CLIMATE CHANGE AND DEGRADATION OF SURFACE WATER: MIKKES BASIN (MOROCCO)

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ABSTRACT

The Mikkes basin is located at the north centre of Morocco. The yearly approach of the P<2T ratio reveals a very bad monthly distribution of precipitations and a seasonal drought which is apparently observed well after the Eighties era. The extent of the drought can be shown clearly by the strong deficit of the river between the periods 1970-1979 and 1980-2000 which is considerable with around 75 % percentage. The analysis of the monthly medium flows between 1970 and 2000 shows a rough oceanic system and which is characterized by two hydrological seasons: one period of high waters in winters which is conditioned by the pluviometric contributions; in addition to another period of low waters and is conditioned by an evapotranspiration. The mode of this course can be a pluvio-evaporal type.

Keywords: drought; pluviometry; flow; deficit.

INTRODUCTION

In the Maghreb, the water resources play a fundamental role in the socio-economic activities. The climate of this region is a Mediterranean climate, characterized by a strong contrast between summer and winter, especially for precipitation and the hydrological cycle to the surface. These Mediterranean countries with their ecosystems are sensitive and vulnerable to change of climate. Under the influence of the anticyclone, the Mediterranean basin is experiencing a decline in the rain (Laurent LI [1]). The scientific community provides an increase in global temperature of 2 to 6 degrees (IPCC [2]), on the horizon of 2100. At the centre of this region, Morocco is a country that may face water shortage, which is expected to be beyond 2025, a situation of water scarcity (Prennes [3], Agoumi [4]). The Mikkes basin is located in north-central Morocco. This work aims to study the intra-annual drought and its impact on the flow of River Mikkes. The weather stations selected for this study belong to the Mikkes basin. The basin encompasses three main different geographical: Middle Atlas Tabular, Prerif (zone prerifaine and Rides Prerifaines) and Sais (Figure 1).

