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SWAT streamflow modeling for hydrological components' understanding within an agro-sylvo-pastoral watershed in Morocco

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Abstract

Being generally described as coherent entities in hydrological sense, watersheds are considered as study units to assess hydrological cycles and to come up with water management strategies. Hydrological modeling is a tool that can offer the chance to achieve these goals. The model Soil and Water Assessment Tool (SWAT) has been widely used in various parts of the world to support decision making on water management, and proved its efficiency in many arid and semi-arid areas even when different economical activities are held in the watershed (farming, pasture, forestry...). In this study, the SWAT model has been applied over R'dom watershed, agro-sylvo- pastoral basin located in a semi-arid area in North-Western Morocco, with the aim to simulate the hydrological processes occurring in the study basin as a preliminary step. The simulation was performed across the period 2004 to 2009 and gave satisfactory goodness-of-fit levels in daily time step (NSE= 0.58, R^2= 0.79, PBIAS=19% during calibration and NSE=0.65, R^2= 0.73, PBIAS=20% during validation). The results of the study showed that the water balance in R'dom watershed is dominated by evapotranspiration (61% of rainfall); surface runoff and water yield represent 8.3% and 25.2% of rainfall respectively. The water resources distribution within the watershed is uneven and follows a decreasing gradient matching the flow direction. The SWAT model succeeded to reflect the different hydrological processes in the study watershed and can be used to build integrated watershed management strategies within the studied basin and in other similar contexts.

1. Introduction

Water cycle is generally depending on various biotic and climatic factors that can facilitate or hinder the flow process in its different modes [**1**]. Some factors that interact in the hydrological cycle are soils, topography, vegetation cover, climate, water bodies...etc. Studying hydrologic cycle (especially in watershed scale) can be achieved by assessing all interacting components, ideally under an integrated approach [**2**].

Hydrological modeling of watersheds has known a long journey of development from a basic rational method of relating rainfall and runoff, to advanced models integrating more complex system components [**3, 4**]. Nowadays models can incorporate physical and chemical components in addition to their interactions with human and natural systems at watershed scale [**5**]. Therefore, the watershed space is often taken as the planning unit for rational management of natural resources, within strategic and political actions plan [**6**]. While the main purpose behind the use of models is to simulate part of the reality at the best possible approximation, many of conceptual models are useful for understanding a particular problem or for predicting future behaviours of a system [**3**].

In addition to the use of models to interpret the complexity of a situation, results can sometimes be extrapolated to larger spatial or temporal scales or higher levels of organization with similar conditions [**7**].

Hydrological models are simplified representations of real hydrological systems, from which we can study the "cause-effect" relationship of a basin through input and output data leading to a better understanding of the physical and hydrological processes that take place in the basin.

Selection of the right model to simulate hydrologic processes in a specific watershed has always been a key step of the whole modeling project. Many Geographic Information System (GIS)-based and watershed scale models are available giving researchers a wide array of choice. The MIKE SHE model is an integrated hydrologic modeling tool for building and simulating both surface and groundwater flows and offers a large manoeuvrability interval over the hydrological component handling [8]. ECOMAG model incorporates hydrological and water quality sub-models, which run at daily time step, and replicates the main land phase processes of the hydrological cycle [9]. TOPKAPI is a fully distributed physically-based hydrological model that can provide high resolution information on the hydrological state of watershed [10].

The Soil and Water Assessment Tool (SWAT) is a hydrological modeling program developed by the United States Department of Agriculture (Agricultural Research Service) [**11**]. This model simulates the production of water and sediments in large-scale watersheds, complex basins, with various soil types, land uses and management conditions; it also simulates the effect of agronomic practices or any other activity on water quality [**12, 13**]. It has been used in various situations, especially in areas known for their environmental vulnerability [**14**]. The model has proven efficiency in semi-arid conditions in many cases over the world (California, Mexico, Spain, Morocco, Tunisia, Iran, Italy…) [**15, 16, 17, 18, 19, 20**].

The objective of the present study is to apply the SWAT model to a Mediterranean semi-arid basin to assess its current water balance. The R'dom, a sub-watershed within the Sebou watershed, is considered as typical basin of the Sais plateau in North-western Morocco, in which forestry, pasture and agricultural activities are cohabitating and it faces similar challenges in terms of vulnerability of its land and water resources.

2. Study area

Located in the Northwestern of Morocco, R'dom watershed is covering an area of 1993 km^2 and it lays partly on the Saiss plateau in the south and the upper Gharb plain in the north (Figure 1). It is characterized by a semi-arid climate and plays a major socio-economic role due to the various activities held inside it.

The average annual precipitation varies between 300 mm and 500 mm; the rainiest seasons are winter (44%) and spring (25 %). The annual mean temperature is 16.2 °C, with January being the coldest month (minimum of 1.6°C) and august the hottest month (maximum of 39.3°C) [**21**].

This watershed presents a highly variable topography (altitude between 32 m and 1800 m) and farming is the dominating activity (45% of total surface of the watershed); the major grown crops are rainfed cereals, sunflower, onion and olive trees. The rest of R'dom watershed surface is hosting forest and pasture lands. Soil types in the study watershed are characterized by large variability ranging from well drained sandy soils to loamy-clay soils with high swelling activity.

