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Modelling of the rain–flow by hydrological modelling software system HEC-HMS – watershed's case of wadi Cheliff-Ghrib, Algeria

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Abstract

The purpose of this study is to make a hydrologic modelling type of rain–flow on watershed of wadi Cheliff-Ghrib, by means of HEC-HMS model. Afterwards, this model is used to predict hydrologic response of the basin to the climate changes scenarios and land use. The model calibration was made in two phases; the first one is to select events, formalism of transfer function and appropriate NRCS downpour. The second is to deduce optimised parameters set which is used in validation. By using optimised parameters set, we were able to predict impact of quantiles downpours, changes in land use due to urbanisation, deforestation and reforestation on the peak flow and on runoff volume. Towards the end, we reconfirmed that influence of land use decreases for extreme storms.

Key words: *Algeria, HEC-HMS – watershed, modelling, rain–flow, wadi Cheliff-Ghrib*

INTRODUCTION

In hydrology, a simplified mathematical representation of all or in part of hydrological cycle process is essential. Thus hydrological concepts are expressed in mathematical language to represent the corresponding behaviour observed in the nature. For the user, interest of a model, resides in it capacity to provide a "satisfactory" response to the asked questions about modelled object. Nowadays there are different models types: from physical model and empirical model, from distributed and overall, and each type expresses some way to design the hydrological cycle. [MOUELHI 2003]. A classification may be done on some differentiating keys according to criteria set out by CLARKE [1973] and AMBROISE [1998].

The decision-support tools can help in the best development options in order to allow human to check water, soil and potentials. A solution and reliable approach to this challenge is use of appropriate hydrological models for efficient management of watersheds and ecosystems [YENER *et al.* 2012], hydrological modelling is a tool generally used to estimate the hydrological response of the basin due to rainfall. It forecasts hydrological response at various management practices of watershed and have better impacts understanding of these practices [KADAM 2011].

It is obvious through extended review of literature that studies on comparative assessment models of watershed for hydrological simulations are quite limited in developing countries including India [KUMAR, BHATTACHARYA 2011]. This explains necessity to

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undertake study of hydrological simulation by developing an appropriate model to the watershed. The hydrological modelling system of hydrological centre of technology (HEC-HMS) is a model widely used to simulate process of run-off and rainfall.

Several studies have used model of HEC-HMS in different regions (soils and different climatic conditions). Chu and Steinman [2009] have used HEC-HMS model for event and continuous hydrological modeling in watershed of Mona lack in western Michigan. The HEC-HMS model has also been used to simulate rainfall-runoff process with geo-informatics and atmospheric models for flood forecasting and early detections in different regions of the world [Ali *et al.* 2011; Arekhi 2012; Arekhi *et al.* 2011; Dzubakova 2010; Halwatura, Najjim 2013; Hu *et al.* 2006; Knebl *et al.* 2005; Majidi, Shahedi 2012; Majidi, Vagharfard 2013; McColl, Aggett 2006; Panigrahi 2013, Yener *et al.* 2012; Yusop *et al.* 2007]. Also, it has been used for management of watersheds in different regions of India [Bhatt *et al.* 2012; Kadam 2011; Choudhari *et al.* 2014; Kumar, Bhattacharya 2011]. The model has been found précis in response's basin in time and space at event scale and for a longue and continuous period as well as simulating various scenarios in flood forecasting and early detections. Al-Ahmadi [2005] made a rainfall-runoff by HEC-HMS, GIS and RS in three sub-basins in south-west of Saudi Arabia.

He carried out the model with automatic method of calibration and obtained acceptable results Shaghaeghi Fallah [2001] applied the model of HEC-HMS to simulate runoff of river into the watershed of Mohammadabad (located to the North of Iran). Results of simulation were reliable and valid compared with observations' data. The goal of the present study is to simulate rainfall-runoff process through hydrological model of HEC-HMS in watershed of Cheliff-Ghrib Algeria, in order to verify its feasibility in this mountainous area well known by its spatio-temporal heterogeneity. Furthermore, we will try to predict the future hydrological response of this basin, due to scenarios of climatic change by quantile rain showers, and other caused by land use changes and types of soil, in order to make decision makers aware of anthropogenic actions, notably, urban development and excessive deforestation at level of Cheliff-Ghrib on hydrological regime.

STUDY AREA

The watershed of wadi Cheliff-Ghrib is a part of wadi Cheliff's basin (Fig. 1 and 2). It is located at 100 km south-west of Algiers, between, 2°25' and 3°45' of east longitude and between 35°45' and 36°00' of nord altitude, of average altitude of 895 m. It drains an area of 1.390,32 km^2. Wadi Cheliff Ghrib flows for a distance of over 79.9 km following orientation south-east to west of watershed, the landform reaches an altitude of 1.500 m, while the lowest point is at the outlet with altitude of 400 m. The watershed of wadi Cheliff-Ghrib is elongated in shape in the axis of the main stream. The wadi is tributary of wadi Cheliff. The outlet is about 20 km on the south-west of Medea wilaya (Fig. 1 and 2).

