AG-WaMED

SWAT Soil & Water Assessment Tool

The Soil and Water Assessment Tool (SWAT) for sustainable water management in the Mediterranean Area

Second Online Masterclass, 20 -11- 2023

Application of SWAT models in the dry Mediterranean Area: Case Study of Tunisia

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PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

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Outline of the Presentation

1- The historical utilization of the SWAT model in Tunisia:

Rim Haddad **& Mohamed Ouessar –** ***IRA Médenine***

2- Refinement and Assessment of the SWAT Model in arid zones of Tunisia

Fethi Abdelli & Mohamed Ouessar – ***IRA Médenine***

1- The historical utilization of the SWAT model in Tunisia:

Rim Haddad – IRA Médenine

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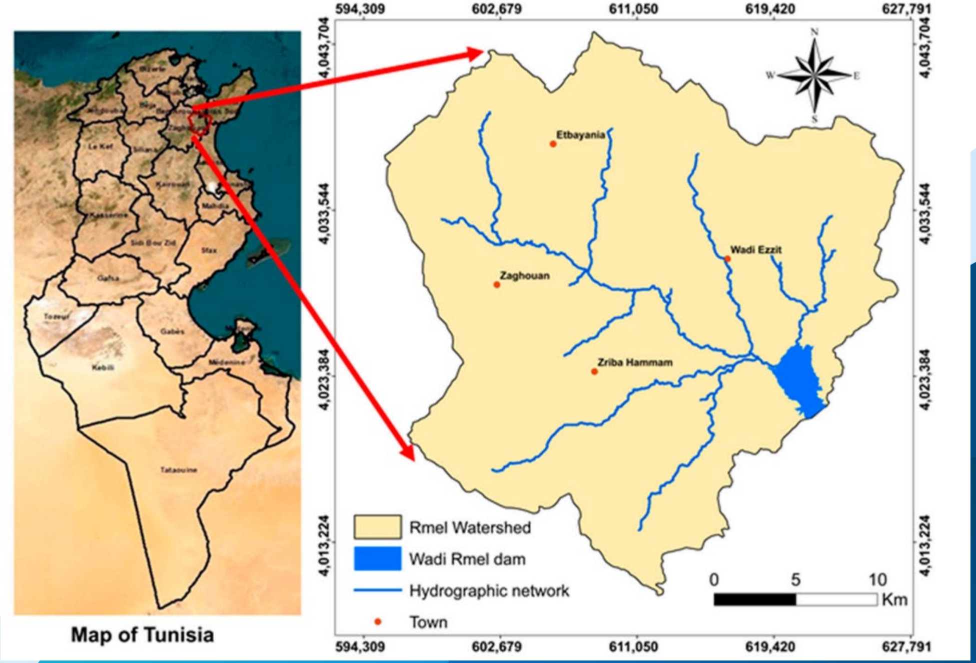
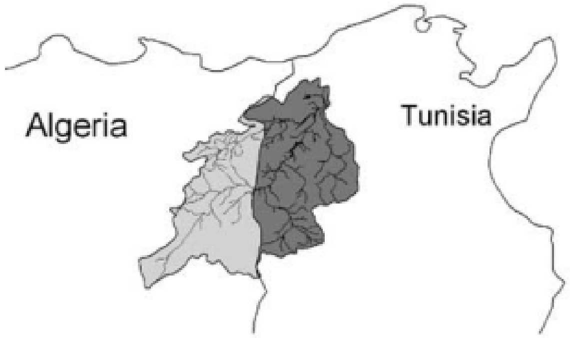
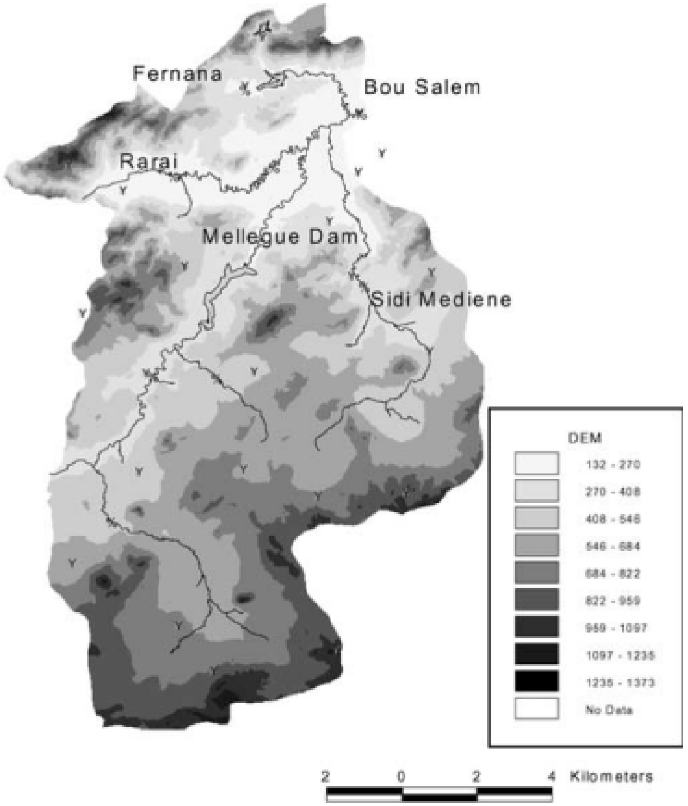
- Bouraoui et al. 2005 (the Medjerda watershed, north of Tunisia)
- Ouessar 2007, Ouessar et al. 2009 (Koutine watershed, Medenine, South of Tunisia)
- Mosbahi et al. (2012, 2019) (Sarrath river catchment, north of Tunisia)
- Aouissi et al. 2016 (Joumine basin, northern Tunisia)
- Chaâbane & Abida 2016 (Wadi Hatab watershed , Central Tunisia)
- Abdelli 2017 (wadi Jir watershed, Gabès , South of Tunisia)
- Mtibaa et al. 2018 (Joumine watershed, northern Tunisia)
- Mosbahi et al. 2023 (Sejnane watershed, northern Tunisia)
- Jarray et al. 2023 (Wadi Rmel watershed, northern Tunisia).



Bouraoui et al. 2005 applied the SWAT model to study the potential impact of land management scenarios on the major Tunisian river, ***the Medjerda***.

- The catchment lies in the sub-humid to Mediterranean humid bio-climatic region
- Two large dams have been constructed in the study area.
- SWAT model : Water balance and the water quality





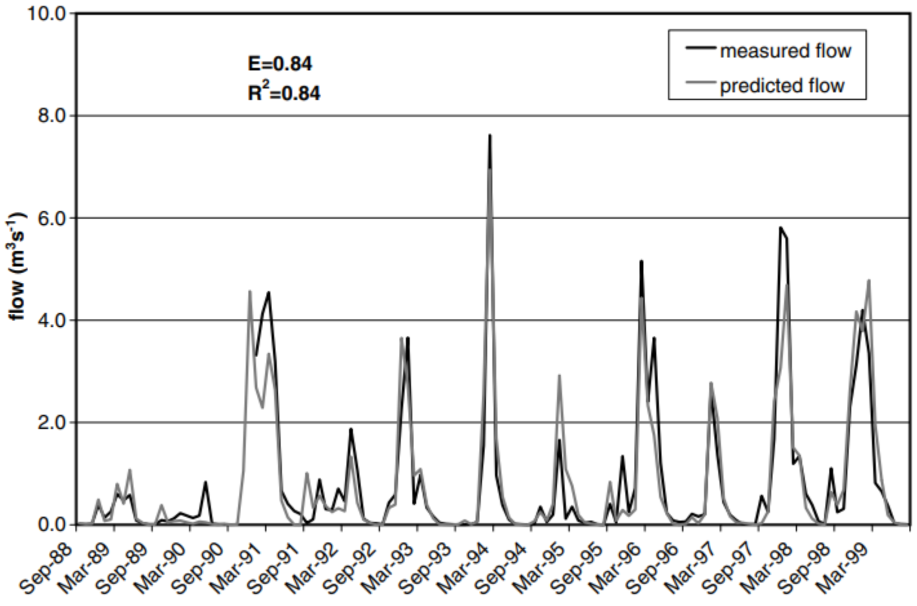
Bouraoui, S. Benabdallah b , A. Jrad b , G. Bidoglio (2005) Application of the SWAT model on the Medjerda river basin (Tunisia) Physics and Chemistry of the Earth 30 (2005) 497–507

- Concerning water balance : About 87% of the precipitation were lost through evapotranspiration.
- water quality: 80% of the nitrates present in surface water was due to agriculture.

Two scenarios:

- The conversion of the total agricultural area to irrigated wheat with an increase of the fertilisation rate to 30% for nitrogen and phosphorus. This intensification of agriculture resulted in a predicted increased nitrate load in the river by 22%.

- The introduction of additional wastewater treatment plants. The most significant impacts on water quality were a reduction of the phosphorus load by 50% and the predicted reduction in ammonium load is around 25%.

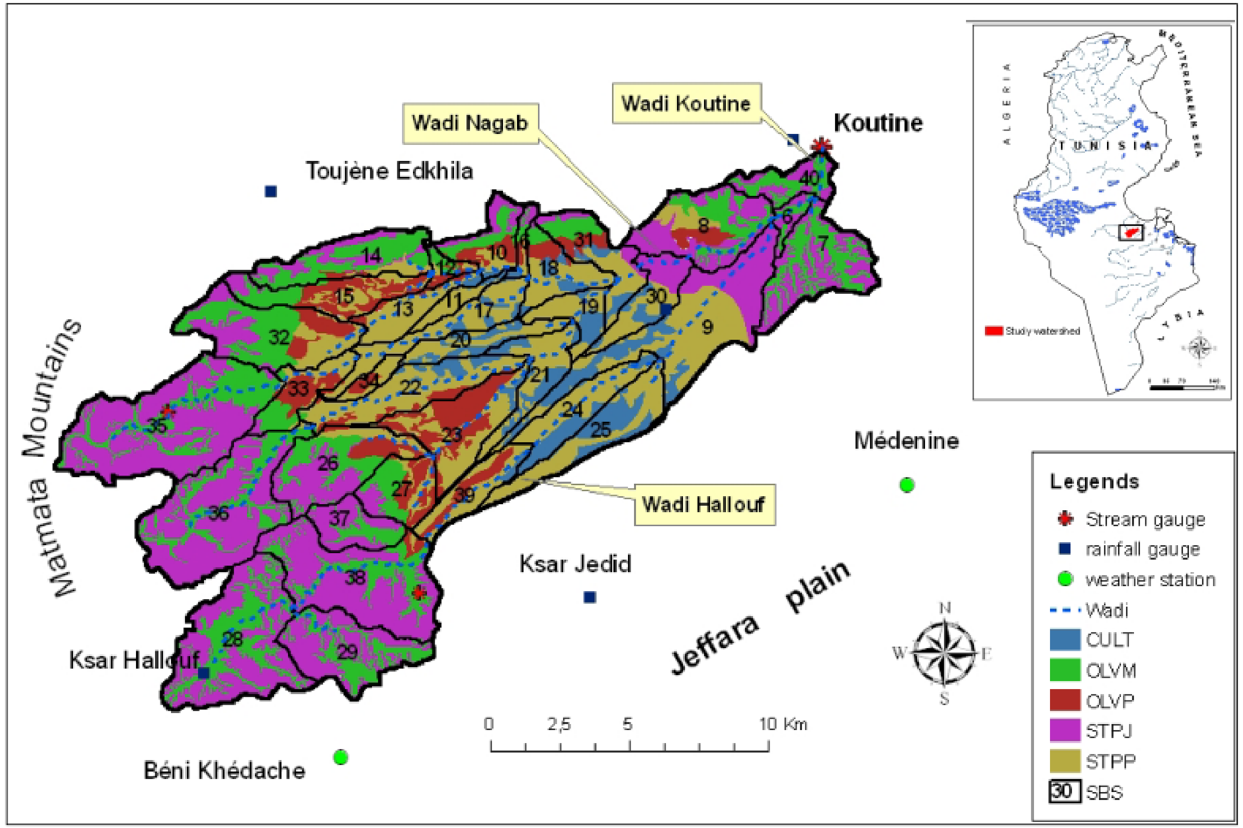


Predicted and measured monthly flow for the Fernana gauging station.

Ouessar 2007, Developed an adapted GIS-based SWAT model for water balance assessments in arid watersheds with water-harvestings system (***Koutine watershed, Medenine***)

Ouessar M, Bruggeman A., Abdelli F. , Mohtar R. H. , Gabriels D., and Cornelis W. M. (2009) Modelling water-harvesting systems in the arid south of Tunisia using SWAT. Hydrol. Earth Syst. Sci., 13, 2003–2021.

- It lies in the upper arid bioclimate region
- Specific soil types and land uses for the study area
- The soil map was modified to take into account the soils built up behind the water-harvesting units as deposited sediment
- The land use map was adjusted by adding the different soil and water management practices (jessour/ tabias)

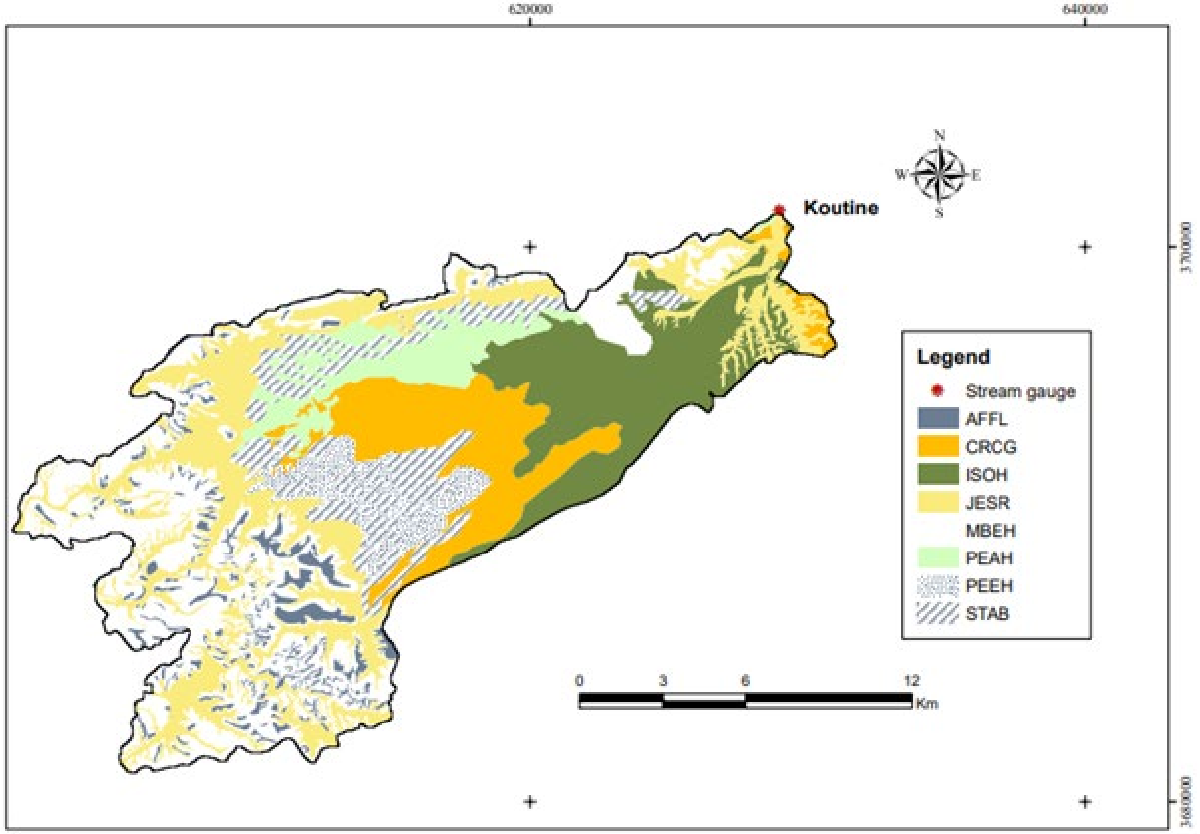


Watershed scale assessment of land use changes

Land use evolution before and after project

Landuse	Before project "1991"		After project "2004"		Changes (before/after)	
	ha	% (tot)	ha	% (tot)	ha	%
Halophyte ranges	949.4	2.7	949.4	2.7	0.0	0.0
Mountain ranges	12409.4	35.4	12409.4	35.4	0.0	0.0
Plain ranges	7105.2	20.3	2827.1	8.1	-4278.1	-12.2
Cereals	3947.3	11.3	1806.7	5.2	-2140.6	-6.1
Olives on jessour	8275.3	23.6	8275.3	23.6	0.0	0.0
Olives on tabias	2380.3	6.8	8799.0	25.1	6418.7	18.3

- To adapt the model to the arid conditions, specific adjustments were made,
- The redistribution of runoff water within a subbasin
- The SWAT code was modified to simulate the collection of runoff water behind the water-harvesting structures (jessour and tabias) by bringing the surface runoff and lateral flow generated in the subbasin back to the water-harvesting HRUs in the subbasin.
- The adjusted version of the model was named SWAT-WH.



