*iEMSs Conference 2020*
*International Environmental Modelling and Software Society*

# Assessing the Transferability of a Conceptual Rainfall Runoff Model within the Medjerda catchment (Tunisia)

**Ahlem Gara, Khouloud Gader, Slaheddine Khlifi, Christophe Bouvier, Marnik Vanclooster**

# ❖Introduction

- **Issues and general framework**

Spatial and temporal irregularity of WR/ rainfall!!
Multiplication of extreme events

Developping a simple Rainfall-runoff modelling with a minimum of input data?

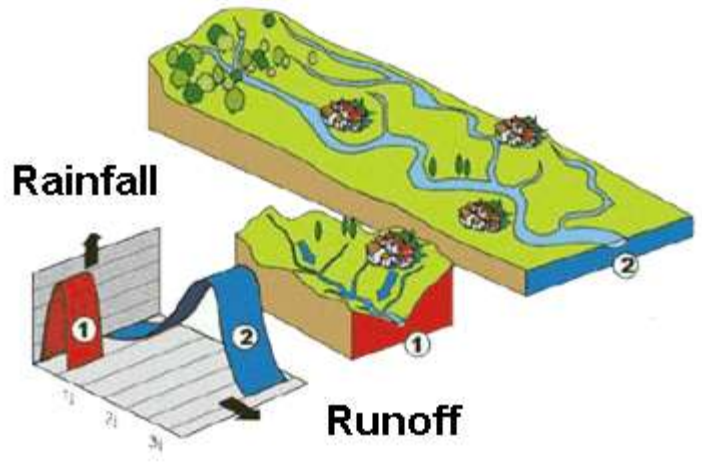
Medjerda waterway: The only permanent waterway with problems related to data quality and quantity!!!

Management of water resources in the Northern region of Tunisia with integration of CC?

Difficulties to predict runoff for ungauged catchments within the Medjerda!!

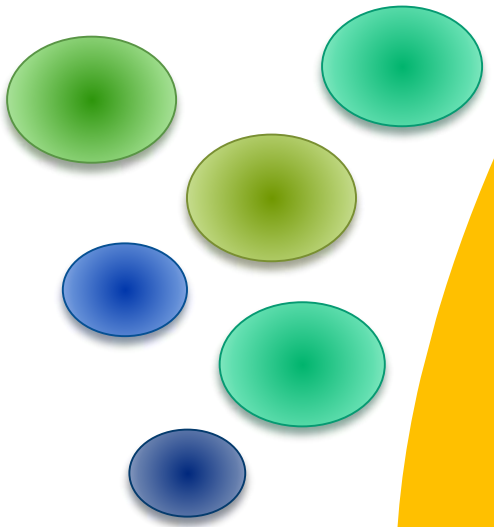
# • Objectives

## Goal 1



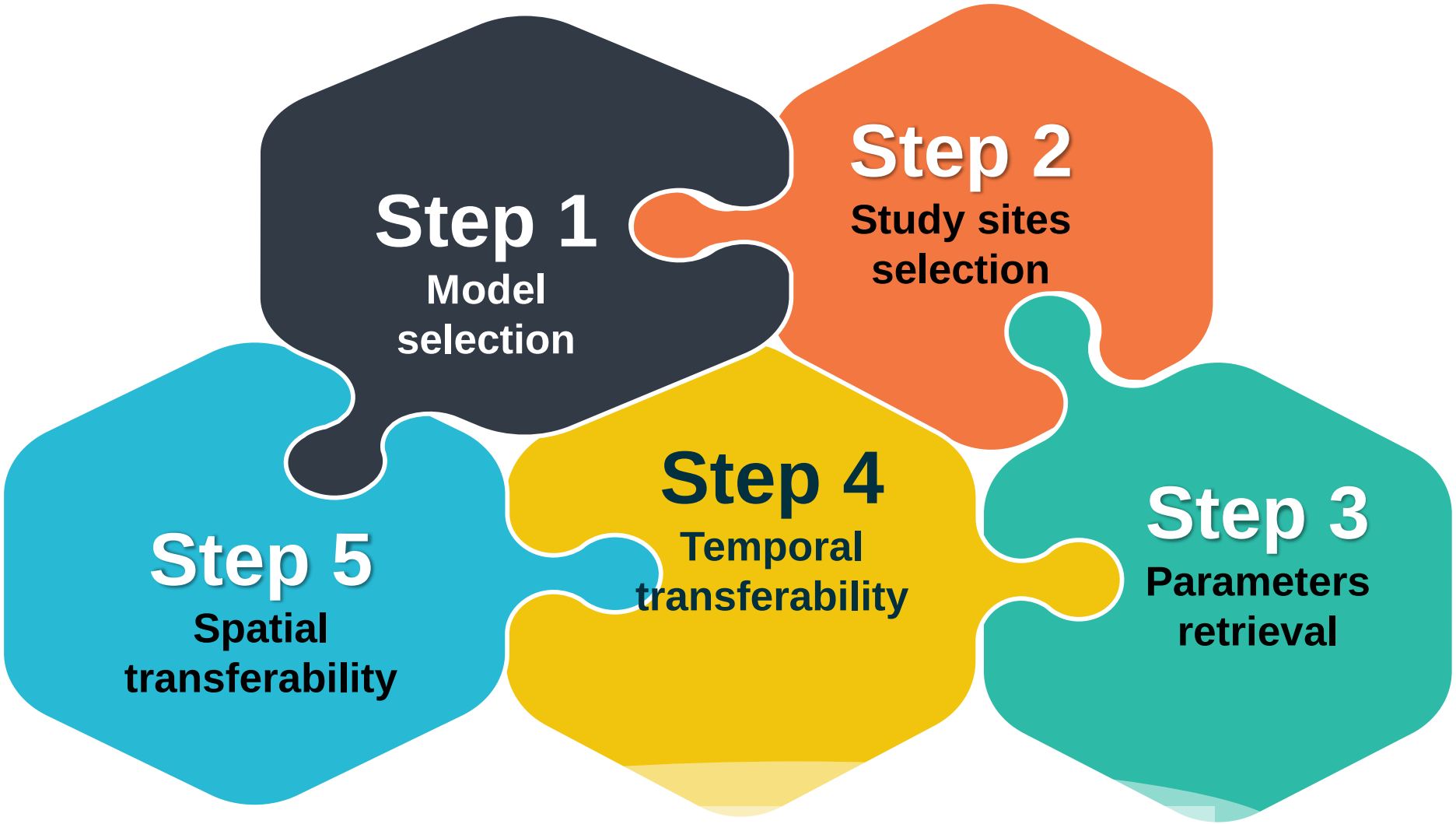

To apply a simplified and modified version of a conceptuel RR model of the Medjerda catchment

## Goal 2

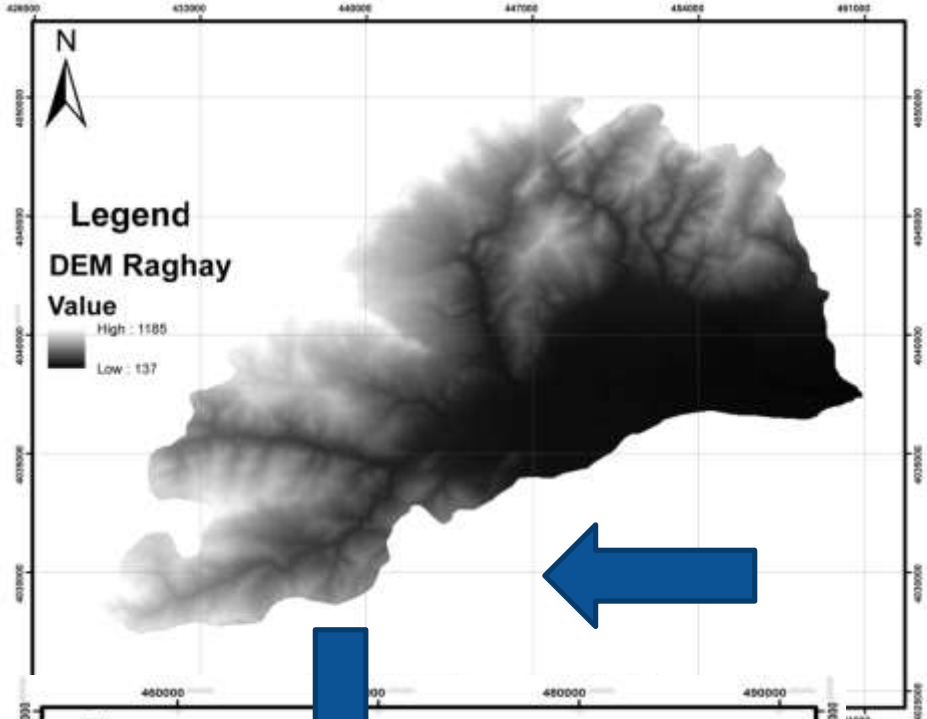


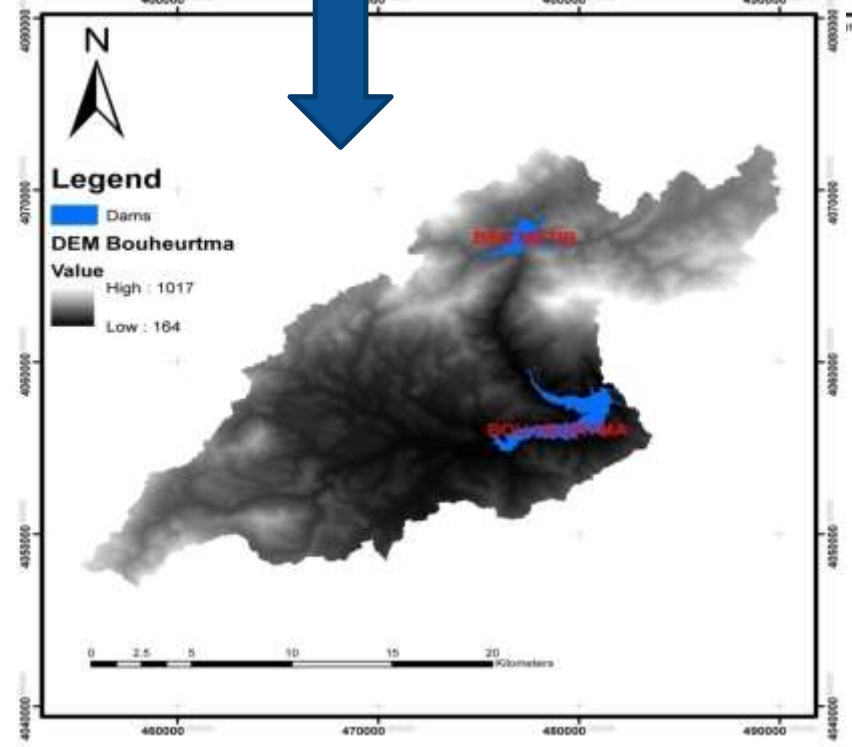
To analyse the spatial and temporal transferability of the RR model in the Medjerda catchment

