# Optimizing the use of water surface. Application to a dam in the area of Ouarsenis in North Algeria.

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## Abstract

This work focuses on the identification of optimal management rules that allow the improvement of the exploitation of surface water resources in a semi-arid zone. The management model is applied to the dam of Koudiet Rosfa (semi-arid zone of northern Algeria) mainly established in order to provide drinking water , to satisfy industry and agriculture water demand and leisure as secondary objectives. This work was about making a prediction on water demand in a deterministic way and also the examination of the forecast of hydrological input probabilities.
The structure of the optimal management rule is formulated as a sequential optimization problem, solved by the stochastic dynamic programming. The model seeks the management decisions that minimize distances relatively to the ideal solutions previously defined by managers. Optimal management rules will allow identifying monthly the volumes of water needed, taking into account the reserve status of the dam and the temporal persistence of hydrological inputs in the dam. A simulation model is used to evaluate various management alternatives. The most satisfying alternative is selected in relation to defined performance criteria.
The method is based on the assumptions of the independence of monthly average rainfall. The multiple linear regressions are used, to estimate, the magnitude of the inputs to the dam.
This approach was used to overcome the shortcomings of hydrometric data at the mouth of the dam. The method provides more accurate estimates of the regression coefficients, and better estimates of the model error.

**Key words:** Algeria, Optimization, semiarid, Simulation, Water management.

## 1. Introduction

The current estimate of the total reservoir storage (surface water) in the world is about 7000 km3. This storage is used for drinking water, irrigation, electricity and energy production. The demand for water for domestic use is expected to grow significantly in the coming years in developing countries [1].

In a recent study, the United Nations reported that nearly 1.1 billion people lack in potable drinking water and that the water problems in developing countries will be exacerbated by the high rate of population growth and the gradual concentration of population in major cities [2]. The two banks north and south of the Mediterranean basin manage a potential flow of 602 billion

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m3/year, north (518 billion m3/year) and south (84 billion m3/year). Thus, the south bank represents only 14% of the basin supplies. [3]

Surrounded by the Mediterranean and Saharan influences, Algeria is subject to an arid and semi-arid climate characterized by a scarcity of water [4].

To meet the needs of water of a growing population, agriculture and industry, the country has implemented a dynamic program of development of water resources, based on a series of dams, reservoirs and canals to manage surface waters.

The future hydraulic of Algeria will focus primarily on the improvement of the performance of mobilization of water resources, in addition, to the management of the balance between water resource and use. Water incomes in Algeria are directly related to climate, while demand is linked to the strategy of use.

In this context, the mobilization of surface water and control of the runoff is essential. Such mobilization involves the development of efficient prediction models and serious monitoring of the evolution of pressure and preparation of long-term solutions.

In this work, it is rather to apply the concept of dynamic stochastic optimization, to evaluate the performance and relevance of hydraulic structures. The main objective is to develop a method of optimizing the management in order to improve the performance of the infrastructure by applying the stochastic dynamic optimization model. The expected results are primarily technical developments of flow prediction by regionalization methods, which represent a tool for the management of water of Koudiet Rosfa.

## 2. Materials and Method

### *2.1. Study area*

Koudiet Rosfa dam is located in the watershed of Oued Fodda (Figure 1), at 35°50'39" of north latitude and 1° 47'3" of east longitude, with an average temperature of 15.8 ° C, a relative humidity ranging from 70 to 83% from November to March and 40 to 63% from April to October. The prevailing winds during October to May are West and North West wings, whereas during June to September East and South East wind prevails, with a maximum speed of 36 m/s,

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recorded during the November and December. The average annual evaporation is estimated to 1241 mm and the average annual rainfall of 435 mm by [5].

The lithology of the watershed is dominated by marls and flysch. Under the impact of the long rains or intense rain, erosion phenomena are triggered (gullies, badlands, solifluction, scree and undermining at the side of wadis).