The adapted soil map for SWAT application

Ouessar M, Bruggeman A., Abdelli F. , Mohtar R. H. , Gabriels D., and Cornelis W. M. (2009) Modelling water-harvesting systems in the arid south of Tunisia using SWAT. Hydrol. Earth Syst. Sci., 13, 2003–2021.

Watershed scale assessment of land use changes

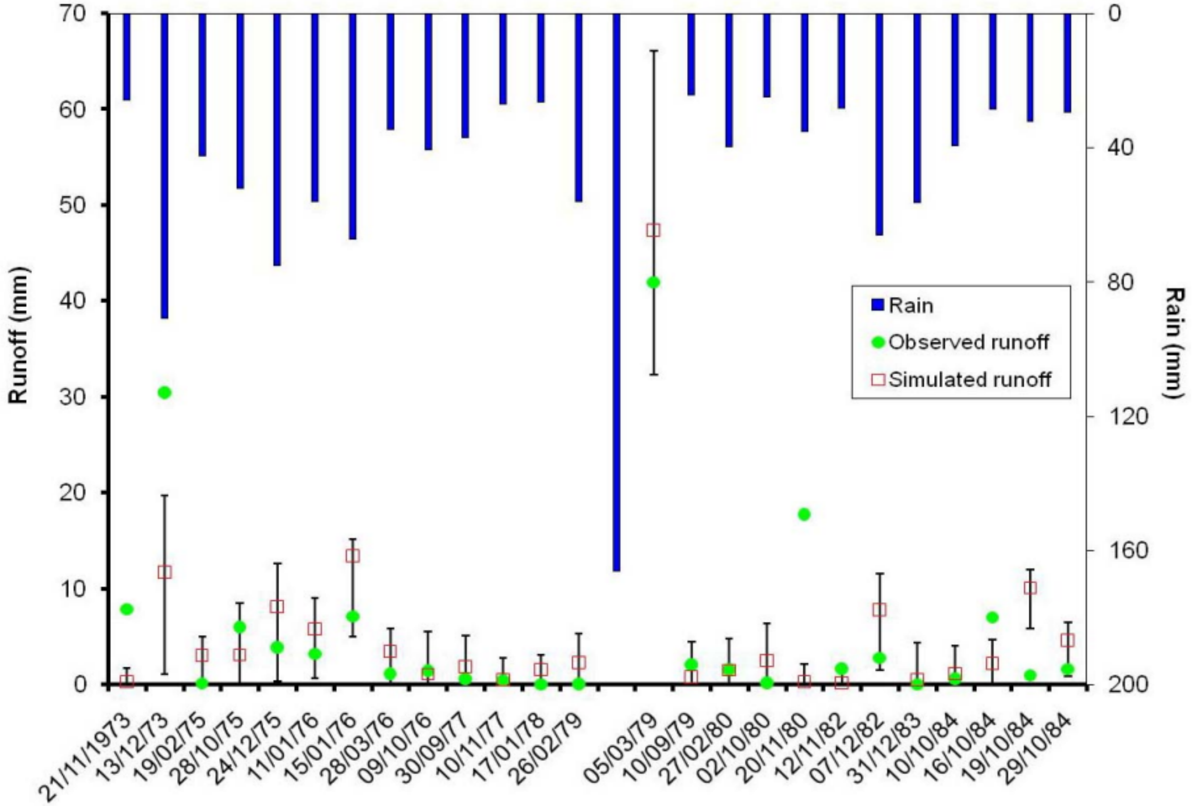
Objective

to assess the **long-term effects** of the large scale implementation of **WH works** on the main **water balance components** (evapotranspiration, outflow and recharge) using **SWAT model** in ***wadi* Oum Zessar watershed**.

- The R^2 (coefficient of determination) ranged between 0.77 and 0.44; and the E (Nash-Sutcliffe coefficient) between 0.73 and 0.43; indicating that the model could reproduce the observed events reasonably well

In such arid conditions :

- The model predicted that the average annual watershed rainfall of the 12-year evaluation period (209 mm) was split into ET (72%), groundwater recharge (22%) and outflow (6%).



Rainfall, observed and simulated runoff and the simulated minimum and maximum error bounds for events with more than 20 mm rain

Ouessar M, Bruggeman A., Abdelli F. , Mohtar R. H. , Gabriels D., and Cornelis W. M. (2009) Modelling water-harvesting systems in the arid south of Tunisia using SWAT. Hydrol. Earth Syst. Sci., 13, 2003–2021.

Watershed scale assessment of land use changes

Scenarios

- **SC0:** It is a hypothetical scenario: natural watershed, no water harvesting works nor crops.

- **SC1:** water harvesting systems: *jessour* on the mountain area and *tabias* on the foothills.

- **SC2:** new *tabias* in the plain zone; gabion check dams for aquifer recharge and flood spreading.

- **SC3:** The land use is similar to SC2 with partial silting up of the gabion check dams.

Watershed scale assessment of land use changes

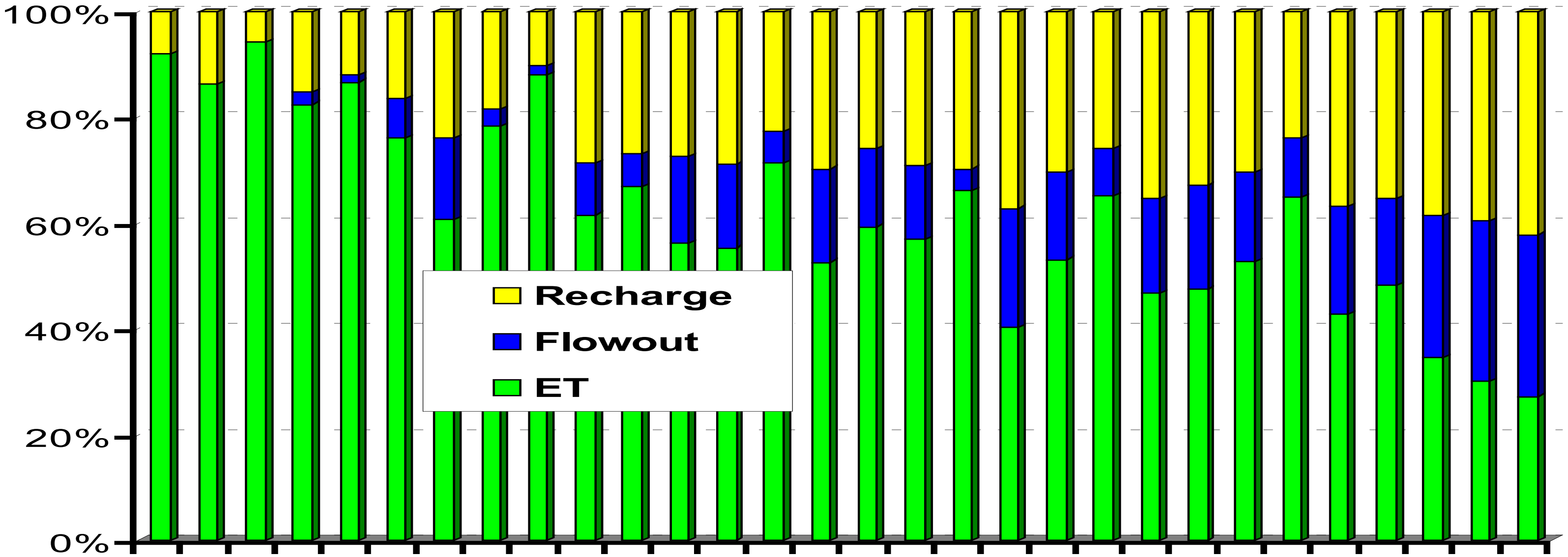
Results

	SC0		SC1		SC2		SC3	
	mm	%	mm	%	mm	%	mm	%
Rainfall	183.9	-	183.9	-	183.9	-	183.9	-
ET	107.0 [a]	58.2	147.2 [b]	80.1	150.9 [b]	82.0	150.9 [b]	82.0
Outflow	34.3 [a]	18.7	4.0 [b]	2.2	0.1 [c]	0.0	0.1 [c]	0.0
Perco	14.5 [a]	7.9	24.3 [b]	13.2	28.2 [b]	15.4	28.3 [b]	15.4
TLOSS	28.0 [a]	15.2	8.2 [b]	4.4	3.1 [c]	1.7	3.2 [c]	1.7
Seepage	0 [a]	0.0	0 [a]	0.0	1.1 [b]	0.6	0.9 [b]	0.5

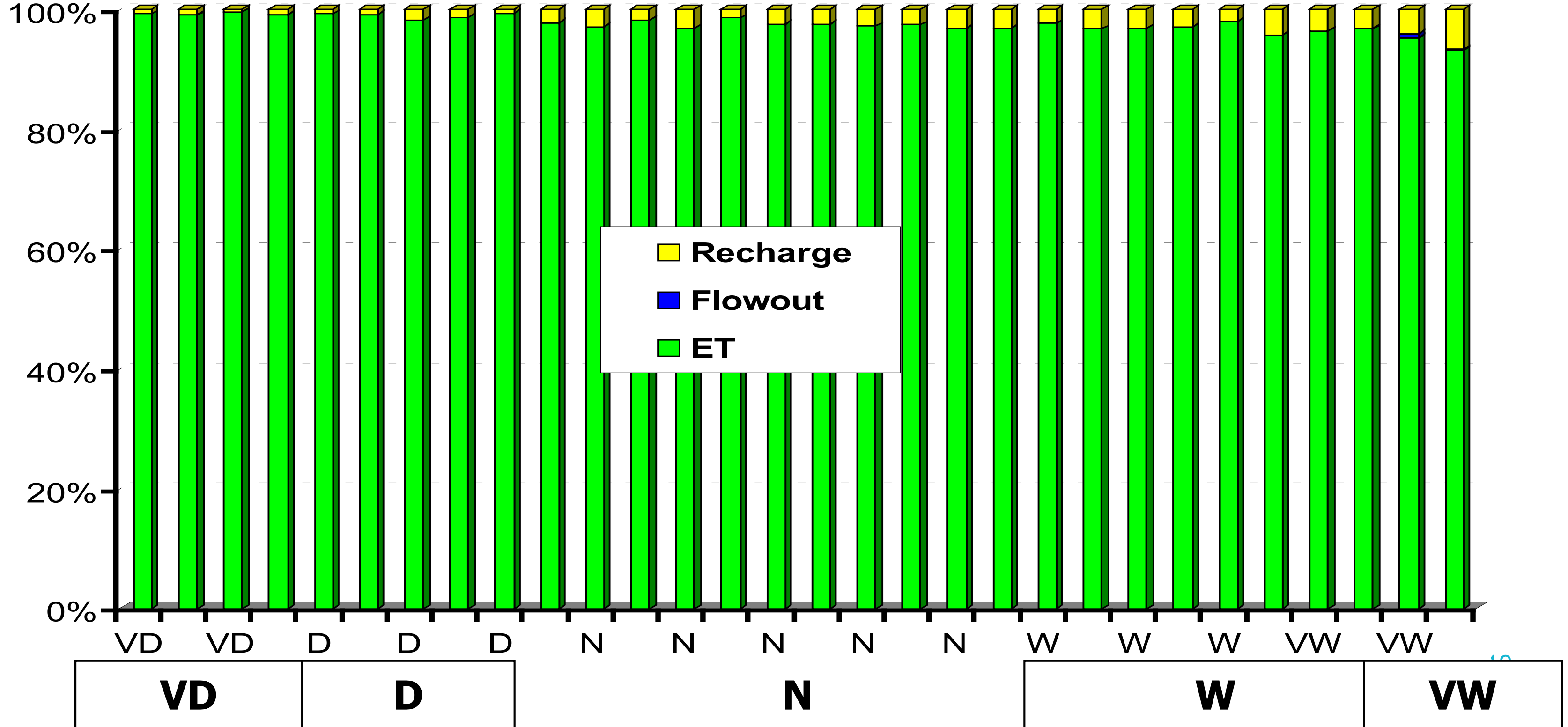
Watershed scale assessment of land use changes