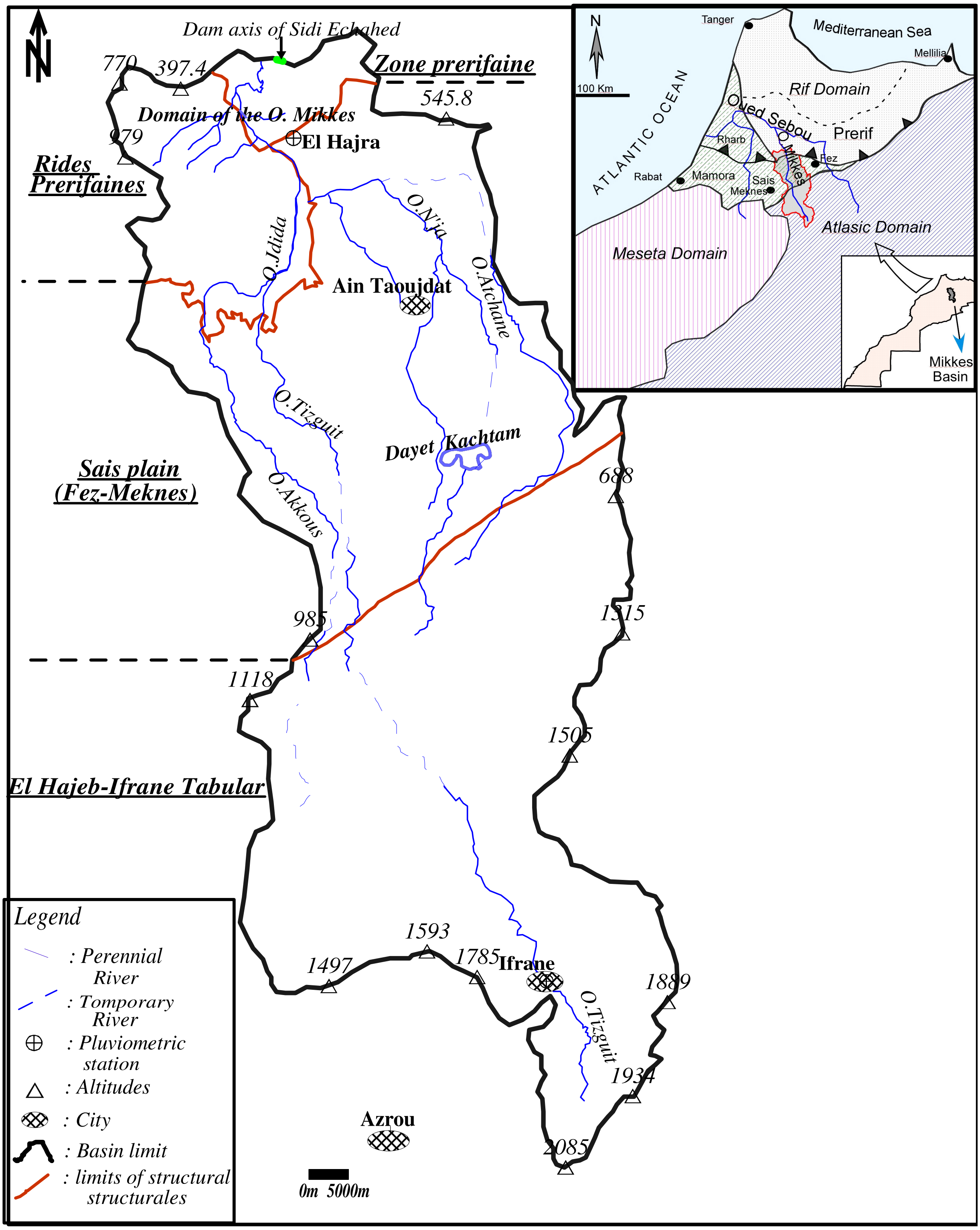


Figure 1. Location of the Mikkes basin and their effluents (taken from the topographic map 1/100000, geology division, Rabat, Morocco, 1943)

But this study is based on two stations only because of the lack of a characteristic station in the Prerif; Ifrane (Z = 1600 m), a characteristic station of Tabular Middle Atlas, provides complete data, and precipitation between 1970 and 2000 and temperature measurements are between 1958 and 2000. However, El Hajra (Z = 215 m), station Sais (Trough South Rifain) presents monthly series of precipitation between 1970 and 2000 and temperatures destitute the 1980 years before (1980-2000). To establish some consistency in the analysis of seasonal droughts between the two stations, we based on the Ifrane station for to know the rise of the temperature degree during the period 1958-2000, the magnitude of the drought between the period before 1980 and after 1980 (temporal drought year). While in the El Hajra station, measurements of rainfall are between 1970-2000 and temperatures are between 1980-2000; it is used to compare the drought in the Tabular and the Sais (Space drought). The measurements of flow of the Mikkes stream basin are made at El Hajra station.

PRESENTATION OF THE AREA OF STUDY

The stream of Mikkes is an effluent of the stream Sebou. Its waters are regulated by the dam of Sidi Echahed. Its watershed is located between the cities of Meknes and Fez. Its area is about 1600 km². Its compactness index is around 1.93, so this basin is considered an extended watershed (Figure 1). The average slope of the basin is about 15 ‰. This slope varies widely between 5 % level of the talus that separates El Hajeb-Ifrane Tabular to the Sais plain and 5 ‰ at down stream of the basin (Sidi Echahed). The average slope is so much correlated with altitude. Near the down stream of the basin, the slope is relatively void. In the Sais plain, the slope is low. The slopes of the highest in the area are those in the plateau of Ifrane. Indeed, the flow is from south to north, so the runoff is very much influenced by the relief. The Mikkes basin is limited by three major geological differences: The Tabular Middle Atlas located in the south, which is represented by Carbonate rocks, principally Dolomite, Limestone and Dolomite Limestone. These are consolidated and permeable rock. From structural point of view this sector is affected by a panel faults. So it will generally have a low density of drainage (Figure 1) and thus a very low runoff and very high infiltration. The zone prerifaine is formed by the Triassic Clays. The Rides Prerifaines are predominates by Marls of the Miocene. These Clays and Marls are often impermeable rock but furniture and erodable. The Sais, the principals formations characterizing this sector are Marls of Miocene and fauves Sands of Pliocene (erodible rocks) and Pliocene Limestones (consolidated rocks). Thus, the northern basin is often present a high density of drainage (Figure 1). It plays through a high flow and low surface infiltration (Belhassan et al. [5]).

RESULTS AND DISCUSSION

1- Climate of the study area

The study of climate is important for understanding the climate constraints on surface water reserves within the study area. It involves two principals' parameters which include precipitation and temperature.

1-1 Precipitation

The precipitation is very differentially distributed in both space and time (Figure 2). In space, from the southern basin to northern, altitude becomes more low and too precipitation. The maximum annual average recorded sector Tabular (Ifrane station). The minimum average annual rainfall is recorded in the Sais plain (El Hajra station). As elsewhere in the Mikkes, a general decrease in rainfall is observed. This trend started much since 1980. In the Tabular, the average annual rainfall recorded over the period of 31 years (1970-2000) is 592 mm. However, the annual rainfall varies greatly from year to year, it ranges from 250 mm in 2000 and 1215 in 1996 (Figure 2). The average annual rainfall during the period 1970-1979 is 694 mm, while for the period 1980-2000, it is 543 mm. The deficit of rainfall in the Tabular is about 22 %. At the Sais plain, the average annual rainfall recorded in the period of 31 years (1970-2000) is 367 mm. However, the annual rainfall varies greatly from year to year, it varies between 165 mm in 1998 and 586 mm in 1995 (Figure 2). The average annual rainfall in the period of 10 years (1970-1979) is 436 mm, but falls to around 335 mm (1980-2000). The deficit is around 23 %. As a result, the inter-annual variation of precipitation since the 1980 reflects a rain deficit observed at two stations representing the Mikkes basin which could be the effect of drought year that Morocco has known since the 1980. While the difference between the rain deficit in the Tabular and Sais can be expressed by hydro-spatial differences between Ifrane and El Hajra. Ultimately, these results may show the altitude influence on the spatio-temporal distribution of intra-annual droughts (Figure 2).

