International Research Journal of Earth Sciences ISSN 2321 – 2527
Vol. **8(2),** 31-43, August **(2020)** *Int. Res. J. Earth Sci.*

Simulation of the impacts of hill dams and lakes on water and sediment yields: case of Wadi Hatab Basin, Central Tunisia

Narjes Ben Salah Chaabane[1] and Habib Abida[2]
[1]Higher Institute of Technological Studies of Sfax, Sfax, Tunisia
[2]Faculty of Sciences, University of Sfax, Sfax, Tunisia
narjes.chaabane@isetsf.rnu.tn

Available online at: www.isca.in
Received 23rd February 2020, revised 16th June 2020, accepted 25th July 2020

Abstract

Semi-arid regions are particularly subjected to water erosion because of erratic rainfall distributions, alternating from long drought periods to severe flash floods. The protection against this phenomenon usually requires the implantation of Soil and Water Conservation Works (SWCW) such as water retention facilities. The hydrological impacts of these latter on water and sediment fluxes in the Wadi Hatab Basin (Central Tunisia) are simulated. The tool used is SWAT model (Soil and Water Assessment Tool). The implementation of hill dams resulted in a reduction of discharge at the outlet of 6 to 42%. It also yielded a reduction of 4 to 41% of sediment concentration. The integration of dams in the simulation led to an increase in groundwater flow of 14% to 84%, an increase of the total flow of 1% to 36% and a maximum reduction in sediment yield of 25% during the year 2010, when the six dams were operational. The integration of hill lakes led to a maximum reduction of 6% in flow rates and 4% of the sediment concentration at the outlet of the study basin in 2010.

Keywords: Hydrological modeling, SWAT, Soil and Water Conservations Works, Central Tunisia.

Introduction

Hill dams and hill lakes are structures considered to mitigate water erosion and retain runoff water for agricultural use. Compared to hill dams, hill lakes are characterized by much smaller water retention capacities. Both of these water retention facilities have been widely implemented in Central Tunisia since the early 1990s in a context of a national strategy for the Conservation of Water and Soils[1] "CWS", which was phased over two successive decades 1990-2001 and 2002-2011.

The study watershed is subjected to a semi-arid climate, where torrential rains usually result in a loss of the top soil layer. In addition, intense runoff is conveyed quickly, without much infiltration, through the wadis to salty depressions. The study basin, administratively attached to the Governorate of Kasserine, is strongly affected by water erosion. Indeed, according to the regional program of action to combat desertification, water erosion affects 53% of Kasserine Governorate, of which 19% (160,000 ha) are extremely threatened and need prompt interventions[2]. Rugged terrain, heavy rainfall, poor soil conditions, overgrazing and agricultural practices have aggravated the erosion phenomenon in the region.

Several techniques of Water and Soil Conservation Works (WSCW) have been widely developed in Tunisia for several years in order to preserve water resources and limit soil degradation. These anti-erosion techniques are classified into two categories: i. traditional techniques such as Jessour, terraces and Meskat and ii. new techniques such as, contour ridges, water spreading structures, groundwater recharge facilities, hill lakes, hill dams, and pastoral plantations.

In recent decades, several studies were conducted to study the impact and the effectiveness of WSCW. Hamza and Hamou[3] conducted a study on erosion and erosion control in the Wadi Zeroud Watershed (Central Tunisia) and identified priority sub-basins for urgent erosion control intervention. Dridi[4] studied the impact of WSCWs on the availability of surface water in Wadi Marguellil Watershed. The author concluded that hill dams implemented in this basin resulted in a reduction of runoff to the El Haouareb Dam downstream.

Nasri et al.[5] examined the efficiency of mechanical benches implemented in the catchment of El Gouazine (Central Tunisia). They concluded that the construction of benches significantly reduced runoff and also led to a reduction in siltation of small reservoirs. On the Marguellil Watershed, Abouabdillah et al.[6] used SWAT model to simulate the impact of erosion control on basin hydrology and water resources management. They showed that the implemented benches resulted in reducing runoff and holding sediments. In Wadi Marguellil Basin, Sakka[7] applied SWAT model to study the impact of the variation of climate and land use on the hydrologic response of the watershed. The author concluded that SWAT showed encouraging results for conducting scientific research on soil erosion and the identification of potential hydrological impacts of land use variation and climate change. Several other applications of SWAT model were also successfully carried out in different basins in Tunisia[8-14]. These applications were carried out to simulate flows, water erosion, and diffuse pollution and to assess the impacts of water and soil conservation works.

Mishra et al.[15] showed that the construction of check dams in a small Indian basin reduced sediment loss by more than 64%. Melaku et al.[16] found that the implantation of WSCWs in the Northern Ethiopian highlands resulted in a decrease of sediment yield by 25-38% in the study period. Li et al.[17] studied the impact of check dams in Yellow River Watershed and found that these structures gave a variable decrease in runoff and sediment transport. Ma et al.[18], Lemann et al.[19] and Zuo et al.[20] found that modeling results of SWAT represent a valuable tool for water and soil resources management.

In this context, SWAT agro-hydrological model is applied to examine the impacts of hillside reservoirs on the hydrologic response of Wadi Hatab Watershed. The study basin is subjected to a semi-arid climate, where water resources are scarce and erratically distributed in time and space. In addition, it is characterized by rugged terrain, steep slopes and severe water erosion.

Data required, including topography, pedology, land use, and climate were first collected. The model was then applied over the period extending from 1985 to 1990. The model was warmed up based on data of the years 1985 and 1986. Next, the model was calibrated and validated for both daily and monthly time steps, by comparing simulated and measured flows over the periods (1987-1988) and (1989-1990) respectively[22]. The impact of water retention facilities was examined over the period (1990-2010) by integrating dams and hill lakes separately for four different scenarios, with and without hillside reservoirs. The effects of both hill dams and hill lakes on water and sediment yields were first evaluated. The impact of each type of water retention facilities is also examined on the sub-basin scale.

Study area description: Wadi Hatab Watershed, located in Central Tunisia (Figure-1), has an area of 2200km² at the Khanguet Zazia hydrometric station. The Hatab Wadi represents the upstream part of the southern tributary of Wadi Zeroud which flows into the Sidi Saad Dam. The study basin is subjected to an arid climate in the center and on the southeastern plains and semi-arid at the culmination points. Rainfall is irregular, marked by long drought periods followed by intense rains with high erosive potential. Mean annual precipitation during the period (1985-2010) is 261mm and average annual temperature is 17.5°C. The relief is marked by topographic irregularities; it is rugged on the mountain massifs and weak on the plains and the plateaus.

Soils in the study basin are classified into three majot types: i. complex soils that account for 34.8% of the study area, ii. calcareous brown soils which account for 26.3% and iii. poorly evolved soils which represent 17.3% of the watershed. Regarding land cover, it is mostly represented by range brushes (34.7%) and forests (33.2%). Wheat, alfa, olive trees and cactus represent 11.2%, 8.1%, 4.9% and 4.6% respectively. The rest is made up of various occupations (bare soil, market gardening, fodder and urban areas, apple and almond trees).

The study basin has been subjected to severe water erosion due to torrential rainfall and uneven terrain. Therefore, Soil and Water Conservation Works (SWCW) were integrated throughout the watershed in order to slow down runoff and reduce water erosion. These are mainly hill lakes, hill dams, water spreading structures, groundwater recharge facilities, contour ridges and pastoral and fodder plantations in rangelands and waterways[23].

