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Analysis of the climatic variability of the Dradère-Souière water table in Morocco

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Abstract

The present study concerns the Dradère-Souière water table and consists of characterizing the climatic variability at the level of the aforementioned basin and looking for the links between this hydrological variability and climatic fluctuations, based on climatological data that have been studied using a methodological approach based on the Nicholson Index, the Pettitt Test.
The analysis of the evolution of the rainfall indices shows that there is a wet and dry period, and a break in 1995.

Key Words: climate variability, hydrology, Dradère-Souière aquifer

Analyse de la variabilité climatique de la nappe phréatique Dradère-Souière au Maroc

Résumé

La présente étude concerne la nappe phréatique Dradère-Souière et consiste à caractériser la variabilité climatique à l'échelle dudit bassin et à rechercher les liens entre cette variabilité hydrologique et les fluctuations climatiques, à partir de données climatologiques qui ont été étudiées selon une approche méthodologique basée sur sur l'indice Nicholson, le test de Pettitt.
L'analyse de l'évolution des indices pluviométriques montre qu'il y a une période humide et sèche, et une pause en 1995.

Mots Cles : variabilité climatique, hydrologie, aquifère Dradère-Souière

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INTRODUCTION

In recent studies, including the Intergovernmental Panel on Climate Change (IPCC) (2007), long-term climate change refers to changing climate parameters over time and space (local, regional and global) and whose impact may include sea level rise, desertification [7], depletion of biodiversity and freshwater resources [6], and exacerbation of extreme hydrological events such as floods and droughts [1]. Climate also varies due to astronomical factors (solar radiation, atmosphere) [3], geographical factors (topography, ocean) [2] and weather.

The watersheds integrate the heterogeneities of many parameters, including hydrological, sedimentary and climatic. In addition, they are affected by human activities. They can therefore be considered as indicators representing both climate change and human activities, in a context of global change. Many studies of the overall functioning of the Earth system have used water transfers from large watersheds as an "archive" of climate and environmental change on a global scale. For example, using historical flow records, Labat et al. (2004) and Labat (2006, 2008, 2010) [5] conclude an increase in global runoff in relation to global warming.

Hydrological variability in Africa has been studied by many authors since the onset of the recent drought in the 1970s. Many studies have focused on the Sahelian areas [11]. Some authors have compared Sahelian rainfall with rainfall in other parts of Africa, particularly in West Africa, but also in Central Africa [8]. and others used standardized hydrological time series anomalies in North Africa [9]. Morocco is currently experiencing the longest dry period in its modern history, characterized by a decrease in precipitation and a clear upward trend in temperatures [4]. During the period 1961-2004 the frequency and severity of droughts increased considerably.

In climatology, as in many areas of research, time series analysis is a fundamental question [10]. Different methodological approaches exist to detect potential changes in historical hydrological and climatic records (for example statistical trend analyses). These methods have already been used in several studies at the level of Morocco.

The main objective of this work is to better understand the climate variability of the Dradère-Souière watershed.

PRESENTATION OF THE STUDY AREA

The coastal basin of the Dradère-Souière lies between X= 410 to 450 and Y= 460 to 495 in coordinates Lambert Nord-Maroc [12].This basin open to the sea is separated from the Sebou basin to the south by the hills of Lalla-Zohra (altitude less than 100 m) and to the south east by the hills of Lalla-Mimouna (Draa-Bou-Hafate: 230m); it is separated from the Loukkos basin to the north east by the hills of EL-Ferjane (197m), Lalla-Rhano (158m) and Kourricha (143m). In the extreme North West, no true natural separation isolates it from R'mel de Larache [12] (Figure 1). The climate is very temperate thanks to the oceanic influences. The stations closest to this basin give an average annual rainfall around 650 to 700 mm and the average annual temperature at 18°C, varying between 5°C to 10°C in January and 25°C to 47°C in August. Geologically speaking, the Dradère-Souière basin is in the preifain area. The pre-glacial rock waters constitute the general substratum of this region; they outcrop wide the edges and appear locally in the basin itself in the form of saliferous soils, in particular in the centre of the El-Mellah basin and in the east of Lalla-Rhano. To the south east of Lalla Mimouna a large outcrop of marl-limestone is also attributed to the pre-ifaine sheets.

