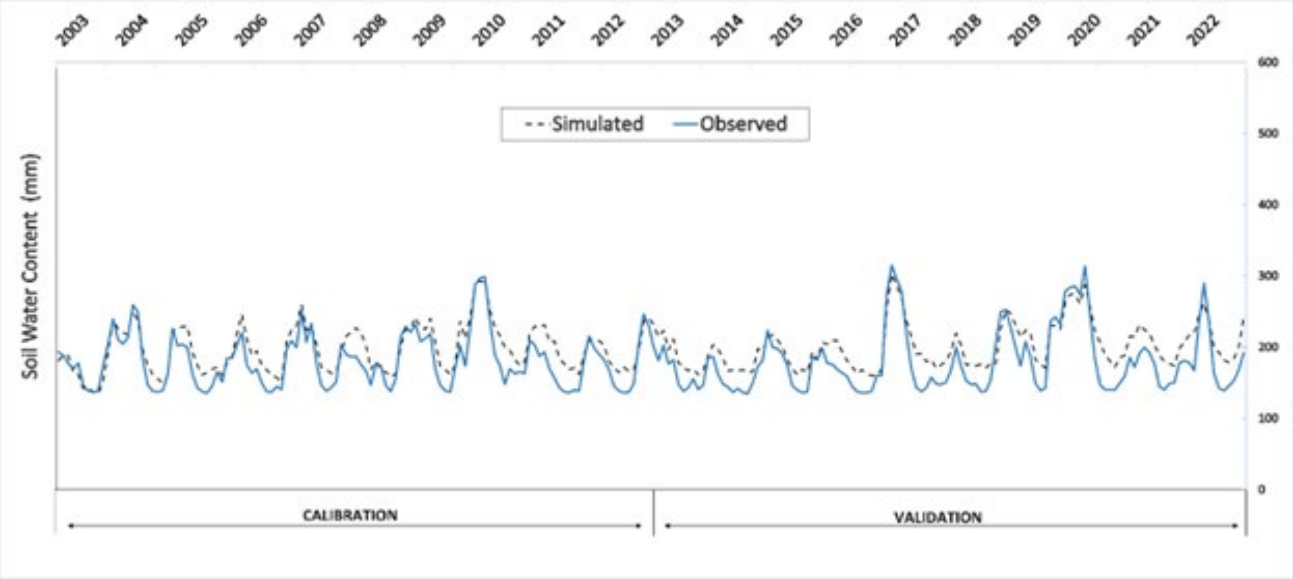
Input data	Source
Digital elevation map	National Geographic Institute of Spain
Land use map	Crop and Land Use Map 2000-2010
Soil map	Digital Soil Open Land Map
Weather data	IMIDA weather stations
Calibration and validation data	GLEAM v3.7b (ET y SW)

RESULTS: SWAT+ model performance



Monthly AET GLEAM 3.7b (2003 – 2022):

