Hydrological and hydroclimatic regimes in the Ouergha watershed

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Abstract: This work consists in studying the hydrological and hydroclimatic regime of the Ouergha watershed and frequency analysis of extreme flows and extreme rainfall for peak estimation and return periods, in order to prevention and forecasting against risks (flood...). Hydrological regime analysis showed a regime of the rain type, characterized by rainfed abundance with very high winter flows, so strong floods. The annual module and the different coefficients show hydroclimatic fluctuations in relation to a semi-humid climate. The water balance has highlighted the importance of the volumes of water conveyed upstream than downstream, thus confirming the morphometric parameters of watershed and the lithological nature. Frequency study of flows and extreme rainfall showed that these flows governed by dissymmetrical laws based on methods Gumbel, GEV, Gamma and Log Pearson III.

1 Introduction

The watershed Ouergha is one of the main rivers of Morocco, it has severe hydrological characteristics that can cause risks. In order to prevent and forecast against these risks, an understanding of the hydrological and hydroclimatic functioning of the entire watershed is necessary. The study was started by a morphological characterization of the studied area, followed by a geological and climatological synthesis, and finally an analysis of the hydrological behavior. The Sebou watershed is located in the north-west of Morocco has 30% of the national surface water reserve and 50% of these reserves are provided by the Ouergha sub-watershed. The Ouergha Wadi extends over most of the Rif Mountain and forms a passage between the Rif and the Middle Atlas over an area of 6190 Km², this watershed represents 16.5% of the Sebou watershed of which it is part, this geographical situation favors the penetration of the freshness and humidity of the air

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masses to allow it to be the most rainy region in Morocco especially at the level from its climax Jbel Outka.