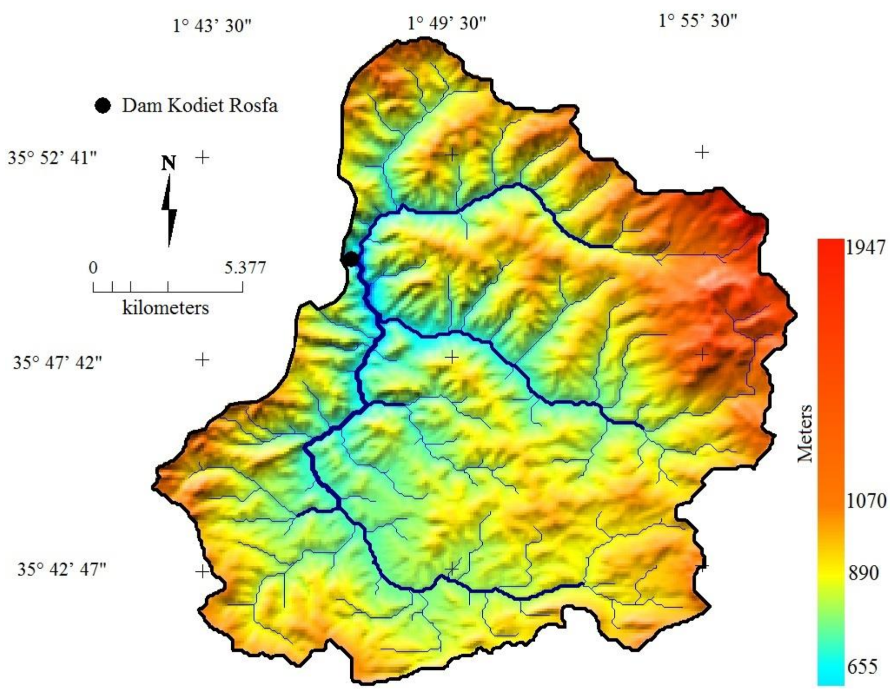


**Figure 1.** Location of the study area

### *2.2. Methodology*

In this study, we examined the monthly variations of the flow upstream Oued Fodda river, watershed Koudiet Rosfa (480 km $^2$). Traditionally, hydrological regimes study refers to the regimes defined by [5]. It is the study of seasonal variations of the average interannual flow measured monthly. This type of representation provides information on flow variations, face to the cycle of seasons: recharge during wet seasons and drain during dry seasons.

The monthly time step seems more appropriate to study the flow according to the seasons cycle, the flow the seasonal variability smoothing increases as the laps of time increases. Time reduction leads to an increase of the relevant information. The monthly time step gives more information on the interaction between rainfall, evaporation and soil capacity to store or restore

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water. We sampled the average monthly flow (seasonal variation) in 7 stations located around Kodiet Rosfa watershed. We studied the average monthly chronicle flow retrieved by ANRH (Algiers) and ANBT. All these chronicle flow have been criticized visually to identify outliers (unit coding error), these errors were corrected manually or by restoring the true chronicles in case of simple errors, or by setting bad values gap. All the 7 selected stations with the exception of Ouled Ben Abdelkader, present a gaps of several years. The series of Oued Fodda is certainly the most disturbed because of the lack of data in successive years (September 1971-january 1972), (July 1975 - August 1979) and (July 82 - August 90). Restoration of missing data was determined by using principal components method. Concerning standardization, the considered variable is the flow by unit area (A) of the watershed or specific flow (q), which can be expressed in litre/s/km2, mm / year, or mm / month, where "j" is the station number:

$$q_j(\text{mm}/\text{mois}) = 2592\left(Q_j(\text{m}^3/\text{s})/A_j(\text{km}^2)\right) \quad (1)$$

The factor 2592 converts m3 / s / km2 in millimeters of monthly water (mm / month) assuming a 30 day month. The Standardization was achieved by drained area (A), $q = Q/A$ (2) or by variability $q = \left(Q - m_Q\right)/\sigma_Q$ (3)