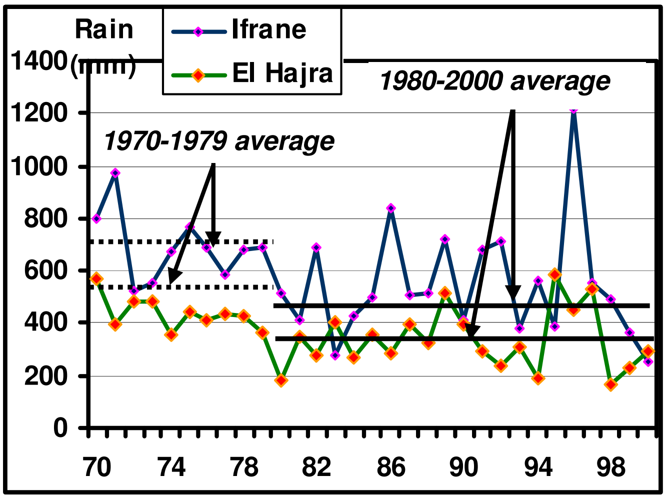


Figure 2. Annual pluviometry at Ifrane station (1970-2000) and at El Hajra station (1970-2000)

The distribution of monthly average rainfall in the two stations representative of the Mikkes basin (1970-2000), shows a similar evolution but with most rain heights at Ifrane station. It shows high water amounts in winter (maximum in December, January and February), and low water amounts in summer (June, July and August). Indeed, the seasonal rhythm of the basin is uni-modal. December has the highest average with 135.9 mm in Ifrane and 57.21 mm in El Hajra, while July comes with lowest average 8.35 mm in Ifrane, while in El Hajra station, August has the lowest average of 0.95 mm (Figure 3).

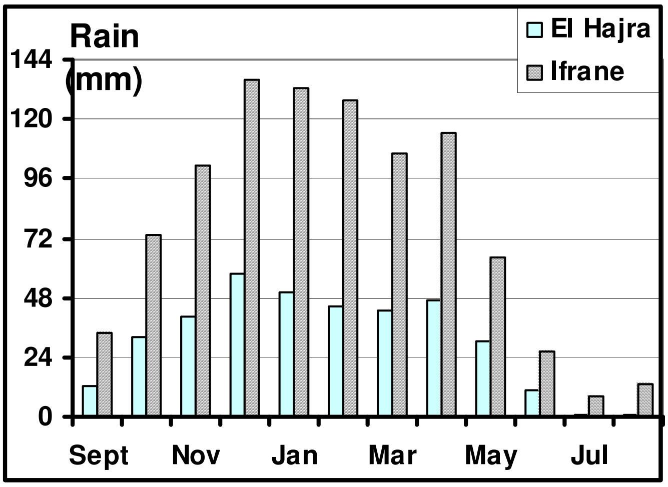


Figure 3. Monthly Pluviometry at the station of Ifrane (1970-2000) and at the station of El Hajra (1970-2000)

1-2 Temperature

To visualize the change climate that has seen the Mikkes basin, a study of variations in temperature is very useful to figures it out; it is based primarily on the Tabular resort (Ifrane station) where the database has a long period (1958-2000) then in Sais plain (El Hajra station) for period (1980-2000). In the Tabular, the annual average temperature during the period 1958-1979 is 11.16 °C. The drought period (1980-2000) has increased the annual average at around 12.06 °C (Figure 4). The temperature increase is the result of the greenhouse effect has been observed in Morocco and especially Mikkes basin (drought year). The inter-annual average temperature in the Sais during the period 1980-2000 is 18.56 °C. There is obviously a big difference between the temperature recorded in the Sais and that observed in the Tabular (1980-2000). The difference is 6.5 °C. This can be explained by the influence of altitude on the space-time distribution of intra-annual droughts (Figure 4).