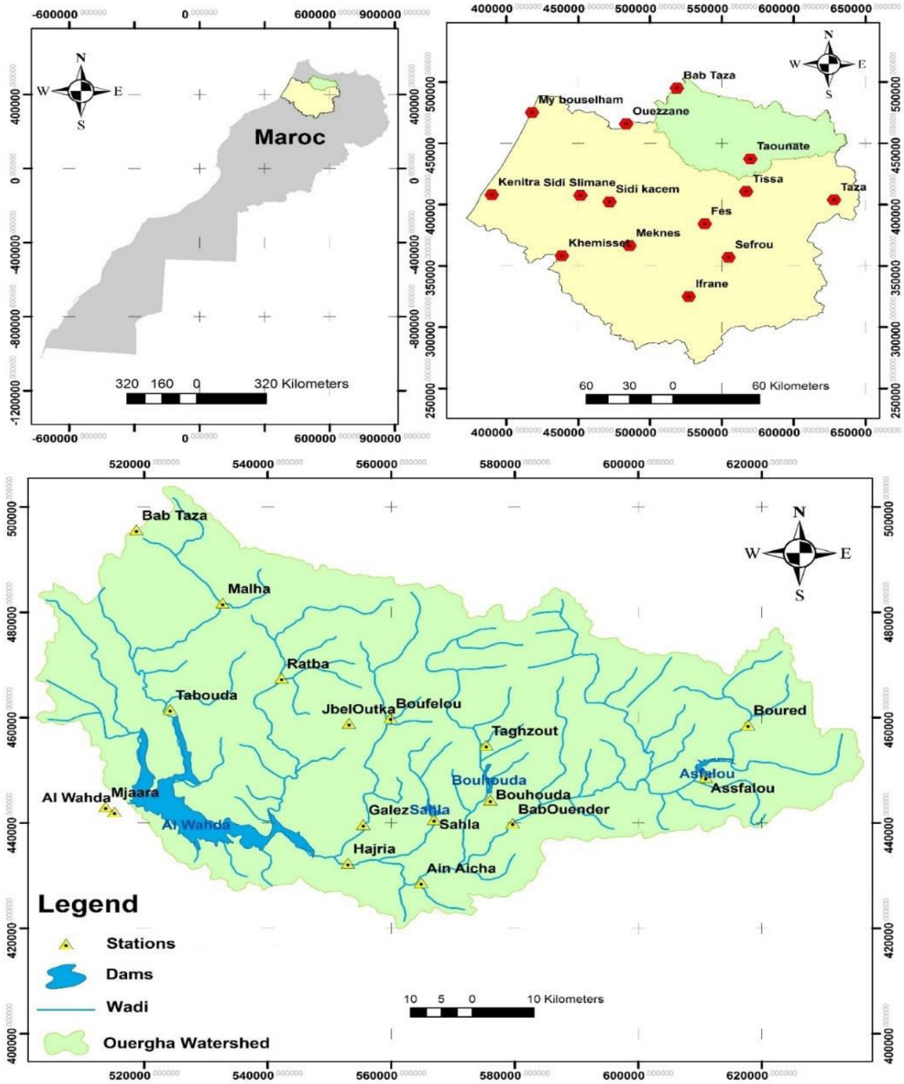

Fig. 1. Map of the geographical location of the Ouergha watershed

2 Materials and methods

2.1 Data

The data used must respect two important criteria: first, the length of the chronicles (cover the greatest possible period of time) and secondly, the quality of the data (the least possible missing data).

The hydroclimatic study is based on rainfall data at seven meteorological stations (Mjaara, Ain aicha, Bab Ouender, Bab taza, Boured, Jbel Oudka et Tabouda) which are represented in the following table provided by the management of the Sebou Hydraulic Basin Agency (Tab.1) and temperatures at the station (hajria) during the period (1981 to 2011).

Table 1: Coordinates of rainfall stations in the Ouergha watershed during the period (1981 to 2007)

Station	N° Station	X(Km)	Y(Km)	Z(m)
Mjaara	5128	513,6	443,2	92
Ain aicha	236	564,7	428,8	230
Bab ouander	1568	579,5	440,1	312
Bab taza	1586	518,5	495	902
Boured	2338	617	458	815
Jbel oudka	4626	553	459	1115
Tabouda	7283	524,25	461,6	180

Analysis of hydrological behavior based on flow and precipitation data at the stations (Ain Aicha, Galaz and Tabouda) during the period (1981 to 2011).

The figure below shows the different stations of the Wadi Ouergha watershed (Fig.2):

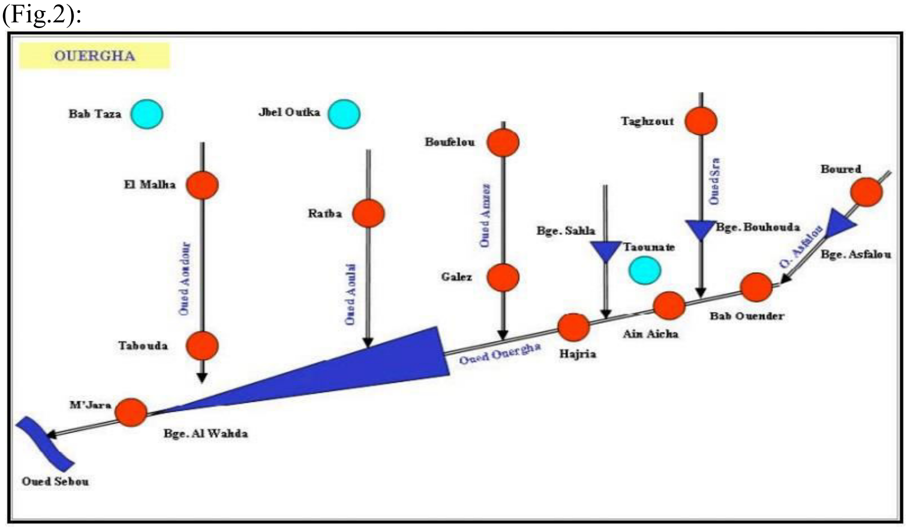

Fig. 2. Ouergha wadi watershed stations

2.2 Methods

The study was divided by four chapter:

- The first chapter presents general data on the basin and determines the physical characteristics of the watershed: it's about determining geometric characteristics (area, morphology, shape, topography, relief) and its hydrographic network. The purpose is to determine the role of these characteristics in the basin's hydrologic response (flow regime).