Results

SC0

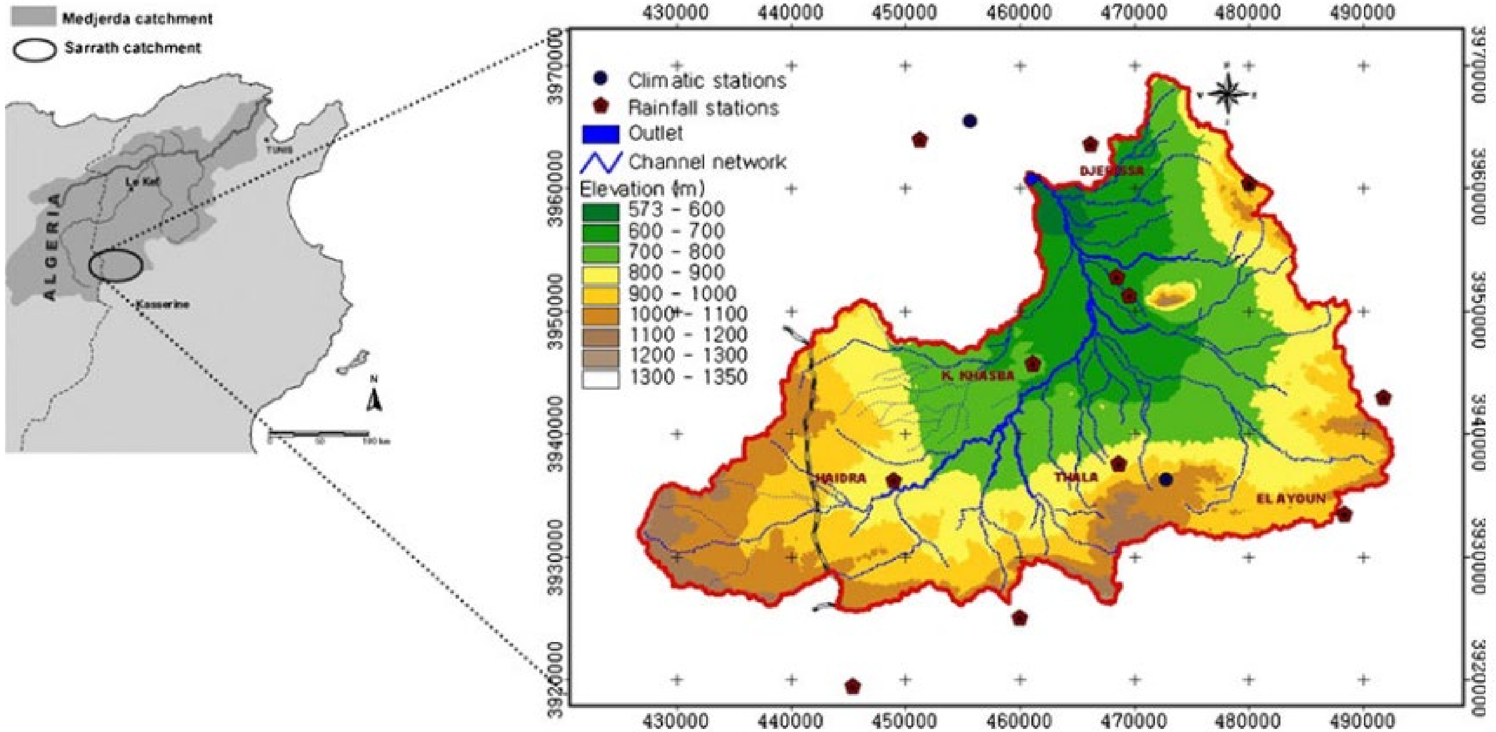


SC2



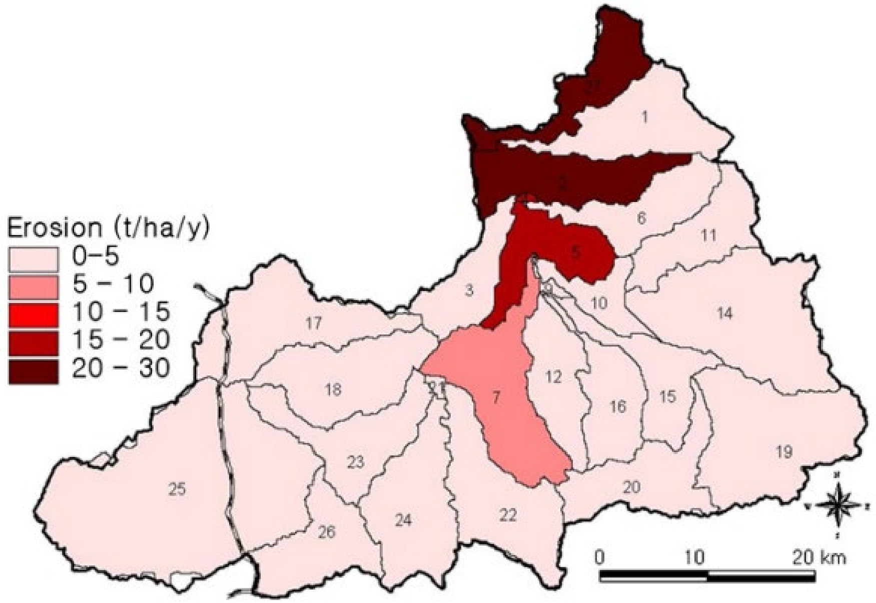
Mosbahi et al. (2012, 2019) used the SWAT model to predict surface runoff generation patterns and soil erosion hazard and to prioritize most degraded sub-catchment in order to adopt the appropriate management intervention (***Sarrath river catchment, north of Tunisia)***

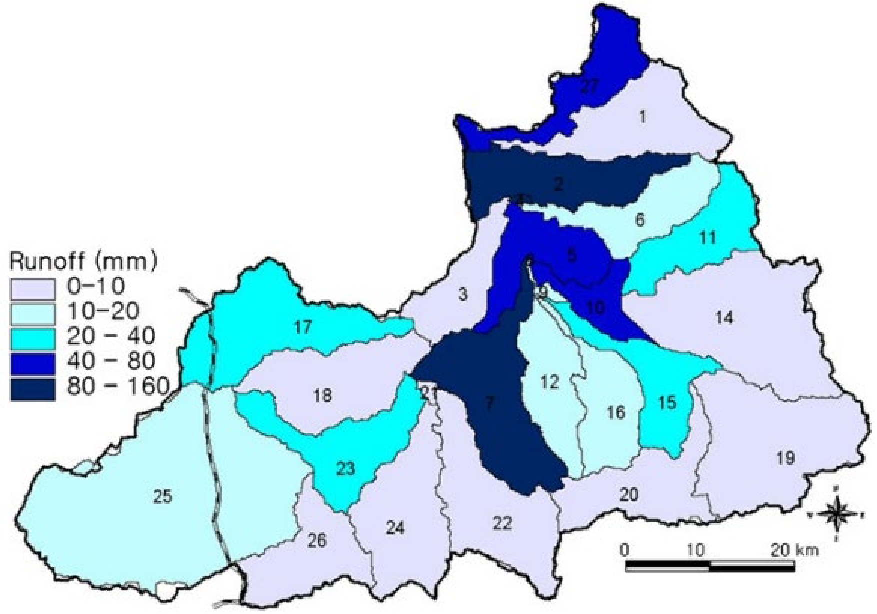
- It lies in sub-humid to semi-arid climate
- SWAT: to estimate surface runoff and soil erosion
- The spatial differences in erosion rates within the Sarrath catchment were mainly caused by differences in land cover type and gradient slope.
- More forest cover produced generally less runoff and soil loss



Mosbahi Manel, Sihem Benabdallah, Mohamed Rached Boussema (2012) Assessment of soil erosion risk using SWAT model. Arab J Geosci DOI 10.1007/s12517-012-0658-7

- Results showed that a larger part of the watershed (90 %) fell under low and moderate soil erosion risk and only 10 % of the watershed was vulnerable to soil erosion
- Seven conservation practice scenarios :
- land conservation measures could reduce sediment yield by about 5 to 43% and runoff by 5 to 32%.
- parallel terraces were the most effective both for runoff and for sediment loss, followed by forestation.
- The best results were obtained for combined scenarios.



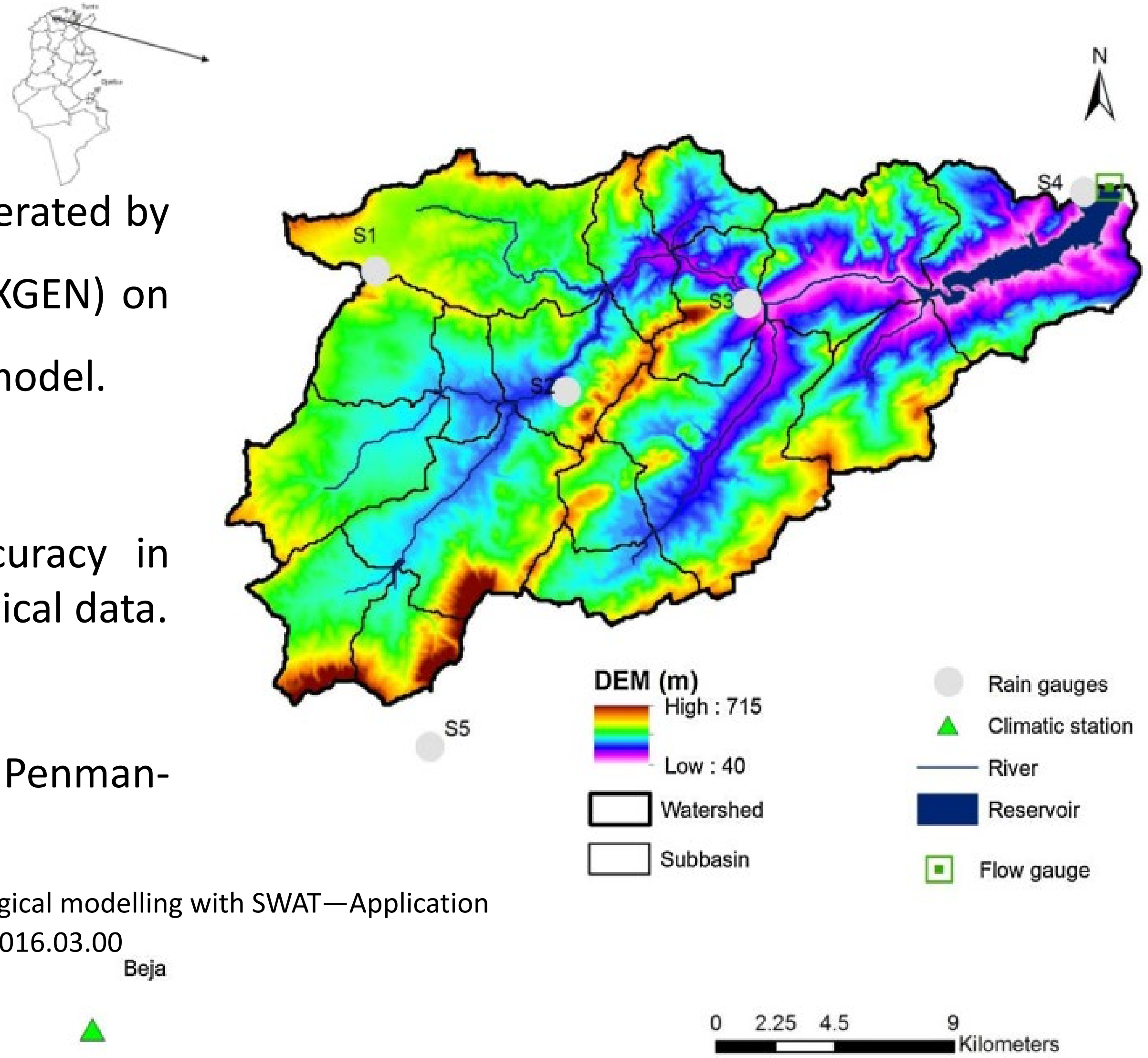


Mosbahi Manel, Sihem Benabdallah, Mohamed Rached Boussema (2012) Assessment of soil erosion risk using SWAT model. Arab J Geosci DOI 10.1007/s12517-012-0658-7

Aouissi et al. (2016) used the SWAT model to estimate PET, actual ET and streamflow. The model was applied to the ***Joumine*** basin, located in ***northern Tunisia***

The objectives of this work were :

- to evaluate the effects of various climatic parameters generated by the statistical weather generator embedded in SWAT (WXGEN) on the hydrologic outputs (PET, ET and streamflow) of SWAT model.
- to evaluate the Penman-Monteith (PM) method's accuracy in calculating PET using generated and measured meteorological data.
- to compare the three methods to predict PET in SWAT : Penman-Monteith (PM), Hargreaves (HA) and Priestly-Taylor (PT).

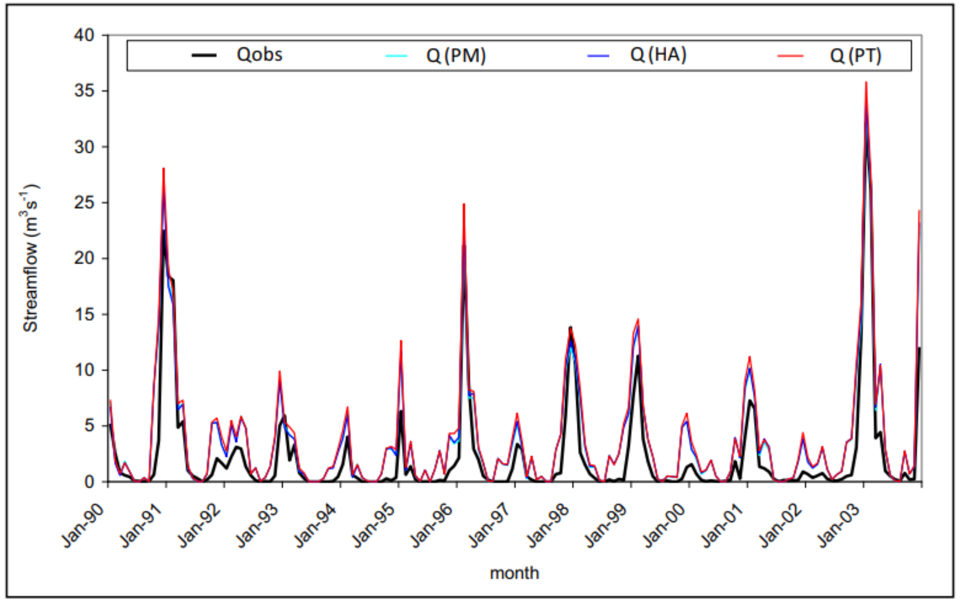


Aouissi, J., et al., Evaluation of potential evapotranspiration assessment methods for hydrological modelling with SWAT—Application in data-scarce rural Tunisia. Agric.Water Manage.(2016), http://dx.doi.org/10.1016/j.agwat.2016.03.00

- The WXGEN generated data reproduced PET estimated by the PM method.

Main results:

- The best results were obtained with measured climatic data. However , The PM method predicted PET well with generated data.
- Daily PET values using generated weather data were highly correlated with those using observed data ($R^2 > 0.8$ and $NSE > 0.74$).
- The method used to calculate PET did not considerably affect stream flow predictions.
- Model predictions of streamflow were close to observed values, with a Nash-Sutcliffe efficiency of 0.90 and R^2 value of 0.92after monthly calibration using HA method

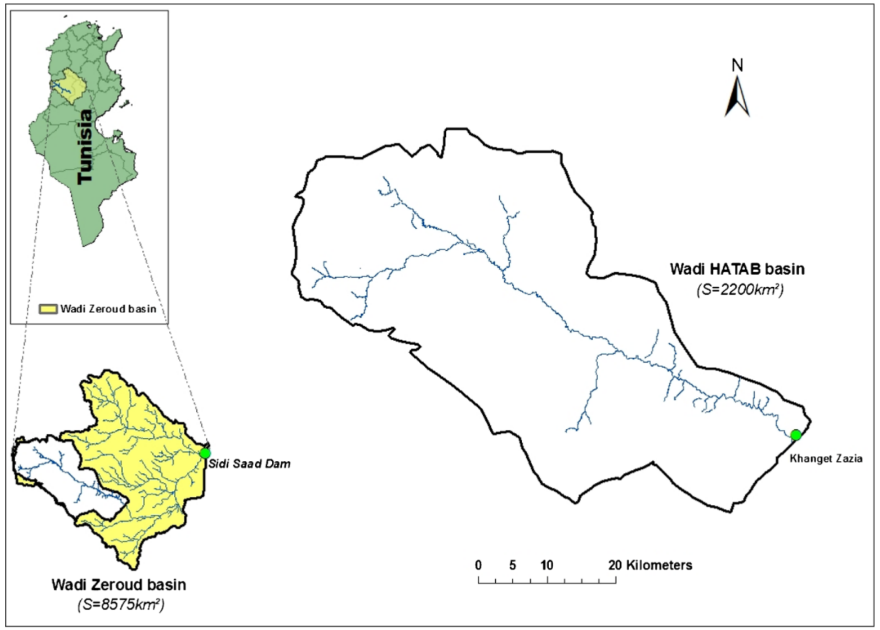


Comparison of monthly observed and predicted streamflow using PM, HA and PT methods

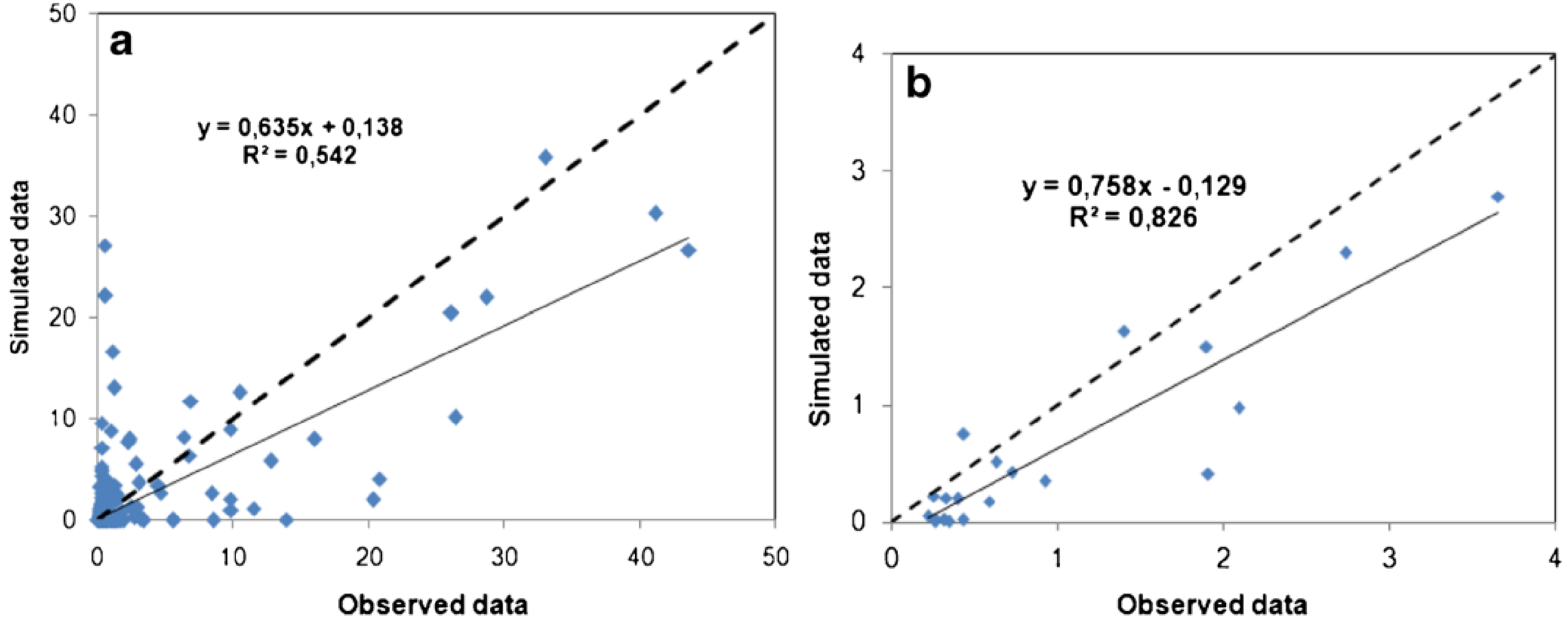
Aouissi, J., et al., Evaluation of potential evapotranspiration assessment methods for hydrological modelling with SWAT—Application in data-scarce rural Tunisia. Agric.Water Manage.(2016), http://dx.doi.org/10.1016/j.agwat.2016.03.00