A thick series of marls of the Miocene Supérieure (Tortonien) called «series of blue marls», after the installation of the pre-ifaine sheets, covers the pre-ifaine formations on almost the entire surface of the basin. This series is several hundred metres thick, as shown by the oil holes in the buttonhole of Lalla-Zohra. This large thickness of marl makes it possible to consider this formation as an impermeable floor. These marls largely outcrop to the S (Lalla-Zohra) and to the east of El-Mellah-Haut Bouhira [12].

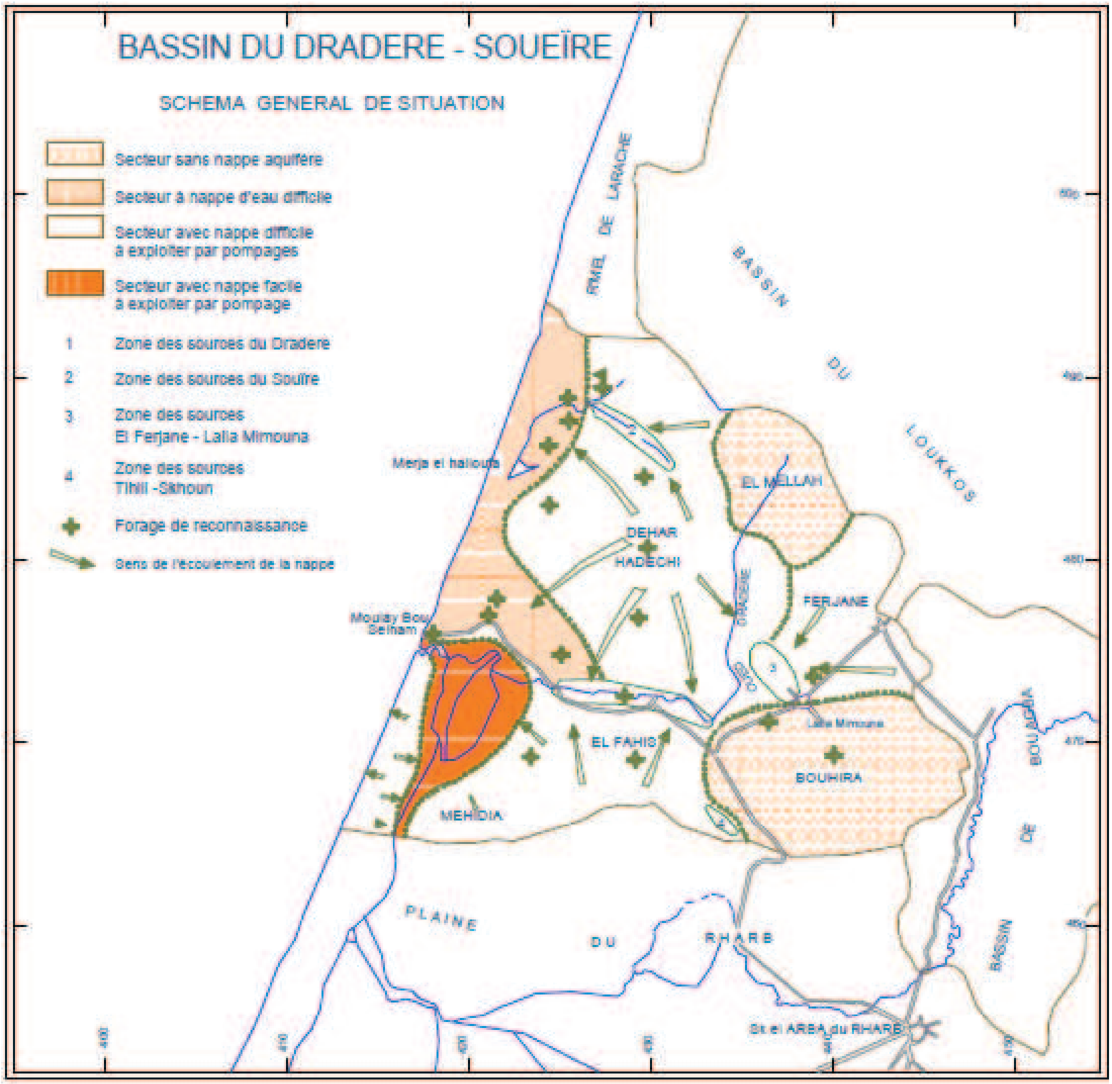

Figure 1 : Carte de situation de la nappe Dradère-Souière

EQUIPMENT AND METHODS:

Our approach in this study is based on the use of climate data. These data were obtained primarily from Global Weather Data for SWAT. In this statistical study, we use two software programs for the treatment of climatological data: Khronostat and XLSTAT. In addition, the use of Excel.

