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DETECTING TRENDS IN ANNUAL DISCHARGE AND PRECIPITATION IN THE CHOTT MELGHIR BASIN IN SOUTHEASTERN ALGERIA

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ABSTRACT

In this study data from 30 catchments in the Chott Melghir basin in the semi-arid region of southern East Algeria were analyzed to investigate changes in annual discharge annual precipitation over the 1965-1994 periods. These data were analyzed with the aid of *Kendall* test trend and regression analysis. The results indicate that (1) the major variations in all catchments discharge in Chott Melghir correspond well to the precipitation. (2) Changes in total annual discharge of Chott Melghir were lower than changes in annual precipitation. Annual precipitation decreased by 66 percent and annual discharge decreased by 4 percent. (3) No significant trend is detected for annual discharge and precipitation at major catchments up to 95% confidence level. The decreasing trend in Chott Melghir discharge is mainly attributed to the decrease of precipitation.

Keywords: trends, climate change, precipitation, discharge, Kendall test, regression analysis, Chott Melghir catchments.

INTRODUCTION

Over the past 10 to 20 years, scientists have estimated that changes in climate may affect hydrologic variables, such as discharge. Many rivers are altering their discharges due to climate change and human activities. Studies of yearly precipitation reveal trends over many regions of the world. The research results indicate increasing or decreasing trend in annual, seasonal and monthly precipitation trend, but such trends mostly are weakly significant. Over the past decades, about 22% of the world's rivers showed statistically significant decrease in annual discharge (*Walling* and *Fang*, 2003) due to water consumption and diversion and reservoir construction, which led to great environmental problems (*Wigley* and *Jones*, 1985; *Yang* and *Saito*, 2003). On the other hand, about 9% of the world's rivers showed statistically significant increasing trends in annual discharge (*Walling* and *Fang*, 2003). For Europe, the precipitation trend is positive in the north and negative in the south. *Turkes* (1996) pointed out that most of regional mean normalized annual precipitation of Turkey have negative trend which are not significant at 5 percent level. *Ramos* (2001) did not find a clear and significant trend in annual precipitation of Mediterranean area while *De Luis* and *al*. (2000) and *Gonzales* and *al*. (2001) found a significant decrease in rainfall amount associated with a significant increase in interannual variability in more humid areas of Valencia (Spain). *Piccarreta* and *al*. (2004) concluded that annual precipitation in most of Basilica stations (Italy) show negative trend with mean yearly precipitation decrease about 156 mm in recent 30 years. In arid and semi-arid regions of Iran, *Raziei* and *al*. (2005) found that most of the stations investigated were characterized by insignificant trend indicating that annual precipitation did not experience appreciable changes during study period. Based on parametric and non parametric statistics tests, *Xu* and *al*. (2003) concluded that annual precipitation of Japan experienced gradual changes while there is no evidence for any monotonic trend century. A statistically significant trend shows only if changes are strong enough and the time series is long enough (*Radziejewski* and *Kundzewicz*, 2004). More reliable trend analyses of river discharge require longer data sets, but very few rivers have annual discharge data sets longer than 50 to100 years (*Milliman*, 2001). The question of how climate change has affected, and will affect the river discharge has retained our attention. In region of Biskra, recent report indicated a downward trend of annual precipitation comparing to 1946, 1951 and 1969 yearly data (*ANAT*, 2003). The Chott Melghir basin is one of the great basins of Algeria. The trend in annual discharge and annual precipitation at Chott Melghir basin was examined for the period 1965 to1994. The objectives of this study are (1) to quantify the statistical relationships between annual discharges and annual precipitation at thirty sub catchments at this basin and to test their significance levels; (2) to reveal the trend and inter annual variations of discharge and precipitation and to examine their causes.

STUDY AREA

The catchments area of Chott Melghir (Figure 1) covers a surface of 68,750 km^2. This catchment is one of the 17 hydrological basins classified by the National Agency of the Hydraulic Resources (*A.N.R.H.*). Since 1999, this classification was modified and the 17 basins were grouped in 5 hydrographic areas. In this new classification the basin of Chott Melghir belongs to the hydrographic area of the Sahara. Figure 1 gives a representation of these basins.