## 3. Results

The two firsts axis of the principal component analysis (Figure 2) explained 77.93% of variability, the variability explained by the first axis was 64.07% this axis was positively correlated to all stations except Ouled Ben Abdelkader (012311). The second axis with 13.86% of variance explained w positively correlated with Ouled Ben Abdelkader station (012311) and negatively correlated with stations (012201, 011906 and 012001). These results showed that hydrometric regimes of stations used in this study were generally identical except Ouled Ben Abdelkader station which has a different regime.

It can be concluded that the amount of water registered in the six watersheds can be estimated only from the first component F1 = [0.107, 0.404, 0.421, 0.421, 0.370, 0.383, 0.433], with represent approximately 80% of the total water. The annual correlation coefficients were not always representative of the actual hydrometric basin, because hydro climate regimes vary from one region to an another. Also the degree of correlation is different between months and between seasons (Table 1).

**Table 1.** Correlation matrix (at monthly scale) - (1971/72-2001/02)

| Oued fodda (01 21 17) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | Mai | Jun | Jul | Aug | Year |
| 01 23 11 | 0.63 | -0.07 | 0.33 | 0.61 | 0.81 | 0.60 | 0.64 | 0.13 | 0.25 | 0.13 | 0.54 | 0.31 | 0.17 |
| 01 21 17 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1 |

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| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 22 01 | 0.72 | 0.99 | 0.92 | 0.26 | 0.54 | 0.96 | 0.73 | 0.89 | 0.40 | 0.68 | 0.65 | 0.84 | 0.74 |
| 01 19 06 | 0.06 | 0.10 | 0.18 | 0.17 | 0.22 | 0.83 | 0.64 | 0.48 | 0.57 | 0.51 | 0.77 | 0.67 | 0.74 |
| 01 20 01 | 0.78 | 0.44 | 0.50 | 0.73 | 0.35 | 0.75 | 0.94 | 0.36 | 0.43 | 0.58 | 0.57 | 0.90 | 0.51 |
| 01 22 03 | 0.83 | 0.34 | 0.59 | 0.77 | 0.46 | 0.73 | 0.53 | 0.38 | 0.74 | 0.89 | 0.50 | 0.36 | 0.58 |
| 01 20 04 | 0.00 | 0.59 | 0.79 | 0.41 | 0.48 | 0.70 | 0.79 | 0.22 | 0.80 | 0.84 | 0.86 | 0.45 | 0.82 |

