SWAT+ ecohydrological modeling of the Cervaro river basin in southern Italy

Council for Agricultural Research and Economics – CREA

Rome, Italy

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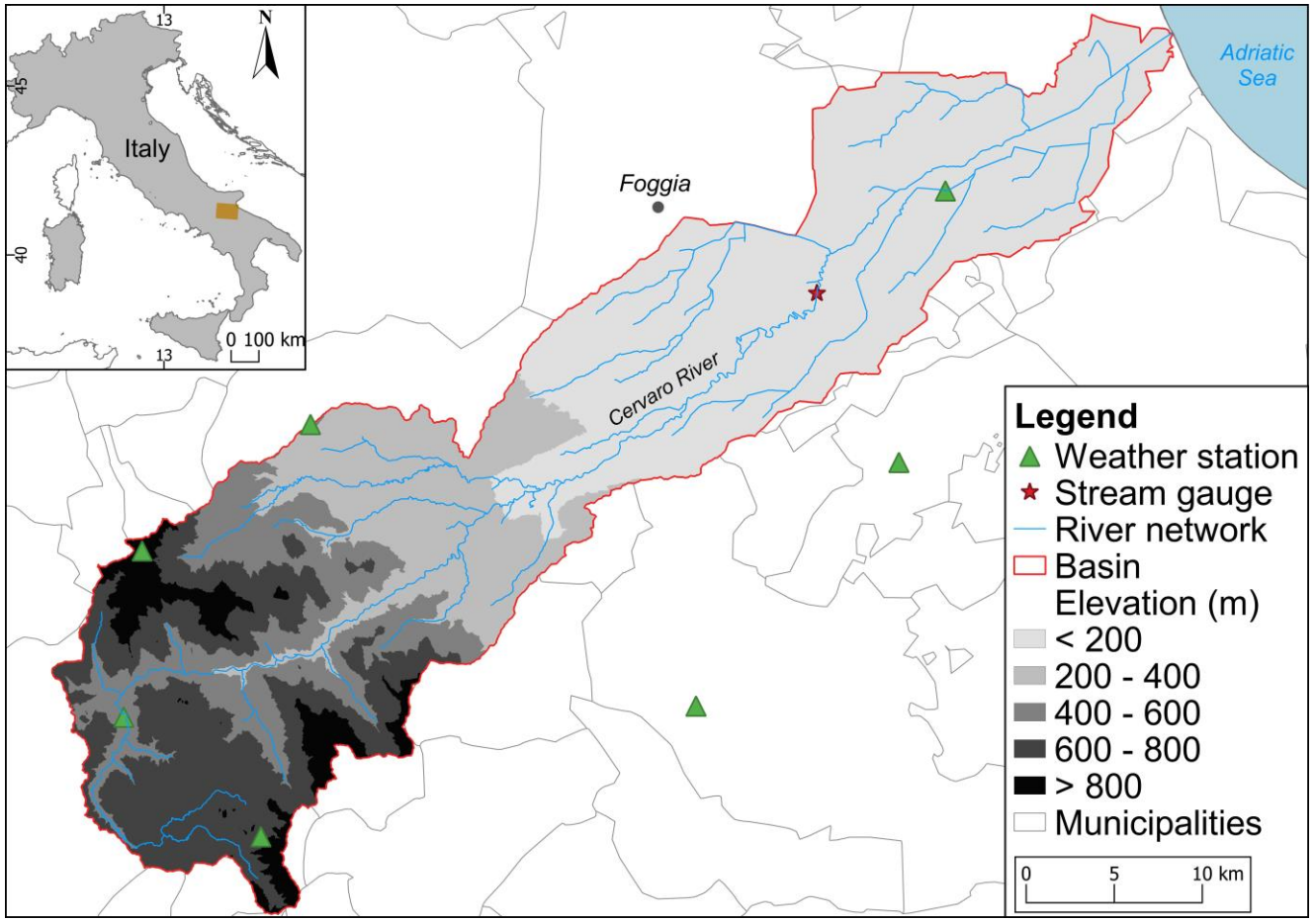
Case Study:
Cervaro River Basin (Puglia, Italy)

Focus on *semi-arid Mediterranean regions* to manage drought and climate change impacts.