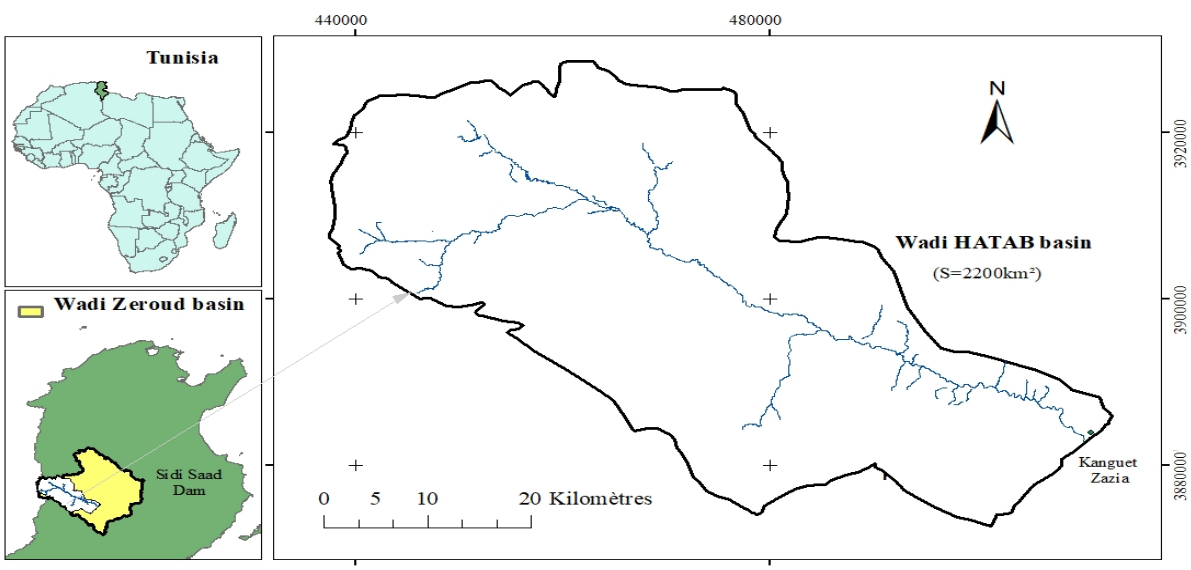

Figure-1: Location of the study basin.

SWAT Model Description: Modelling principle: SWAT is a semi-distributed physically based model which operates at a daily time step. The study watershed is first sub-divided into sub-watersheds and Hydrologic Response Unit (HRU), characterized by a spatial combination of soil and land use. Access to variables and spatial parameters is facilitated by coupling the model with a GIS.

Runoff is simulated using two methods: i. the Curve Number (CN) method of the USDA Soil Conservation Service[25] and ii. the Green and Ampt Method[26]. In this study, the CN method was chosen. Potential evapotranspiration may be estimated either by the Penman-Monteith method[27], the Hargreaves method[28] or Priestley-Taylor Method[29]. Based on the availability of weather data, the Hargreaves method was used in this work. Sediment yield is estimated based on the Modified Universal Soil Loss Equation MUSLE method[30]. Modeling runoff in the stream network may be performed by Muskingum formalism, developed by McCarthy[31] or variable storage method developed by Williams[32]. The Muskingum was adopted in the present study because of its widespread use in the literature.

Modeling small dams: SWAT model offers the possibility of incorporating water storage structures such as dams, lakes, ponds and wetlands in the modeled basin. Hill dams are modeled as reservoirs. A reservoir is represented by a retention basin located on the drainage system of a watershed, and no distinction is made between natural basins and artificial structures. The equation of the water balance in the structure is given by the following equation:

$$V = V_{stored} + V_{flowin} + V_{flowout} + V_{pcp} - V_{evap} - V_{seep} \quad (1)$$

V is the volume of water retained at the end of the day (m^3) V_{stored} is the volume of water available in the reservoir at the beginning of the day (m^3), $V_{flow\ in}$ is the runoff volume reaching the water retention facility during the day (m^3), $V_{flow\ out}$ is the volume of water flowing out of the system during the day (m^3), V_{pcp} is the volume of precipitation falling on the water body during the day (m^3), V_{evap} is the volume of water evaporated from the reservoir during the day (m^3), and V_{seep} is the volume of water lost by seepage (m^3).

Modeling hill dams: SWAT considers lakes as bodies of water located in sub-basins that have received a contribution from a fraction of the sub-basin area. The algorithms used to model this type of water bodies differ from those of dam modeling only by the options allowed for the calculation of outflow. The water balance equation in lakes is the same as that used in dams.

Methodology

Database creation: Input data to SWAT include topography, hydrography, land use, pedology, meteorology and information on SWCW. The Digital Elevation Model (DEM) was produced from topographic maps at 1: 50000 covering the entire study area. The pedological map of the study basin was extracted from the Kasserine soil map (scale 1/25000). Soil physical parameters required by the model were collected and determined from previous studies carried out on the study basin and the use of the pedo-transfer functions for the determination of unmeasured parameters. The land use map was obtained based on Kasserine's agricultural map. This latter as well as daily rainfall data and flow rates were provided by the Regional Department of Agriculture and Water Resources in Kasserine. Regarding climatic data (temperature, average wind speed and relative humidity), they were supplied by the Tunisian National Institute of Meteorology.

Soil and water conservations works: According to the guidelines of the two plans of the national strategy for water and soil conservation in the Kasserine Region, WSCW were implemented in Wadi Hatab Watershed over the period (1990-2010). They are represented essentially by 125 groundwater recharge structures, 23 water spreading structures, six hill dams, 20 hill lakes and about 30000 ha of contour ridges. The chronology of the implementation of these structures is presented in Figure-2. Data on the years of realization of contour ridges in the different treated areas are not available.

In this study, we are interested in the modeling of hill dams and hill lakes. Six small dams were implemented for the purpose of water harvesting for irrigation and recharge of the groundwater table. They make it possible to mobilize a volume of approximately 16 million cubic meters of water. The twenty hill lakes resulted in the mobilization of a runoff volume of approximately 3 million cubic meters of water. The distribution of hill dams and hill lakes over the study basin is shown in Figure-3 while their characteristics are displayed in Tables-1 and 2 respectively.

Model set up: Input data and watershed discretization: SWAT model operates on homogeneous units, called hydrological response units "HRU". To discretize the basin into homogeneous units, we start with the integration of the digital elevation model and soil and land use maps. Tables of parameters characterizing each spatial unit are associated with these spatialized data. The location of the weather stations and the tables containing climatic data are also required for modeling. Indeed, the output quality of the model is strongly conditioned by the precision and the consistency of used data. The 2005 SWAT version (AVSWAT-X), coupled with ARCVIEW software, was used in this study. The watershed was subdivided into 47 sub-basins based on topography, stream network configuration and a threshold area. The combination of the sub-basin map, the land cover map and the soil map resulted in the decomposition of the study basin into 374 HRUs (Hydrological Response Unit). Modeling was considered for the period (1985-1990). Years 1985 and 1986 were used to warm up the model. Calibration and validation, on a monthly and daily basis, were made in the (1987-1988) and (1989-1990) periods respectively. The model performance was tested using statistical and graphical indicators[33].

