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COMPARATIVE PERFORMANCES ANALYSIS OF FOUR DAILY RAINFALL-RUNOFF MODELS, APPLIED ON SEMI-ARID WATERSHEDS (ALGERIA)

ANALYSE DES PERFORMANCES DE QUATRE MODELES PLUIE-DEBIT, EN ZONE SEMI-ARIDE (ALGERIE)

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ABSTRACT

In this paper, we have tested four rainfall-runoff models on daily time scale that we have picked out amongst more than ten models the most used in hydrology. These models were applied on four basins situated in North of Algeria, that are characterized by an arid climate and different hydrologic regime. The aim of this work is to choose a best rainfall-runoff model that we can use for simulation and prediction runoff. The comparative analysis between these models is based on numerical criterions like Nash-Sutcliffe criterion and has been geared towards the capacity of models to reproduce flood events and base flow. The results of simulation confirm that the GR4J model has given the best performances and is regarded as the most robust for semi-arid regions and fluctuant hydrological regime.

Keywords: Rainfall-runoff Model, Hydrology, Algeria, Semi arid Climate, GR4J model

RESUME

Dans cet article, nous avons testé quatre modèles pluie-débit au pas de temps journalier que nous avons sélectionnés parmi dix modèles les plus utilisés en hydrologie. Ces modèles ont été testés sur des bassins du Nord de l’Algérie, caractérisés par un climat semi-aride et un régime hydrologique variable. L'objectif principal est de valider un modèle qui sera utilisé dans le cadre d'une simulation des débits et des apports liquides au niveau d'une station hydrométrique. Après une analyse comparative, quantitative et qualitative entre ces modèles, il est apparu que le modèle GR4J a donné les meilleurs résultats de modélisation, et est considéré comme le plus robuste pour la simulation des débits pour les climats semi-arides et irréguliers.

Mots clés : Modèle pluie-débit, Hydrologie, Algérie, Climat semi aride, Modèle GR4J.

INTRODUCTION

Flood and runoff forecasting in outflow watershed is an important focus of research in hydrology, since it enables to anticipate devastating events of the flood and adverse impacts of drought. Stream flow generation from surface water inputs (rainfall) is a complex relationship that depends on many parameters varying on temporal and spatial scale (Ambroise, 1999).

The development of the digital computer has added a new dimension to hydrology. In fact, much more complex methods of analysis are feasible because of the speed of solution by the computer (Roche *et al.* 2012). The impact of the computer has been particularly great in the area of rainfall-runoff modeling. It is worth remembering that rainfall–runoff modelling has a long history and that the first hydrologists attempting to predict the flows that could be expected from a rainfall event (Beven, 2012). Theoretically, hydrologic models are particularly useful tools in that they enable us to investigate many issues that arise during planning, design, operation, and management of water resources systems.

According to their mathematical complexity and numerical resolution, these models can be classified into three categories (Edijatno *et al.* 1999): (I) empirical models or black box models: in this situation rainfall-runoff process is modeled using a formula more or less complex without giving an "hydrological meaning" to the models, (II) Conceptual models, which integrate in their structures a concept based on hydrological cycle, represent a structure built of simple conceptual elements, (III) Physically based models: in this case the rainfall-runoff process is modeled by the finite difference approximation of the partial differential equation representing the mass, momentum and energy balance.

Due to their simplicity, conceptual models (storage-type rainfall-runoff models), are the most important and most tested in hydrology, because they need a minimum of information. These models are generally "lumped" models and treat the catchment as a single unit with state variables (reservoirs).

During the last years, Algeria faced two hydrological contrasts phenomena: on the one hand, heavy flooding, generally flash floods (Algiers: 2001, Bejaia city: 2007) which generated important damage to human and property, and on the other side, a decrease of water resources reserves, exacerbated by the quasi-cyclical phenomena of drought, hence an important protection against flooding and rational water resources management.

Indeed, semi-arid areas such as Algerian basins, are characterised by an intermittent flow: on one side, by base flow in a low–water period, on the other side, by flash and violent floods which makes more delicate the forecasting of this hydrological contrast.

The daily rainfall-runoff models can intervene at two levels: first of all by floods flows estimating (Yang and Michel 2000) for flood control and flood routing of a dam, then by contributions forecast and this for a best water resources management. However, the irregularity of flows and so the hydrological feature of certain Algerian basins make a test of several rainfall-runoff models seem to be more useful than ever (Benkaci, 2006). In fact, in semi-arid regions the spatio-temporal variability of rainfall and flows and so the hydrological process complexities (interception, infiltration, intermittent runoff), make more complex the modelling of rainfall-runoff process in those countries (Pilgrim *et al.* 1988; Mc Intyre and Al-qurashi 2009).