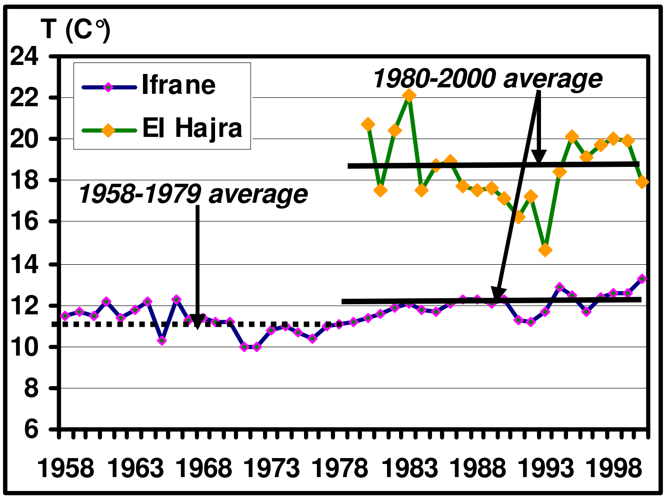


Figure 4. Annual temperature at the station of Ifrane (1958-2000) and the station of El Hajra (1980-2000)

Figure 5 represents the change of monthly temperatures in Ifrane and El Hajra stations during the period 1980-2000. The rain evolution in Ifrane is parallel that it in El Hajra. But the minimum temperature during all months is observed at the Ifrane station; the warmest month on average is August with 22.21 °C in Ifrane and 26.79 °C in El Hajra, while the coldest month is January with 3.95 °C in Ifrane and 10.76 °C in El Hajra (Figure 5).

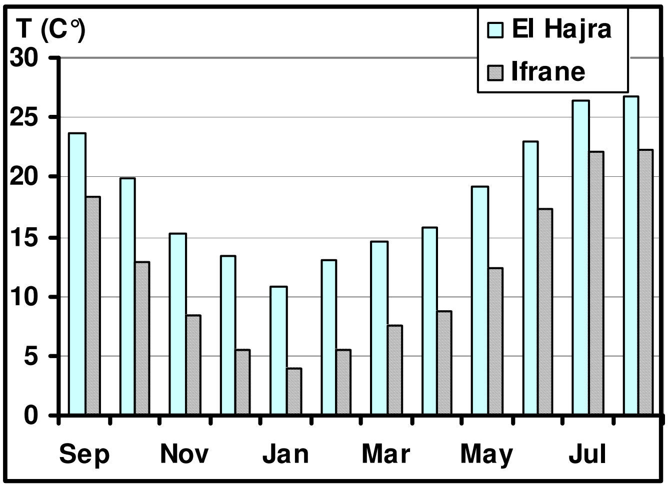
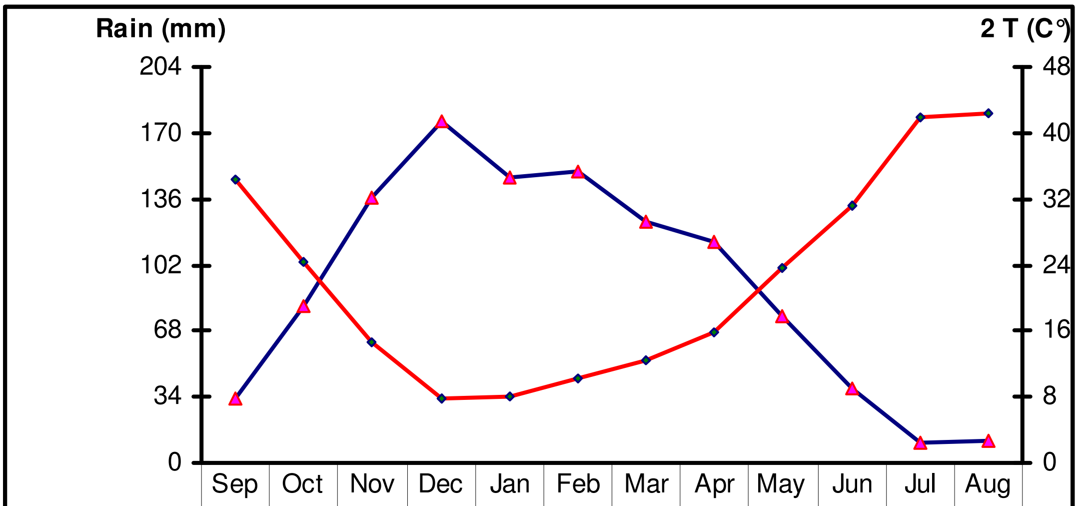


Figure 5. Monthly temperature at the station Ifrane (1980-2000) and the station of El Hajra (1980-2000)