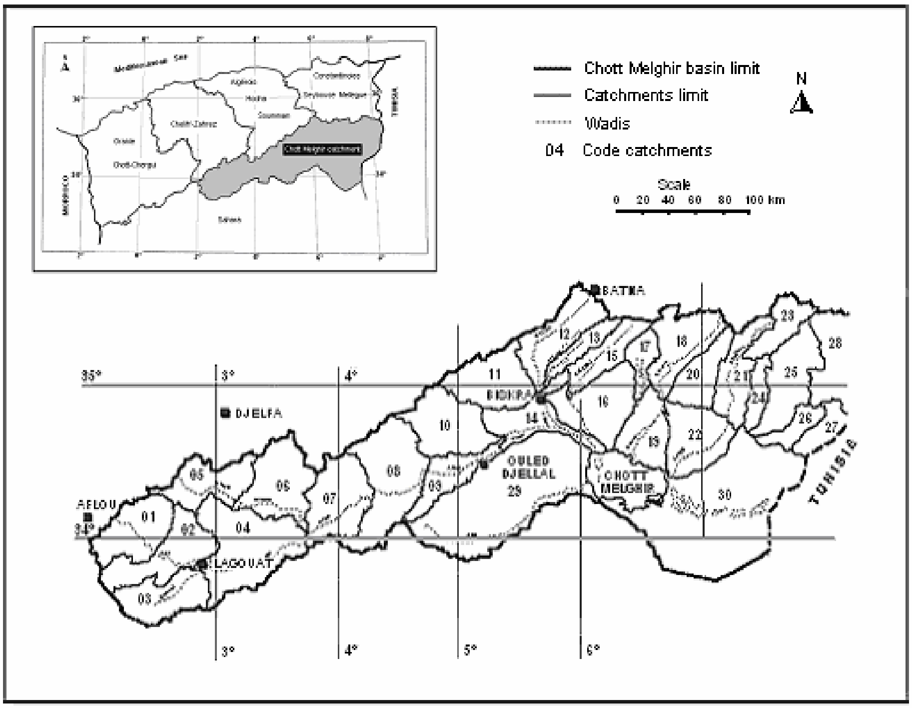

Figure 1: Location of the study area

The drainage area of Chott Melghir counts 30 catchments. The average annual precipitation values are low, characterizing the semi arid and arid climate in which the Chott Melghir catchments are located. Potential evapotranspiration lies between the two curves envelopes 2100 and 2200 mm. The climate is heat and dryness. Dominant winds are directed South-eastern in June, July, August and September and North-West during autumn, winter and at the beginning of spring. The sand wind lasts on average 39 days by year and its frequency increases in winter and at the end of the summer. The hydrological mode to which the catchment belongs is of the type " Saharian Atlas and High Plains ". The area of study is drain primarily by the main Wadis Djeddi, Biskra, El Arab, El Abiod which are characterized by an intermittent flow. During floods, these Wadis spread in Chott Melghir.

DATA SET AND METHODS

Annual discharges and precipitation data were collected from the Hydrographic Basin Agency of Sahara of Algeria (*ABHS*, 2006). The annual discharge and precipitation were observed between 1965 and 1994 (Table1).

Table1: Mean annual flow and precipitation of basins

Code of the basin	Name of the basin	Drainage area (Km^2)	Mean annual precipitation (mm)	Mean annual discharge (m^3/s)
06 01	Mzi Wadi upstream	2068	115,70	1.09
06 02	Mzi Wadi downstream	2336	128.83	2.10
06 03	Messaad Wadi	1819	189.76	5.51
06 04	Djedi Fedj Wadi	3696	139.80	3.47
06 05	Tadmit Wadi	1768	251.36	48.31
06 06	Demmed Wadi	2401	83.66	2.20
06 07	Djedi Djorf Wadi	2471	164.45	6.17
06 08	Djedi Douiba Wadi	3470	168.96	9.14
06 09	Djedi Kebb Wadi	1445	120.64	4.38
06 10	Melh ouzene Wadi	2426	133.17	4.13
06 11	Salsou Abiod Wadi	2119	184.88	5.97
06 12	Biskra Hai Wadi	2056	174.85	9.23
06 13	Djemorah Wadi	696	107.46	3.20
06 14	Djedi Biskra Wadi	1750	127.04	2.80
06 15	El Abiod Wadi	1320	188.63	8.53
06 16	Bir Az AtrousWadi	2300	173.28	9.64
06 17	Dermoun Wadi	791	138.29	4.11
06 18	El arab Wadi	2105	132.70	4.41
06 19	Zeribet Wadi	1435	69.55	1.82
06 20	Derradj Wadi	1393	160.68	8.05
06 21	Djedida Wadi	1591	140.69	8.75
06 22	Beggour Mitta Wadi	2383	129.04	2.51
06 23	Cheria Wadi	1110	110.96	0.94
06 24	Halail Wadi	622	120.76	1.88
06 25	Mechra Wadi	2400	207.31	9.06
06 26	Soukies Wadi	746	147.19	6.12
06 27	Horchane Wadi	1037	189.90	5.39
06 28	Oum El Ksob Wadi	2085	110.49	2.10
06 29	Ittel Wadi	6700	77.51	0.74
06 30	Chott Melghir	10140	153.09	4.03