In this paper, we compare four daily conceptual rainfall-runoff models the most employed in hydrology, on wide range of basins well enough heterogeneous located in North of Algeria, focusing primarily on peak flow and base-flow simulation by the models with a view to validate a robust model that will allow a correct flow prediction an outlet of basins.

STUDY AREA

North of Algeria is divided into several watersheds, supplied by rivers having different lengths. The Cheliff's basin in western part of the country is the most important by its area (43500 km^2) and its river is the longest (725 km), followed by Rhumel Kebir's basin (10500 km^2). Relating to the hydrographical network, it is generally not consistent; the distribution of stream gauge stations is in certain basins very heterogeneous. As examples, the Sebbaou's basin (2400 km^2), has a single operating stream gauge station, El-Harrach's basin, is controlled only par three stations, whose only one downstream, the outlet of Cheliff's basin is no longer gauged (since 2010).

In this research, and due to lack of data, we have studied four basins:

The Bouna Moussa's basin

It is a basin located in the extreme East of Algeria, it covers a total area of 943 km^2 and is a part of the Coastal East Constantinois basin, coded 0315 by National Agency of water Resources (ANRH). It is limited on the East by El-Kebir's river basin and on the west by Seybouse's basin. Several rivers have their origin in the Cheffia's massif and branch into several tributaries such as river of Bouna Moussa. The basin is deemed by its heavy rains which can lead to overflowing of streams in winter season.

The Isser's basin

Located in the North of Algeria (coded 09 by ANRH), its total area is of 4170 km^2 from Ain Boucif summit until the outlet of the basin. A part of the basin is drained by Mellah and Hammam streams, these two rivers form Isser, which branches in several tributaries, the peak of the basin is Djebel Dira, reaching 1810 m. The basin climate is Mediterranean, and average annual rainfall is of 700 mm.

The basin of Saf-Saf river

Located on the North-East of Algeria (coded 0309 by ANRH), it is limited by: Mediterranean Sea on the North, Rhumel-Kebir's basin in the East and in the South-East, the basin of Soumam in the west. The climate is of Mediterranean type, cold and relatively wet in winter, and hot in summer. The total area of the basin is of 1158 km^2 presenting a high drainage density (3.8 km/km^2), its relief is characterized by rugged terrains developing the torrential nature of streams and leave basin's soil vulnerable to erosion. The studied stream gauge data is located downstream of Zardezas dam (area is 345 km^2).

The basin of Seybouse

Coded 14 by ANRH, is located on the North-East region of Algeria and spreading on an area of 6400 km^2. Seybouse River originates in the heights of

Heracta and Sellaoua mountains, and drains four towns of the Algerian East. Downstream, Seybouse river floods the surrounding plains practically every two years. The quality of its waters is often lacking and very poor. In effect, pollution of the river is accentuated by urban and industrial water discharges.

On the hydrological plan, except Seybouse and Isser rivers, others present an intermittent flow, in summer these rivers are dried. However, it should be noted during flood period, flows pass of zero flow until flows exceeding 300 m^3/s.

This contrast of flash floods and extended low-water characterize Algerian semi-arid basins response, which make difficult their modelling and their forecasting.

The hydrologic characteristics of studied basins for 1986-1996 periods are presented in Table 1, and the basins are presented in Figure 1:

Table 1: Hydrological characteristics of studied basins

Characteristics of basins	units	Bouna Moussa	Isser	Safsaf	Seybouse
Area	km²	575	3615	345	4955
River length	km	55	114	18	225
Mean precipitation	mm	748	636	602	615
Mean annual Runoff	m^3/s	3.49	5.13	1.63	11.5
Standard deviation of runoff	m^3/s	14.02	19.37	7.11	34.8
Max runoff	m^3/s	270.5	321.87	124	512.0
Min runoff	m^3/s	0.1	0.5	0.	0.7