The R'dom river is an intermittent river with a mean annual discharge of 2.1 m^3/s measured at Souk El had flow-gauge (*Projected Lambert coordinates*: x=*465943, y=410043*) (Figure 1).

3. Model presentation

SWAT model offers the possibility to simulate a large number of physical processes in the basin through the subdivision of the basin to several sub-basins based on a threshold area value depending on the accuracy and the objectives of the study [**19**]. Sub-basins are then divided into hydrological response units (HRU) that represent a unique combination of soil type, land use and slope [**13**].This subdivision allows the model to reflect different hydrologic processes occurring at the level of each unit (evapotranspiration, percolation, runoff...) [**19**].

The daily water balance simulated by the SWAT model is based on the following equation [**11**]:

$$SW_t = SW_0 + (R_{day} - Q_{surf} - E_A - W_{seep} - Q_{gw}) \qquad (1)$$

Where;

SW_t : the daily final soil water content (mm H_2O),
SW_0 : the initial soil water content on day *i* (mm H_2O),
t : the time (days),
R_{day} : the amount of precipitation on day *i* (mm H_2O),
Q_{surf} : the amount of surface runoff on day *i*(mm H_2O),
E_a : the amount of evapotranspiration on day *i*(mm H_2O),
w_{seep} : the amount of water entering the vadose zone from the soil profile on day *i*(mm H_2O), and
Q_{gw} : the amount of return flow on day *i*(mm H_2O).

The SWAT model requires a set of input data to be able to start simulations, the input data are generally covering weather data (i.e. daily min and max temperature, daily rainfall, humidity), topography, land use, soil types...etc.[**11**]; In this study, SWAT 2012 version was used with ArcGIS 10.

As all HRUs are connected and runoff drainage simulation is based on slope, the basin water balance was studied in the basin outlet where measured outflow data is available (Souk Elhad gauge station).
Concerning the plants growth module, SWAT uses a simplified version of EPIC model(Erosion Productivity Impact Calculator) to simulate crop growth process and yield based on actual evapotranspiration, leaf area development, light interception [22].

4. Materials & Methods

4.1. Input data collection and preparation

- *Topography:* For the topographic characterization of the study watershed, the digital elevation model (DEM) of R'dom basin has been extracted from the Shuttle Radar Topography Mission (SRTM) with a resolution of 30 meters.
- *Delineation and reach definition:* The ArcSWAT interface tool was to delineate and divide the watershed into several hydrologically connected sub-watersheds with their outlets, and to define the stream network based on the drainage calculations. The Souk El Had gauge station (*Projected Lambert coordinates: x=465943 m, y=410043 m*) was matched to be the discharge outlet monitoring point of R'dom river in this study.
- *Soil types:* SWAT soil database was updated by soil parameters of R'dom watershed obtained from the soil survey reports and maps covering the basin at a 1:50000 scale. Data included soil texture, soil hydrological group, number of soil layers, organic carbon, clay, sand and silt contents, erodibility factor, pH and electrical conductivity, etc); Saturation hydraulic conductivity and available water content were estimated from the other parameters using Soil Water Characteristics Software *(Version 6.02)* [23].
- *Land use:* Land use map of R'dom basin was developed based on satellite image processing; two LANDSAT8 image scenes (April 2^{nd}, 2015) were classified using several ground truths sites.
- *Crops management:* Farming practices patterns were added to the model according to the agricultural practices adopted within the study watershed, especially those that are considered to have significant effect on water cycle and crop yield such as: start and end of season dates, irrigation, tillage, fertilization, etc.
- *Climatic data:* Observed weather parameters including daily temperature (max and min) records and daily rainfall from 10 recording stations in and around the watershed were imported to the SWAT model. The data series were from January 2003 to December 2010 obtained from the ABHS records (*Agence de Bassin Hydrique de Sebou*) and privately owned farms equipped with weather variables measurement stations.

The SWAT model uses USDA Soil Conservation Service's (SCS) runoff equation [13] to provide a consistent basis for estimating the amount of runoff under varying land use and soil types:

$$Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)} \qquad (2)$$

Where:
Q_{surf}: the accumulated runoff or rainfall excess (mm H_2O),
R_{day}: the rainfall depth for day (mm H_2O),
I_a: the initial abstractions which includes surface storage interception and infiltration prior to runoff (mm H_2O)
S: the retention parameter (mm H_2O).

The adopted evapotranspiration equation was Hargreaves and Samani [22]:

$$\lambda E_0 = 0.0023(H_0)(T_{mx} - T_{mn})^{0.5}(\overline{T_{av}} + 17.5) \qquad (3)$$

Where:
λ: the latent heat of vaporization (MJ Kg^{-1}),
E_0: the potential evapotranspiration (mm d^{-1}),
H_0: the extraterrestrial radiation (MJ m^{-2} d^{-1}),
T_{mx}: the maximum air temperature for given day (°C),
T_{mn}: the minimum air temperature for given day (°C),
$\overline{T_{av}}$: the mean air temperature for given (°C).

4.2. SWAT calibration and Validation

The SWAT model was run over the period of January 2004 to December 2009.The first two years have been allocated to the model warm up process which is a very essential simulation part to bring the hydrologic processes to an equilibrium condition; the period of January 2006 to December 2007 was dedicated to the model calibration, and the period of January 2008 to December 2009 was used for validation.