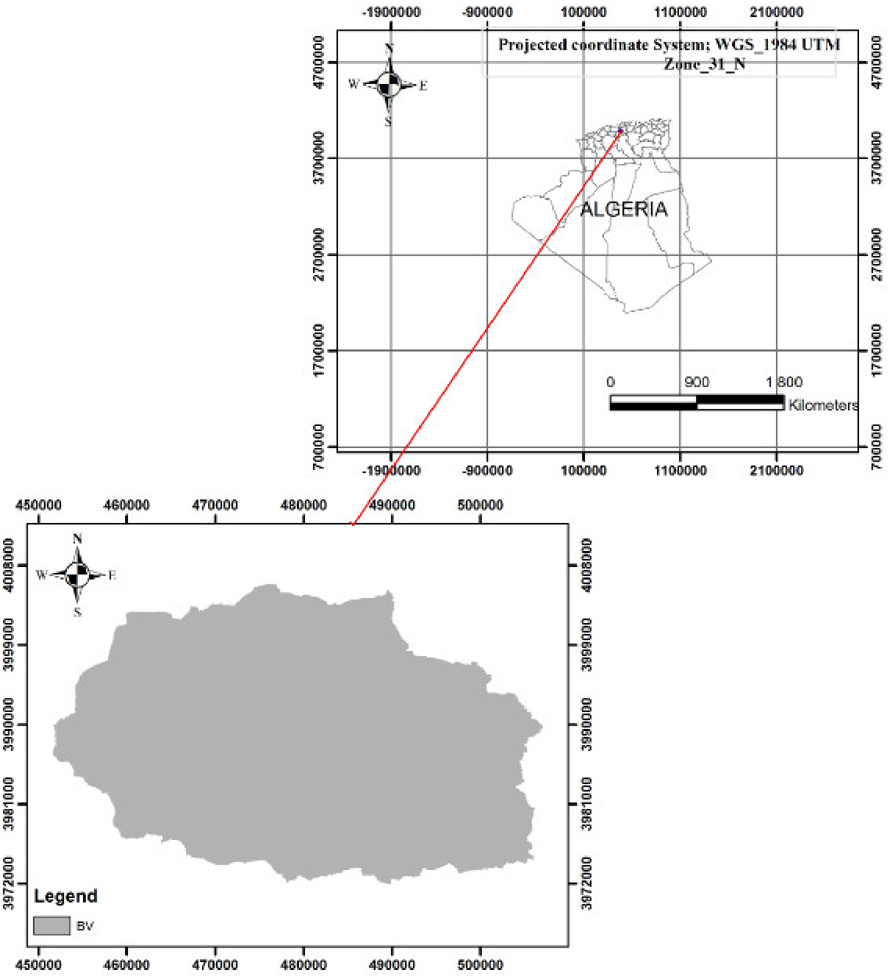


Fig. 1. Location of basin study (wadi Cheliff-Ghrib); source: own elaboration

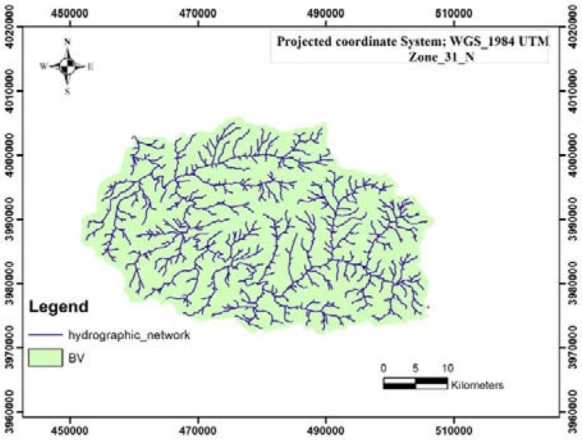


Fig. 2. Hydrographic network map of wadi Cheliff-Ghrib's basin; source: own elaboration

HEC-HMS HYDROLOGICAL MODEL

HEC-HMS is hydrologic modeling software developed by the US Army Corps of Engineers- Hydrologic Engineering Center (HEC) [FELDMAN (ed.) 2000]. It is the physically based and conceptual semi distributed model designed to simulate the rainfall-runoff processes in a wide range of geographic areas such as large river basin water supply and flood hydrology to small urban and natural watershed runoff. The system encompasses losses, runoff transform, open channel routing, and analysis of meteorological data, rainfall-runoff simulation and parameter estimation. HEC-HMS uses separate models to represent each component of the runoff process, including models that compute runoff volume, models of direct runoff, and models of base flow. Each model run combines a basin model, meteorological model and control specifications with run options to obtain results.

Following methods were selected for each component of runoff process such as runoff depth, direct runoff, base-flow and channel routing in event based hydrological modeling. These methods are selected on the basis of applicability and limitations of each method, availability of data, suitability for same hydrologic condition, well established, stable, and widely acceptable, researcher recommendation etc.

INPUT DATA OF MODEL

Digital Elevation Model

Before undertaking any operation of a simulation file preparation HMS, it is essential to have at his disposal the DEM of the study area, where its role is fundamental in physical characterization and calculation of the parameters (Fig. 3).

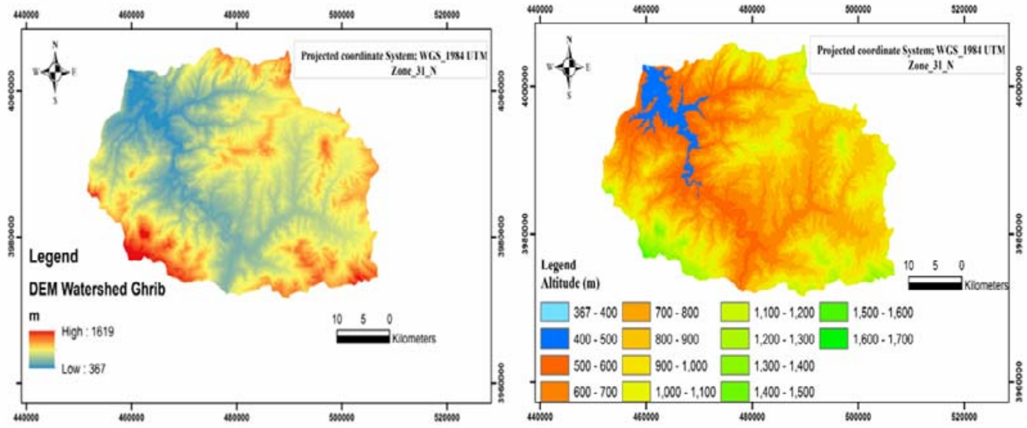


Fig. 3. Digital Elevation Model (DEM) and altitude map of Cheliff-Ghrib's watershed; source: own elaboration

Land use

Considering particular requirements of selected modular combination, specifically the NRCS CN method as production function, producing of land use map on the whole study area was an unavoidable way. However, information supposed found in this map should be authentic to the recognised by NRCS classification; consequently, we had to do connexions between classes of NRCS and information gathered from all identified bibliographic data dealing this part (Fig. 4).

The rain data

For each event, rain should be regarded in the form of rainfall height fell on the watershed during the day where this event occurred, of which we associate every time one of the four NRCS distributions [NRCS 1997]. In our case, we have been limited to period 06–09.03.1980, 18–21.04.1982, 08–12.03.1986, 23–25.09.1993 and 23–26.09.1994.

MODEL'S DEVELOPMENT

Before to begin calibration, we prepared all simulations files of the five events previously preselected, in taking into account the four rain showers of NRCS types and the two formalisms of transfer function to analyse the sensitivity of the model successively to rain showers types and to the formalisms. So, we have 40 simulation files (Fig. 5 and 6). For every simulation files, we will have the following data (Tab. 1).

