

# Climate evolution and possible effects on surface water resources of North Algeria

Laborde Jean-Pierre<sup>1,\*</sup>, Gourbesville Philippe<sup>1</sup>, Assaba Mohamed<sup>2</sup>, Demmak Abdelmatif<sup>3</sup> and Belhouli Larbi<sup>4</sup>

<sup>1</sup>EuroAqua Research Group, UMR 6012, University of Nice-Sophia Antipolis, Polytech'Nice-Sophia, 930 route des Colles, 06903 Sophia Antipolis, France

<sup>2</sup>Cabinet Risser, 954 route de Saint-Laurent, 06610 La Gaude, France

<sup>3</sup>Indépendant expert, 1, chemin Guerouard, El Mouradia, Alger, Algérie

<sup>4</sup>Agence Nationale des Ressources Hydraulique (ANRH), Bir Mourad Raïs, Alger, Algérie

**North-east Algeria benefits from a Mediterranean and semi-arid climate. The surface water resource is a factor restricting the economic development of the country. Within the framework of the National Water Plan, we studied the quantity of water that can be mobilized on several dozens of dam sites. A first hypothesis would be to base the simulations on the rainfall recorded during the last 40 years which were relatively dry. A second hypothesis would consist of assuming a reduction of about 15% in rainfall as the work of IPCC would suggest. This 15% reduction would in turn generate a reduction of approximately 40% of surface water resources. Such a decrease would thus drive a rather profound review in the programming of the works regarding the storage and transfer of water.**

**Keywords:** Algeria, climatic change, rainfall–runoff modelling, water resources.

## Introduction

THE National Agency for Hydraulic Resources (ANRH) has initiated a project on the surface flows for northern Algeria. The main objective is to develop tools for assessing the surface resources in any catchment for the coming decades. One of the objectives is to assess 60 potential sites for reservoirs and dams and evaluate them for different uses (irrigation, water supply, etc.).

## Rainfall, evapotranspiration and runoff data

ANRH is charged with conception, installation and management of national hydroclimatological network intended for the development of hydrologic balance assessments. It is also in charge of handling, shaping, archiving and diffusing these hydrological data. Finally, it leads the general methodological studies on the hydro-

climatological regimes to make an inventory of the water resources.

As presented in Figure 1, the main part of the study area benefits from a Mediterranean climate or semi-arid climate. Rainfall is estimated between 100 and 500 mm/year, even if the annual rainfall exceeds 1000 mm/year on the eastern coast area.

## Potential evapotranspiration

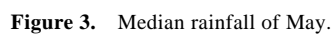
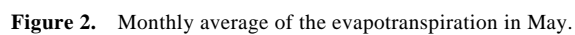
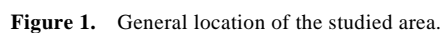
In 1997, ANRH published a report<sup>1</sup> on the monthly average of potential evapotranspiration (ETP) for any given month and territory. A good estimate of ETP, using Penman's formula, is available. Figure 2 gives ETP for the month of May.

## Monthly rainfalls

ANRH manages a network of over 1000 rain gauges. From September 1965 to August 1995, 500 rain gauge stations have benefitted from more than 20 years of observation. For all these stations and for every month, the monthly rainfall is fitted to a Galton's law. The parameters are presented as maps. Figure 3 gives the median rainfall for the month of May. These maps have been prepared according to the punctual rainfall data and also by taking into account the landscape and distance from the sea<sup>2</sup>.

Using the monthly rainfall, we can, for every month of the studied data period, transform the observed rainfalls into reduced Gauss values. These values are independent of landscape and the distance to the sea side, and can be interpolated easily by kriging<sup>3</sup>. Then, using the value of the reduced variable of Gauss on the territory and parameters of the Galton's law, the rainfall map for the considered month can be drawn. With this method, 360 maps of monthly rainfall from September 1965 to August 1995 have been produced<sup>4</sup>. Figure 4 shows the observed monthly rainfall and parameters that fluctuate according to the landscape and distance to the sea side.

