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STATISTICAL APPROACH OF THE PHYSIOGRAPHICAL PARAMETERS INFLUENCE ON RUNOFFS OBSERVED AT THE EXIT OF BASINS- A CASE OF ALGERIAN BASINS

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ABSTRACT

The predetermination of the runoff in the non gauged basins constitutes the objective of numerous researches because of a lack of data covering them. Thus, the use of mathematical models became the suitable approach. Runoffs at the exit of basins, in addition to being influenced logically by rainfalls and their intensities, they are under the influence of other factors which condition the surface discharge such as the physiographical parameters of the basins, lithology, vegetation cover and evaporation. The aim of this work is to seek statistical relations which bind runoff observed at the exit of basins to rainfalls and some physiographical factors for basins of Algeria between September 1985 and September 1993. The simple and multiple correlations carried out on 23 basins made it possible to emphasize that some physiographical characteristics are explanatory of the variance of the runoff to significant thresholds.

Keywords: rainfall, runoff, basin, physiographical parameters, multiple correlations, Algeria.

Abbreviations

A: surface
Ct: coefficient of torrentiality
Dd: drainage density
Hmoy: medium altitude
Ip: slope index
Kc: compactness index of a basin (Gravelius index)
Lr: length of the equivalent rectangle
Lt: length of the principal stream
P: rainfall
Q: runoff
R: coefficient of simple correlation
R: coefficient of multiple correlations
R^2: coefficient of multiple determinations
Δ: standard deviation

1. INTRODUCTION

The runoff importance at the exit of a basin is obviously conditioned by rainfalls, especially their intensity, but other factors intervene and influence with various degrees the surface flows. They are the physical characteristics of the basin (surface, form, density of drainage...), the lithological characteristics and the nature and the density of the vegetation cover.

The many hydrological rainfall-runoff models, distributed or lumped, used nowadays, do not assign coefficients to the physiographical factors during the phases of moistening of the ground or during the surface flow and hypodermic flow which are however under direct influence of the physiographical characteristics of the basins. The approach suggested here aims to determine statistical relations witch can bind runoffs observed at the exit of basins and their physiographical parameters through simple and multiple correlations, especially by the incremental ascending correlation method.

2. METHODS ADOPTED FOR THE NON GAUGED BASINS

To evaluate the runoff at the exit of a non gauged basin, different approaches can be adopted:

The geographical interpolation of data obtained on gauged basin which can give tangible results only in the case of basins having the same physiographic characteristics (morphologic parameters, vegetation cover, geology…). A current practice in the distributed models aims to assign spaces according to their physiographical characteristics (geomorphology, geology, vegetable cover…) in order to understand the specific behaviour of each unit but also in the objective to constitute units which could be correlated with others not measured (Klemes, 1975). In the same order of idea, modelling of the influence of the agricultural soils occupation on the flows of Karvonen (1999) reposes on units witch have the similar hydrological behaviour by a distribution of spaces according to the type of soil occupation, type of soil, topographic slope and vegetation.