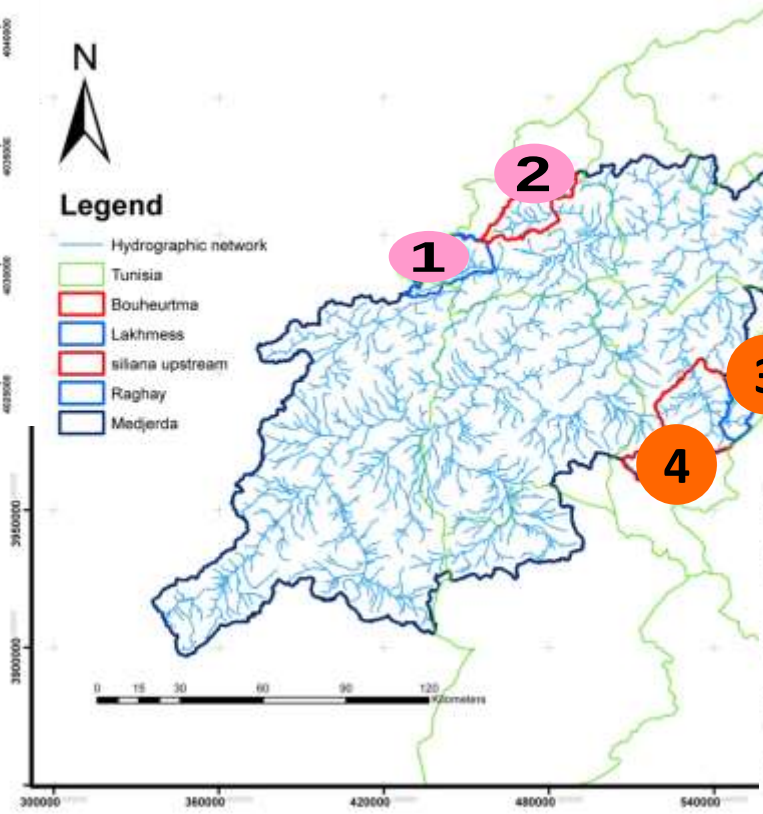
# ❖Methodology

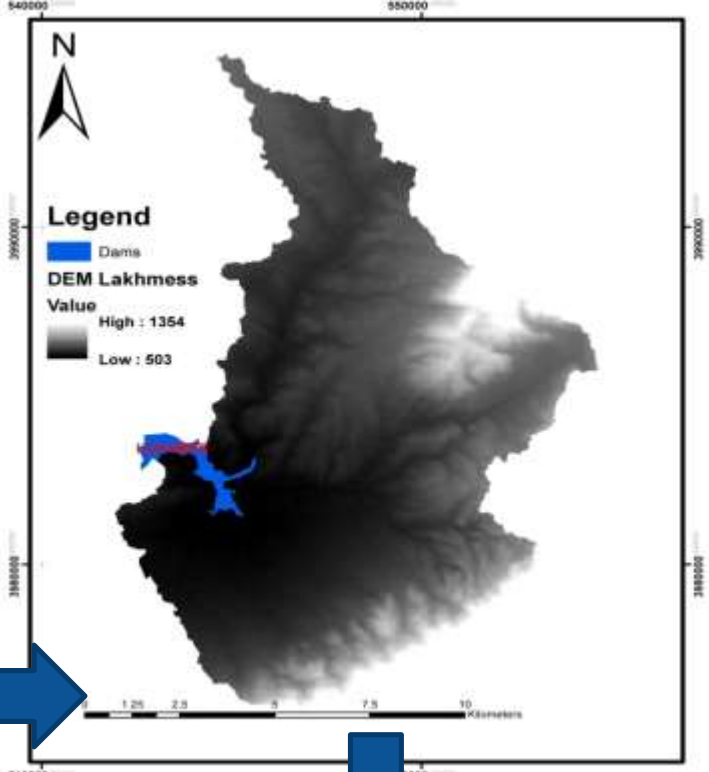


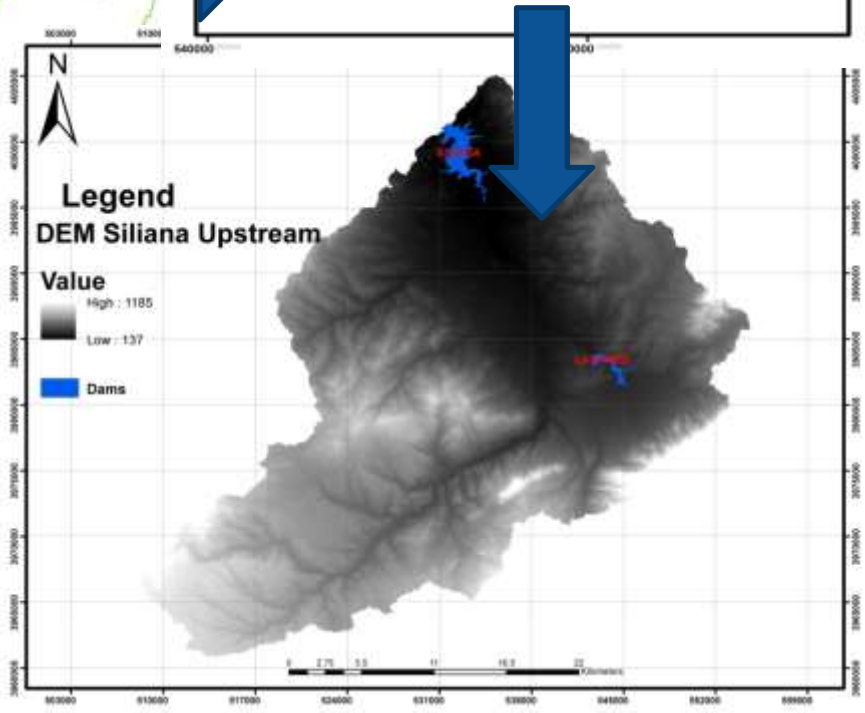

- **Methodology flowchart**


N
Legend
DEM Raghay
Value
High : 1185
Low : 137


N
Legend
Dams
DEM Bouheurtma
Value
High : 1017
Low : 164


N
Legend
Hydrographic network
Tunisia
Bouheurtma
Lakhmess
siliana upstream
Raghay
Medjerda
1
2
3
4


N
Legend
Dams
DEM Lakhmess
Value
High : 1354
Low : 503

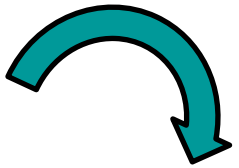

N
Legend
DEM Siliana Upstream
Value
High : 1185
Low : 137
Dams

- **Study sites**

# Physiographic Characteristics of the donor catchments

## 1 The Raghay

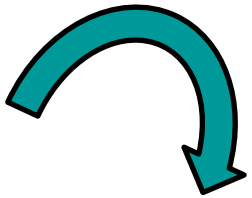
| S ($km^2$) | P (km) | $L_t$ (km) | $Alt_{max}$ (m) | $Alt_{min}$ (m) | $L_r$ (km) | $I_r$ (km) | $k_c$ |
|---|---|---|---|---|---|---|---|
| 362 | 106.44 | 43.650 | 1183 | 138 | 45.148 | 8.106 | 1.57 |



Stretched shape

## 3 • The Lakhmess

| S ($km^2$) | P (km) | $L_t$ (km) | $Alt_{max}$ (m) | $Alt_{min}$ (m) | $L_r$ (km) | $I_r$ (km) | $k_c$ |
|---|---|---|---|---|---|---|---|
| 127 | 54.5 | 43.650 | 1354 | 503 | 18.833 | 8.600 | 1.207 |



rectangle shape

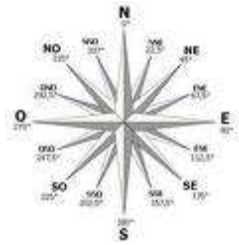
# Climatology

## 1 • The Raghay

Between 450mm and 1200 mm

winter mean minT 5.2°C in January
summer mean max T 36.8°C in August


South-West in August and North-West in Winter
Mean speed: 3 à 5 km/h




## 3 • The Lakhmess

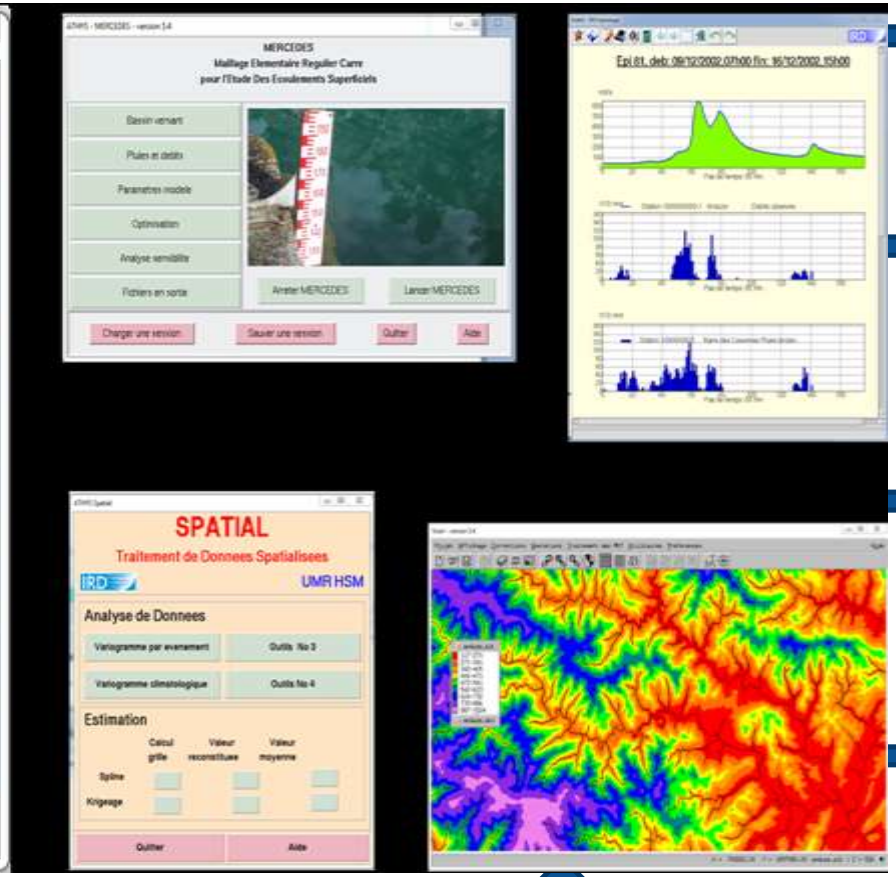
Between 300mm and 600 mm

winter mean minT 3.8 °C in February
summer mean max T 36.4°C in July

North-West in August and North-West in Winter
Mean speed: 4.6 à 5.9 km/h

# • Rainfall-Runoff Model

## ▪Components of the ATHYS software


File of elevations

File of corrected direction of draining

File of slopes

File of hydrographic network

DEM

*(http://www.athys-soft.org).*

# ▪Justification of the software choice

- Distributed software, permetting the correction of the maps and the generation of its own derived maps
- Time-step of entries is very variable: from few minutes to days and can be used for a continuous or single event
- Variety of production and transfer functions :mathematical, conceptual and physically based
- Tested on different types of Mediterranean basins
- Allowing to modify, to add or to simplify parameters
- Multivariable field of application : Simulation of runoff in the outlets, dimensionning and managing hydraulic constructions, prediction of floods and base flow
- **Conceptual hydrological modelling using a modified version of the SCS-SMA-LR model with PE**