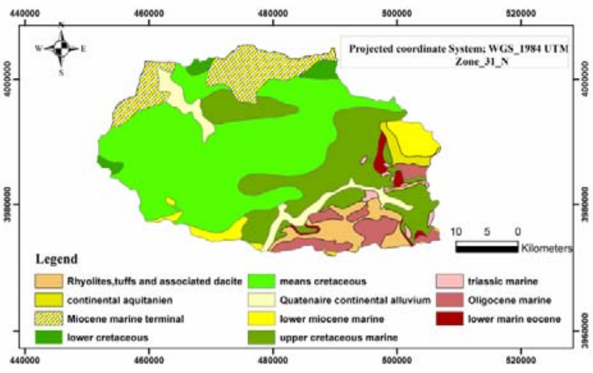


Fig. 4. Rock type map of watershed Cheliff-Ghrib; source: own elaboration

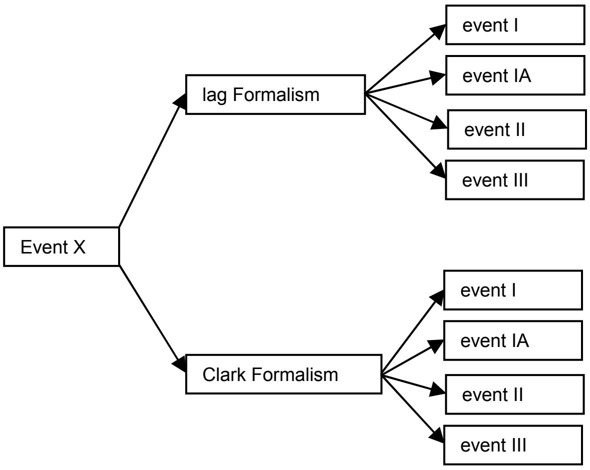
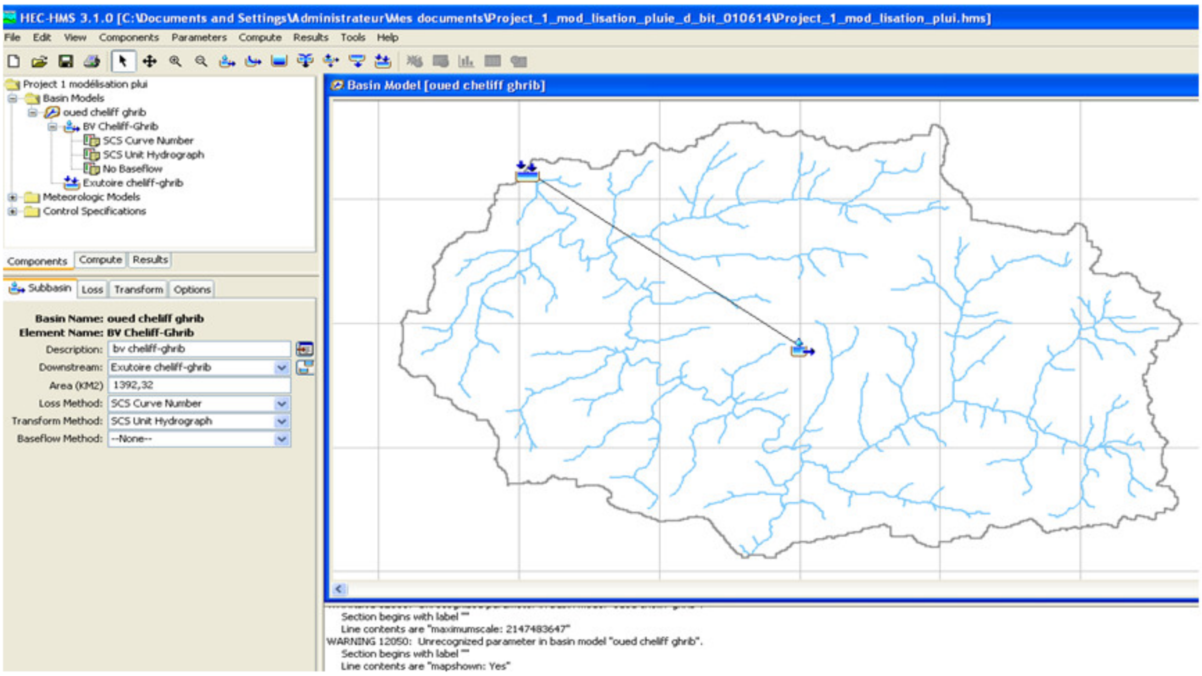


Fig. 5. Number of simulation files prepared for every event; source: own elaboration