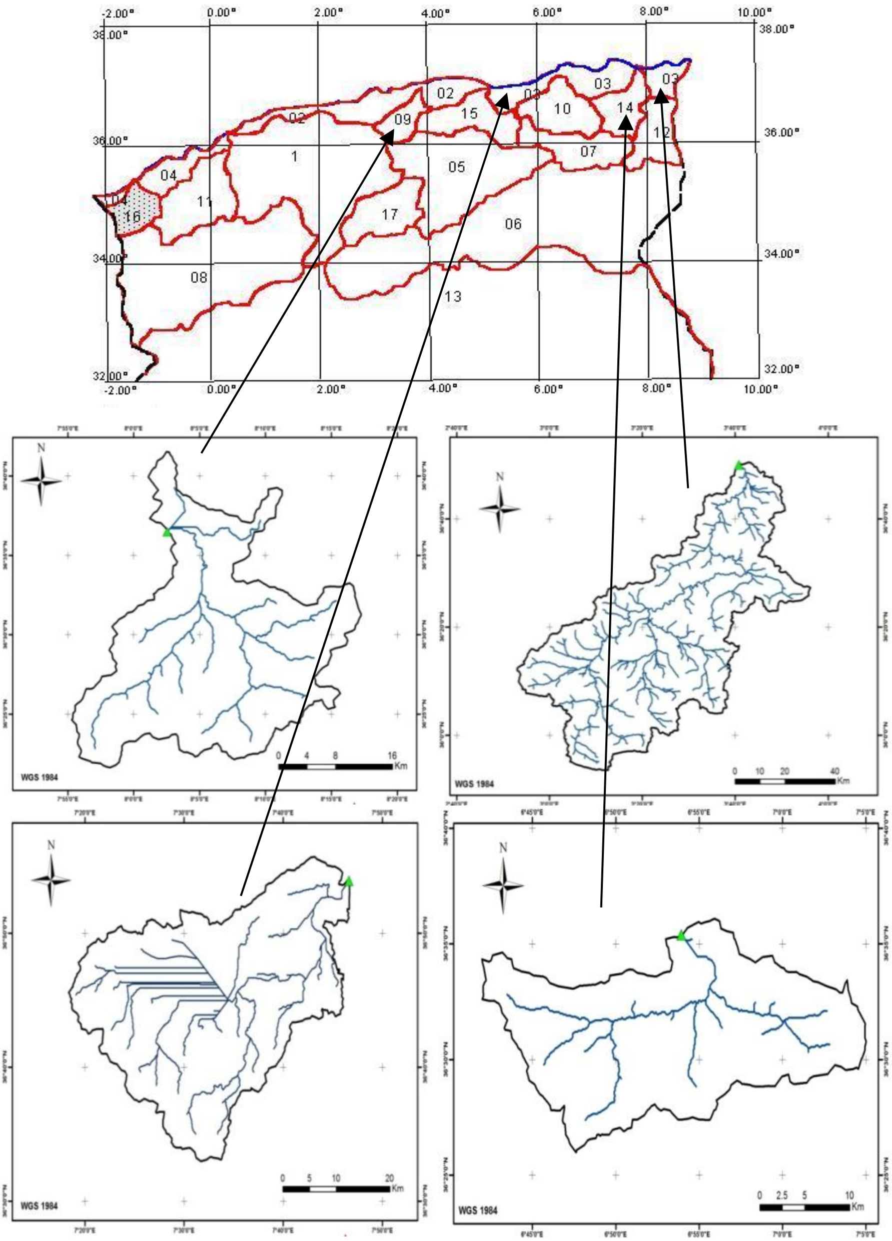

Figure 1: Algerian Watersheds studied: a) Bouna Moussa basin, b) Isser basin, c) Safsaf basin, d) Seybouse basin

METHODS

Description of the models

Hydrological literature includes an important number of rainfall-runoff models emerged from various researches. After testing from over ten daily rainfall-runoff models (ABC, CREC, GR3J-6J, HBV, Ihacres, NAM, Sacramento, Tank, Topmodel, Xinanjiang…), we retained four conceptual models that have particularity to require only the observed of rainfall, flows and potential evapotranspiration (or temperatures) as input data to models. The modules which are not involved in the case of our climate such as the snow module have been ignored. The models studied in this work are detailed as follow:

The GR4J model: Developed in France, this model is the last modified version of the GR4J model (Makhlouf 1994) and then improved (Perrin 2000). Many modifications were introduced to the model particularly the first store of model. The version of GR4J model used in this paper is that developed by Perrin *et al.* (2003) as showed in figure 2:

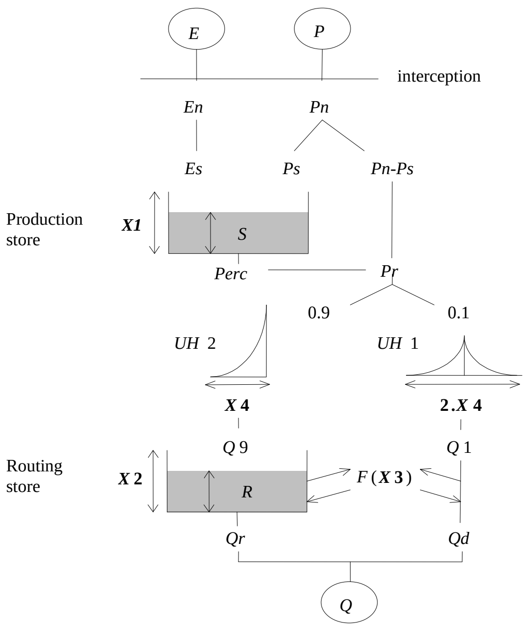

Figure 2: Scheme of GR4J model.

This model has the distinction of introduction of two unit hydrographs for routing store: the first unit hydrograph (UH1) to give a direct runoff from a part (10%) of effective runoff. The other part, (90%) which reaches the routing store through unit routing store through the second unit hydrograph (HU2) with base time $X4$. In the GR4J model one of the four calibrated parameters is meant specifically to account for intercatchment groundwater flows "F", calculated as follows:

$$F = X2.\left(\frac{R}{X3}\right)^{\frac{7}{2}}$$

where "R" is the current level of the routing reservoir, "$X2$", "$X3$" are the parameters of the models: *X2* its "reference" capacity and *X3* the water exchange coefficient. $X3$ can be either positive in case of water imports, negative for water exports or zero when there is no water exchange.

Alternatively, we have tested GR6J model (Pushpalatha, 2013), with six parameters: the five parameter "X5" is a dimensionless threshold parameter and It allows a change in the direction of the groundwater exchange, the sixth parameter "X6" represents time constant of exponential store. However, the results obtained by GR6J model are not better than those of GR4J model.

IHACRES Model: Acronym for «Identification of unit Hydrographs And Component flows from Rainfall Evaporation and Stream-flow data» initially developed in Australia (Jackeman *et al.* 1990), and has undergone many modifications. This model was tested on a wider range of basins, particularly on semi-arid basins. The IHACRES model comprises essentially two parts: (a) a component that divides rainfall into effective rainfall and the remainder, which is assumed to be lost by evapotranspiration (b) and a linear transfer function (or unit hydrograph) component that transforms effective rainfall to streamflow.

In this paper, after many versions trials, we used the last modified and called IHACRES_cmd (Croke and Jackeman 2004):

In this IHACRES model version, effective rainfall is calculated from drainage equation relatively complex which can adopt many forms f(M):

$$\frac{dU}{dP} = 1 - f(M)$$

U, P are respectively the effective rainfall and the observed rainfall, M represents catchment moisture deficit (CMD). Four parameters (d,b,m,f) are necessary to quantify CMD module, in addition to two others parameters (p et e) governing evapotranspiration and correction of rainfall. The linear routing module translates effective rainfall into streamflow by routing it through two parallel, linear stores.

Total streamflow (*Qsim)* is the sum of quickflow and slowflow:

$$Qsim(t)= Qq(t)+ Qs(t)$$

Mordor Model: Mordor model is a conceptual rainfall-runoff model developed and intensively used by EDF for operational hydrology in different contexts such as flood forecasting (Paquet 2004). In this research, we tested the modified version with six parameters (Mathevet 2005), in which the runoff are propagated with unit hydrograph similar the one of GR4J (SH2), this version was adapted on daily time scale. In this paper, the groundwater reservoir capacity (Z) is not fixed, then became seventh parameter "X7", is therefore Mordor7.

