AG-WaMED

An efficient approach for simulating the effect of small agricultural reservoirs on water management with SWAT+

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PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Funded by the European Union

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SWAT conference, Strasbourg, 10-12 July 2024

Outline

1. The research context: the AG-WaMED project
2. Representing small agricultural reservoirs (SmARs) in SWAT+
3. Calibration and validation strategy: the simplified and complex models
4. Participatory modelling, next activities and conclusions

The AG-WaMED project

- **Full name:** Advancing non-conventional water (NCW) management for innovative climate-resilient water governance in the Mediterranean Area
- **Objective**: providing innovative, evidence-based participatory management solutions to water scarcity governance that can be scaled at the Mediterranean level, mainly by including NCW (wastewater, runoff water harvesting, desalination) in water governance policies.
- **Duration**: September 2022 – August 2025
- **Funding**: PRIMA Foundation Consortium Section 2
- **Number of partners**: 8
- **Countries involved**: 7
- **Living Labs (LL)**: 4 in 5 countries

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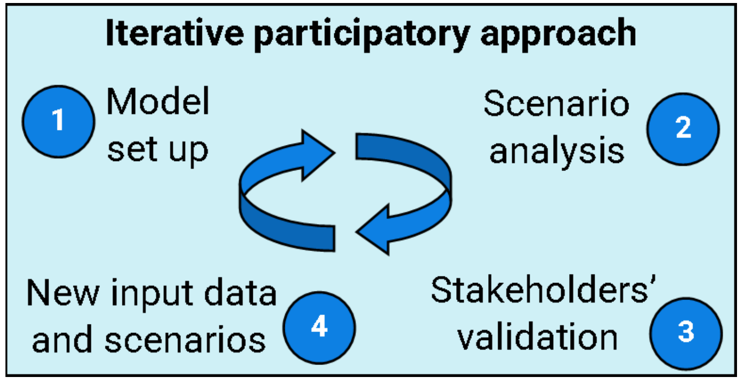
AG-WaMED methodology

Living Lab

Agro-hydrological models
to evaluate NCW use



Economic model

Models' results and living lab discussion **(co-modelling)**

Creation of **new policies** for integrated water resources management

2 out of 4 workshops were carried out so far

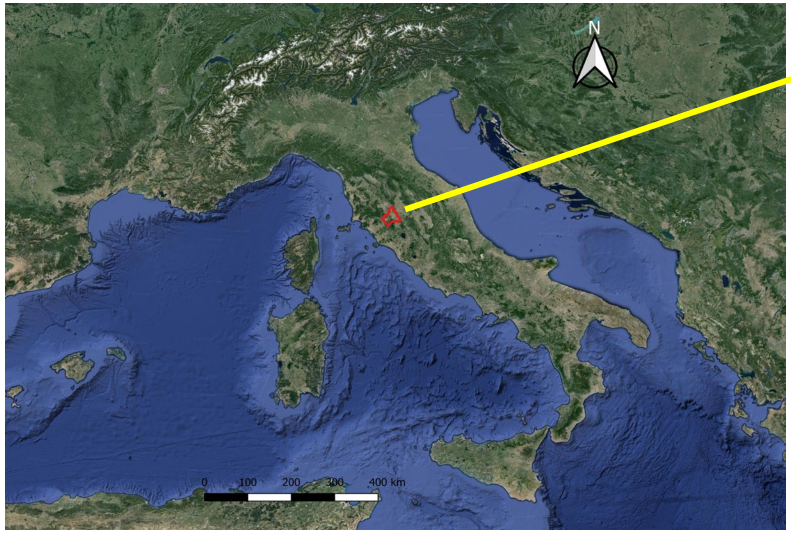
Val d'Orcia Living lab, Tuscany (Italy)