Basin Name: oued cheliff ghrib
Element Name: BV Cheliff-Ghrib
Description: bv cheliff-ghrib
Downstream: Exutoire cheliff-ghrib
Area (KM2) 1392,32
Loss Method: SCS Curve Number
Transform Method: SCS Unit Hydrograph
Baseflow Method: --None--

```
   Section begins with label ""
   Line contents are "maximumscale: 2147483647"
WARNING 12050:  Unrecognized parameter in basin model "oued cheliff ghrib".
   Section begins with label ""
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```

Fig. 6. Software HEC-HMS interface; source: own study

Table 1. Inputs to be entered for each simulation file

Model's module		Input	Value	Unit
The basin		the surface	1390.32	km^2
Meteorological module		rain	event function	mm
		rain shower type	–	–
Module of function production	NRCS CN	initial abstraction	ni	mm
		curve number CN	72	–
		impervious percentage	10	–
Module of transfer function	NRCS	time lag T_{Lag}	476	min
	Clark	concentration time Ct	13.22	hours
		destocking coefficient ST	21.52	hours

Source: own study.

RESULTS AND DISCUSSION

RESULTS OF SIMULATION

The simulation results for both transfer functions NRCS CN and Clark are in Table 2 and 3.

Results of simulation for both functions of NRCS and Clark transfer are the following graphs (Fig. 7, 8).

MODEL CALIBRATION

In order to achieve optimising values of model parameters, calibration was made for the 40 simulation files using the objective function on peak flow.

Table 2. Simulation results: NRCS CN formalism

Event	Rain shower	Model parameters			Simulation results					
		NRCS CN			Qp, m^3·s^{-1}			V_r, mm		
		Ia	CN	Tlag	observed	simulated	difference %	observed	simulated	difference %
1980	1	1	72	476	197.14	276.4	28.67	8.56	11.73	27.02
	1A					228.9	13.87		11.73	27.02
	2					333.4	40.80		11.75	27.15
	3					337.3	41.55		11.75	27.15
1982	1	1	72	476	159.34	225.8	29.43	7.26	10.02	27.54
	1A					189.3	15.83		10.02	27.54
	2					274.3	41.90		10.02	27.54
	3					274.3	41.90		10.02	27.54
1986	1	1	72	476	351.0	186.5	46.87	45.03	8.29	81.59
	1A					85.8	75.55		8.25	81.59
	2					97.0	72.36		8.25	81.59
	3					98.5	71.94		8.25	81.59
1993	1	1	72	476	126.5	127.7	0.90	4.67	5.51	15.24
	1A					105.8	16.50		5.51	15.24
	2					154.2	17.96		5.51	15.24
	3					156.0	18.91		5.51	15.24
1994	1	1	72	476	126.5	131.6	3.90	5.63	5.87	4
	1A					110.3	12.81		5.87	4
	2					150.4	15.89		5.87	4
	3					159.9	20.90		5.87	4

Explanations: Qp = peak flow, V_r = runoff volume, CN = curve number, Tlag = time lag.
Source: own study.

Table 3. Simulation results: Clark formalism

Event	Rain shower	Simulation Results							V_r, mm		
		NRCS CN		Clark		Qp, m^3·s^{-1}					
		Ia	CN	*tc* h	*St* h	observed	simulated	difference %	observed	simulated	difference %
1980	1	1	72	13.22	21.52	197.14	128.9	34.61	8.56	11.28	24.11
	1A						122.9	37.65		11.48	25.44
	2						139.9	29.03		11.47	25.37
	3						141.3	28.32		11.47	25.37
1982	1	1	72	13.22	21.52	159.34	108.7	31.78	7.36	9.17	19.74
	1A						103.7	34.92		9.17	19.74
	2						117.3	26.38		9.16	19.65
	3						119.1	25.25		9.15	19.56
1986	1	1	72	13.22	21.52	351.0	89.8	74.42	45.03	8.25	81.62
	1A						85.8	75.56		8.25	81.62
	2						97.0	72.36		8.25	81.62
	3						98.5	71.94		8.25	81.62
1993	1	1	72	13.22	21.52	126.5	63.5	71.15	4.67	5.72	18.36
	1A						60.6	52.09		5.72	18.36
	2						68.6	45.77		5.72	18.36
	3						69.6	44.98		5.72	18.36
1994	1	1	72	13.22	21.52	126.5	59.8	52.72	5.63	4.03	28.42
	1A						57.0	54.94		4.04	28.42
	2						65.0	48.62		4.01	28.77
	3						63.5	49.80		5.72	1.60

Explanations: Qp, V, CN, Tlag as in Tab. 2, *tc* = concentration time, *St* = storage time.
Source: own study.

From calibration results, we can generally see that value of objective function; optimised values of parameters, peak flows and simulated volume vary all in function of the event, of the selected rain shower type and the chosen formalism for transfer function. Results of model calibration are found in the following graphs (Fig. 8).

In effect, by carefully searching results, we can clearly note that: in the case of NRCS formalism choice, the objective function is null for the four rain shower types of events 18–21.04.1982, 23–25.09. 1993 and 23–26.09.1994. For other events 06–09.03.1980 and 08–12.03.1986 objective function takes null values for rain showers 1.2 and 3 and values

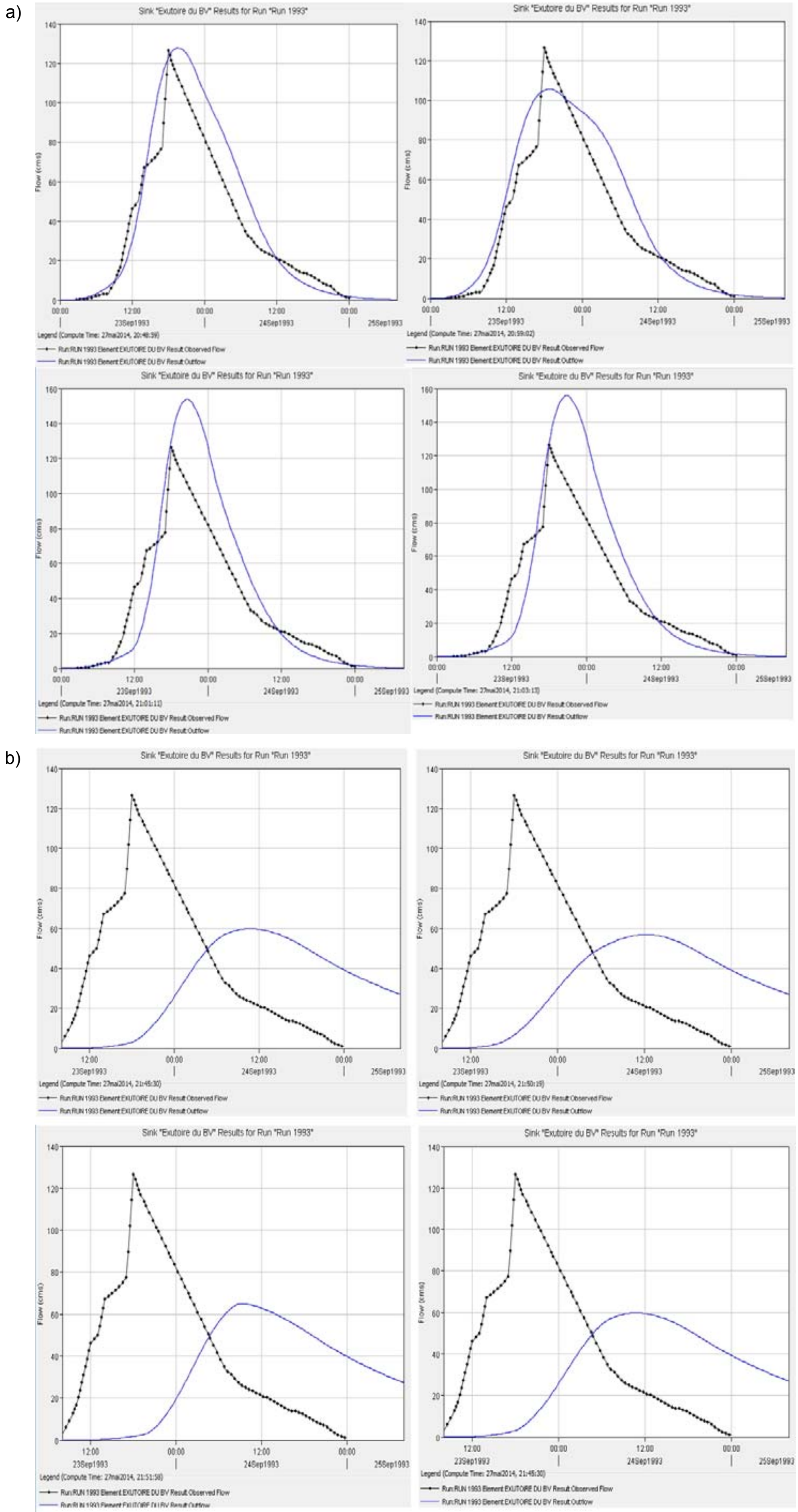

Fig. 7. Flood hydrographs of event 23–25.09.1993 with: a) NRCS transfer function b) Clark transfer function; source: own study