- The second chapter presents the geological context which is a determining element in the understanding of superficial and underground flow mechanisms in this basin. Substrate geology influences not only groundwater flow but also surface runoff. The geological study of a watershed in the context of a hydrological project is mainly intended to determine the permeability of the substratum and the influence of geology on the differentiation of the hydrogeological context.
- The third chapter is interested to study of the climatic characteristics whose study is necessary to the understanding of the mechanisms of water supply and circulation of the superficial waters. It intervenes in the establishment of the equation of the hydrological balance essentially by the precipitations, secondarily by the temperatures and thirdly by evapotranspiration.
- The fourth chapter will focus on hydrological characterization, to determine the flow regime in the watershed, as well as a frequency analysis to determine the period of flood return and flow adjustment by statistical laws.

3 Results and discussion

3.1 The physical characteristics of the watershed

3.1.1 Relief

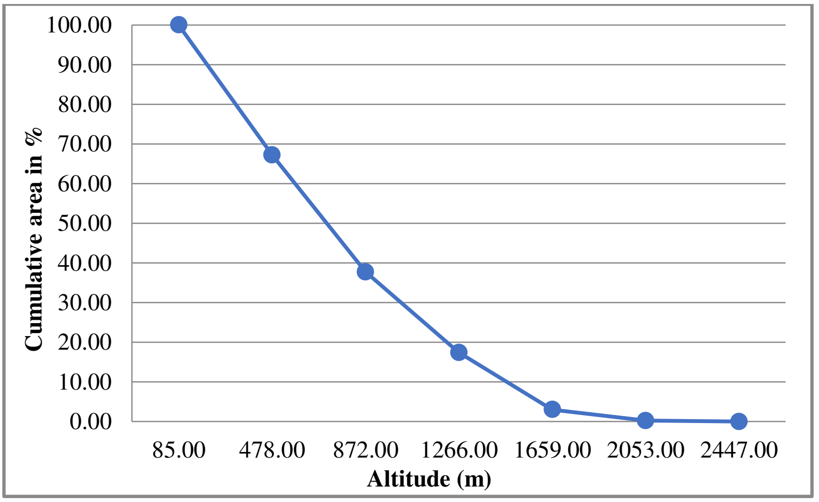

Fig. 3. Hypsometric curve of the Ouergha watershed

The analysis of the hypsometric curve confirms that there is an old basin in which the area is small compared to the altitude change. The differences in altitudes are very marked, which will make it easy to circulate the waters inside the basin and consequently larger earth losses.

3.1.2 Study of the slope

The index of the global slope (Ig) makes it possible to determine the importance of the relief on the basin. This index characterizes the relief of the basin. its formula is:

$$I_g = \frac{DU}{L_{eq}} = \frac{H_{5\%} - H_{95\%}}{L}$$

Ig : Overall slope index in m / km
Leq: Length of the equivalent rectangle (Km)
H5% : Altitude corresponding to 5% of the total area of the watershed
H95% : Altitude corresponding to 95% of the total area of the watershed

Table 2: Classification of relief according to (Ig) given by ORSTOM

Relief	Value of Ig
very low relief	Ig<0,002
low relief	0,002<Ig<0,005
rather weak relief	0,005<Ig<0,01
moderate relief	0,01<Ig<0,02
strong enough relief	0,02<Ig<0,05
strong relief	0,05<Ig<0,5
very strong relief	Ig>0,5