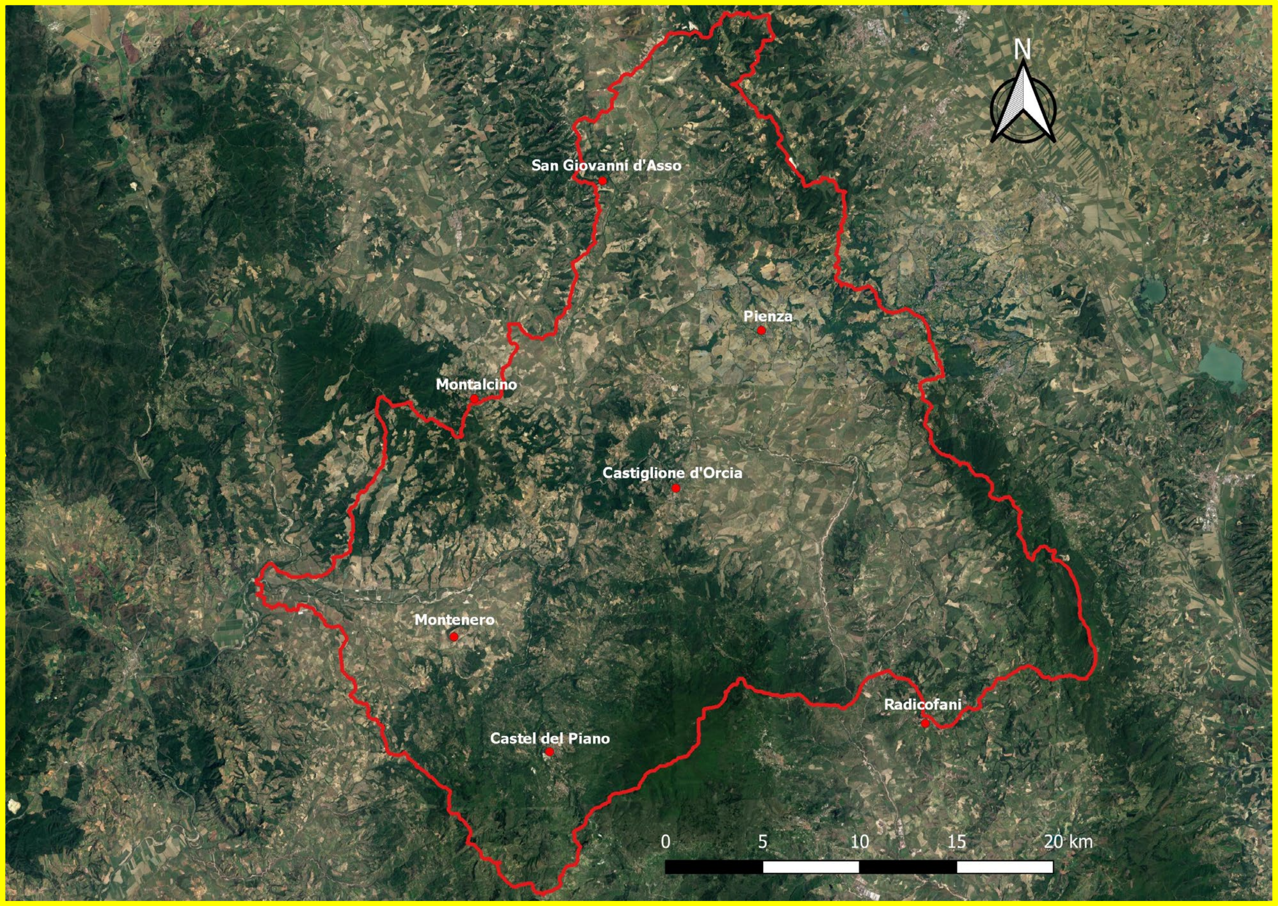
Size: 748 km^2

Precipitation: 715 mm

Main activities: agriculture and tourism

Main crops: vineyards, olive, cereals





First workshop

Project presentation and establishment of the Living Lab

Analysis of the situation related to (non)conventional water:

- Typically rainfed crops now require supplemental irrigation, and **Small Agricultural Reservoirs (SmARs)** can play a crucial role
- Economic and regulation problems hinder the restoration of existing SmARs and realization of new ones
- Sedimentation problems are a major issue, and agricultural practices can contribute to limit erosion
- Community irrigation development is challenging but could be very useful

Small agricultural reservoirs (SmARs)

Number of SmARs	**1097**
Average surface	**1432** m^2 = **0.14** ha
Biggest SmAR	**45429** m^2 = **4.54** ha
% of SmAR with area < 500 m^2	**58%**
Number of SmARs with area > 1 ha	**29**
Total SmARs surface	**161** ha
Total SmARs volume (estimated)	**6.7** millions m^3

SWAT+ modelling in AG-WaMED

Final objective:

- To provide information and input data for the other analyses and the integrated watershed management plan, mainly focusing on:
  - SmARs impact on water balance
  - Large planned dam impact on water balance
  - Erosion and good practices

What is done:

- Simplified SmARs representation
- SWAT+ cal/val

SWAT+ SOIL & WATER ASSESSMENT TOOL

Problems in representing SmARs

Problems:

- in SWAT+ we can represent only in-stream reservoirs
- Difficult representation of reservoir management (irrigation and releases), also due to lack of data

↓

Outputs and analysis only valid at the catchment scale

Impact of SmARs on flow

Sedimentation

Approaches to represent SmARs

1. by creating a grid model, **considering a cell as a reservoir** if the latter covers >50% of the cell area
2. by **including SmARs when creating HRUs**, so that SWAT+ considers a floodplain as a SmAR
3. by adding them in the watershed delineation step **using the SmARs shapefile**

} Not feasible

4. by **considering them as "playa lakes",** hence not connected to the channel network but just as a different land use → Not representative