# Modified runoff model

p(t)

Runoff rate

$$R(t) = p(t) \times C(t)$$

PE(t)

Intensity of infiltration

$$f(t) = (1 - C(t)) \times p(t)$$

Subsurface delayed runoff

$$D(t) = \omega \times E(t)$$

Linear emptying intensity

V(t): Level of the soil reservoir

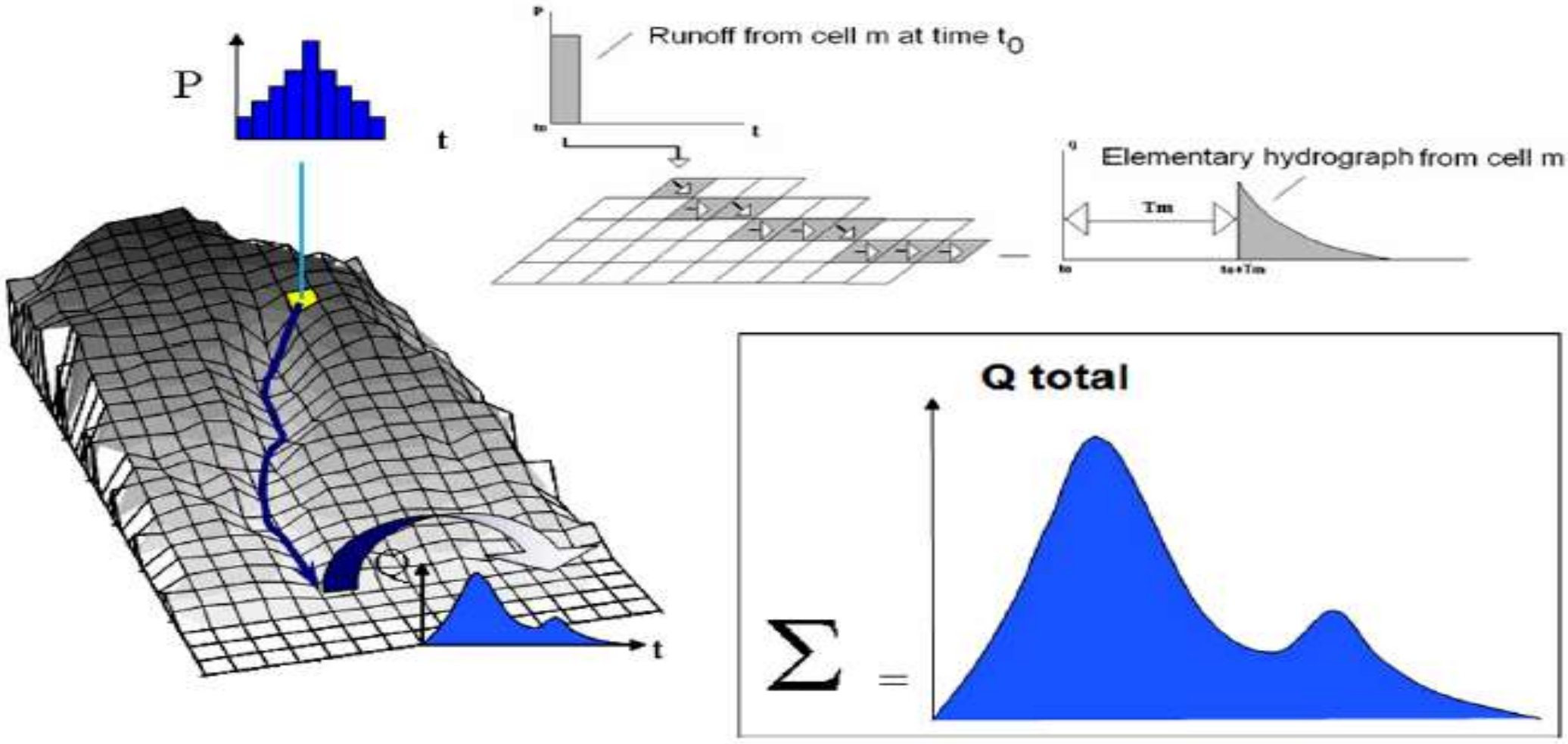
$$\frac{dV(t)}{d(t)} = f(t) - E(t) - PE(t)$$

Soil reservoir

$$E(t) = ds \times V(t)$$

Adapted from (Gara et al. 2020)

# Routing model




Adapted from (Tramblay et al. 2011)

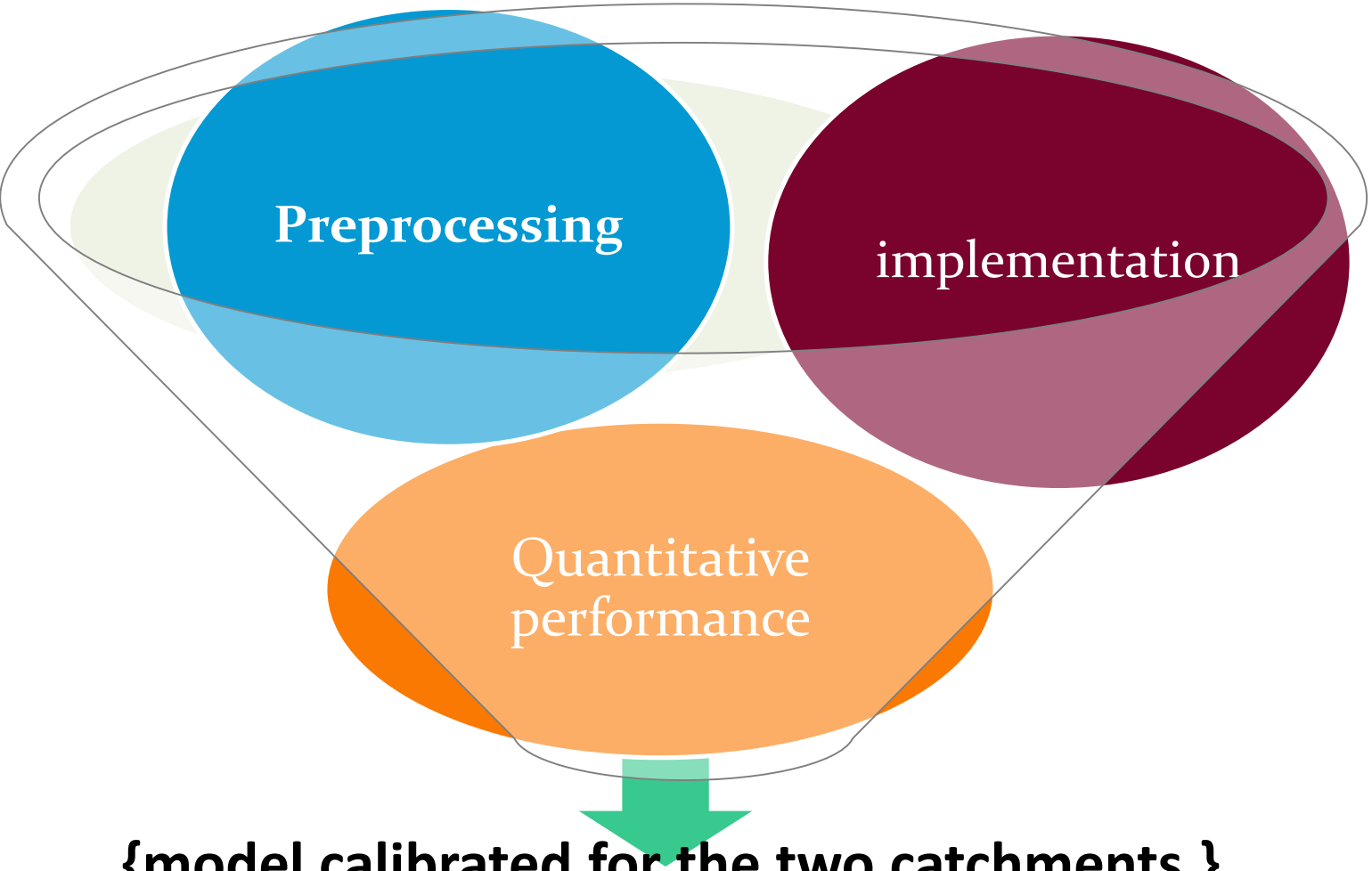
- Data

## Input data for the model implementation in the Raghay and Lakhmess catchments (donor catchments)

| Data type | Source | Description |
|---|---|---|
| **Discharge flow** | DGBGTH (Ministry of Agriculture Tunisia) and DGRE (Ministry of Agriculture Tunisia) | Daily water balance of “Lakhmess dam “station and daily discharge flow of the “Raghay plaine” station (1990-2017) |
| **Rainfall** | DGRE (Ministry of Agriculture Tunisia) | Daily rainfall data from 2 rainfall stations (The Lakhmess catchment) and from 6 rainfall stations (the Raghay catchment) (1990-2017) |
| **DEM** | https://gdex.cr.usgs.gov/gdex/ | 30 meter resolution Aster GDEM image , mission of 19 June 2014 |
| **PE Penman** | National Institute of Meteorology | Siliana climatic station and Jendouba climatic station (1990-2017) |

# • Modelling procedure

## ▪Calibration procedure on the donor catchments




**{model calibrated for the two catchments }**

**Model preprocessing**

Preparing input data under the ATHYS platform and obtain derived maps and hydro-climatic data per rectangular mech

**Model implementation**

**Model's performance quantification**

Using the BLUE optimisation method (Best Linear Unbiaised Estimator)

# Modelling accuracy evaluation

| Evaluation criteria | Formula | Value | Performance ranking |
|---|---|---|---|
| **1*. Nash-Sutcliffe (NS)** | $1-\frac{\sum_{i=1}^{n}(S_i-O_i)^2}{\sum_{i=1}^{n}(O_i-\overline{O})^2}$ | NS>0.7 | Good and very good |
| | | 0.5<NS<0.7 | Acceptable |
| | | NS< 0.5 | Inacceptable |
| **2*. Root Mean Square Error (RMSE)** | $\left(\sqrt{\frac{\sum_{i=1}^{n}(S_i-O_i)^2}{N}}\right)$ | Value below half of the standard deviation | Satisfactory |
| **3*. Ratio of the RMSE to the standard deviation of the observed Q, (RSR)** | $\frac{\left(\sqrt{\sum_{i=1}^{n}(O_i-S_i)^2}\right)}{\left(\sqrt{\sum_{i=1}^{n}(O_i-\overline{O})^2}\right)}$ | RSR<0.6 | Good and very good |
| | | 0.6<RSR<0.7 | Satisfactory |
| | | RSR>0.7 | Unsatisfactory |
| **4*. Percent BIAS** | $\frac{\sum_{i=1}^{n}(O_i-S_i)\times 100}{\sum_{i=1}^{n}(O_i)}$ | Pbias <= + or – 0.15 | Good and very good |
| | | +or- 0.15<Pbias<+or – 0.25 | Satisfactory |
| | | Pbias > (+or - 0.25) | Unsatisfactory |
| **5*. Kling-Gupta efficiency** | $1-\sqrt{(r-1)^2+(\alpha-1)^2+(\beta-1)^2}$ | KGE > (0.5) | Satisfactory |