The overall slope index given by the formula is **7.3** or **0.07%.** According to the classification of relief given by ORSTOM (Tab.2), the value of the overall slope index of the Ouergha catchment shows that **the relief is strong.**

3.1.3 Morphological characteristics

The determination of the various physical parameters of the Ouergha watershed enabled us to define the topographic characteristics. The topographic watershed has a perimeter of 462Km, an area of 6190Km2 and a watercourse of 255Km long. The analysis of the distribution of the altitudes shows that the average altitude of this watershed is 776m. The watershed of Ouergha shows that the relief is strong, we have summarized the different physical parameters studied in the table (Tab.3):

Table 3: Morphological characteristics of the Ouergha watershed

Parameters	Values
Area	6190 Km²
Perimeter	462 Km
Gravelius compacite index	1,64
Length of the main watercourse	255 Km
Length of the equivalent rectangle	199,35 Km
Width of the equivalent rectangle	31,04 Km
Maximum altitude	2744 m
Minimum altitude	85 m
Average altitude	1266 m
Average slope	0,06%

3.2 Climatic characteristics

3.2.1 Emberger's climagram

The rainfall quotient of Emberger (Q2) corresponds to a synthetic expression of the Mediterranean climate taking into account the average annual rainfall and temperature (Sauvage, 1960). These last taken into consideration of a part, the average of the minimums of the coldest month «m» and secondly, the average of the maximums of the month the lime «M». These two extreme thermal values make it possible to evaluate the average temperature (M + m) / 2 and the average extreme thermal amplitude (M-m).

$$Q_2 = \frac{P}{\frac{(M+m)(M-m)}{2}} \times 1000$$

Q2 : The rainfall quotient of EMBERGER
P : Average annual precipitation (P=741mm)
M : Average of maximum of the hottest month (M=303.25°Kelvin)
m : Average of the minima of the coldest month (m=284.15°Kelvin)
Q2 =132

Emberger's climate is subdivided into zones corresponding to various Mediterranean bioclimatic floors (Fig.4).

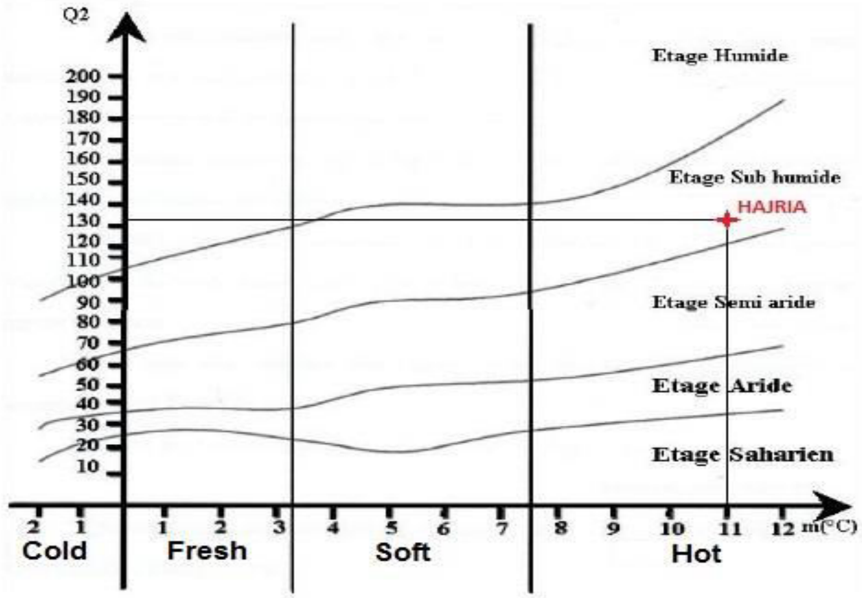

Fig. 4. Emberger's climagram in the watershed Ouergha (Hajria)

The result of this climagram shows that the watershed of Ouergha, at the Hajria station, is in a **semi-humid** climatic stage.