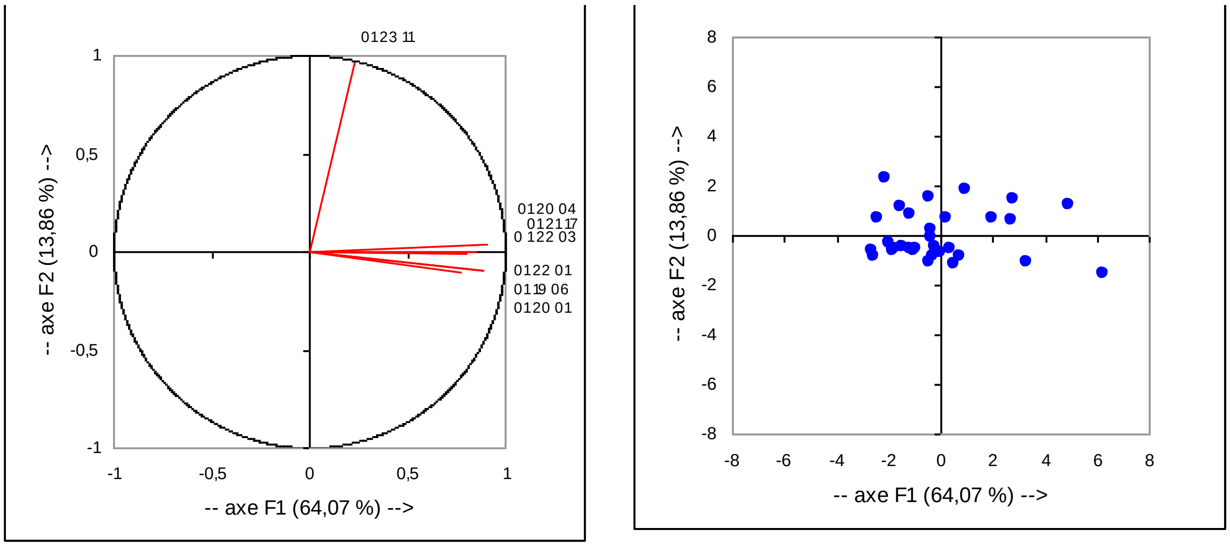


**Figure 2.** Principals components analysis

The best correlation between stations were observed in winter and late spring (period where water is abundant in wadis), the lowest correlations were observed during summer.
Thus, the stations to confront were not selected according to the best annual correlation coefficient, but according to the geographical realities of the station (same climate and geographic environment).

### *3.1. Estimating hydrometric features by multiple linear regression*

Multiple linear regressions showed that the best hydrometric estimates were those of October, November, January, February, March, April and July (Figure 3). With a well increase in $R^2$ and a strong explanatory power of all variables introduced (for the seven selected stations), the estimation error was always less than 5%. The comparison of results of the statistical models and those obtained by hydrological analogy (Figure 4) showed a perfect match.