Chaâbane & Abida (2016) applied the SWAT model to simulate **daily** and **monthly** water flow and sediment fluxes in the ***Wadi Hatab watershed , Central Tunisia***

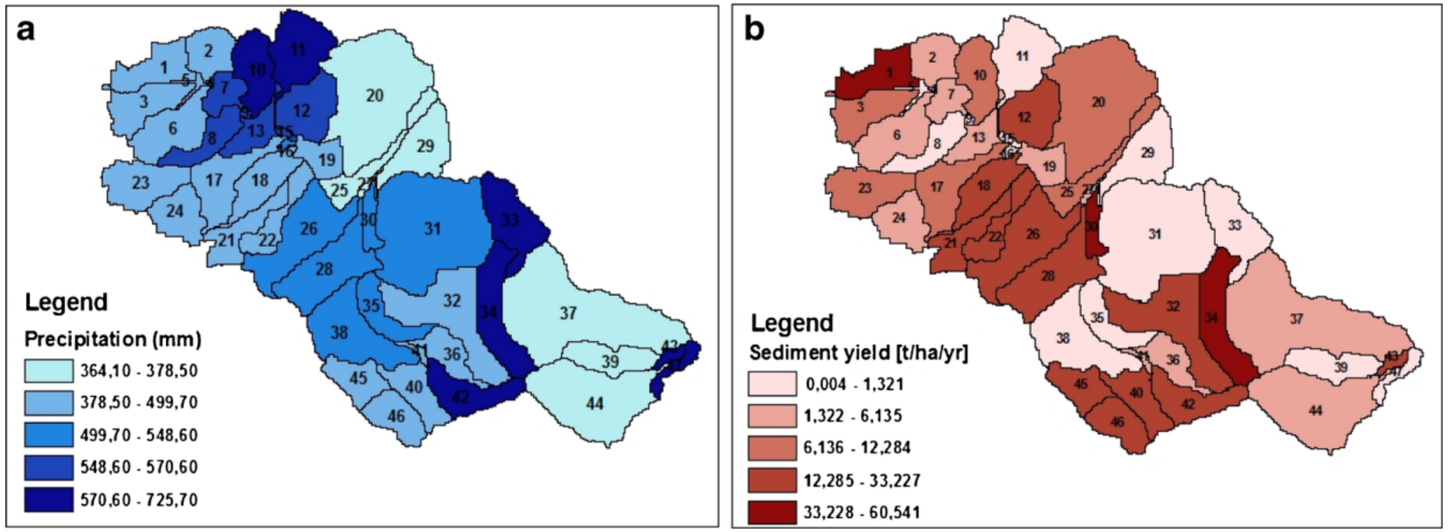
- Semi-arid to arid climate
- Soil and land use map were extracted from the regional maps (local data)
- results clearly showed the reasonably good agreement between simulated and observed **flow rates.**
- For the **daily time step** application, the Nash—Sutcliffe efficiency (NSE) values were 0.52 and 0.61, and the coefficient of determination (R2) was 0.54 and 0.61 for calibration and validation, respectively.
- As for the **monthly time-step** application, the obtained NSE values were 0.67 and 0.89 while R2 values were 0.83 and 0.87 for calibration and validation, respectively.
- **In terms of erosion**, the model gave sediment yield values of 1.15 and 5.37 t/ha/year during the periods of calibration and validation, respectively.



Chaâbane N B S & Habib Abida (2016) Runoff and sediment yield modeling using SWAT model: case of Wadi Hatab basin, central Tunisia. Arab J Geosci (2016) 9 : 579. DOI 10.1007/s12517-016-2607-3



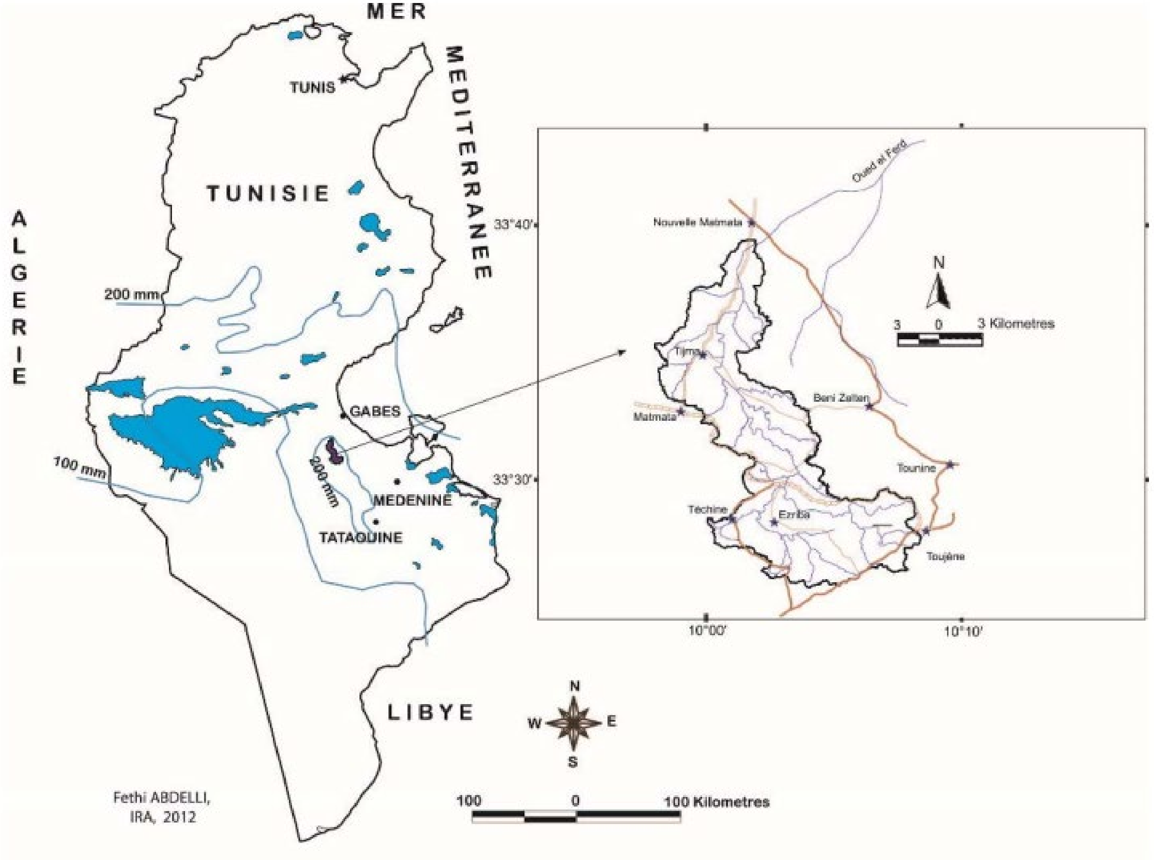
Scattergrams of observed and simulated discharges for the calibration period: a daily time step and b monthly time step



Spatial distribution for 1990 of: a precipitation b sediment yield, predicted by SWAT

Chaâbane N B S & Habib Abida (2016) Runoff and sediment yield modeling using SWAT model: case of Wadi Hatab basin, central Tunisia. Arab J Geosci (2016) 9 : 579. DOI 10.1007/s12517-016-2607-3

Abdelli (2017) applied the SWAT model for the determination of the main hydrodynamic and erosive soils characteristics of the ***wadi Jir watershed, Gabès , South of Tunisia***

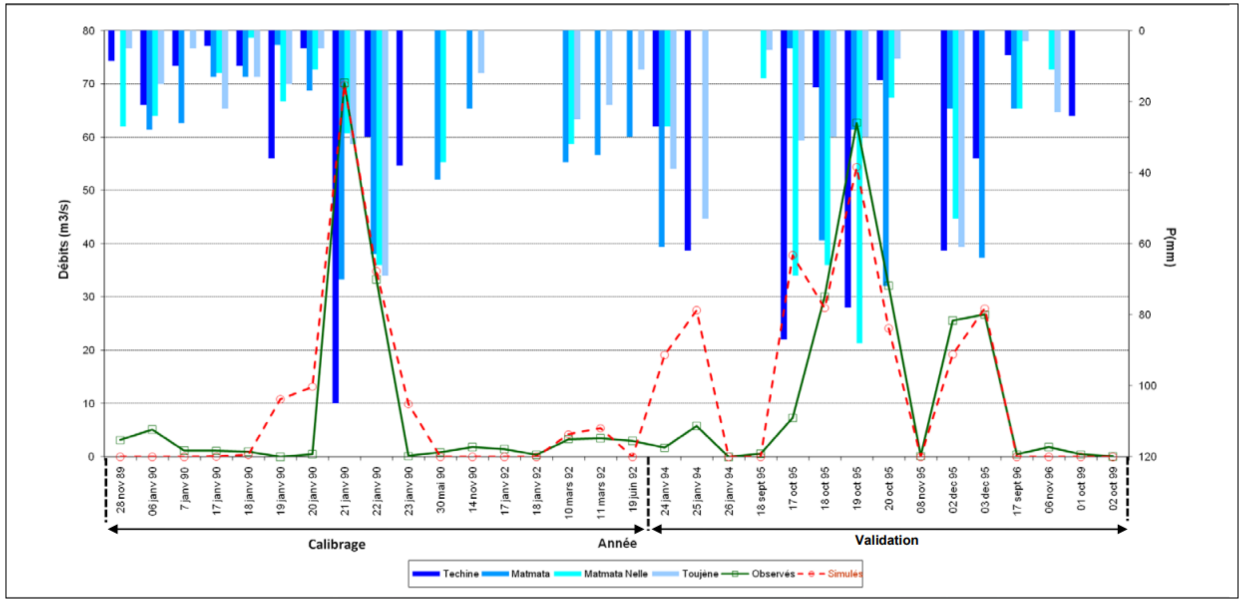


- Arid climate
- Specific Local soils and land uses were introduced to SWAT DB.
- An adapted version of SWAT (SWAT-WH2) by the integration of different WHT in the model through programming.
- The SWAT 2000 code was modified by modifying and activating the "Potholes" option.

Abdelli F (2017) FONCTIONNEMENT HYDROLOGIQUE POUR L'AMENAGEMENT D'UN BASSIN VERSANT ARIDE MOYENNANT L'ADAPTATION DU MODELE SWAT : CAS DU BASSIN VERSANT D'OUED JIR (GABES). Ph.D. thesis, INSTITUT NATIONAL AGRONOMIQUE DE TUNISIE. Ecole Doctorale Sciences et Techniques de l'Agronomie et de l'Environnement, 226 pp.

1- The historical utilization of the SWAT model in Tunisia

- The calibration (Nash (E) = 0,92 and the coefficient of determination (R2) = 0,96)
- Validation (E = 0,89 and R2 = 0,80)
- For a rainfall series of 15 years (AAR 188 mm), the water balance at wadi Jir watershed was:
  - evapotranspiration is estimated at 121 mm (65%),
  - the flowout is estimated at 19 mm (10%)
  - groundwater recharge (infiltration + percolation) is assessed at 47 mm (25%)
- 4 scenarios were considered
- For different scenarios, the dominant term is evapotranspiration (between 106 and 121 mm : 57 to 65% of the AAR).
- Recharge takes second place with a variation of 47 to 60 mm (25 to 32%) of the AAR

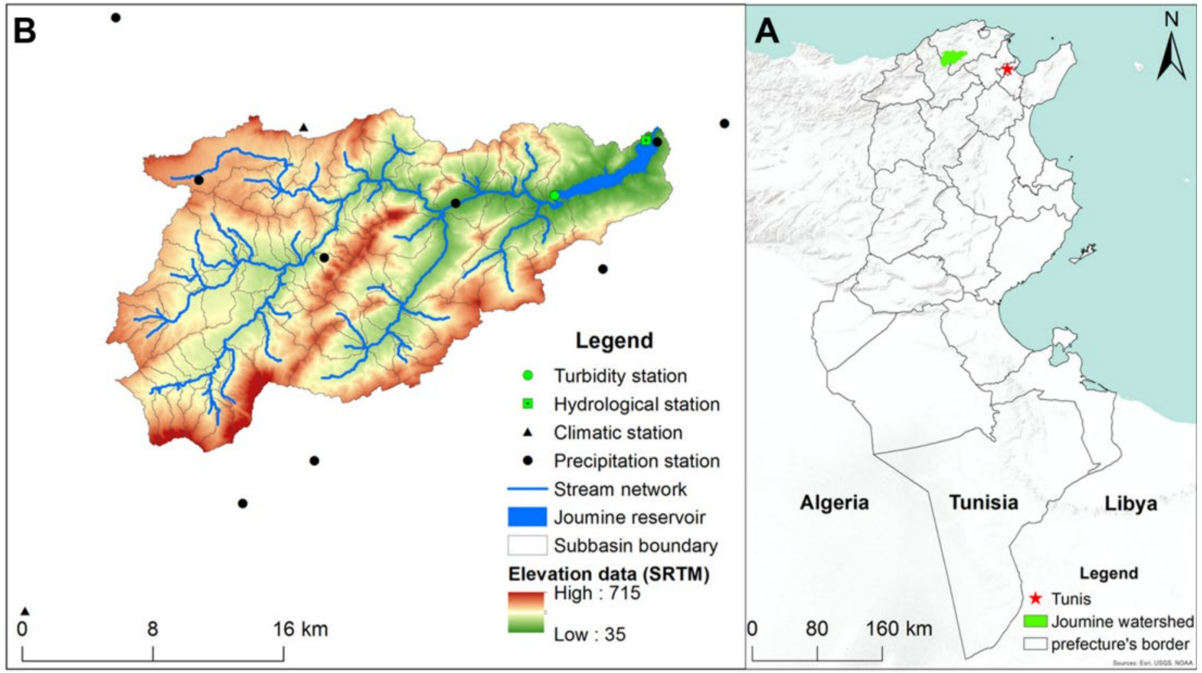


Correlations between simulated and observed flow rates

Abdelli F (2017) FONCTIONNEMENT HYDROLOGIQUE POUR L'AMENAGEMENT D'UN BASSIN VERSANT ARIDE MOYENNANT L'ADAPTATION DU MODELE SWAT : CAS DU BASSIN VERSANT D'OUED JIR (GABES). Ph.D. thesis, INSTITUT NATIONAL AGRONOMIQUE DE TUNISIE. Ecole Doctorale Sciences et Techniques de l'Agronomie et de l'Environnement, 226 pp.