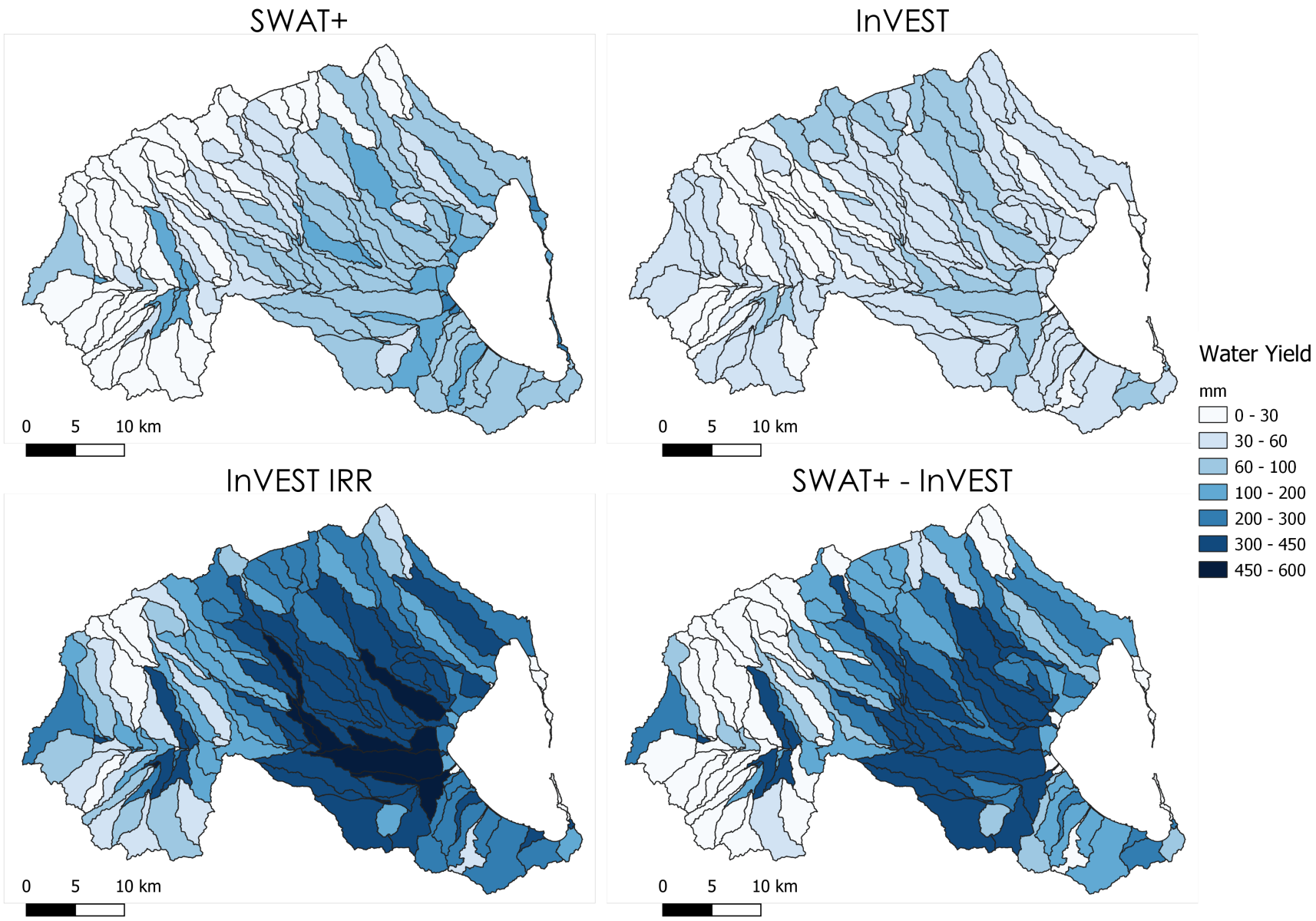
- Calibration [2003-2012]: R^2=0.62, PBIAS=1.86%, NS=0.59 and KGE=0.77
- Validation [2013-2022]: R^2=0.63, PBIAS=5.89%, NS=0.61 and KGE=0.73



Monthly SWC GLEAM 3.7b (2003 – 2022):

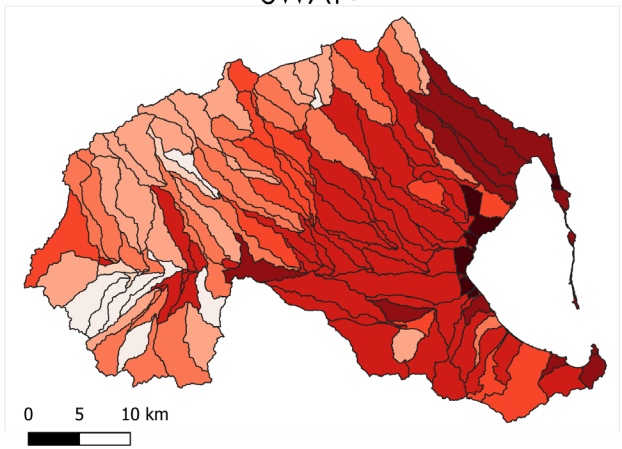
- Calibration [2003-2012]: R^2=0.81, PBIAS=-0.11%, NS=0.81 and KGE = 0.85
- Validation [2013-2022]: R^2=0.87, PBIAS=-2.99%, NS=0.81 and KGE=0.72