3.2.2 Water balance

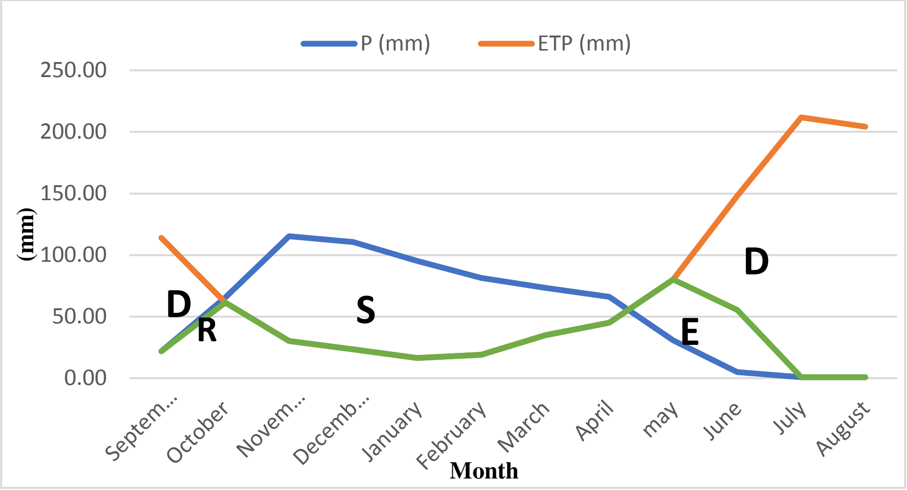

Fig. 5. Water balance of the Ouergha watershed at Hajria, estimated from precipitation, ETP and ETR from the Thornthwaite method

The future of the water brought by the precipitation during the year can be described by the water balance. The latter makes it possible to reveal the nature of each period of the year according to the entries and exits. According to the water balance of the Ouergha watershed (Fig.5), from the average balance sheet of the station Hajria, we can distinguish the periods:

- Phase D : considered a deficit phase and extends from June to the month of September.
- Phase R : it is a phase of reconstitution of soil water reserves, used during the previous months. This reconstitution is favored by an inversely proportional evolution of precipitation and evapotranspiration during the month of October.
- Phase S : It start from November to April.This is a phase where a surplus of water appears because of precipitation that far exceeds evapotranspiration. This surplus will be streamed and ensures the supply of groundwater.
- Phase E : It start from April until June. In this phase, evapotranspiration be done at the expense of easily usable reserves which are gradually depleted and disappear in the month of July. According to the water balance of the Ouergha watershed, four periods can be distinguished: a deficit period from June to September. The second period during the month of October corresponds to the period of return of the soil water reserves. A surplus is observed in the third period starting from November to April. The last the period starts from the month of April until the month of June it is considered as a phase of exhaustion of the reserves easily usable.