5. by **manually adding each SmAR** individually

Placing SmARs on the channel network

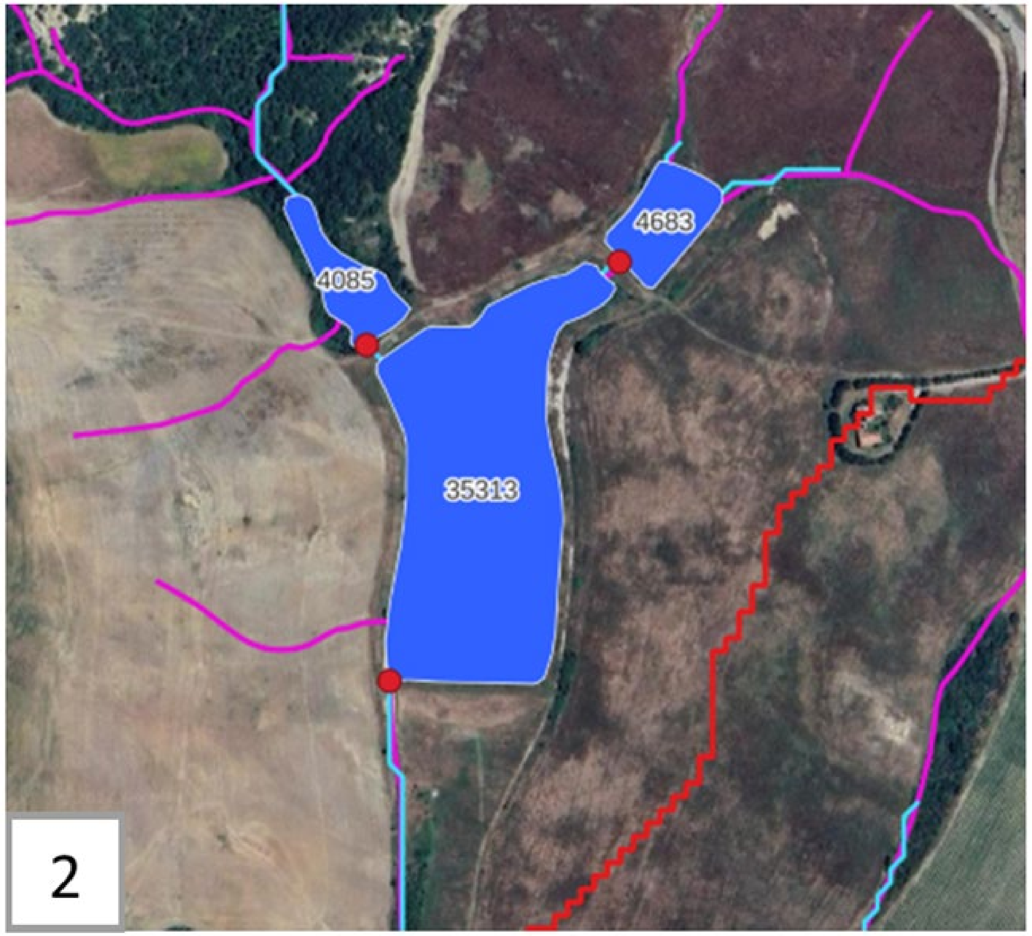
Only 177 SmARs out of 1097 are on the channel network.

Should we move some SmARs on the channel network?

Yes,

- If movable on a channel (not on streams)
- If the reservoir has a reasonable upstream area
- If it is clear to which channel they can be moved on
- If the distance between the reservoir and the channel is up to 150 m for reservoirs with area >400 m^2
- If the distance between the reservoir and the channel is up to 80 m for reservoirs with area <400 m^2