***Ref**: 1 :(Nash and Sutcliffe 1970), 2 and 3: (Moriasi et al. 2007), 4: (Singh et al. 2004), 5: (Gupta et al. 2009)

# Temporal transferability


**Calibration period C0 (1990-1994)** — Calibration of the model for the two catchments

**Evaluation period C1 (1994-1997)** — Using the obtained parameters for each catchment for the first evaluation period

**Evaluation period C2 (2001-2004)** — Using the obtained parameters for each catchment for the second evaluation period

**Evaluation period C3 (2014-2017)** — Using the obtained parameters for each catchment for the third evaluation period

# ▪Spatial transferability

**Receptor catchment (Catchment 2)**

**Receptor catchment (Catchment 4)**

**The left bank of the Medjerda**

•Calibrated parameters transferred to the nearest catchment fed by the same watershed, The Bouheurtma catchment with a similar area as for the donor catchment and with data input from 2008-2017

**The right bank of the Medjerda**

•Calibrated model was upgraded to 10 times greater catchment, The Siliana Upstream catchment which is fed by the same watershed including the donor catchment, for the data input from 1994-2016.

**Based on:**

•Data availability

•Spatial proximity

•Similarity Index

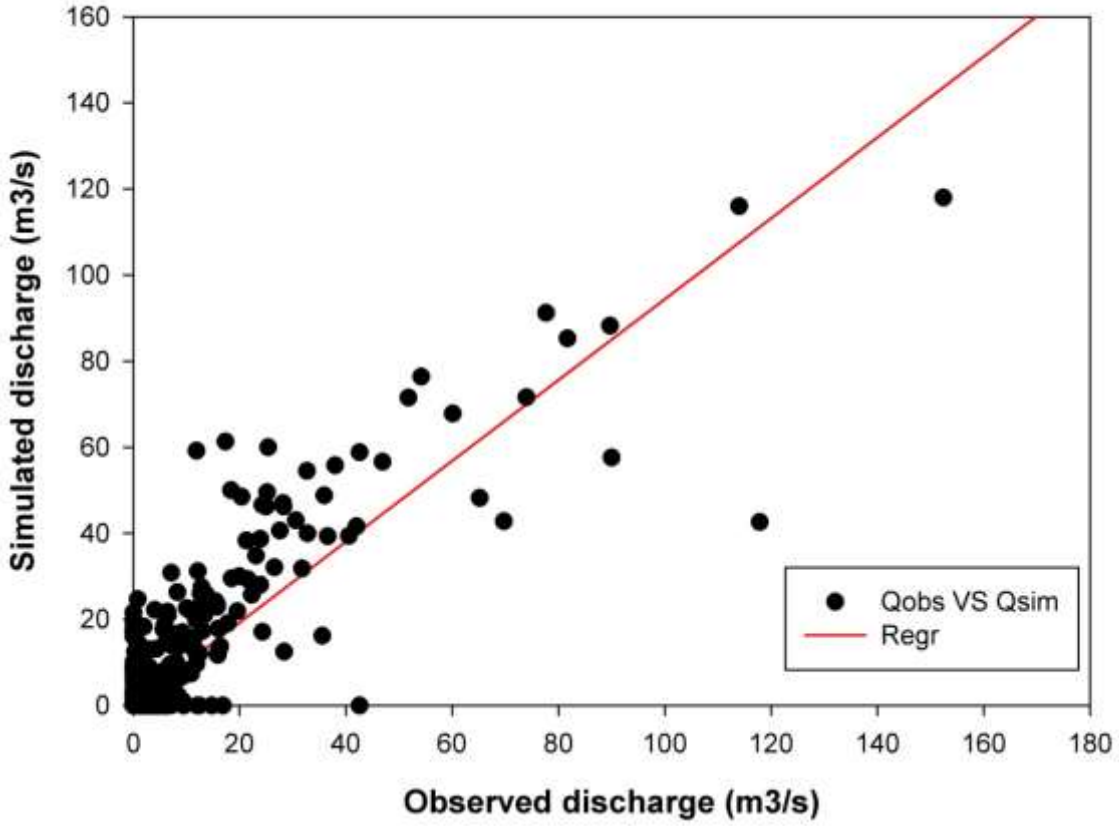
# ❖Results and discussion

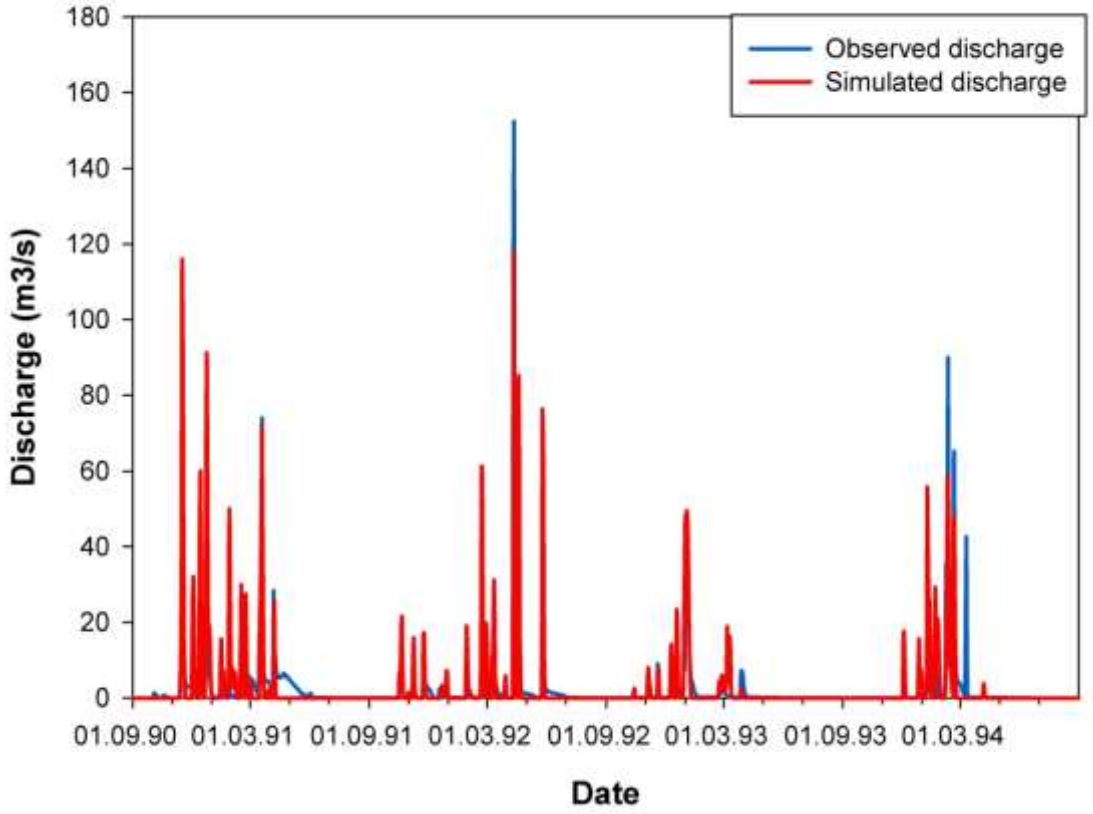
- **Calibration on the two donor catchments on C0**

  - **The obtained evaluation criteria for the two donor catchment calibrated on C0**

| Accuracy criteria | The Raghay | The Lakhmess |
|---|---|---|
| NS (%) | 71 | 86 |
| RMSE (%) | 5.1 | 6.72 |
| RSR | 0.53 | 0.42 |
| PBIAS | 0.15 | 0.11 |
| KGE(%) | 73 | 85 |

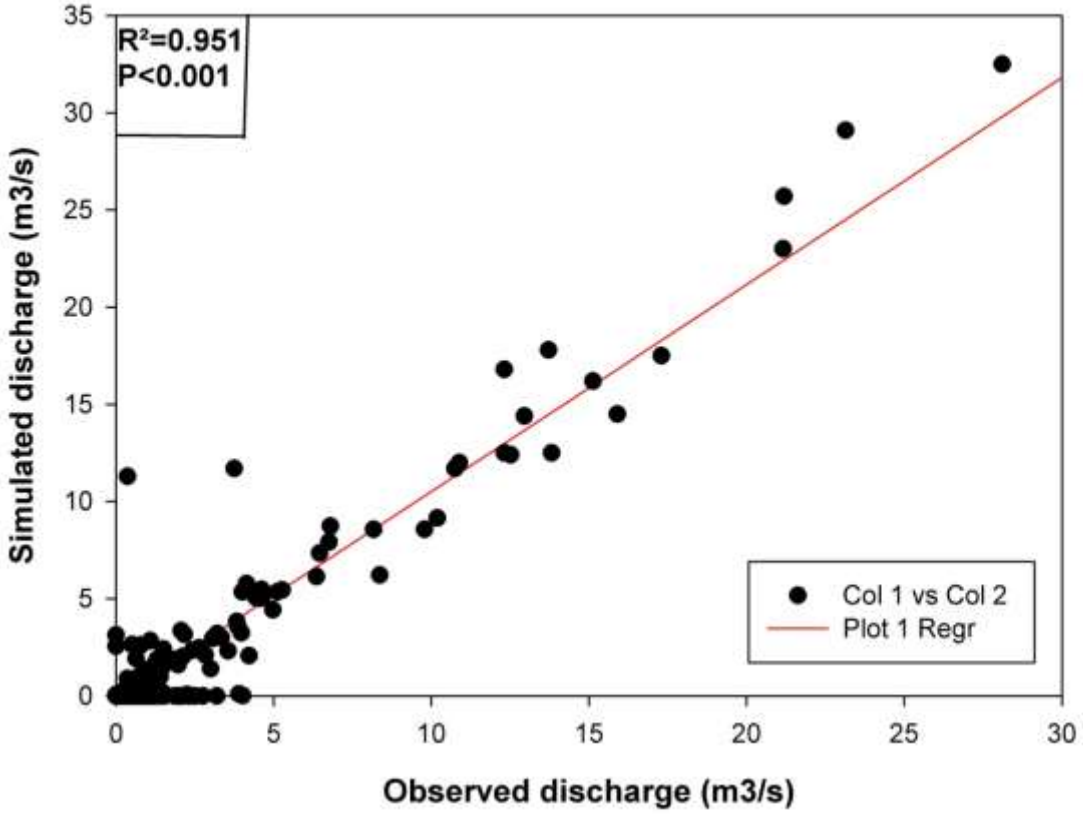
# Graphical results for the Raghay catchment

