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Towards an efficient characterization of the hydrological behavior of the watershed of wadi Louza (NW-Algeria) using the GARDÉNIA model

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Short Abstract

The GARDENIA model is one of the strategies that could play a constructive role in improving the performance of the rainfall- runoff conceptual models. The main objective of this article is to identify and characterize the hydrological behavior of the wadi Louza watershed. The model simulates the main mechanisms of the water cycle in a watershed through simplified physical laws. These correspond to a flow through a succession of tanks. Data from 1987 / 1988-2007 / 2008 are used with some wet and other dry periods. The results show that in the calibration phase the model has a robustness to produce reliable simulation of flows in the monthly time step. Its application over different periods (dry and wet) has shown a certain efficiency for all periods. During the validation phase, the model was able to generate the series of flows for most periods. In terms of hydrological balance, the model was able to quantify the different components (real evapotranspiration, runoff, infiltration, recharge) and to separate the different components of the flow. The assessment of recharge during the dry period and the wet period, has shown us the effects of climate variability on water resources.

Keywords: GARDENIA model; Conceptual models; Louza wadi; Hydrological balance.

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1. Introduction

In recent years, several studies are moving towards simple hydrological models such as conceptual models and physical base models, offering speed and ease of increased calibrating (Bardossy and hey, 2006). These models have many practical applications in the field of water resource management and the fight against natural disasters associated with floods. The objective of this article is to characterize the hydrological behavior of a watershed by the use of a GARDÉNIA global hydrological model (Thiéry 2009, 2013, 2014, 2015), which simulates by a succession of reservoirs, the main mechanisms of the water cycle in a watershed (rain, evapotranspiration, infiltration, flow). This rainfall- runoff modeling and its representation on a monthly scale in the wadi Louza watershed is based on a series of rainfall stations data (Telagh, Merine, Sid Ahmed) and hydrometric station (Tenira) for the purpose of identify the impact of climate variability on water resources.

2. Methods

2.1 Study area: watershed of Wadi Louza is located in basin of wadi El Hammam in northwestern Algeria, between latitudes 34.68° - 35.03° North and longitude 0.70° - 0.37° West, with an area of 746km2. The main tributaries are the Telzaa River, Telagh River, Neksifia River, Teghalimet River, and then the Louza River with altitudes ranging from 580m to 1460m (the average elevation is 855m). Its climate is classified as semi-arid, with an average precipitation of 286 mm / year (1978-2008) (Figure 1) .

2.2 The data used: In this research, three pluviometric stations (Telagh, Merine, Sid Ahmed) and a runoff station (Tenira) are selected. Characteristics and locations of these stations are presented in (Table 1).

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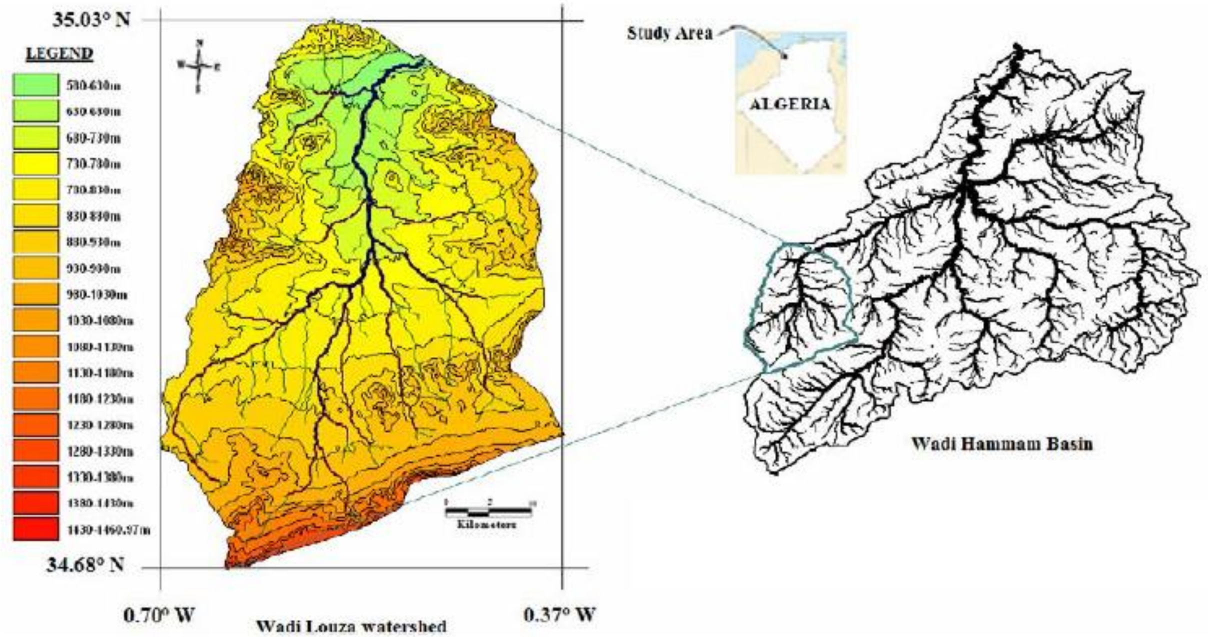

Figure 1: Situation of wadi Louza watershed.