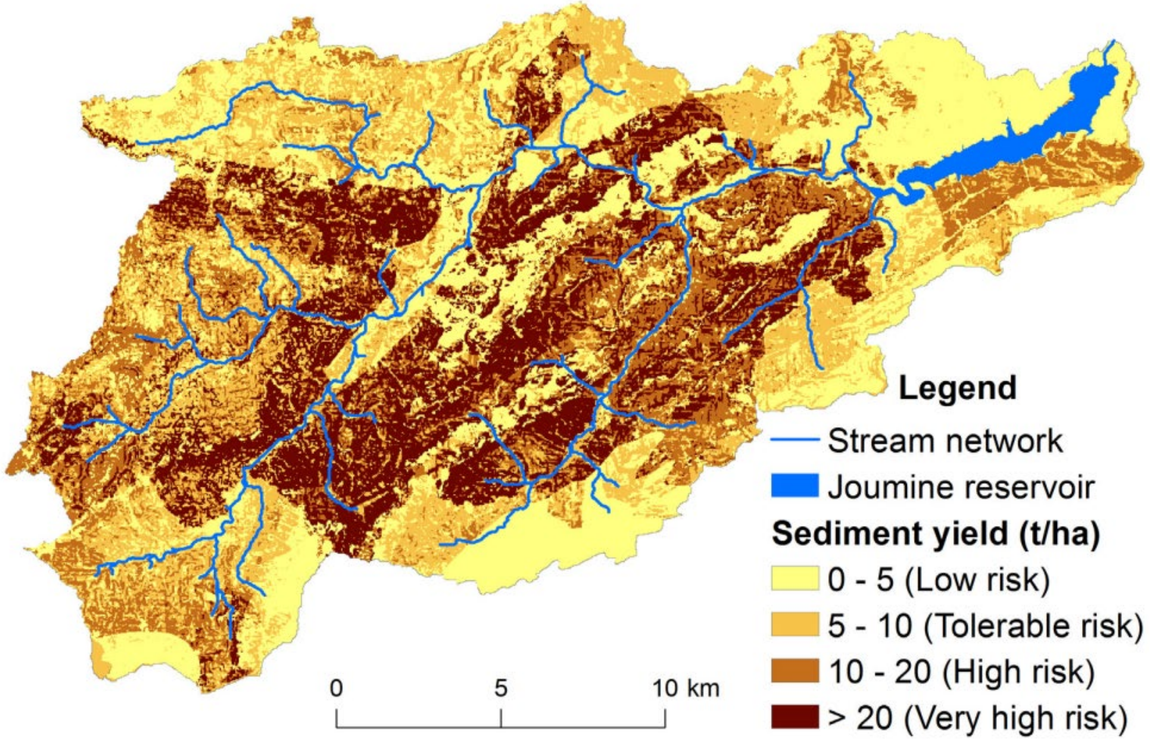
Mtibaa et al. 2018 used the SWAT model to identify critical source areas (CSAs) and investigate the effectiveness of different best management practices (BMPs) in reducing sediment yield in the ***Joumine watershed***, ***northern Tunisia***

- semi-arid climate
- SWAT : the simulation of streamflow and sediment yield
- Presence of a large dam
- A cost-benefit analysis (CBA) was used to evaluate the cost-effectiveness of different BMP scenarios.
- The objective of the present study was to determine the most cost-effective management scenario for controlling sediment yield.



Mtibaa Slim , Norifumi Hotta , Mitsuteru Irie (2018) Analysis of the efficacy and cost-effectiveness of best management practices for controlling sediment yield: A case study of the Joumine watershed, Tunisia. Science of the Total Environment 616–617 (2018) 1–16. https://doi.org/10.1016/j.scitotenv.2017.10.290

- About 34% of the catchment area consisted of critical source areas (CSAs) that were affected by high to very high soil erosion risk.
- Contour ridges were found to be the most effective individual (best management practices) BMP in terms of sediment yield reduction.
- At the watershed level, implementing contour ridges reduced sediment yield by 59%.
- Combinations of BMP scenarios were more cost-effective than the contour ridges alone.
- Combining buffer strips (5-m width) with other BMPs depending on land slope was the most effective approach in terms of sediment yield reduction and economic benefits.
- This approach reduced sediment yield by 62% with a benefit/cost ratio

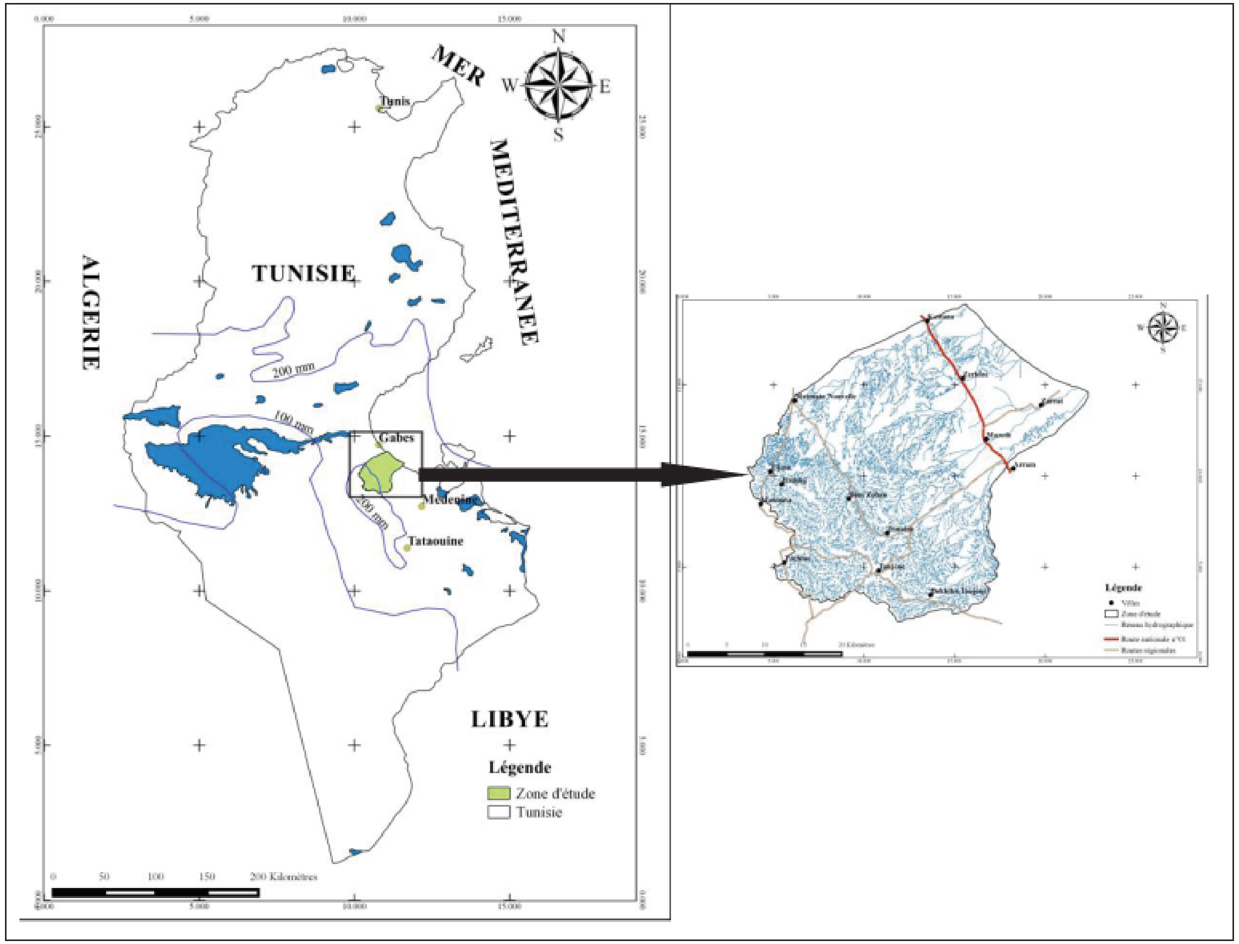


Spatial distribution of sediment yield at HRU level in the Joumine watershed

Mtibaa Slim , Norifumi Hotta , Mitsuteru Irie (2018) Analysis of the efficacy and cost-effectiveness of best management practices for controlling sediment yield: A case study of the Joumine watershed, Tunisia. Science of the Total Environment 616–617 (2018) 1–16. https://doi.org/10.1016/j.scitotenv.2017.10.290

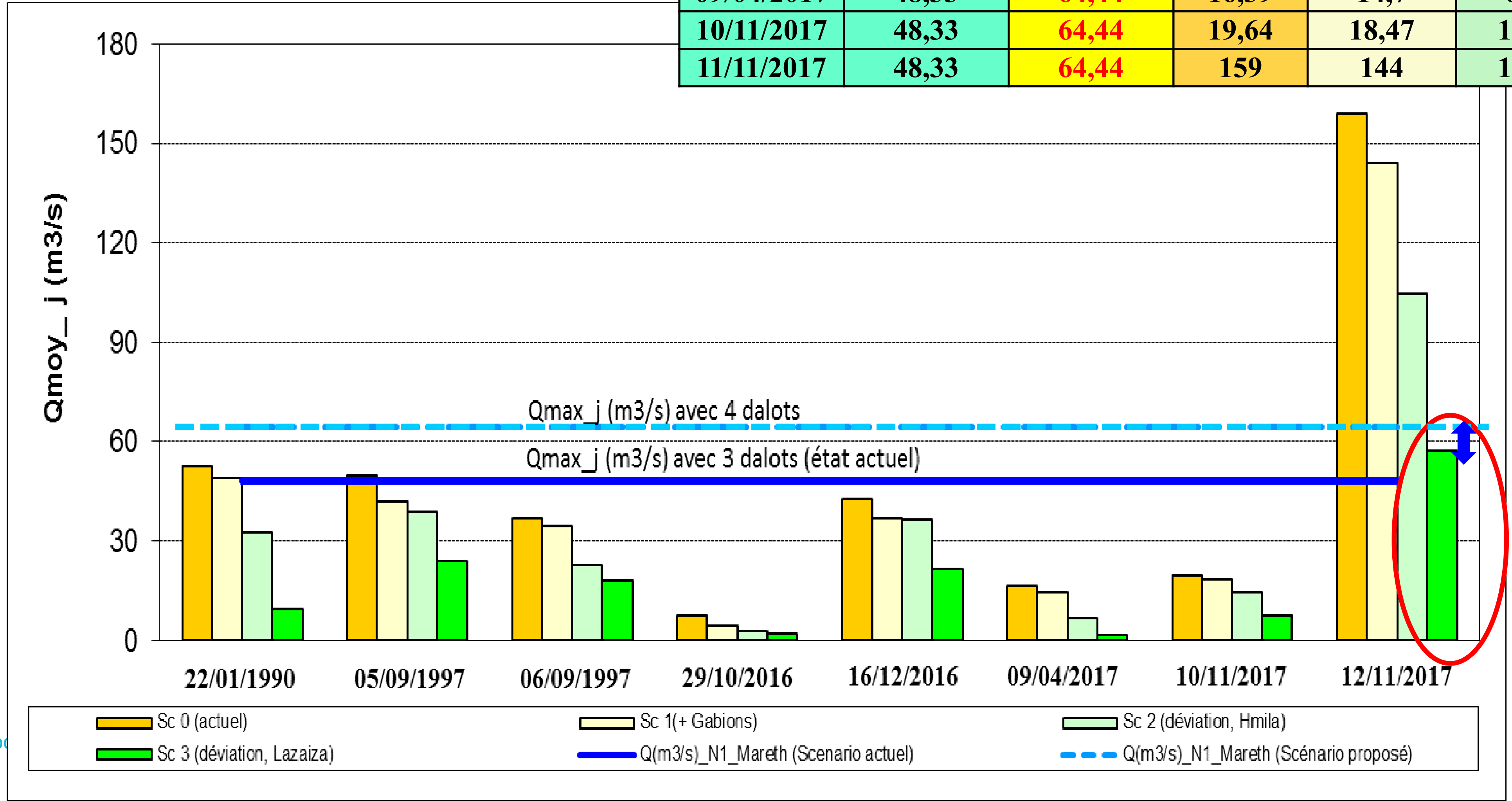
Kerdi , Abdelli 2019: Stormwater management and reduction of flood risk for the town of Mareth (Case of rain of November 11 and 12, 2017), ***Oued Segui watershed, Gabes***

- In Tunisia, the extent of the damage caused by recurrent floods in recent years has revealed deficiencies in water-related risk management.
- The floods on November 11 and 12, 2017, in Gabès caused significant human and material damages.
- Objectives :
- Management of stormwater and reduction of flood risk for the city of Mareth.
- Specific objectives:
  - Identify the causes and effects of the flooding on November 11 and 12, 2017.
  - Develop scenarios for urban planning to protect the city of Mareth from future flooding incidents.



1- The historical utilization of the SWAT model in Tunisia

Date	Q des dalots (m3/s)		Q moy_j (m3/s)			
	à l'état actuel	proposé	SC0	SC1	SC2	SC3
22/01/1990	48,33	64,44	52,46	49,04	32,59	9,35
05/09/1997	48,33	64,44	49,91	42,15	38,65	23,86
06/09/1997	48,33	64,44	36,82	34,42	22,87	18,07
29/10/2016	48,33	64,44	7,68	4,42	2,76	2,2
16/12/2016	48,33	64,44	42,8	36,86	36,61	21,48
09/04/2017	48,33	64,44	16,39	14,7	6,75	1,59
10/11/2017	48,33	64,44	19,64	18,47	14,42	7,59
11/11/2017	48,33	64,44	159	144	104,6	57,12

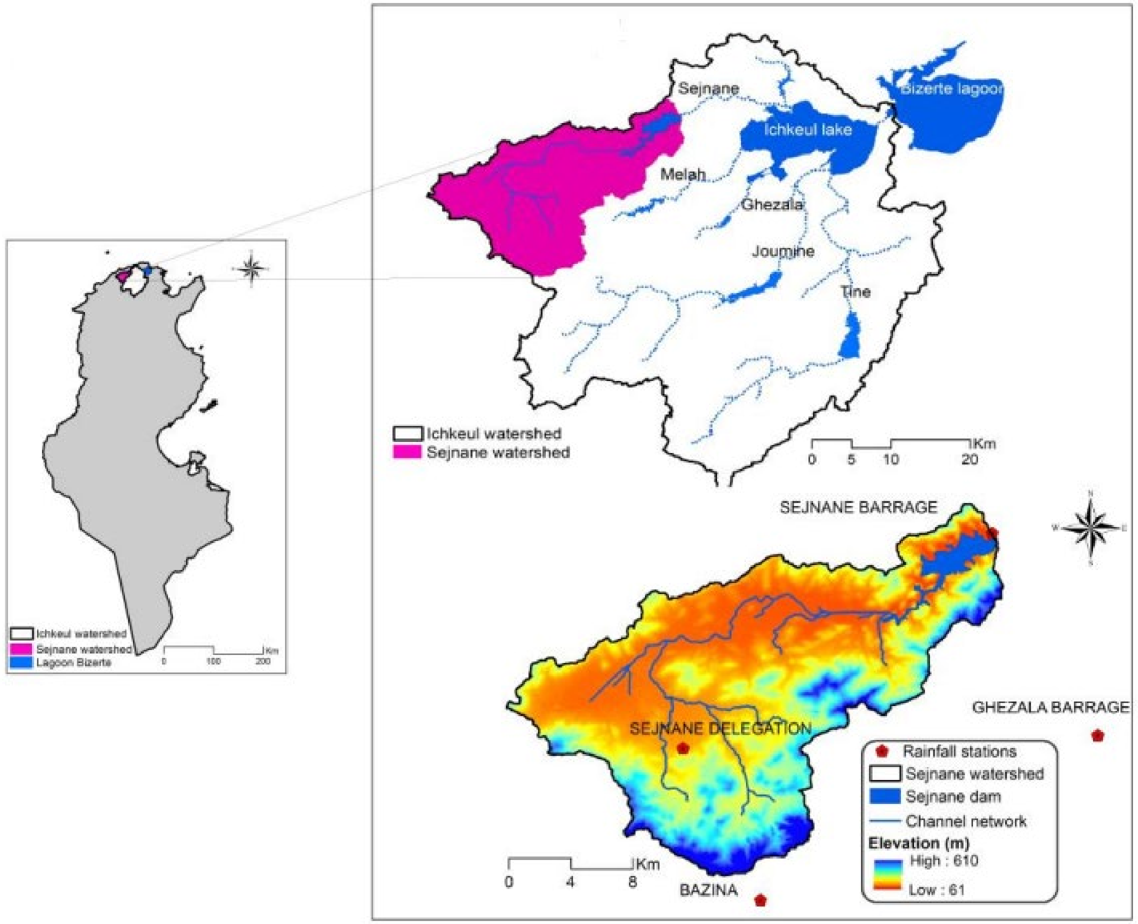


Kerdi, Abdelli 2019: Stormwater management and reduction of flood risk for the town of Mareth (Case of rain of November 11 and 12, 2017), ***Oued Segui watershed, Gabes***

- To protect the city of Mareth from floods, decision-makers was urged to choose Scenario 3 (the 100% diversion of water flow from Wadi Ségui to Wadi Zigzaou in the Lazaiza region), coupled with increasing the width of Wadi Ségui in Mareth by adding a fourth culvert.