RESULTS: Water supply

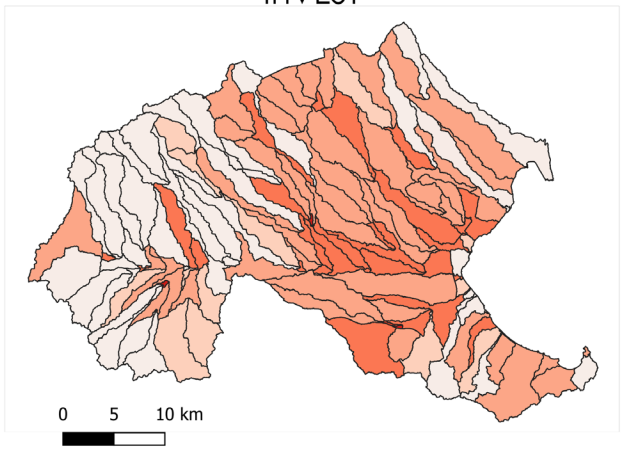


RESULTS: Water purification

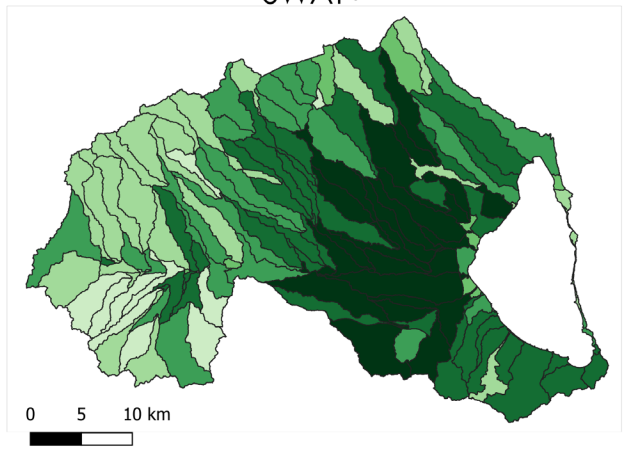
SWAT+



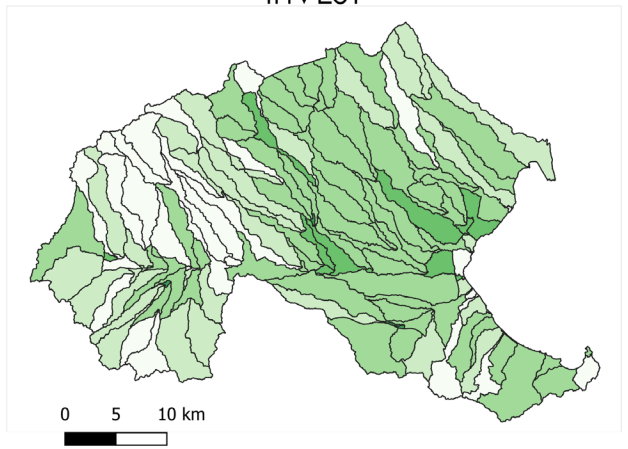
InVEST



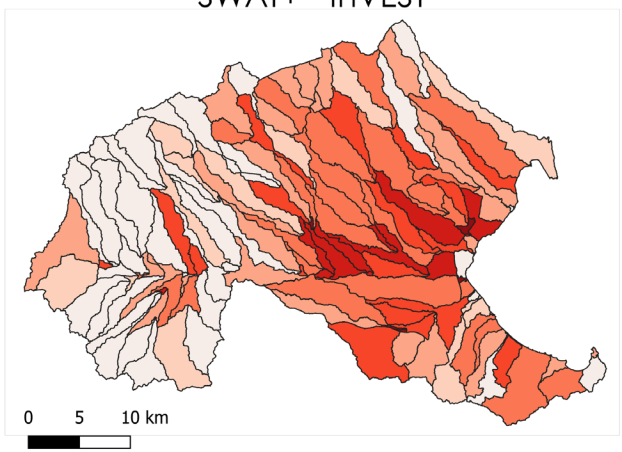
SWAT+



InVEST



SWAT+ - InVEST

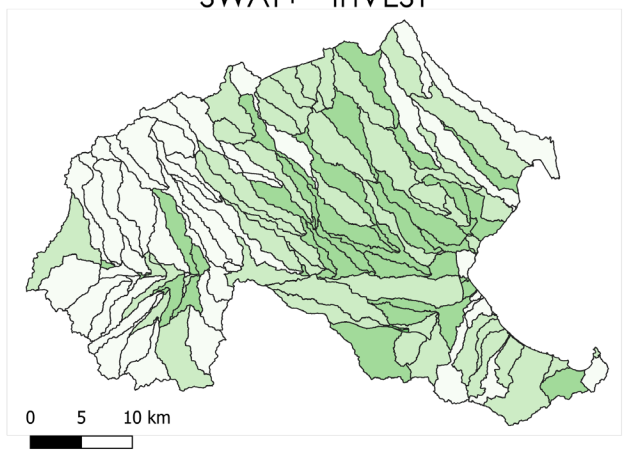


Nitrogen export

Kg/ha

- 0 - 0.005
- 0.005 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.15
- 0.15 - 0.25
- 0.25 - 2
- 2 - 6