Climate-smart agr. practices: Essential for water quality, soil erosion control, and economic sustainability.

Long-Term Resilience: Ensuring sustainable and productive farming operations.



Study Area - Cervaro Watershed

Location:

- **Region:** Puglia, southern Italy
- **Coordinates:** 41°07’– 41°32’ N latitude, 15°06’–15°54’ W longitude
- **Area:** 889 km²
- **Geography:** From Daunia mountains (1100 m altitude) to Gulf of Manfredonia

River System:

- **Main River:** Cervaro
- **Tributaries:** Primary and secondary, non-perennial streams
- **Climate:** Mediterranean with wet winters and dry summers
- **Land Use:** Dominated by durum wheat, horticultural crops (tomato, potato, green beans)

Research Objectives

1) Establish Baseline Conditions

Develop a robust project to represent business-as-usual conditions in the watershed.

2) Model Calibration and Validation

Calibrate and validate the SWAT+ model using a multi-variable dataset from different sources.

3) Impact Assessment of Management Strategies

Evaluate the effects of four management strategies on:

- Water balance
- Soil erosion
- Crop yields
- Provide empirical evidence on their effectiveness and scalability for CAP-aligned practices.

Model Setup and Input Data

SWAT+ Model Setup:

- **Version:** SWAT+ (revision 60.5.7)
- **Platform:** QGIS
- **Time Scale:** Daily (01/01/1990 – 31/12/2021)

Model Input Data:

- **Topographical Data:** Digital Elevation Model (DEM – 10m)
- **Land Use Map:** Detailed map with 56 units (crops, vegetation, water bodies, urban areas)
- **Soil Map:** Physical and chemical characteristics (16 units)
- **Climate Data:** From 7 stations, includes temperature, precipitation, humidity, wind speed, solar radiation
- **River Network and Agricultural Management Practices**

Data for Calibration and Validation:

- **River Discharge Data**
- **Crop actual Evapotranspiration (ETa)**
- **Crop Yields**

Soil and Land Characteristics

Soil Types:

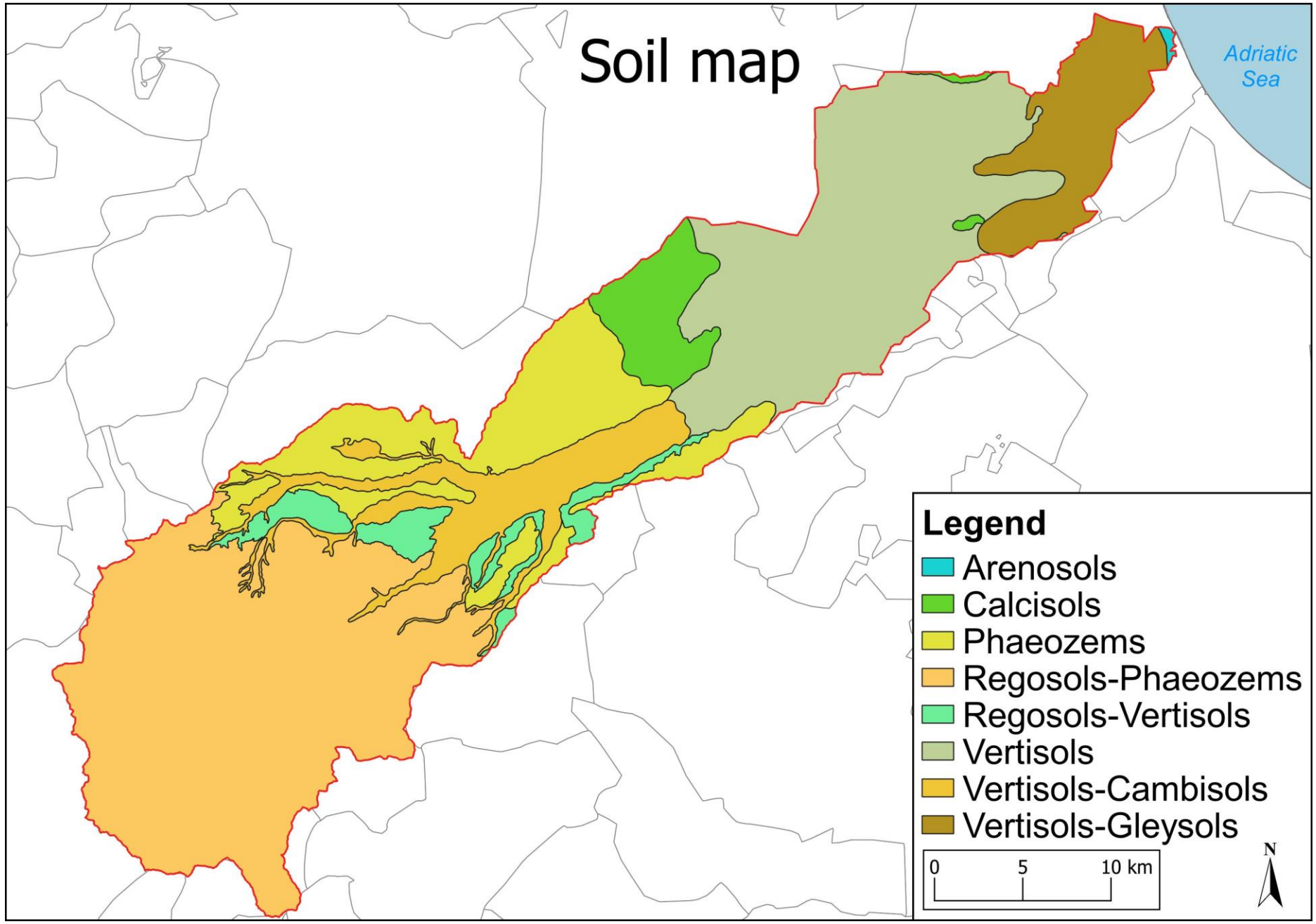
- **Haplic Calcisols:** Deep soils with calcareous parent materials
- **Soil Taxonomy:** Includes Haploxererts and Calcixererts
- **Soil Groups:** Vertisols and regosol

- Physico-chemical properties of **16 soil mapping units** based on **soil profiles Agro-ecological Characterization of the Apulia Region ACLA2**. Resolution: **1 :50.000** Source: (Caliandro et al., 2011)

Agricultural Use:

- **Intensively Used:** Tavoliere di Puglia Plain, second largest plain in Italy
- **Crop Rotation:** Durum wheat with irrigated horticultural crops

- Spatial information of **56 crop types** and natural vegetation **from IACS geodata conflation**. Resolution **1:5.000**. Source: own elaboration/Gallinelli *https://doi.org/10.3390/IOCAG2022-12241*