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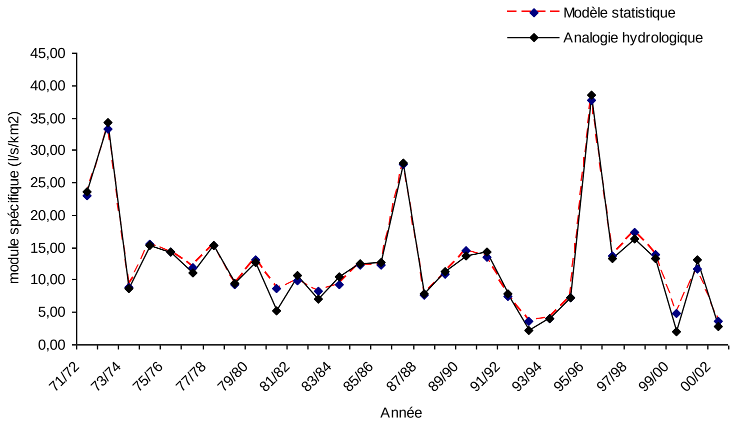
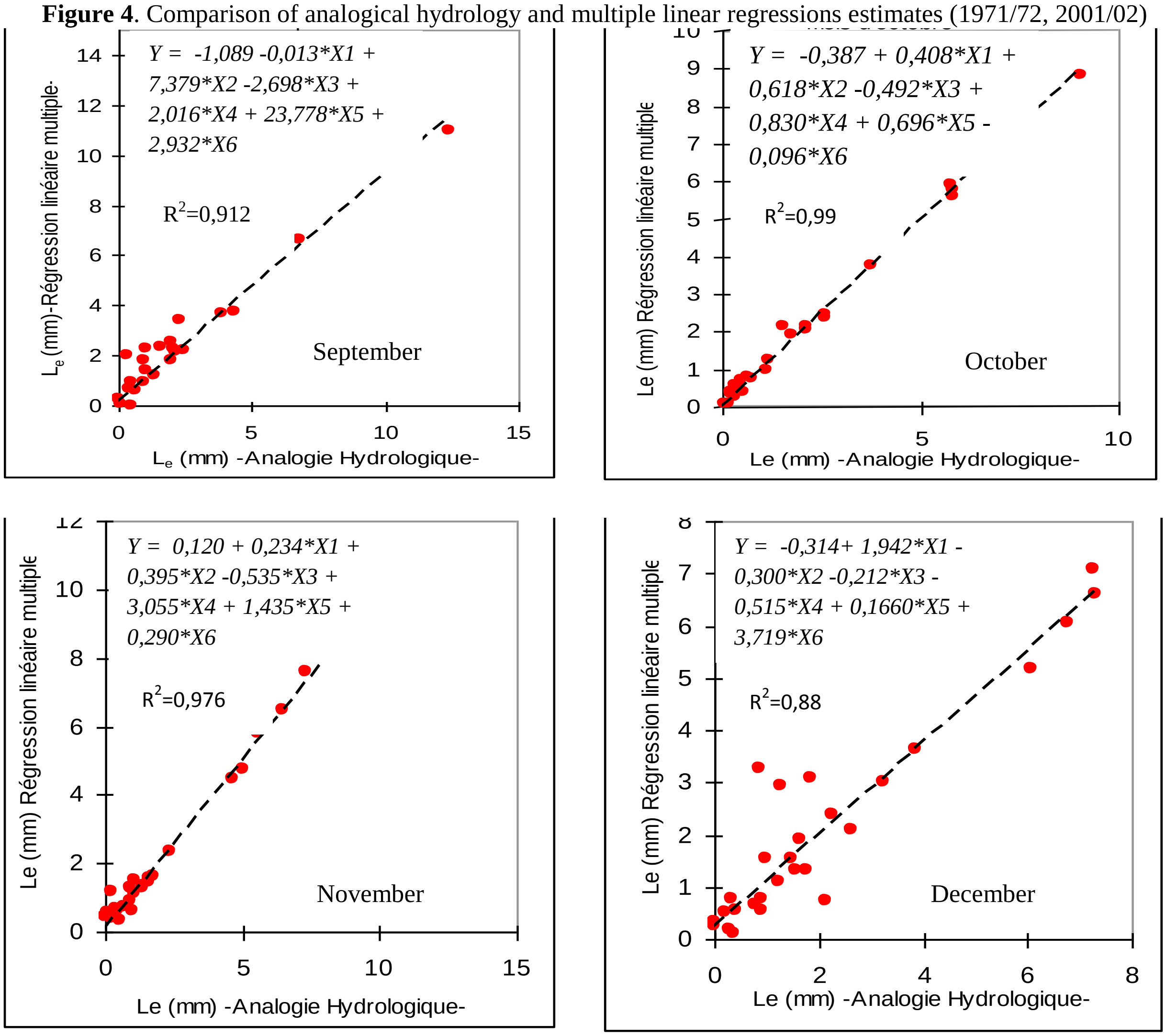