SWAT+ - InVEST



Phosphorus export

Kg/ha

- 0 - 0.001
- 0.001 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1
- 1 - 1.5

RESULTS: Global Results

Global results	SWAT+	InVEST	SWAT+InVEST
Water yield (ES: Water supply)	74.8 mm	No IRR: 41.59 mm IRR: 235.37 mm	165.29 mm
Nitrogen export (ES: Water purification)	0.41 kg/ha (no3)	0.031 kg/ha	0.062 kg/ha
Phosphorus export (ES: Water purification)	0.52 kg/ha (SolP)	0.022 kg/ha	0.08 kg/ha

Lessons learned and limitations

Spacial distribution

- In the Campo de Cartagena, water is mostly concentrated in the lower basin due to fewer irrigated crops in the upper areas.
- Specific areas exhibit higher water production and greater nutrient concentrations, due to fertigation.

Model performance

- InVEST: Overestimates water availability but underestimates nutrient loads compared to SWAT+.
- SWAT+: Delivers more reliable results due to its calibration process.

Conclusions

- SWAT+ is preferable when sufficient data is available, thanks to its higher accuracy.
- For ungauged basins like Mar Menor, satellite data is essential to improve model performance.

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InVEST set up

INPUTs		InVEST	SWAT+InVEST
Precipitation		PCP IMIDA (Thiessen polygons)	PCP + IRR SWAT+
Reference Evapotranspiration		ETo IMIDA (Thiessen polygons)	ETP SWAT+ (Penman-Monteih)
Root Restricting Layer Depth		BDTICM (Absolute depth to bedrock) https://doi.org/10.1371/journal.pone.0169748	BDTICM (Absolute depth to bedrock)
Plant Available Water Content		DSOLMap (swc33 – swc1500)	DSOLMap (swc33 – swc1500)
Land Use/Land Cover		Mapa Cultivos Y Aprovechamientos España 2000-2009	Mapa Cultivos Y Aprovechamientos España 2000-2009
Biophysical Table	**lucode**	SWAT+	SWAT+
	root_depth	FAO56	SWAT+
	kc	FAO56	No Needed (ETP)
Z Parameter*		CLIMATE IMIDA (TP42)	SWAT+
Watersheds		SWAT+	SWAT+
Sub-Watersheds		SWAT+	SWAT+

InVEST set up

INPUTs		InVEST	SWAT+InVEST
Digital Elevation Model		MDT25 IGN	MDT25 IGN
Land Use/Land Cover		Mapa Cultivos Y Aprovechamientos España 2000-2009	Mapa Cultivos Y Aprovechamientos España 2000-2009
Nutrient Runoff Proxy		PCP (IMIDA)	Surface runoff (SWAT+)
Watersheds		SWAT+	SWAT+
Biophysical Table	**lucode**	SWAT+	SWAT+
	load_[NUTRIENT]	Balance de Nitrógeno/Fosforo en la Agricultura Española MAPA (Ministerio de Agricultura Pesca y Alimentación)	SWAT+
	eff_[NUTRIENT]	Balance de Nitrógeno/Fosforo en la Agricultura Española MAPA (Ministerio de Agricultura Pesca y Alimentación)	SWAT+
	crit_len_[NUTRIENT]	150 (Default)	150 (Default)
	proportion_subsurface_n	No Used (0)	No Used (0)
Subsurface Critical Length (Nitrogen) / Subsurface Maximum Retention Efficiency (Nitrogen)		150 (Default) / No Used (0)	150 (Default) / No Used (0)
Threshold Flow Accumulation		3107 pixels (QSWAT+)	3107 pixels (QSWAT+)
Borselli K Parameter*		2 (Default – User Guide)	2 (Default – User Guide)