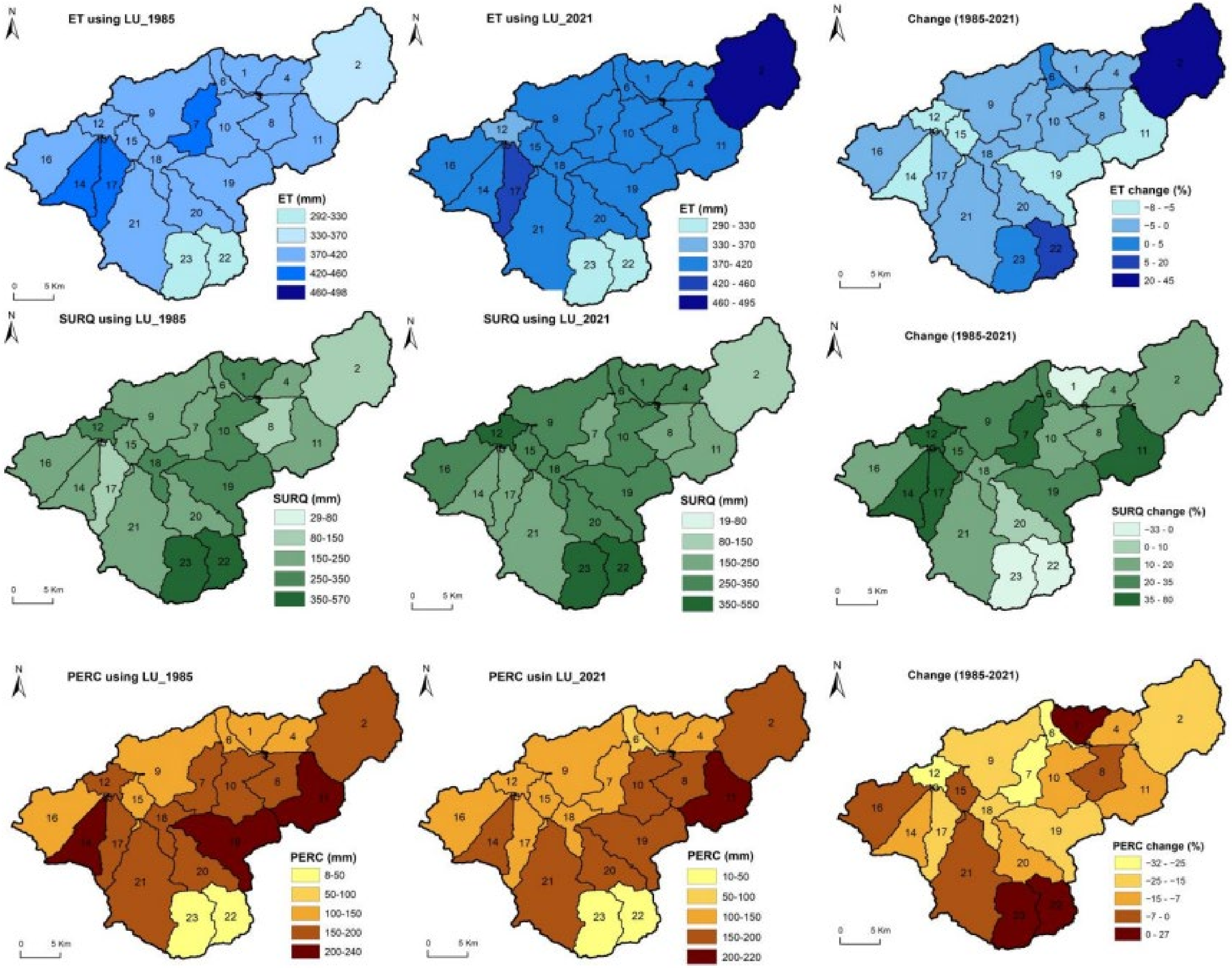
Mosbahi et al. 2023 used SWAT model to quantify and analyze land use change and its impacts on water resources of the ***Sejnane watershed, northern Tunisia.***

- Mediterranean sub-humid climate
- The Sejnane dam was constructed at the outlet of the basin
- Different land use maps were used to show the landscape pattern of the basin before and after the construction of the dam
- The impact of land use change on hydrological processes, including evapotranspiration (ET), surface runoff (SURQ), percolation (PERC) and water yield (WYLD)



Mosbahi, M.; Kassouk, Z.; Benabdallah, S.; Aouissi, J.; Arbi, R.; Mrad, M.; Blake, R.; Norouzi, H.; Béjaoui, B. Modeling Hydrological Responses to Land Use Change in Sejnane Watershed, Northern Tunisia. Water 2023, 15, 1737. https:// doi.org/10.3390/w15091737

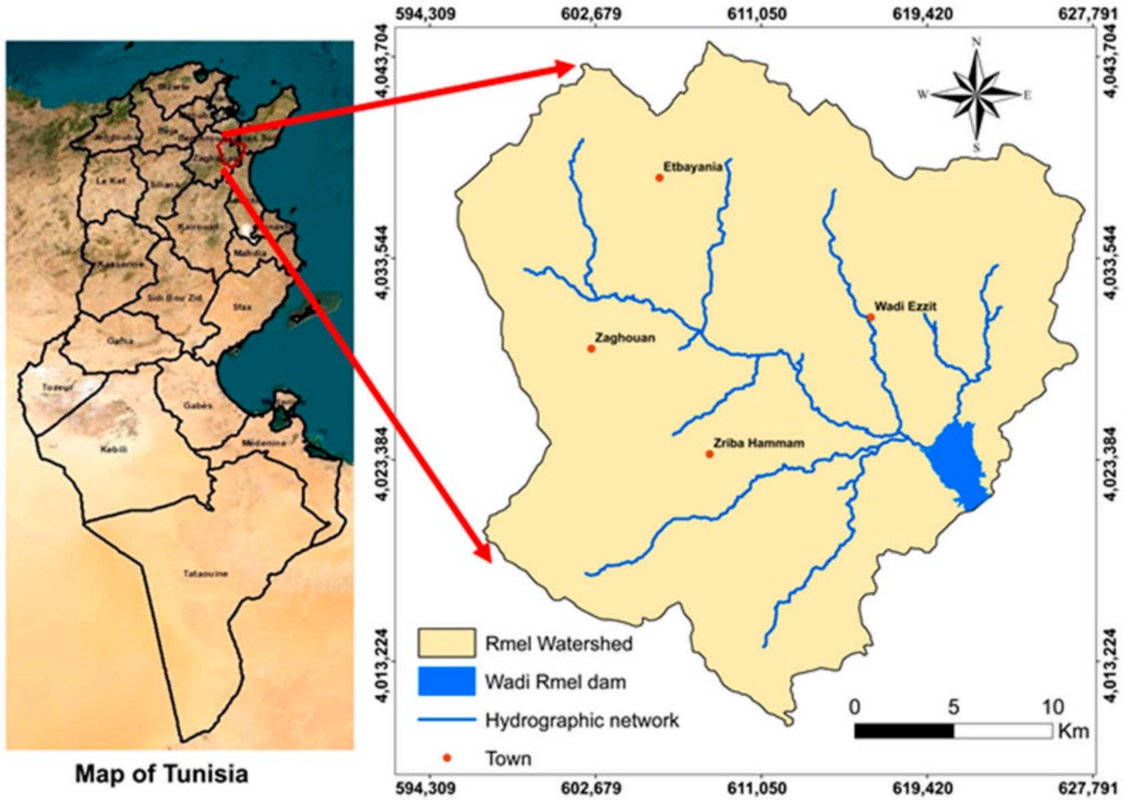
- It was found that land use change strongly affected surface runoff that was increased by 36.6 mm.
- However, percolation declined by 22.6 mm, followed by lateral flow, with a reduction of 9.4 mm.
- Evapotranspiration was variable and depended on the land cover change



Spatial and temporal change in evapotranspiration (a), surface runoff (b) and percolation (c) in the watershed

Jarray et al. 2023 used SWAT model to measure and analyze the impact of the soil and water conservation (SWC) interventions on sediment yield in ***Wadi Rmel watershed, northern Tunisia.***

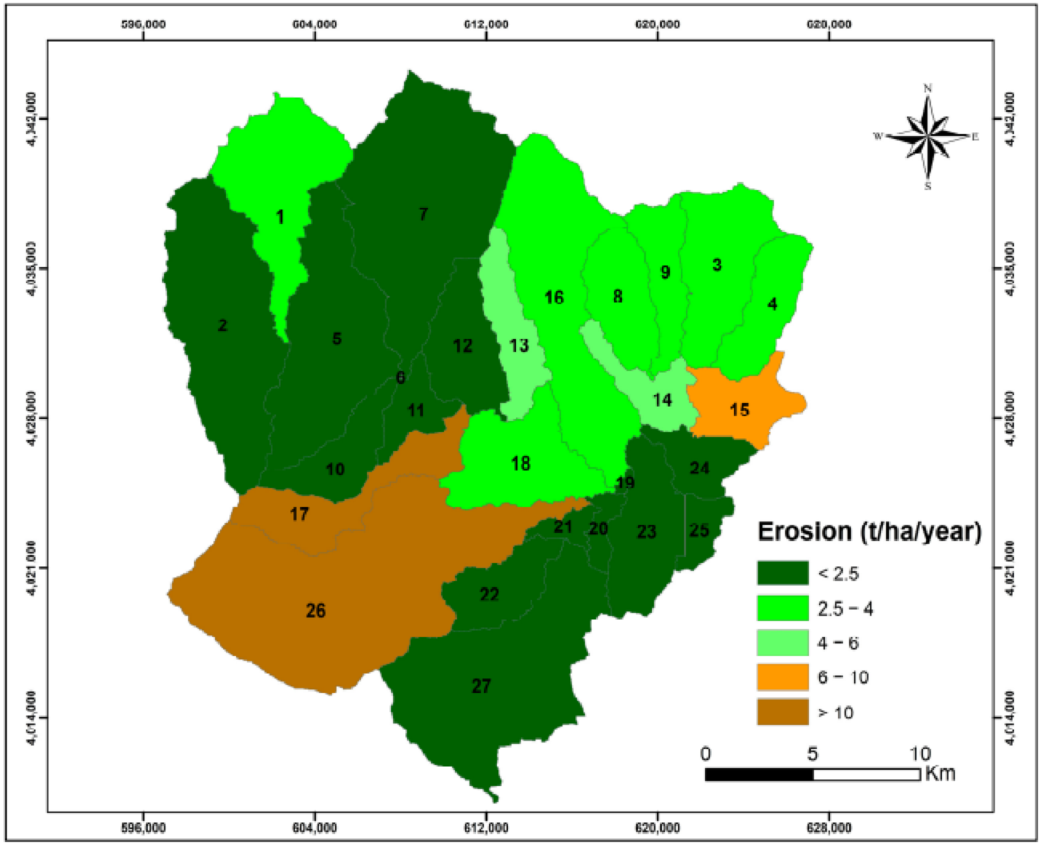
- semi-arid climate
- LANDSAT satellite imageries were used to classify and generate a land use/land cover map
- The different soil classes were defined based on digitized Tunisian soil map



Jarray Fathia, Taoufik Hermassi, Mohamed Mechergui , Claudio Zucca and Quang Bao Le (2023) Long-Term Impact of Soil and Water Conservation Measures on Soil Erosion in a Tunisian Semi-Arid Watershed. Land 2023, 12, 1537. https://doi.org/10.3390/land12081537

Good model performance,

- The calibration (2001–2014) with a (NSE) of 0.61 for the runoff and a coefficient of determination (R2) of 0.66.
- The validation process (2015–2020) with NSE value equal to 0.83 and R2 value of 0.85.
- The result showed that the increase in terracing areas led to a cumulative decrease in watershed sediment yield in long-term,
- This finding suggests that maximal benefits of soil and water conservation SWC should be expected in the long-term (beyond a decade).
- These findings enable stakeholders to plan effective management in semi-arid wheat-based agricultural areas with scarce data



Spatial distribution of sediment source areas in the Wadi Rmel watershed.

Jarray Fathia, Taoufik Hermassi, Mohamed Mechergui , Claudio Zucca and Quang Bao Le (2023) Long-Term Impact of Soil and Water Conservation Measures on Soil Erosion in a Tunisian Semi-Arid Watershed. Land 2023, 12, 1537. https://doi.org/10.3390/land12081537

2- Refinement and Assessment of the SWAT Model in arid zones of Tunisia

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Two new versions available to users (Tunisian arid areas):

- **SWAT-WH** (Ouessar et al., 2009)
- **SWAT-WH2** (Abdelli, 2017).

- **Objectives**

Main objective:

Develop a Decision Support System (DSS) for controlling the management of watersheds in arid areas.

Specific objectives:

1. **Determination of the different components of the hydrological balance of the watershed;**
2. **Simulation of the impacts of new land management scenarios.**

- General problem

Natural factors (CC)
- Droughts
- Floods
- Rare and irregular precipitation
- Etc.

Human factors
- Overexploitation of resources
- Rural exodus
- Pollution
- Etc.

DEGRADATION OF THE NATURAL ECOSYSTEMS

Consequences
- Food insecurity
- Deterioration of soil and water resources
- Decrease in animal and plant biodiversity
- Exodus of populations
- Poverty

Actions taken?