\*For correspondence. (e-mail: laborde@unice.fr)



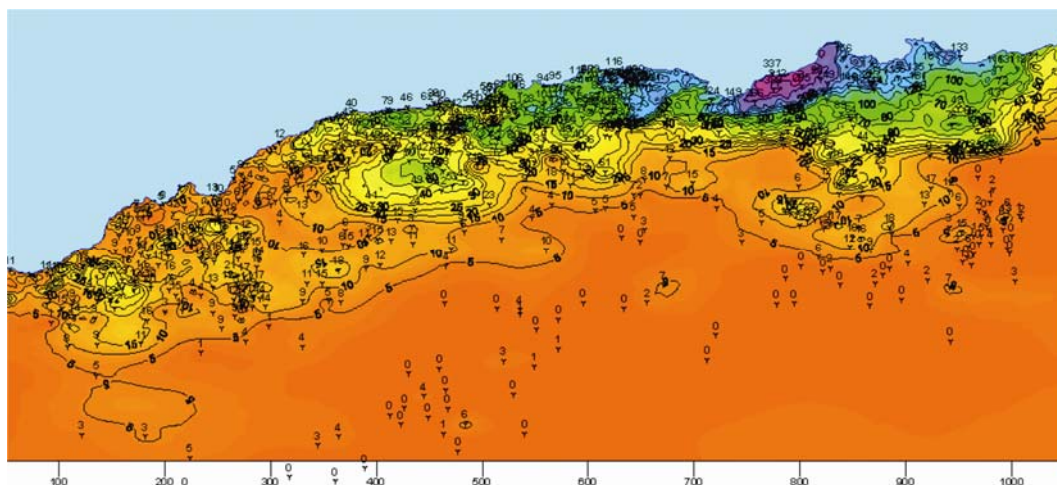


Figure 4. Rainfall in December 1994.

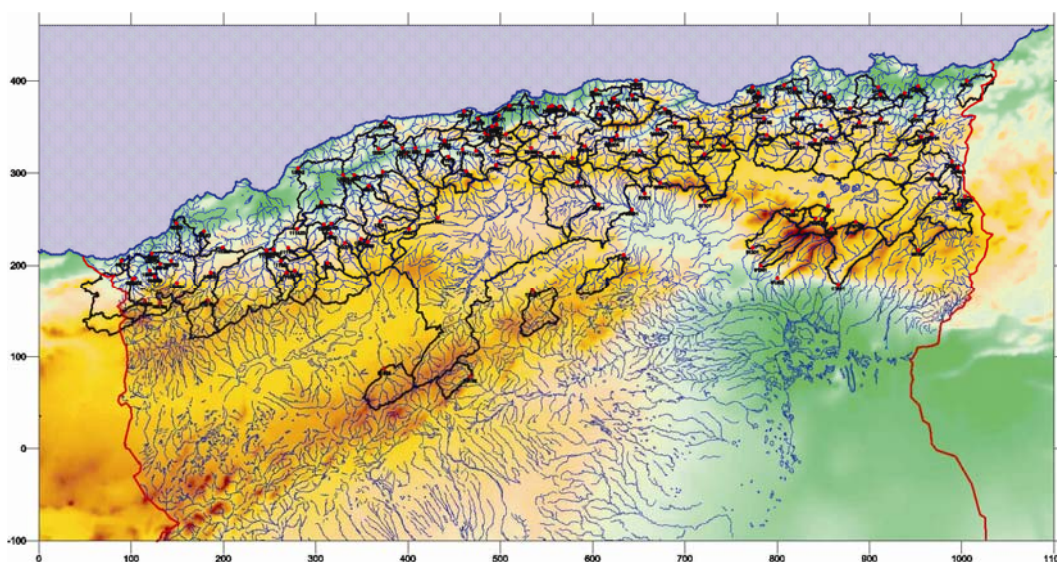


Figure 5. Basins provided with gauging station.

## Runoff data

For the period studied, ANRH collected data on 147 different gauge stations. The location of the stations and the borders of the basins are given in Figure 5.

Using the rainfall maps and ETP maps, it is possible to calculate the rainfall and ETP of a basin (spatial averages for every month) and to confront them with the runoff. Figure 6 gives an example for the gauge 01 26 01 on the oued Cheliff.