Two methods, namely simple linear regression and *Kendall* trend test are used in this study to detect trend and to test its significance for the annual discharge and precipitation of the Chott Melghir basin. Each method has its own strength and weakness (*Yue* and *al*., 2002). The results given by the two methods can complement each other as will be shown in the following section. The statistical tests used here are well documented in the recent WMO publication (*WMO*, 2000). The simple linear regression method, the parametric t-test is powerful in testing the significance of the linear trend while Kendall test can show changing trends of period in the analyzed time series and does not require the data to be normally distributed. The simple regression method consists of two steps, fitting a linear simple regression equation with the time t as independent variable and the hydrological variable as dependent variable, and testing the statistical significance of the slope of the regression equation.
An important feature of the statistical analysis in the study is that provides objective criteria for making decisions and interpretations about the data. The statistical tests for trends result in a p-value. The p-value is a measure of the strength of evidence (data) for determining if the change in flow over time is a random occurrence or if it is a significant trend that did not occur by chance. As the p-value decreases, the evidence to support a conclusion for a trend becomes stronger. A threshold significance level of 0.05 was used in the study; a p-value of less than 0.05 means that the trend is considered significant. A p-value of 0.05 means that there is a 5-percent probability that the conclusion for a trend is incorrect.

RESULTS AND DISCUSSION

Variability of discharge in response to climate episodes

The discharges showed inter annual variations. The variations were synchronous, especially for those of precipitation (Figure 2). The annual discharge varied greatly with scales from a few years to several decades. These interannual variations are mainly attributed to climate variability. The major variations in all catchments discharge correspond well to the precipitation. It is reasonable to assume that covariations in annual precipitation and discharge will be more significant if the precipitation is representative for the entire catchments.

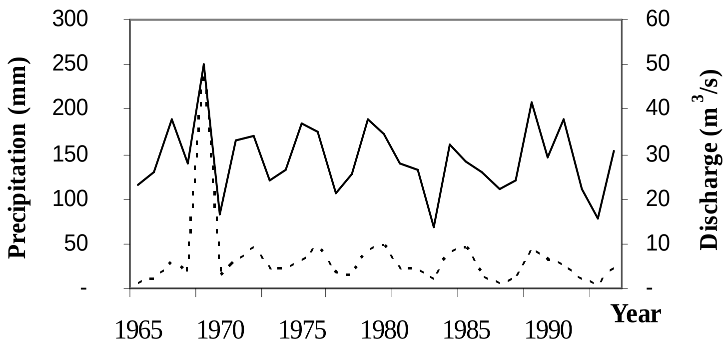

Figure 2 : Time series of average discharge and precipitation at Chott Melghir basin from 1965 to 1994 showing covariations.
(—) : Average precipitation, (– –) : Average discharge

The average precipitation in Figure 2 was based on 70 meteorological stations representatively distributed in the Chott Melghir basin. One can observe that more than 90% of the interannual variations in discharge and precipitation are covariants, i.e. synchronously increasing or decreasing.
Some of the global climate episodes were reflected by annual discharges. For example, there was a globally dry period in the study period (1965-1994), during which precipitation strongly declined (1970; 1983; 1993). The minimum precipitation and discharge in 1983 in the Chott Melghir catchment well reflect this tendancy. The highest discharge in 1969th corresponds to an exceptional wet year. On the other hand, some of the Chott Melghir rivers discharge episodes were not consistent with global climate changes. For instance, in 1991, the global precipitation was at over a mean level, whereas high discharge occurred in the same year was at under a mean level. Except this year, we suggest that regional climate coincide with the globally-averaged climate

Because of the covariations, a significant regression exists between discharge and precipitation in Chott Melghir (Figure 3). Figures 2 and 3 suggest that the interannual variations in Chott Melghir discharge are governed by climate variability in the catchments.