14.2 and 11.9 for rain showers type 1A. This finding is valid for peaks flows, where they are better recovered when using of rain showers 1.2, and 3. For simulated volumes, they are well estimated for event of 06–09.03.1980, 18–21.04.1982, 23–25.09.1993 and 23–26.09.1994 and are underestimated for event of 08–12.03.1986 and whatever is the rain shower type. Concerning optimised values of parameters, we note that these parameters change by passing from event to the other; and they are less variable within the same event. These parameters sets can serve to validate the model since they are close to events 23–25.09.1993 and 23–26.09.1994.

In the case of choice of Clark formalism, the objective function is null for the four rain showers types of all events. As for flood volumes, we note that problem of the excessive overestimate is still persisting, subject which is well understood because the transfer function has no effect on the flood volume, but it is rather on the movement of this volume that it intervenes.

According to this first calibration, we were able to highlight some conclusions which are going to allow us to limit simulation number from which we deduce the optimal parameter set, these conclusions are: the formalism of the unitary hydrograph of NRCS is much more adapted to our study context that of Clark, thus, research of optimal parameters values had to be concentrated in its results, detailed in Table 2.

By use simplified results presented in Table 4, we have made several approaches to reach the optimal parameters set, in this case:

- **method 1:** use of the average parameters values of the 5 events;
- **method 2:** use of the maximum parameters values of the 5 events;
- **method 3:** use of the minimum parameters values of the 5 events.

These approaches were carried out on the both rain shower types 1 and 2 in order to detect that one which allows, with its parameters set, to converge towards a model validation.

Rain shower type 1: the percentage difference between the peak flow observed and simulated varies of 0.74 (method 2, event 1980) until 56.83 (method 1. event 1982). As for efficiency on volume, it appears that it has a different behaviour according to the method and to the event, for instance it fell for event 1986 whichever the method, it increased for event 1993 and 1994. Generally, the problem of overestimating volumes still endures which require checking hypothesis stated previously.

Rain shower type 2: the validation results for the different methods are much the same to those of rain shower 1.

This first test of validation allowed qualifying the method of the average values as the one that gives the best results, this is justified in part of the fact that the model is closely linked to the surface state of the basin, namely that if we consider that land use of Cheliff-Ghrib varies intensely on short periods of time, thus optimal parameter sets of events will never be stable since every one of them occurs during a different surface state. However, we cannot talk about a model validation basing on this first test on the one hand because we have not enough events in each year, and on the other hand, the lack of efficiency observed during validation cannot be linked only to the change in land use, but we also need to check the above hypothesis quoted at the beginning of this part, notably:

- choice of the objective function,
- percentage estimation of impervious,
- the daily rainfall distribution.

MODEL VALIDATION

By applying parameter set defined in Table 5 to events, we reach the following results:

This optimised parameter set is composed of accepted and realistic parameters values such as case of concentration time equal with which we have calculated by method of Giandothi, and CN value very close of that estimated by land use map and soil type. Graphs of flood hydrograph for different events are as follow (Fig. 9).

The Table 5 shows that with the new optimised parameter set, model was able to reproduce the peak flow in a fair way for event 23–26.09.1994, as for the rest, we realize a flow underestimation for event of 06–09.03.1980 and for 08–12.03.1986 and overestimation for event 18–21.04.1982.

Simulated volumes for their part, they vary between 26.74% for event 18–21.04.1982 and 81.79% for 08–12.03.1986.

The overestimated volumes are essentially caused by use of project NRCS rain showers in place of acquired temporal distributions from rainfall recorders as we have demonstrated it in the calibration part.

In order to quantify level of achievement of these different objectives, the performance criterion used is the NASH one [NASH SUTCLIFE 1970]. This latter one gives an overall appreciation of flood reconstitution.

