# SWAT+ model set up and soft calibration in a highly relevant area for water management: the Tagus River headwaters.

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# Introduction

## Spain situation:

- Water resources management faces various challenges :
  - scarcity
  - overexploitation of aquifers
  - climate variability
  - climate change
- Climate change is having a significant impact on Spain's water resources. These changes affect:

Availability

Distribution

## Tagus River basin:

- Crucial role in the management of water resources in Spain
- Supplies water to important cities, industries and agricultural areas of the Iberian Peninsula.
- It has valuable aquatic ecosystems and biodiversity

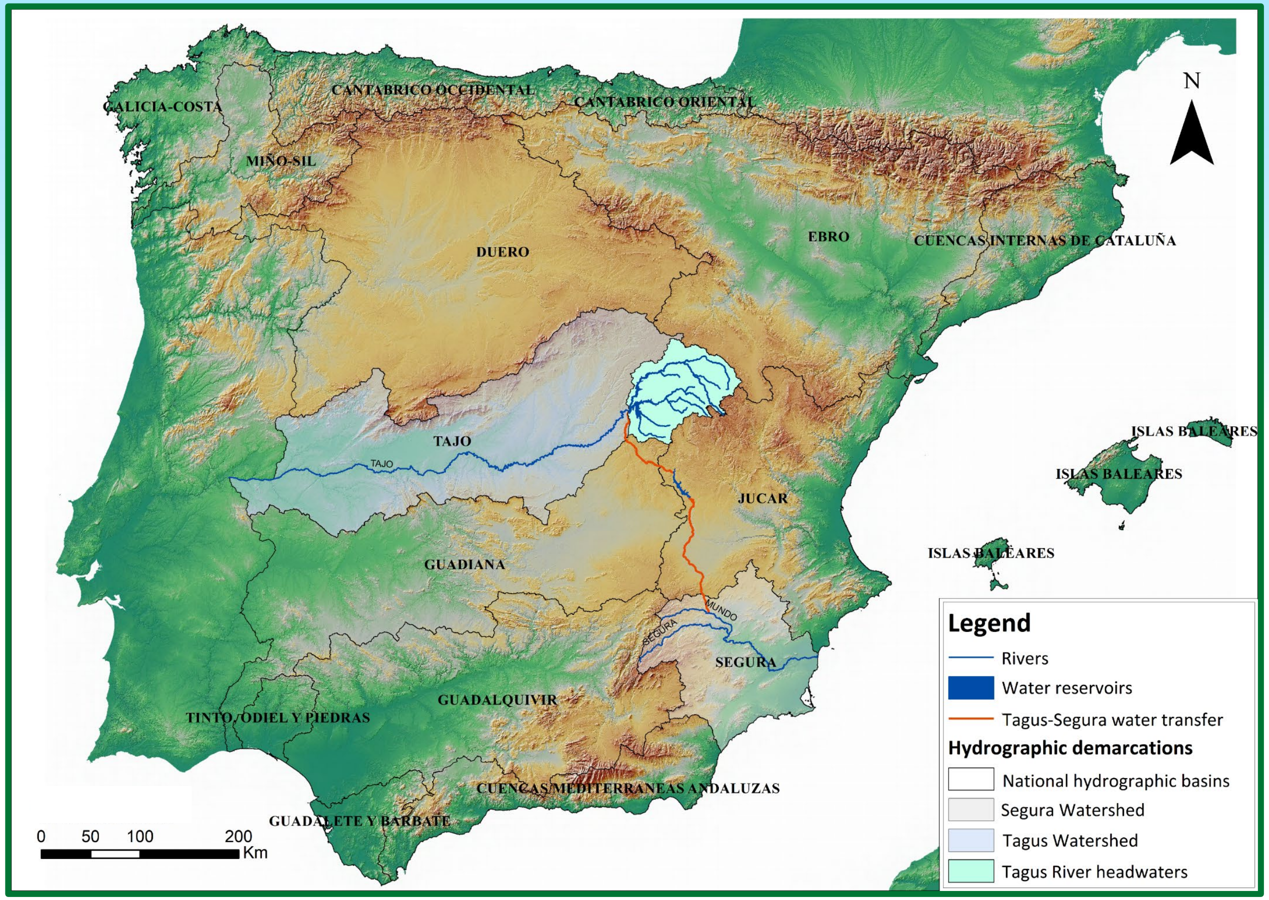
*Sustainable management needed to preserve and protect water resources.*

## Tagus River basin:

- Most populated basin in the Iberian Peninsula (11 M inhabitants, + 3 M extra in the Segura Basin).
- Intense regulation through reservoirs, presence of important water transfers.
- Already noticeable effects of climate change.

## Tagus headwaters → Great relevance

- Problem of water scarcity due to climate conditions and overexploitation of water resources
- Subject to the Tagus-Segura water transfer to southeast Spain (330 $hm^3$ /year ).