METHODS OF ANALYSIS OF THE CLIMATIC VARIABILITY: THE PLUVIOMETRIC INDICATION OF NICHOLSON :

It is an index that makes it possible to measure the deviation from an average an average established over a long period by referring to the data of stations. « The annual pluviometric index is defined by Nicholson (Nicholson and al, on 1988 ; Servat, on 1994). It is obtained by calculation by means of the equation (1) :

$$I_i = \frac{X_i - \bar{X}}{\sigma} \quad (1)$$

With :

I_i:Pluviometric Index ;

X_i:Rainy height of the year i in (mm) ;

$\bar{X}$:Rainy height averages over the period of study in (mm) ;

σ : Standard deviation of the rainy height over the period of study.

The interannual average of a series corresponds to the nil index (0) according to the method of Nicholson. A normal period is a period during which an identical fluctuation is observed on both sides of the abscissa axis. In this case, the annual average is approximately equal to the average of the total rainfall. During the humid period, the annual average is greater than the average of the total rainfall. Finally, the dry period corresponds to a period or the annual average is lower than the average total rainfall.

STATISTICAL TEST OF DETECTION OF BREAK : THE TEST OF PETTITT (1979) :

the test of Pettitt was used because of its performance and its robustness (Lubès-Niel and al ., on 1998). A break is defined as a change in the law of probability of the unpredictable variables the successive realizations of which define the chronological studied series (Servat and al ., on 1998). This test has been used in several studies of hydroclimatic changes, particularly in West Africa (Servat and al ., on 1998; Lubès-Niel and al ., on 1998; Paturel and al ., on 1998; Goula and al ., on 2006; Kouassi and al ., on 2008; on 2010; 2012a; Kouakou and al ., on 2012). It consists of cutting the main series of N elements in two under series all the time t between 1 and N-1. The main series presents a break at the moment t if both sub-series have different distributions. The variable of Pettitt $\boldsymbol{U_{t,N}}$ is defined by the equation (2) **[13]** :

$$\boldsymbol{U_{t,N}} = \sum_{i=1}^{t}\sum_{j=t+1}^{N} \boldsymbol{D_{ij}} \qquad (2)$$

$$\boldsymbol{D_{ij}} = \boldsymbol{Sgn}(\boldsymbol{X_i} - \boldsymbol{X_j})$$

Sgn(X)=1 si X>0
Sgn(X)=0 si X=0
Sgn(X)=-1 si X<0

The approximate probability of exceeding of a value K is defined and allows to appreciate the importance of the break (equation (3)) :

$$\boldsymbol{Prob}(\boldsymbol{K_N} > \boldsymbol{K}) \approx 2\mathbf{exp}\left(-\frac{6\boldsymbol{K}^2}{\boldsymbol{N}^3+\boldsymbol{N}^2}\right) \qquad (3)$$

The absence of a break in the series of size N constitutes the null hypothesis. If the null hypothesis is rejected, an estimate of the break date is given by the moment t defining the maximum in absolute value of the variable $\mathbf{U_{t,N}}$.

The test of pettitt was applied from the program Khronostat 1.01.

CALCULATION OF PLUVIOMETRIC DEFICIT :

For the hydroclimatic variables the chronological series of which presents a break, it is interesting to calculate the average variations before and after the break to have the existence or not of pluviometric deficit. For this, applying the following formula **[14]:**

$$\boldsymbol{D} = \left(\frac{\boldsymbol{X_j}}{\boldsymbol{X_i}}\right) - 1$$

Where $\mathbf{X_j}$ represents the average over the period after the break and X_i averages it over the period before the break.

INDICATED BY ARIDITIES :

The influence of the climatic factors is major on the vegetation. Indeed, the climate supplies conditions essential to the evolution of vegetables as the light, the water, the carbon dioxide …

The indications are quantitative indicators of the degree of the water scarcity and a given place, most are simple hydro-thermal relationships based on the average heights of the precipitation and the temperature. The best known are those of De Martonne (1926), Emberger (1931), Thornthwaite (1948), Dubief (1950), Capot-Rey (1951), Bagnouls and Gaussen (1952) and Birot (1953) **[15].**

INDEX OF MARTONNE :

The aridity index of " De Martonne, 1926 ", noted I, makes it possible to determine the degree of aridity of a region (Table 1). To calculate it, we use the following formula :

$$\boldsymbol{I} = \frac{\boldsymbol{P}}{\boldsymbol{T} + 10}$$

With :
P : Annual total precipitation ;
T : Annual average temperature.