For efficient calibration, sensitivity analysis was carried out to indentify the most influential SWAT parameters to focus on during the calibration process using the relative sensitivity equation described by Haan [**24**]:

$$S_r = \left[(O_{P+\Delta P} - O_{P-\Delta P}) / O_P \right] / (2\Delta P / P) \quad \textbf{\textit{(4)}}$$

Where:

- S_r: relative sensitivity;
- $O_{P+\Delta P}$: model outputs with the input parameter being studied, set at the base value (equal to the initial calibrated value) plus a specified percentage (often taken to be between 10% and 25%);
- $O_{P-\Delta P}$: model outputs with the input parameter being studied, set at base minus a specified percentage (often taken to be between 10% and 25%);
- O_p: Model output with input parameter set at the base value
- ΔP: The prescribed absolute change in the value of the input parameter
- P: The initial calibrated value (base value) of the input parameter

Following sensitivity analysis, Streamflow (cms) was examined during the calibration process and a maximal agreement between observed and predicted water budget components was the ultimate goal. This agreement was monitored by three statistical measurements: the Nash-Sutcliffe coefficient (NSE), Determination Coefficient (R^2) and percent bias (PBIAS), with:

$$NSE = 1 - \frac{\sum_{i=1}^{n} (O_i - P_i)^2}{\sum_{i=1}^{n} (O_i - O_{avg})^2} \quad \textbf{\textit{(5)}}$$

$$R^2 = \left(\frac{\sum_{i=1}^{n} (O_i - O_{avg})(P_i - P_{avg})}{\left[\sum_{i=1}^{n} (O_i - O_{avg})^2 \sum_{i=1}^{n} (P_i - P_{avg})^2 \right]^{0.5}} \right)^2 \quad \textbf{\textit{(6)}}$$

$$PBIAS = \frac{\sum_{i=1}^{n} (O_i - P_i) 100}{\sum_{i=1}^{n} O_i} \quad \textbf{\textit{(7)}}$$

Where:

- O_i: the observed water yield for time period i
- Pi: the simulated value for the same period
- O_{avg}: the mean of observed water yield per time period
- n: the number of time intervals

The NSE represents the model's precision in simulating the flood streamflow; the maximum NSE value of 1.0 occurs if predicted values are perfectly matching measured ones [**25, 26**]. The R^2 provides how well the correlation between measured and simulated values is [**27**]. PBIAS determines average tendency of simulated data to be greater or lesser than their observed counterparts, the ideal value of PBIAS is zero **[28].**

5. Results & discussion

5.1. DEM and Reach definition

The DEM of R'dom watershed shows that the basin can be divided to 4 main elevation classes with a decreasing trend from South to North; the highest point is at 1786 meters altitude (Figure1).

After watershed delineation, the basin was segmented into 27 hydrologically connected sub-watersheds; Based on watershed definition stream network, 13 linking stream outlets were created and the discharge-monitoring outlet was manually added to the location of the measured discharge station (Figure 1).

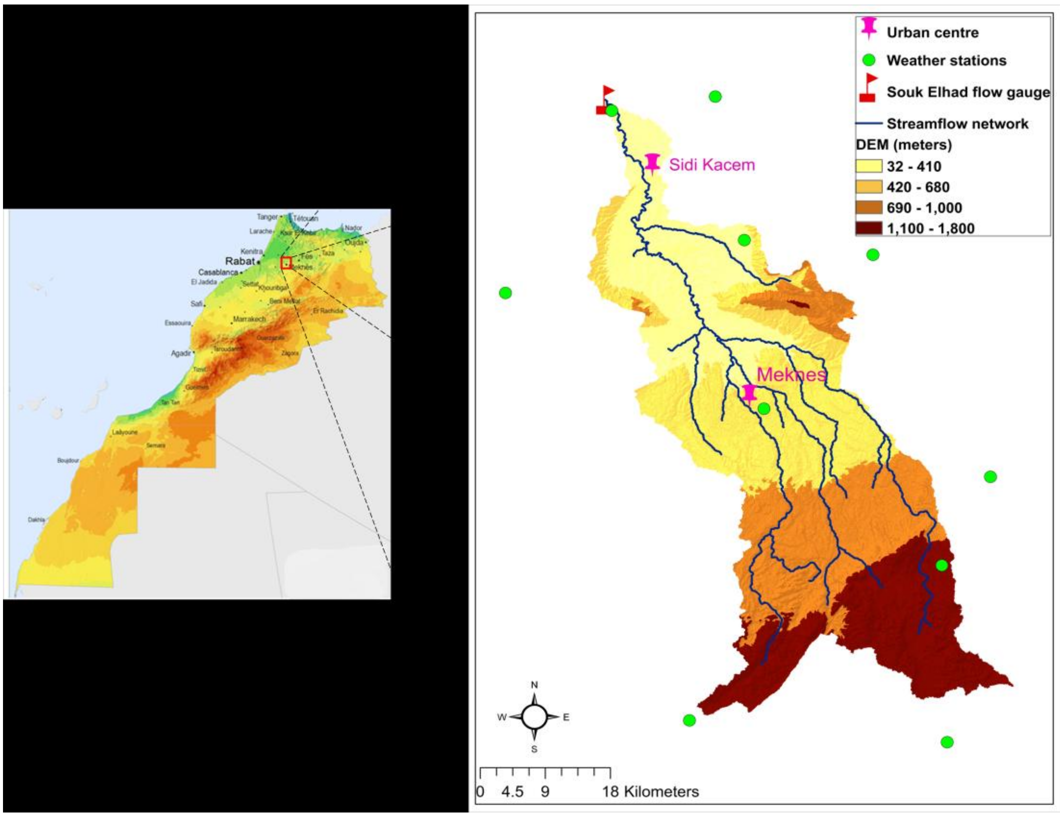

Figure 1: *Digital elevation model, streamflow network and the used weather stations of R'dom watershed*