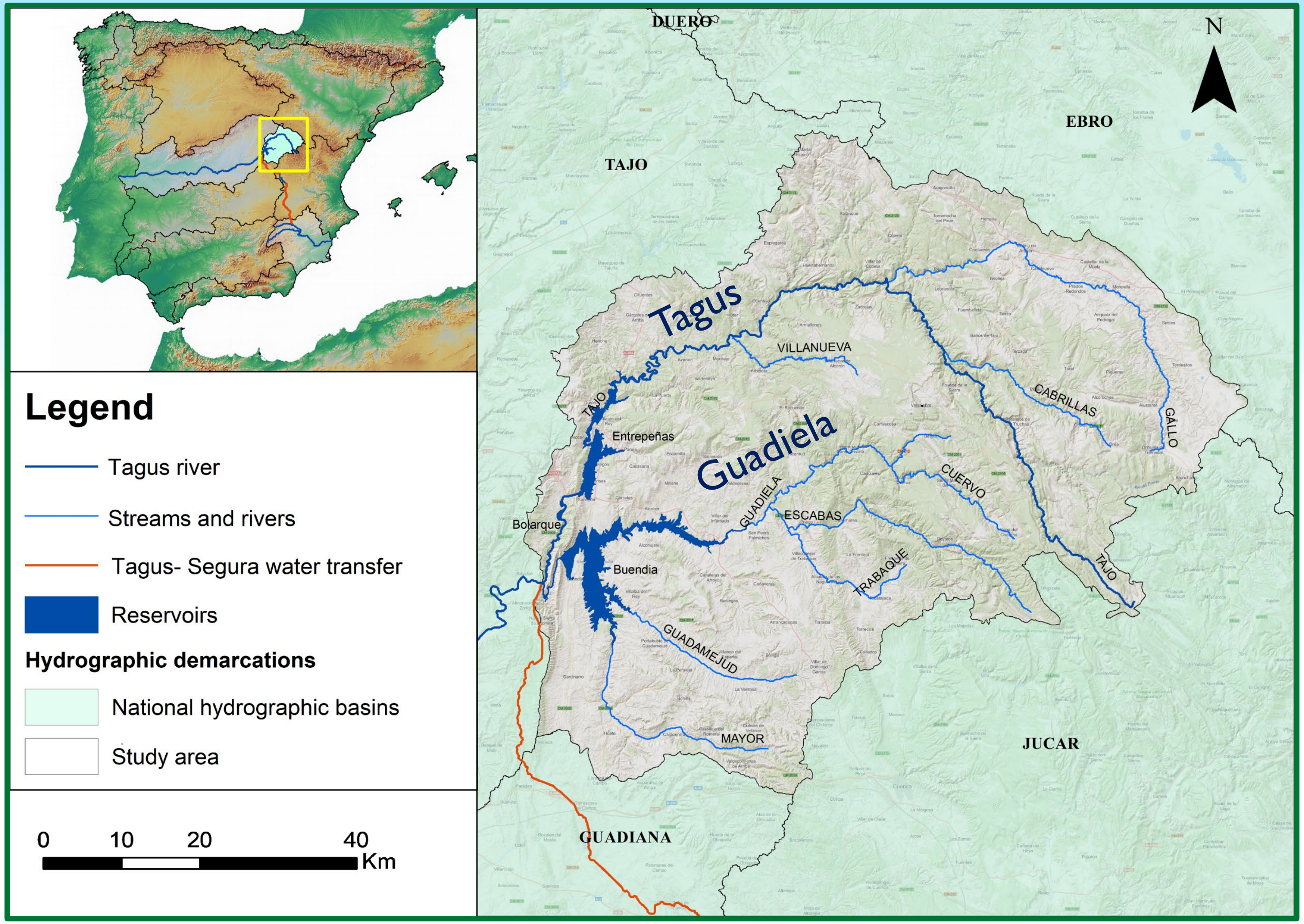



*Applying SWAT+ in this study area might help*

## To simulate the headwaters of the Tagus River basin

- ***To set up a hydrological model with SWAT+***
  - Model construction
  - Introduction of the geological factor and zoning of the model
  - Characterization of subbasins.
- ***To address a multi-spatial calibration of the model.***
  - Soft calibration
  - Results analysis – model ready for hard calibration

# **Study area:** Tagus River headwaters




**Study area location**

- Area: ≈ 7.300 km$^2$
- Significant streams
  **Tagus River**: Flows into Entrepeñas Reservoir
  **Guadiela River:** Flows into Buendía Reservoir
- Singular and varied lithology, from Paleozoic to Quaternary