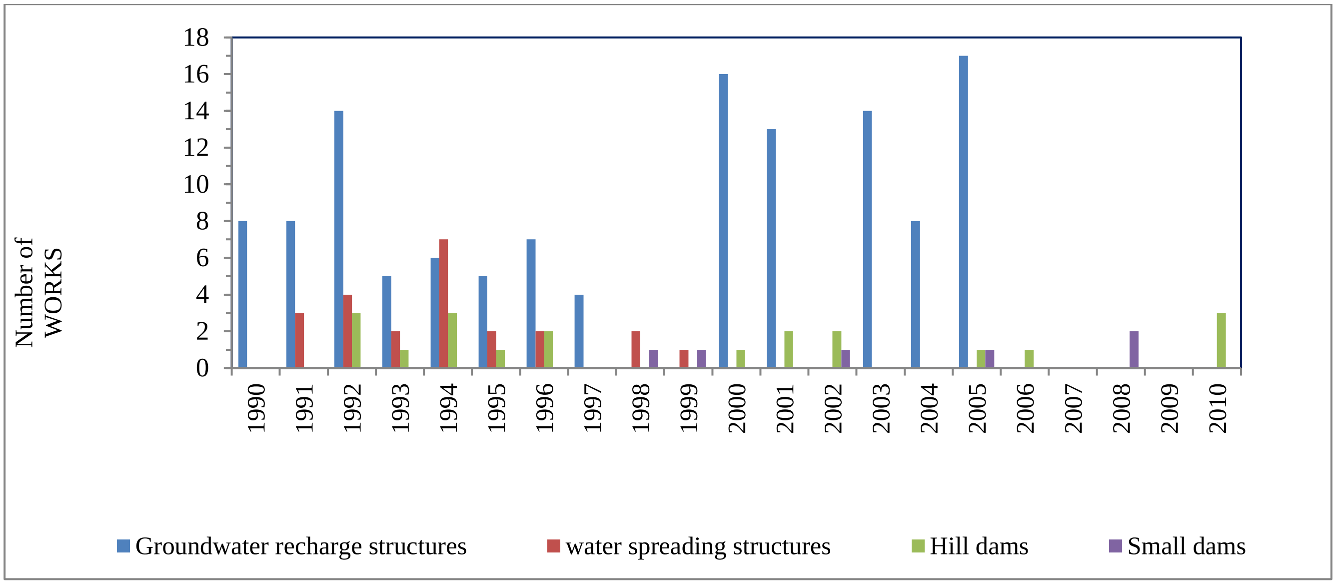

Figure-2: Chronology of implementation of Soil and Water Conservations Works (1990-2010).

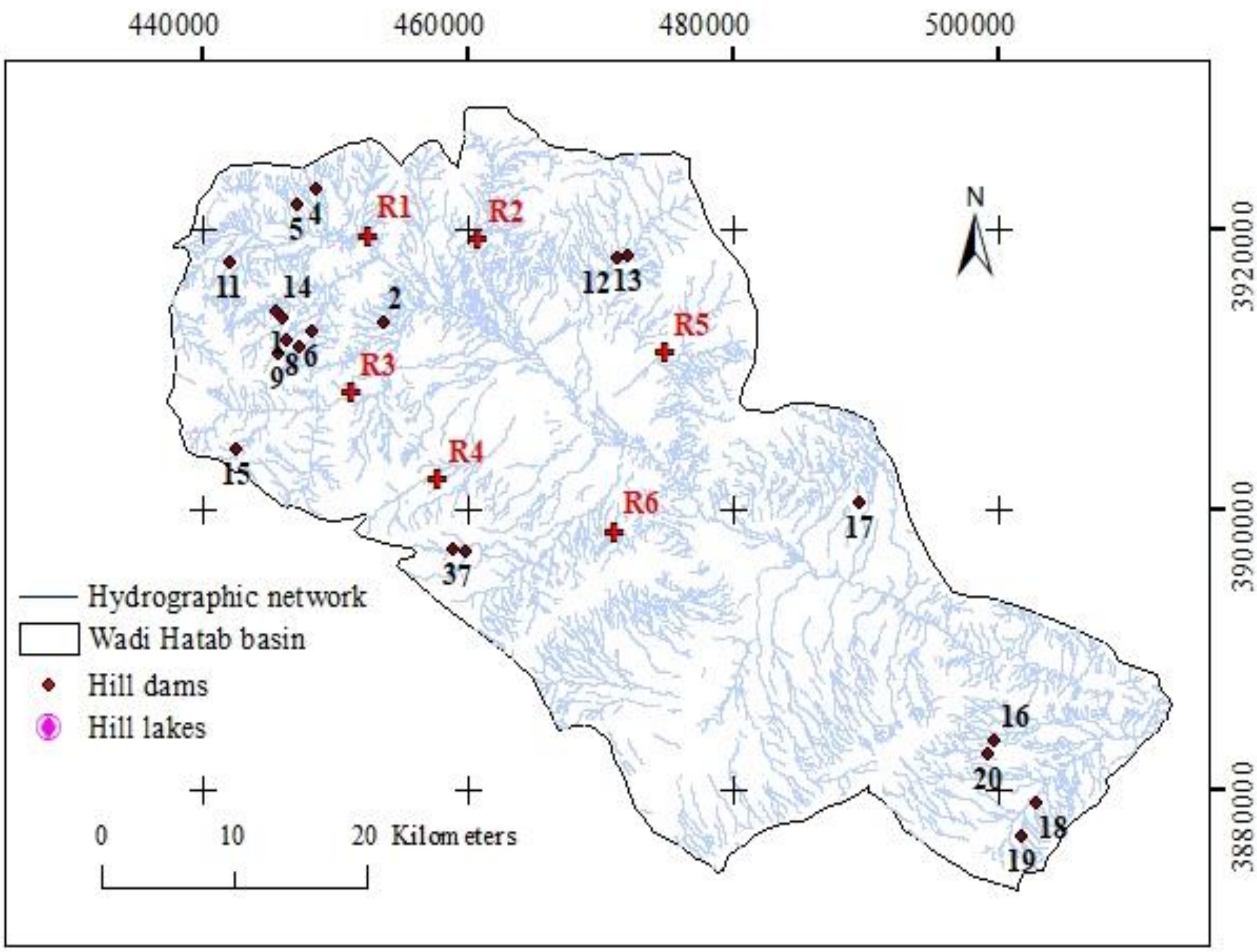

Figure-3: Location of hill dams and hill lakes in Wadi Hatab Watershed.

Table-1: Characteristics of hill dams in Wadi Hatab Watershed[34].

N°	Name	Watershed Area (km²)	Average annual runoff (Mm^3)	Capacity (Mm^3)	Year of implementation
R1	Khanguet Sloughi	40.1	4.3	4.54	1998
R2	Ain Bidha	55.9	3.3	4.42	1999
R3	Erriahi	-	3.0	2.27	2008
R4	Charchara	34.3	1.6	1.16	2005
R5	Khmouda	56	1.4	0.35	2002
R6	El Battoum	80.8	3.5	3	2008

Table-2: Characteristics of hill lakes in Wadi Hatab Watershed[34].