Soil map
Adriatic Sea
Legend
Arenosols
Calcisols
Phaeozems
Regosols-Phaeozems
Regosols-Vertisols
Vertisols
Vertisols-Cambisols
Vertisols-Gleysols
0
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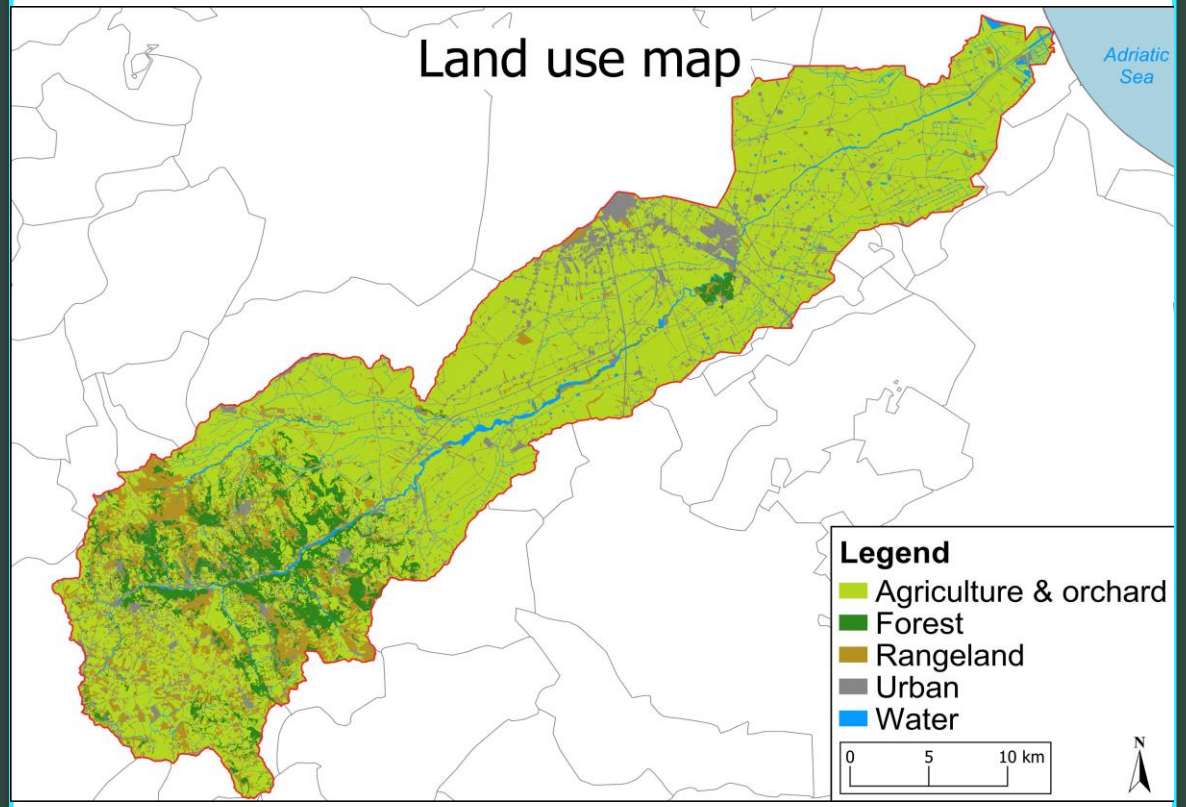
10 km
N