3.3 Hydrological characteristics

3.3.1 Relationship between flows and precipitation

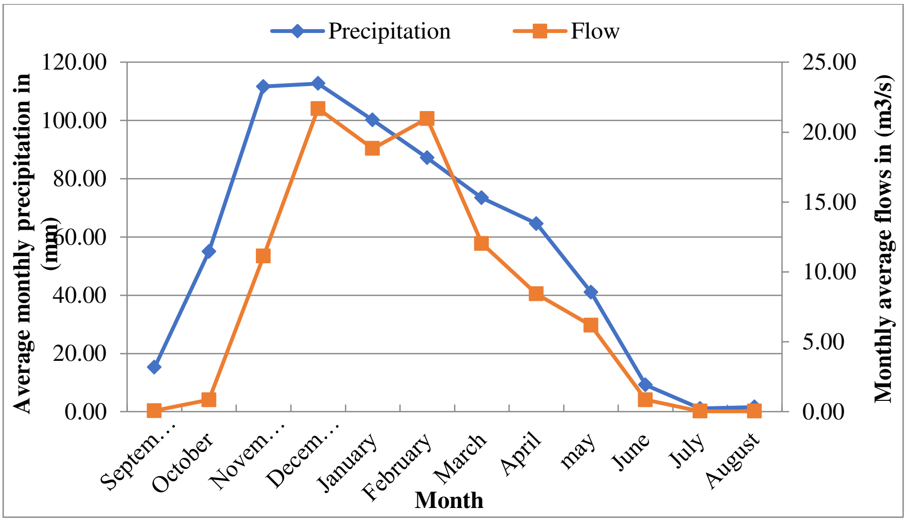

Fig .6. Evolution of precipitation and flow at the Galaz station

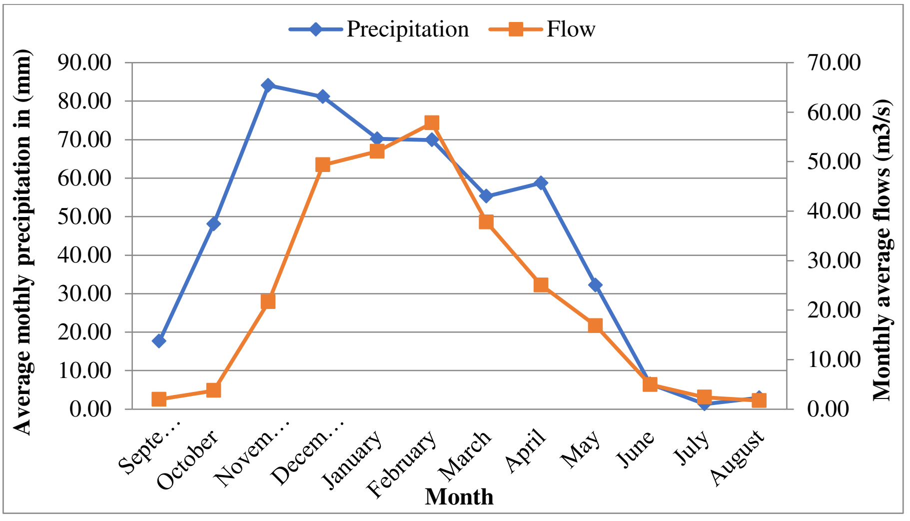

Fig. 7. Evolution of precipitation and flow at the Ain Aicha station

The analysis of these figures shows that there is a succession of floods and showers. For the Galaz station, there is a maximum of precipitation and flow in December, contrariwise Ain Aicha station has a maximum of precipitation in November followed by a maximum of flow with a delay of two months in February. This shift can also be explained by the lithological nature of the Ouergha watershed (semi-permeable to permeable). Thus, the waters that precipitate there runoff immediately after their arrival on the ground. The delay due to the lapse of time separating the triggering of the rain and its circulation after infiltration is very low and thus denotes the impermeability of the medium.

However, the monthly mean flow curve shows for both stations that runoff responds only to heavy rainfall. The low intakes of the months of March, April,

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May, June and July can be explained by intense evapotranspiration and may also be by irrigation.

3.3.2 Flood power

Floods are characterized by their suddenness and violence. The power of a flood can be determined by the coefficient of Mayer and Coutagne «I» whose formula is:

$$I = \frac{Q}{\sqrt{S}}$$

Q: The maximum flow of flood (m3/s)
S: Watershed area (Km2)

The values of the Mayer and Coutagne «I» index (Fig.8, Fig.9) at the Ain Aicha station are much larger than that of the floods at the Galaz station, which confirms a spatiotemporal variation of the rainfall and the brutal and violent floods especially upstream of the basin.