SMARG Model: The Soil Moisture Accounting and Routing model "SMAR" was introduced by O'Connell *et al.* (1970) its water-balance component being based on the 'layers Water Balance Model', it preserves the balance between the rainfall, the evaporation, the generated runoff and the changes in the various elements (layers) of soil moisture storage. The version of SMAR model used in the present study (called SMARG), is that which incorporates some modifications by Liang (1992): r_1, r_2, r_3 are the simulated runoff by each reservoir as detailed in figure 3:

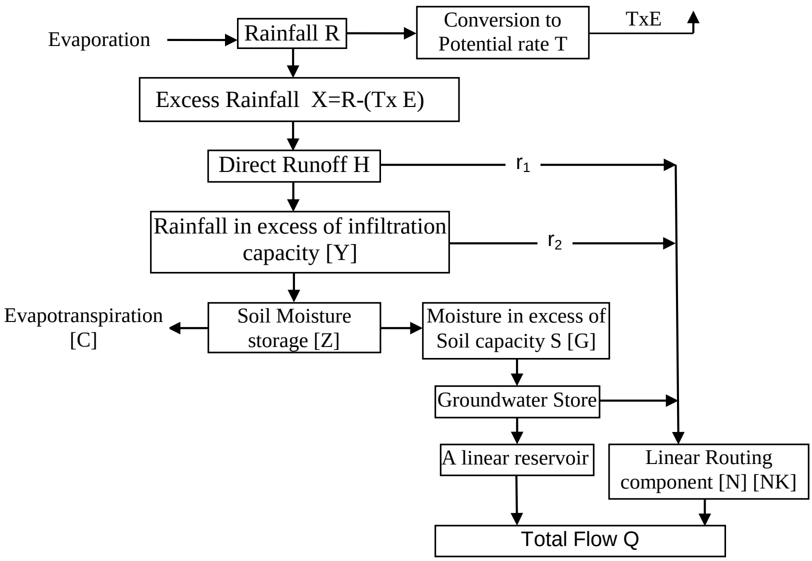

Figure 3: Structure of SMARG model.

Models calibration and data used

Rainfall-runoff models include (unknown) parameters expressing various hydrological factors intervening in flows generation. These models must therefore be adjusted to the observed flows during the calibration period until the error between observed and simulated flows becomes minimal. To bring to light climatic conditions variations, the rainfall-runoff models performances are then checked during another period which is the one of validation or of the test.

Models assessment

As quoted in the previous paragraph, the calibration is to aim at reducing error between the observed and simulated flows. We therefore introduce performance criteria which will allow appreciating the simulation error. Several criteria, generally numerical have been used by hydrologists. In our case, we based on the most used criterion namely the Nash efficiency (Nash and Sutcliffe 1971), the NSE which is an adimensional criterion:

$$NSE(\%) = \left(1 - \frac{\sum_{i=1}^{n} (Q_{i_{obs}} - Q_{i_{sim}})^2}{\sum_{i=1}^{n} (Q_{i_{obs}} - Q_{moy})^2} \right).100$$

Where Q_{sim} of the ith element is the simulated runoff in time and Q_{obs} is the observed runoff at the same point in time, Q_{moy} is average of observed runoff, n is the size of the sample, and this criterion is generally simple to be appreciated compared to others criteria such as the squared error for instance, which is greatly influenced by variance of simulated series. Appreciations of model according to NSE values are given by Table 2 (Rakem, 1999):

Table 2: Evaluation of models according to Nash-Sutcliffe efficiency (NSE)

NSE (%)	Appreciation
NSE <65	poor
65≤ NSE ≤ 70	insufficient
70≤ NSE ≤ 80	Average
80≤ NSE ≤ 90	good
NSE > 90	Excellent

In this work, the average flows will be that of all observed runoff, rather than using average of each period, in order to avoid any discrepancies between both periods calibration and test, because the NSE criterion is heavily dependent on average values used.

This comparison by NSE criterion is a global assessment, and does not allow measuring the simulation accuracy of certain flows, such as extreme flows. In our case, we tested another flood simulation index (Ic) calculated as follows (Benkaci, 2006):

$$I_c = \frac{QFsim}{QFobs}$$

where *QFsim* is the simulated discharge in the flood event (maximum simulated runoff) and *QFobs* is the maximum observed discharge. This index based on the maximal flow ratio simulated to that observed must be equal to one (1), it enables to better characterising the flood simulation.

Parameters estimation of models

It is a matter of introducing an algorithm which allows finding the best parameters reducing error between simulated and observed flows; it is therefore an optimisation method. In our case, given the high number of certain models to be optimised, the SCE-UA method (Duan *et al.* 1993) was used for its robustness. In effect, several authors (Franchini *et al.* 1998) tested this method on different models and have confirmed its performance and its robustness even with a high number of parameters to be optimised.

SCE-UA algorithm is a global optimisation method, in the sense that they constitute a parallel search of the search space by using a population of potential solutions. This capability of such techniques for effective "exploration" of the search space makes them less probable to get trapped into local minima.