Temperate Mediterranean climate

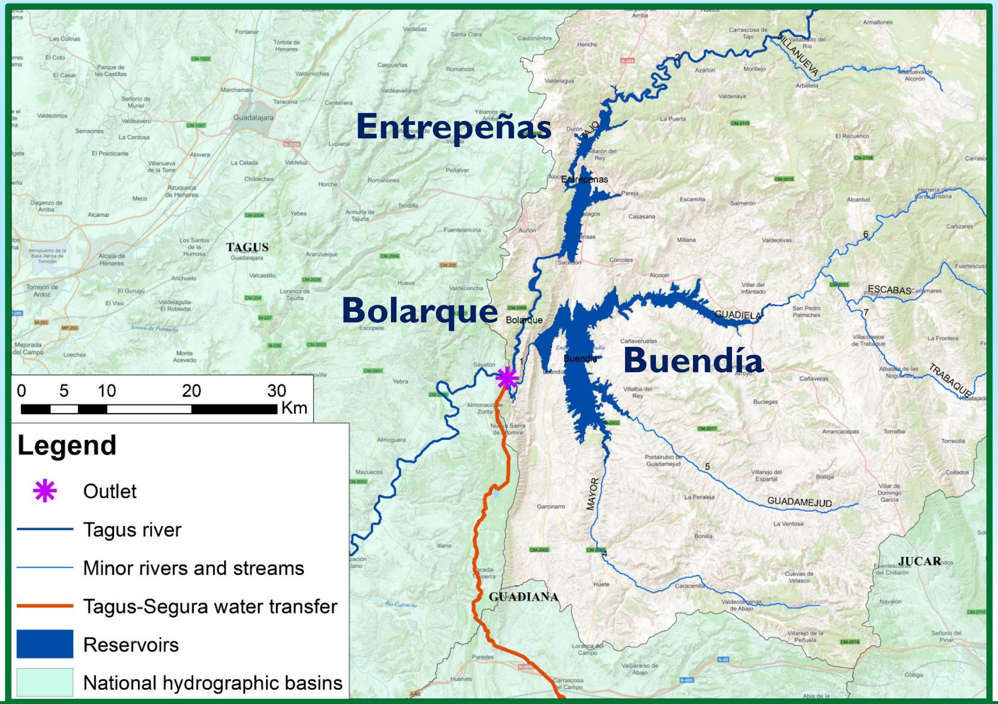
$P_{avg.}$ ≈ 600 mm

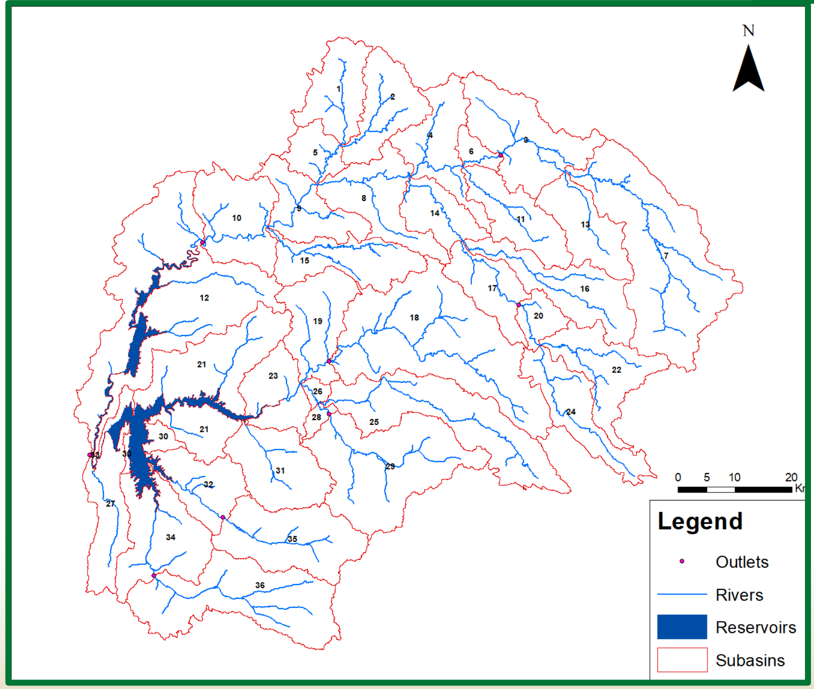
$T_{avg,}$ ≈ 11,5 °C

# SWAT+ model set up

**Inputs:**

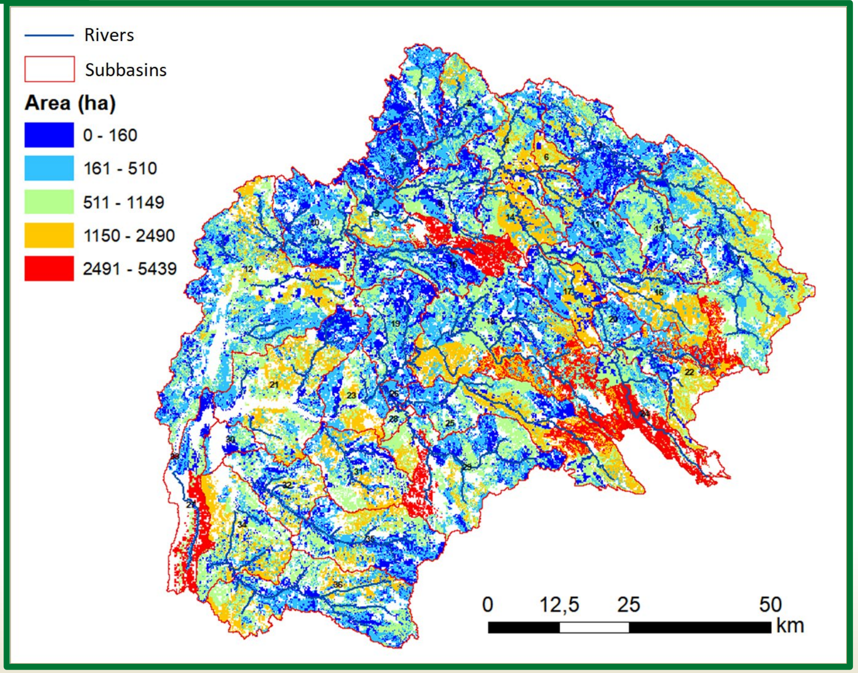
- 25 x 25 m DEM
- Reservoirs shapefile (3)
- 250 x 250 m landuse map
- 250 x 250 m soil types map
- 3 slope classes



