International Journal of Global Science Research **ISSN: 2348-8344 (Online)**
Vol. 9, Issue. 2, October 2022, pp. 1866-1883 **DOI: 10.26540/ijgsr.v9.i2.2022.216**
***Available Online* at www.ijgsr.com**

Research Paper

Hydroclimatic Variability and Water Resources in the Upper Cheliff Basin

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Received: 17/09/2022
Revised: 24/09/2022
Accepted: 30/09/2022

Abstract: The Upper Cheliff area has experienced seasonal and annual rainfall declines over the last three decades. This variability has particularly increased since the 1980s and has had significant negative impacts on both surface and underground water resources, as well as on the precipitation cycle. The objective of this work is to study the impact of hydroclimatic variability and drought on water resources. The decrease in rainfall clearly led to a downward trend in water supplies. The analysis of the average minimum and maximum temperature during the period from 1968 to 2005 revealed an increase of the minima and maxima with an average of 1.4° C at Khemis Miliana station and 2.5° C at the station of Miliana.

The results obtained through the study of the severity of drought, using different indices such as rainfall indices and the standardized precipitation index, confirm the persistence and abundance of deficit years during the last three decades. The static level of the Upper Cheliff water table, during the period from 1990 to 2014,shows an irregular evolution characterized by a decrease during the period of low water, under the effect of the evaporation and a rise during the period of high water, due to the effect of artificial recharge (releases of water from the dam and / or the return of irrigation water).

Keywords: Hydroclimatic variability, severity of drought, water resources, Upper Cheliff.

Introduction:
Over the past two decades, the issue of hydroclimatic variability has been recognized as one of the major development issues at the local, regional and even international levels, alongside sustainable development, conservation and environmental protection Bi Tié Abert et al., (2006), Elmeddahi et al., (2016). Most areas of concern overlap or converge in the area of water resources management . In fact, the current trend is to consider that climate change responses are an integral part of decision-making on the sustainable management of water resources Adger et al., (2007).
Responses should be integrated into national planning for economic, social and regional development and harmonized with other resource and environmental management activities, both in practice and in decision-making (Agoumi, 2003).

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In Algeria, it is recognized that measures are needed to improve the ability to adapt to the hydrological variability and extreme events (floods and droughts), observed today in dynamic circumstances (including the current pressures of demography, economy, land use and regional development), as well as to reduce the significant vulnerabilities of society, the economy and the environment to future impacts (PNUD, 2009), (Khaldi, 2005).

The water resource in Algeria is limited and unequally distributed in space and time. This problem could limit the dynamics of economic growth, which will be aggravated by the decrease of this resource because of the impact of climate change that has become a reality in Algeria and whose effects on the environment are already visible Elmeddahi et al., (2016)

The issue of water is an ongoing challenge for North African countries in general and Algeria in particular (Khaldi,2005). Demand is constantly increasing, especially for the agriculture sector, which absorbs more than 87% of the available potential. In addition, and like the Mediterranean riparian countries, the socio-economic development of the countries of this region has been accompanied by a profound change in the relationship that man has with the water resource (Sassi, 2010), (Nassopoulos, 2012). Dependence on surface and groundwater is extremely variable from one country to another Milano et al., (2012).

In Algeria, the associated demand for water and drought has caused a decrease in groundwater resources. The scarcity of surface water resources has, in recent years, led to the intensive exploitation of groundwater resources, mainly for agricultural use, which has led to sharp drops in phreatic levels (Yahiaoui , 2015). Several works on rainfall in Algeria have been conducted since the last century Matari et al.,(1999), (Meddi & Humbert. 2000), (Meddi Hubert, 2003) Meddi , (2009), Dahmani et al., (2009), Medejerab et al.,(2011), Meddi et al., (2013), Assaba et al., (2013), Taibi et al.,(2015). Our study would complement those conducted in this area. It will allow us to analyze climatic parameters such as rainfall, temperature and flow deficit at the spatial and temporal scale and its consequences on water resources.

The impact of drought on water resources has become an increasingly pressing imperative in the western region of Algeria (Dahmani & Meddi, 2009). And as an objective to study mainly drought indicators as essential elements for the management of water scarcity (Khaldi, 2005), (Meddi, 2009). With this in mind, we study the climatic and hydrological data observed in the Upper Cheliff region; To identify the characteristics of drought and to study the consequences of reduced rainfall on groundwater potential.

Methodology:

Study area

The study area corresponds to the Upper Cheliff basin, located 110 km southwest of Algiers and is part of the Cheliff watershed.The Upper Cheliff basin, with a surface area of 6,905 Km2, is located between latitude 35° 71' and 36° 44' north and longitude 1° 73 'and longitude 3° 08'. The area corresponds to large mountain ranges and a plain with a relatively low slope (15%). Nevertheless, the sub-basins of the study area generally have fairly elongated shapes favoring slow runoff (Table 1). But the influence of relief is more important (Fig.1).

The alluvial plain is bordered to the north by debris cones which constitute the transition zone between the valley and the mountain. It is limited to the north by the dolomitic limestones of Jebel Zaccar (1578 m) and the sandstone of Jebel Gantas, to the south by the foothills of the Ouarsenismarno-clay-sandstone massif Touhari et al., (2015). We enter the east by the threshold of Djendel at 308 m above sea level and we

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come out to the West by the threshold of Doui at 248 m Mania et al.,(1990).

The use of various indices allows us to define the type of climate of the region. The annual aridity index of DeMartonne Moisselin et al., (2002) (I = 12.68) and that of the Emberger method (Morat,1969) Q2 = 42.2) indicate that the region is experiencing a semi- arid climate.

The climatic regime of the Haut Cheliff watershed is characterized by high aridity, the intensity of which is conditioned mainly by altitude and, to a lesser extent, by continentality Mehaiguene et al.,(2012).

In addition, the seasonal contrast is very marked, the rains that are often concentrated during the autumn, winter and spring are irregular, intense and violent (Mebarki, 2003), Meddi et al.,(2009), (Meddi & Boucefiane, 2013). During the rest of the year, the drought is considerable, especially in lowland areas where temperatures and evaporation are high.

Climatology is therefore characterized by:

- A semi-arid climate of continental type. Thermal amplitudes are quite significant between winter and summer: 36.75° C as the maximum temperature and 3.48° C as the minimum temperature.
- Average interannual rainfall ranging from 300 to 600 mm, with significant interannual and inter-seasonal variations. It is more concentrated in the altitudes, about 700 mm recorded on the southern slopes of Zaccar and 500 mm on the northern slopes of Ouarsenis.

The construction of the dams of Ghrib, Deurdeur, Harreza and Sidi Mhamed Ben Taiba has made it possible to regulate the flow of wadis and to supply irrigation water from April to September.