5.2. SWAT Soils and land use outputs classification

The SWAT processing of R'dom watershed soil map revealed that there are 106 different soil units according to the classification parameters used (Texture, structure, depth, permeability, drainage, electrical conductivity, organic matter rate...).

Based on the evaluation of the developed SWAT soil map for the study watershed, Four key soil parameters were analyzed for better understanding of soil-water balance interactions. The Four soil parameters are: Hydrologic Soil Groups[1] (HSG) according to U.S. Natural Resources Conservation classification, Soil depth, Available Water Content (AWC) and Saturated Hydraulic Conductivity (K_{SAT}). The distribution of these parameters within the 27 sub-basins of R'dom basin is given in figure 2.

In terms of soil groups, most of upstream sub-basins are dominated by soils from the group A (Figure 2.c) characterized by well drained soils and high water transmission rates according to the U.S. Natural Resources Conservation [**11**]. Soils from the groups B and C are dominating the centre of the study watershed; these soil groups have moderate runoff potential and moderate to low water transmission rates. Soils at the downstream of R'dom watershed belong to hydrologic soil group D which is known for the very low water transmission rate [**11**].

Based on Figure 2.b, soils depths in R'dom watershed are showing a NW-SE gradient. The deepest soils (1500 mm) are located in the North West of the study watershed.

According to figure 2.d, soils with the highest available water content values are dominating the Southern sub-basins with a decreasing gradient from South to North. It is worthy to mention that this gradient, that is not necessary in total agreement with the gradient of soil depth and K_{SAT} gradient, concerns only the common upper 200 mm of all soil classes across the watershed.

The other relevant soil parameter is saturated hydraulic conductivity which is advising about the permeability of the different soils in the study watershed. Most of downstream sub-basins are characterized by low saturated hydraulic conductivity, while soils at the centre and the upstream of the watershed, are the ones with the highest K_{SAT} values (Figure 2.a).

[1] Description of the main HSGs attributes [**22**]:
- A: high infiltration rate, consistent chiefly of sands or gravel that are well drained; high rate of water transmission.
- B: moderate infiltration rate, chiefly moderately deep to deep, moderately well to well drained, coarse texture.
- C: low infiltration rates, fine texture with slow infiltration rate, slow rate of water transmission.
- D: Very slow infiltration rate, chiefly clay soils with high swelling potential; very slow rate of water transmission.