Table 1 : degree of aridity of regions according to the value of "i" (de martonne, 1926).

I < 5	Hyperdry regions
5 < I < 10	Arid regions
10 < I <20	Semi-arid regions
20 < I < 30	Semi-wet regions
I > 30	Wet regions

INDEX OF ARIDITY OF BAGNOULS AND GAUSSEN :

The Ombrothermal diagram was developed by the botanists Gaussen and Bagnouls (1953), to highlight the periods of droughts defined by a curve of the precipitation is situated below the curve of the temperatures. An Ombrothermal diagram is a particular type of climatic diagram representing the monthly variations over one year of the temperatures and the precipitation according to gradations standardized : A gradation of the precipitation scale corresponds to two gradations of the temperatures scale : P= 2*T

INDEX BIOCLIMATIC OF EMBERGER :

The name Emberger (1931), remains attached to the study of the natural distribution of the plant groupings, in contact with the climatic elements, in the geographical areas being of the " Mediterranean climate " characterized by the existence of thermal seasons and of precipitation concentrated in the cold season **[16].** The approach of Emberger leaves a conviction, it is the uniqueness enters the climate defined by its parameters and the nature of the natural vegetation. Speaking various Mediterranean climate, Sauvage (1963) notes that in each of these climates corresponds a set of plant groupings which have the same general aptitudes. This set is the level of vegetation : its definition is only climatic but its expression is in the vegetation ; it is the " biological replica of the climate " (Emberger, on 1939). Wherever from the name of bioclimatic floor we give him most of the time. The name adopted for the floors is the same that of the corresponding climates. We thus distinguish the following bioclimatic floors: Saharan, dry, semi-arid, Subhumide, and of High mountain **[16].** This double definition of the bioclimatic complex, through the data of the vegetation and the climate, allows to associate with the qualitative gradation of the aridity drawn by a certain botanical experiment, a quantitative obtained gradation by combining diverse climatic parameters **[16].** In this purpose, Emberger creates in 1930 the pluviothermique quotient, which is a function of precipitation and of the air temperature. In this quotient, the contribution in water intervenes in the numerator by the total P in (mm) of the average of the annual precipitation. For the temperatures, Emberger takes into account the fact that the plant life takes place between two thermal extremes, that we can in first approximation assimilate to the average of the minimums of the coldest month m and in the average of the maximums of the month the hottest M. These two thermal variables allow to introduce into a climatic formula, on one hand an average temperature ((m+M)/2) (neighbor generally of the real annual average temperature), and on the other hand the extreme thermal amplitude averages (M - m). L. Emberger notes that this amplitude expresses the continental character and that it varies most of the time as the evaporation. These two values intervene by their product in the denominator of the quotient, but no interpretation is given to this operation. Such a formulation not allowing to discriminate between the positive and negative values of m, the quotient is modified by Emberger in 1955. The average temperature is then expressed in degrees Kelvin and the pluviothermique quotient takes its current shape **[16] :**

$$\boldsymbol{Q}_2 = \frac{2000 * \boldsymbol{P}}{(\boldsymbol{M} + \boldsymbol{m} + 546.4) * (\boldsymbol{M} - \boldsymbol{m})}$$

Or :
P : The annual pluviometry in mm ;
M : The maximum temperature of the hottest month °C ;
m : The minimum temperature of the coldest month °C.

RESULT ANALYSIS OF THE CLIMATIC AND BIOCLIMATIC VARIABILITY ANALYSIS OF THE NICHOLSON INDEX:

The variation of pluviometric index is represented for the station of the tablecloth Dradère-Souière. The figure (2) illustrates this variability in the station of Moulay Bousselhem. The analysis of pluviometric index shows a dry period and a wet period. The characteristics of these periods are recorded in the figure (2) and the Table (2).