Table 1: Morphometric characteristics of watersheds in the study area.

Basin	Sub basin	Area (A) (km^2)	Perimeter (P) (km)	Minimum Altitude (m)	Maximum Altitude (m)	Compactness Index	Slope Index (m/km)	Specific slope (m)	Class of relief
Upper Cheliff	Cheliff Djellil	992,85	179,96	600	1800	1,6	16,91	532,84	Very strong relief
	Cheliff Ghrib	1383,69	176,81	500	1600	1,33	17,67	657,29	Very strong relief
	Cheliff Harbil	767,29	168,95	300	1300	1,7	15,01	415,78	Strong enough relief
	Deurdeur	743,97	142,68	300	1800	1,46	19,41	568,42	Very strong relief
	Cheliff Harraza	857,64	185,65	300	1600	1,76	23,87	651,09	Very strong relief
	Ebda	690,55	141,1	200	1500	1,51	23,73	619,08	Very strong relief
	Rouina Zeddine	898,54	173,69	200	1700	1,62	21,38	640,87	Very strong relief
	Cheliff Tikazele	570,52	142,58	200	1100	1,67	14,49	346,1	Strong enough relief
Total		6905,05		200	1800				

Hydrogeology

Jurassic limestones which constitute an important reservoir which is particularized by the presence of the cracks representative of a suitable medium for the storage of groundwater. However, the poorly known distribution density of its cracks poses enormous problems for the implantation of the wells. In the Zaccar Massif, the limestone is scarce only in the higher parts, it is found below the 750m (Mattaeur ,1958) .

The Mio-Pliocene sandstones are observed east of the plain on Djebel Gantas, the Pliocene sandstones can reach 200 m thick in the North, on the left bank they are non-existent since the

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quartenary alluvium are discordant on the Miocene marl. Above this reservoir is developed the alluvial reservoir whose hydraulic vertical continuity with the previous one can be locally disturbed by clay lenses (Mania & Djeda, 1999). This aquifer is characterized essentially by coarse alluvium and pebbles in the center of the valley with a thickness of 50 and 145m, a layer of clay and silt covers the coarse alluvium in the Southwest with a thickness of 7 and 20m. This alluvial layer is placed on a substratum of sometimes gravelly clay or marl Touhari et al.,(2015).

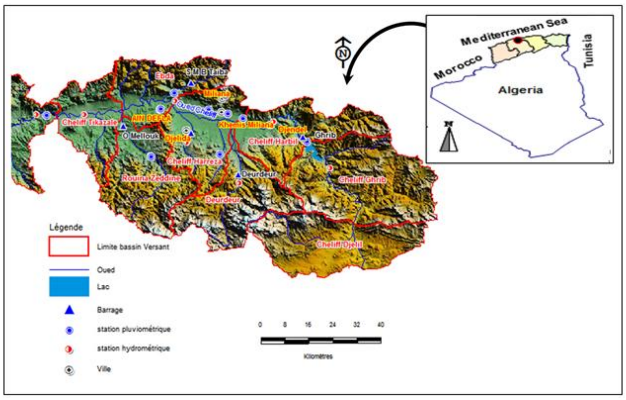

Figure 1: Location of the Upper Cheliff basin.

Data collection

The basic data of this work comes from the directories of the National Water Resources Agency and the National Office of Meteorology. We have data from three climate stations whose characteristics are shown in Table 1, the data, in question, are the maximum, minimum and average daily temperatures provided by National Office of Meteorology for a period from 1967 to 2005.

To highlight this trend, we have begun a study of climate variability over the last four decades. To characterize interannual climate variability, the National Office of Meteorology recommends a period of thirty years. In our case, 11 rain stations were selected for this study (Table 2 and Fig.1). They are spread over the whole of the studied region at different altitudes, of which the SidiMedjahed station remains the highest of the rainfall network is 850 m contrary to the station of Chlef presenting the lowest altitude of the network is 110 m, spreading for some from 1968/1969 to 2003/2004 for the others from 1968/1969 to 2016/2017. They have some gaps that do not exceed 10% at the time scale. The positions observed are positioned in Fig 1.

The stations in the study area provide daily rainfall data and are managed by the National Agency for Hydraulic Resources. As it can be seen that the coverage density in rainfall information is very unequal, from an area of low altitudes (high Cheliff plains where the network is more concentrated) to a zone of high altitudes (Ouarsenis and Dahra mountains where the network density is less important).

The Upper Cheliff Basin is virtually unheard of in hydrometric information. The hydrological data includes daily flow time series for 09 sites, the location of which is shown in Fig 1. They were all commissioned by the National Water Resources Agency (NWRA). The hydrometric station was chosen to meet two requirements: the length of the record must be equal to or greater than 30 years; refer to unaltered data. The series of data used extend over a period of 33 years (1968 to 2001). Watershed characteristics are shown in Table 2.

Methods

To characterize the severity of a drought, it is necessary to consider various aspects such as the rainfall deficit and its duration (Medejerab & Henia,2011).

We first analyzed trends in annual average minimum and maximum temperatures at the selected 03 climate stations. To assess the variability of annual precipitation over the region, we have used simple climatic formulas that are able to give good information, and also allow an efficient representation of the phenomenon (Zahar & Laborde,2007).

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In this respect we used the coefficient of variation expressed in percentage (%) knowing that:

$$CV = \left(\sigma / \bar{x}\right) \times 100 \quad \text{.........................(1)}$$

$\bar{x}$: Average of the series;
σ : Standard Deviation.

Table 2: Climatic and rain stations selected.

N°	station Code	Station name	Coordinates (m)			Observation period
			X	Y	Z	
Climatic stations (National Office of Meteorology)						
1	014401	Miliana	457 789	333 784	715	1967-2005
2	014411	Khemis Miliana	456 864	328 242	300	1967-2005
3	010201	Chlef	376 827	323 455	143	1967-2005
Rain stations (National water resources Agency)						
1	011405	GHRIB Bge	487250	318400	460	1968-2003
2	011512	Ain Soltan	464100	326500	295	1968-2003
3	011703	Bordj El Amir Khaled	455850	313800	500	1968-2003
4	011706	Khemis Miliana	458800	328200	285	1968-2013
5	011711	Sidi Lakhdar	452000	329650	250	1968-2003
6	011801	Arib Ebda	439650	335550	280	1968-2010
7	011803	Sidi Medjahed	452150	337050	850	1968-2014
8	011804	Ain Defla	434600	329900	270	1968-2014
9	011901	El Touibia	431350	312850	360	1968-2012
10	012203	Ponteba Defluent	393900	327400	140	1968-2003
11	012219	Chlef	378650	320500	110	1968-2017

The coefficient of variation often characterizes this variability; it is the ratio between the standard deviation of a series and its average (Camberlin , 1994).