Discharge Q was fitted to precipitation P with the following power law, obtained with a satisfactory coefficient of regression equal to 0.89 :

$$Q = 0.0002P^2 - 0.4677P + 28.476 \qquad (1)$$

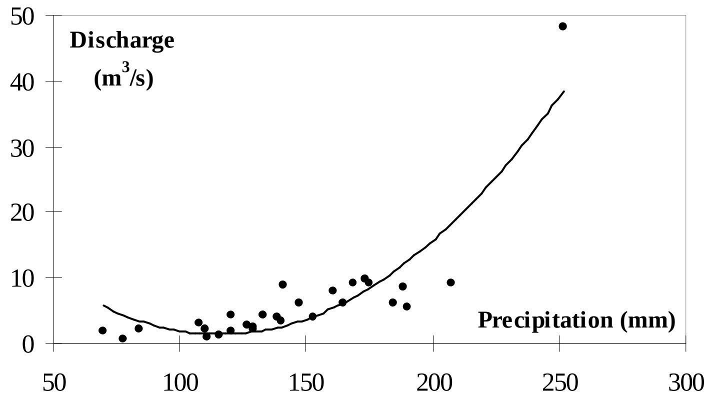

Figure 3 : Regression plot of average annual discharge-average precipitation at Chott Melghir catchments (1965–1994).

Precipitation trend analyses

The *Kendall*'s tau trend test was done on the 1965-1994 data for the Chott Melghir basin. Tests were done on the annual precipitation for the individual catchments. The results of the trend tests on precipitation are summarized in table 2.

Statistically significant ($p \leq 0.05$) downward trends were found in the precipitation for two catchments during the period tested. Of a total of the period tested, nineteen show possible negative trends, and eleven show possible positive trends. Of these possible trends, two are negative (Mzi Wadi and Cheria Wadi). The strongest significant change is in the East of the basin. The precipitation has decreased in the west of the basin.

Table 2 :. Results trend tests to the precipitation data for all basins over the period 1965-1994. Bold numbers indicate a significant trend.

Code of the Basin	*Kendall*'s Tau	P value	Trend slope (mm/year)
06 01	**- 0.269**	**0.037**	-3.43
06 02	- 0.108	0.402	-0.07
06 03	- 0.067	0.605	-0.54
06 04	- 0.044	0.735	-0.32
06 05	- 0.214	0.097	-2.47
06 06	- 0.223	0.084	-2.88
06 07	- 0.228	0.077	-2.13
06 08	- 0.218	0.090	-2.21
06 09	0.039	0.762	-0.17
06 10	0.021	0.872	-1.53
06 11	- 0.030	0.817	-2.05
06 12	- 0.067	0.605	-1.43
06 13	0.030	0.817	0.06
06 14	0.085	0.509	-0.48
06 15	0.080	0.532	0.83
06 16	- 0.030	0.817	-0.52
06 17	0.053	0.682	0.93
06 18	- 0.016	0.901	-0.04
06 19	- 0.177	0.170	-0.82
06 20	- 0.136	0.293	-0.59
06 21	0.021	0.872	0.33
06 22	- 0.168	0.193	-0.88
06 23	**- 0.260**	**0.044**	-2.4
06 24	0.209	0.104	1.91
06 25	- 0.016	0.901	-0.24
06 26	0.076	0.556	0.81
06 27	0.071	0.580	0.76
06 28	- 0.094	0.464	-0.85
06 29	0.007	0.957	-0.14
06 30	- 0.177	0.170	-0.76

Linear regression test shows that annual precipitation decreased by 66 percent for the basin (Figure 4). For $p < 0.05$ and with a coefficient of regression equal to 0.156, the following relationship between precipitation P and year Y was obtained:

$$P = -0.71Y + 1554 \quad (2)$$

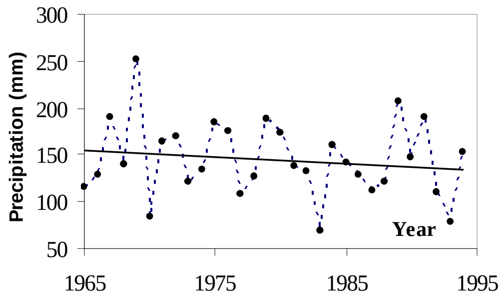

Figure 4 : Regression trend of average precipitation at Chott Melghir basin.