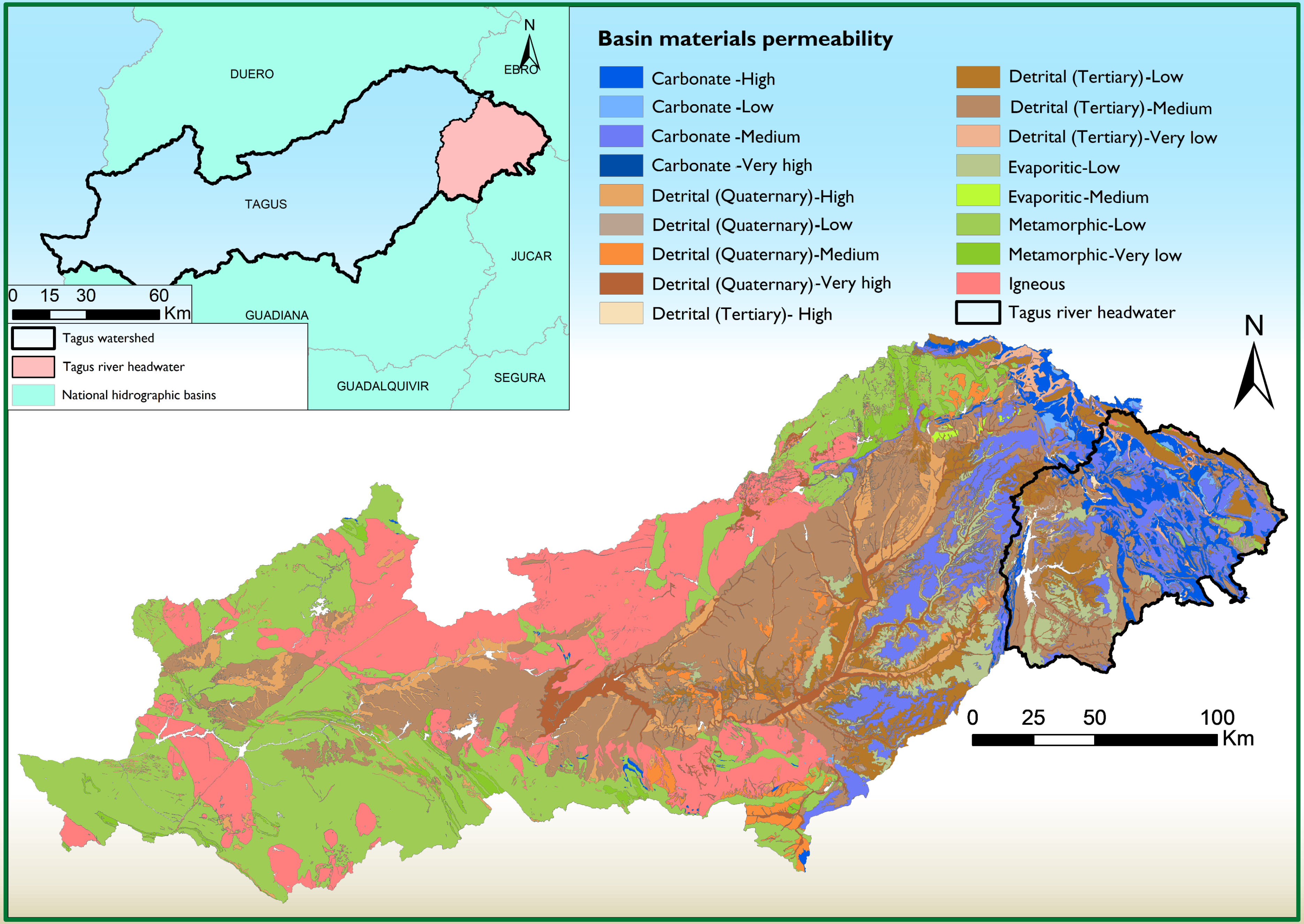




**> 5.000 HRUs**

**36 subbasins**



# **Lithology and permeability:** Geological classes




Tagus basin geology and permeability

# **Lithology and permeability:** Geological zoning

## Geological zoning for model response units:

**Tagus headwaters**

↓

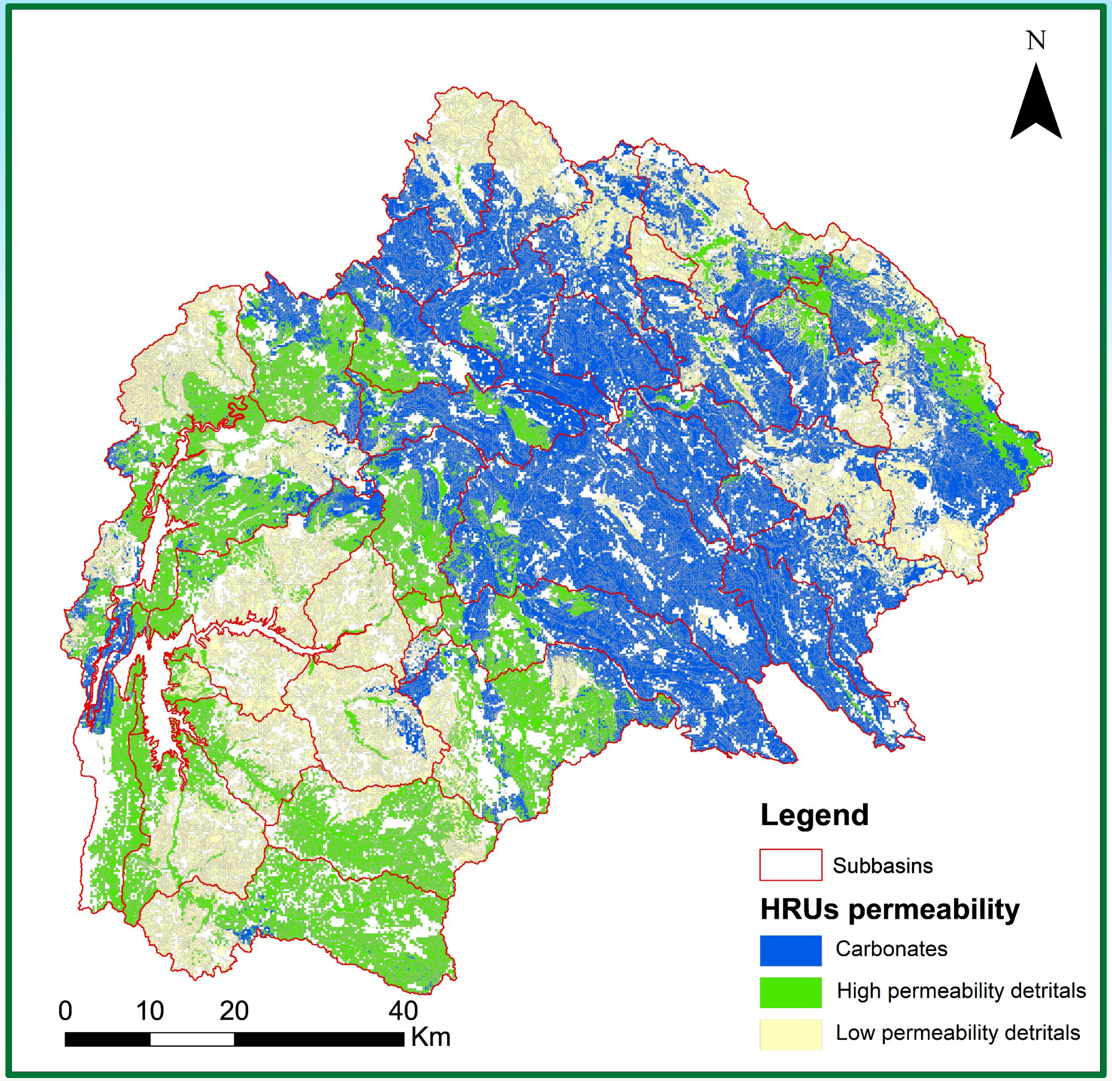
**Introduction of geological factor**

↓

Independent parameterization of similar geological zones for a more realistic model

3 classes created

- **Carbonates (C)**
- **Detrital – High permeability (D-H)**
- **Detrital – Low permeability (D-L)**




Geological zoning model (HRUs).

# **Pre-soft calibration :** Sub-catchments characterization

Choice Sub-catchments

↓

Availibility streamflow records

↓

Characterization (2010-2018)

**Runoff coefficient**

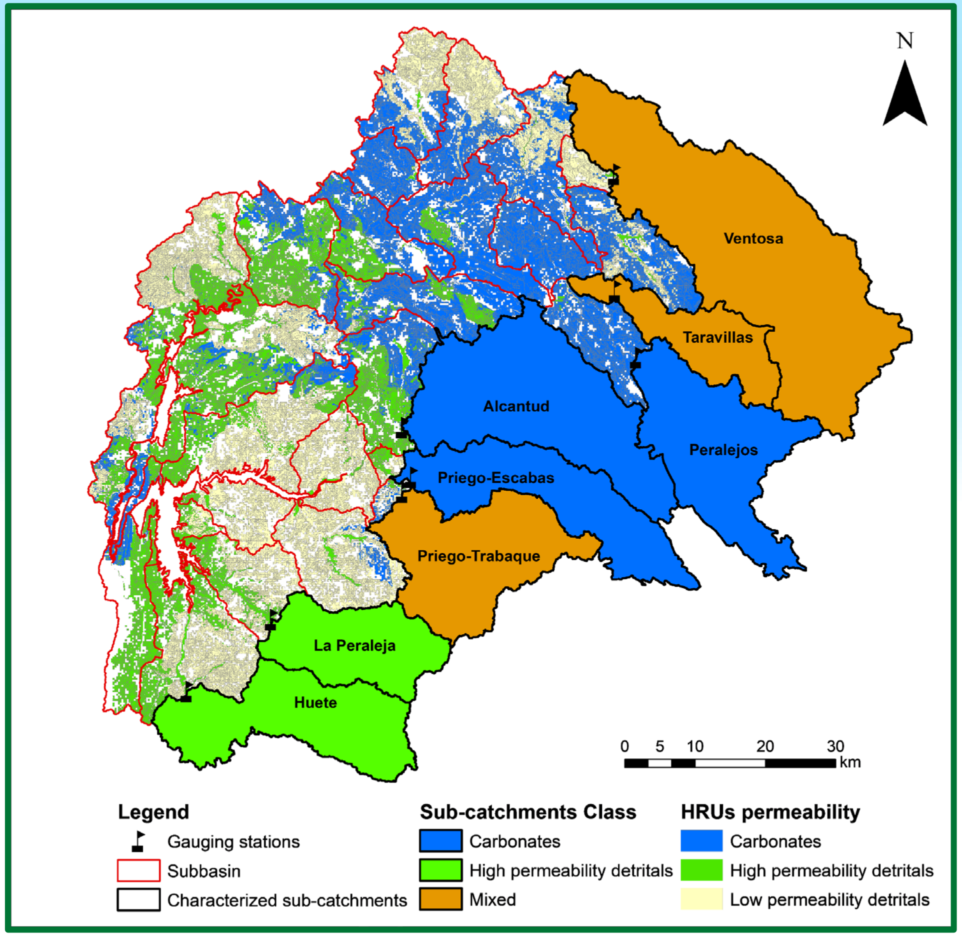
↓

Climate and gauging station data

**Baseflow coefficient**

↓

Hydrograph separation using baseflow filter




| | | |
|---|---|---|
| 13:30 - 15:00 | **Session I2: Hydrology**<br>Mogens Zieler Stuen, Building 1422 | **Friday** |
| 13:30 - 13:50 | **Alejandro Sánchez Gómez**<br>Soft data collection for realistic hydrological modelling: | |