## Rainfall–runoff modelling

One of the main objectives of the National Agency was to obtain an operational tool to properly evaluate the monthly discharges over ungauged catchments. The number of parameters used in the model has to be adapted to

the nature and accuracy of available data. Due to these constraints, the Loieau model was selected because it provides results similar to more sophisticated models like SMAP and GR2M but offers the advantage to have a parameter describing the annual average flows and a second parameter focussed on the distribution of flows during the year.

This modelling aims at working out a model which could recreate the monthly water resources surface from rainfall and evapotranspirations. This model must be simple enough so that its parameters can be easily adapted to non-gauged basins.

## Loieau's model

Of the various hydrologic models tested, the simplest and most successful is the Loieau model. It is a simple



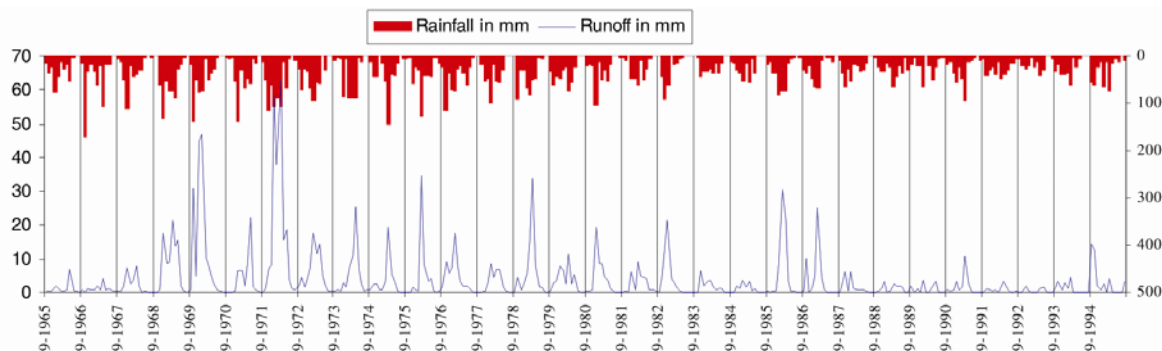


Figure 6. Monthly runoff and rainfall on the oued Cheliff.

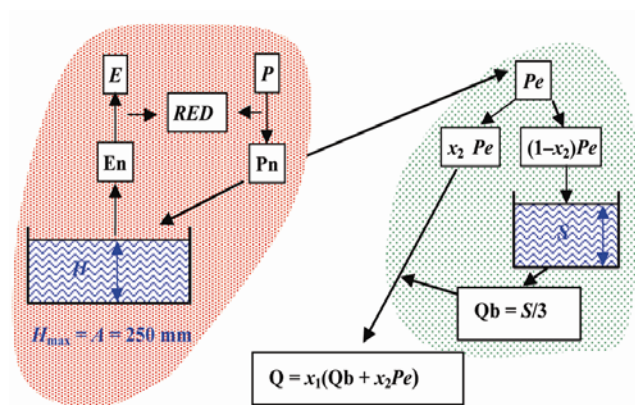


Figure 7. Principles of the Loieau model.

model with reservoirs derived from the GR2M model<sup>5</sup>. This model has two tanks, one of which is superficial with a height  $H$  limited to 250 mm. The state of this reservoir is mainly used for checking the real evapotranspiration  $E$  and the runoff. The second tank with a height  $S$  is used for delaying the runoff in time (Figure 7).

The entries of the model are the ETP  $E_i$  and the rainfall  $P_i$  of the considered month. The initial state of the system is given by the height  $H_{i-1}$  and  $S_{i-1}$  of both tanks at the end of the previous month.

First we correct the ETP estimations and rainfall by a common reduction  $RED_i$  in order to get  $En_i$  and  $Pn_i$ :

$$RED_i = \frac{P_i * E_i}{(P_i^{1/2} + E_i^{1/2})^2}$$

$$\Rightarrow PN_i = P_i - RED_i \Rightarrow EN_i = E_i - RED_i.$$

Then, we calculate an intermediate state for the first tank (ground) noted  $H$ , that will depend on the rainfall of the considered month and on the previous state  $H_{i-1}$  of the tank level.

$$H = \frac{H_{i-1} + A * Th(Pn_i/A)}{1 + \{(H_{i-1} * Th[Pn_i/A])/A\}}$$

( $A$  is the maximal capacity of the tank which is expressed in this case by  $A = 250$  mm and  $Th$  indicates the hyperbolic tangent.)