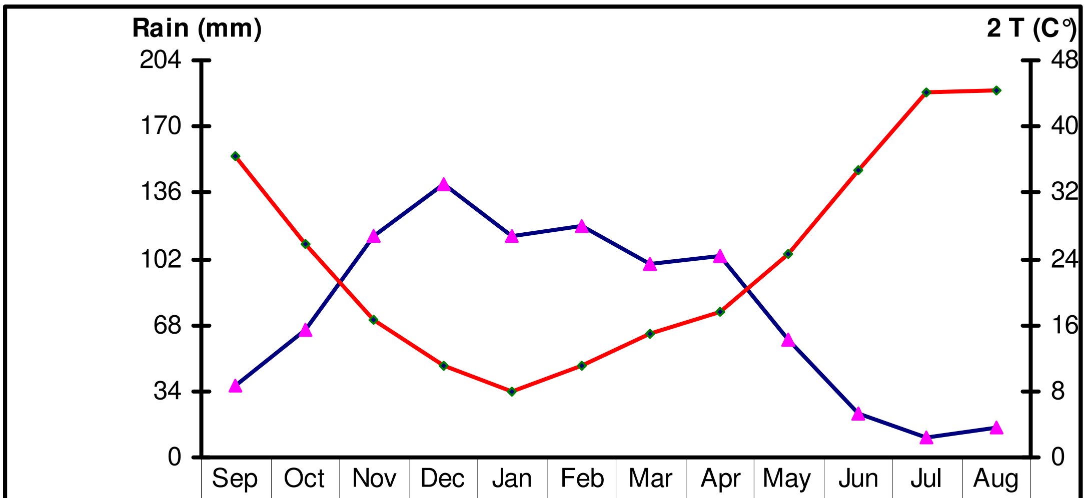
1-3 Ombrothermic diagram of Gaussen

By combining the monthly rainfall expressed in millimetres (P) and temperature in degrees centigrade (T), the botanist H. Gaussen defined biologically dry months by a rapport simple P < 2T (Bagnouls et al. [6]). It is important to know whether it could be a difference between the drought period in the Tabular and the Sais plain. The change in rainfall (P) and temperature (T) in the Tabular is shown in Figure 6 (1958-1979) and Figure 7 (1980-2000), this variation in the Sais during the period 1980-2000, is observed in Figure 8.



	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Rain (mm)	33.09	80.78	136.2	176.3	147.2	150.1	124.2	113.8	75.22	38.67	9.94	10.93
2 T (C°)	34.44	24.26	14.51	7.74	7.92	10.27	12.46	15.78	23.66	31.21	42.00	42.46

Figure 6. Ombrothermic diagram at the station of Ifrane (1958-1979)

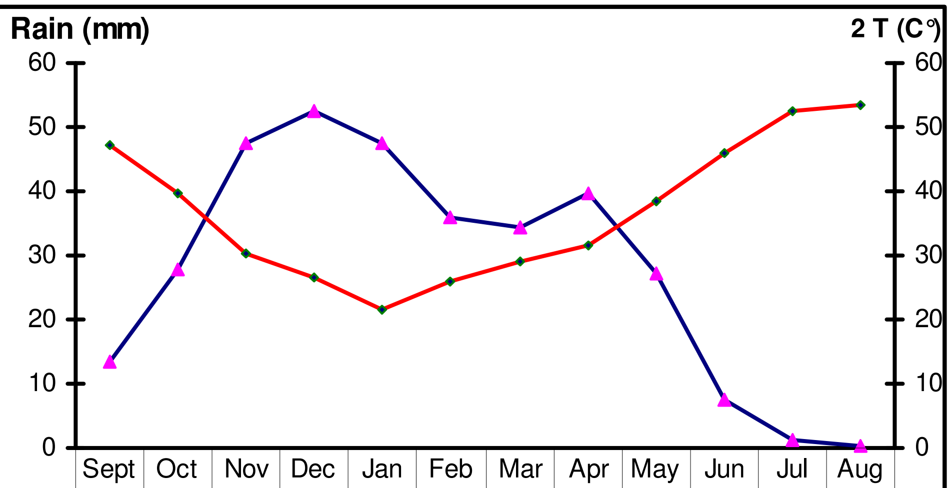


	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Rain (mm)	36.81	66.04	113.6	140.3	114.1	118.4	99.01	103.5	60.12	22.86	10.64	14.93
2 T (C°)	36.53	25.80	16.71	11.04	7.90	11.00	15.03	17.54	24.60	34.73	44.10	44.42

Figure 7. Ombrothermic diagram at the station of Ifrane (1980-2000)

Tabular is represented by Ifrane station, the variability of monthly precipitation between the period 1958-1979 and 1980-2000, is clearly (Figures 6 and 7). The general trend shows increasing in temperatures by an average about 1 °C for each month. While the rainfall trend is downward, except for the months of June, July and September where an increase in the rain is observed.