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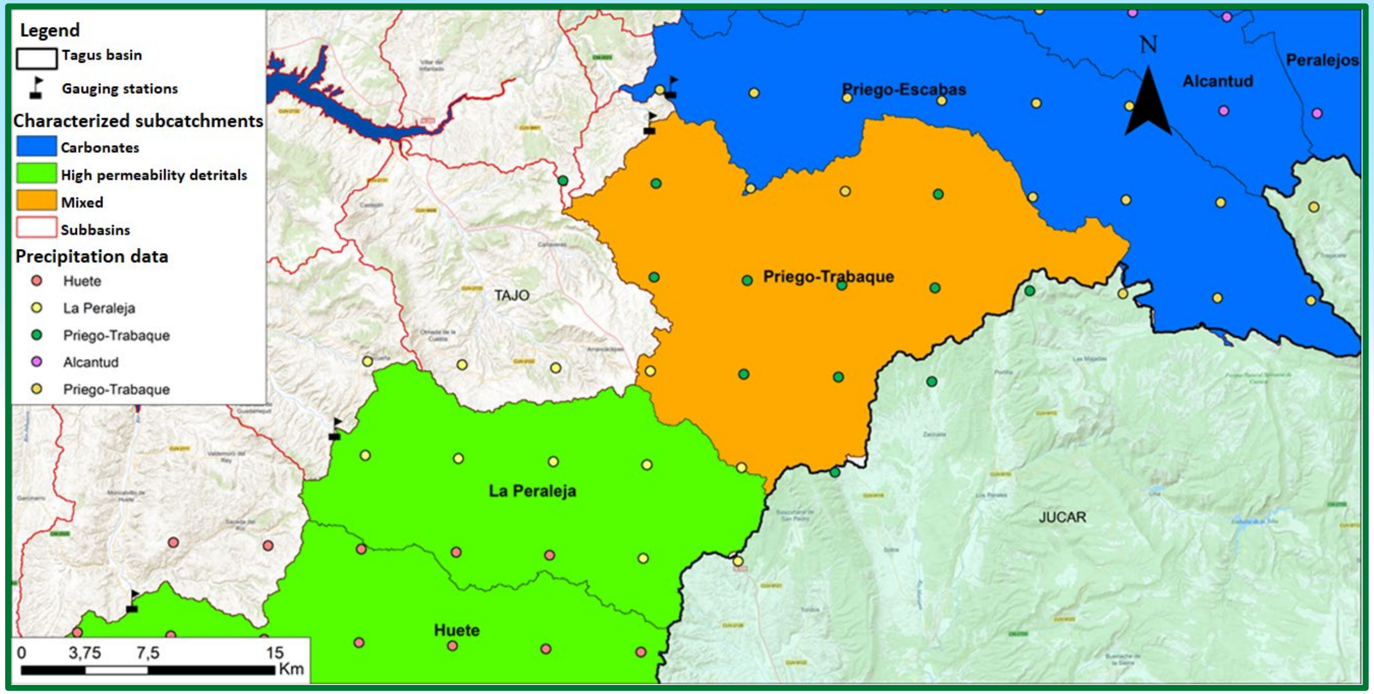
**Runoff coefficient (Streamflow/P)**




Hydrological variables estimated for each sub-catchment

| Sub-catchments | Geology | Rainfall (mm) | Runoff (mm) | Runoff coefficient |
|---|---|---|---|---|
| Peralejos | CRB | 773 | 297 | 0.38 |
| Huete | D-H | 529 | 31 | 0.06 |
| La Peraleja | D-H | 547 | 19 | 0.03 |
| Priego-Trabaque | MIX | 648 | 25 | 0.04 |
| Taravillas | MIX | 699 | 132 | 0.18 |
| Ventosa | MIX | 556 | 44 | 0.08 |
| Alcantud | CRB | 760 | 284 | 0.36 |
| Priego-Escabas | CRB | 734 | 266 | 0.36 |

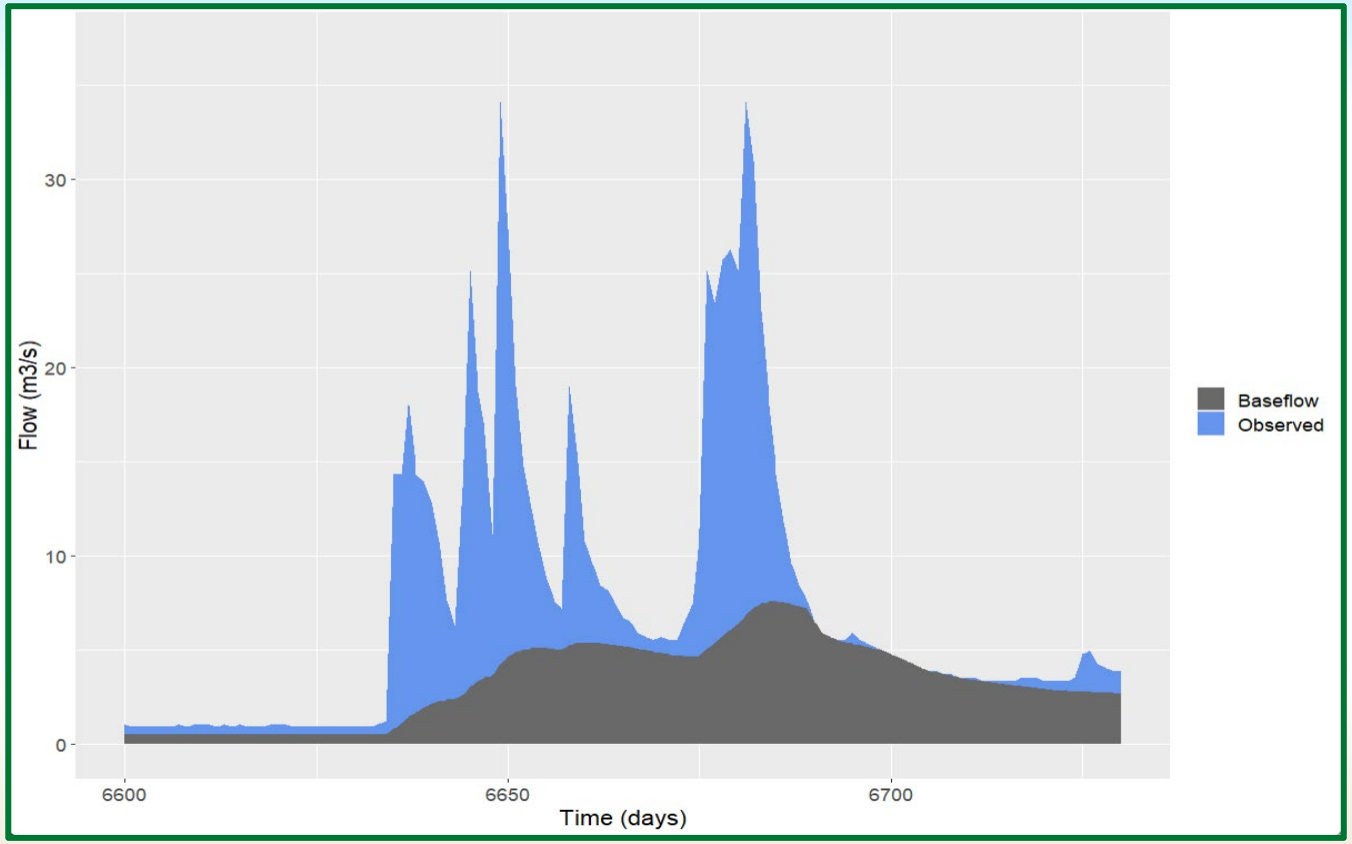
**Large variability**

**Higher values: CRB**

**Lower values: D-H**

# **Presoft-calibration:** Sub-catchments characterization

**Baseflow Coefficient**
**(GW flow / Streamflow)**




**Baseflow filter example**

| CRB | Baseflow coefficient |
|---|---|
| Peralejos | 0.53 |
| Alcantud | 0.52 |
| Priego-Escabas | 0.56 |

| DT-H | Baseflow coefficient |
|---|---|
| Huete | 0.58 |
| La Peraleja | 0.29 |

| Mix | Baseflow coefficient |
|---|---|
| Taravillas | 0.54 |
| Ventosa | 0.56 |
| Priego-Trabaque | 0.34 |

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# **Soft-calibration:** Workflow

**Soft-calibration**

↓

10 parameters / 3 set-ups
(one per geological region)