Adjustment of rainfall-runoff models, of which nearly forty are described by Perrin (2000), on gauged basins and the establishment of statistical relations between physiographical factors of these basins and some parameters of models, like evapotranspiration, to then carry out the transposition on not gauged basins. This approach was adopted by using a global hydrological model in the objective to predetermine flows in not measured basins of Bretagne and Moselle (France), where it gave acceptable results (Thierry, 1992). The same approach was used by Kabouya (1990) on Algeria northern basins. A similar approach was also adopted by Nonguierma and Dautrebande (1995) through the determination of a retention parameter of soils starting from statistical relations to the physiographical characteristics of a Sahelian basin and its use in deterministic and global rainfall-runoff models. The hydrophysiographical model of Girard *et al.* (1972) integrates physiographical parameters in production and transfer functions of distributed spaces. The meshs physiographical characteristics of the distributed basin are stored in database which is used during calculations of the hydrous assessments by the use of simple laws, but to our knowledge, it is not question of statistical processing and correlations between physiographical parameters and flows. The difficulties to adjusting various models used in the Sahel during ten years of investigations have lead Girard and Rodier (1979) to recommend the need of a characterization of the physiographical characteristics during production functions and during flows transfer in the hydrographical system. Ibiza (1985) was also interested by infiltration mechanisms on basin slopes and the underground storage by the means of the hydrous assessment, while trying to simplify parameters which intervene in production and transfer functions. The roles of the vegetation cover and of the nature of soil are integrated indirectly in the hydrous assessment. A study connecting the flow regimes to the physiographical characteristics was carried out by Javelle (2001) on the Moselle basin (27,000 km²). It enabled him to identify some explanatory parameters in addition to the rainfall such as the medium altitude and the percentage of cultivated soils. The topographic and soils occupation characteristics are used more and more as criteria of validation in the distributed models because they intervene in a determining way in functions of production and of transfer of flows (Gnouma, 2005). Arora (2002) described for example fifteen figures suggested by authors relating to transfers which intervene in the phase ground-vegetation-atmosphere which has a decisive role in the hydrous assessment and consequently on the flows. Each one of these figures can be integrated in a distributed model. In the objective to highlight performance differences between global and distributed solutions and in order to explain them starting from the physical characteristics of basins, Plantier (2003) directed by Loumagne and Andréassian of the CEMAGREF, has centred its work on a sample of 307 basins of France by integrating twenty descriptive indices of the physiographical characteristics of these basins starting from MNT and databases of soils occupation. He concluded that in addition to rainfalls, it is necessary to distribute the physiographical parameters likely to improve the distributed approach of the models. These parameters are "the hypsometric integral", "the relative index of response of the basin" and the soils occupation. We note the multiplicity of the approaches and the parameters which intervene in the hydrous assessments in a general way.

This work aims to seek statistical relations which can bind runoffs measured at the exit of basins to some physiographical parameters through simple and multiple correlations. The step of selected time is annual because it permits to neglect temporal variability specific to rainfall intensity which incidence is undeniable on runoffs of floods but which isn't the object of this study. Annual step time permits also to not be encumbered by variations of the evapotranspiration which, with short steps time, influences directly all the terms of the water balance. The observed flow at the exit of a basin is "implicitly" cut down of the quantities taken by the evapotranspiration and the infiltration; in fact the flow keeps only the print of the physiographical characteristics of the basin. Databases of rainfalls, runoffs and physiographical characteristics are those of Algerian basins. They cover a period between September 1985 and September 1993.

The lack of data concerning lithological characteristics and vegetation cover didn't make it possible to integrate these characteristics which have undeniable roles on the hydrological behaviours of the basins, like the forest cover which was the subject of many works, like those of Andréassian (2002).

3. DATA

Directories of the ANRH to which we refer contain hydrometric statements of 61 stations which are classified by great hydrographical areas. After a data processing for the period between September 1985 and September 1993, only 23 basins were retained for this study. They belong to 11 large watersheds of different areas of Algeria.

The rainfall annual variation for stations taken into account in this study (52 stations) presents, with rare exceptions, a similar variation tendency with however great variations compared to the average (P_{moy}: 437.5 mm, P_{min}: 213 mm and P_{max}: 761.1 mm).The runoff annual variation presents a variation tendency similar to that of rainfall (Q_{moy} 1.137 m^3/s, Q_{min}: 0.075 m^3/s and Q_{max}: 5.920 m^3/s), but 20 basins have annual runoffs lower than the average.

4. CORRELATIONS

4.1. Simple correlations

In a first step and on the basis of data of 27 basins, the best simple correlation obtained between variables, is the exponential form binding the annual medium runoff to rainfalls with a correlation coefficient r = 0.752 (Figure-1).

We note the existence of atypical points which can either artificially increase the value of the correlation coefficient, or to decrease the value of a legitimate correlation. According to the approach of Frees and Hunter (1980) which exclude values leaving the interval: ± 1.5 to 2 δ around the average of the group, 4 basins are in this case (runoff Q = 5.11m^3/s, 5.92, 4.95 and 2.98m^3/s). The adoption of this "rule" in our case reposes also on the fact that these values move away from the groups for all correlations. Basins which present these atypical points have large surfaces and belong to wetlands where great relative values of rainfall are measured.

The results of significant correlations between physiographical characteristics and observed runoffs for the 23 remaining basins are summarized in Table-1.

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Table-1. Simple correlations runoffs-physiographical characteristics.