Table 1. Characteristics of rainfall and runoff stations in Wadi Louza Basin

Station name	Gauge type	Longitude	Latitude	Elevation (m)	Selected period
Telagh	Rain gauge	0°34'28.9726" W	34°47'4.9442" N	889	1980-2009
Merine	Rain gauge	0°24'12.1733" W	34°47'34.5859" N	959	1980-2009
Sid Ahmed	Rain gauge	0°32'41.3488" W	34°57'54.1487" N	653	1980-2009
Tenira	Runoff gauge	0°31'30.6286" W	35°01'1.0492" N	606	1978-2008

2.3 Hydrological model: As with any hydrological model, the GARDÉNIA model (A Global Tank Model for Simulating Flows and Aquifer Levels) (Thiéry, 2009; 2010; 2011; 2014; 2015) is also a formalization of knowledge about the process involved in the water cycle. From the sequence of meteorological data (rainfall, potential evaporation), it allows to associate them dynamically, to better understand their the spacial and temporal interactions, with the aim to identify and characterize the hydrological behavior of watershed. It involves several global parameters (useful reserve, drying time, etc.) defined for a watershed. The diagram of the functioning of the model GARDÉNIA that we used involving only two tanks (Figure 2)

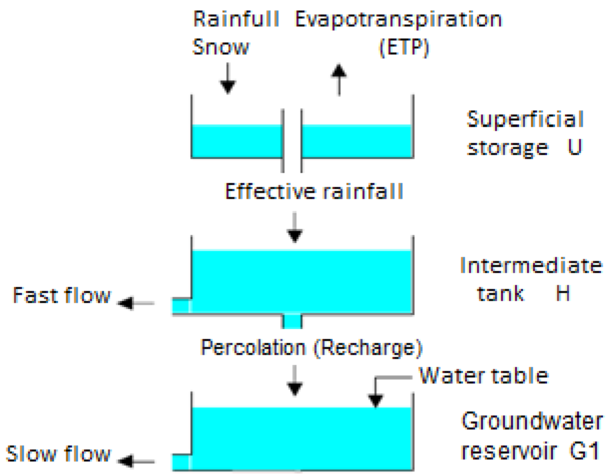

Figure 2: Diagram of how the GARDÉNIA model works (Thiery, 2014).

Using the GARDENIA model, we will calibrate and validate the model using the monthly observed rainfall,

runoff and potential evapotranspiration over the wet period (2001-2007) and the dry period (1988-1996). Then we will analyze the balance of the different flows, to identify the impact of climate variability (drought) on water resources.
The evaluation criterion used is that of Nash and Sutcliff [Nash and Sutcliffe, 1970] which is expressed by:

$$Ns = 1 - \frac{\sum_{i=1}^{n}(Qcalc,i - Qobs,i)^2}{\sum_{i=1}^{n}(Qcalc,i - Qm)^2}$$

Q_{calc}: calculated flows, Q_{obs}: observed flows, Q_m: observed average flow

3. Results and discussion

3.1 Calibration and validation during the wet period and the dry period

The different calibration and validation Nash values obtained over the wet period (2001-2007) and the dry period (1988-1996) are presented in Table 2.

Table 2: Hydrological parameters and values of Nash in calibration and validation with the GARDENIA model on the dry and wet period.

Hydrological parameters	Wet period (2001-2007)	Dry period (1988-1996)
Start-up period	Jan2001-Dec2002	Jan1988-Dec 1990
Calibration period	Jan2003-Dec2004	Jan1991-Dec1993
Validation period	Jan2005-Dec2007	Jan1994-Dec1996
Tank capacity RU (mm)	44.74	44
Progressive soil tank capacity (mm)	80.97	230
Height of distribution runoff = percolation (mm)	1.00	1.00
½ of time of recovery (months)	7.79	2.24
½ time of depletion Underground (months)	15.00	6.01
retard of the propagation of flows (months)	8.42	0
External Exchange Factor (%)	-30.18	-70.00
Nash(Q)-Calibration	**77.35%**	**94.84%**
Nash(Q)- validation	**19.62**	**9.90%**

Its rapid analysis shows that Nash values during calibration are greater than 70% for the dry period and the wet period. In addition, optimized parameters, in calibration over the dry period produce a better simulation than a calibration during the wet period. In the validation phase, for the dry period and the wet period, the Nash values are degraded (Table 2). This result could be explained by the poorer quality of the data (low rainfall network) (Figure 3 and 4).