↓

Run 500 simulations

Scatterplot representation
Parameter value vs:

- **Runoff coefficient**
- **% GWQ contribution**

New parameters' ranges adjustment

***Repeated 3 iterations***

# **Soft-calibration:** Results

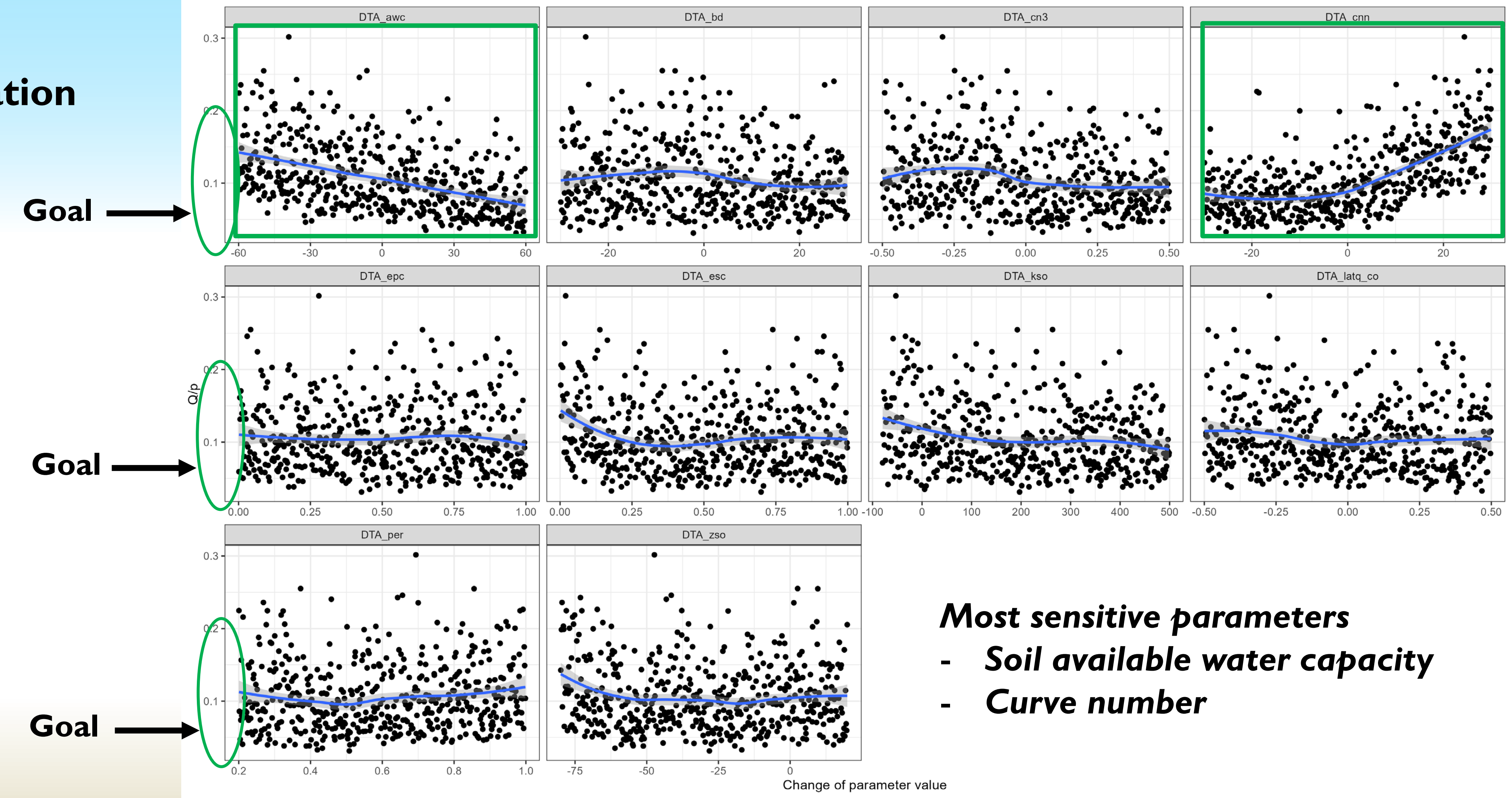
*Iteration 1 example Q/P*

**Runoff coefficient in Huete subcatchment (D-H)**

**Values after first round → ≈ 0.1%**

**Goal value → 0.06**

**1st Iteration**




***Most sensitive parameters***

- ***Soil available water capacity***
- ***Curve number***

# Soft-calibration: Results

## *Iteration III example Q/P*

## Runoff coefficient Huete subcatchment (D-H)

**Final value achieved→ ≈ 0.06%**

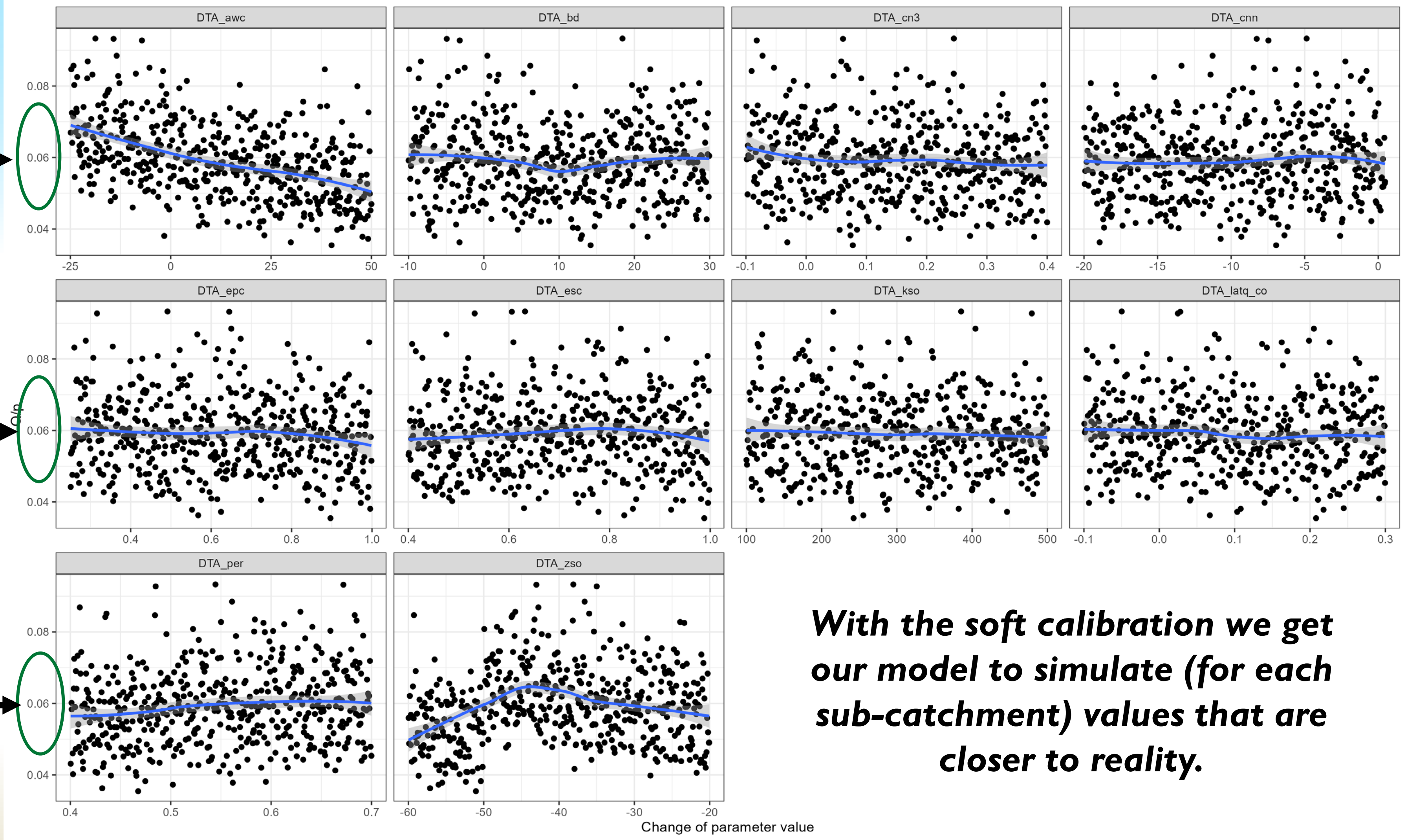
**Goal → 0.06**

## 3rd Iteration

Goal

Goal

Goal

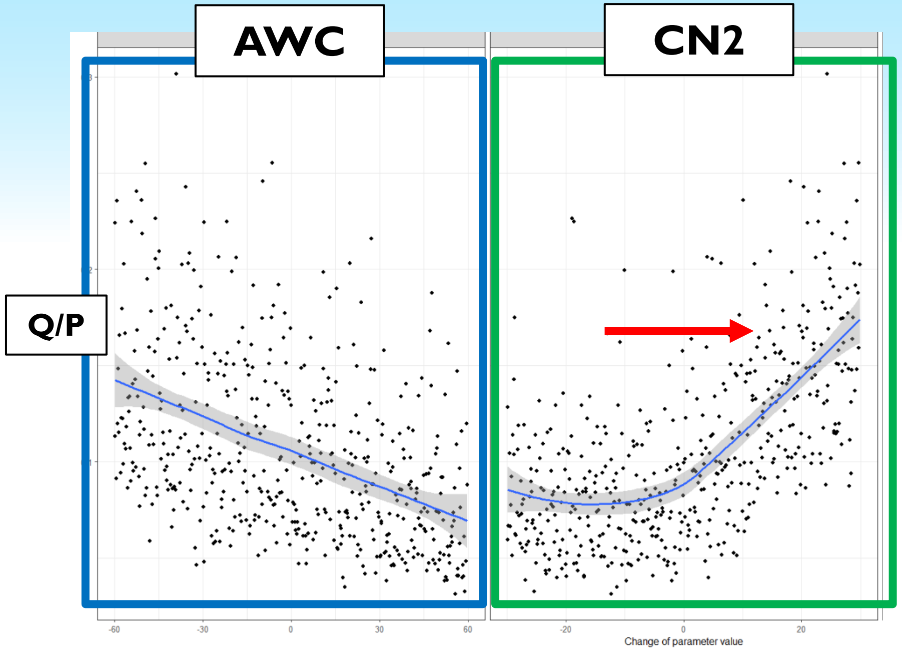