In essence, the SCE-UA begins with an "initial population" of points sampled randomly from the feasible space. The population is partitioned into one or more complexes, each containing a fixed number of points. Each complex evolves based on a statistical "reproduction" process that uses the "simplex" geometric shape to direct the search in the correct direction. As the search progresses, the entire population tends to converge toward the neighbourhood of the global optimum, provided the initial population size is sufficiently large.

Data used for calibration and testing the models

Once calibration has been conducted to estimate the best parameters of the models, the outcome needs to be verified to determine if the results provide adequate information for answering the questions that face decision-makers. Thus with a view to making interpretation of the results of such models easier, the calibration and test period time are similar, and this for a better comparison between these two periods (Table 3), the mean of observed flow ($\bar{Q}$) for each period will also presented:

Table 3: Calibration and test periods used for the models

Basin	**B.Moussa**	**Isser**	**Safsaf**	**Seybouse**
Calibration	1986/1988	1991/1993	1991/1993	1991/1992
$\bar{Q}$ (m^3/s)	4.52	4.82	1.57	13.31
Test	1989/1991	1994/1996	1994/1996	1993/1994
$\bar{Q}$ (m^3/s)	2.47	6.88	1.70	9.55

RESULTS AND DISCUSSIONS

The models were employed to analyze the rainfall-runoff relationship in semi-arid context. For models results and in order to compare the performance for each model, we present the Nash-efficiency values NSE (in %), flood reproduction index (I_c), for the two periods: calibration (in Table 4) and test of models (in Table 5).

Table 4: Models results (Calibration period)

Basins	**B.Moussa**		**Isser**		**Safsaf**		**Seybouse**	
Criteria	NSE (%)	I_c	NSE (%)	I_c	NSE (%)	I_c	NSE (%)	I_c
GR4J	74.0	0.58	75.7	0.92	87.0	1.12	73.0	0.88
Ihacres	42.6	0.34	20.8	0.20	63.8	.60	28.90	0.37
Mordor	71.8	0.63	68.8	0.71	88.3	0.98	51.6	0.78
SMARG	64.1	0.55	32.1	0.35	84.0	0.94	44.1	0.44

Table 5: Models results (Test period)

Basins	**B.Moussa**		**Isser**		**Safsaf**		**Seybouse**	
Criteria	NSE (%)	I_c	NSE (%)	I_c	NSE (%)	I_c	NSE (%)	I_c
GR4J	70.6	0.57	67.7	1.3	71.0	0.75	68.5	1.23
Ihacres	30.0	0.60	37.1	0.3	32.3	0.20	28.9	0.20
Mordor	74.0	0.71	66.7	0.53	73.9	0.65	67.0	0.72
SMARG	65.1	0.98	57.0	0.54	71.5	0.62	40.1	0.35

Comparison between calibration and test periods

The results of the models set out in Tables 4 and 5, show us variable performances between models and for each basin. We see that for calibration period, all four models give best results; Nash efficiency (NSE) values are generally greater than those observed during the test period. As for Saf-Saf‘s basin, the models (except Ihacres) have produced appreciable results, and even the best, Nash efficiency exceeds 80% which is respectively 87% and 88% as for models Mordor, GR4J.The same case is for Bouna-Moussa and Isser’s basins but with a lesser Nash efficiency, its average is of 63%. In calibration period, GR4J model finds its superiority (Figures 4a and 4b):