**Figure 4**. Comparison of analogical hydrology and multiple linear regressions estimates (1971/72, 2001/02)

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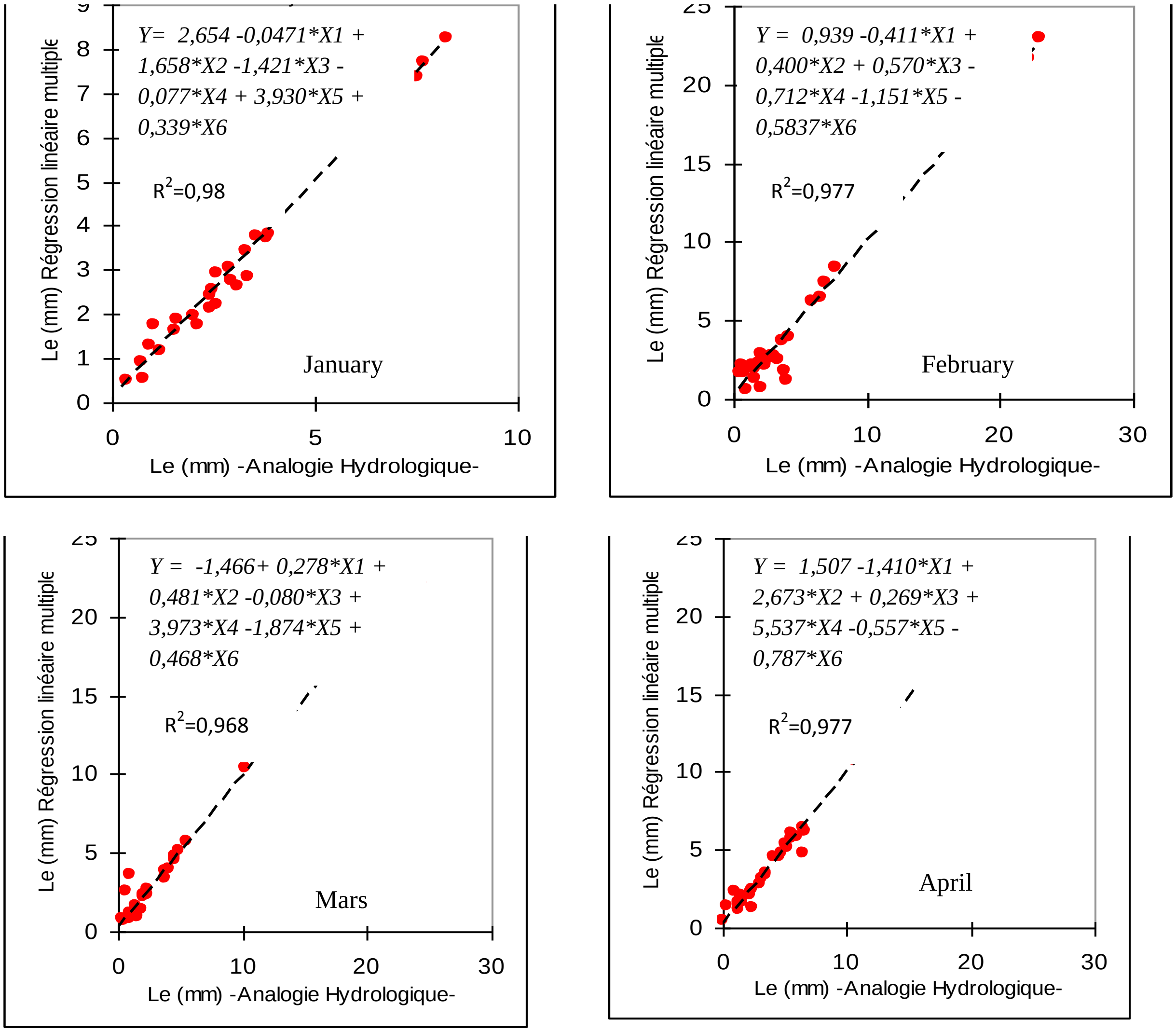