SmARs: Example 1

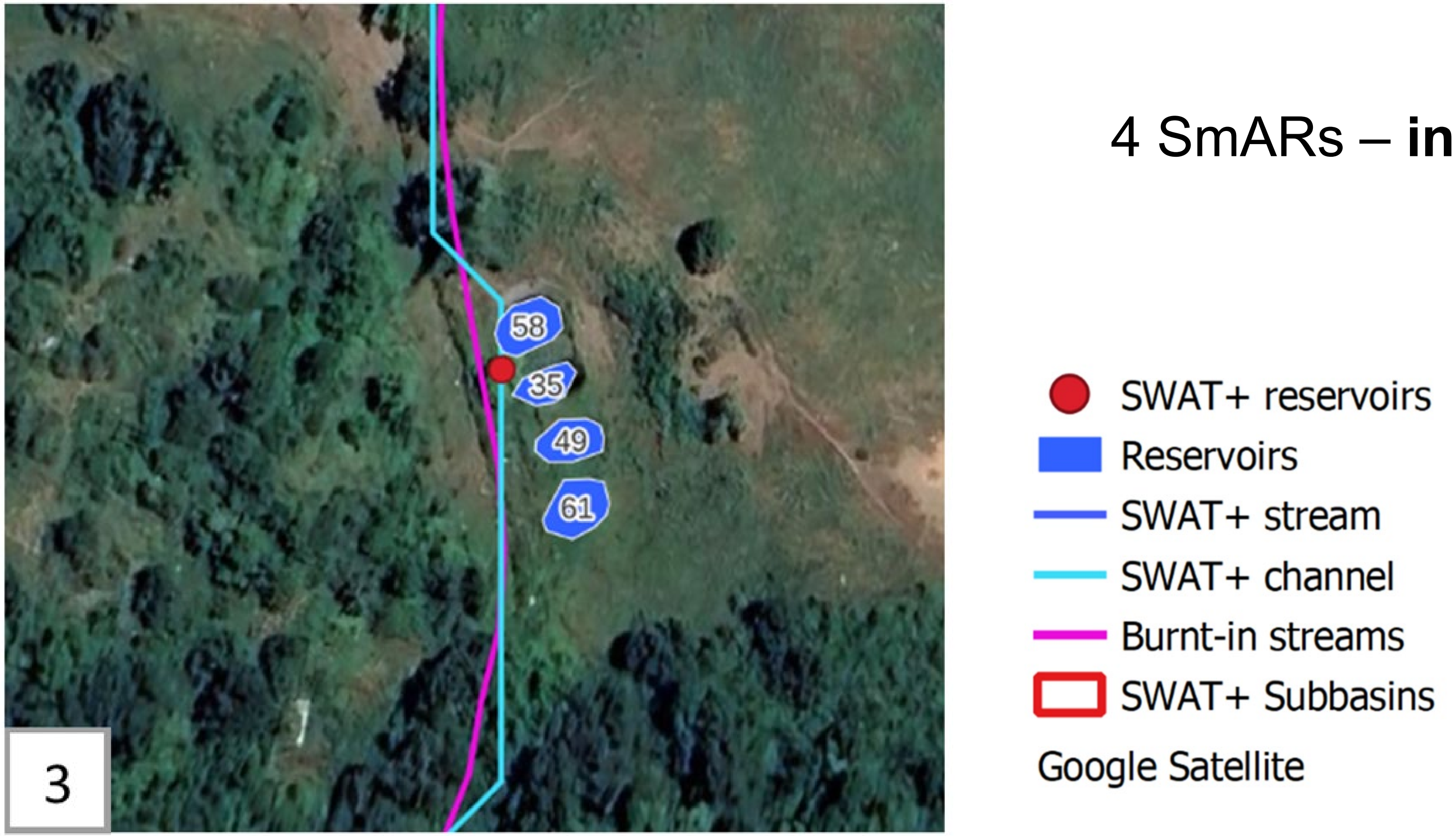


3 SmARs - **included**

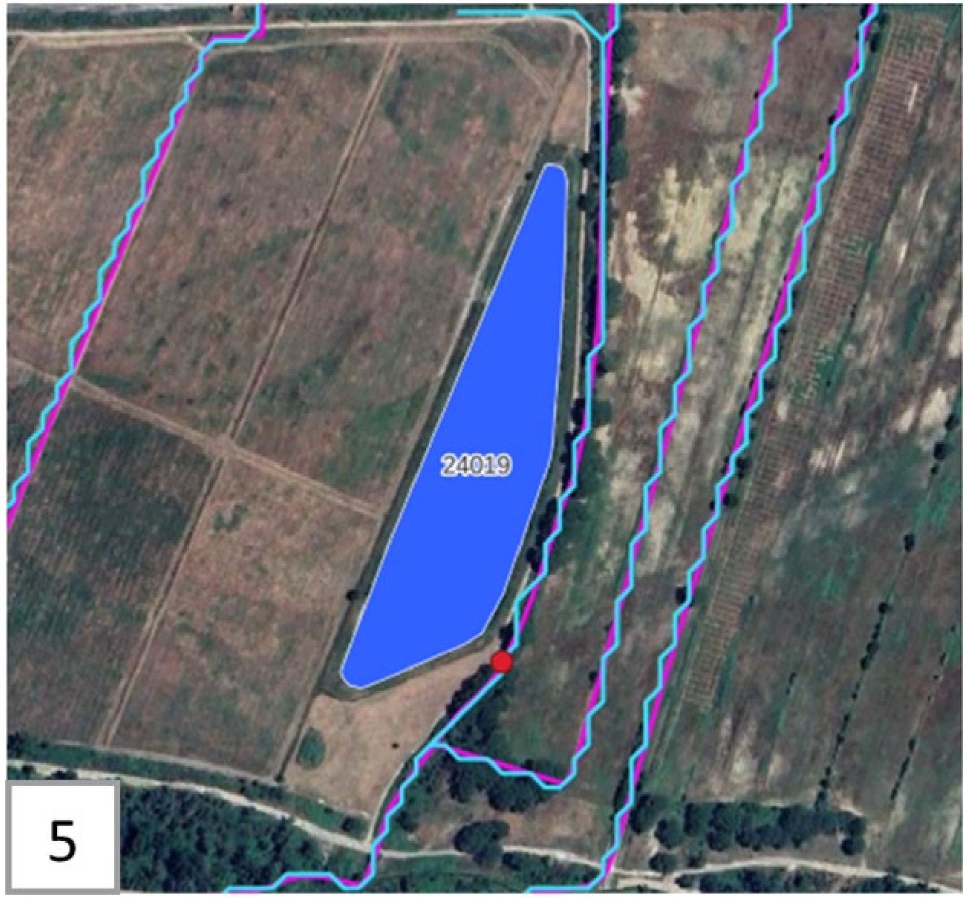
SWAT+ reservoirs
Reservoirs
SWAT+ stream
SWAT+ channel
Burnt-in streams
SWAT+ Subbasins
Google Satellite

SmARs: example 2

4 SmARs – **included** and **merged**



SmARs: example 3



1 SmAR – not on the channel network but **included** since we assumed that it is filled by the channel

- SWAT+ reservoirs
- Reservoirs
- SWAT+ stream
- SWAT+ channel
- Burnt-in streams
- SWAT+ Subbasins