The rain in excess  $Pe_i$  is then given by  $Pe_i = Pn_i + H - H_{i-1}$ .  $Pe_i$  is the part of the rain of the month which is going to pass by.

At this stage, we can estimate the final level of the tank on the surface:

$$H_i = H * \frac{1 - Th(En_i/A)}{1 + Th(En_i/A) * 1 - (H/A)}.$$

The rain in excess  $Pe_i$  is partially allocated  $(1 - x_2)$  in the deep tank. Therefore its levels go into  $S_i$  by the following relation:  $S_i = S_{i-1} + (1 - x_2)Pe_i$ .

The  $x_2$  parameter of the model then gives the part of drainage through deep aquifers. The flow going out of this deep tank for the month  $i$  is  $Qb_i$ :  $Qb_i = 1/3S_i$ .

The total flow  $Q_i$  for the month is then the sum of the flow coming out of the aquifers as well as the rain in excess during the month concerned, evenly corrected by the parameter  $x_1$ .

$$Q_i = x_1(Qb_i + x_2Pe_i).$$

In this model,  $x_1$  monitors the function of production (falling rain transit, rain that passes by) and  $x_2$  controls the function of transfer (falling rain transit that passes by in the hydrograph).

It is important to define the  $Qb_i = 1/3S_i$  relation. In fact, it is easy and simple to obtain the depletion coefficient by a simple analysis of low flows. However, it is impossible to forecast a similar value for an ungauged catchment. The  $Qb_i = 1/3S_i$  relation has to be applied as an average and uniform value over the entire study area. This option allows the discharges to be correctly reproduced. Figure 8 gives an example of adjustment.

## Model parameters

Several criteria of adjustment were used, but no significant differences in parameters  $x_1$  and  $x_2$  were observed.

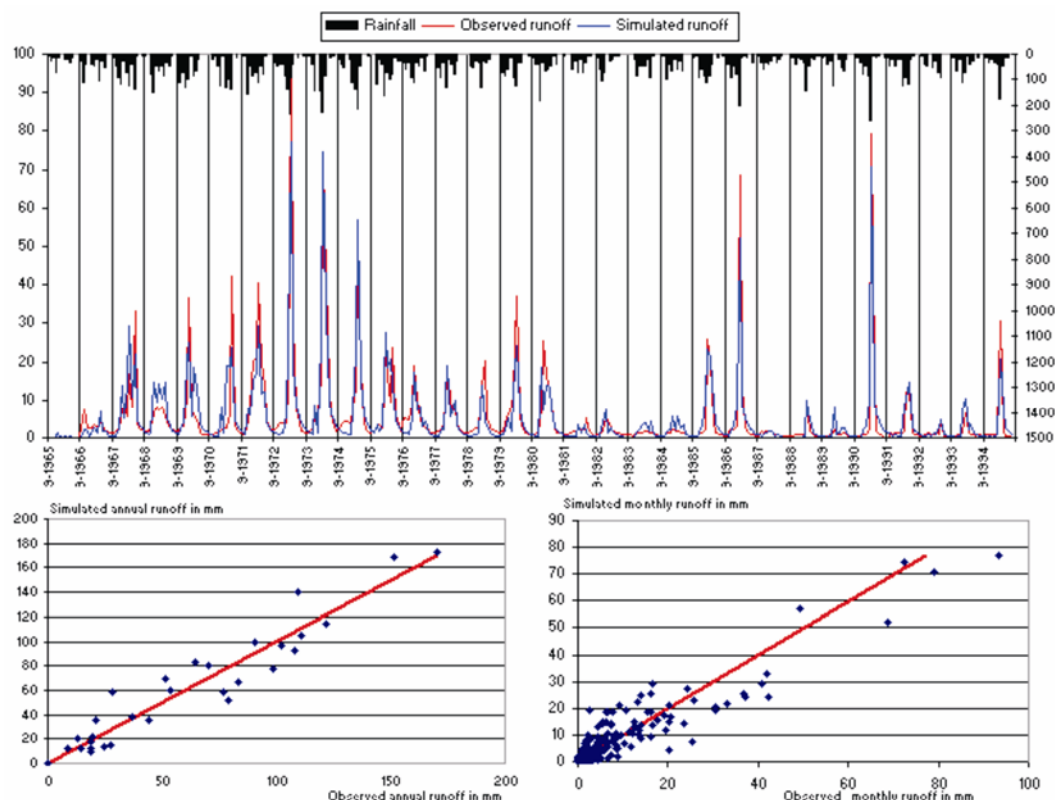


Figure 8. Example of adjustment of the model for the station 16 06 01 on the oued Tafna.