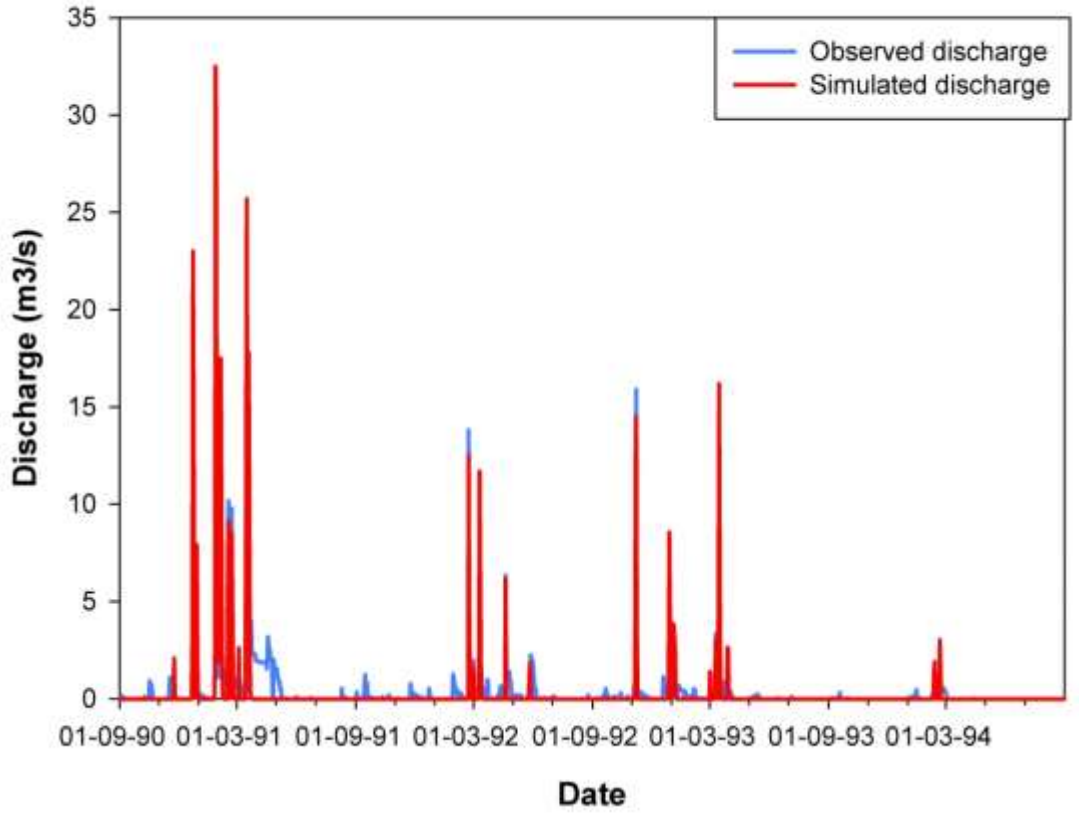



**Scattered plot and timeline presentation of the calibration on C0 for the Raghay**

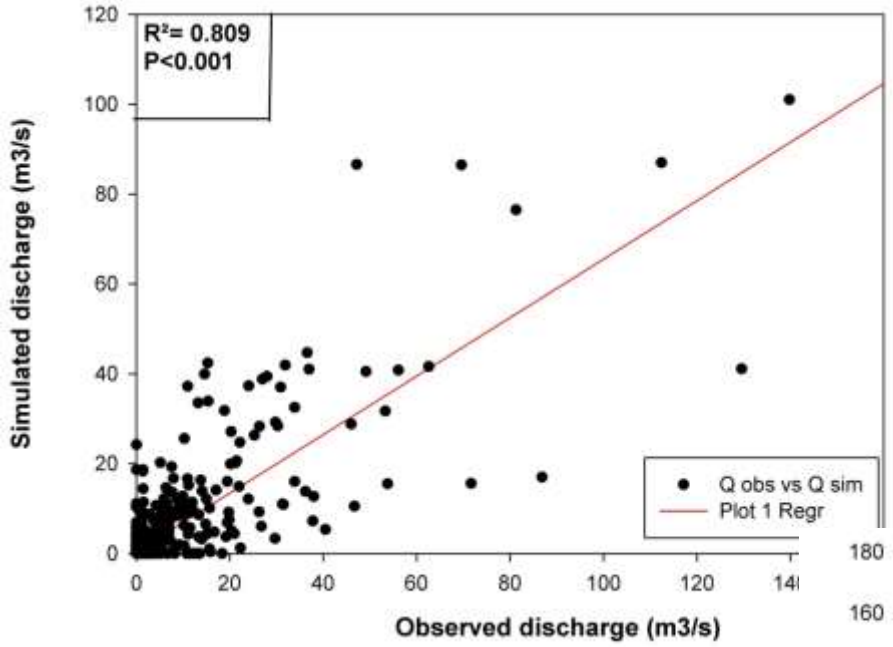
# Graphical results for the Lakhmess catchment




**Scattered plot and timeline presentation of the calibration on C0 for the Lakhmess**

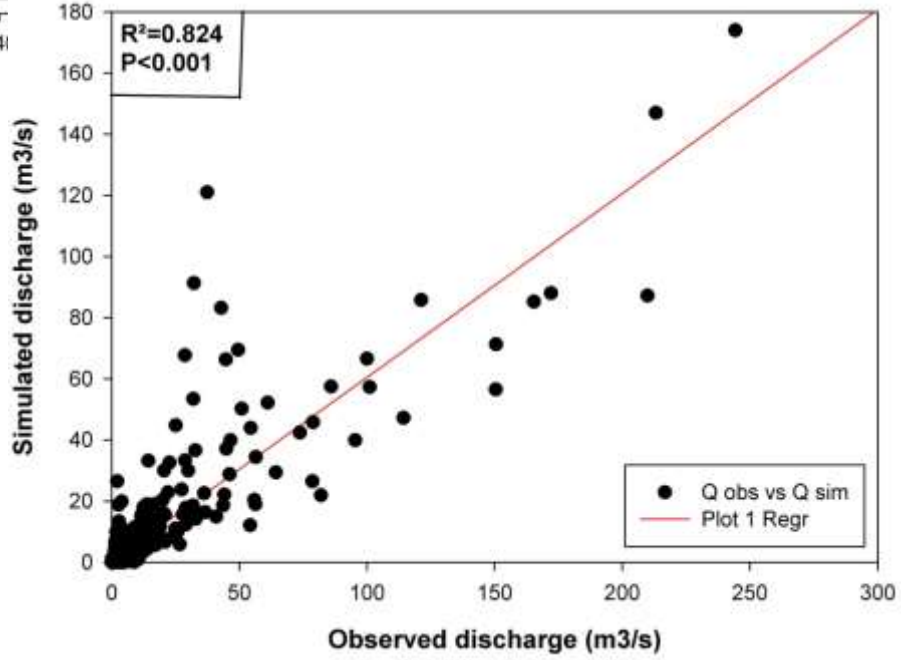
# • Temporal transferability on the donor catchments