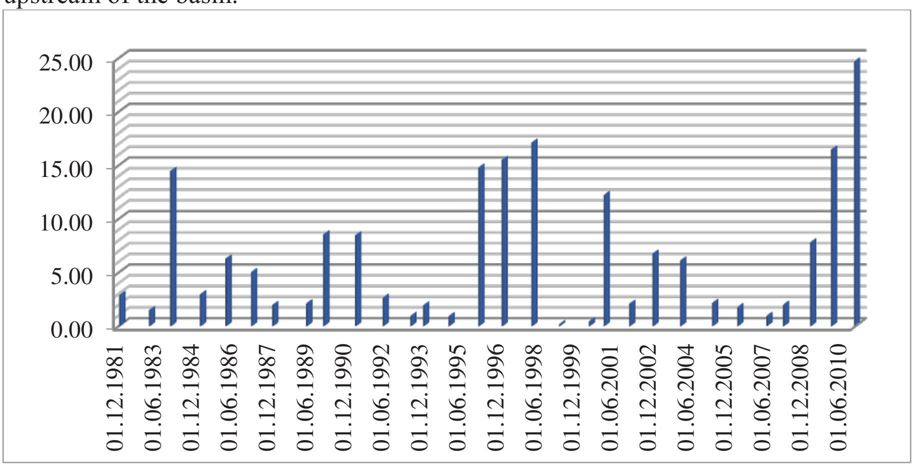

Fig. 8. Evolution of Coutagne and Mayer indice in the Ain Aicha station

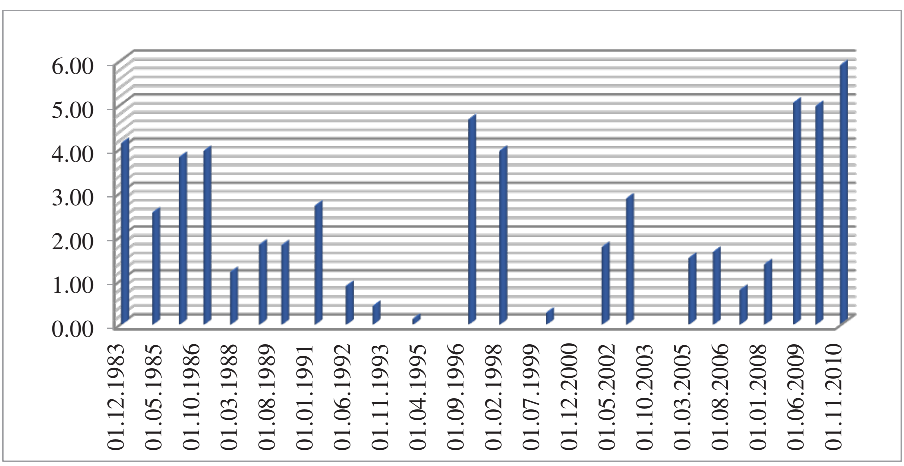

Fig. 9. Evolution of Coutagne and Mayer indice in the Galaz station

3.3.3 Quantiles estimated for different return periods

The return period T of an event is the average duration that separates two floods greater than or equal to this event. Conversely, a return period flood T is a flood where the average is equal to or exceeded at all time units return periods T. In general, the unit of time is the year. However, a return period flood T = 100 year, does not mean that it occurs once every 100 years, but this flood has a 1% chance of arriving each year for 100 years (Zian, 2011).

The results of the estimate quantiles for different return periods T, at the two stations, are shown respectively in (Fig.10, Fig.11).

The analysis of the fugures shows that the estimated quantiles are very close for the low return periods (T≤20), but beyond that, they deviate according to the law of adjustment in the two stations. For large periods of return (T≥2000years), the quantiles estimated by the law of GEV are very important at Ain Aicha level and for the other laws, the evolution is globally constant. For the Galaz station, the quantiles estimated by Gumbel and Gamma law are larger, but those estimated by the law of GEV and Log-pearson III are lower.