Parameters	Correlation to	r	Best regression		Variance explained at
			Form	Expression	
Rainfall	Ln Q and P	0.577	Exponential	$Q = 0.065 \exp(0.004\, p)$	33.3 %
Surface	Ln Q and Ln A	0.474	Power	$Q = 0.029\, A^{0.444}$	22.5 %
Perimeter	Ln Q and Ln Per	0.500	Power	$Q = 7.7\ 10^{-3}\, Per^{0.898}$	25 %
Length of the principal torrent	Ln Q and Ln Lt	0.495	Power	$Q = 0.033\, Lt^{0.686}$	24.5 %
Torrentiality Coefficient	Q and Ct	0.584	Linear	$Q = 0.009\, Ct + 0.297$	34.1 %

We note, after elimination of aberrant points, that the torrentiality coefficient (*Ct*) becomes the first explanatory variable of the runoff, almost with equality with rainfalls. Calculation of simple and multiple correlations and graphics are obtained by using the free version of the Statistica 6 demo software (Statistica, 2008).

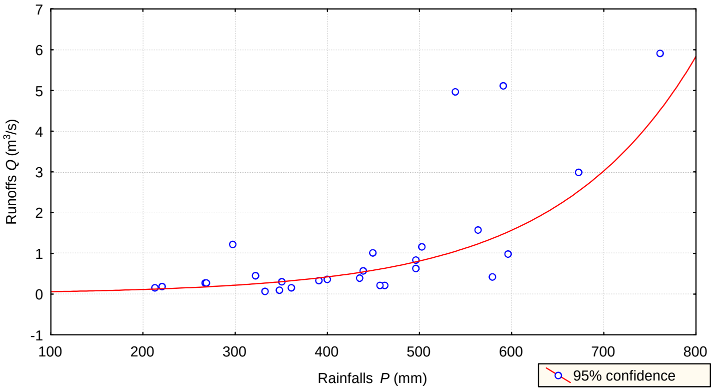

Figure-1. Correlation of runoffs-rainfalls annual averages.

4.2. Multiple correlations

The multiple regression incremental ascending method was adopted in our case. The variable is introduced into the regression line when the value of the partial correlation coefficient which bind the runoff to this variable, by taking into account of the other variables, is significant with the threshold of 5 % (Scherrer, 84; Legendre, 98). If there are more than two explanatory variables, the equation is that of a hyper plan with ρ dimensions, the ρ^{th} variable is the dependent variable:

$$Y = a_1x_1 + a_2x_2 + \ldots + a_jx_j + \ldots + a_{\rho-1}\, x_{\rho-1} + b$$

As in simple linear regression, we measure the variance explained by the regression using the multiple determination coefficient r^2 (Scherrer, 84).

In term of hypothesis tests, multiple regressions are subjected to same constraints as the simple linear regression concerning the normal distribution of the variables, the equal variance and the independence of residues. The inference study in multiple regressions is based on the examination of the principal statistical tests carried out on the significance of the regression and on the model parameters, to only retain the explanatory variables which have a significant effect (Delannee and Saada, 1999). The results of the various stages of the regression are summarized in Table-2 and Figure-2 (a, b and c).

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Table-2. Steps of the multiple regression incremental ascending.

	Coefficient of determination	**Coefficient of partial correlation between *Q* and each explained variable**		
Regression	R^2	*Q* and *Ct*	*Q* and *Per*	*Q* and *P*
$Q = 0.009\ Ct + 0.297$	0.341	0.584		
$Q = 0.009 + 0.005\ Per - 0.117$	0.573	0.676	0.595	
$Q = 0.008\ Ct + 0.005\ Per + 0.002\ P - 0.898$	0.826	0.776	0.784	0.769

The tests of significance are conclusive. Three variables: the torrentiality coefficient, the perimeter and the rainfall explain 82.6 % of the runoff variance according to the following equation:

$Q = 0.008\ Ct + 0.005\ per + 0.002\ P - 0.898$ with $R = 0.909$ and $R^2 = 0.826$

The correlation coefficients of remaining variables (Hmoy, Kc, Lr, Ip and Dd) are all below the breaking value (R = 0.413) and by consequent are considered as non significant.