Land use map
Adriatic Sea
Legend
Agriculture & orchard
Forest
Rangeland
Urban
Water
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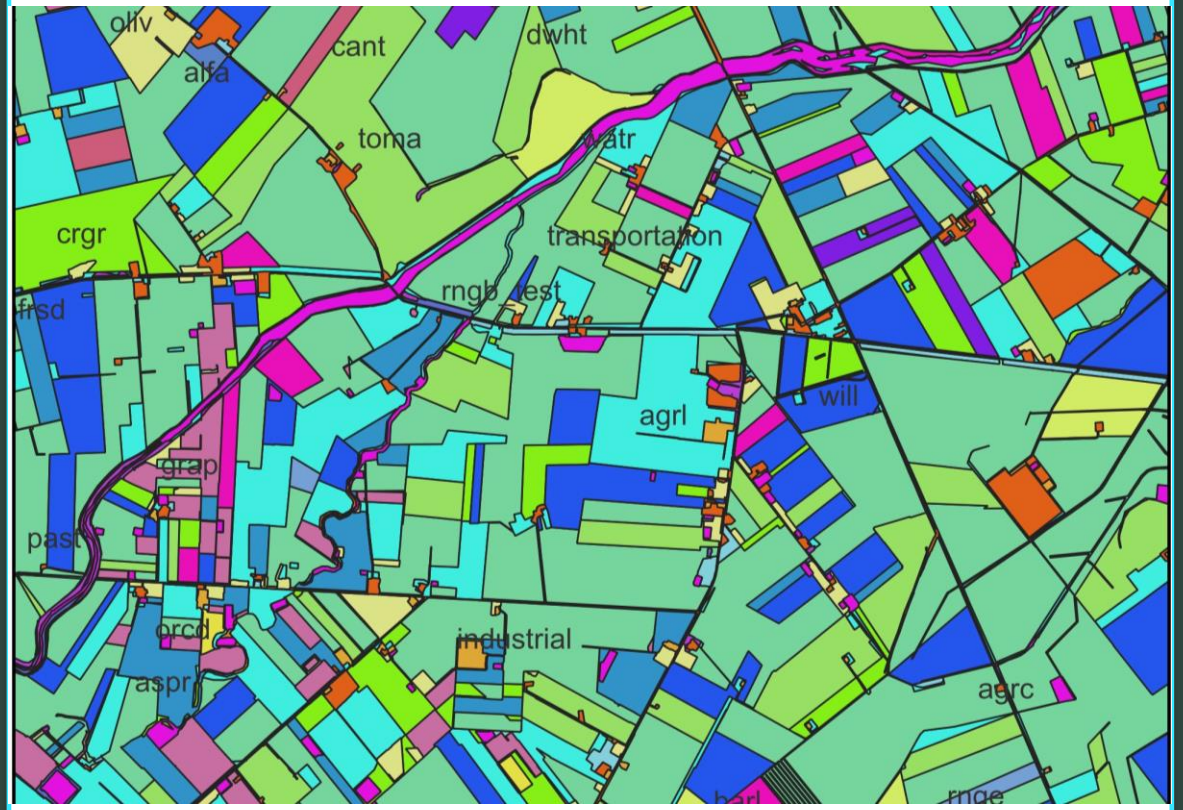
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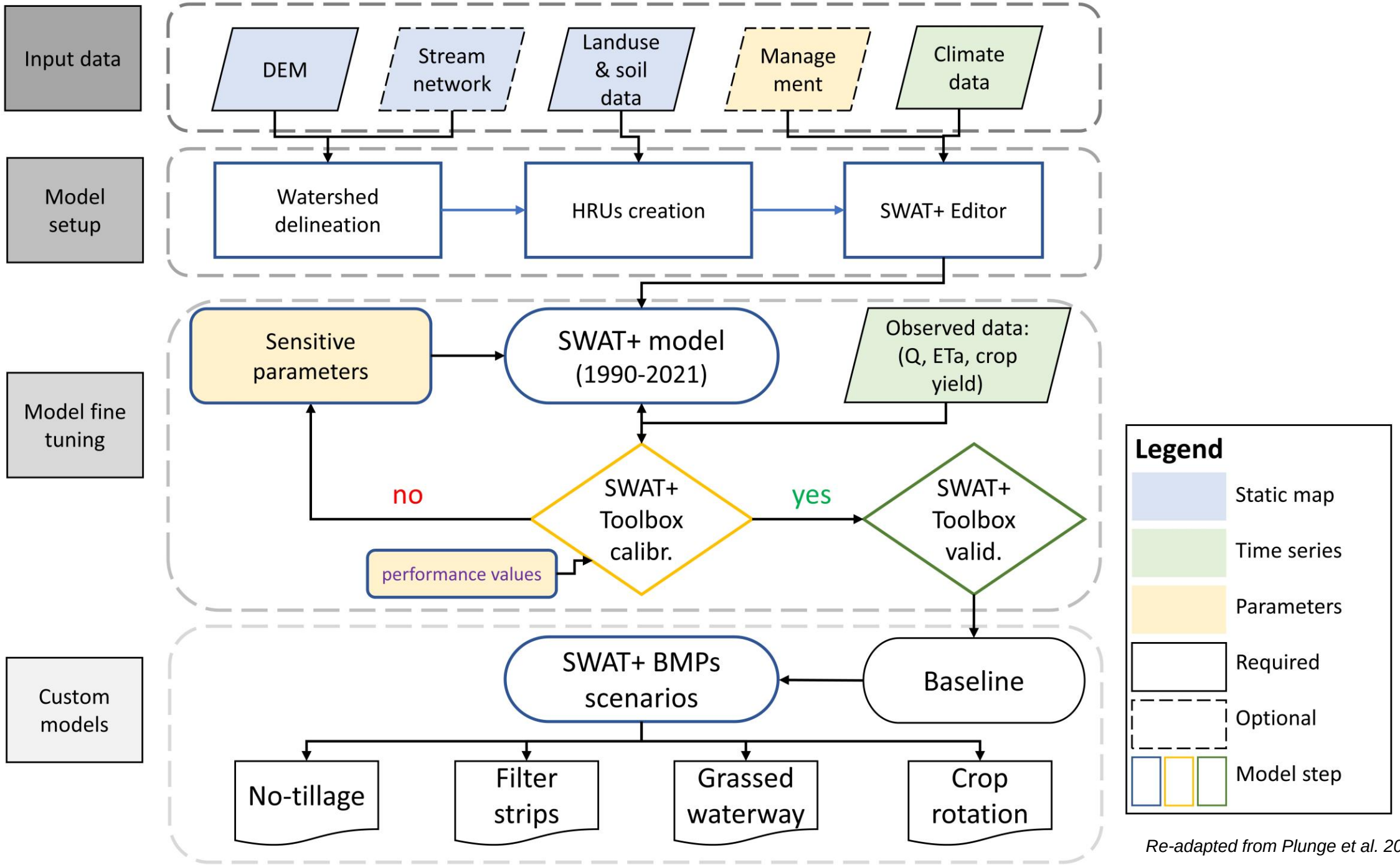