To study the evolution of the spring and winter rainfall totals, the method of cumulation of deviations from the mean and the moving average method was applied Loup et al.,(1963). In our study we used three values: xi is replaced in the series by:

$$\frac{x_{i-1} + x_i + x_{i+1}}{3} \quad \text{.......................... (2)}$$

To help track inter-annual rainfall trends, several approaches have been developed. The methods used are:

Rainfall index(RI)

It is the ratio of the annual precipitation height Pi to the average annual precipitation height Pm.

$$RI = P_i / P_m \quad \text{.............................(3)}$$

where

RI Rainfall index

Pi Precipitation of the year i

Pm Average precipitation

A year is qualified as wet if this ratio is greater than 1 and dry if it is less than 1. To locate a rainfall in a long series of rainfall records, we use the proportional deviation to the mean (RIm) which differs from the rainfall index by subtracting 1 from this index.

$$RI_m = RI - 1 \quad \text{...................... (4)}$$

where

RIm Rainfall index mean

RI Rainfall index

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Cumulative indexes of successive years make it possible to identify major trends while ignoring slight fluctuations from one year to the next. When the sum of the indices increases, it is a wet trend. The trend is of the "dry" type, otherwise.

Standardized precipitation index (SPI)

Among the most used clues McKee et al.,(1993) is, too, often used; its calculation requires only long rainfall series and it has the great advantage of operating at various timescales and allowing short, medium, and long-term drought assessments.

The SPI is expressed as follows:

$$SPI = {(P_i - P_m)}/{\sigma} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

where

Pi Precipitation of the year i

Pm Average precipitation

σ Standard deviation

The interannual hydrological variations are characterized from the average annual flows of the different stations of the sub-watersheds. The method adopted is that of the flow index show a rainfall surplus or deficit for the year in question compared to a reference period:

$$L = {(Q_i - \bar{Q})}/{\sigma} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

where

Qi…..Average flow of the year i,

$\bar{Q}$ Average flow over the reference period,

σ Standard deviation of the hydrometric series over the reference period.

The analysis of monthly flows allows to highlight the river regimes can be translated by various numerical and graphical criteria among which we will remember, mainly the monthly flow coefficients (M.F.C)

$$M.F.C = {Q_m}/{\bar{Q}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where

Q_m Average monthly flow,

$\bar{Q}$ Average flow over the reference period.

Results and discussion

Climate trend

Temperature Variation

The annual average temperature analysis revealed an increase in the minima and maxima over the stations studied over the last four decades. This upward trend in temperature will result in an acceleration of evapotranspiration accompanied by a lack of water in the soil. Warming is approximately 1.4° C 2.1° C and 2.5° C between the first and last decade at the Chlef, Khemis Miliana and Miliana stations respectively (Fig. 2).

Rainfall Interannual variability

One of the main features of rainfall in our region is its great interannual variability. In fact, from one year to the next, the annual total can vary greatly, which has led to a detailed study of the interannual variability of rainfall.

The statistical parameters of the annual daily rainfall data series are calculated and summarized in Table 3

The ratio between the wettest year and the driest year may be greater than 4; the coefficient of variation represents this relative variability and can exceed 40%. This same table shows that the averages of the 11 stations are quite close to the medians and shows that the distribution law is symmetrical.

For a more detailed analysis, we will characterize interannual variability by interannual mean, moving average and precipitation index variables. Fig 3 represents this interannual rainfall variability over 4 typical stations for the period 1968 to 2014/2016.

Through these graphs, we observe that annual precipitation is characterized by irregular spatial and temporal variability. All the studied stations knew from the 80s until 2000, one of the periods most deficits in intensity and persistence. We also note the concordance of deficit years from 1980 to 2000 stations Chlef, Khemis Miliana and Ain Defla. For the Sidi

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Medjahed station the deficit was recorded from the mid-1980s until 2014.

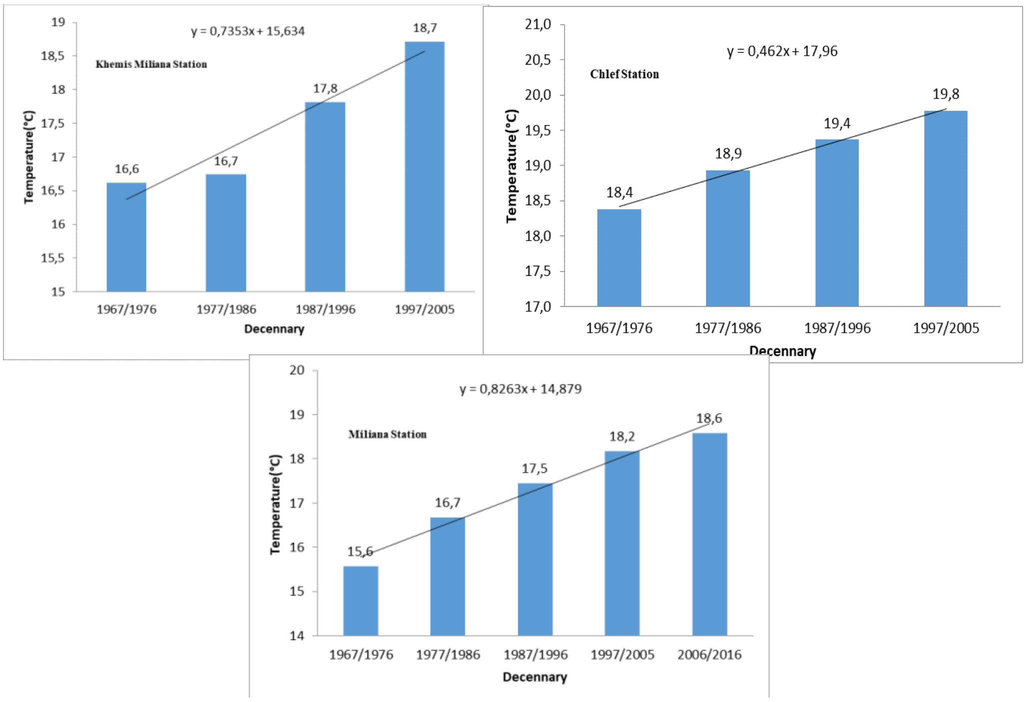

Figure 2: Ten-year average temperature at the Chlef,, Khemis Miliana and Miliana stations (1967-2005).

Table 3: Interannual precipitation Analysis at the different stations.