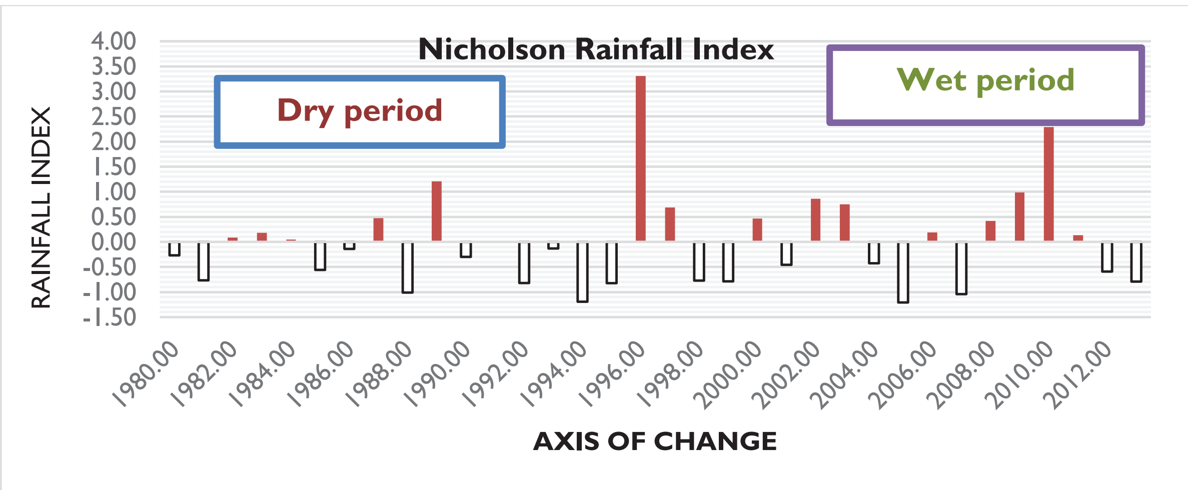

Figure 2: Annual rainfall trend at the Dradère-Souière aquifer station.

Table 2: characteristics of wet and dry periods.

Dradère-Souière Basin Station.	
Dry period	1980 - 1995
Average (mm)	591,92
Standard deviation	141,10
Wet period	1996 - 2013
Average (mm)	701,08
Standard deviation	271,97

PETTITT RUPTURE TEST

The application of the Pettitt test detected in 1995 a break. The break detected corresponds to rainfall decreases in the Moulay Bousselham region from 1980 to 1995 (figure 3).

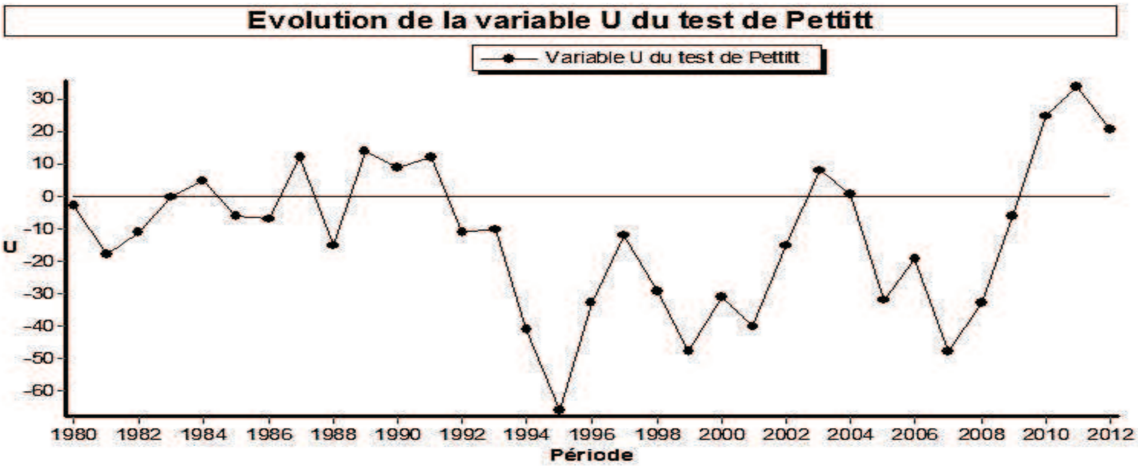

Figure 3 : curve of the pluviometric series stemming from the test of pettitt (1980-2013).

INCIDENCE OF RAINFALL OVER ANNUAL RAINFALL AVAILABLE :

The analysis in Table 3 reveals that the rainfall deficit recorded in the study station is of the order of 18%.