Re-adapted from Plunge et al. 2024

Model Configuration

Watershed Delineation:

- 3 Specific gauging stations added
- River network added *(our hydrographic network)*

Land Use and Soil Data:

- Slope divided into 4 classes: 0-2%, 2-5%, 5-10%, >10%

HRU Generation:

- No thresholds applied for aggregation
- Study area divided into 11 sub-basins and 4259 HRUs

Climate Data Integration:

- Daily curve number method for surface runoff
- Variable storage method for water routing
- Penman-Monteith method for potential evapotranspiration (PET)

Time range:

- Simulation period: 01 January 1990 to 31 December 2021

Baseline Management Practices

a) Tomato-Durum Wheat Rotation:

2-year rotation system typical in southern Italy.
Implemented using the «Management Schedules» within the SWAT+ Editor.

b) Barley:

Assumed to grow in the same field year by year without rotation.

c) Automatic Management for Other Crops:

- Less prevalent crops handled automatically by the model.
- Includes auto-fertilization and auto-irrigation.
- Based on accumulated heat units, plant stress, or water deficit triggers.

CROP	DATE	OPERATION
	1 November	Moldboard plow
	10 November	Fertilization (diammonium phosphate 18-46) – 220 Kg/ha
	11 November	Harrow tillage
Durum wheat	15 November	Planting
	15 February	Fertilization (33-00-00) – 180 Kg/ha
	1 April	Fertilization (urea 46-00-00) – 100 Kg/ha
	15 June	Harvest and kill

CROP	DATE	OPERATION
	1 November	Moldboard plow
	10 November	Fertilization (diammonium phosphate 18-46) – 220 Kg/ha
	11 November	Harrow tillage
Barley	15 November	Planting
	15 February	Fertilization (33-00-00) – 120 Kg/ha
	1 April	Fertilization (urea 46-00-00) – 100 Kg/ha
	15 June	Harvest and kill

CROP	DATE	OPERATION
	1 April	Moldboard plow
	2 April	Fertilization (diammonium phosphate 18-46) – 280 Kg/ha
	3 April	Harrow tillage
Tomato	20 April	Planting
	automatic	Irrigation
	automatic	Fertilization
	10 August	Harvest and kill

Model Calibration and Validation

Sensitivity Analysis and Calibration:

- **Tools:** SWAT+ ToolBox *v2.0*
- **Method:** Multi-objective functions, *Latin hypercube sampling* estimator method for parameter sensitivity.