Station name	Maximum (mm)	Minimum (mm)	standard deviation	Mean (mm)	Median (mm)	Coefficient of variation %
Ghrib Bge	676,9	237,5	111,2	456,3	462,7	24
Ain Soltane	752,2	209,7	134,4	454,2	450,5	30
Bordj El Amir Khaled	1065,4	174,1	180,05	413,23	388,2	44
Khemis Miliana	711	174,3	103,39	431,25	435,1	23
Sidi Lakhdar	683,09	187,8	103,25	405,33	401,4	25
Sidi Medjahed	1109,80	291,50	198,50	647,67	643,60	30
Arib Ebda	786,1	283	134,7	514,3	525,9	26
Ain Defla	627,1	246,9	99,9	447,7	450,8	22
El Touaibia	503,7	153,5	86,7	314,2	309,2	28
Ponteba Defluent	696,3	174,1	112,04	407,65	413,2	27
Chlef	559,5	165	92,27	351,95	352,3	26

Moreover, we observe in the same stations, rainfall surpluses relating to the period from 1968 to 1979 and the period from 2002 to 2009, except at the station of Miliana the rainy year is 1990-1991.

From these criteria, following the evolution of the SPI index during the analyzed period presented in Fig 3, it was possible to estimate the intensity and the duration of the drought in the studied stations.

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The SPI index allows us to observe the interannual variability at the Sidi Medjahed station as well as the periods of surplus which extend from 1968 to 1984 interspersed with rare periods of deficit, while the really deficit period extends from 1985 up to 2014 with wet years in 1995, 2000 and 2010. This is mainly due to the decrease of winter rains.

The most intense events during 1993 and with extreme values reaching -2.49 at the Milian khemis station, -2.02 at Chlef and -2.01 at Ain Defla, located in the Upper Cheliff plain and the most intense, reaching +2.72 at Milian khemis station during 1971.

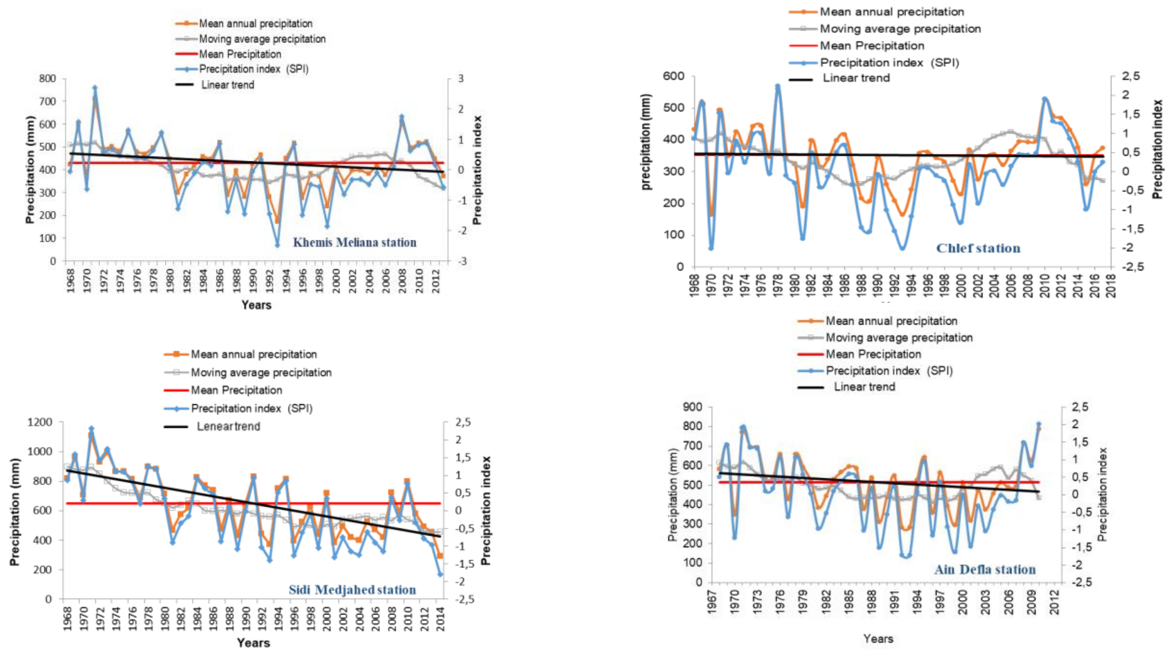

Figure 3: Mean annual precipitation, moving average and precipitation index at Chlef, Khemis Miliana, Ain Defla and Sidi Medjahed stations.

Seasonal variation

The study of seasonal variability is essential to see whether the decrease or increase in rainfall is specific to a particular season or to several seasons Assaba et al.,(2013).

Table 4 gives the winter and spring averages for the 5 stations selected, considering the two periods (1968-1981) (1982-2014 / 2016). The latter shows that the average for the second period is always lower by contribution to the first, considering the two seasons.

The spring totals are down sharply in the early eighties, this appears very clearly for the stations of Bordj el Amir Khaled (-43%), Sidi Medjahed (-47%) and khemis Miliana (-30%). The winter season also experienced fairly similar variations for the three stations, so that there was a decrease in rain during the three decades from 1980 to 2016.

Interannual flows variability

The strongest variability obviously characterizes sub-basins with semi-arid climatic influence; it is in the Cheliff Harreza basin in El Ababsa that the record variability is noted (C.V = 1.28) (Table 5). The coefficient of variation decreases to 0.68 in Oued Cheliff at Ponteba Déflue, but remains high in the Cheliff Tikazale basin in El Abadia (around 1.06) and Arib Cheliff (0.91) reflects the compensating effect of the interannual variability of the flow in the tributaries of the left and right bank of the basin.

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Table 4: Analysis of winter and spring averages over the two periods (1968-1981) and (1982-2014 / 2016).

Stations	Winter			Spring		
	Mean 1	Mean 2	% of reduction	Mean 1	Mean 2	% of reduction
Khemis Miliana	198,75	167,77	-16%	154,06	107,73	-30%
Bordj el Amir Khaled	229,48	134,59	-41%	168,56	95,51	-43%
Sidi Medjahed	357,63	257,28	-28%	280,62	149,81	-47%
Ain defla	216,54	175,98	-19%	157,47	118,45	-25%
Chlef	172,51	135,79	-21%	111,06	96,87	-13%

Table 5: Annual flows variability of (m^3/s) in the study area.