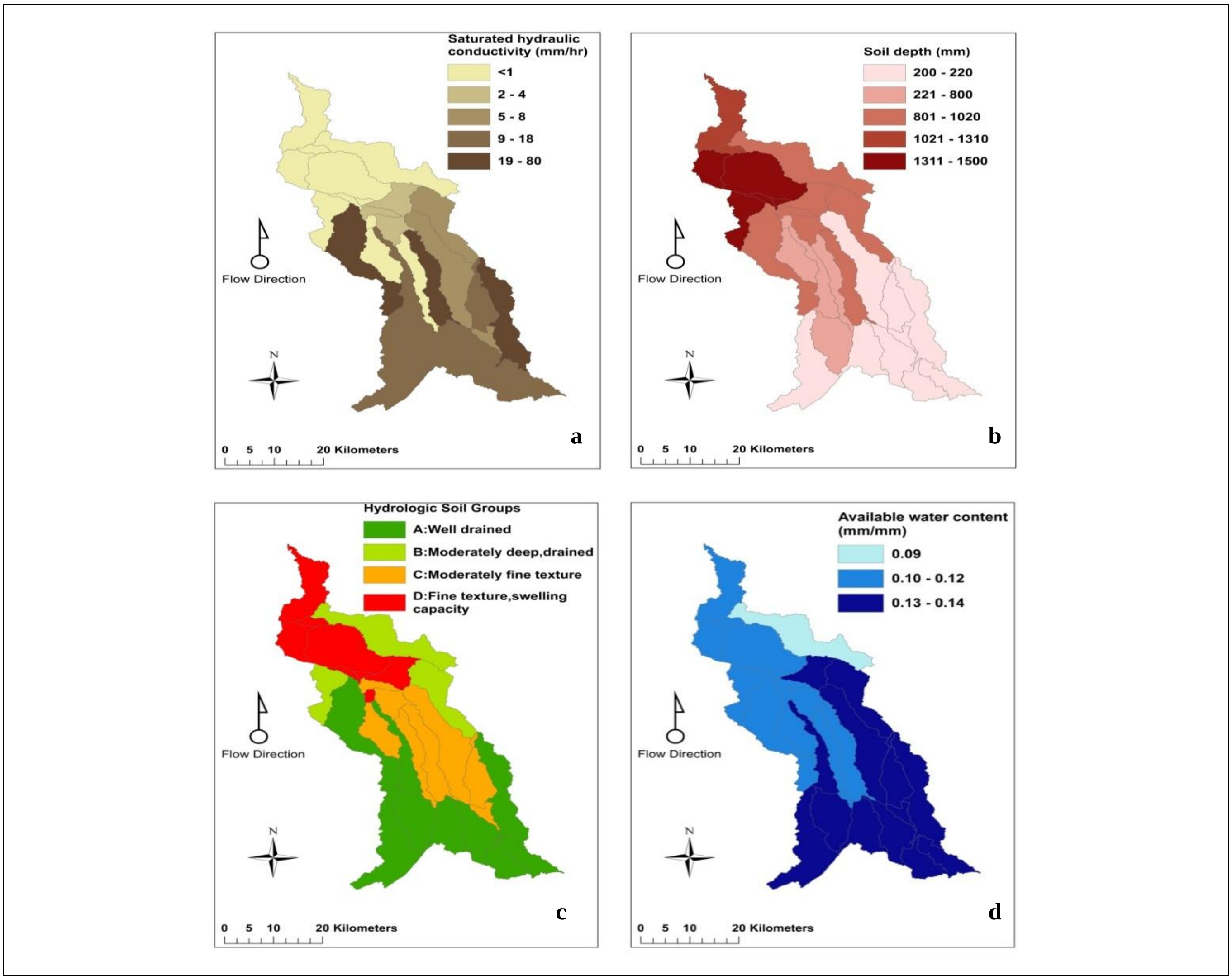

Figure 2: *Distribution of the main soil characteristics by sub-basins*

Figure 3 illustrates the SWAT land use of the R'dom watershed after processing of the imported land use map and the link with the SWAT database.

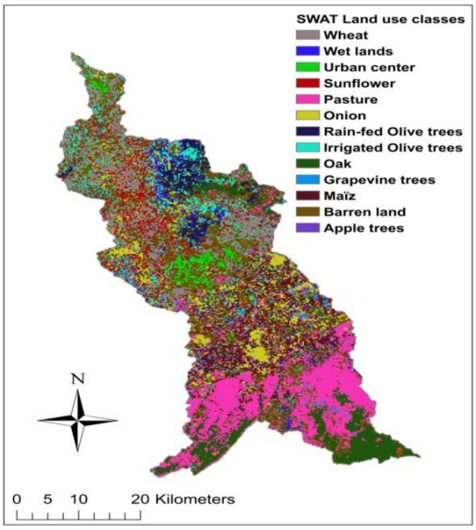

Figure 3: *SWAT land use of the R'dom watershed*

It shows that more than 40% of the basin area is either barren or pasture lands and they are dominating the watershed upstream area. Around 45% of total R'dom basin surface is covered by farming lands and located in centre and Northern part.

5.3. Percolation and rainfall distribution

The simulated rainfall over the study watershed during the period 2004 to 2009 (Figure 4.a) showed a decreasing gradient from south to north in overall following the altitude gradient. The highest rainfall value (520mm) was simulated in the watershed upstream, the lowest one (250mm) was simulated around the downstream.

Percolation distribution within the study watershed showed the same gradient as rainfall (Figure 4.b), matching the flow direction. The high percolation activity in the South of the R'dom watershed is related to the high precipitation average and to the dominant soil types in this part of the study watershed which are well drained and with high water transmission rates. The percolation activity is decreasing toward the downstream as the rainfall average and drainage capacity of soils are decreasing.