Calibration and Validation Data:

- **Streamflow:** Incoronata river gauge
  - 4 years warm-up (1990-1993)
  - Calibration: 1994-2002 (daily time step)
  - Validation: 2008-2013 (monthly time step)
- **Evapotranspiration (ETa):** *Data from WaPOR portal*
  - Calibration: 2018-2021 (monthly)
  - Validation: Insufficient data; need 4-5 more years.
- **Crop Yields:** Long-term regional data for durum wheat
  - Calibration: 1998-2010
  - Validation: 2011-2019

Objective Functions:

- Nash–Sutcliffe Efficiency (NSE)
- Root Mean Square Error (RMSE) and Normalized RMSE (NRMSE)
- Percent of Model Bias (PBIAS)
- Kling–Gupta Efficiency (KGE)

Performance Evaluation:

- Updated model with optimal parameter values for baseline scenario

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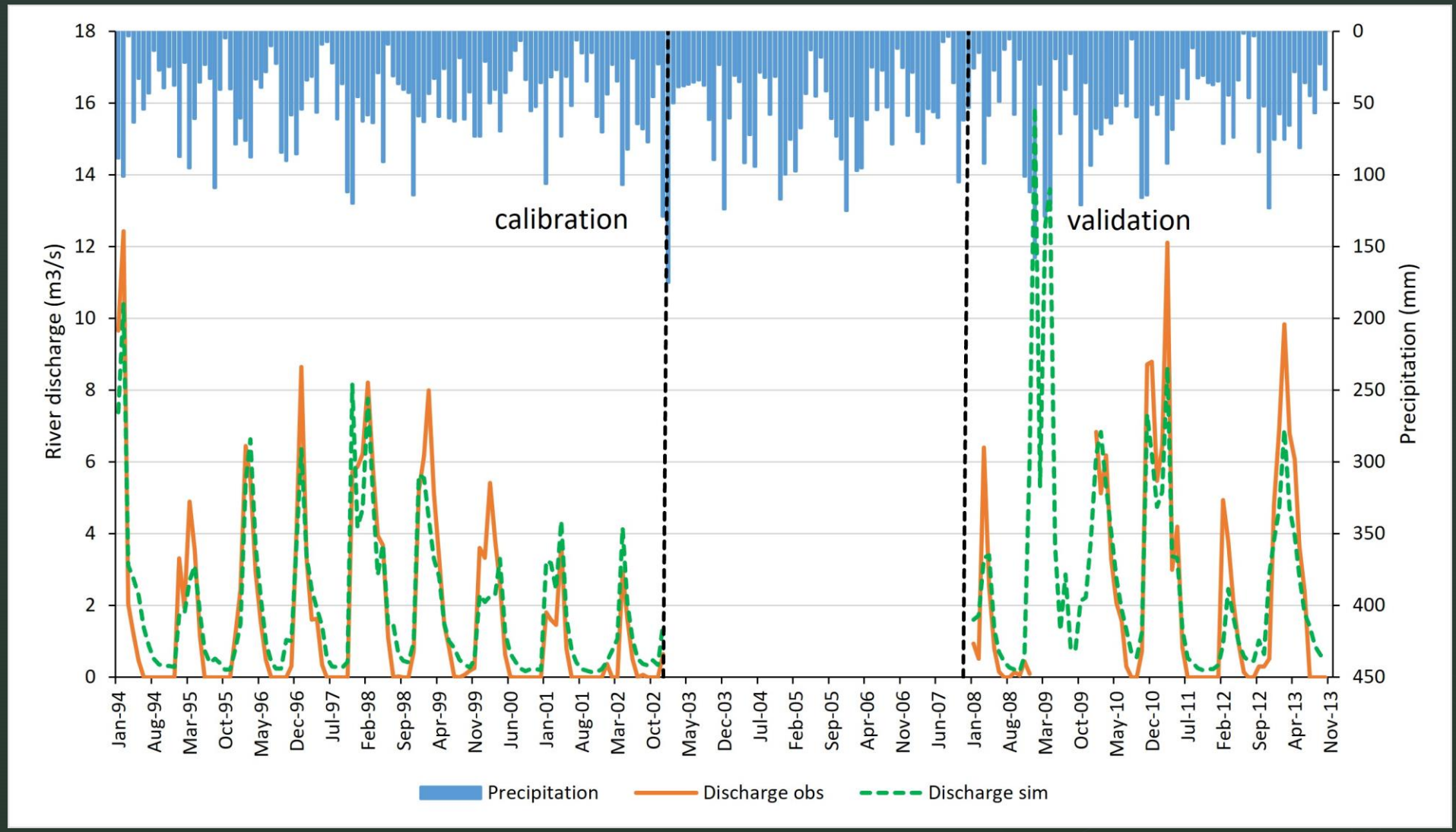
Parameter sensitivity