Google Satellite

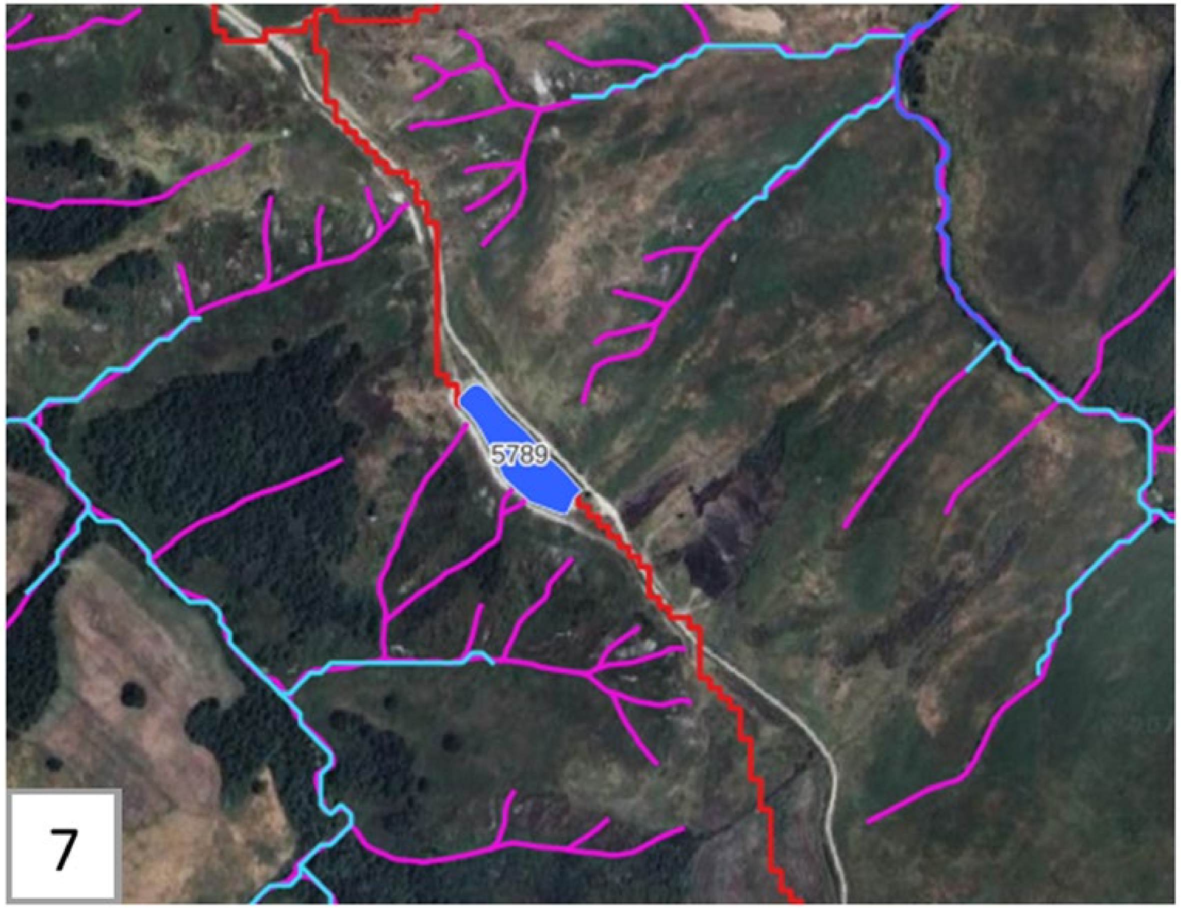
SmARs: example 4

2 SmARs – **excluded** since they are filled by the Orcia river (stream network)

- SWAT+ reservoirs
- Reservoirs
- SWAT+ stream
- SWAT+ channel
- Burnt-in streams
- SWAT+ Subbasins

Google Satellite

SmARs: Example 5



1 SmAR – **excluded** because too far from channel network

SWAT+ reservoirs
Reservoirs
SWAT+ stream
SWAT+ channel
Burnt-in streams
SWAT+ Subbasins
Google Satellite