N°	Name	Year of implementation	Watershed area (ha)	Capacity ($10^3 m^3$)
1	El Arara	1992	610	44
2	Khanaat Ezzitoun	1992	200	50
3	Battoum	1992	700	253
4	Rafed Errmila	1993	120	120
5	Errmila	1994	700	350
6	Fajj Lazrag [1]	1994	1300	260
7	Fidh El Rmila	1994	460	175
8	El Kolla	1995	170	85
9	Essedra	1996	200	60
10	Fajj Lazrag [2]	1996	250	60
11	Mssala	2000	211	72
12	Chtib	2001	916	50
13	El Maleh2	2001	415	85
14	Etrafett	2002	815	473
15	Tmar ouzi	2002	148	80
16	Sfaya	2005	610	200
17	Abboud	2006	180	94
18	Khour	2010	200	78
19	Araar	2010	250	83
20	El Brije	2010	1300	402

Integration of Soil and Water Conservation Works (SWCW): The two types of the SWCW considered in this study were integrated separately into SWAT model. Hill dams were integrated simultaneously with a single continuous simulation while hill lakes were integrated in several periods with successive simulations. Figure-4 shows the considered hill dams and hill lakes and the corresponding sub-basins.

Hill dams: The six small hill dams treated in SWAT model as reservoirs. The model input data for dam simulation is presented in Table-3. The integration of hill dams into SWAT model was performed in a single simulation. It consists in inserting simultaneously all the required parameters and the year of implementation of each structure. The six dams were introduced in a chronological order depending on the year of implementation: 1998, 1999, 2002, 2005 and 2008 for sub-basins 7, 11, 17, 21, 25 and 28 respectively. Table-3 presents the geometric characteristics of the implemented hillside reservoirs.

Hill lakes: The characteristics of the hill lakes, required by SWAT, are shown in Table-4. In the modeling exercise, a single lake is integrated in each sub-basin. However, in the study basin, several sub-basins contain more than one small retention reservoir while others do not contain any water retention facility. To have only one lake per sub-basin, the characteristics of the retention facilities that are in the same sub-basin were added. This is the case, for instance, for sub-basins (1) and (6), where two and six hill lakes respectively are encountered.

Hill lakes were implemented during the period (1992-2010) in the chronological order shown in Figure-2. The three lakes realized during the year 2010 were not integrated in the simulation (end of the simulation period). The seventeen hill lakes were introduced into SWAT model in seven distinct time intervals, according to the methodology presented in Table-5. Each time interval corresponds to a simulation.

In simulation "sim 1" we integrated the characteristics of hill lakes related to sub-basins (8) and (26). Then, with each new simulation, the characteristics of the other hill lakes are added according to the chronology presented in Table-5.

POND_ESA: pond surface area associated to emergency spillway level; POND-EVOL: stored water volume in pond when filled to the emergency spillway; POND_PSA: pond surface area corresponding to principal spillway level; POND_PVOL: stored water volume associated with the principal spillway level.

Results and discussion

Simulation results corresponding to both types of water retention facilities (hill dams and hill lakes) shall be presented and discussed. Four scenarios, with and without incorporation of the considered small retention facilities, are considered.

Impact of dams on runoff and sediment yields: Figure-5 shows the impact of the integration of hill dams on the simulated flow rates. This figure shows that the decrease in flow started from the year 1998, when the first hill dam was implemented. The difference between flow rates with and without hill dams increases with the integration of other dams. Runoff volumes decreased by 6% in 1998, 36% in 2003 and the decrease is maximum (42%) in 2010, when all the dams were in service.

The implemented water retention facilities also affect sediment yield. Figure-5 shows the combined effect of the six dams on sediment production at the outlet of the study basin. A reduction of sediment yield was noted since the year of realization of the first dam (1998) and this reduction increased from year to year with the integration of each retention facility. It ranged from 4% in 1998 to 41% in 2010.

Table-3: Physical characteristics of the implemented hillside reservoirs required by SWAT model.

Name		YEAR_RES	RES _ESA (ha)	RES_EVOL (10^4m^3)	RES_PSA (ha)	RES_PVOL (10^4m^3)	Sub-basin
R1	Khanguet Sloughi	1998	97,49	987	71,43	454	7
R2	Ain Bidha	1999	79,4	658	62,7	442	11
R3	Erriahi	2008	55	291,1	33	227	17
R4	Charchara	2005	21	166	12,9	116	21
R5	Khmouda	2002	10,3	68,7	5,5	35	25
R6	El Battoum	2008	61	451	45,5	300	28

YEAR_RES: Year of implementation; RES_ESA: top area of the lake at the emergency spillway level; RES-EVOL: remaining volume to reach the emergency spillway level; RES_PSA: top area of the lake at the principal spillway level; RES_PVOL: remaining volume to reach the principal spillway level.

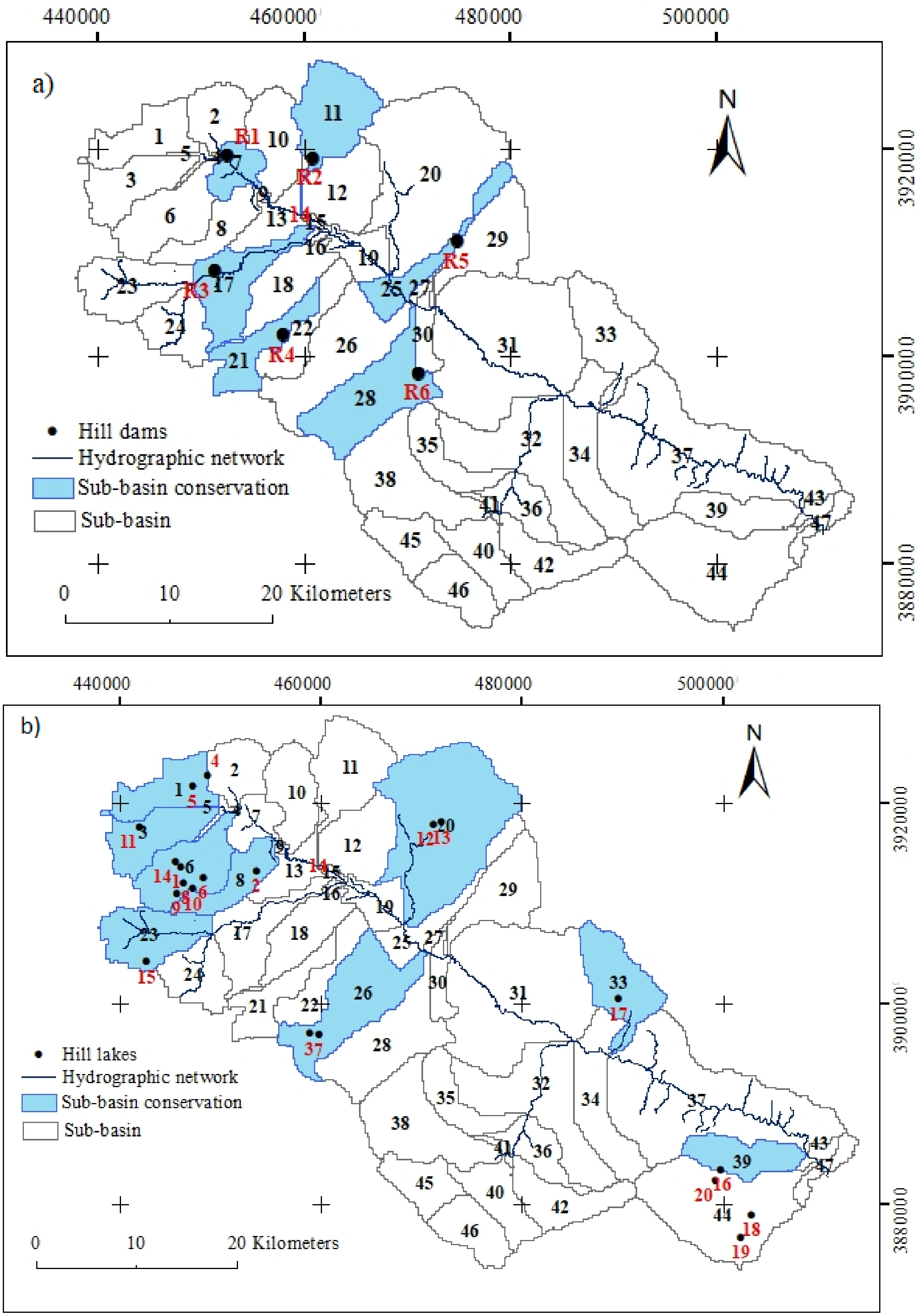

Figure-4: Identification of sub-basins controlled by: a) hill dams, b) hill lakes.