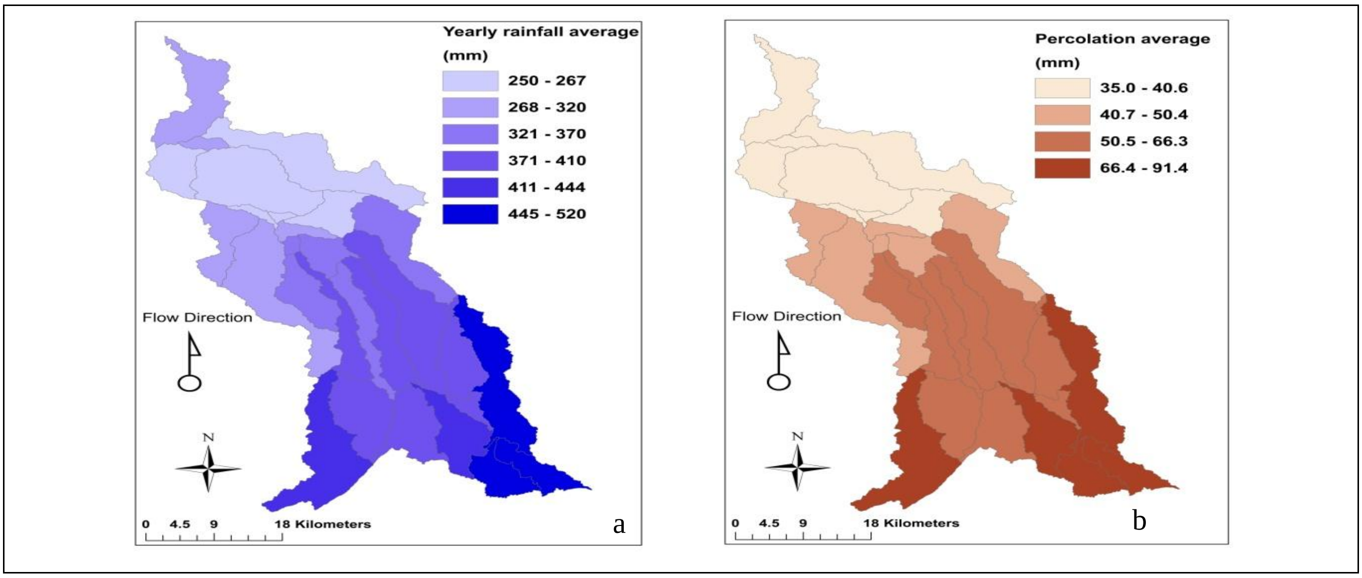

Figure 4: *distribution of the yearly rainfall average (a) and percolation average(b)*

5.4. Calibration and validation

The assessment of relative sensitivity of twelve different SWAT flow input parameters, revealed that four parameters were the most influential (Table 1) with different sensitivity degrees.

Table 1: Relative sensitivity values for all tested SWAT input parameters

Parameters	TWYD*	Runoff	Baseflow
CN2: *Initial SCS runoff curve number for moisture condition II*	1.77	5.57	-0.55
SOL_AWC: *Available water capacity of the soil layer (mm H2O/mm soil)*	-0.31	-1.25	-0.64
ESCO : *Soil evaporation compensation factor*	0.06	0.10	0.06
GWQMN: *Threshold depth of water in shallow aquifer required for return flow to occur (mm H2O)*	-0.24	0.00	-0.38

**TWYL: Total Water Yield*

During manual calibration process, the focus was on the 4 most influential parameters to parameterize SWAT to the local R'dom watershed condition by comparing model flow prediction with observed data at outlet level (Table 2). Calibration was considered satisfactory (Figure 5) when R^2 and NSE values were higher than 0.5 [**13, 29, 25**] and when PBIAS values are equal or lower than ±25 **[28].**

Table 2: Default values and range of amendment of input parameters during calibration

Parameters	Default values	Range of change
CN2: *Initial SCS runoff curve number for moisture condition II*	39 to 94	↓12%
SOL_AWC: *Available water capacity of the soil layer (mm H2O/mm soil)*	0.11 to 0.15	↑ 22%
ESCO : *Soil evaporation compensation factor*	0.95	↓ 20%
GWQMN: *Threshold depth of water in shallow aquifer required for return flow to occur (mm H2O)*	1000	↑ 30%

After several SWAT iterations, a satisfactory agreement between simulated and measured discharge in both monthly and daily time steps was obtained (Figure 5) with NSE, R^2 and PBIAS values of 0.68, 0.85 and 17% for the monthly time step and 0.58, 0.79 and 19% for the daily time step, respectively.

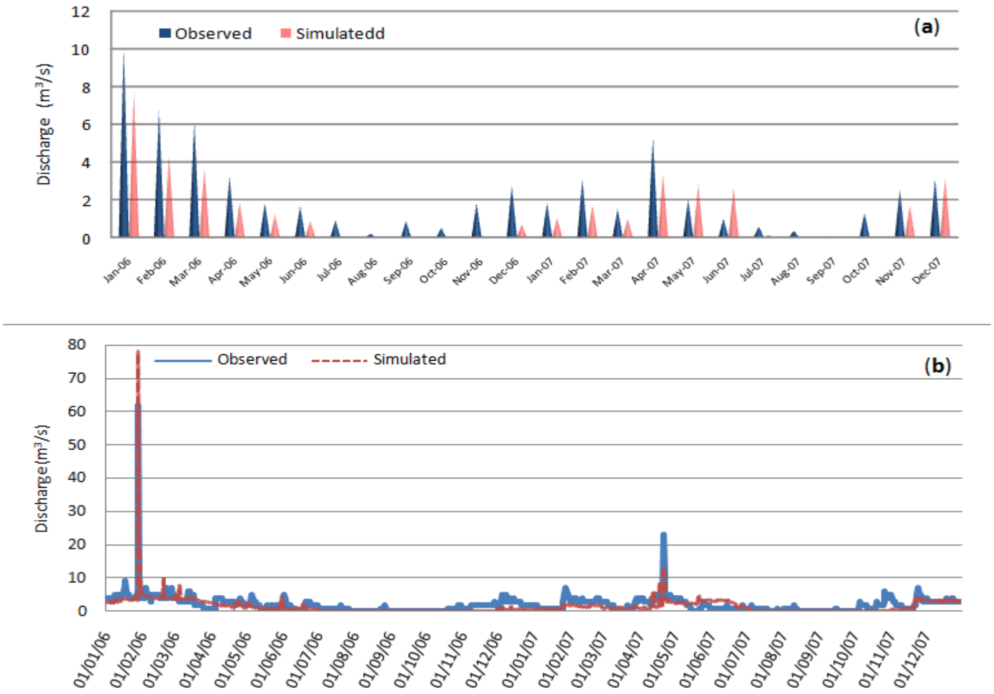

Figure 5: Observed vs simulated monthly (a) and daily (b) discharge after manual calibration at the Souk Elhad flow gauge

During SWAT model validation process, predicted and observed discharge followed similar trends during the entire validation period, with NSE, R^2 and PBIAS values of 0.88, 0.91 and 13% for the monthly time step, and of 0.65, 0.73 and 20% for the daily time step, respectively (Figure 6).