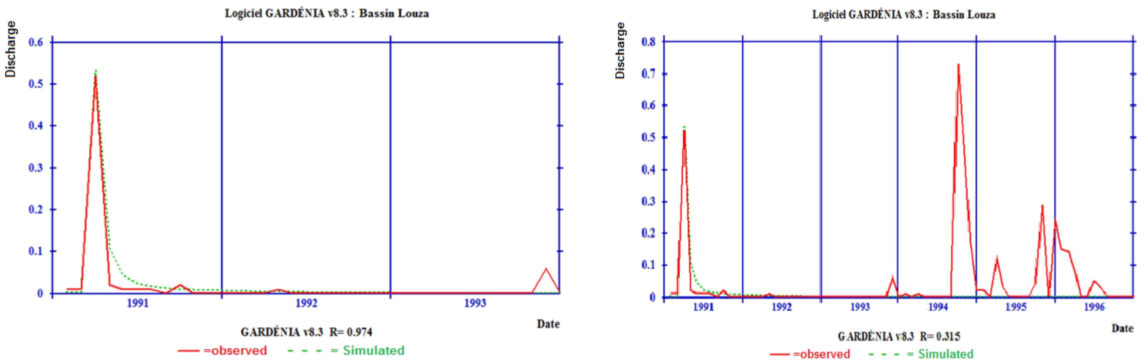

Figure 3: Calibration and validation on the dry period (1988-1996)

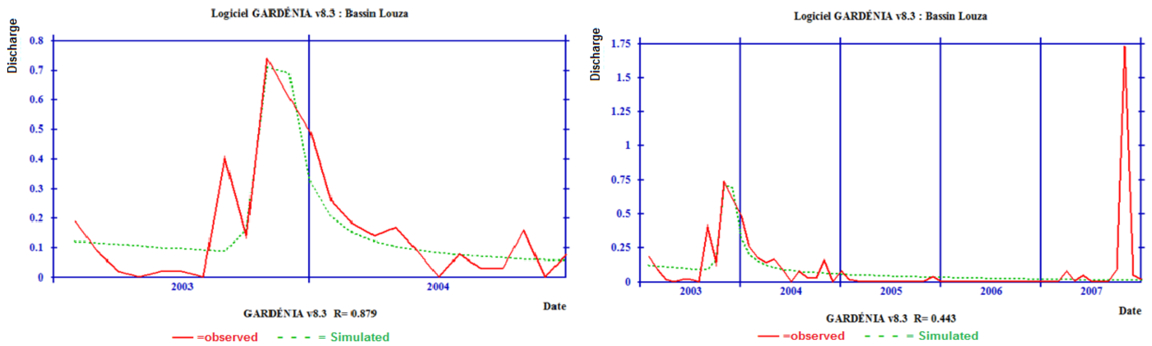

Figure 4: Calibration and validation during the wet period (2001-2007)

3.2 Hydrological balance: first, the GARDENIA model enables to quantify the different components of the hydrological balance for the two periods (Table 3). Namely real evapotranspiration, runoff, infiltration and groundwater recharge. In addition, it provides an opportunity to separate the different components of the flow, the fast flow and the slow flow.

Table 3: Hydrological balance for the wet and dry Periods

Periode	Wet period (2001-2007)	Dry period (1988-1996)
Rainfall (mm)	372.30	300.767
ETR (mm/an)	367.78	302.606
Effective rainfall (mm/an)	4.52	1.332
Fast flow (m^3/s)	3.36	0.796
Discharge of groundwater (m^3/s)	2.62	0.182
Exchange flow (m^3/s)	-1.134	-0.425
% of discharge of groundwater	43.89	18.618
% of exchange flow	-25.09	-31.891
% of Fast flow	74.22	59.742
Groundwater recharge (m^3/s)	1.165	0.5362

The results of the model shows that:

1- The correct calibration during wet and dry periods approves the existence of an export of flow to other adjacent basins which reach its maximum (1.13 m^3/s) in a humid period,

2- the effective infiltration that recharges the water table in wet weather (1.16 m^3/s), increases the slow component of the flow (discharge of groundwater) which is estimated in the dry period to 0.182 m^3/s,

3- The effects of climate variability on water resources have been highlighted by the increase in recharge during wet periods by 0.62 m^3/s, or 115% in dry periods, confirm that the watershed of wadi Louza went through periods of extreme drought.

4. Conclusion:

The GARDENIA model has shown its robustness to produce reliable simulations of flows in the monthly time step. Its application over different periods has shown a certain efficiency expressed by the Nash value which remains higher than 70% for all periods. The model was able to generate the flow series for most periods.

In terms of water hydrological balance, the model was able to quantify the different components (real evapotranspiration, runoff, infiltration, recharge) and to separate the different components of the flow, in slow flow and fast flow. The assessment of recharge during the dry period and the wet period, has shown us the effects of climate variability on water resources. The increase in groundwater recharge during the wet period of 115% in the dry period, confirms that the Louza wadi watershed has gone through periods of extreme drought.

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