Criterion formula of NASH is as follows:

$$NASH = 1 - \frac{\sum (Q_{sim} - Q_{obs})^2}{\sum (Q_{obs} - \bar{Q}_{obs})^2} \qquad (1)$$

This criterion is true for 100% for a perfect reconstitution of the flood and is cancelled for model "called at every hour", the computed flow is equal to average flow of the flood. So, it shows that if simulation which comes through the model is better than estimation which would give an average flow throughout the calibration period.

As it uses squared deviations, it is sensitive to the reconstitution of heavy flows. We consider as bad a NASH below 80%. Validation criterion of NASH model = 88%. Statistically, the NASH criterion shows that the model is validated.

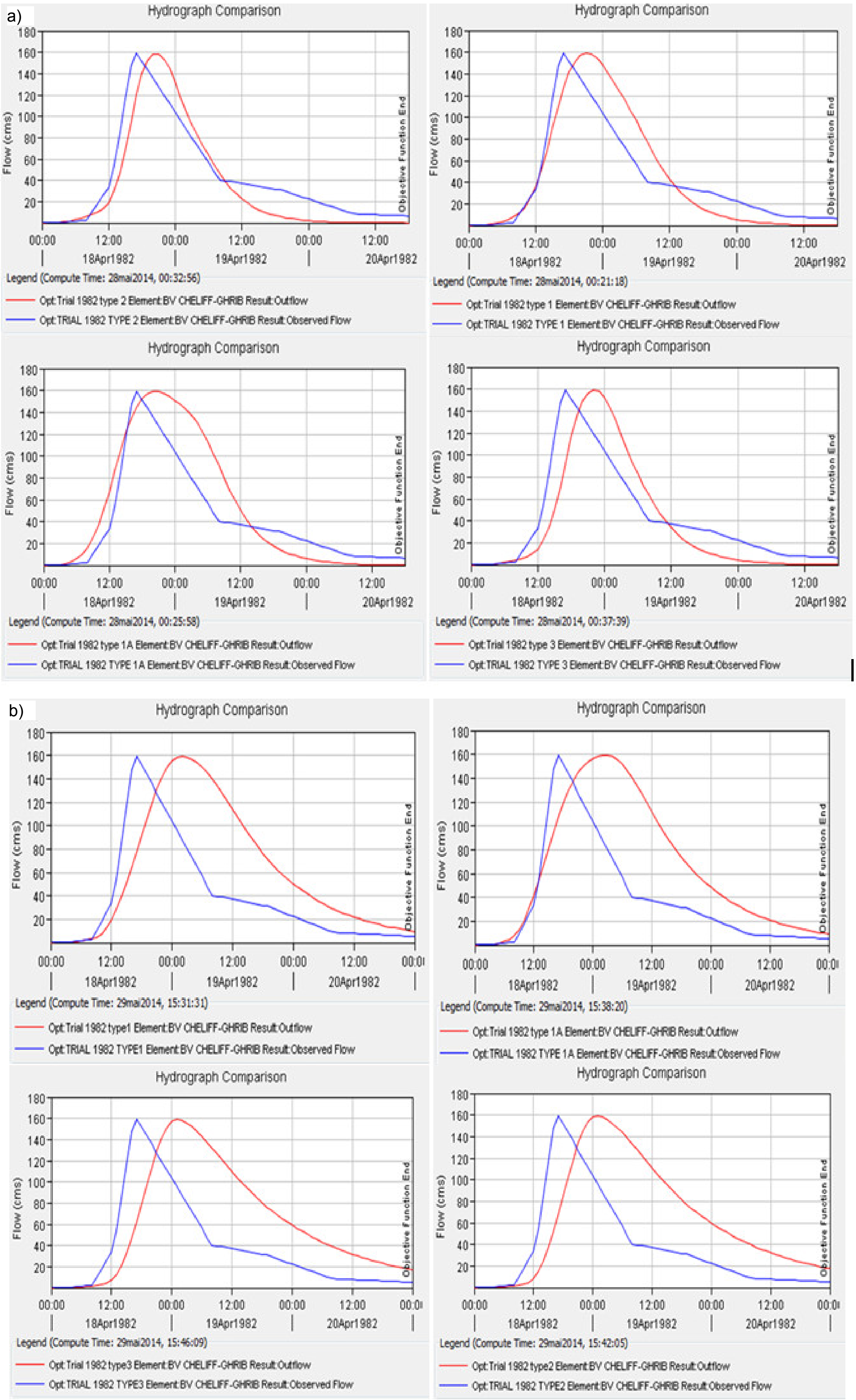

Fig. 8. Flood hydrographs of event 18–21.04.1982 after calibration by: a) NRCS transfer function, b) Clark transfer function; source: own study

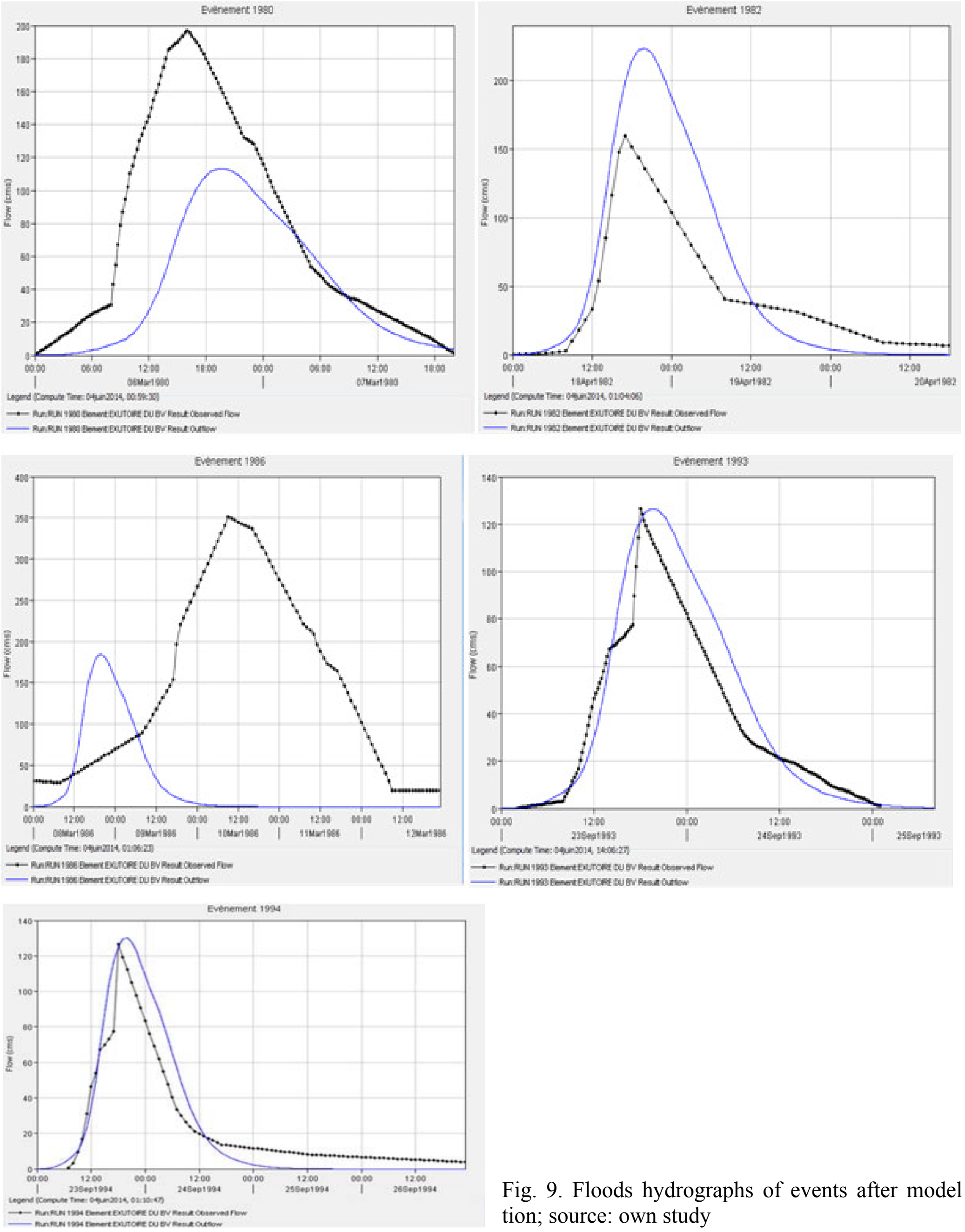

Fig. 9. Floods hydrographs of events after model validation; source: own study

Table 4. Simplified results of Lag's formalism use

Rain shower	Event	Calibrated parameters			Calibration results				Function Obj %
		NRCS CN			Qp, m^3·s^{-1}		V, mm		
		Ia	CN	Tlag	observed	simulated	observed	simulated	
1	1980	1	85.77	399.68	197.1	197.1	8.56	7.58	0
	1982	1	60.03	547.40	159.3	158.8	7.26	7.64	0
	1986	1	89.74	457.15	351.0	354.2	45.03	14.97	0
	1993	1	71.56	476.00	126.5	126.4	4.67	5.45	0
	1994	1	70.56	478.18	126.5	126.7	5.63	5.67	0
2	1980	1	80.10	403.21	197.1	197.2	8.56	6.18	0
	1982	1	47.11	481.38	159.3	158.7	7.26	6.02	0
	1986	1	84.05	422.69	351.0	350.5	45.03	11.91	0
	1993	1	68.04	547.07	126.5	126.5	4.67	5.02	0
	1994	1	62.98	483.91	126.5	126.5	5.63	4.81	0

Explanations: Qp, V, CN, Tlag as in Tab. 2.
Source: own study.

Table 5. Optimised parameter set used for HEC-HMS model validation on Cheliff-Ghrib's basin

Parameters	Ia mm	CN	T_{lag}	Imperviousness	Rain shower type
Optimised values	1	71.56	476	10	1

Explanations: CN, Tlag as in Tab. 2.
Source: own study.

Table 6. Results of model validation

Event	*Qp*, $m^3 \cdot s^{-1}$		Difference %	*V*, mm		Difference %
	observed	simulated		observed	simulated	
06–09.03.1980	197.14	113.2	42.58	8.56	4.85	43.34
18–21.04.1982	159.34	223.3	28.64	7.26	9.91	2674
08–12.03.1986	351.0	184.4	47.46	45.03	8.20	81.79
23–25.09.1993	126.5	126.4	0	4.67	5.45	14.31
23–26.09.1994	126.5	130.1	2.76	5.63	5.80	2.93

Explanations: *Qp* and *V* as in Tab. 2.
Source: own study.

PREDICTION OF THE FUTURE BEHAVIOUR OF CHELIFF-GHRIB

INTRODUCTION

Nobody can deny effect of climatic changes and land use on hydrological processes and disturbance of the natural environment of runoff. Consequently, planners and decision-makers are supposed knowing which will be the impacts downstream of their anthropic actions undertaken in upstream of watershed, such as urban development, deforestation and reforestation.

Based on this, the present part tries to reuse the HEC-HMS model adjusted to the watershed of Cheliff-Ghrib to predict its response to the positive and negative scenarios by taking into consideration, changes at climatic level by exploitation of predetermined quantile rain showers, and other relating land use. All these scenarios will be implemented on event of 23–26.09.1994 of which model was able to restitute the peak flow. As for flood volume, it will be compared to that simulated by model and afterwards to the one actually observed at the outlet station.

SCENARIO 1: THE QUANTILES RAIN SHOWERS

This first scenario simulates effect of rain showers of different return periods on flow's hydrograph at station of Ghrib. So, we have replaced the average rain height of the event by estimated heights by the statistical laws.

Input data

The following table summarises the estimated rain values for return periods which will be used in simulations (Tab. 7).

Each rainfall height will be added to optimised parameters set defined in Table 5 to configure a file of distinct simulation. Consequently, we have to compare six simulation files, in addition of the simulated and observed results for event of 23–26.09.1994.

Table 7. The estimated of rainfall-heights of basin Cheliff-Ghrib for different return periods

Return period, year	Estimated value, mm
10	63.43
25	75.79
50	84.95
100	94.05
200	103.11
1 000	124.11

Source: own study.

Simulation results