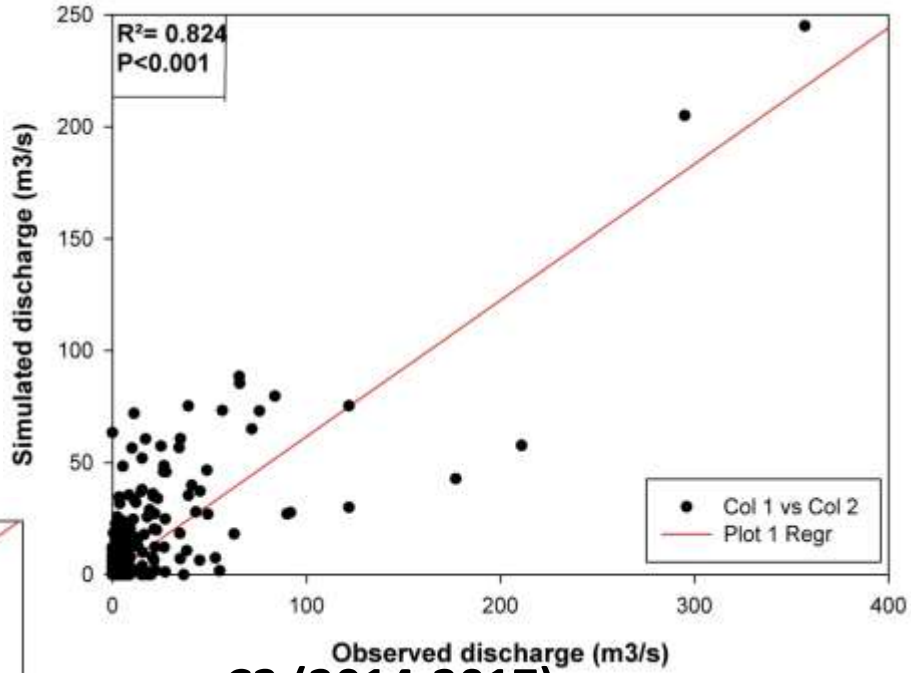



**C1 (1994-1997)**
**NS**: 0.64

## ▪ Diachronic analysis on the Raghay

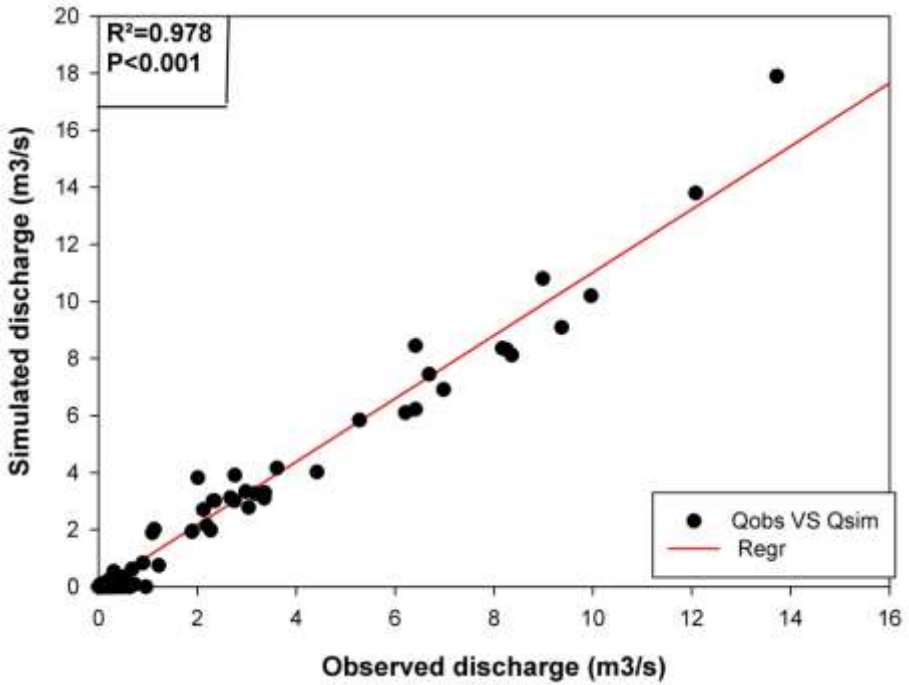
**C2 (2001-2004)**
**NS**: 0.68



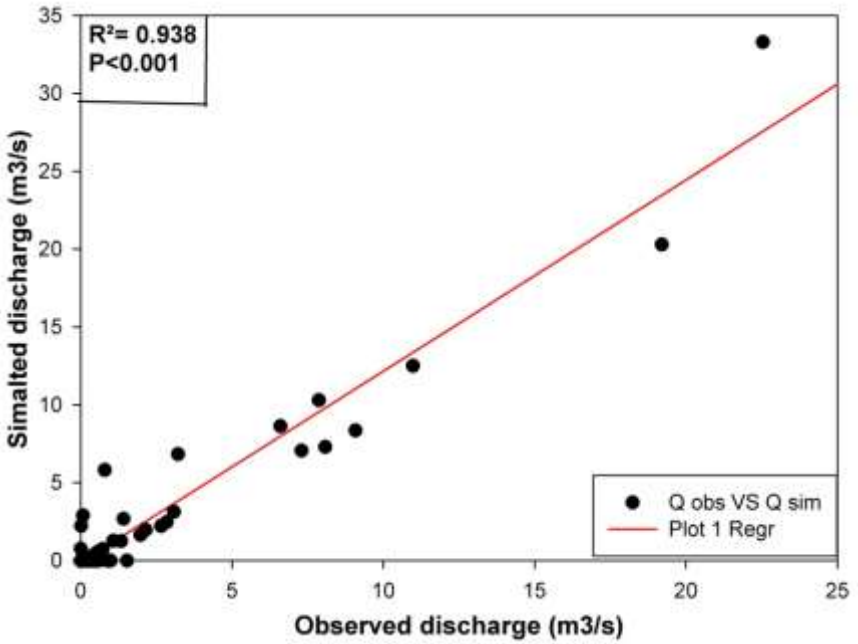




**C3 (2014-2017)**
**NS**: 0.72

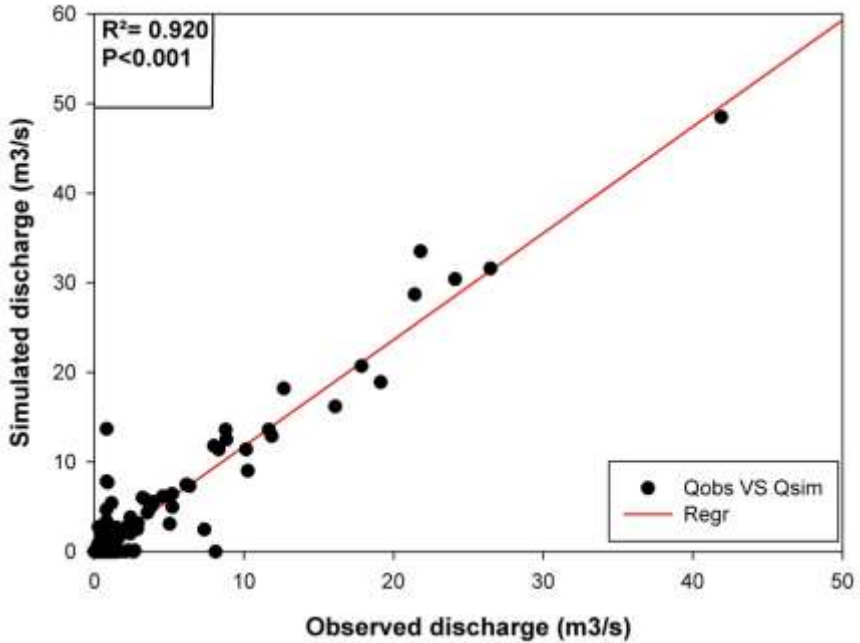
# ▪ Diachronic analysis on the Lakhmess




**C1 (1994-1997)**
**NS**: 0.96




**C2 (2001-2004)**
**NS**: 0.84




**C3 (2014-2017)**
**NS**: 0.84

# • Spatial transferability

## ▪ Similarity Index

$$\phi = \sum_{i=1}^{K} \frac{|X_i^G - X_i^U|}{\Delta X_i}$$

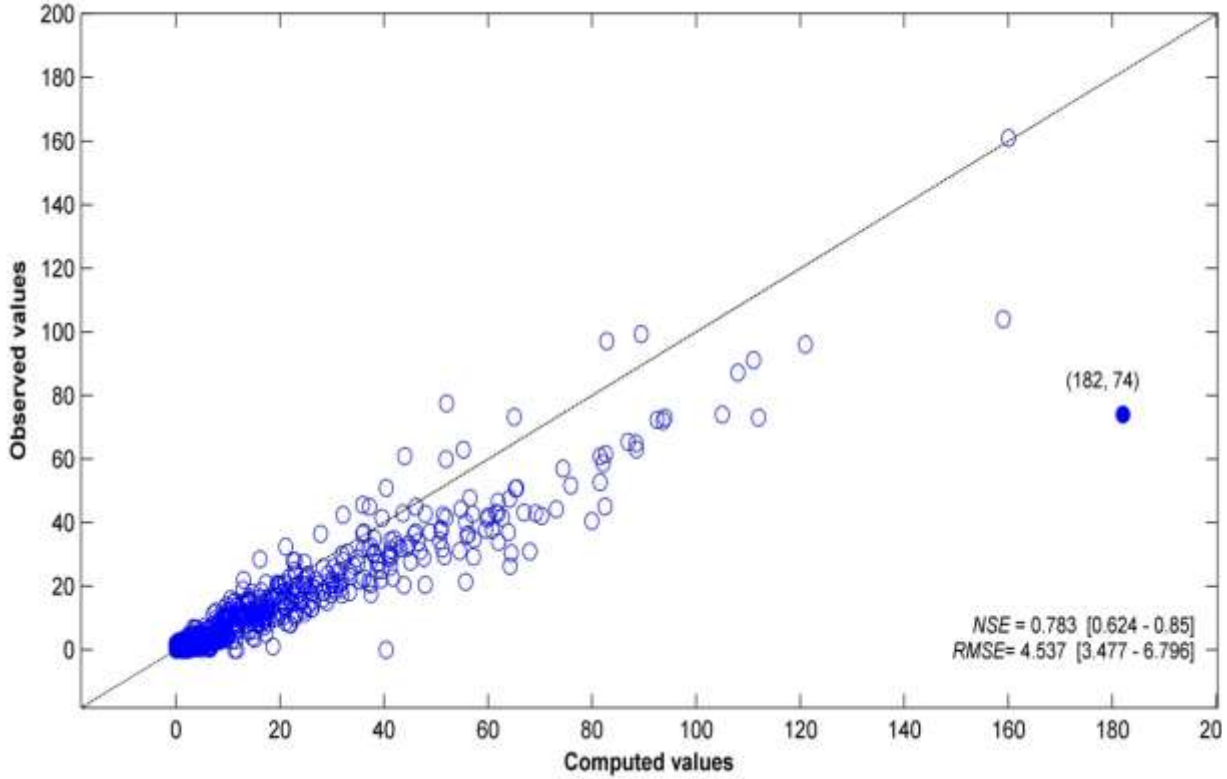
•i is a character of the basin, XG and XU are character values for gauged and ungauged basins, respectively
•ΔX is a range of values for XG in the dataset
•Lower ϕ indicates a higher similarity between basins

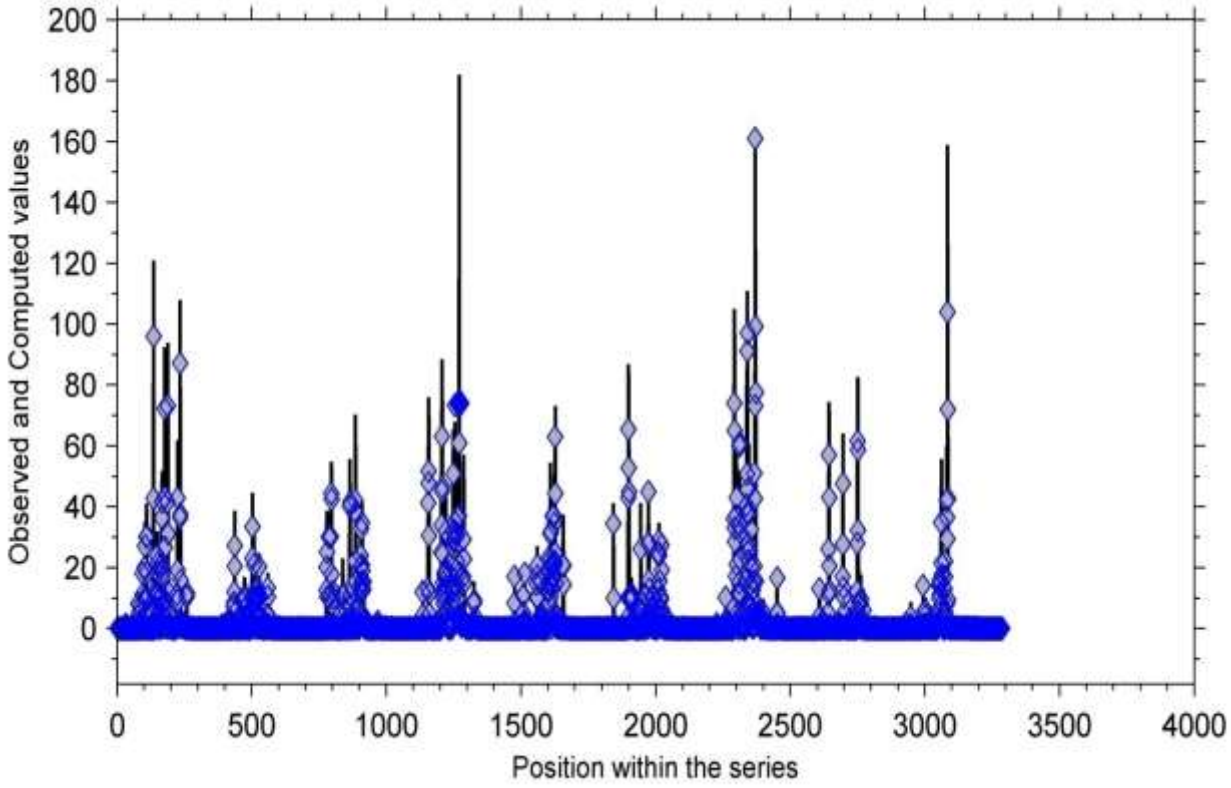
**Adapted from Arsenault et al., 2015**

# ▪ Physical caracteristics for the studied catchments

| Data type | Raghay | Bouheurtma | Lakhmess | Siliana Upstream |
|---|---|---|---|---|
| **Drainage area (km)** | 362 | 390 | 127 | 1040 |
| **Drainage density (km/km²)** | 3.44 | 3.25 | 4.22 | 3.98 |
| **Mean elevation (m)** | 661 | 590 | 924 | 949.5 |
| **Compactness index (km/km)** | 1.57 | 1.61 | 1.207 | 1.273 |
| **Average slope (m/m)** | 13 | 11 | 17 | 13 |
| **Dominant soil (%)** | 27 | 22 | 18 | 21 |
| **Forest (%)** | 35 | 28 | 40 | 32 |
| **Crops (%)** | 25 | 29 | 17 | 21 |
| **Olives (%)** | 31 | 35 | 7 | 13 |
| **Mean interannual rainfall (mm)** | 720 | 660 | 420 | 470 |
| **Similarity Index (%)** | 0.83 | | 0.76 | |