- General problem

Water and Soil Conservation Works (SWC)

Implementation of **National SWC Strategies (1990- 2000 & 2001-2010 & 2011-2020)**

Evaluation of the performance and impacts of WHT on the hydrological balance of watersheds

Decision Support System (DSS)
(Hydrological Modeling…)

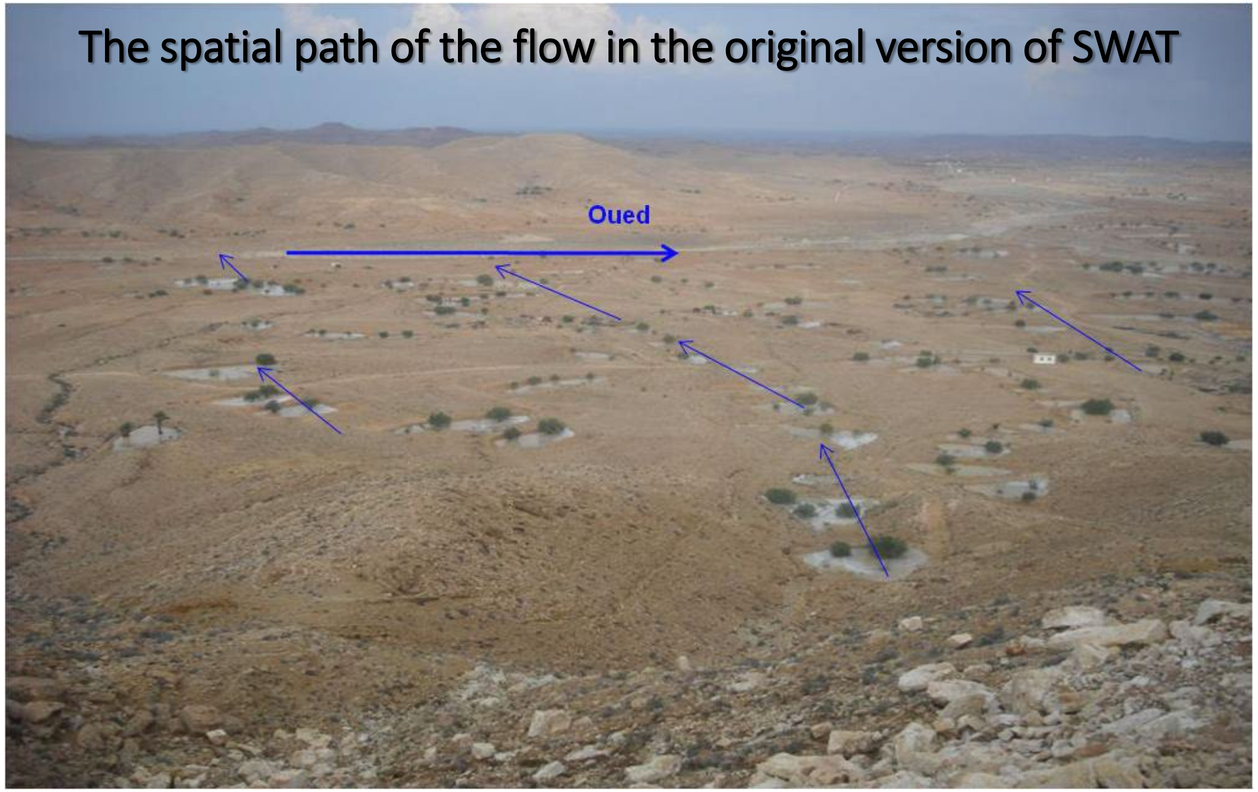
Responding to issues related to watershed management in arid areas

• Choice of SWAT model

- ✓**Open source**: The availability of the source code and executable of the model for free
- ✓SWAT has a module to **generate missing data** from weather stations taking into account the topography of the terrain and the proximity of the station to the basin;
- ✓Using **GIS**
- ✓Etc.

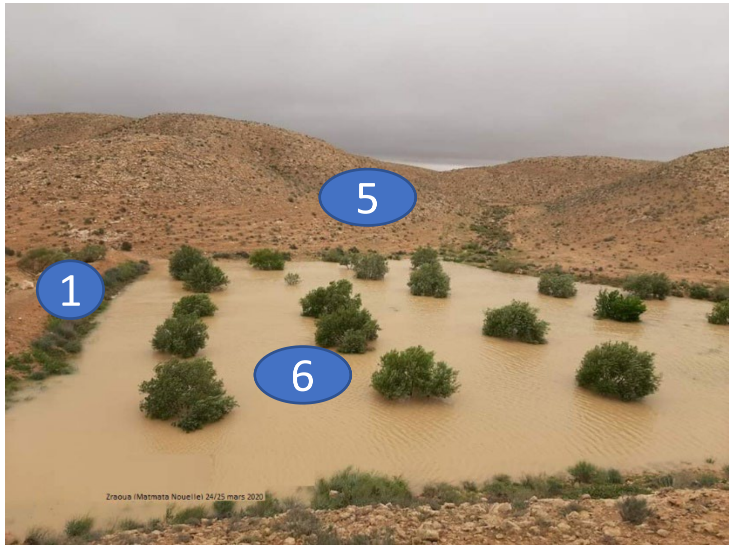
SWAT model modifications

- ✓For each subbasin, **SWAT (SWAT2000)** summarizes the runoff coming out of all HRUs and adds this to the reach.
- ✓SWAT irrigation operation, which limits the water application to what can be stored in the soil profile.
- ✓ **WHT** typical for arid watersheds in southern Tunisia are **not represent**!



To represent the processes, a number of modifications need to be made in the model.

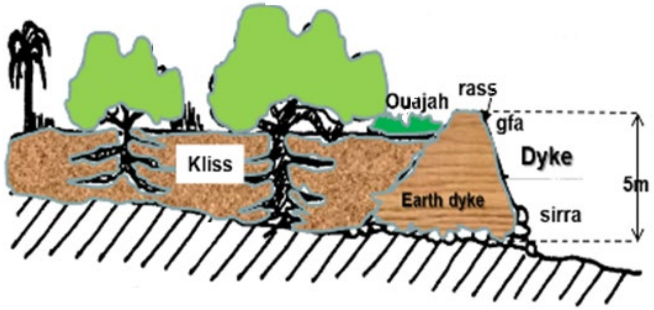
Description of the Jessour System



Every "jesr" is composed by the following elements:

- 1 **Dyke**: (*Katra*) made of earth, it's a barrier for stopping the runoff water
- 2 **Sirra:** the dyke is armed in the downstream by a wall of dry stones to become more powerful.
- 3 **Kliss**: an important volume of materials (silt and sand) extracted from the slope by runoff is accumulated over time behind the dyke.
- 4 **Menfess**: is a lateral spillway in the end of dyke , to evacuate the excess water .
- in same cases they use a **Masraf**: it is a central spillway (its considered as innovation system (Benvallot 1979)
- 5 **Catchment area (impluvium):** is the area which collects and transmit runoff water to cropped area
- 6 **The Cropped area** (terraces): its the area in which farming is practiced.

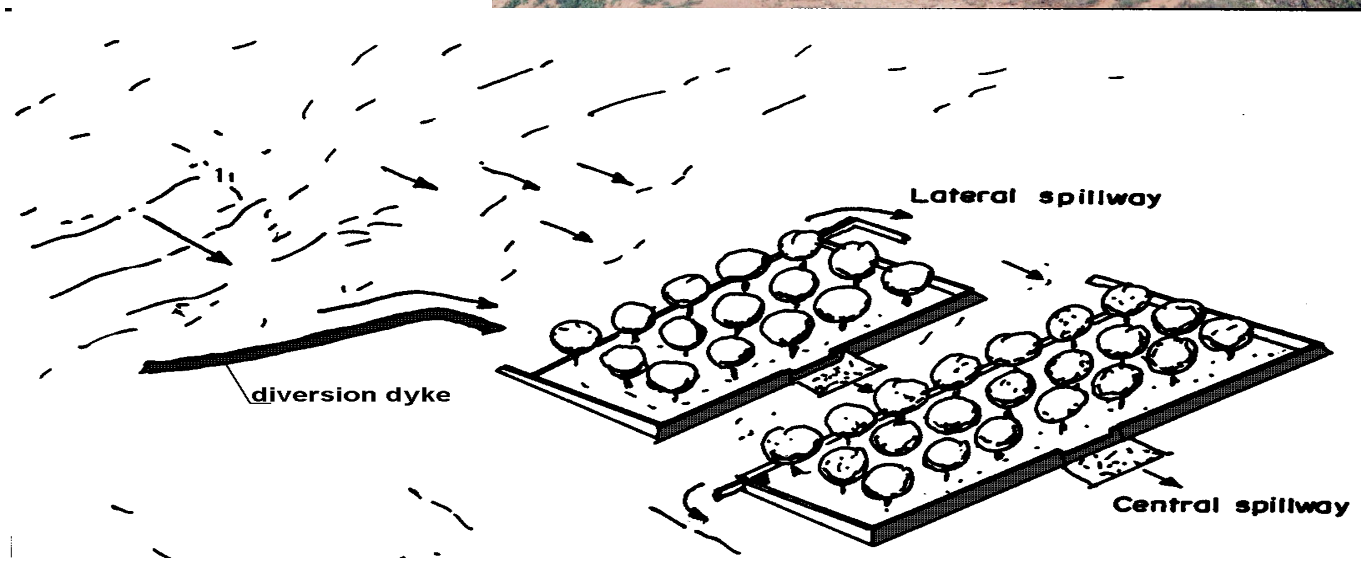
It is formed progressively by the deposition of sediment. An artificial soil will then be created, which can be up to 5 m deep close to the dyke. Generally, **fruit trees** (olive, fig, almond, and date palm), **legumes** (e.g., pea, chickpeas, lentil, and faba bean) and **barley and wheat** are cultivated on these terraces.



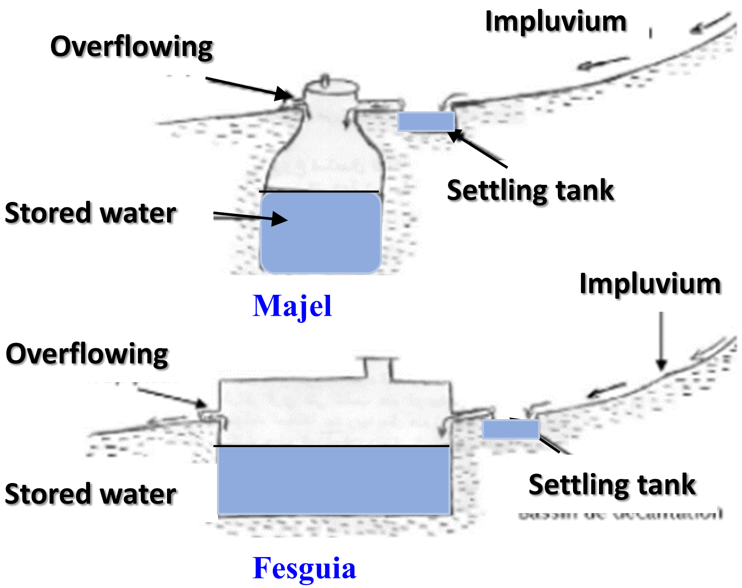
• Description of the Tabia System

The ***Tabia*** technique is similar to the Jessour system used in the **foothill and piedmont areas**.

It is considered to be a relatively new technique, developed by mountain dwellers who migrated to the plains (Ouessar, 2007).



- Description of Cisterns System



- ✓ Used to **supply the rural community with water for different uses** (drinking water, livestock watering and irrigation).
- ✓ Runoff water is collected and stored in stone-faced underground tank, of various sizes, called ***Majel*** and ***Fesquia***.
- ✓ It is estimated that a tank with a capacity of **35 m³ can meet the annual water needs of a family and its livestock** (Ennabli, 1993).

• Description of the Gabion and masonry check dams

small **check dams** are installed on the wadi beds in order to **slow down the water flow** in the wadi courses and **improve its infiltration,**

These dams are made of **gabion or in masonry**.

The use of **gabion check dams** for **groundwater recharge** and **runoff diversion** is widely practiced all over the country.

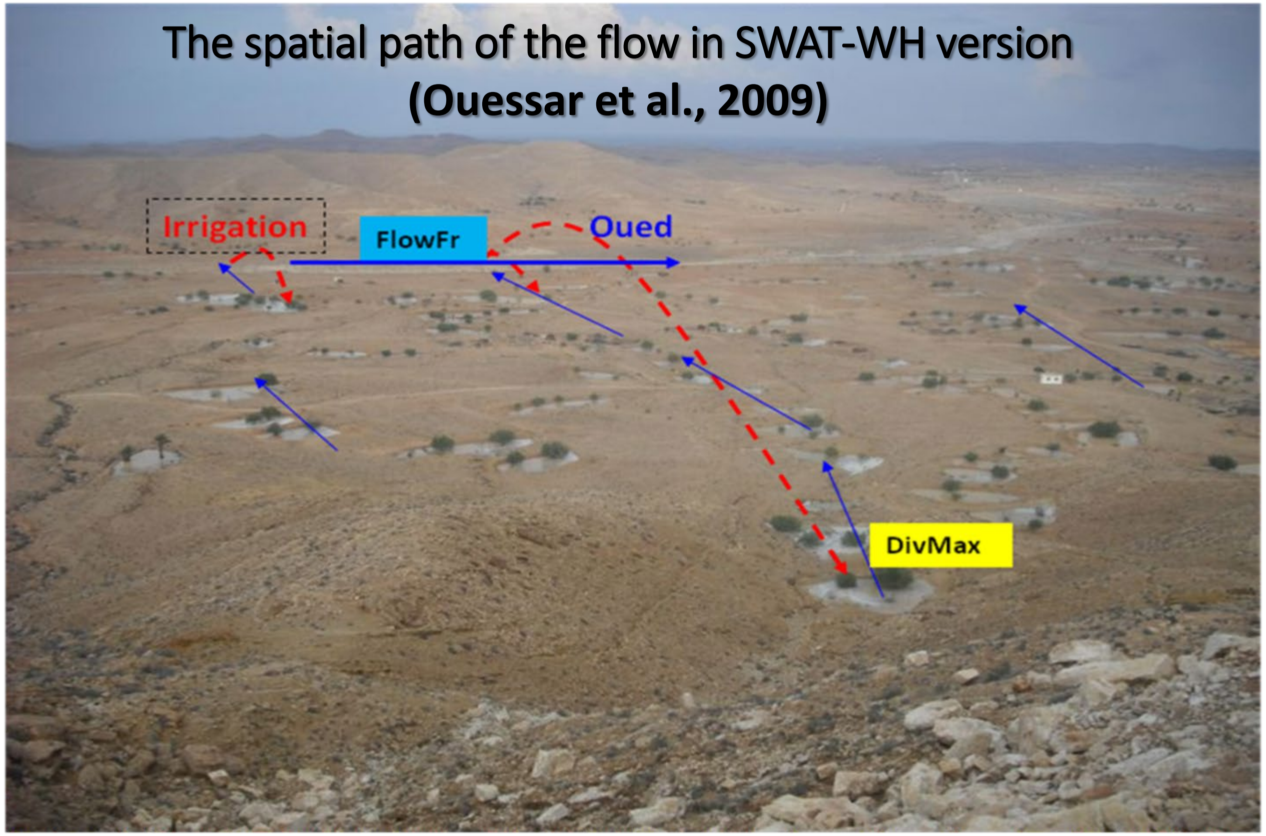
SWAT model modifications

Two new versions available to users (Tunisian arid areas):

- **SWAT-WH** (Ouessar et al., 2009)
- **SWAT-WH2** (Abdelli, 2017).

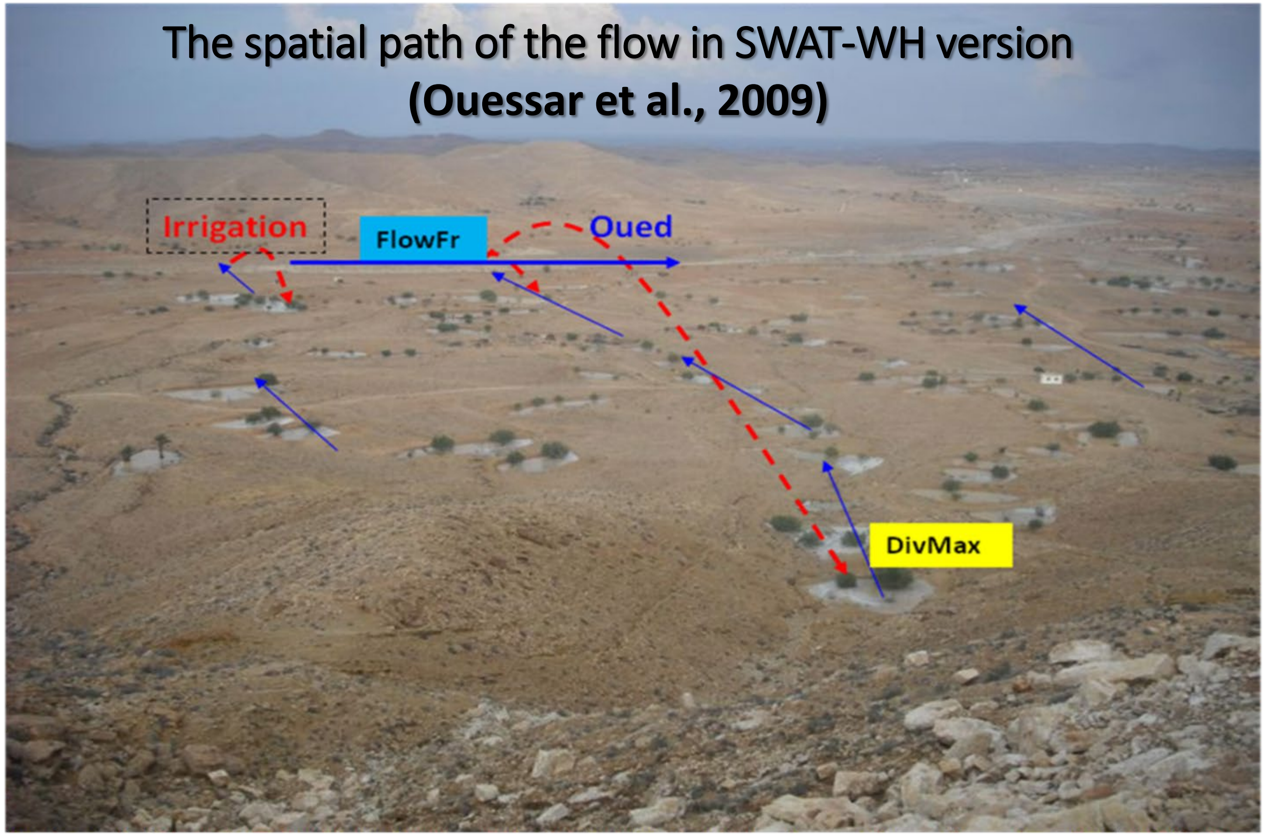
- **SWAT-WH** (Ouessar et al., 2009)

The **SWAT code was modified** to simulate the collection of runoff water behind the WH structures (*Jessour* and *Tabias*), by bringing the surface runoff and lateral flow generated in the subbasin back to the water-harvesting HRUs in the subbasin.