Simulated results in Table 5 and graphs in Figure 10 present expected values by HEC-HMS model in watershed of Cheliff-Ghrib in terms of hydrographs' peak and of runoff volume They show amongst other, a linear correlation of $R = 0.99$ for both variables with the rain. These results impose to responsible to strengthening the protection of measuring equipment of flow to the outlet in order it would not be dragged by anticipated flood, and to implement structural measures that can support the huge simulated volumes (Tab. 8).

SCENARIO 2: CHANGE IN LAND USE IN A NEGATIVE SENSE

Input data

In this scenario, we try simulating effect of deforestation and urbanisation on flows and on flood volumes at Ghrib's station. But due to the raisons linked essentially to absence of information and to global character of the model, we have opted for general changes on land use and soil type. These changes being made to the map, mainly affects:

- surface expansion of the urbanised area;
- disappearance of forest cover where density is low (light juniper, light oak and clear forest);
- percentage growth of bare lands favouring deforested land;
- percentage growth of impervious due to urbanisation.

From these changes, we have recomputed the new CN composite of the basin passing to 71.56 to 77. Impervious percentage is evaluated to 15%.

These CN values and impervious percentage will replace the old ones in the optimised parameters' set, and then we launch the simulation.

Simulation results

The following table shows peak flow values and volume obtained for the scenario studied, then results by associating it to quantiles rain showers (Tab. 9).

We can clearly see that peak flow has increased about 22% knowing we have used a rain height simi-

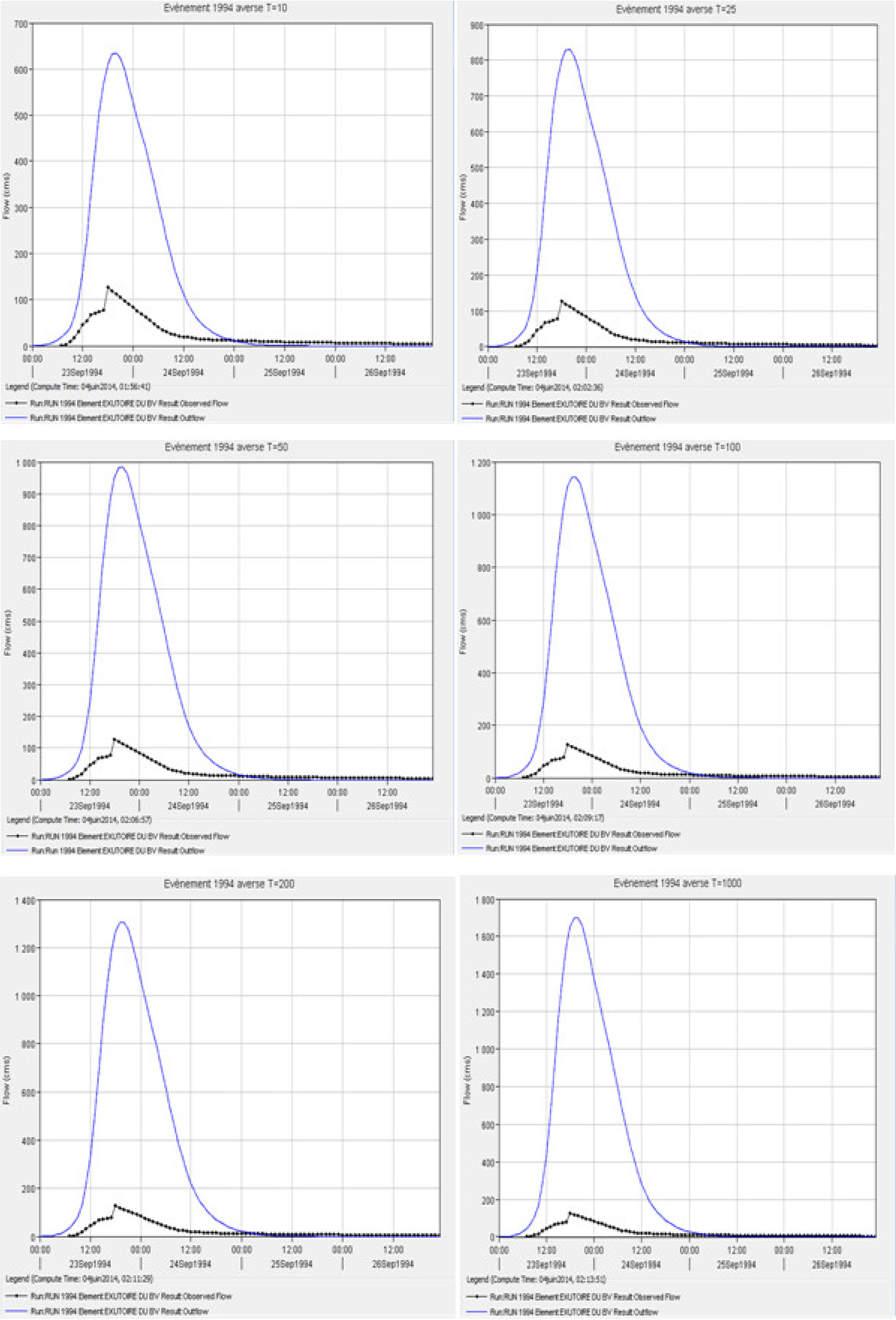

Fig. 10. Flood hydrographs for different events and different return period; source: own study

Table 8. Predicted values of peak flow *Qp* and volume *V* at Ghrib's station for scenario 1

Parameter	Observed	Simulated	*T* = 10	*T* = 25	*T* = 50	*T* = 100	*T* = 200	*T* = 1 000
Qp, m^3·s^{-1}	126.5	130.1	635.2	830.5	983.8	1 142.0	1 304.7	1 700.5
V, 1000 m^3	7 827.50	8 063.85	38 669.4	50 364.6	59 505.4	68 922.4	78 586.0	101 897.2

Explanations: *T* = return period.
Source: own study.

Table 9. Predicted values of the peak flow *Qp* and volume *V* at Ghrib's station for scenario 2

Parameter	Observed	Simulated	Scenario	*T* = 10	*T* = 25	*T* = 50	*T* = 100	*T* = 200	*T* = 1 000
Qp, m^3·s^{-1}	126.5	130.1	167.1	750.4	968.3	1 137.6	1 311.2	1 488.6	1 914.1
V, 1000 m^3	7 827.5	8 063.8	10 326.5	45 518.9	58 452.8	68 451.0	78 670.3	89 086.0	113 975.4

Explanations: *Qp* = peak flow, *V* = volume, *T* = return period.
Source: own study.

Table 10. Comparison between results of scenario 1 and 2

Parameter	Return period, year					
	T = 10	*T* = 25	*T* = 50	*T* = 100	*T* = 200	*T* = 1 000
Qp scenario 1, m^3·s^{-1}	635.2	830.5	983.8	1 142.0	1 304.7	1 700.5
Qp scenario 2, m^3·s^{-1}	750.4	968.3	1 137.6	1 311.2	1 488.6	1 914.1
Difference, %	15.36	14.23	13.52	12.90	12.35	11.16
V scenario 1, 1000 m^3	38 669.4	50 364.6	59 505.4	68 922.4	78 586.0	101 897.2
V scenario 2, 1000 m^3	45 518.9	58 452.8	68 451.0	78 670.3	89 086.0	113 975.4
Difference, in %	15.05	13.83	13.07	12.39	11.79	10.59

Explanations: *V* and *T* as in Tab. 9.
Source: own study.

lar to that recorded during event. If we compare peaks flows during the six return periods with their homologues of the first scenario (Tab. 9), we note that as large is the return period as this percentage of 22% decreases, in other words, for heavy downpours, influence of land use on the flows decreases, this finding has been demonstrated in other contexts [JENÍČEK 2007]. Also are volumes behaving in identical way, that is to say as frequency of rain shower is small less will be the effect of surface state on the streamed volume (Tab. 10).

SCENARIO 3: CHANGE IN LAND USE IN A POSITIVE SENSE

Input data

As for this third scenario, action is put on evaluation of an urbanisation impact of the basin with the same scale of that of scenario 2, but in parallel, we undertake actions of bare soils reforestation and strengthening of forest cover with low density, so:

– bare soils will become a clear forest;
– clear density will become average;
– urbanised area is similar to that of scenario 2.

From these changes, we have recomputed the new CN composite of the basin that is equal to 65. The impervious percentage is evaluated to 15%.

This value will replace that of optimised parameters set, then we launch simulations.

Simulations results