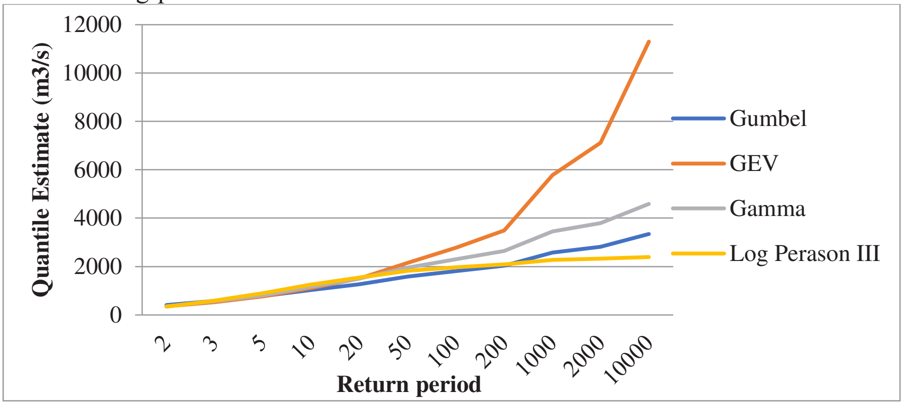

Fig. 10. Return times corresponding to the annual maximum flows recorded at the Ain Aicha station

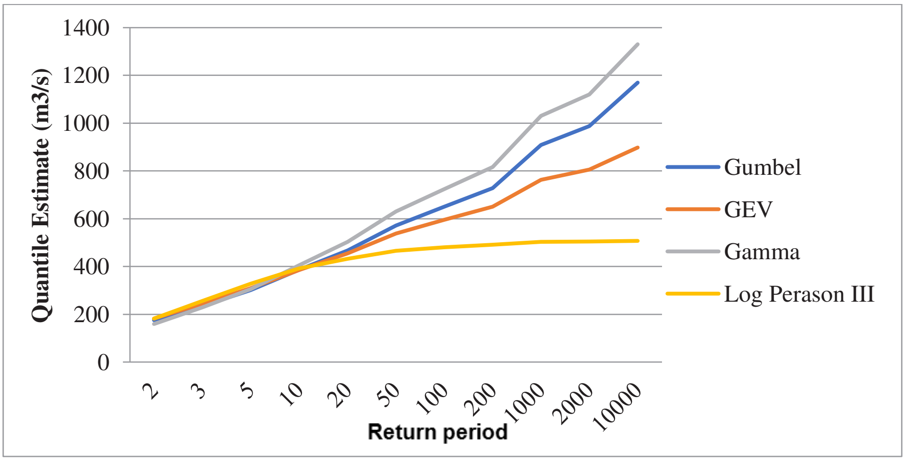

Fig. 11. Return times corresponding to the annual maximum flows recorded at the Galaz station

4 Conclusion

The catchment area of Ouergha is spread over an area of 6190 Km² and a perimeter of 462 Km. The watershed of Ouergha is elongated, the hypsometry of which is characterized by decreasing altitudes from North North-East to South South-West (barrage Al Wahda). According to the hypsometry curve, the average altitudes occupy the majority of the basin area. The relief is strong according to the index of the overall slope.

This watershed has three alignments oriented substantially E-W, located in the furrows, synclines Miocene and in the middle and upper valley. After the Mjaara station, the Ouergha takes a N-S direction along a fault line.

Rain has an annual average of 741mm throughout the basin with an average annual temperature of 18.7 ° C. The combination of precipitation and temperature, by different methods, has shown that the basin is in a semi-humid climate. The average value of the actual evapotranspiration is 523.6 mm / year.

The hydrological regime can be considered as a rain regime, characterized by the abundance of rain with very strong winter flows, thus of strong floods.

The estimated quantiles are very close for the low return periods ($T \leq 20$) for the two satations, On the other hand the large return periods ($T \geq 2000$ans), the quantiles estimated by the law of GEV are very important (11000m3/s) at the level of Ain Aicha and for the satation Galaz the law of Gumbel and Gamma are more important (1300m3/s).

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