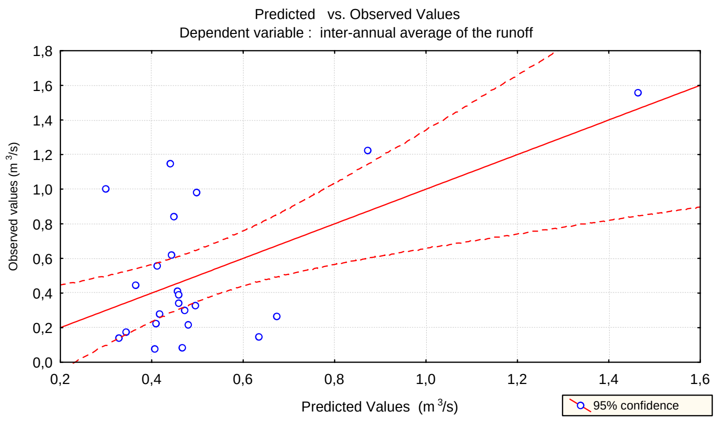

Figure-2a. Step 1 of the incremental ascending correlation.

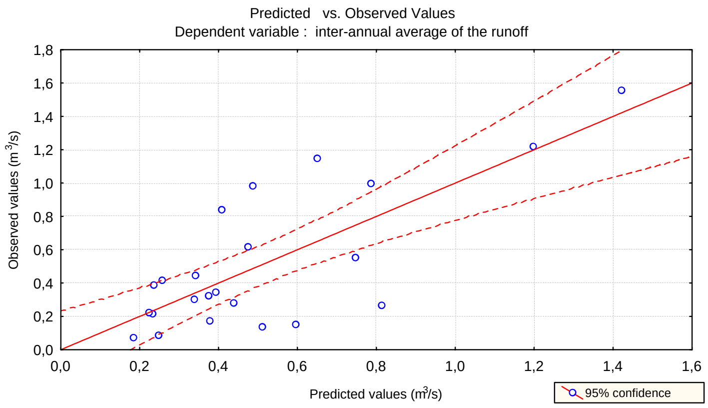

Figure-2b. Step 2 of the incremental ascending correlation.

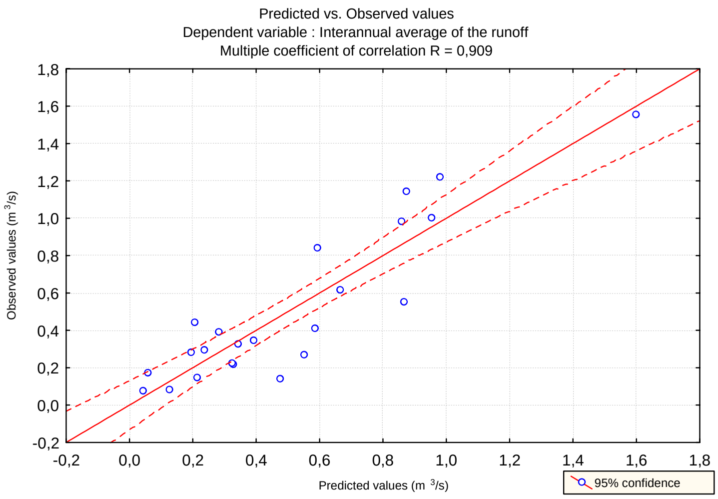

Figure-2c. Step 3 of the incremental ascending correlation.

5. CONCLUSIONS

The simple and multiple regressions which are based on data of rainfalls and runoffs covering 23 Algerian basins for the period between September 1985 and September 1993, showed connections at significant thresholds which bind runoffs at the exit of the basins treated with their physiographical characteristics.

In addition to the rainfall which is a normally explanatory variable of the runoff, this one is strongly correlated with the perimeter (selected as variable indicator of the other variables which are strongly correlated to it: surface, length of the principal torrent and concentration time) and with the torrentiality coefficient. The combination of these three parameters explains approximately 83 % of the variance of the runoff.

The concentration time which includes in fact the time of moistening of the ground, the time of the surface flow and in sub-surface until a system of collection and the time of routing in the system of collection (Musy, 2003), is the indirect expression of the time in the functions of production and transfer in the distributed models. The torrentiality coefficient which reflects the drainage density of order 1 indicates the dynamic of the surface flows during the transfer phases.

It appears, according to these results, the need for integrating the physiographical factors of basins in the deterministic models, joining Mr. Hubert (2004) who, in its study on the predetermination of the floods, pled for reconciliation between deterministic hydrology and statistical hydrology.

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