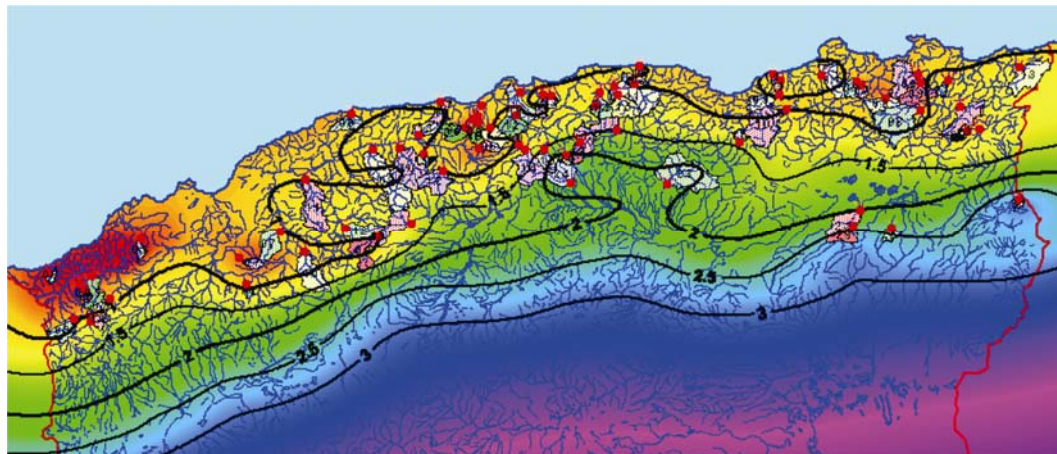


Figure 9. Map of the  $x_1$  coefficient.

For basins with an area less than  $1500 \text{ km}^2$ , we notice a rather good spatial layout of  $x_1$  and it is possible to produce a coherent map (Figure 9).  $x_2$  is much more sensitive to the geology of the basin and it is difficult to produce a consistent map.

### Effects of a possible reduction in rainfall

According to IPCC in the next few decades, the temperatures around the Mediterranean basin will increase.

However, the evolution of rainfall is much more discussed. Within the framework of the National Water Plan, the first hypothesis would be to suppose that the rainfall will not encounter any substantial change in the next 30 years. However, it is wise to consider the consequences of a decline in rainfall. At this stage, we suppose that rainfall could possibly decrease by 15% and a consistent decline with regard to all seasons. The temperature trends show a rise but there is little indication that they will have any effect on the real evapotranspiration, which would be limited by the available rain. For all

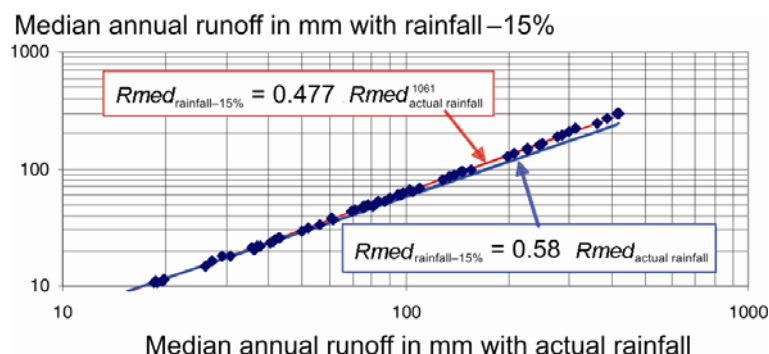


Figure 10. Impact of a decline of the rainfall on the annual median runoff.