Table-4: Physical characteristics of Hill lakes required by SWAT Model.

Sub basin	N°	Name	PND_PVOL (10^3m^3)	PND_EVOL (10^3m^3)	PND_PSA (ha)	PND_ESA (ha)
6	1	El Arara	44	100	1,5	2,7
	6	Fajj Lazrag 1	260	360	2,9	3,5
	8	El Kolla	85	120	1,2	1,8
	9	Essedra	60	150	0,9	1,65
	10	Fajj Lazrag 2	60	120	1,5	2
	14	Etrafett	473	600	4,2	5,5
8	2	Khanaat Ezzitoun	50	120	1,7	3
3	11	Mssala	72	120	1,4	2,1
1	5	Errmila	350	500	3,5	5
	4	Rafed OErrmila	120	210	2	2,8
20	12	Chtib	50	90	1	1,9
	13	El Maleh2	85	200	1,8	2,3
26	7	Fidh El Rmila	175	280	2,5	3,2
	3	Battoum	253	450	2,8	3,7
39	16	Sfaya	200	350	2,6	3,5
23	15	Tmar ouzi	80	130	1,3	2
33	17	Abboud	94	150	0,9	1,2

Table-5: Simulation experiments associated with hill lakes.

Simulation experiment	Starting date	Ending date	Number of hill lakes considered	Sub-basin
1	01-01-1992	31-12-1993	2 and 3 - 7	8 et 26
2	01-01-1994	31-12-1999	4 – 5 et 1 - 6 - 8 - 9 - 10 - 14	1 et 6
3	01-01-2000	31-12-2000	11	3
4	01-01-2001	31-12-2001	12- 13	20
5	01-01-2002	31-12-2004	15	23
6	01-01-2005	31-12-2005	16	39
7	01-01-2006	31-12-2010	17	33

The integration of dams (sub-basins 7, 11, 17, 21, 25 and 28) in the modeling exercise resulted in an increase of groundwater flow and total flow and a reduction of sediment yield. For the analysis of these variations we took the results of the year 2010 when all the dams were in service. Figure 6 shows the variations of subsurface flow, total runoff, and sediment yield of the six sub-basins controlled by hill dams at their outlets. The increase in groundwater flow varies from 14% for sub-basin (25) to 84% for sub-basin (17). For the total flow, the increase varied from 1% for sub-basin (28) to 36% for sub-basin (11). Regarding the variation of sediment yield, the year 2010 is shown to be a year with average rainfall and low erosive potential. There was a maximum reduction of 25% of sediment yield in sub-basin (28). For the other sub-basins, there is no significant change with a slight increase in sub-basin (7). From these results, we can deduce that these hill dams have favored an increase in groundwater flow and total flow and a reduction of sediment transport at the outlet of each sub-basin.

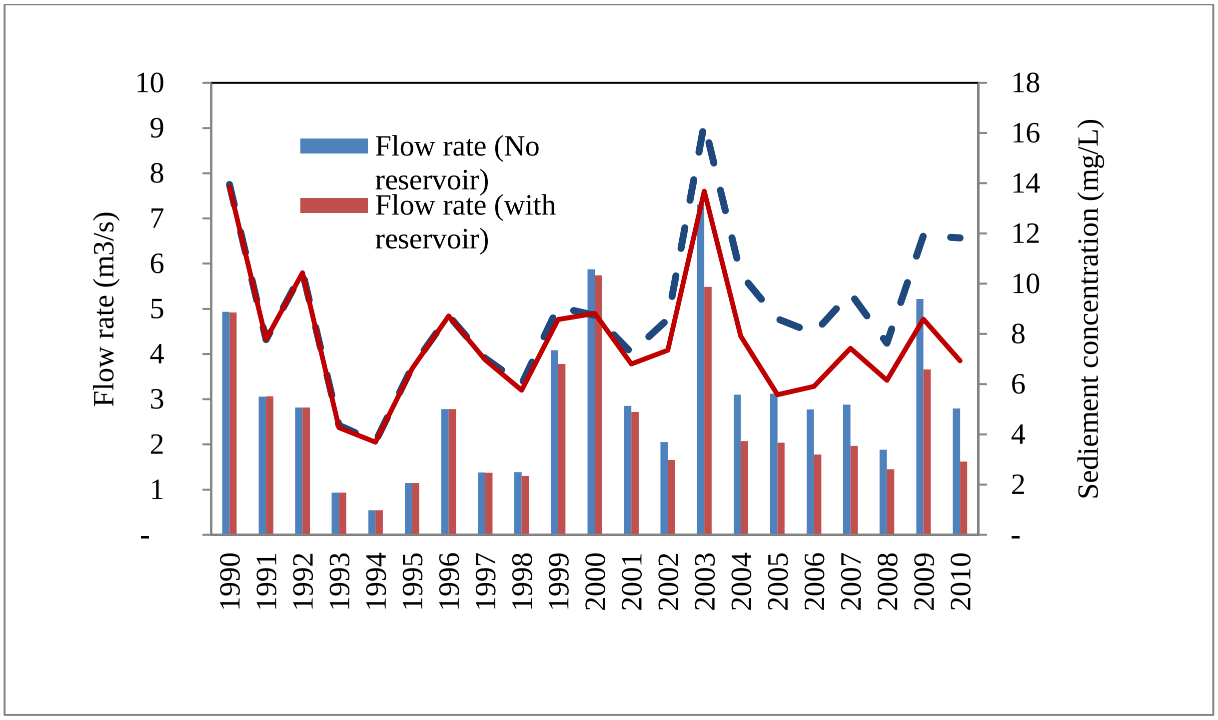

Figure-5: Impact of hill dams on flow rates and sediment concentrations.