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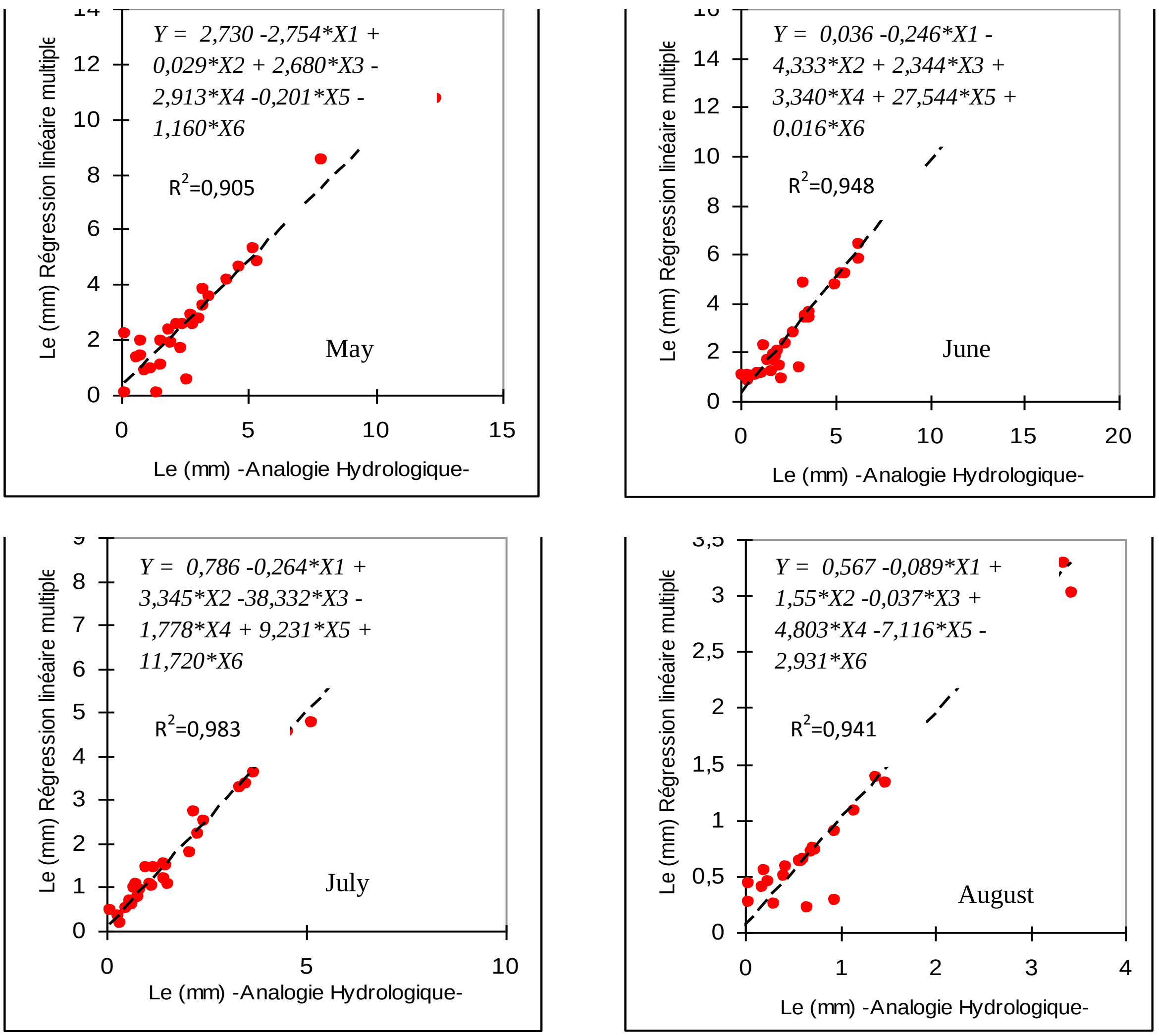


Figure 3. Estimates [analogy hydrological / multiple linear regressions] for monthly rates 1971/72, 2001/02

### *3.2. Monthly variations in average flows*

According to Figure 5 the wet season from December to June is the most abundant in the mean flow, the a maximum average speed in Koudiet Rosfa basin was observed in March (1.90 $m^3$ / s) with an occurrence probability of 10%, and a maximum range observed in February 1975 (3.13 $m^3$/ s), followed by February 1987 (3.81 m3 / s) the maximum value was observed during February 1996 (3.59 $m^3$/s). The amount (T) were calculated for a return periods of 50 years, estimating that the exponential law (2-18) is no longer valid beyond that period, and that extrapolation couldn't be done given the size of the sample (N = 31).