Figures 5.a to 5.f illustrate the results given by linear regression method for some cases

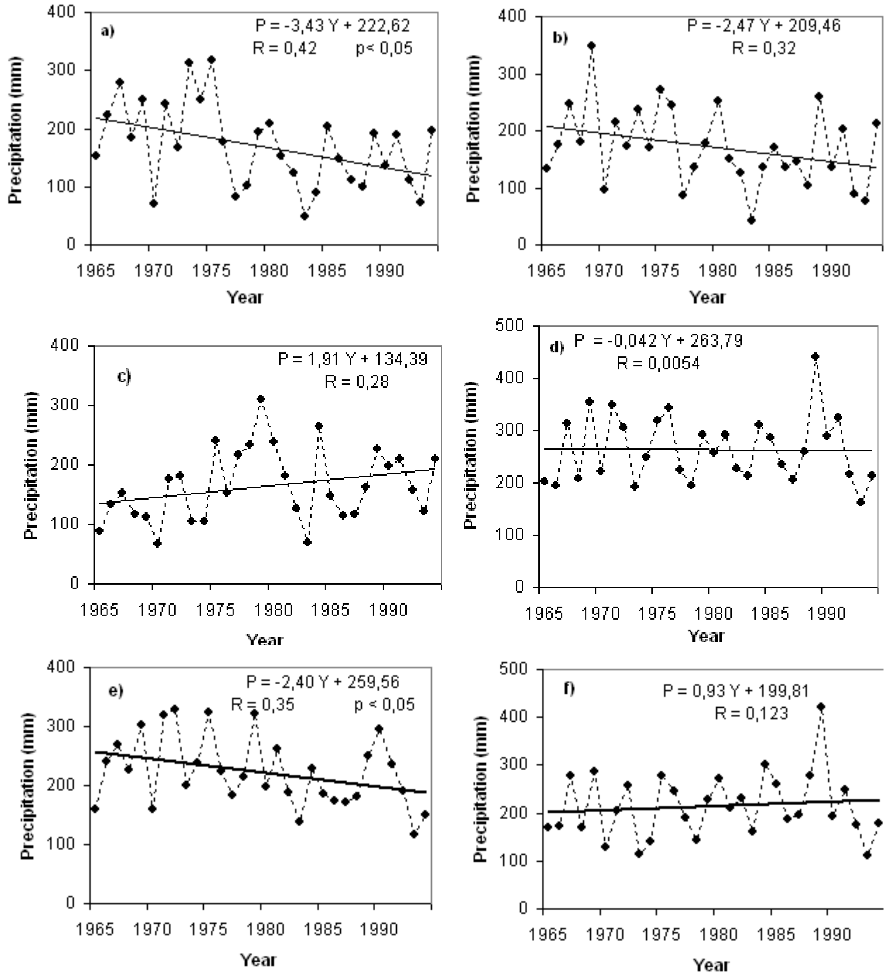

Figure 5 : Regression trend of precipitation at :
a) : Mzi, b) : Tadmit, c) : Halail, d) : El arab,e) : Cheria, f) : Dermoun

Figure 6 shows disproportional changes in precipitation for all watersheds. There have been changes of the same sign (increasing or decreasing). The large precipitation changes were occur in Mzi Wadi upstream where trends tests consider a reduction in precipitation of 100 mm over 30 years.

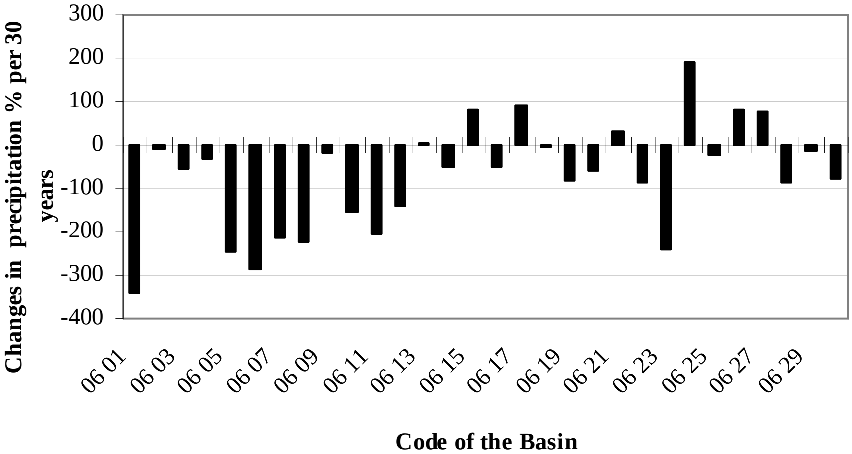

Figure 6 :. Trends of annual precipitation in percent in all watersheds of Chott Melghir basin

The slopes of the trends for the 30 basins were about -3.43 to 1.91 mm per year. Changes in precipitation in the west of the basin were greater than changes in annual precipitation at the other parts of the basin for the same period (1965 to 1994). The most negative trends are detected in the western part of the basin of Chott Melghir (figure 7) in particular for the basins tributary of Djedi Wadi (Tadmit, Demmed, Djorf, Douiba, Kebb, Melh Ouzene, Salsou, Abiod Wadi Biskra, Hai Wadi).