This evolution is reliable to the hypothetical global warming due to the greenhouse effect. Global uncertainties of change highlighted by many researchers (Douguedroit [7], Lamarre et al. [8], Vigneau [9]) and will be increased more when descending to a local reduced. Therefore, this development is accompanied by an increase in the number of dry months. For the period 1958-1979, the dry months are July, August and September (Figure 6). While for the period 1980-2000, there are four dry months (June-July-August and September) (Figure 7). The question that arises now is about this change and if it is the same for the entire basin or some differences existed? To answer that question, a diagram of Gaussen for Sais plain is useful and can be used. In comparison, the diagram for Tabular Gaussen and the Sais plain during the period 1980-2000, the number of dry months in the Sais is 6 months (Figure 8), whereas the number in the Tabular is 4 months (Figure 7). Indeed, other factors may intervene in the distribution of drought in the Mikkes basin (Belhassan [10]).



	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Rain (mm)	13.44	27.69	47.58	52.39	47.37	35.93	34.52	39.55	27.10	7.61	1.38	0.18
2 T (C°)	47.34	39.65	30.35	26.68	21.52	26.06	29.21	31.47	38.57	45.84	52.64	53.58

Figure 8. Ombrothermic diagram at the station of El Hajra (1980-2000)

The variability in the month of dry between Tabular and Sais is linked to variability in temperature and precipitation (altitude and latitude). The Tabular, presents the wettest season which has the highest rainfall and the lowest temperatures. As we approached a plain lands, temperatures rise and rainfall decreases and therefore the length of the rainy season becomes increasingly lower.

1-4 Evapotranspiration (1980-2000)

The evapotranspiration is one of the principal parameters of water balance. The method used for assessing the actual evapotranspiration (ETR) and / or potential (ETP) in this study is that of Thornthwaite [11]. To distinguish spatial variations of ETP between Tabular and Sais plain, Tables 1 and 2 show the monthly evolution of ETP in the two representative's stations. The ETP evolution at El Hajra is similar that it in Ifrane. In the Sais, the ETP evolving from 22.9 mm in January to 133 mm in August. While, in the Tabular, ETP evolving from 11.7 mm in January to 110 mm in July.

At the annual scale, evapotranspiration is greater in El Hajra (834 mm) than the one in Ifrane (633 mm), which is explained by thermal differences between the Sais plain (Trough South Rifain) and Tabular. The real evapotranspiration (ETR), is relatively stable both in El Hajra (330 mm) at Ifrane (380 mm). Therefore, the water deficit (DH = ETP − ETR) is disproportionate between the two stations, it is two once higher in El Hajra (504 mm) than Ifrane (253 mm). It is the lack of water needed to satisfy potential evapotranspiration (the water requirements of plants). The comparison of ETR and precipitation shows about the surplus water (HS = P − ETR) supplying the flow in all its forms. The surplus water is zero in El Hajra, than in Ifrane, it presents a considerable quantity: 520 mm. At a result, the stream Mikkes Basin is alimented by the Tabular Middle Atlas well watered (Tables 1 and 2).

Table 1. Hydric balance of El Hajra (1980-2000)

Month	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Annual
P (mm)	12.87	26.54	45.71	54.21	45.23	34.67	34.36	41.20	26.35	7.30	1.31	0.17	330
ETP (mm)	104.82	74.46	44.46	34.66	22.90	33.12	41.29	47.67	70.59	98.53	128.68	133.12	834
P-ETP	-91.96	-47.93	1.25	19.55	22.33	1.56	-6.93	-6.47	-44.24	-91.23	-127.37	-132.94	-504
RFU	0.00	0.00	1.25	20.80	43.13	44.69	37.76	31.29	0.00	0.00	0.00	0.00	179
ETR	12.87	26.54	44.46	34.66	22.90	33.12	41.29	47.67	57.64	7.30	1.31	0.17	330
Deficit	91.96	47.93	0.00	0.00	0.00	0.00	0.00	0.00	12.95	91.23	127.37	132.94	504
Surplus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0

Table 2. Hydric balance of Ifrane (1980-2000)

Month	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Annual
P (mm)	36.81	66.04	113.60	140.31	114.10	118.49	99.01	103.54	60.12	22.86	10.64	14.93	900
ETP (mm)	86.13	54.75	31.07	18.10	11.70	18.02	27.06	33.09	51.44	80.64	110.09	110.90	633
P-ETP	-49.31	11.30	82.52	122.21	102.39	100.47	71.95	70.45	8.68	-57.78	-99.45	-95.97	267
RFU	0.00	11.30	50.00	50.00	50.00	50.00	50.00	50.00	50.00	0.00	0.00	0.00	361
ETR	36.81	54.75	31.07	18.10	11.70	18.02	27.06	33.09	51.44	72.86	10.64	14.93	380
Deficit	49.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.78	99.45	95.97	253
Surplus	0.00	0.00	43.82	122.21	102.39	100.47	71.95	70.45	8.68	0.00	0.00	0.00	520

2- The surface water

The stream of Mikkes basin is like all the Morocco basins has experienced a dry periods since 1980 with a rainfall deficit differentially distributed in space. Figure 9 shows that the flow of the Mikkes stream has a temporal variation, which generally tends to decrease. This fall is becoming stronger between 0 and 2 m^3/s during the period 1980-2000. It is also apparent from this figure the influence of the average annual rainfall on the average annual flow of the river.