Nom station	Minimum	Maximum	Variance	Mean	Standard deviation	Cv%
Djenen.B.Ouadah	0,52	15,13	14,88	5,16	3,86	75%
Arib cheliff	0,23	17,11	19,21	4,83	4,38	91%
El Abadia	0,11	46,84	104,83	9,66	10,24	106%
Ponteba defluent	0,59	25,00	50,15	10,39	7,08	68%
El Ababsa	0,01	0,96	0,05	0,18	0,23	128%
Arib Ebda	0,26	9,57	4,82	2,56	2,19	86%
Bir ouled Taher	0,06	1,73	0,17	0,52	0,41	78%
Sidi Mokarfi	0,20	4,81	1,06	1,095	1,03	94%

This variability, which is generally strong, is related to the predominantly rain fed watercourses. The low contribution of groundwater reserves accentuates the phenomenon even more since it is a "dry" climatic period.
The corresponding graphs (Fig. 4 and 5) show large year-to-year flow fluctuations and an abundance of runoff during the period (1968 to 1982) and indigence from 1983 to 2001.
As evidenced by the values of the flow index, which in addition to high amplitude, are mostly less than unity: 18 hydrological years out of 34 are, in fact, deficient and most, 15 years since 1987 to 2001. This fact confirms the hypothesis formulated during the "dry" climatic trend of these two decades of 1980-2001. The exceptional water supply of 1969, represented by an index of about 3.63 at El Abadia station, can be attributed to strong cold-season floods experienced by Oued Cheliff during this year; it clearly opposes the strong deficit of 1992 (-0.79).
The flow index rose to 3.60 and 2.95 during 1984 and 1986 at Sidi Mokarfi and Bir Ouled Tahar stations respectively (Fig. 5).
Thus, it can be said that the annual flow undergoes great variations during the period considered for the different stations of the Upper Cheliff basin.

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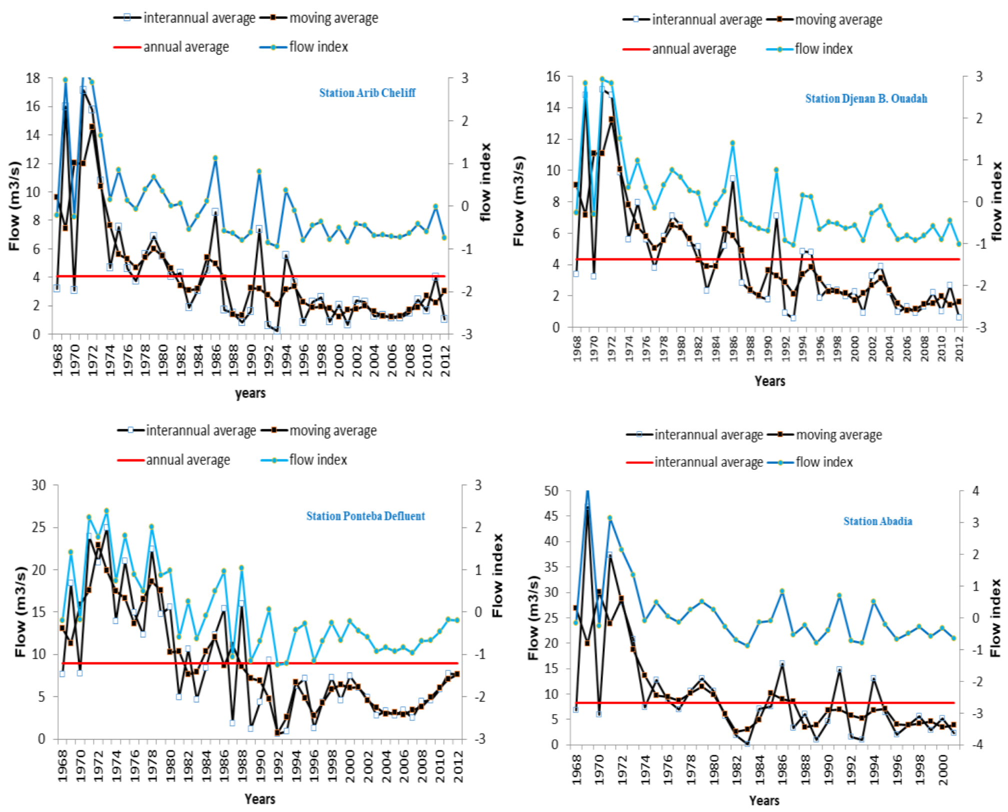

Figure 4: Interannual mean, moving average and flow index at stations in the main wadi of Cheliff (1968-2001).

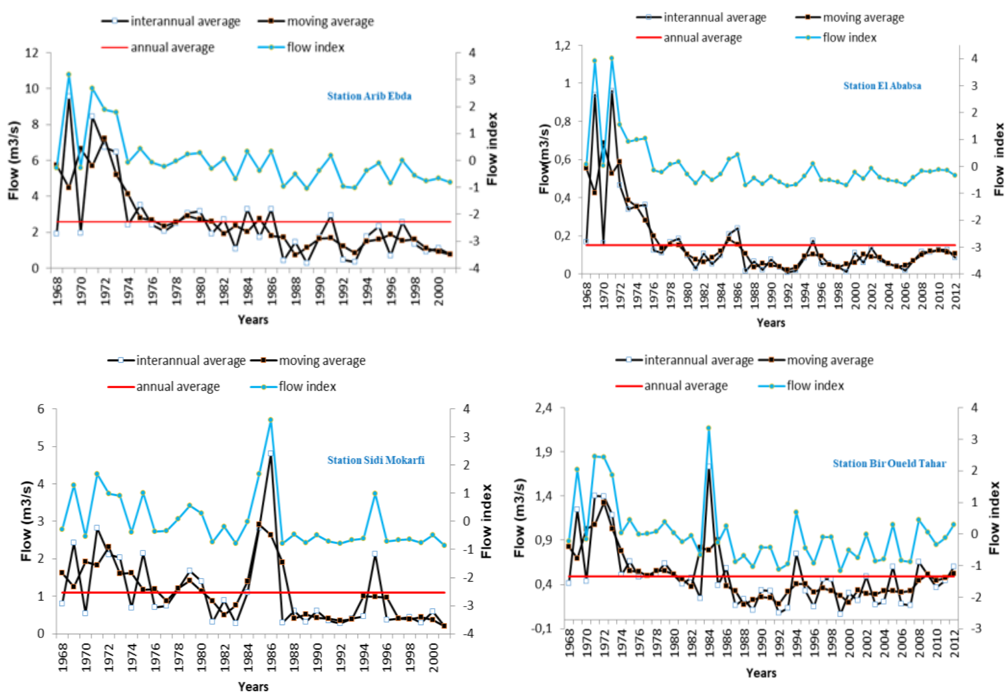

Figure 5: Interannual mean, moving average and flow index at stations in the main wadi of Cheliff (1968-2001).