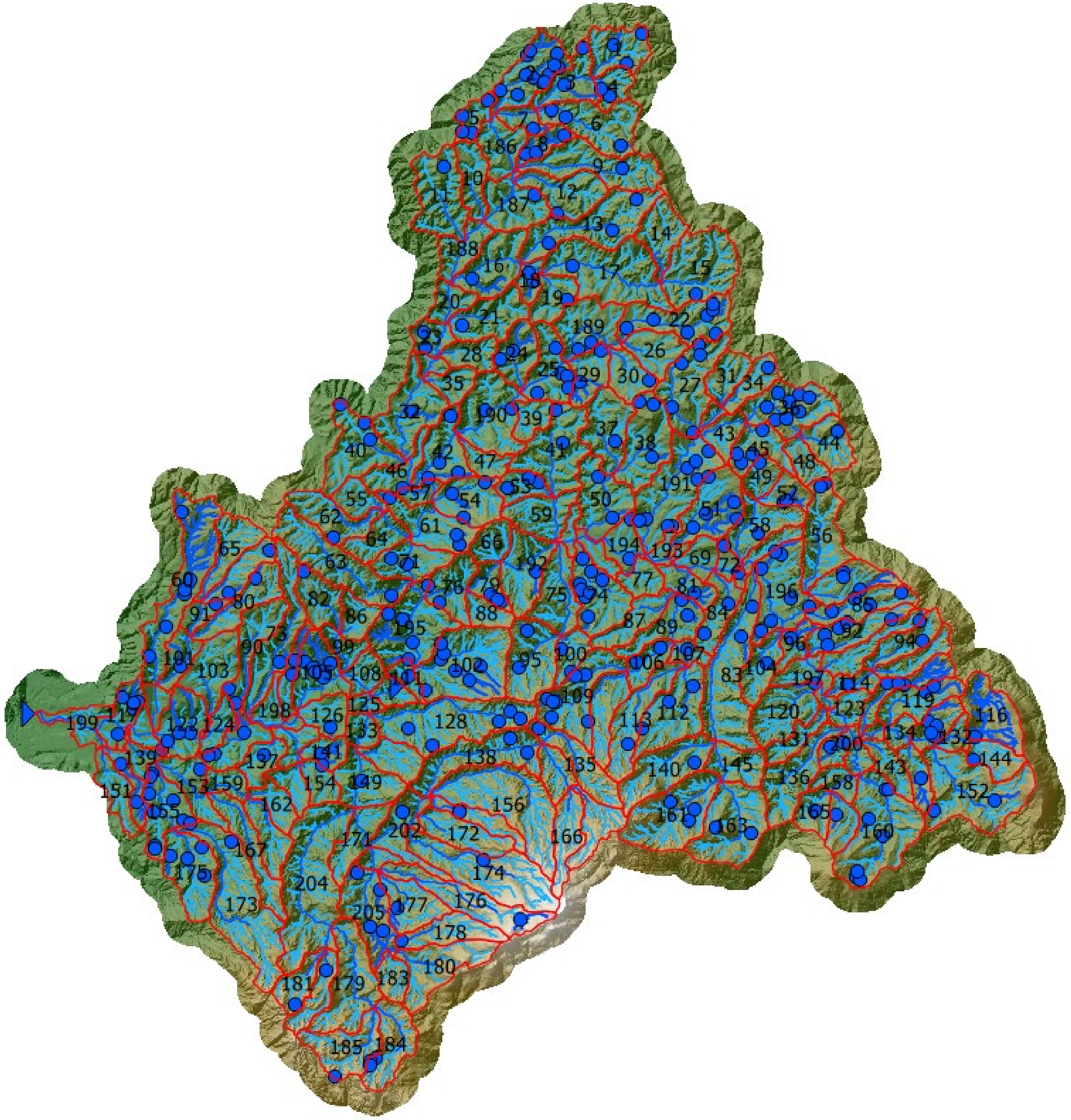
Representing SmARs

With this procedure, we **included:**

358 / 1097 SmARs (32.6%)

127 / 161 ha of SmARs surface (80%)

5.3 / 6.7 million m^3 of SmARs volume



Calibration and validation strategy

To include the maximum number of SmARs as possible, we created as many channels as possible using a **small threshold** (5 ha).

⇩

Very complex model that required **long simulation time**

⇩

Simplified version of the model to perform calibration and validation

⇩

Transfer of the calibrated parameters to the complex model

Model	HRUs	Channels	Reservoirs
Complex	112401	1111	329
Simplified	3773	220	0

Calibration and validation characteristics

Variables:

1. Monthly streamflow with rating curve modelled with HEC-RAS

2. Monthly actual evapotranspiration (ET) at basin scale from MODIS

Statistics and performance criteria:

NSE, Pbias, RSR, R^2; Moriasi et al. 2007, 2015

Software:

SWAT+ Toolbox

Periods:

Warm up 1 year, calibration 2011-2016, validation 2017-2020

Results:
Calibration and validation of the simplified version

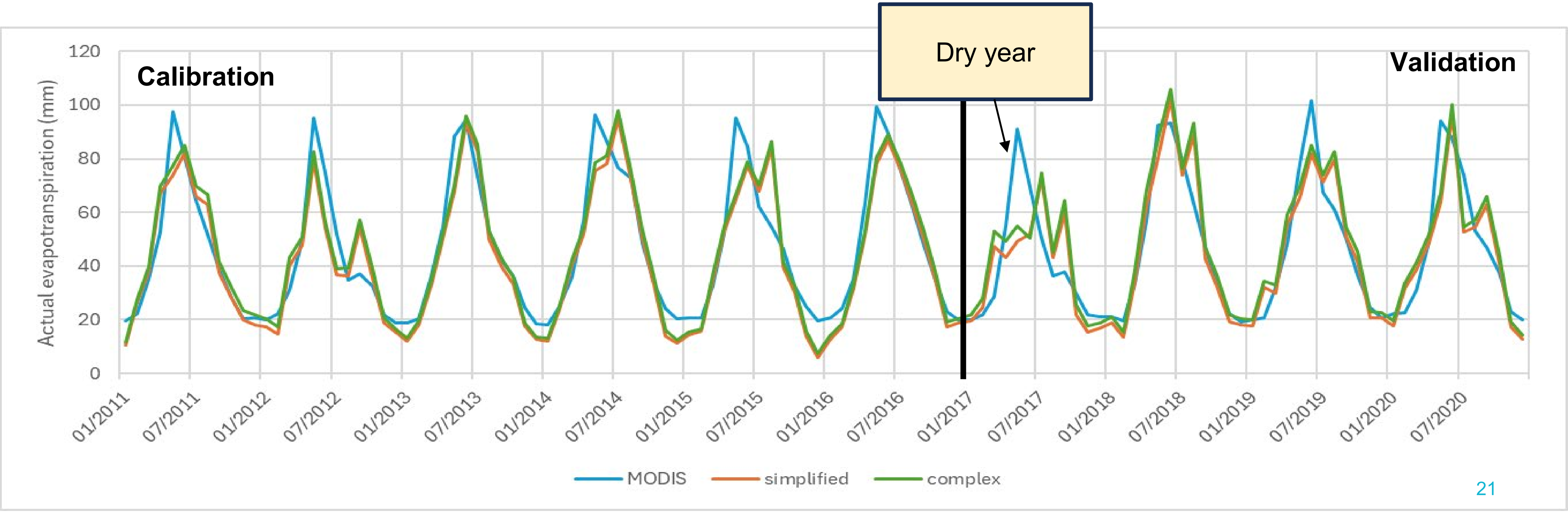
- Sensitive parameters for ET and flow were similar.
- Focus on flow since ET was always simulated satisfactorily, regardless of the changes.
- Final adjustment required due to a problem in the SWAT+ Toolbox.