Table 3 : Rainfall deficit recorded in the study station

stations	Deficit (%) Date break	Average before break	Average after break	Deficit (%)
Moulay Bousselham	1995	91,92	701,08	18.44

BIOCLIMATIC INDICES

CALCULATION OF THE ARIDITY INDEX OF DE MARTONNE

The aridity index of the region of study is equal in : 19,5. According to this value, the studied region is a semi-arid region.

INTERPRETATION OF THE OMBROTHERMIC DIAGRAM :

Table 4 : average climate data of basin dradère-souière (during 1980-2013).

	Septembre	Octobre	Novembre	Décembre	Janvier	Février	Mars	Avril	Mai	Juin	Juillet	Aout
P (mm)	19,80	59,05	117,01	118,73	88,44	72,22	63,16	60,46	35,39	10,13	2,65	2,67
T(°C)	28,51	25,32	21,08	17,84	16,77	17,55	20,09	21,20	23,56	26,83	29,69	29,93

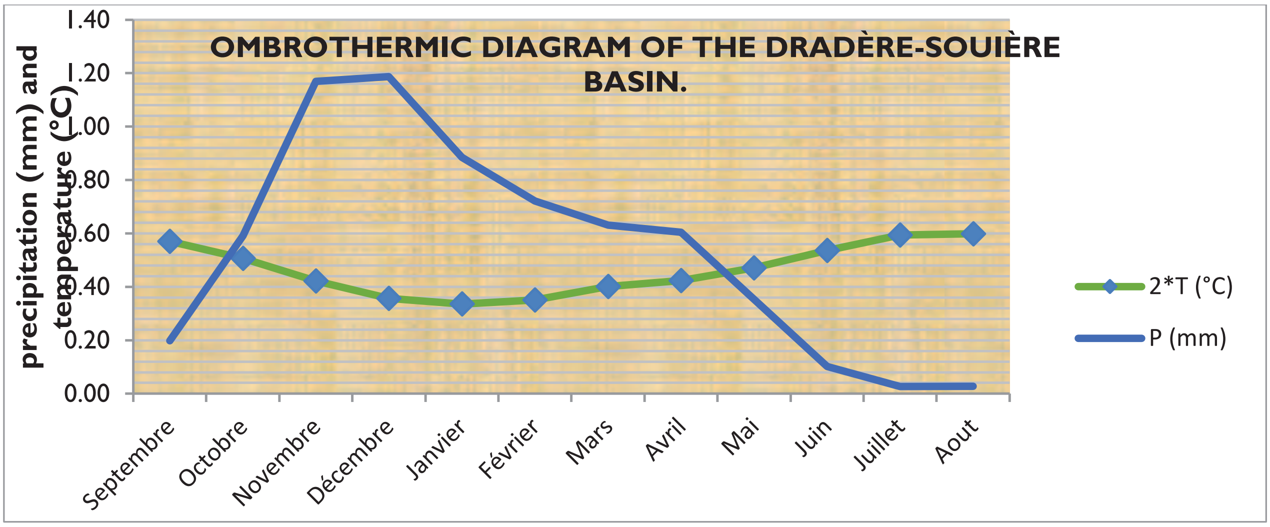

Figure 4: Ombrothermic diagram of the study area during the period (1980 - 2013).

The climatic diagram (figure 4) of the region of study, shows that the dry period precipitation twice lower the temperature of the month) extends from June in September, and the wet period extends from October to May.

INTERPRETATION OF THE PLUVIOTHERMIC QUOTIENT :

The influence combined by the sea and by the ocean, the presence of the mountains of atlas and Rif and the desert of Sahara in the South create a diverse range of climates in Morocco **[15].** For our region of study, the calculation of the quotient pluviothermique which is equal to **110.76** and the value of minimal temperature of the coldest month **(m = 9.9 °C)**, Show that coat Dradère-Souière belongs to the bioclimatic floor " subhumide " in variant "hot" winter (figure 5).