SWAT's irrigation-from-reach option was used to allow the entry of input data for controlling the amount of water harvested by the different HRUs. This option allows the user to specify the **fraction of the runoff water** (**FLOWFR**) and a **maximum height of the water impoundment on each HRU** (**DIVMAX**).

- **SWAT-WH** (Ouessar et al., 2009)



1. First the water is distributed to **all Jessour HRUs** and **secondly to the Tabia units**, which are generally located downstream from the Jessour. Finally the remainder of the runoff flows downstream.

2. If the **total water harvested** by the HRU exceeds the field capacity of the soil profile, it will become **percolation**. This is different from the SWAT2000 irrigation operation, which limits the water application to what can be stored in the soil profile.

- **SWAT-WH** (Ouessar et al., 2009)

3. The initialization of **the heat unit accumulation** was changed to allow the perennials and annual crops to **grow during the Mediterranean hydrologic year from autumn to summer.**

4. The **dormancy period** was removed because the crops in the watershed do not become dormant.

5. Furthermore, as **olives are permanently green**, the shedding of leaves for trees, present in the model, was removed.

6. The change of the runoff CN as specified in the management file, **did not function in SWAT2000**, this **was corrected**.

The modified SWAT model is referred to as **SWAT-WH**

SWAT model modifications

Improvements in content based on the SWAT_WH version (Ouessar et al., 2009);

- **SWAT-WH2** (Abdelli, 2017).

• SWAT-WH2 (Abdelli, 2017)

- **The improvement of SWAT-WH took place at two levels:**

1. **Integration of the Jessour** system by modifying the source code of the model, more precisely by activating and modifying the "***Pothole.f***" subroutine, using the "***Visual Fortran***" compiler.

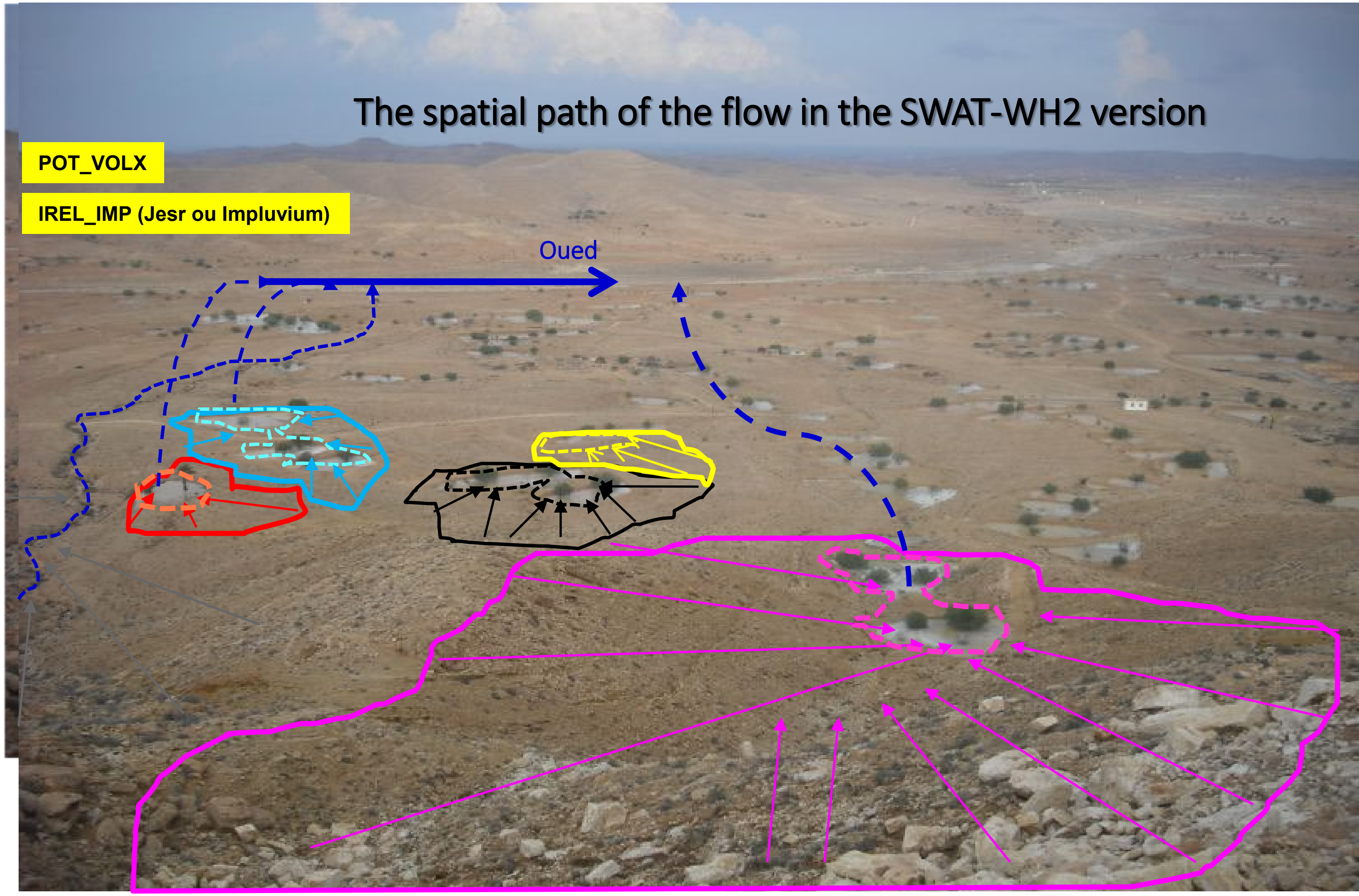
2. **Direct use of the hydraulic structures** already represented in the model:
   - Use of the "***Reservoir***" option to represent the **Recharge Check dams**;
   - USE of ***« Ponds »*** option to represent the **Cisterns**.

• SWAT-WH2 (Abdelli, 2017)

1. Integration of the Jessour

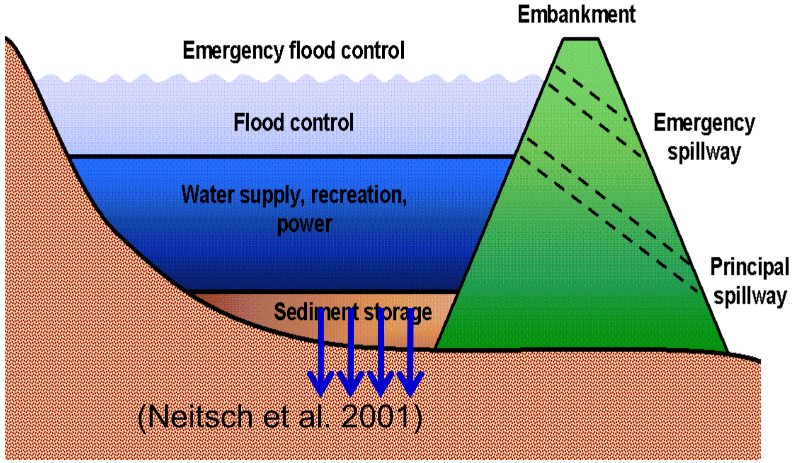
In SWAT-WH version all Jessour units receive the same quantity of water, regardless of the quantity generated by their own impluvium

By modifying the "***Pothole***" subroutine, each unit "***Jesr***" **receives water only from its own impluvium**, the excess goes directly to the wadi



• SWAT-WH2 (Abdelli, 2017)

2. The "*Reservoir*" option to represent Gabion check dams in SWAT-WH2



The "***Reservoir***" is a hydraulic structure located in the **main wadi**.

It receives water from upstream sub-basins. The water is evacuated by a spillway towards the downstream part of the wadi.

The characteristics that need to be modified are:

- ✓ **Ks (mm/h),**
- ✓ **Emergency spillway.**

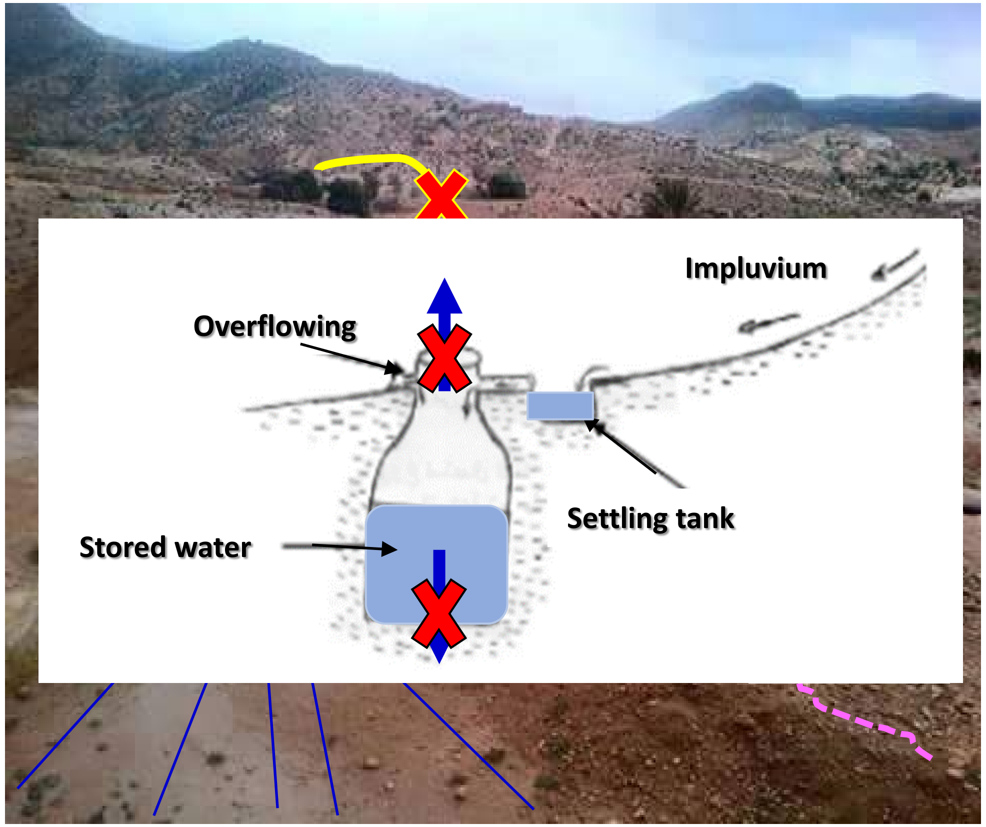
• SWAT-WH2 (Abdelli, 2017)

3. The "*Ponds*" option to represent Cisterns in SWAT-WH2

"Ponds" are hydraulic water storage structures **located within the subbasin**.

The **impluvium** of the "*Pond*" is defined as a **fraction of the total surface area of the subbasin**.

It does not receive water from other sub-basins, it only receives run-off water generated by the subbasin where it is located.



To get closer to reality, we modified the characteristics of the '*Pond*' by **reducing the two flows to zero: evaporation and infiltration**.

• SWAT-WH2 (Abdelli, 2017)

4. APPLICATION

The results of the application of SWAT-WH2 for various Scenarios.

Senarios	Description
SC0	**Natural scenario (without human intervention)**
SC1	The land is only occupied by the jessour
SC2	**The current state of the basin (reference)**
SC3	**SC2 + Cisterns** (1650 units)
SC4	**SC2 + deactivation of the effects of Gabion Check dams + intensification of Cisterns**

• SWAT-WH2 (Abdelli, 2017)

4. APPLICATION

Reference

	SC0		SC1		SC2		SC3		SC4	
	mm	%	mm	%	mm	%	mm	%	mm	%
Rainfall	187	-	187	-	187	-	187	-	187	-
ET	106,6	56,8	121	64,5	119,7	63,8	119,7	63,8	121	64,5
Flowout	26,9	14,3	18,9	10,1	7,6	4,1	7,6	4,1	18,9	10,1
Percolation	41,3	22,0	36,5	19,4	36,1	19,2	36,1	19,2	36,5	19,4
TLOSS	12,6	6,7	11,1	5,9	20,5	10,9	20,5	10,9	11,1	5,9
Seepage	-	-	-	-	3,4	1,8	3,4	1,8	-	-
Recharge	53,9	28,7	47,5	25,3	60,0	31,9	60,0	31,9	47,5	25,3

The new version **"SWAT-WH2"** has well reproduced the effect of WHT in the Matmata region.

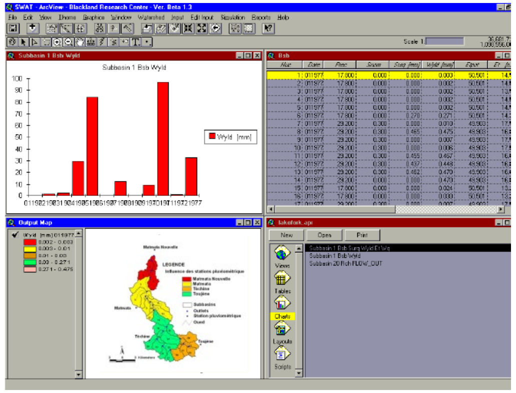
• SWAT-WH2 (Abdelli, 2017)

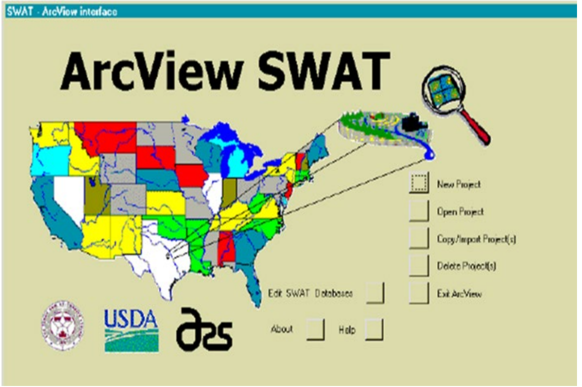
5. CONCLUSION

The modifications to the **SWAT code** as well as the calibration and validation operations resulted in:

The new version of SWAT « SWAT-WH2 »

Able to study hydrological processes under the arid conditions of southern Tunisia.





General conclusion

Two new versions available to users (Tunisian arid areas):

- **SWAT-WH** (Ouessar et al., 2009)
- **SWAT-WH2** (Abdelli, 2017).

AG-WaMED

SWAT Soil & Water Assessment Tool

The Soil and Water Assessment Tool (SWAT) for sustainable water management in the Mediterranean Area

Second Online Masterclass, 20 -11- 2023

Thank you

Institut des Régions Arides

November 20th, 2023

PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Funded by the European Union

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