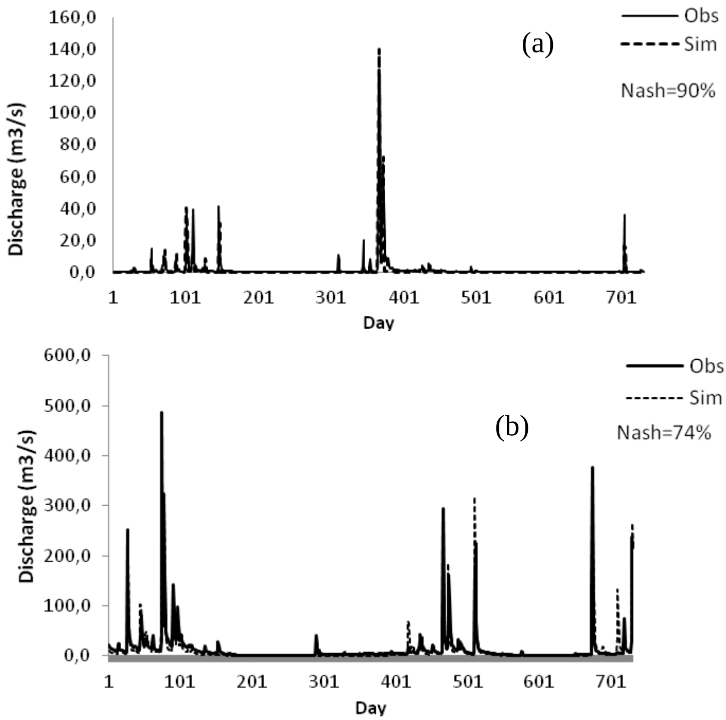

Figure 4: GR4J Simulation: (a) Safsaf basin, (b) Seybouse basin (93/94years)

Average of NSE is more than 77%, compared with others models with high number parameters (SMARG), the latter give average Nash efficiency of 56%, which is very poor for a rainfall-runoff model.

This performance decrease, that is similar for IHACRES_cmd model case. By comparing the two periods, we note that the efficiency decrease of models is relatively significant, but remains less for GR4J model, which has after all kept a simulation level relatively close to an average of Nash efficiency at 70%. For other models, we note insufficient performances.

Models Performances

By analysing the models results showed in tables 4 and 5, we can see differences of simulations and variable performances:

As for IHACRES_cmd models, we note very limited performances, and this regardless the periods or the tested basins, the NSE values are so poor, and simulated peak flow are widely underestimated (Figure 5). With nine parameters, including five for production function, IHACRES model is considered less efficient particularly for heterogeneous basins. As for model SMARG, the simulated flows are relatively better, but becomes less efficient for the great basins (case of Isser and Seybouse basins). In this model, the linear routing store of surface runoff has fallen sharply the model performance. In addition, by analysing low flows, we note a rapid drying out of the soil, in effect, base flows are largely underestimated. For Mordor model, with seven parameters, this model has correctly simulated flows of certain basins (Safsaf and Bouna Moussa), but facing a decline for heterogeneous basins such as Isser and Seybouse particularly on test period.

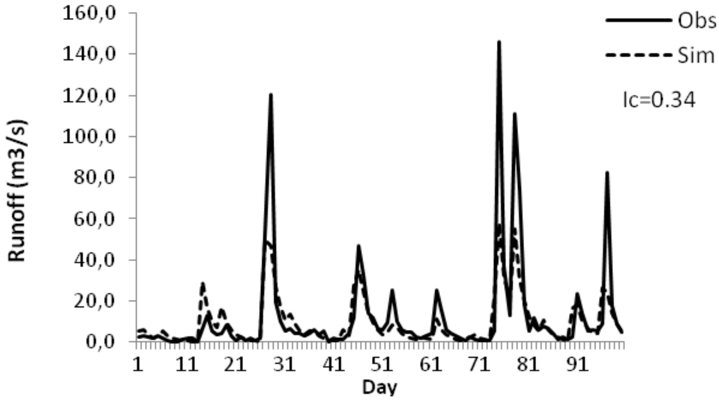

Figure 5: Underestimation of simulated peak flow for Ihacres model (Bouna Moussa Basin- 1988 year)

For GR4J model, results are more performing. We obtained the best simulations on the whole of the basins, whether in calibration period or in test, then is regarded as the best model.

Concerning the peak flow, even trends are correctly reproduced; we note a bad reproduction of the maximal flows.

For the whole of models, I_c index is generally less than 0.8 in calibration period, and in certain case below 0.5 on test period, which may be interpreted as reject indicator of the models. However, the GR4J model simulates rather correctly maximal flows in calibration periods; index I_c is on average of 0.95, but remains relatively insufficient in test period. In response to a flood event, the majority of models tested (except GR4J) underestimate therefore peak flows, like IHACRES and SMARG models.

The optimised parameters of the models are summarized in Table 6.