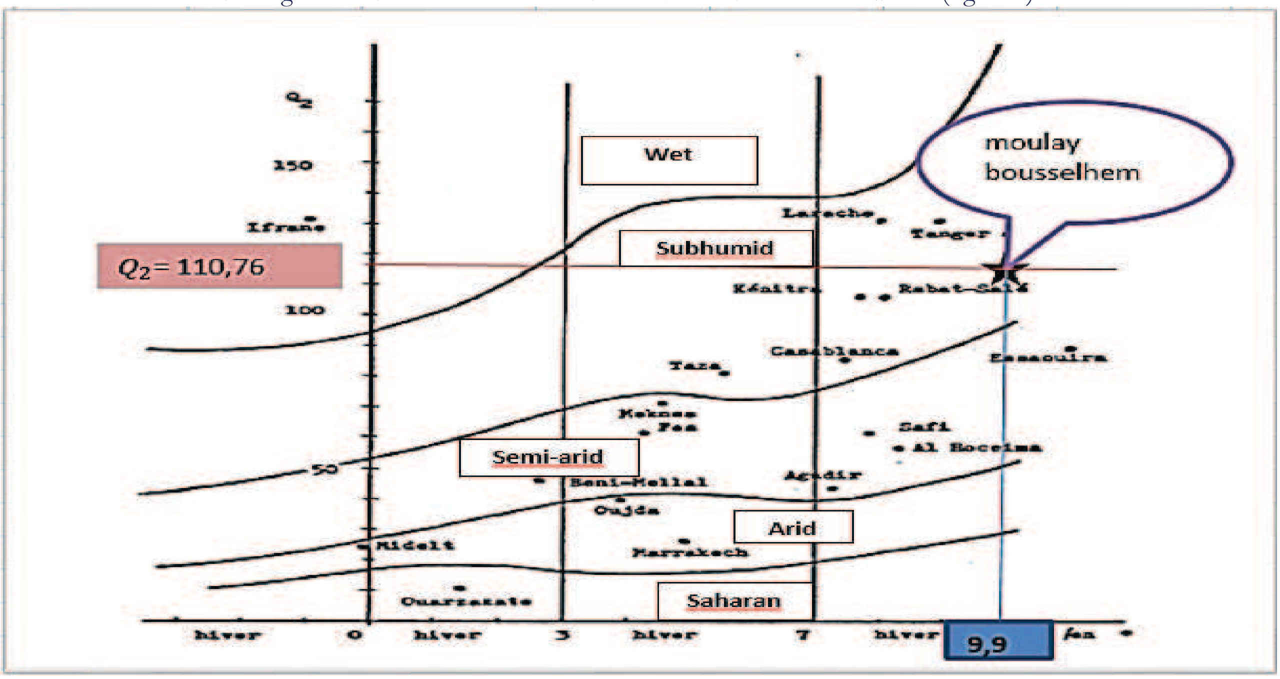

Figure 5: climagramme pluviothermique, resorts of the tablecloth dradère-souière, period 1980-2013.

DISCUSION

In this work, the analysis of the results of the climatic indications, shows that the tablecloth Dradère-Souière knows a climatic variability which notices on the following levels : At the monthly and seasonal level, the region of study is characterized on one hand by a dry period which spreads out over four months, from July till September of every year, and on the other hand by a rather important pluviometry. What explains that the climate of the pond of study is semi-aride. In this party the calculation of the pluviometric Quotient of Emberger, show that the zone of study belongs to the bioclimatic floor " subhumide " in variant " hot winter ". This quotient as the index of aridity, its denominator would express the potential evapotranspiration ETP. The value of this denominator is very significant, what explains that the maximal water consumption been imperative by the climatic demand is importantIn the temporal scale, the annual analysis of the precipitation of the station of the tablecloth of study for period 1980 - 2013 shows a temporal irregularity which is characterized by a strong variability. So, the annual precipitation can vary from one year to the next. During the period 1980 until 1994, we have low annual heights of pluviometry contrary in the period from 1995 till 2013 which where the pluviometry reaches very significant values. The interannual variation of the pluviometry determined by the pluviometric index coincides with the statistical tests. Indeed, the pluviometric break in the zone of study is characterized by a reduction in the pluviometry preceding year 1995. Beyond the period of 1995 is characterized by a certain pluviometric resumption and the successions of dry years are replaced by wet years. The climatic variability shows itself by an a little brought up air temperature, what has for consequence an affection of the hydrological cycle.

CONCLUSION

The results of this study have made it possible to characterize the main manifestations of climate variability (1980-2013) of the Dradère-Souière water table. The study shows that prolonged rainfall deficit conditions were evident before 1995, from 1980 to 1995. After 1995, there is a rebound in precipitation. Climate variability is manifested by an increase in air temperatures.The pluviometric deficit in the station of study is of the order of 18%, it is important. This pluviometric reduction has entraine a reduction of the blade of water infiltrated that is a reduction of the refeeding of tablecloths.

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