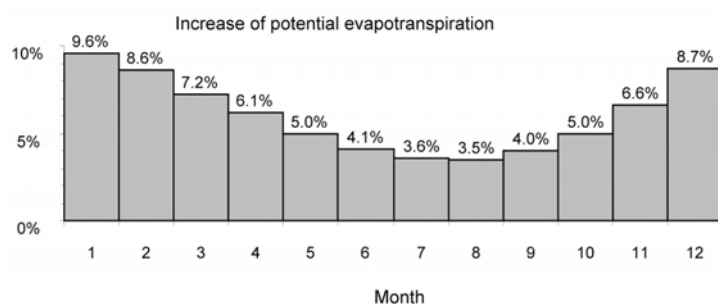


Figure 11. Impact of an increase of 1°C on the average monthly potential evapotranspiration.

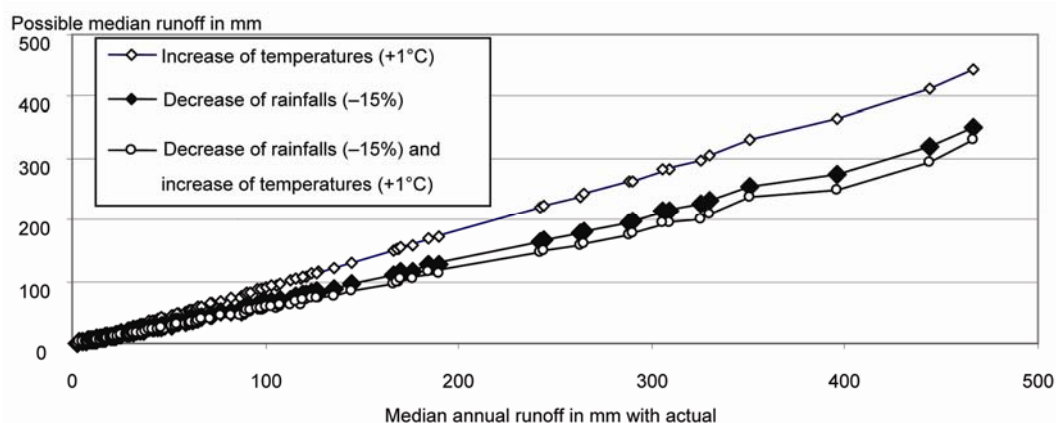


Figure 12. Impact of variations of the rainfall and temperatures on the annual runoff.

the hillside basins, where the surface is lower than 1500 km<sup>2</sup> and where the modelling is particularly reliable, we have to recreate the monthly contributions by setting 360 months of the former series, and by multiplying it by 0.85.

We notice that whatever be the rainy series, the runoff follows a Galton's layout (log-normal). However, the parameters change strikingly and in particular the annual median runoff  $R_{med}$  (Figure 10).

$$R_{med_{rainfall-15\%}} = 0.477 R_{med_{actual\ rainfall}}^{1.061} \quad (\text{for all the stations})$$

$$R_{med_{rainfall-15\%}} = 0.58 R_{med_{actual\ rainfall}}$$

(For the territory with the exception of the coastal landscapes,  $R_{med} > 100$  mm.)

A potential modification of rainfall over the northern part of Algeria will append with an increase in temperatures. The modification of ETPs is more difficult to express and analyse according to the actual status of the available data at the National Agency.

This potential increase of temperature has been integrated into the Penman ETP evaluations over 141 climatic stations. The increase of 1°C over the year generates an increase in ETP from 4% during summer and up to 10% during winter (Figure 11).

If the decrease in rainfall by 15% is combined with an increase in ETP, the effect is limited on the flows. As