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Monthly flows variation

Based on Fig 6, the high water period begins in December for Wadi Cheliff at the stations studied; the maximum flow is reached in February and March. The period of low water begins in the month of April. The minimums are in June, August, September. Moreover, there is an increase again in July and August at the station of Ben Ouadah Djenan probably due to the enormous release of water Ghrib dam located on Wadi Cheliff upstream of the station. It should be noted that the minimums in this basin are high (0,16).

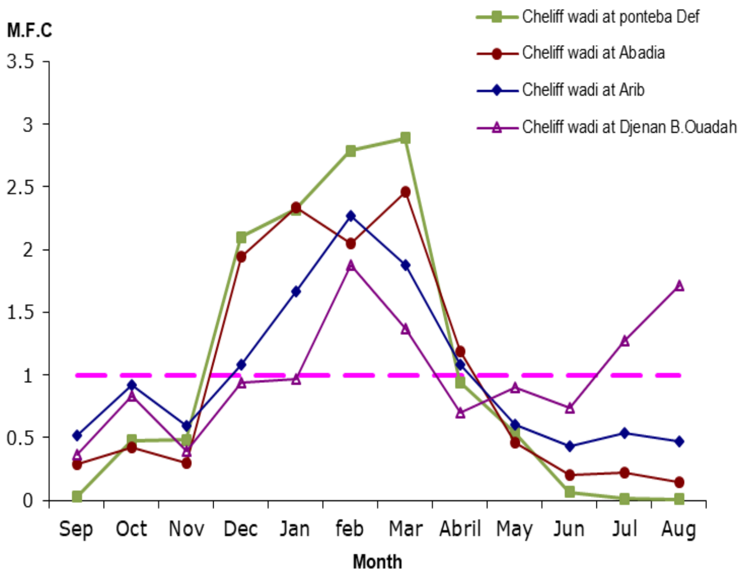

Figure 6: Curves of M.F.C at stations on the main wadi of Cheliff.

Relationship between flow and precipitation

An analysis of the relationship between rainfall and runoff shows that it increases with increasing rainfall (Fig. 7). The correlation by the simple linear regression method between the mean rainfall over the Upper Cheliff Basin and the flow shows a good correlation. The correlation coefficient varies from r = 0.70 (between the rainfall station 011901 and the hydrometric station 011905) to r = 0.83 (between the rain station 011703 and the hydrometric station 011715), for the confidence interval equal to 95% (Fig.7). Surface flow and rainfall are clearly attached. The flow and the climate are strongly dependent (Riad, 2003) .

Annual deficit of the flow and its correlation with precipitated water heights

To make the balance sheet expression more meaningful, another variable is the flow coefficient which, as a relative value, better reflects the diversified role of the physicogeographic factors specific to each basin Mehaiguene et al.,(2012) . The results presented in Table 6 are only approximate because of the artificial disturbances of the natural flow regime.

In general, there is a decrease in the coefficients of flow from north to south and precisely from east to west, the increase is very sensitive to the North and East; in the mountainous areas of the basin, Ce = 45.5% in the Arib Ebda basin, Ce = 25% and 24% at the Ghrib Amont and Djenen.B.Ouadah stations respectively.
The flow deficit varies between 282.9 mm at Ghrib Amont and 460.90 mm at Arib Ebda (Table 6). The main advantage of the runoff

International Journal of Global Science Research
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Available Online at www.ijgsr.com

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DOI: 10.26540/ijgsr.v9.i2.2022.216

deficit is to estimate the relation that links it to the precipitated water heights, in order to extrapolate the average annual water slide that has passed through various uncontrolled areas of the basin. This is why the curve of Coutagne's law D = f (P) established represents only a solution approach (Fig. 8). The points obtained tend to represent two curves likely reflecting the two major opposing climate regimes of the basin.

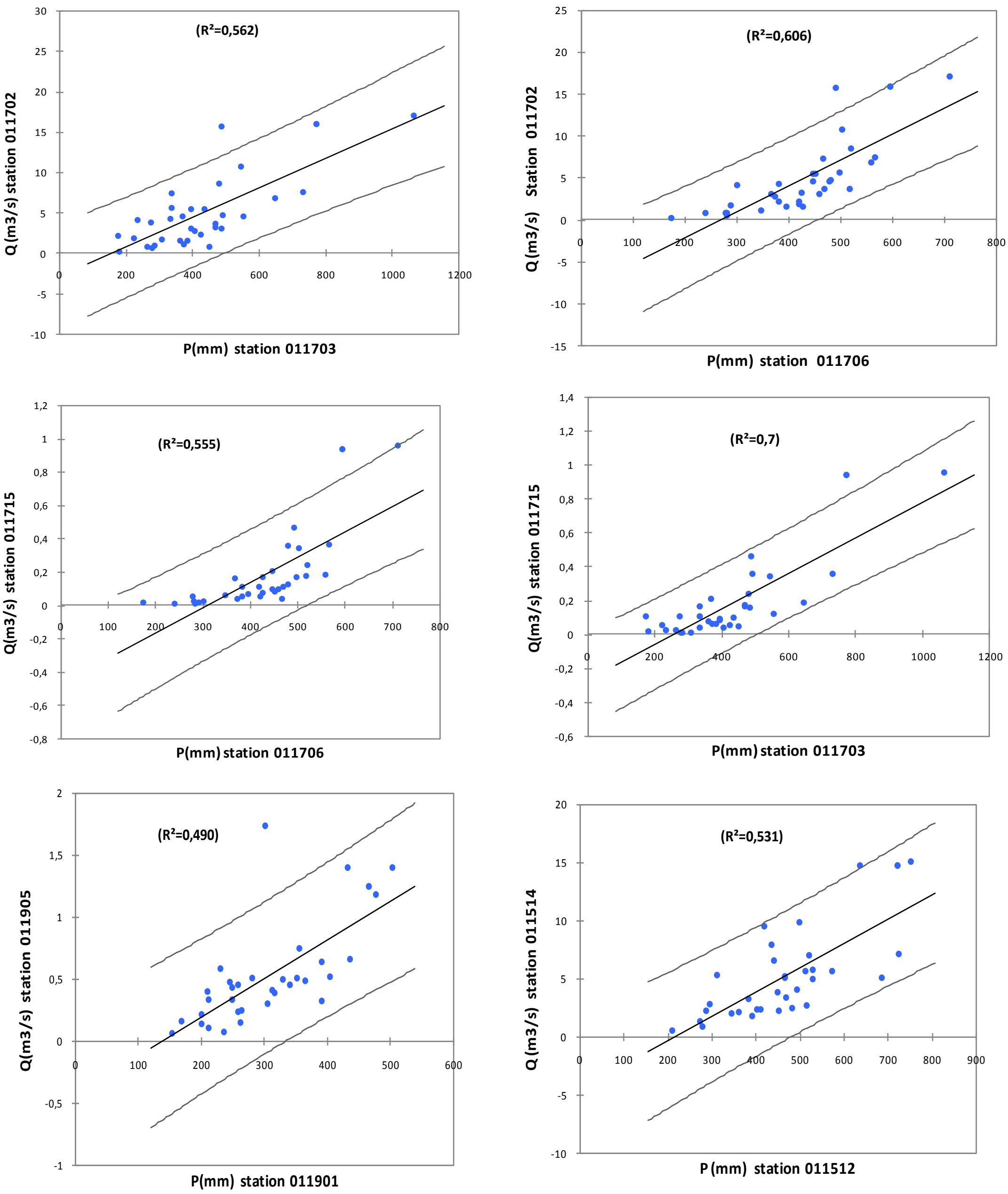

Figure 7: Relationship between rain and flow, period (1968-2001).