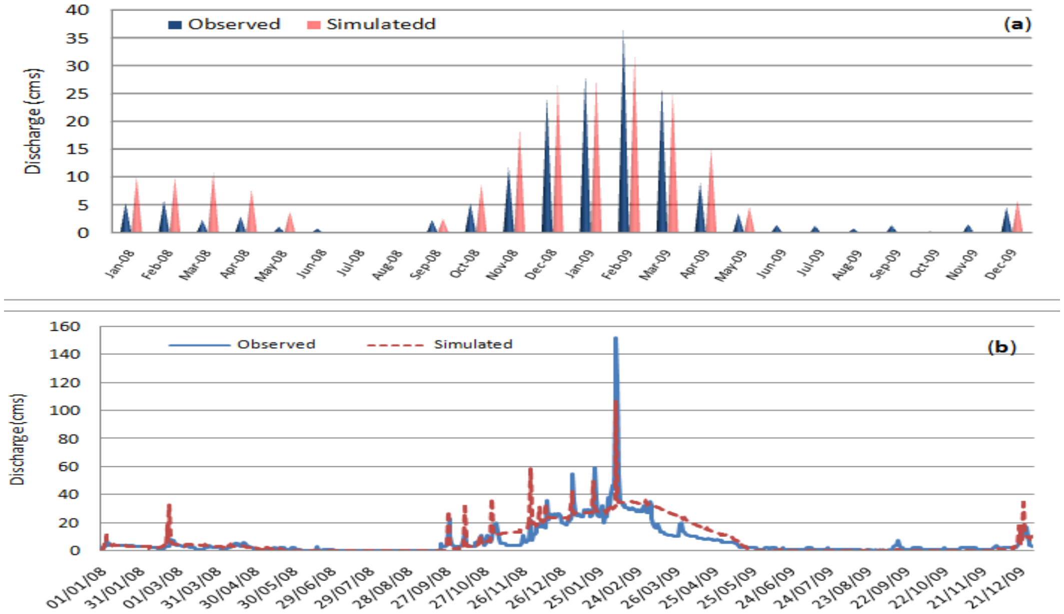

Figure 6: Observed Vs predicted monthly (a) and daily (b) discharge during the validation period at the Souk lhad flow gauge

1.1. Water balance components & water yield distribution

Table 3 illustrates the monthly averages of water balance components in R'dom basin for the simulation period (2004 to 2009). The results show that the water balance is dominated by evapotranspiration (215.39 mm). Being a quite common role in a such Semi-arid context [**30**], The major contribution of evapotranspiration in water balance of the study basin is mainly related to high ratio of bare soils (increasing the evaporation process) and crop surfaces with long growing seasons or under year long rotation schemes (with high transpiration rates). The surface runoff represents 8.3% and the total water yield[2] is around 25.3% of the yearly rainfall average.

[2]Total water yield is simulated by SWAT model as the sum of surface runoff, lateral flow, groundwater contribution net of transmission losses [10].

The highest flows are observed from December to March. While during summer season, the river generally dried out due to a long drought period (Table 3).

Table 3: Simulated water balance components of R'dom watershed over the period 2004 to 2009

MONTH	RAIN (mm)	SURF (mm)	LAT (mm)	TWYD (mm)	ET (mm)
1	71.15	7.96	3.17	19.28	11.43
2	37.75	4.28	1.13	13.92	16.15
3	29.5	3.98	1.14	9.44	15.68
4	20.35	1.78	0.1	7.9	32.5
5	15.79	0.5	0.1	1.27	33.86
6	5.38	0.14	0.08	0.73	25.52
7	4.75	0.04	0.04	0.43	14.47
8	2.19	0.38	0.06	0.65	14.15
9	20.32	0.7	0.13	0.98	16.31
10	33.47	0.97	0.13	4.28	12.62
11	49.28	1.74	0.09	13.06	12.7
12	56.33	6.85	3.1	17.22	10
Total	352.48	29.32	9.27	89.16	215.39
Percentage out of rainfall		**8.31%**	**2.62%**	**25.29%**	**61.1%**

With:

- LAT: Lateral subsurface flow, streamflow contribution which originates below the surface but above the zone where rocks are saturated with water.
- SURF: Surface Runoff, flow that occurs along a slopping surface.
- ET: Actual evapotranspiration, all processes by which water in the liquid or solid phase at or near earth's surface becomes atmospheric water vapour; this includes evaporation from rivers, lakes, bare soil and vegetative surfaces.
- TWYD: Total Water Yield, the sum of surface runoff, lateral flow, groundwater contribution net of transmission losses.

Synonymous with surface runoff and soil water interflows entering the adjacent stream minus total of transmission losses [**31**], total water yield (TWYD) parameter was taken as the hydrological indicator to investigate hydrologic resources distribution within the study watershed. The R'dom basin is characterized by uneven water resources distribution with a decreasing gradient from South to North following the flow direction (Figure 7). The highest TWYD value is simulated in the sub-basins located around the watershed upstream (up to 223.1 mm/year); the lowest TWYD value is simulated around the watershed downstream (12.50mm/year).