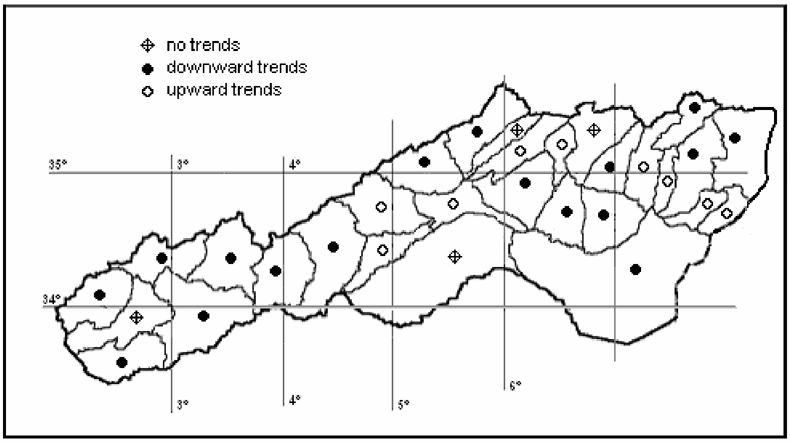

Figure 7 :. Trends in annual precipitation in Chott Melghir catchment for the period 1965 to1994

Discharge trend analyses

Mean annual discharges on the Chott Melghir basin were tested for trends using the Kendall's test and regression analysis. The results for all catchments are listed in table 3.

Because of the large variability in annual discharges in this region (average coefficient of variation = 2.2 and exceptional flow of 1969 year), trends are sometimes difficult to visualize. However, the tend tests for most of the gaging stations in the Chott Melghir basin shown in table 3 clearly indicate a decline. The only question is one of timing and whether that decline is statistically significant. The trend tests results (Table 3) for 1965-1994 periods at 30 catchments show that 7 tests give positive changes, but none of those were statistically significant trends. There were 2 catchments that had statistically significant declines (06 01 and 06 23). There is no trend for catchments 06 09 and 06 15. Thus the trend tests results for the discharges are in particularly agreement with those for the precipitation in particularly for these two catchments. The decreasing discharge of all basins is mainly the result of decreasing precipitation.

Table 3 : Results of trend tests on discharge data for all basins over the period 1965-1994. Bold numbers indicate a significant trend.

Code of the Basin	Kendall's Tau	P value	Trend slope (m^3/s per year)
06 01	**-0.256**	**0.047**	-0.473
06 02	0.023	0.858	0.043
06 03	0.081	0.531	0.037
06 04	0.051	0.694	-0.046
06 05	-0.131	0.309	-0.345
06 06	-0.108	0.402	-0.426
06 07	-0.130	0.314	-0.403
06 08	-0.187	0.147	-0.768
06 09	0.005	0.971	-0.209
06 10	-0.058	0.653	-1.300
06 11	-0.048	0.707	-0.858
06 12	-0.025	0.844	-0.247
06 13	-0.016	0.901	-0.010
06 14	-0.047	0.718	-0.479
06 15	-0.002	0.986	0.010
06 16	-0.048	0.707	-0.117
06 17	0.067	0.605	0.140
06 18	-0.080	0.532	-0.112
06 19	-0.234	0.069	-0.044
06 20	-0.062	0.630	0.007
06 21	-0.046	0.721	-0.012
06 22	-0.129	0.317	-0.034
06 23	**-0.301**	**0.019**	-0.499
06 24	0.122	0.344	0.073
06 25	-0.149	0.246	-0.063
06 26	-0.021	0.872	-0.008
06 27	-0.025	0.844	-0.009
06 28	-0.154	0.232	-0.062
06 29	0.066	0.609	-0.031
06 30	-0.145	0.260	-0.019

Although the discharge at Chott Melghir basin is highly scattered due to climate variability, it shows a decreasing trend (Figure 8). This figure shows much decrease and disproportional changes in discharge for all catchments. The large discharge changes were occur in Melh Ouzene Wadi (basin code 06 10).