International Journal of Global Science Research **ISSN: 2348-8344 (Online)**
Vol. 9, Issue. 2, October 2022, pp. 1866-1883 **DOI: 10.26540/ijgsr.v9.i2.2022.216**
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Table 6: Flow variations, specific flow and deficit in the upper Cheliff basin (1968-2001).

station code	station name	Wadi	Area S (Km^2)	Annual flow (m^3/s)	Specific flow (l/s/km^2)	Runoff E(mm)	Annual runoff (hm^3/an)	Runoff coefficient C=E/P (%)	Rainfall P (mm)	Deficit D=P-E (mm)
011407	Ghrib Amont	Cheliff	1898	4,3887	2,3123	6,50	138,402	25	289,3	282,90
011514	Djenen.B. Ouadah	Cheliff	1164	4,3641	3,7492	118,24	137,627	24	483,2	364,96
011602	Sidi Mokarfi	Deurdeur	500	1,0947	2,1893	69,04	34,521	15	466,2	397,16
011702	Aribe Cheliff	Cheliff	2204	4,8254	2,1800	69	152,170	15,1	458,2	389,20
011715	El Ababsa	Harreza	102	0,1761	1,7200	54,5	5,550	13,9	392	337,60
011801	Arib Ebda	Ebda	270	2,5649	9,4900	299,6	80,880	45,5	658,70	460,90
011905	Bir Ouled Taher	Zeddine	435	0,5228	1,2000	37,9	16,480	8,3	456,5	418,50
012001	El Abadia	Cheliff	4098	9,6593	2,3500	74,3	304,610	15,9	466,5	392,60
012203	Ponteba Defluent	Cheliff	4704	10,3947	2,2098	69,7	327,807	15,3	456,50	386,90

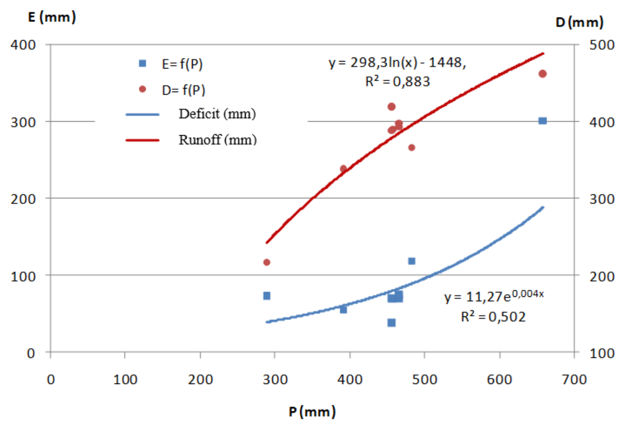

Figure 8: Interannual runoff and deficit (1968-2001).

Impact on groundwater

Static levels variation

The aim of this study is on the one hand to try to find the trend hydroclimatic regimes in the studied aquifer system and on the other hand to evaluate the impact of this trend, if it exists, on the static levels of the aquifer in time.

The monitoring of the evolution of the static level of the water table in time was carried out using the piezometric surveys (the measurements were made by the National Agency for Hydraulic Resources) of several high and low water campaigns during the period from 1988 to 2014. A sampling network of water points (Fig. 9); shows the distribution of 28 points and covers the entire plain from East to West.

The piezometric level of this aquifer varies according to several parameters: precipitation, operating conditions and the nature of the roof of the aquifer Touhari et al.,(2015). Two cases of evolution are observed (Fig. 10 and 11):

the variations of the static level are strongly influenced by the rains (period high and low water);

a temporary operation, where the static level, shows a sudden decrease due to the pumping effect lasts during the period of high water May 2007, in the totality of the water points: W84-12 (South), W84-196 (North), W084-125 and W84 / 127 (West), W084-155 (South), W84-143 (South), W85,23 and W085-38 (East), knowing that this year is an average year with a hydraulicity (Ki = 1,1), the level returns to its initial state during the following year (Fig. 10). Same remark of the disturbance during the dry years of 1991, 1993, 2002, 2005 and 2011, due

International Journal of Global Science Research ISSN: 2348-8344 (Online)
Vol. 9, Issue. 2, October 2022, pp. 1866-1883 DOI: 10.26540/ijgsr.v9.i2.2022.216
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to the overexploitation of the aquifer to ensure irrigation.

Although for the low water period this case occurs for several years 1991, 1993, 2002, 2005, 2007, 2011 and 2013 at the Center, North, South, West and East of the aquifer.

The comparison of the static level between the high and low water periods made it possible to establish the graph of variation of the static water table during the period from 1990 to 2014 (Fig.12). This operation showed that the greatest fluctuations occur in the east, the center and the north of the aquifer and can reach -36 m in 2007 at water point W85-14 (due to overexploitation of the water table). ensure irrigation) and -18.09m in 2002 at water point W84-92.

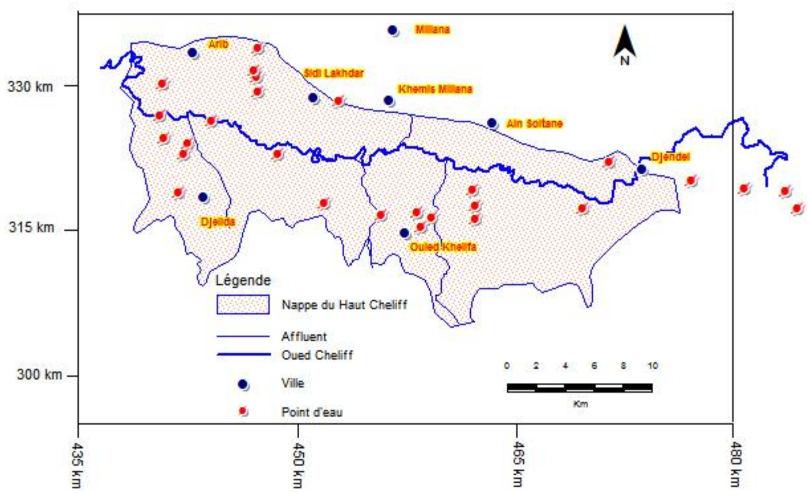

Figure 9: Location of water points in the Upper Cheliff plain.