The simulated spatial distribution of TWYD in R'dom watershed is in perfect agreement with the conceptualized watershed characteristics and can be explained by the previously modelled components in this study. Indeed, TWYD gradient is following the altitude gradient (Figure 1) within the watershed; as generally high altitudes means high runoff rates (that increases TWYD) especially after flash rains that are characterizing semi arid areas [**32**].

On the other hand, most of sub-basins in the downstream of study area are receiving the lowest rainfall amounts and are dominated with soils of the HSGs D and C (figure 2.c) described by fine texture and very active capillary activity; which leads to high evaporation losses through the vertical movement of water. In the other part of the watershed, where group A (coarse texture) is the most dominant HSG, high precipitations are occurring and water losses via capillary movement is less giving place to higher total water yield values [**33**].

It has been found in similar research (in Xitiaoxi watershed, Taihu region in China) that soil depth parameter has positive correlation with total water yield; confirming the finding of current study (Figure 2.b) [**34**].

Saturated hydraulic conductivity, considered as equivalent to the final rate of infiltration by SWAT model [**22**], is generally higher in coarse soils (HSGs: A and B) and very low in fine soils (HSGs: C and D); and taking into consideration that groundwater flow (one of Total water yield components) is greatest with higher hydraulic conductivity values [**35**], the overall decreasing Saturated hydraulic conductivity in R'dom watershed with flow (Figure 2.a) can explain the decreasing TWYD pattern as well.

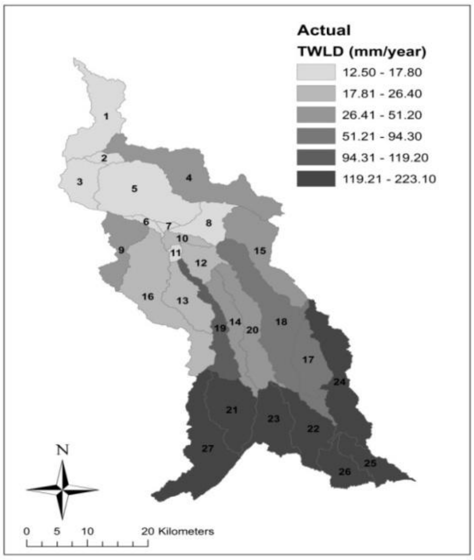

Figure 7: *The simulated yearly average of total water yield per sub-basin*

Available water content parameter is modelled by SWAT model as water content at field capacity minus water content in permanent wilting point, and refers to available water for plants [**22**]. An increase of this parameter is generally leading to higher relative saturation at field capacity and more surface runoff (which means higher TWYD) [**36**]. This is confirming the current situation of TWYD in R'dom watershed as its gradient is generally following the gradient of available water content (figure 2.d).

The land use, and its interaction with the soil, has definitely a strong impact on simulated water yield in this case as the study watershed is showing a high variability in terms of land use along the streamflow (figure 3), and the SWAT model is incorporating plants growth module giving chance to include impact of land use on hydrological processes [**19**]. The contribution of land use to explain the spatial distribution of total water yield in R'dom watershed came from the fact that dominant land use categories in the basin downstream are crops (Onion, grapevine and apple trees...) with significantly high water needs in comparison with those covering most of the basin upstream (Pasture lands), which leads to high water uptake in the basin downstream [**32**] .the second difference is that crops grown in the basin downstream have longer vegetation or production season (or used in rotation schemes) in comparison with grasslands and forests in the watershed upstream which increases the transpiration rates and decrease the total water yield [**36, 37**].

6. Conclusions

The SWAT model has been calibrated and validated to simulate the hydrologic cycle in the R'dom watershed; the different steps of model setup have been allocated high priority to push SWAT to reflect the real conditions (soil, weather, flow, crop management...) as much as possible.

The model application gave satisfactory goodness-of-fits levels, revealed dominated water balance by evapotranspiration due to land use categories dominating the watershed and showed that the water resources distribution has an increasing gradient from North to South.

The uneven spatial distribution of water yield in the study basin has been explained by the gradient of rainfall, different soil properties parameters (AWC, K_{SAT}, Soil depth and texture) in addition to the land use pattern. the high total water yield around the watershed upstream has a link mainly with the high rainfall average in the area and the soils of this part of the watershed which are characterized by coarse texture, low depth and high available water content; the land use of this part of the study area has an impact also as grasslands and forests (the dominating land uses) have generally short production cycle and low water uptake activity in comparison with crops grown in the centre and the downstream of the R'dom watershed.

The investigation of water balance components and the water resources distribution within the R'dom watershed will be useful for local decision makers in order to come up with water resources management strategies. The potential management strategies that can be investigated include: water harvest and distribution within the watershed to uniform the water resources distribution and land use change for better water valorisation.

This study, and by investigating the current hydrologic situation in R'dom watershed, opens a window into futuristic studies in the area to assess potential changes that can occur under different factors (land use change, climate change...) and also gives a methodological approach to be followed in similar watersheds with similar conditions.

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