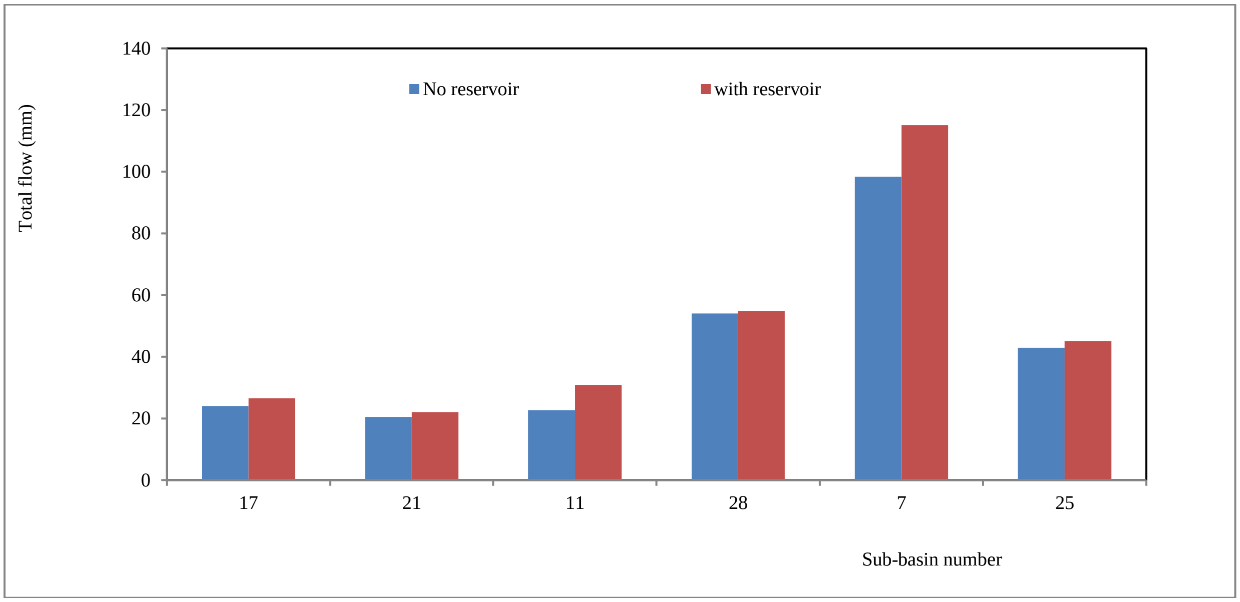

Figure-6- a: Variation of Total flow in the six sub-basins under the effect of hill dams in 2010.

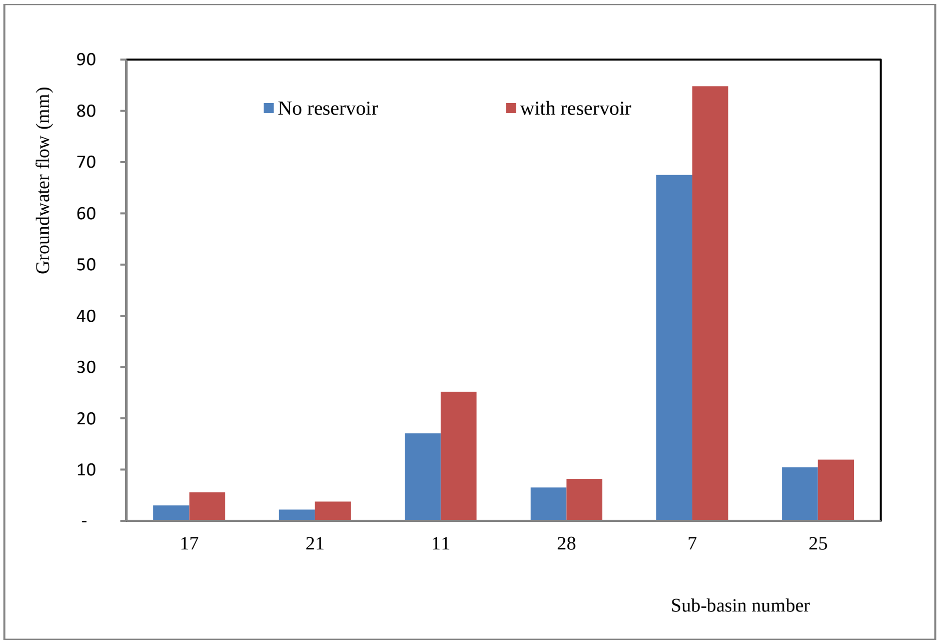

Figure-6-b: Variation of Groundwater flow in the six sub-basins under the effect of hill dams in 2010.

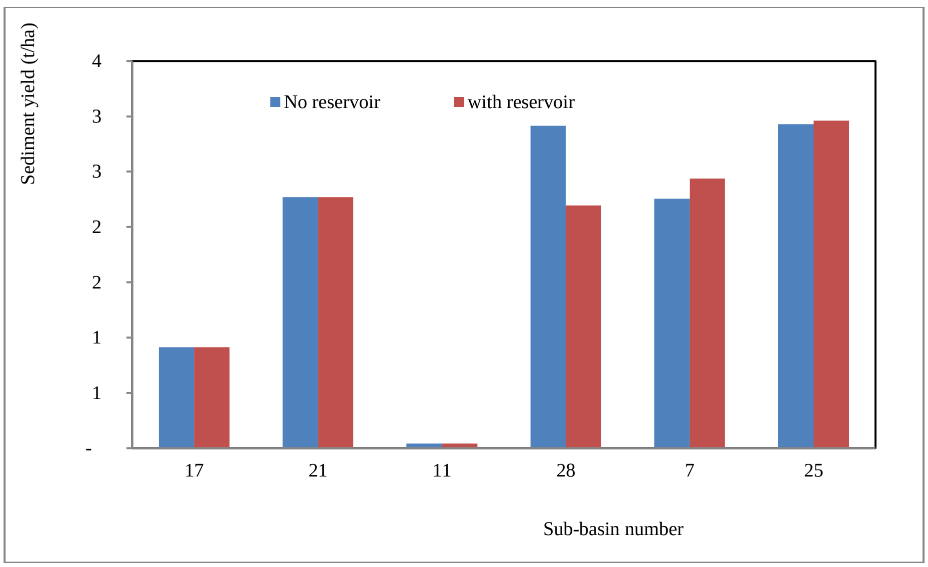

Figure-6-c: Variationt of Sediment yield in the six sub-basins under the effect of hill dams in 2010.

Impact of hill lakes on runoff and sediment yields: The results of the simulations show that the integration of hill lakes has a negligible effect on runoff flow rates and sediment yields at the outlet of Wadi Hatab Catchment. This reduction is a maximum of 6% for flow rates and 4% for sediment concentration in 2010. Compared to the effect of the hill dams, the lakes represent a low holding capacity which represents less than one fifth (1/5) of the holding capacity of all the hill dams.

At the sub-basin scale, we noticed an increase in groundwater discharge and a decrease of total flow and sediment load for the nine sub-basins, characterized by the presence of hill lakes. Figure-7 shows respectively the changes in groundwater flow, total flow and sediment transport for the year 2010, for the studied nine sub-basins. The increase in groundwater flow is maximal (42%) for sub-basin (6) while almost no change was observed in sub-basin (20). The reduction in total flow varies from 1% for sub-basin (23) to 27% for sub-basin (6). The decrease in sediment transport varies from 3% in sub-basin (23) to 20% in sub-basin (1). These results clearly show that hill lakes resulted in a reduction of sediment transport and an increase of groundwater flow. In a similar fashion, Sakka (2010) found through numerical simulations by the model SWAT that surface runoff decreased by more than 40% in Merguellil Watershed (Central Tunisia).