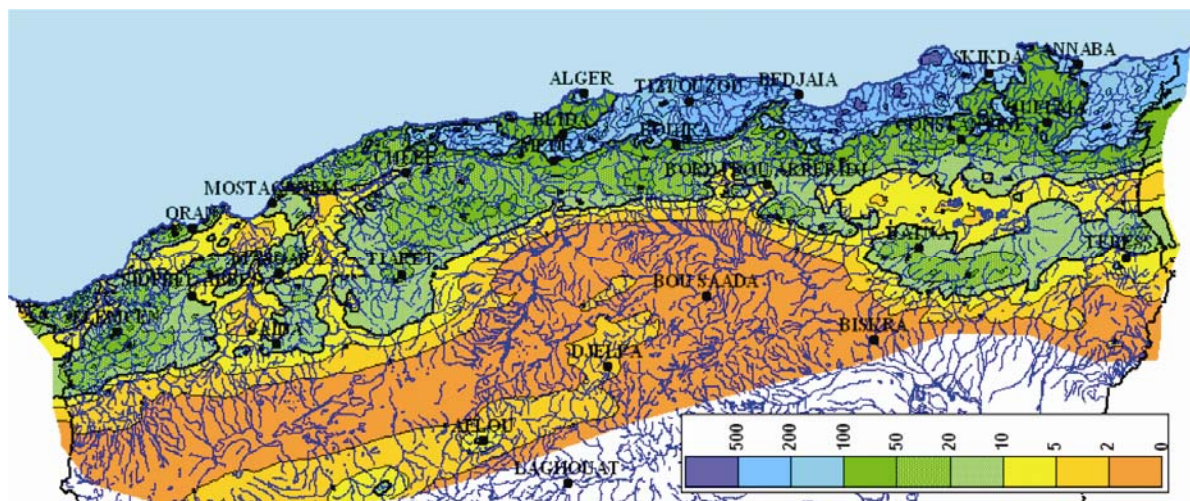


Figure 13. Annual median runoff with the current conditions of rainfall.

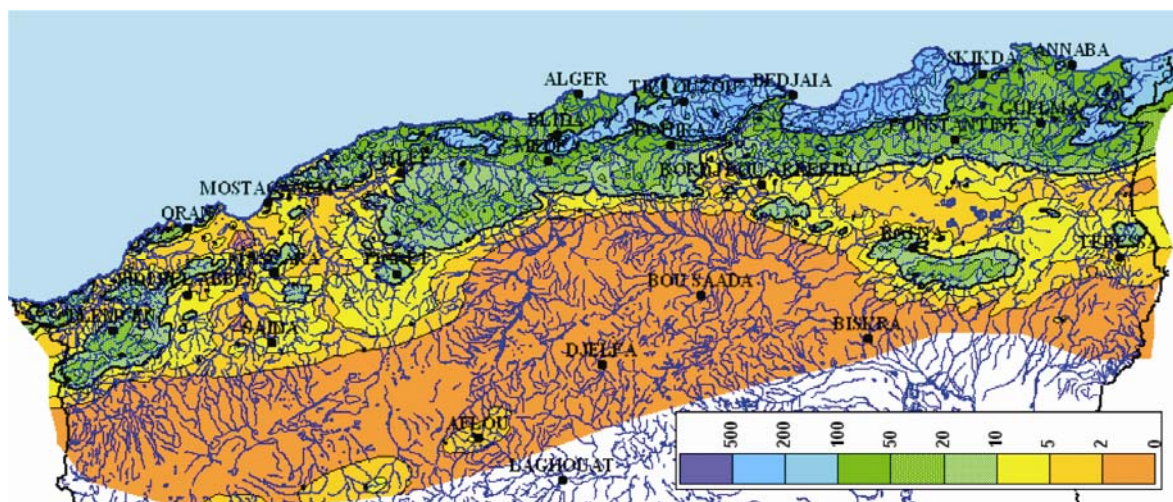


Figure 14. Annual median runoff with a pluviometry decreased in 15%.

shown in Figure 12, the main dominant factor is the decrease in rainfall for a potential modification of the flows.

Another way of assessing all the results of rainfall–ETP–runoff modelling is to draw maps of the annual median runoff. The map in Figure 13 is from ref. 6 and it matches the current conditions of rainfall.

A decrease of 15% in rainfall would translate on the scale of the whole country by a new map such as the one introduced in Figure 14.

## Conclusions

A relatively moderate decrease of the rainfall in North Algeria would have a major effect on surface runoffs and thus on the filling conditions of the hydraulic work. A 15% decrease of the rainfall would translate into a reduction of 40% in the runoffs! This first result urges us to pursue research in this area. Indeed, it is even necessary to refine the possible drop of rainfall in order to study the probabilities within the time of this decrease

and compare them to the likely life expectancies of hydraulic work subject to an important risk of silting up.

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