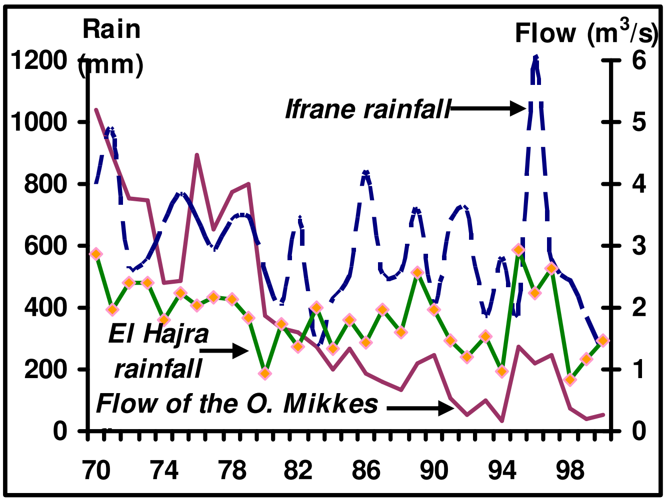


Figure 9. Annual precipitations at the station of Ifrane and El Hajra/annual flows of the Mikkes River (1970-2000)

Generally flows evolution is according to its precipitations which recorded in the basin (Ifrane station and El Hajra). In Ifrane the most rainy years in the series studied, namely 1996 (1215 mm), while in El Hajra year 1995 was the year with highest average which was about 586 mm. This increase in rainfall during the two years (1995 and 1996) is followed by a maximum flow of the stream. Between the periods 1970-1979 and 1980-2000, the water deficit of the Mikkes stream is around 75 %. The deficit of rainfall is around 22 % in the Tabular and 23 % in the Sais. Indeed, the decrease of precipitations and the increase of temperatures. Thus, increase of ETR after 1980 could be caused of deficit flow of Mikkes stream.

Starting from 1980, the flow curve demarcate perfectly of the rain (Figures 10 and 11). In the Sais, the quantity of cumulative rainfall between 1970 and 1979 is 3792 mm and the degree of increased rainfall during these 10 years is about 379 mm/year. In the Tabular, the cumulative rainfall in 1979 is 6140 mm, and the magnitude of increase in rainfall is 614 mm/year. It is established that the cumulative rainfall Tabular is very high compared to that observed in Sais and this can be explained by a high evapotranspiration in Sais and it is low in Tabular. The cumulative flow is about 32 m^3/s in 1979 and the degree of increase is about 3 m^3/s.

After 1980, a fall in the slope between cumulative rainfall and cumulative flow stations in the two features of the basin. This can be explained by a shortage of rainfall and which was started in 1980 because of climate change which has seen the basin in particular and Morocco in general and which resulted in a deterioration of water supplies. At the station of El Hajra, cumulative rainfall in 2000 is 11.393 mm and is 18.348 mm station of Ifrane. The degree of increase in cumulative rainfall in the Sais during the second period (1980-2000) is about 335 mm/year and it is about 543 mm/year in the Tabular. The cumulative flow in 2000 was 57 m^3/s and the degree of elevation of speed is about 1 m^3/s. Indeed, the decline in rainfall is accompanied by a downward flow of rivers (Figures 10 and 11).

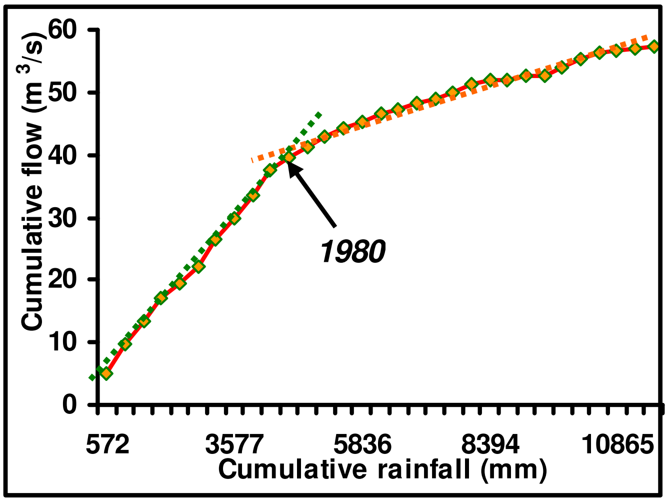


Figure 10. Two cumulatives between precipitation in El Hajra and flow of the wadi Mikkes (1970-2000)