Parameter	Type of change	Min/max	Automatic changes	Final changes
cn2	Percent	+/- 20%	-10.22%	-20.00%
bd	Percent	+/- 20%	15.14%	15.14%
esco	Replace	0 - 1	0.068	0.118
epco	Replace	0 – 1	0.133	0.133
revap_co	Replace	0.02 – 0.2	0.123	0.123

Results: basin monthly actual evapotranspiration

Variable	Monthly ET		Monthly ET	
Model	*Simplified model*	*Complex model*	*Simplified model*	*Complex model*
	Calibration, 2011-2016		Validation, 2017-2020	
NSE	0.84 [1]		0.74 [2]	
PBIAS	6.9% [1]		1.4% [1]	
R^2	0.86 [1]		0.75 [2]	
RSR	0.40 [1]		0.51 [2]	

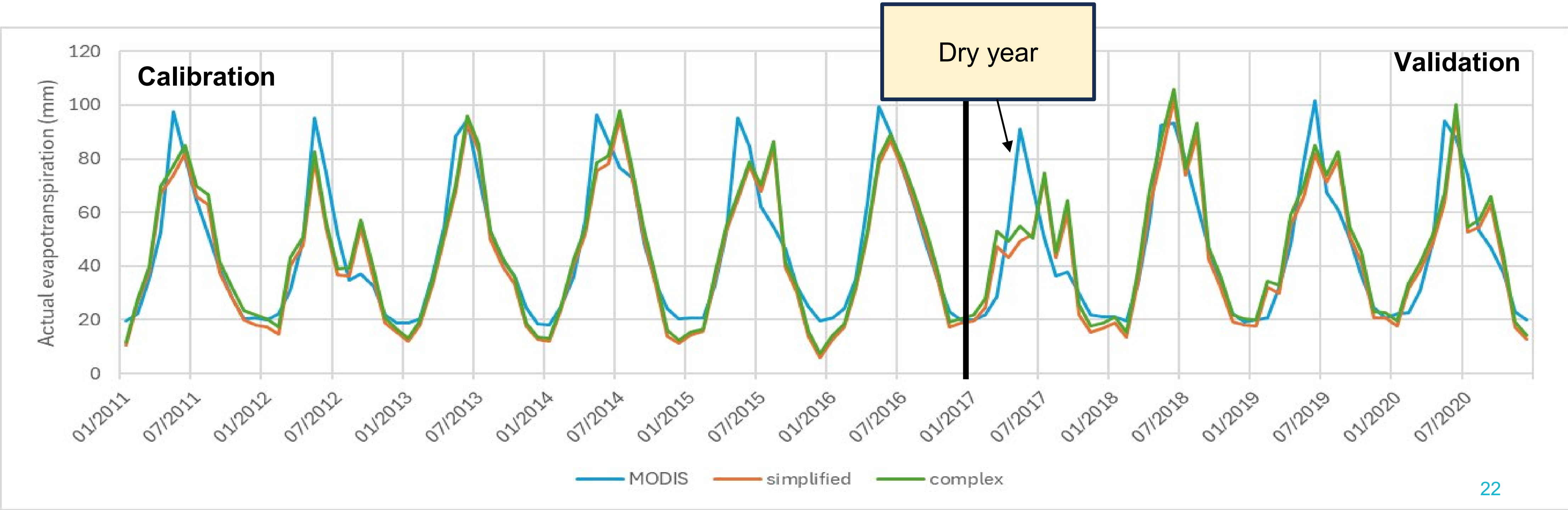
[1] Very good, [2] Good, [3] Satisfactory, [4] Unsatisfactory



Results:
basin monthly actual evapotranspiration

Variable	Monthly ET		Monthly ET	
Model	*Simplified model*	*Complex model*	*Simplified model*	*Complex model*
	Calibration, 2011-2016		**Validation, 2017-2020**	
NSE	0.84 [1]	0.85 [1]	0.74 [2]	0.72 [2]
PBIAS	6.9% [1]	1.9% [1]	1.4% [1]	-5.4% [1]
R^2	0.86 [1]	0.86 [1]	0.75 [2]	0.75 [2]
RSR	0.40 [1]	0.39 [1]	0.51 [2]	0.53 [2]

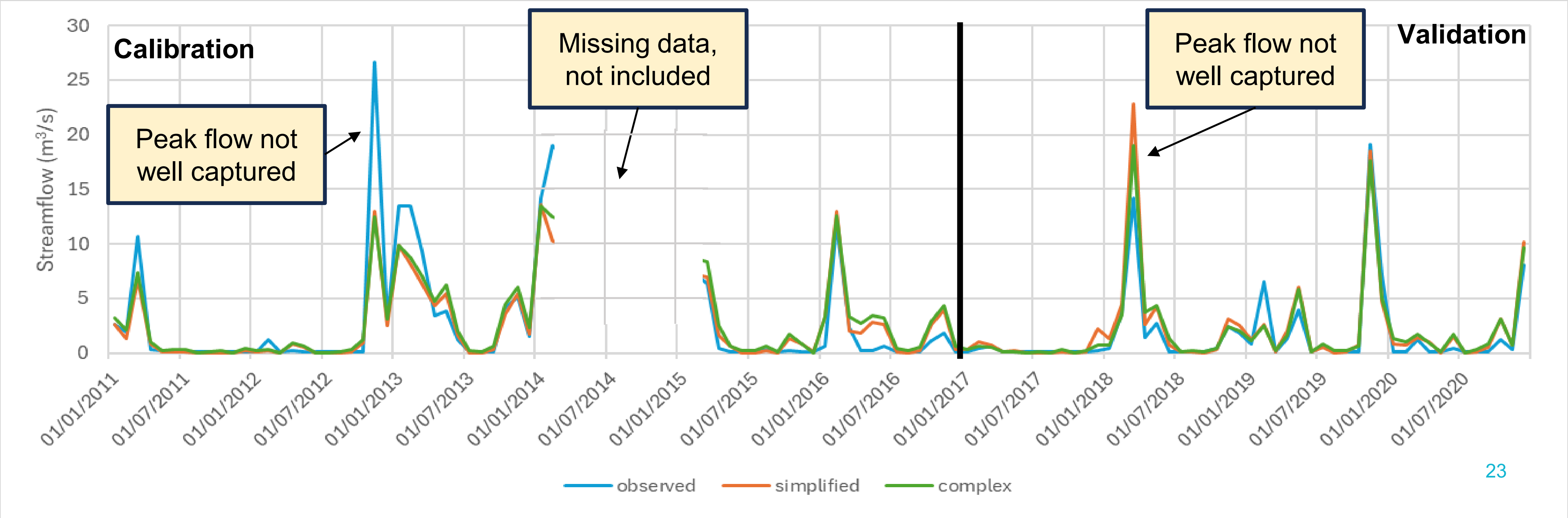
[1] Very good, [2] Good, [3] Satisfactory, [4] Unsatisfactory