*With the soft calibration we get our model to simulate (for each sub-catchment) values that are closer to reality.*

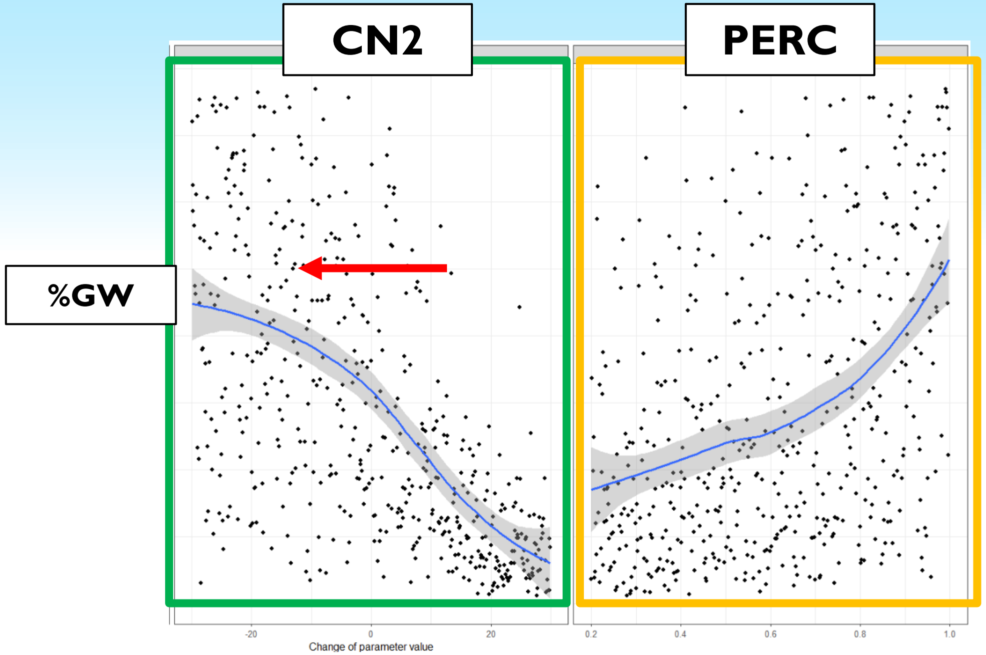
# **Soft-calibration:** Results

**Example for carbonate subcatchment**

**Runoff coefficient:**
**Most sensitive parameters**




**GW contribution:**
**Most sensitive parameters**




Some other parameters showed sensitivity only in a certain geological region
→ eg. Zsoil and BD in carbonate for Q/P and % GW, respectively

**CN-related parameters → Opposite trends for both indices → Challenging**

# **Soft-calibration:** Results

- ☞ Some parameters stay sensible during the entire process (e.g. AWC)
- ☞ Some others gain sensitivity with the process (e.g. KSOIL), others lost it (eg. CN2)

} Depends on the geological region

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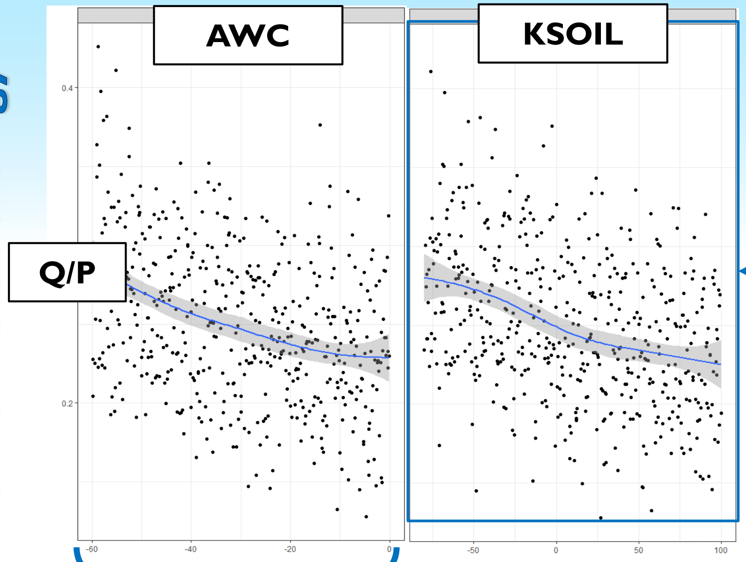
Carbonate lithology