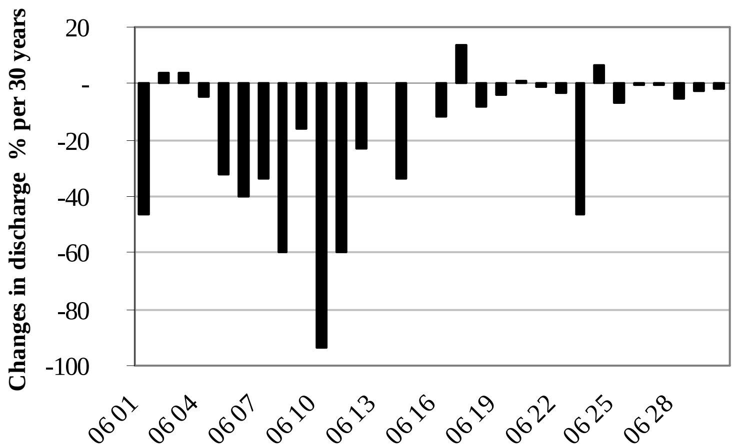

Figure 8 : Trends of annual precipitation in percent in all catchments of Chott Melghir basin.

According to the regression equation in figure 9, the decreasing trend in annual discharge is about 4% from 1965 to 1994. The slopes of the trends for the main gaging stations of Chott Melghir basin were about -1.30 to 0.14 m^3/s /year (Figure 10).

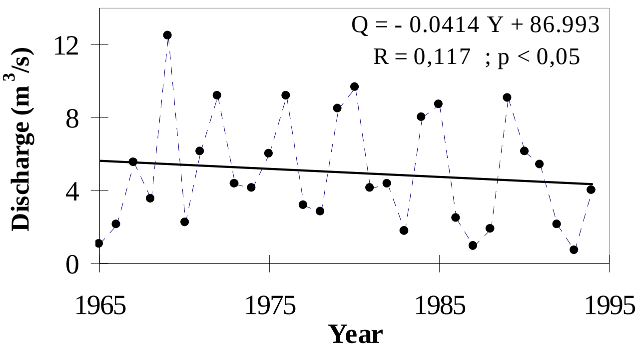

Figure 9 : Regression trend of discharge at Chott Melghir basin.