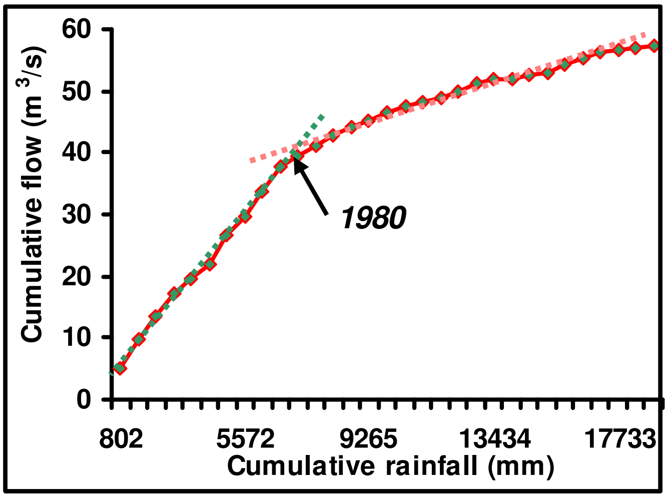


Figure 11. Two cumulatives between precipitation in Ifrane and flow of the wadi Mikkes (1970-2000)

The distribution monthly coefficients of flows Mikkes River for a period of 31 years (1970-2000) (Figure 12) shows that this is a rough system oceanic characterized by two hydrological seasons: a period of high water and a other low water. It is reflected in a sharp contrast between the winter (January to March) and the low water level (from July to September). The period of high water is marked by a maximum in February and whose monthly flow ratio is about 185 %. The high rainfall and low temperatures for the month of December and January have a positive impact on the river flow (low evapotranspiration). The period of low water is demonstrated by a minimum flow in August and whose monthly flow coefficient is the lowest with an average about 36 % (high evapotranspiration) (Figure 12).

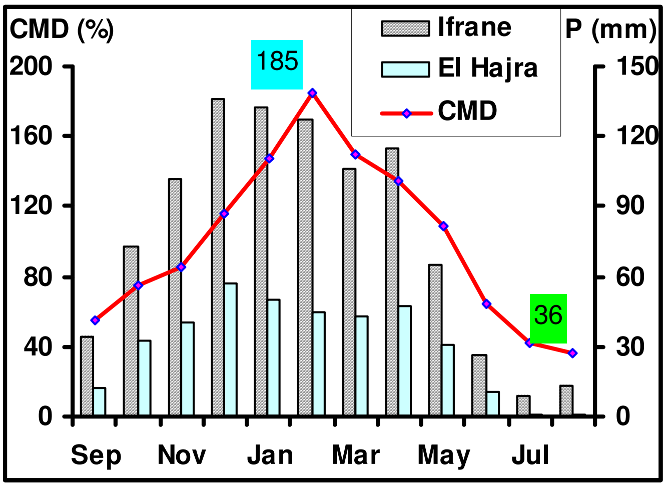


Figure 12. Monthly rains at the station of Ifrane and El Hajra/monthly coefficient of flow (1970-2000)

The low rainfall and high temperatures in June and July had a significant impact on the flow of rivers. Thus, the monthly coefficients of flows Mikkes stream determined in a period of 31 years show the seasonality system and it is conditioned by the supply rainfall in winter and by predominant evapotranspiration in summer. The regime of the Mikkes River is like rain- evaporates, as illustrated in Figure 12. The rapport between the least monthly coefficient least and the highest is around 19 % and the water deficit is 81 %. This deficit of flow water of the Mikkes stream during the years can be caused by evapotranspiration.

CONCLUSION

The stream of Mikkes basin is part of the Mediterranean basin and whose climate has been changed contributing to deterioration in reserves water. The semi-arid climate of this basin is principally characterized by strong irregularity in rainfall, between year and another. The seasonal rate is uni-modal generally and it is characterized by a strong contrast between the winter whose maximum precipitations and minimum evapotranspirations and summer whose minimum precipitations and maximum evapotranspirations (temporal drought). The magnitude of the seasonal drought (1980-2000) is very strong in the Sais and the number of dry months is 6 months while that of Tabular is 4 months (space drought).

The evolution of annual average flows (1970-2000), shows a continue fall and strong since the 1980. The flow deficit of river Mikkes is about 75 %. The monthly measures during the period 1970-2000, shows that the regime of the river is rough ocean system, with maximum flow in winter, when evapotranspiration is low, and minimum in summer when evaporation is high. As a result of this study the type of river can be classified as a rain - evaporal.

ACKNOWLEDGMENTS

Many thanks to the Hydraulic Basin Agency of Sebou (ABHS) for their cooperation and also, for the availability of data necessary for the realization of this work.

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