Parameter	Model Process	Description	Limit min	Limit max	Calibration value
alpha	flow	Baseflow recession constant (day)	0,84	1	0,9676
cn2	flow	Initial SCS runoff curve number for moisture condition	34	95	71,50494
esco	flow	Soil evaporation compensation factor	0	1	0,67918
epco	flow	Plant uptake compensation factor	0	1	0,4454
canmix	flow	Maximum canopy storage	0	10	4,68436
awc	flow	Available water capacity of the soil layer	0,01	0,07	0,02492
lat_ttime	flow	Deep aquifer percolation fraction	5	20	10,89777
latq_co	flow	Lateral flow contribution to reach	0	1	0,10291
surlag	flow	Surface runoff lag coefficient	0,05	5	1,7744
cn3_swf	flow	Coil water factor for curve number 3	0	1	0,29047
revap_co	flow	Groundwater revap coefficient	0,02	0,2	0,04845
ovn	evapotranspiration	Manning's "n" value for overland flow	0,01	28	9,1
biomix	evapotranspiration	Biological mixing efficiency	0	1	0,38
petco	evapotranspiration	Potential evapotranspiration coefficient	0,8	1,2	0,81

Calibration-Validation Plot for Model Reliability



Results

Model output	CALIBRATION				VALIDATION			
	NSE	KGE	PBIAS	RMSE	NSE	KGE	PBIAS	RMSE
Discharge	0,71	0,71	-8,20%	1,82	0,82	0,78	8,13%	1,35
ETa – dwht (hru462)	0,71	0,82	-9,40%	14,9	-	-	-	-
ETa – dwht (hru556)	0,69	0,8	6,30%	16,7	-	-	-	-
ETa - dwht (hru919)	0,73	0,7	3,20%	14,3	-	-	-	-
ETa - past (hru3378)	0,53	0,54	17,20%	24,1	-	-	-	-

Model output	CALIBRATION		VALIDATION	
	PBIAS	NRMSE	PBIAS	NRMSE
Durum wheat yield	10,90%	20%	-	-

Modeling Agricultural Management Practices

Climate-Smart Practices

Focus: Align with CAP instruments, eco-schemes, and environmental conditionality

Target Area: Arable farmland in extensive plains with monocultures

Modeling Agricultural Management Practices

Selected Practices:

No Tillage (NT): Planting into existing crop residue, improving soil organic matter and stability

Filter Strips (FS): Vegetated areas intercepting runoff, reducing soil erosion and pollution

Crop Rotation (CR): Alternating crops to enhance soil health and nutrient cycling

Grassed Waterways (GW): Vegetated channels reducing flow velocity and erosion

Scenarios

Baseline scenario: Current state – Existing conditions without AMP
Scenario 1: No tillage (NT) across all HRUs
Scenario 2: NT + Filter Strips (FS)
Scenario 3: NT + FS + Crop Rotation (CR) with rapeseed catch crop
Scenario 4: NT + FS + CR + Grassed Waterways (GW)

Simulation Period: January 2014 to December 2021

Implementation and Evaluation:
Objective: Maximize CAP’s environmental and climate ambitions
Focus: Water retention, soil quality, and erosion reduction

Thank you
for your attention.

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