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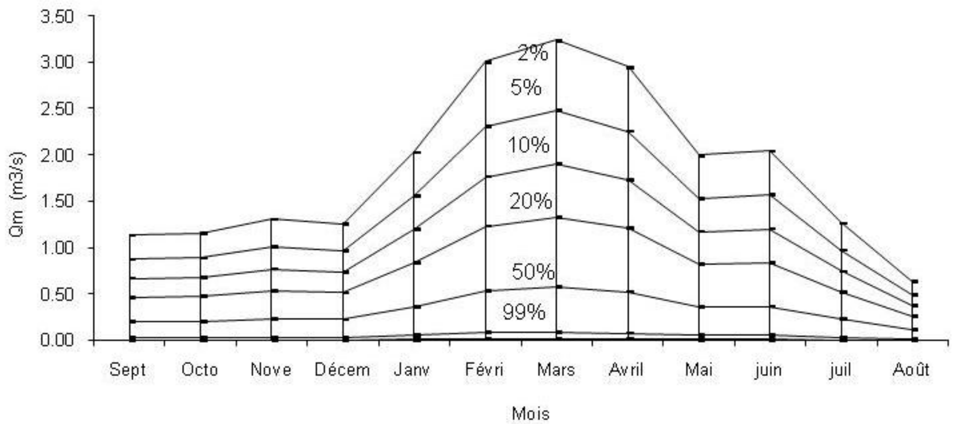


**Figure 5.** Frequency of average monthly flow in Kodiet Rosfa.

### *3.3. Seasonal patterns and monthly flow coefficients*

To compare the seasonal variations in river with different regimes, the monthly flow coefficients (MFC) of Koudiet Rosfa watershed average regimes showed high water flow from December to June and low water flow from July to December. The monthly maximum (1.8) was in March, followed by February (1.64) and April (1.61), while the monthly minimum (0.35) corresponds to August. Moderate variability of low water flow was justified by the main role played by the groundwater feeding of rivers during low flow.

### *3.4. Hydrolicity*

During period 1971/72-2001/02, the highest hydrolicity in Koudiet Rosfa watershed (Figure 6) were registered during the year 95/96, this year was characterized a high rainfall and experienced a real glut river. In contrast, the lowest runoffs were registred during 2001/02, year marked by a strong lack of rainfall.

## 4. Discussion

Water resources systems being the main link between the people and the climate are affected by human activities and climate change. Algeria is a North African country subject to harsh climatic conditions most of its total area is located within the arid, semi-arid and saharian climate characterized by a scarcity of water. To meet the needs of water of a growing population, agriculture and industry, dynamic program of development of water resources and accurate studies related to water management are extremely needed. This study is among a growing numbers of works aiming to the management and providing solutions to manage the lack in water. Our research conducted in Koudiet Rosfa dam located in the watershed of Oued Fodda showed that hydrometric regimes of the 7 stations used in this study were generally identical except Ouled

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Ben Abdelkader station which has a different regime. The best correlations between stations were observed in winter and late spring, indeed these periods are concordant with highest rainfall in north Algeria and the lowest correlations were observed during summer the driest period of the year. The best hydrometric estimates were those of October, November, January, February, March, April and July. Comparison of results of the multiple linear regression models and those obtained by hydrological analogy showed a perfect match, meaning that our models can be of great importance in predicting water flow in order to implement a dynamic program of development of water resources, taking in account that the wet season from December to June is the most abundant in the mean flow with a maximum range observed in February. Indeed the highest water flow was registered during this period (December to June). From an operational perspective Water-resources development projects in our study area inevitably include economic and environmental, as well as statistical models, the models retrieved in this study can be of great importance and major resource of information used by decision makers in order to implement dams, reservoirs and canals to preserve every drop of water in this ecosystem.

## Conclusions

The objective of this study was to provide a forecast of the demand of water in a deterministic way with a forecast of the probability of hydrological flows. The structure of the optimal management rule is formulated as a sequential optimization problem and solved by the stochastic dynamic programming.

The model seeks management decisions that minimize the distance from the ideal solutions previously defined by management. The optimal management rules will identify, for each month, the volume of water to release taking into account the state of the reserves of the dam and the temporal persistence of hydrological flows into the dam.

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