Results: monthly streamflow

Variable	Monthly streamflow		Monthly streamflow	
Model	*Simplified model*	*Complex model*	*Simplified model*	*Complex model*
	Calibration, 2011-2016		Validation, 2017-2020	
NSE	0.78 [1]		0.82 [1]	
PBIAS	11.7% [2]		-27.3% [4]	
R^2	0.85 [1]		0.88 [1]	
RSR	0.47 [1]		0.44 [1]	

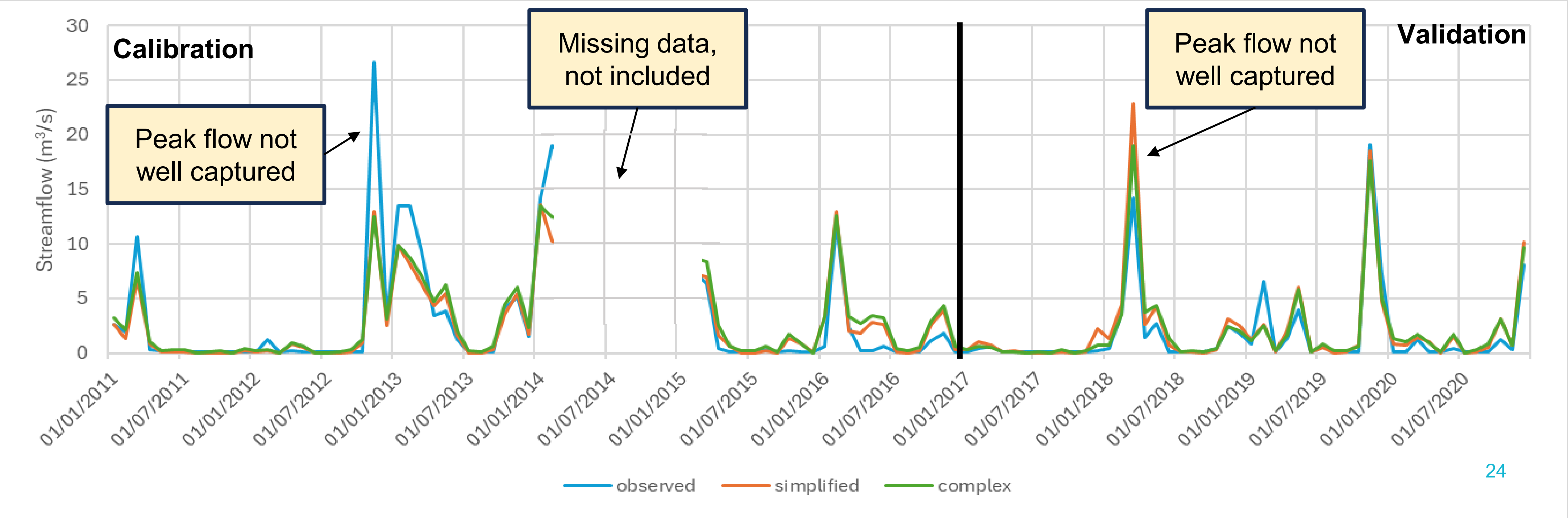
[1] Very good, [2] Good, [3] Satisfactory, [4] Unsatisfactory



Results: monthly streamflow

Variable	Monthly streamflow		Monthly streamflow	
Model	*Simplified model*	*Complex model*	*Simplified model*	*Complex model*
	Calibration, 2011-2016		Validation, 2017-2020	
NSE	0.78 [1]	0.78 [1]	0.82 [1]	0.90 [1]
PBIAS	11.7% [2]	-0.9% [1]	-27.3% [4]	-20.2% [3]
R^2	0.85 [1]	0.83 [2]	0.88 [1]	0.91 [1]
RSR	0.47 [1]	0.47 [1]	0.44 [1]	0.33 [1]

[1] Very good, [2] Good, [3] Satisfactory, [4] Unsatisfactory



Second workshop

The **SWAT+ model results** were presented.

Stakeholders **confirmed the validity** of the approach used to represent SmARs, given the lack of data.

They also committed to **provide further information**.

Next steps

- Simulate effect of SmARs on Orcia streamflow and sedimentation dynamics.
- Improve the model based on stakeholders' feedback.
- 2 additional rounds of revisions through in-presence workshops.
- Preparation of an integrated watershed management plan.

Suggestions? Comments? Collaborations?

Please send me any **references** related to these issues

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Thank you for your attention!

Contacts

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Facebook: AG-WaMED

Youtube: @AG-WaMED-by9bu

X: https://twitter.com/AgWamed

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