Table 6: Mean of optimized parameter's models

GR4J	IHACRES	Mordor	SMARG
X(1)=233.25 X(2)=53.31	d=137	X(1)=0.78 X(2)=67.3	X(1)=0.53 X(2)=0.14
X(3)=-18.32	b=125	X(3)=563	X(3)=245
	e=0.47		
X(4)=1.71	f=0.60	X(4)=1.29 X(5)=123.0	X(4)=0.98 X(5)=0.72
	m=0.46	X(6)=161.9	X(6)=200.8
	p=0.48	X(7)=85.0	X(7)=5.56 X(8)=3.5
	αq=0.11		X(9)=2.14
	αs=0.66		
	vq=0.29		

Great and heterogeneous basins case

To better appreciate the rainfall-runoff models performances, we have tested them on great and irregular basins (Isser and Seybouse basins) whose area exceeds 3000 km^2. In the first approach where we have taken into consideration only one rainfall station relatively representative of the basin, then we obtain bad flows simulation. In effect, concerning the case of river Seybouse's basin characterised by a variable and a significant heterogeneity of the flows, the simulation results are average in calibration phase and even poor in test period for the whole of the models, average of Nash efficiency is only of 46% for the two periods. In this case, the rainfall-runoff modelling using lumped approach is limited for this kind of basins, we cannot expect to the performing results.

Other alternatives consisting to modelling the basin by taking into consideration the hydrological variability: discretization in sub-basins according to their sizes (distributed or semi-global approach) should be tested, this to better characterise the local hydrological phenomena, or to take into consideration several rainfall stations, to better represent variability and dispersion of rainfall on watershed-scale.

Intermittent basins case

Influenced by the semi-arid Mediterranean regime, the majority of Algerian basins are characterised by an intermittent flow (Safsaf and Bouna Moussa basins cases), due to the low-water of summer period. In this case, by comparing graphically and analytically observed and simulated flows, we noted that some models calculate correctly average flows, by contrast, base flows, are largely either underestimated (example of SMARG model) or then overestimated, thus the use of these rainfall runoff models for base flow prediction will be a wrong procedure. However, we should note that observed base flows data are generally subjects to measure and sampling errors.

What validity or practical feature can be provided to these models?

In this paper, we have analysed several rainfall-runoff models deemed for their robustness and their simulation performances, which we have summarized in four models. Theoretically, these models can in certain cases, simulating flows or reproduce the hydrological regime of a watershed. However, from a practical perspective, far of all theoretical approach, it should be noted that most of the models tested (except GR4J) present a significant difference between observed and simulated flows particularly during floods. In this case, the transposition of these models and their application in flood control or in flood routing of dams can cause problem since most of the rainfall-runoff models underestimate maximal flows. An effort in modification of model for peak flood simulation must be brought to correct the probable differences and reduce simulation error of maximal flows.

Considering base flow, exploitation of a rainfall-runoff model in the case of base flow forecast is helpful for water resources management of a dam. However, this procedure cannot be carried out unless base flows are in turn correctly simulated.

Notwithstanding a considerable effort of rainfall-runoff models simulation and progress of optimisation methods of these models, and considering the persistent problems at flood and peak flow simulation, we cannot say that the rainfall-runoff modelling tasks are fulfilled.

CONCLUSION

The rainfall-runoff relationship is a complex process highly non linear, and depends of several variables. Concerning the daily models, the hydrological literature comprises a high number of models.

In this research, we have tested four rainfall-runoff models on Algerian basins, trying establishing an actual balance sheet on their performances particularly in the framework of extreme flows simulation.

In a first observation, it appeared that the most performing results are obtained by a model with low number of parameters (GR4J and Mordor) rather than complex models with several parameters (more than nine), which reminds that the complexity of a model is not a sign of good. Objectively, we noted performances fairly satisfactory for some basins. However, viewed the whole results, most of the models (particularly with linear routing store) present a simulation decline in the test period, which stipulates that the majority of rainfall-runoff models are weak facing climatic or hydrological changes. Facing a rainy event, these models present a bad reproduction of peak flows, and “react badly” in flash floods situation. In this case, a corrective coefficient should be taken into account for flood forecasting. Paradoxically, in semi-arid areas, floods are the most delicate part to be simulated rather than low water flows.

The results relatively correct obtained by GR4J model, for the whole basins, and taking into consideration two comparison criteria, encourage us to use this model, however, an effort in simulation of peak flood should be a subject of extensive researches to improve this model. Viewed the different climatic trends, and for a best simulation, the hydrologist should select and test several rainfall-runoff models to validate the appropriate model.

In this study, we have highlighted that some basins are difficult to be (or no) modelisable by the lumped approach, from their size and/or their homogeneity. Other alternatives of modelling by discretization or by semi-global approach should be tested, and these to better understand local hydrological phenomena of these basins.

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