In the following, are represented results obtained for this scenario, which is the peak flow and volume coming from scenario simulation and those arising by rain substitution of event 23–26.09.1994 by rain at distinct return periods (Tab. 11).

Table 11. The expected values of the peak flow and volume at Ghrib's station for scenario 3

Parameter	Observed	Simulated	Scenario	*T* = 10	*T* = 25	*T* = 50	*T* = 100	*T* = 200	*T* = 1 000
Qp, m^3·s^{-1}	126.5	130.1	135.1	592.7	769.7	909.0	1 053.8	1 053.8	1 568.9
V, 1000 m^3	7 827.5	8 063.8	8 347.9	36 350.6	47 051.0	47 051.0	47 051.4	47 051.0	94 803.5

Explanations as in Tab. 9.
Source: own study.

We realize that the addition of 5% of impervious surface compared to the initial state has generated an increase of 4% for the flow and 3.4% in volume term, even though CN decreased from 71.56 to 65. We can thus understand the negative effect of imperviousness of watershed surfaces, through urbanisation for instance, on its hydrological regime. In addition, we note that both variables flow and volume show less high values than the case of scenario 2, this proves that reforestations although modest, influence on previous urbanisation effects. Finally, influence diminution of land use on flows and volumes for heavy downpour is also valid for this scenario.

From the foregoing, we arrive to recognize the positive and negative effect of some situations which might occur on the ground in the next decades and that the authorities responsible are expected to take into consideration in their land-use planning of Cheliff-Ghrib basin. Furthermore, we have been able to reconfirm that the causal relationship between change of land use on the one hand, and flows and volumes on the other hand, is less and less narrow than downpour are extreme.

CONCLUSIONS

Through these results, it clearly appears that simulations done by HEC HMS model are encouraging. They show that modelling of rivers is complex, requiring a good knowledge of the field and flows; it also requires collection of important data base in spatio-temporal, multi sources and multi-disciplines.

The rainfall-runoff models are tools which allow simulating flows in a given point of a stream from knowledge of rain over the corresponding watershed. This modelling is made at the scale of the watershed, characteristic entity of flows concentration, and allows thus to simulate transformation which carries out the basin on the rains to generate flows.

Applications of rainfall-runoff models are multiple: flood simulation at short term, low flows forecast, floods predetermination and sizing of structures, highlighted of non-stationarity of hydrologic behavior under climatic change effect or of land use evolution. In addition, the rainfall-runoff models allow spreading the forecasting deadlines compared to models flow-flow. After having completely validated the HEC-HMS model on the watershed of Cheliff-Ghrib, we can use it for protection against floods, by using which we call modelling in real time based on reconstitution principle of the flow to outlet for each time-step for which the given rain is measured, consequently, we can progressively reconstitute hydrograph of a flood with recording of rain height. This alarm system proves to be more efficient than one basing on water height measure upstream in the river watershed.

At the end of this work, we can say that application of HEC-HMS model to watershed data of wadi Cheliff-Ghrib provides very satisfactory results.

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Modelowanie relacji opad–przepływ przy użyciu systemu modelowania hydrologicznego HEC-HMS na przykładzie rzeki Cheliff-Ghrib w Algerii

STRESZCZENIE

Celem przedstawionych badań było utworzenie hydrologicznego modelu typu opad-przepływ w zlewni rzeki Cheliff-Ghrib za pomocą systemu HEC-HMS. Następnie model ten użyto do przewidywania reakcji hydrologicznej zlewni na różne scenariusze zmian klimatycznych i zmian użytkowania ziemi. Model kalibrowano w dwóch etapach. Pierwszy polegał na doborze zdarzeń, sformalizowaniu funkcji przejścia i doborze odpowiedniego opadu. Drugim etapem było określenie optymalnego zestawu parametrów użytych do walidacji modelu. Stosując zoptymalizowany zestaw parametrów, można było przewidzieć wpływ opadu i zmian użytkowania ziemi w związku z urbanizacją, wylesianiem i powtórnym zalesianiem na maksymalny przepływ oraz odpływ wody. Potwierdzono, że wpływ użytkowania ziemi maleje w sytuacji ekstremalnych opadów burzowych.

Słowa kluczowe: *Algeria, Ghrib, HEC-HMS – zlewnia, modelowanie, opad–przepływ*