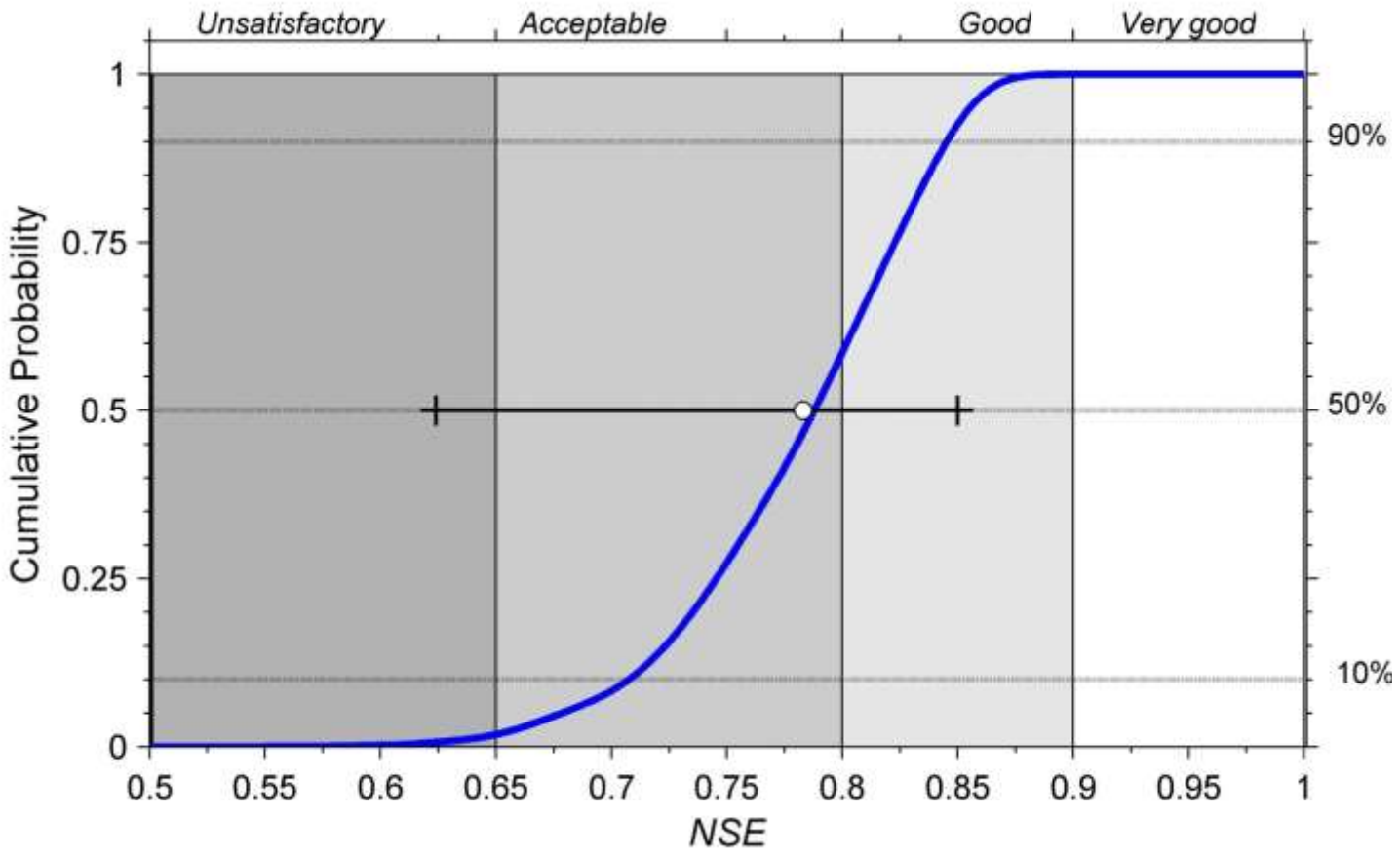
# Spatial transferability of the Bouheurtma catchment




**Hydrometric data presentation for the Bouheurtma catchment (2008-2017)**

# FITEVAL for the Bouheurtma catchment




========== GOODNESS-OF-FIT EVALUATION ==========

Evaluation of *NSE*: **From UNSATISFACTORY to GOOD**

Probability of fit being:

- *Very good* (*NSE* = 0.900 - 1.000): 0%
- *Good* (*NSE* = 0.800 - 0.899): 42.1%
- *Acceptable* (*NSE* = 0.650 - 0.799): 56.2%
- ***Unsatisfactory* (*NSE* < 0.650): 1.7% (p-value: 0.017)**

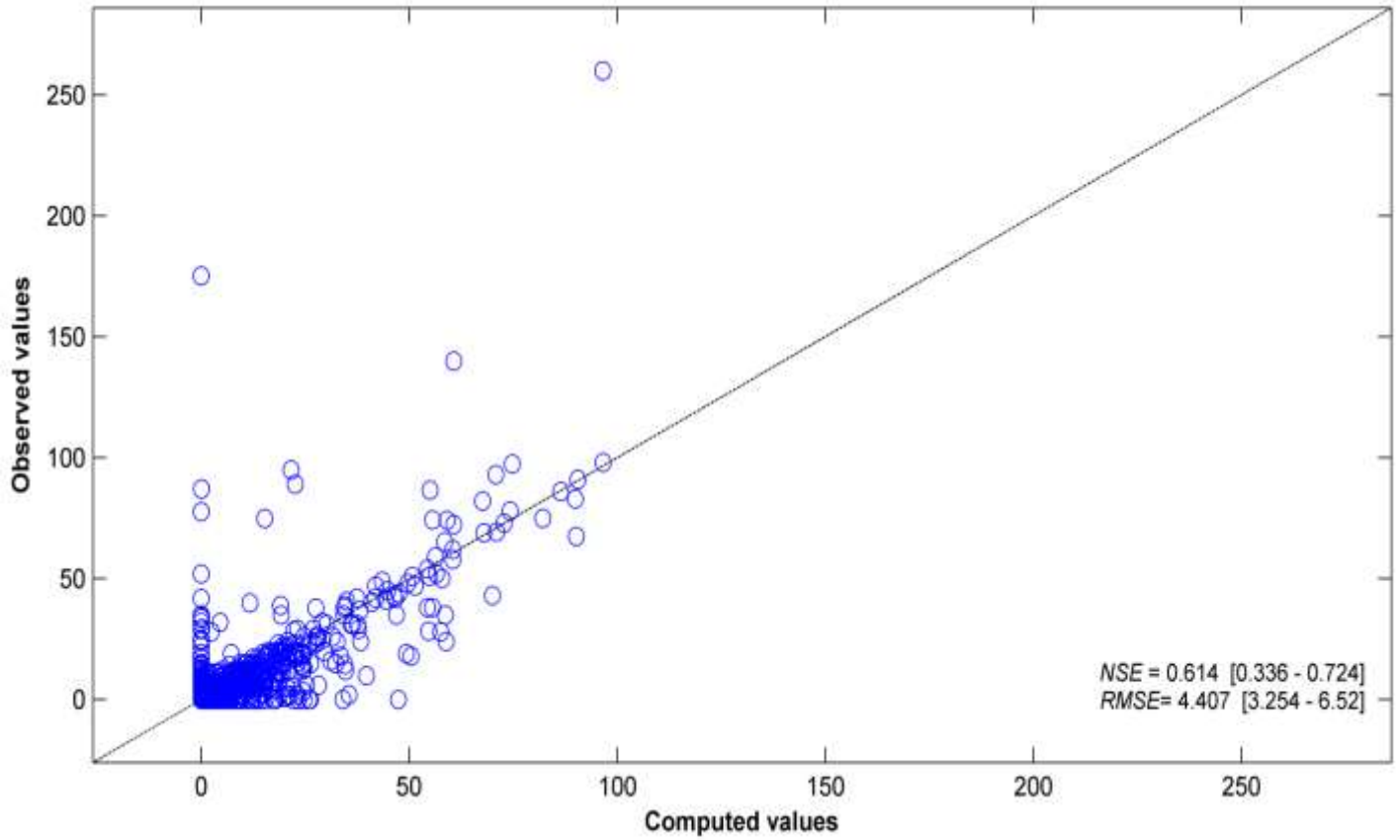
NRMSE= 100·RMSE/SD= 47%

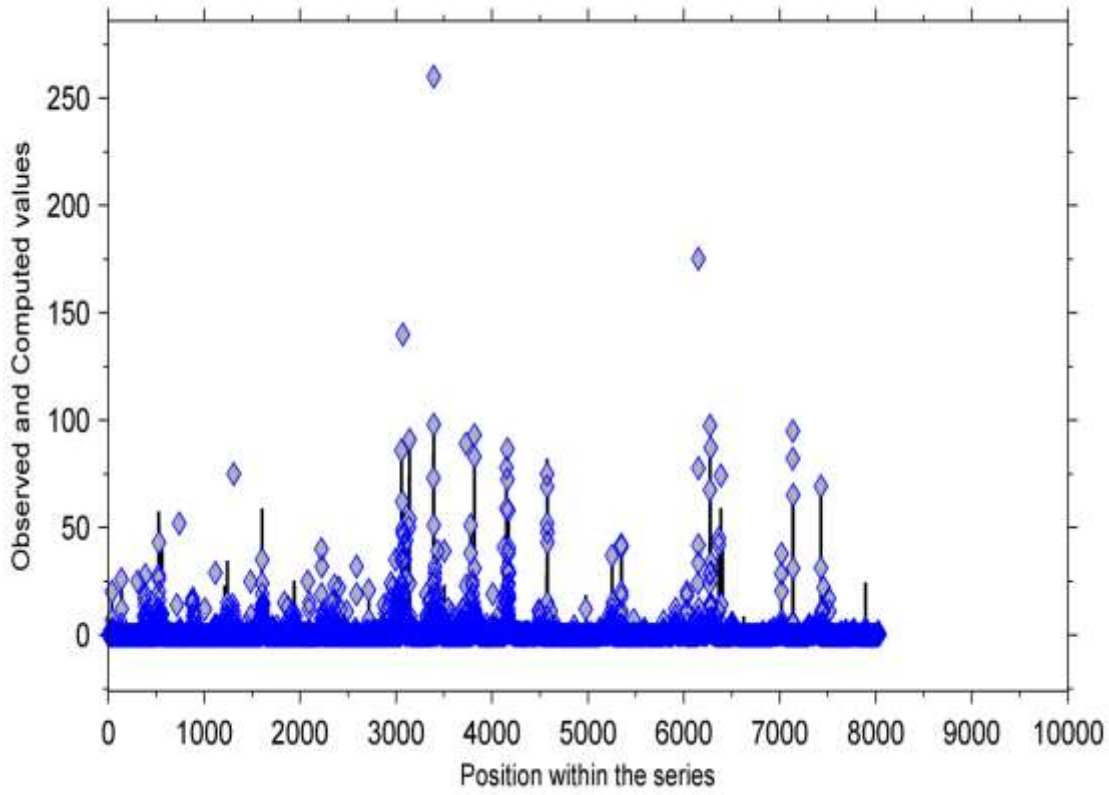
Presence of outliers (Q-test): present and maybe affecting indicators