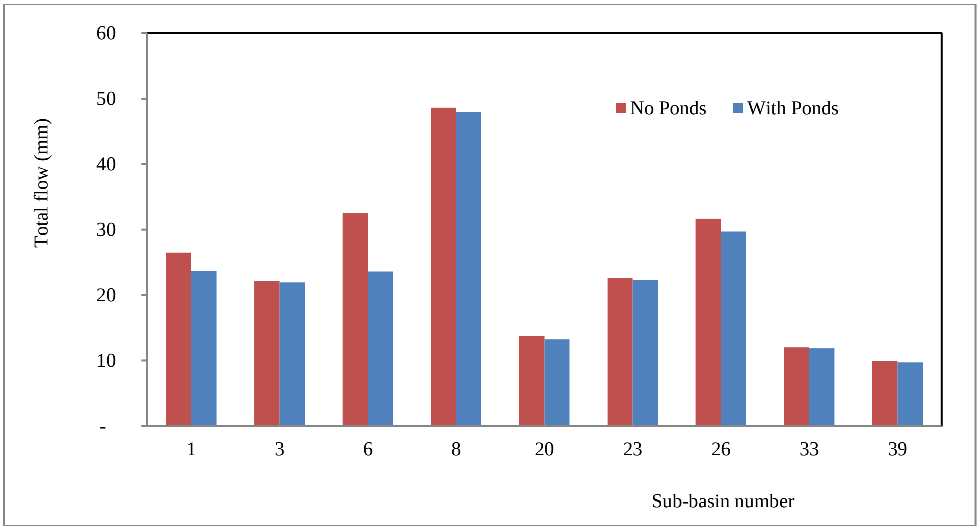

Figure-7-a: Variation of Total flow in the nine sub-basins under the effect of hill lakes in 2010.

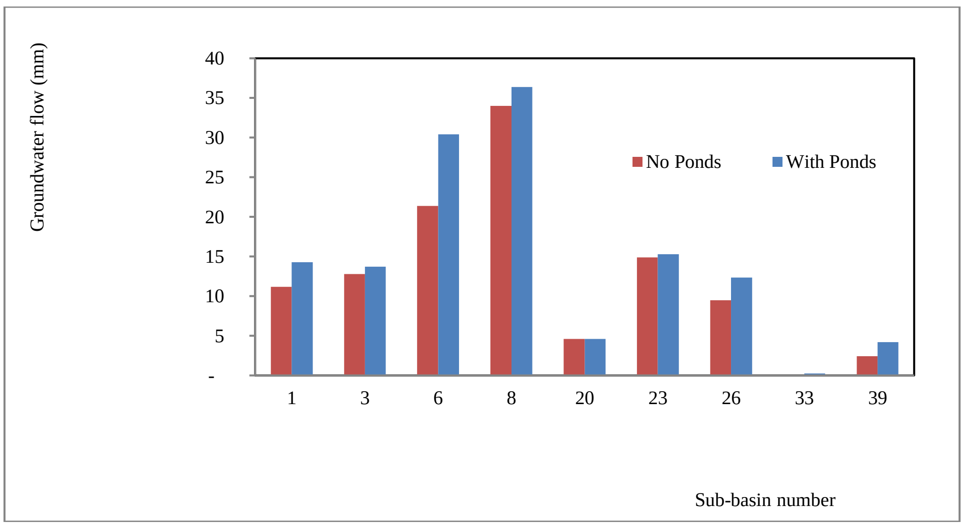

Figure-8b: Variation of Groundwater flow in the nine sub-basins under the effect of hill lakes in 2010.

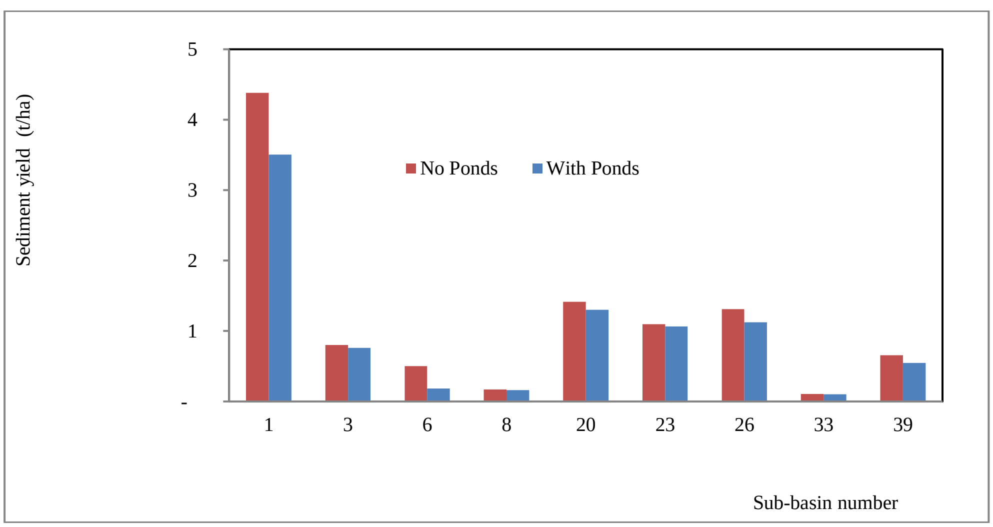

Figure-9-c: Sediment load variability under the effect of hill lakes in 2010.

Conclusion

The natural hydrological regime has been continuously modified in Wadi Hatab Watershed since the year 1990, which represents the beginning of the implementation of Soil and Water Conservations Works. This study showed that the implementation of hill dams resulted in a decrease in discharge and sediment load out of the study basin since 1998 (year of implementation of the first hill dam). This reduction increased with the implementation of the other hill dams. Unlike hill dams, the impact of hill lakes on the reduction of flow, and sediment transport is low. This is explained by the difference in holding capacity between the two types of water retention facilities as hill lakes are much smaller structures. At the sub-basin scale, the integration of dams resulted in an increase in groundwater flow and total flow and a reduction in sediment yield for the year 2010, when all the dams were in service. The implementation of hill lakes resulted in an increase of groundwater discharge and an attenuation of total flow and sediment production rates.

This study showed that the integration of hill dams in SWAT model allowed the evaluation of the impact of these reservoirs on the catchment hydrologic response. The model resulted in reasonably good results, showing thereby good aptitude to simulate the basin hydrologic response, where water retention facilities are included. The obtained simulations may help managers and decision makers to develop strategies for optimal water and soil conservation.

As a recommendation, we propose the integration of other SWCW such as groundwater recharge structures, runoff water spreading structures and contour ridges in the hydrological simulation of water and sediment flows to identify the impact of all of these SWCW on the preservation of water resources and the protection of soil against water erosion. Another perspective of this research is the analysis of the causal factors of the risk of water erosion in the study basin. This analysis will focus on the relationships and the distributions of the effects of the various factors, which are mainly rainfall, topography, pedology and land use, through a Principal Component Analysis "PCA".

Acknowledgments

The authors are thankful to the Tunisian Ministry of Agriculture and Water Resources for providing the data required for this study.

References

1. MEAT, Ministère de l'Environnement et de l’Aménagement du Territoire (2014). #Les indicateurs de développement durable en Tunisie.# Ministère de Ministère de l'Environnement et de l’Aménagement du Territoire http://www.environnement.gov.tn/fileadmin/medias/pdfs/admin_papier/ind_nati_dd_2014.pdf

2. MEDD, Ministère de l'Environnement et du Développement Durable (2006). # en œuvre du programme d’action nationale contre la désertification, Programme d’action régional de lutte contre la désertification du Gouvernorat de Kasserine.# PALCD. 107p

3. Hamza, A., and Hamou, H. (1995). #Rôle des ouvrages de conservation des eaux et du sol dans la lutte contre les inondations.# *Agriculture, durabilité et environnement*. S. Zekri et A. Laajimi (Eds). Zaragoza, CIHEAM-IAMZ, 9, 87-96.