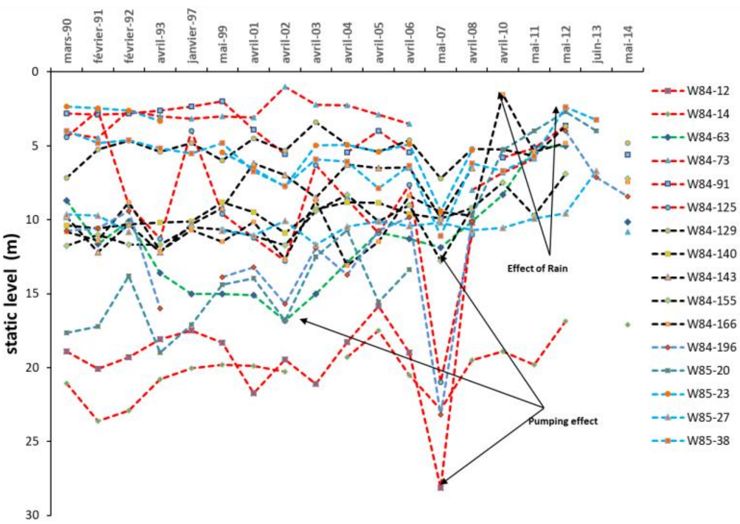

Figure10: Temporal evolution of the piezometric level during the period of high water (1990-2014).

To the west and to the north of the aquifer, these vary between -19.8m in 2008 at point W84-185 and -18.09m in 2002 at point W84-92.

It should be noted that the piezometric level experienced an increase at the water point (W 85-38, + 9.21m and W84-140, +11.6) during the years 2005 and 2008 respectively, this is

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probably due to the artificial recharge from the water releases of the Ghrib and Deurdeur dams in the Cheliff main wadi for the irrigation of the Haut Cheliff perimeter (with an average volume of about 33 and 27Hm3 / year respectively).

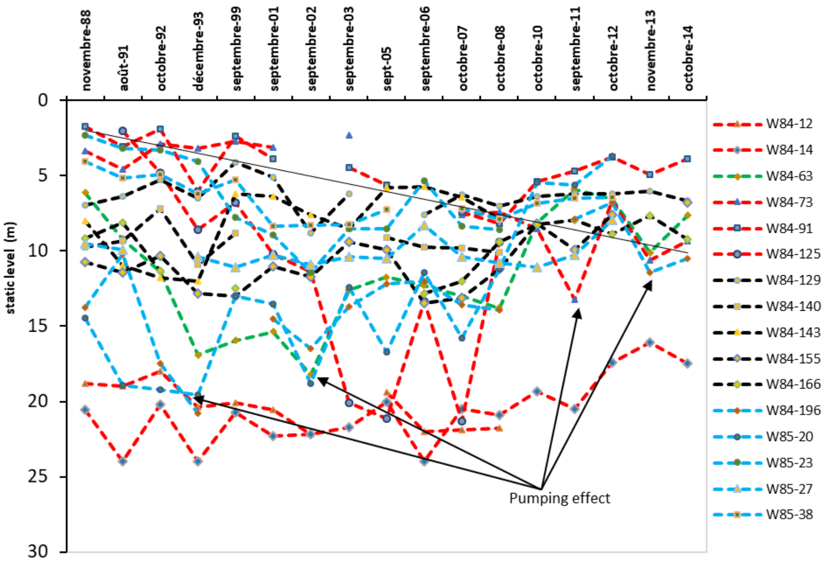

Figure 11: Temporal evolution of the piezometric level during the period of low water (1988-2014).

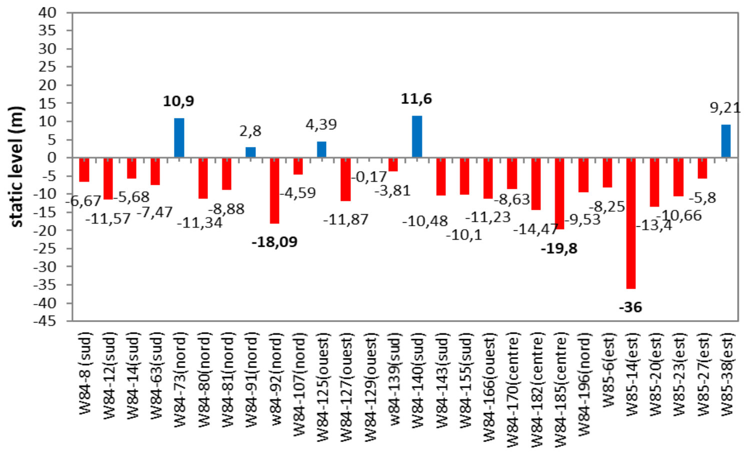

Figure12: Static levels variation in water points.

Conclusion:

At the end of this work, carried out on the Haut Cheliff watershed, with various climatic nuances, we tried to draw the main features on the hydroclimatic variability and the phenomenon of the drought, from the point of view persistence.

The analysis of the average minimum and maximum temperature revealed an increase in the minima and maxima during the last four decades. This upward trend in temperature has led to an acceleration of evapotranspiration accompanied by a lack of water in the soil. The decrease in rainfall associated with the dramatic increase in temperature over the last three decades has influenced the flow regime.

The results obtained by studying the severity of drought, using indices of rainfall and standardized rainfall, confirm the persistence and abundance of deficit years over the last three decades. It is in this specific case that the potentialities of water resources, making them selves felt, are more and more affected.

The studied area is characterized by very different hydrological regimes, because of the great differences between the climatic regimes and the distribution of the geological complexes. The great variability of the hydrological regimes can be interpreted in the large range of variation of calculated coefficients of variation.

The analysis of the evolution of rains and liquid inputs over a period of 46 years (1968 to 2014) showed a perfect synchronism between these two parameters and the effect of periods of drought in the reduction of water resources.

In addition, the variability of the static level of groundwater is very large. Groundwater resources are highly dependent on rainfall inputs. Water inflow for either groundwater recharge or groundwater recharge varies considerably from year to year, irrespective of the area in question.

Acknowledgement:

The authors wish to thank the National Water Resources Agency and the National Office of Meteorology for their material assistance and the data on which the reported analyzes are based.

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