Model bias: Overprediction by 32% of the mean

(NSE may be influenced by model bias)

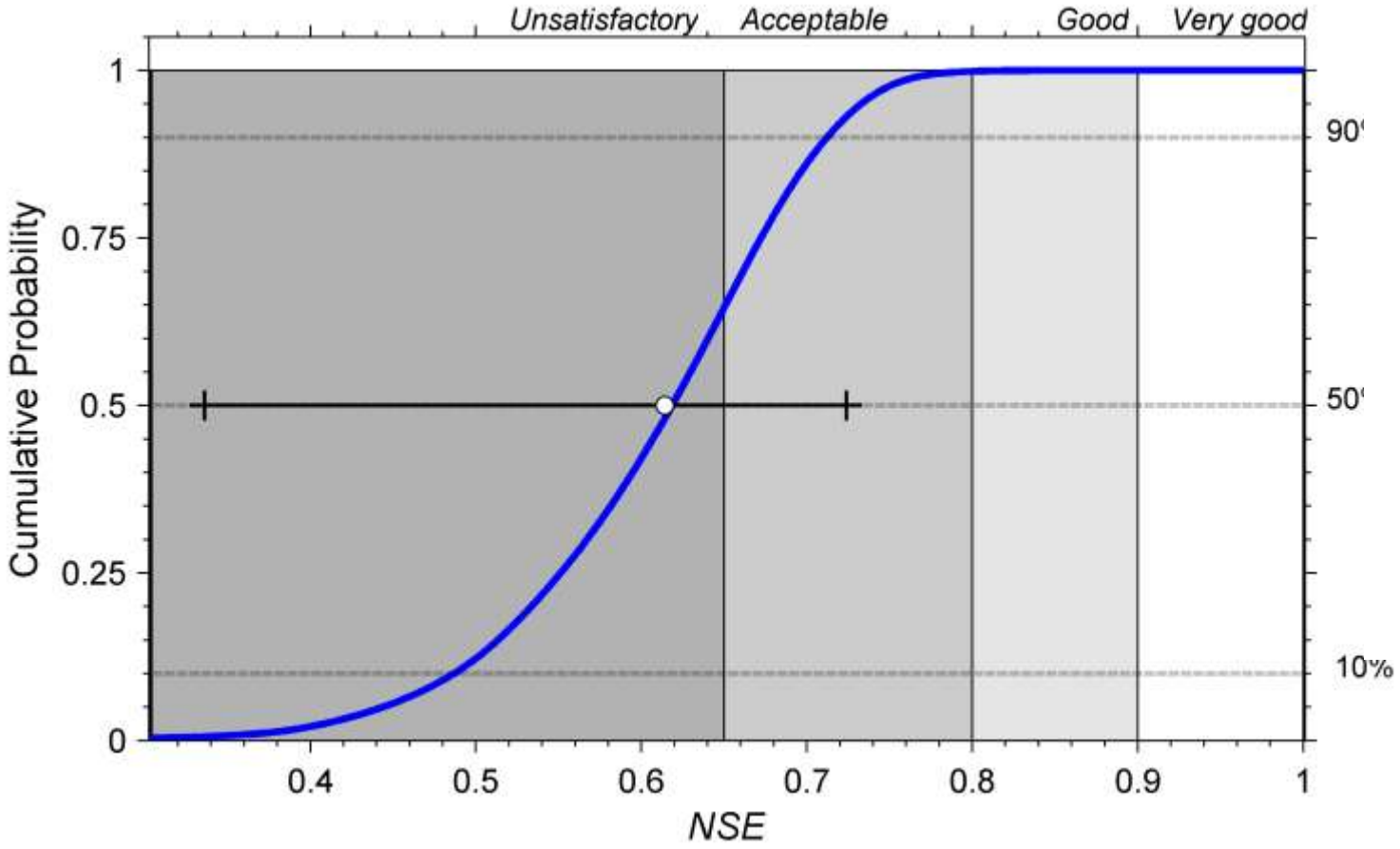
# Spatial transferability of the Siliana Upstream catchment




**Hydrometric data presentation for the Siliana Upstram catchment (1994-2016)**

# FITEVAL for the Siliana Upstream catchment




========== GOODNESS-OF-FIT EVALUATION ========

Evaluation of *NSE*: **From UNSATISFACTORY to ACCEPTABLE**

Probability of fit being:

- *Very good* (*NSE* = 0.900 - 1.000): 0%
- *Good* (*NSE* = 0.800 - 0.899): 0.1%
- *Acceptable* (*NSE* = 0.650 - 0.799): 35.8%
- ***Unsatisfactory* (*NSE* < 0.650): 64.1%  (p-value: 0.641)**

NRMSE= 100·RMSE/SD= 62%

Presence of outliers (Q-test): NO

Model bias: Underprediction by -20.5% of the mean
(NSE may be influenced by model bias)

# ❖Conclusions

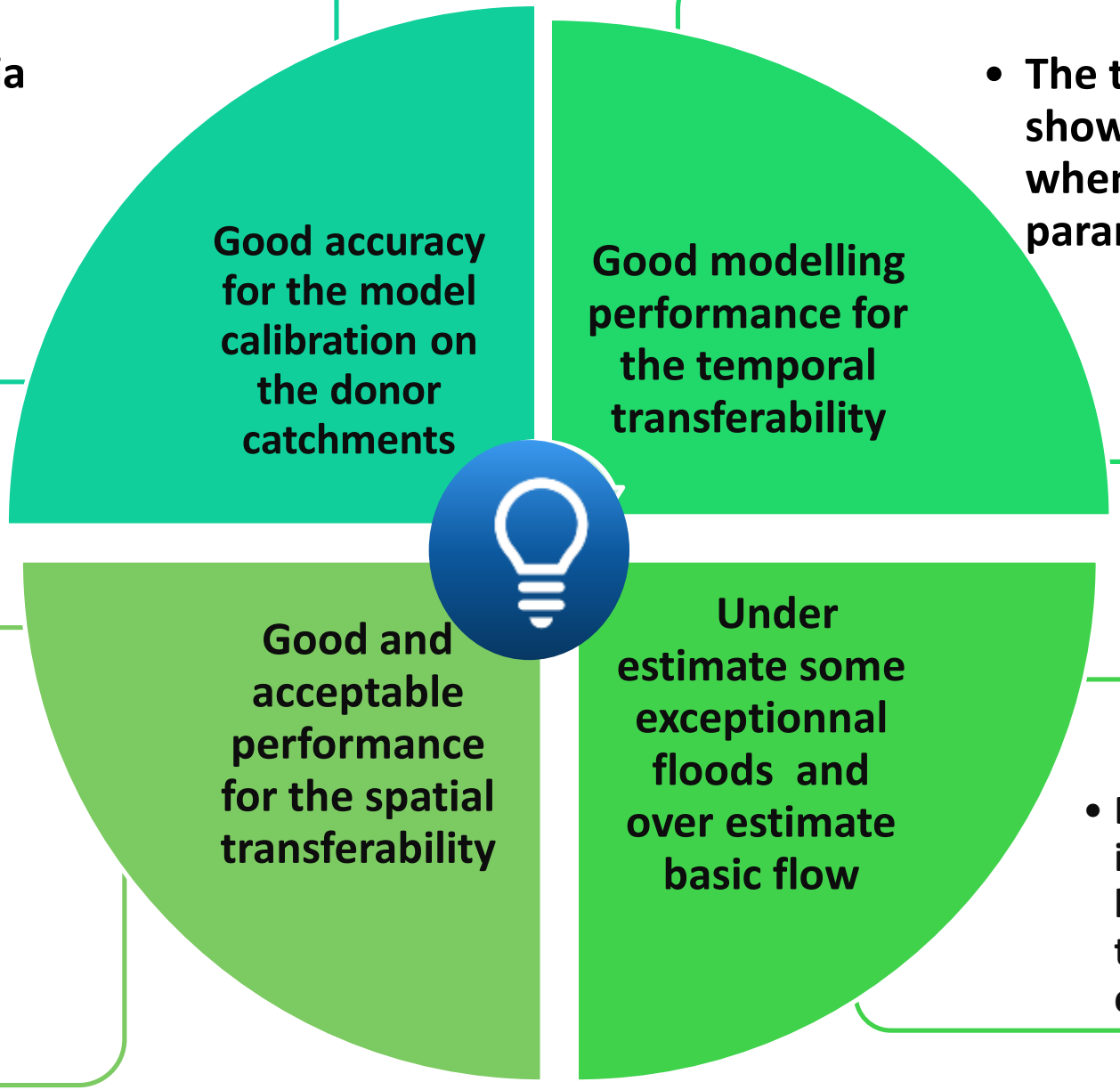
01 A simplified Conceptual RR model applicated on Two donor catchments within the Medjerda

02 Parameters retrieval and model accuracy evaluation

03 Temporal transferability using a diachronic analysis on the donor catchments

04 Spatial transferability by using the calibrated parameters on receptor catchments

- Several accuracy criteria to present modelling quality




- The two donor catchments showed good aspects when using the calibrated parameters for 3 decades

- Based on the FITEVAL classification (NS and RSME) for the receptor catchments

- Due to the interconnection between the dams in the Medjerda catchments

# ❖Limits, perspectives and next steps

## Limits

The model performance quantification was only tested for four catchments and it must be further enhanced for the Medjerda. The model should be tested across many catchments

## A must do (1)

Evaluation of the model robustness by its application on a large range of catchments within the Medjerda basin to enhance the spatial transferability

## Difficulties

Serious problems when collecting data: accessibility, quantity and quality

## A must do (2)

Temporal transferability enhancement by integrating the climate change projections (EUROCORDEX) for different scenarios for the studied catchments since Tunisia is considered a hotspot for CC

# Thank you for your attention

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