4. Dridi, B. (2000). #Impact des aménagements sur la disponibilité des eaux de surface dans le bassin versant du Merguellil (Tunisie central# *Doctoral dissertation*, Strasbourg 1. Université Louis Pasteur Strasbourg.

5. Nasri, S., Lamachère, J. and Albergel, J. (2004). #Impact des banquettes sur le ruissellement d'un petit bassin versant# *Revue des sciences de l'eau/Journal of Water Science*, 17(2), 265-289.

6. Abouabdillah, A., White, M., Arnold, J. G., De Girolamo, A. M., Oueslati, O., Maataoui, A., & Lo Porto, A. (2014). #Evaluation of soil and water conservation measures in a semiarid river basin in Tunisia using SWAT# *Soil use and management*, 30(4), 539-549.

7. Sakka, M. (2011). #Application and comparison of two analytical tools of decision support for the management of resources in a river basin in Tunisia.# Ph. D. Thesis Tuscia University of Viterbo, Italy, P 228. http://dspace.unitus.it/bitstream/2067/2498/1/msakka_tesid.pdf

8. Bouraoui, F., Benabdallah, S., Jrad, A., and Bidoglio, G. (2005). #Application of the SWAT model on the Medjerda river basin (Tunisia).# *Physics and Chemistry of the Earth*, Parts A/B/C, 30(8-10), 497-507.

9. Ouessar, M., Bruggeman, A., Abdelli, F., Mohtar, R. H., Gabriëls, D., and Cornelis, W. (2009). #Modelling water-harvesting systems in the arid south of Tunisia using SWAT.# *Hydrology and Earth System Sciences*, 13(10), 2003-2021.

10. Mosbahi, M., Benabdallah, S., and Boussema, M. R. (2011). #Determination of critical source areas for sediment loss: Sarrath River Basin, Tunisia.# *International Journal of Civil and Environmental Engineering*, 3, 206-2010.

11. Sellami, H., La Jeunesse, I., Benabdallah, S., and Vanclooster, M. (2013). #Parameter and rating curve uncertainty propagation analysis of the SWAT model for two small Mediterranean catchments.# *Hydrological Sciences Journal*, 58(8), 1635-1657.

12. Ben Othman, D., and Gueddari, M. (2014). #Hydrological study of the water quality of the Beja River according to the SWAT model.# *Desalination and Water Treatment*, 52(10-12), 2047-2056.

13. Aouissi, J., Benabdallah, S., Chabaâne, Z. L., & Cudennec, C. (2014). #Modeling water quality to improve agricultural practices and land management in a Tunisian catchment using the Soil and Water Assessment Tool.# *Journal of Environmental Quality*, 43(1), 18-25.

14. Khelifa, W. B., Hermassi, T., Strohmeier, S., Zucca, C., Ziadat, F., Boufaroua, M., & Habaieb, H. (2017). #Parameterization of the effect of bench terraces on runoff and sediment yield by SWAT modeling in a small semiarid watershed in Northern Tunisia.# *Land Degradation & Development*, 28(5), 1568-1578.

15. Mishra, A., Froebrich, J., & Gassman, P. W. (2007). Evaluation of the SWAT model for assessing sediment control structures in a small watershed in India. Transactions of the ASABE, 50(2), 469-477.

16. Melaku, N. D., Renschler, C. S., Holzmann, H., Strohmeier, S., Bayu, W., Zucca, C. and Klik, A. (2018). #Prediction of soil and water conservation structure impacts on runoff and erosion processes using SWAT model in the northern Ethiopian highlands.# *Journal of Soils and Sediments*, 18(4), 1743-1755.

17. Li, E., Mu, X., Zhao, G., Gao, P. and Sun, W. (2017). #Effects of check dams on runoff and sediment load in a semi-arid river basin of the Yellow River.# *Stochastic Environmental Research and Risk Assessment*, 31(7), 1791-1803.

18. Ma, X., Lu, X.X., van Noordwijk, M., Li, J.T. and Xu, J.C., (2014). #Attribution of climate change, vegetation restoration, and engineering measures to the reduction of suspended sediment in the Kajie catchment, Southwest China.# *Hydrol. Earth Syst. Sci.*, 18, 1979–1994.

19. Lemann, T., Zeleke, G., Amsler, C., Giovanoli, L., Suter, H., and Roth, V. (2016). #Modelling the effect of soil and water conservation on discharge and sediment yield in the upper Blue Nile basin, Ethiopia.# *Applied geography*, 73, 89-101.

20. Zuo, D., Xu, Z., Yao, W., Jin, S., Xiao, P., and Ran, D. (2016). #Assessing the effects of changes in land use and climate on runoff and sediment yields from a watershed in the Loess Plateau of China.# *Science of the Total Environment*, 544, 238-250.

21. Arnold, J. G., Srinivasan, R., Muttiah, R. S., and Williams, J. R. (1998). #Large area hydrologic modeling and assessment part I: model development 1.# *JAWRA Journal of the American Water Resources Association*, 34(1), 73-89.

22. Salah, N. C. B., and Abida, H. (2016). #Runoff and sediment yield modeling using SWAT model: case of Wadi Hatab basin, central Tunisia.# *Arabian Journal of Geosciences*, 9(11), 579.

23. MARH, DG/ACTA, Direction Générale de l'Aménagement et de la Conservation des Terres (2009). #Etude de planification intégrée et participative des aménagements de conservation des eaux et du sol dans le gouvernorat de Kasserine. Ministère de l'Agriculture et des Ressources Hydrauliques.# SOLTEC.

24. Neitsch, S. L., Arnold, J. G., Kiniry, J. R., Srinivasan, R., and Williams, J. R. (2005). #Soil and water assessment tool input/output file documentation.# *Blackland Research Center, Temple, Texas*.

25. USDA, S. (1972). #National Engineering Handbook, Hydrology Section 4.# US Department of Agriculture, Soil Conservation Service (Chapters 4–10).

26. Green, W. H., and Ampt, G. A. (1911). #Studies on Soil Phyics.# *The Journal of Agricultural Science*, 4(1), 1-24.

27. Penman, H. L. (1948). #Natural evaporation from open water, bare soil and grass. Proceedings of the Royal Society of London.# *Series A. Mathematical and Physical Sciences*, 193(1032), 120-145.

28. Hargreaves, G. H. (1975). #Moisture availability and crop production.# *Transactions of the ASAE*, 18(5), 980-0984.

29. Priestley, C. H. B., and Taylor, R. J. (1972). #On the assessment of surface heat flux and evaporation using large-scale parameters.# *Monthly weather review*, 100(2), 81-92.

30. Williams, J. R., and Berndt, H. D. (1977). #Sediment yield prediction based on watershed hydrology.# *Transactions of the ASAE*, 20(6), 1100-1104.

31. McCarthy, G. T. (1938). #The unit hydrograph and flood routing. In proceedings of Conference of North Atlantic Division, US Army Corps of Engineers, 608-609.

32. Williams, J. R. (1969). #Flood routing with variable travel time or variable storage coefficients.# *Transactions of the ASAE*, 12(1), 100-0103.

33. Ben Salah, N. C. (2017). #Simulation des flux d'eau et de sédiments dans un basin aménagé moyennant le modèle agro-hydrologique SWAT: Cas du bassin d'Oued El Hatab (Tunisie Centrale).# Thèse de doctorat, Ecole Nationale d'Ingénieurs de Tunis, 221p.

34. RCAD of Kasserine.