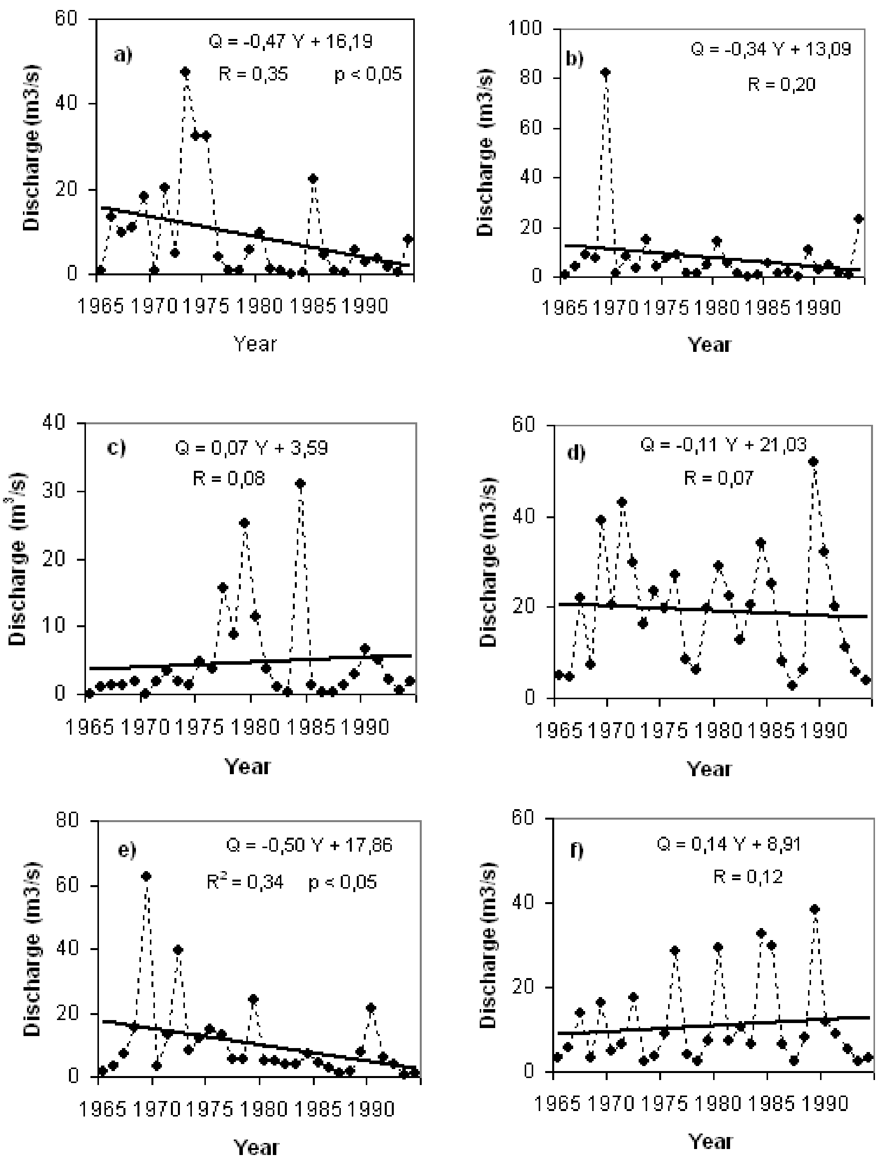

Figure 10 : Regression trend of discharge at : a) : Mzi, b) : Tadmit, c) : Halail, d) : El arab, e) : Cheria, f) : Dermoun

The annual discharge also appears to have begun to decline at the West of the Chott Melghir basin (Figure 11). The annual discharge is mainly following the variations of the precipitation in the catchment. It is of interest in this section to indicate that the detection of statistically significant trends in discharge is largely affected by interannual variability in discharge and to a lesser degree to the length of discharge record.

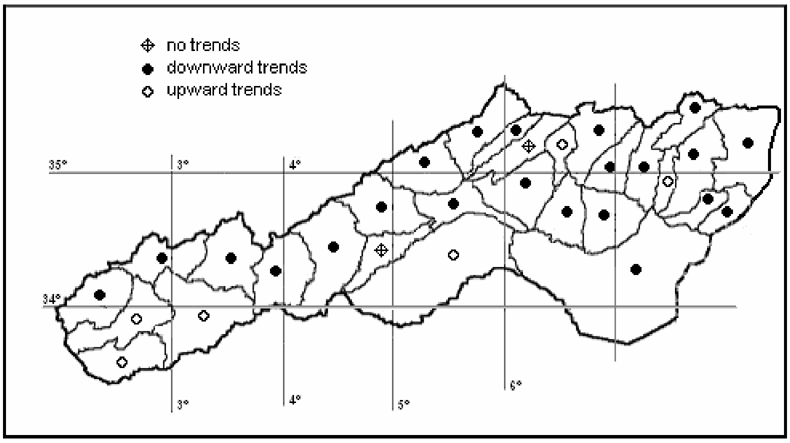

Figure 11: Trends in annual discharge in Chott Melghir catchment for the period 1965-1994

Comparison of results trends

The results of annual precipitation can be compared with the results of annual discharge over the 1965-1994 periods. This comparison reveals downward and upward trends with regard to the annual precipitation and annual discharge (Figures 7 and 11). Half of the analyzed basins present downward trends including two statistically significant (basins 06 01 and 06 23). These results show opposite trends for the basins located between the latitudes 34° and 35° Northern and particularly those located under the latitude 34° N.

CONCLUSION

Trend analysis of precipitation and discharge data at the 30 catchments in chott Melghir catchments in southeastern Algeria has been carried out using annual mean series. The application of trend detection on precipitation and discharge data to chott Melghir catchments has resulted in identification of two significant trends. First, most of the variations in discharge coincide with the variations in

precipitation. Second, according to the trend line, the precipitation discharge decreased by 66 % from 1965 to 1994, whereas the discharge decreased by only 4%. Three, spatial and temporal differences were noted in the occurrence and the direction of trends in this study. The direction of precipitation trends was, in general, downward across the catchments. Both the linear regression and *Kendall* test trend methods yielded more or less similar conclusions. From the annual precipitation variable, the Djeddi, Biskra, El Arab, El Abiod catchments were determined to have strong decreasing and increasing trends, as opposed to discharge variable showing either negative trend in these catchments. There were downward trends in the annual mean precipitation series, predominantly in western of chott Melghir catchments, but a few upward trends were founded in the central and East parts of this catchments. It is now reasonable to postulate that decreases in mean discharge in western catchments were due most likely to decreases in precipitation in the same region.
The similarities in trends between individual catchments and the regional average series (including all catchments) imply that the local effects influencing trend characteristics at each individual sub catchments in a region were not strong enough to mask the large-scale climatic effects in that region. It is worthwhile emphasising that the trend results presented in this study were not sufficient to approve climatic change in chott Melghir catchments. Future studies are needed to address the issue of trend attribution and to attempt to establish a linkage between climatic change and the observed hydrologic trends.

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