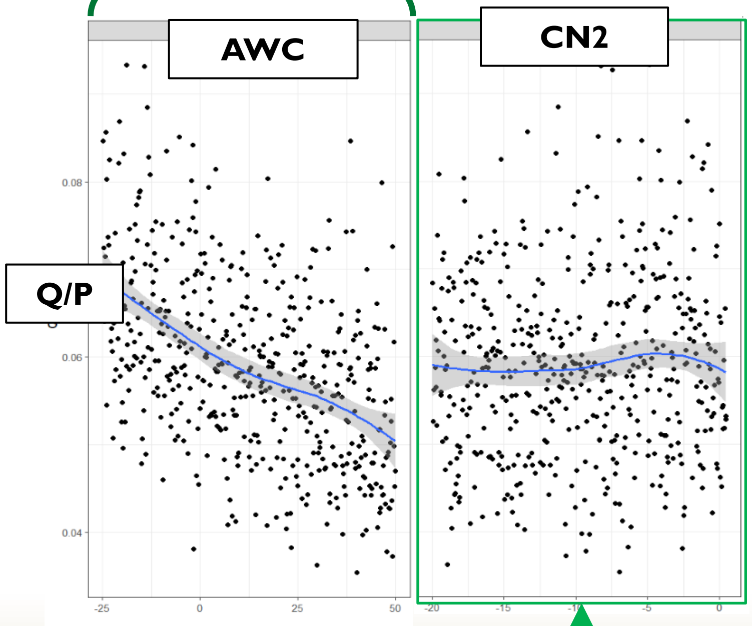



stays sensitive

Becomes sensitive

stays sensitive

Loses relevance




Detrital lithology

# Soft-calibration: Results

| | Coefficients | Obs. Value | Sim. value (It. III) | BIAS % |
|---|---|---|---|---|
| Peralejos | Q/P | **0.38** | 0.25 | 13 |
| | GW rate | **0.54** | 0.38 | 16 |
| Huete | Q/P | **0.06** | 0.06 | 0 |
| | GW rate | **0.58** | 0.44 | 14 |
| La peraleja | Q/P | **0.03** | 0.05 | 2 |
| | GW rate | **0.29** | 0.50 | 24 |
| Priego Trabaque | Q/P | **0.04** | 0.09 | 5 |
| | GW rate | **0.34** | 0.43 | 9 |
| Taravilla | Q/P | **0.18** | 0.16 | 2 |
| | GW rate | **0.54** | 0.38 | 16 |
| Ventosa | Q/P | **0.08** | 0.10 | 2 |
| | GW rate | **0.57** | 0.51 | 6 |
| Alcantud | Q/P | **0.36** | 0.23 | 13 |
| | GW rate | **0.52** | 0.54 | 2 |
| Priego Escabas | Q/P | **0.36** | 0.17 | 19 |
| | GW rate | **0.58** | 0.44 | 14 |

**AVERAGE BIAS**

**Q/P**

**ITERATION I**

**12% BIAS**

**- 2%**

**ITERATION II**

**10% BIAS**

**- 3 %**

**ITERATION III**

**7 % BIAS**

**GW rate**

**ITERATION I**

**25% BIAS**

**- 7%**

**ITERATION II**

**18% BIAS**

**- 6 %**

**ITERATION III**

**12 % BIAS**

## AVERAGE BIAS PER REGION

| | Q/P (%) | GW rate (%) |
|---|---|---|
| Carbonate | 15 | 11 |
| D- H | 1 | 17 |
| Mixed | 3 | 10 |

**Carbonate subcatchments**

⇩

**More challenging**

⇩

**Highest runoff coeficient and large GWQ contribution → parameters' contradiction**

**Mixed sub-basins**

⇩

**Combination of updating ranges in three separate geological regions**

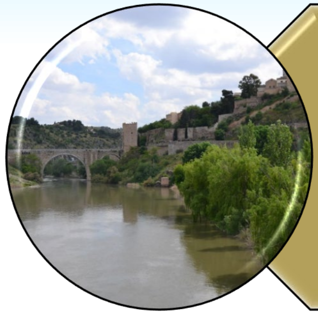
⇩

**Satisfactory results**

⇩

**Proves the usefulness of the method**

Best results were obtained for the runoff coefficient



Values achieved for both calibrated indices were closer to expected targets in D-H and MIX subcatchments

After soft calibration, average BIAS was 7% and 12% for the runoff and groundwater rates, respectively

# Conclusions

- *A detailed SWAT+ model has been set up for the Tagus River headwaters*
- *The model has been parameterized differentiating 3 geological regions*
- *A soft calibration procedure has been designed, optimizing parameter ranges towards two indices: the runoff coefficient and the % of groundwater contribution.*
- *Results were extracted at 8 sub-catchments, and parameters showed different sensitivities depending on both the target index and the geological region*
- *The methodology applied was satisfactory, achieving the target values in both indices*
- *This work guarantees a more realistic and robust model prior to addressing a hard calibration*

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# **Soft-calibration:** Procedure

| Parameter | Type Change | Setting range values **(Round III)**: Carbonate | High perm. detritals | Low perm. detritals |
|---|---|---|---|---|
| **esco** | absval | (0.001 , 0.99) | (0.4 , 0.99) | (0.2 , 0.8) |
| **epco** | absval | (0.001 , 0.4) | (0.25 , 0.99) | (0.001 , 0.75) |
| **cn2** | pctchg | (-10 , 20) | (-20 , 0.5) | (-10,10) |
| **cn3** | abschg | (-60 , 0) | (-25,50) | (-40,20) |
| **perco** | absval | (0.75 , 0.99) | (0.4 , 0.7) | (0.25,0.99) |
| **latq_co** | abschg | (-50,-10) | (-60 , -20) | (-60 , 10) |
| **awc** | pctchg | (-80 , 100) | (100 , 500) | (-100,250) |
| **z.sol** | pctchg | (-0.2,0.2) | (-0.1 , 0.4) | (-0.1 , 0.4) |
| **k.sol** | pctchg | (-30 , 0) | (-10,30) | (-30 , 10) |
| **bd.sol** | pctchg | (-0.5 , 0.1) | (-0.1,0.3) | (-0.5 , 0.1)) |

**Sensitive parameter values took different final ranges in each region**

**Parameter name** (optional) The user can define a unique parameter name. If a name is defined it must be separated with '::'

**SWAT parameter** (required) The SWAT parameter name and the suffix of the file where this parameter is found must be provided.

**Separator** (required) All definitions are separated by a pipe operator '|'

**Type of change** (required) change types are:
- absval (absolute value)
- abschg (absolute change)
- pctchg (percent change)
- relchg (relative change)

**Conditions** (optional) Conditions can be added to constrain parameter changes e.g.spatially or typologically

```
"par_name::parameter.file_suffix | change = change_type | condition A | condition B"
```

```
'CRB_esc::esco.hru | change = absval | unit =          c(60:66) = c(0.001 , 0.999),
```

**SWATplus R logo.**

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