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Relationship Between Hydrology and Climate in the Stream Mikkes (Morocco)

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Abstract: This article tackles the drought and its effects on the flow of the stream Mikkes during the period 1968-2009. Mikkes basin is located at the northern center of Morocco. It is limited on the North by Prerif and Prerif Ridges, on the South by the Middle Atlas Tabular. The yearly approach of the P<2T ratio reveals a bad monthly distribution of precipitations and a seasonal drought which is being observed especially after the Eighties of the last century. Analysis of monthly medium flows between 1968 and 2009 shows a rough oceanic system which is characterized by two hydrological seasons. First a period of high waters in winters which is conditioned by the pluviometric contributions and a second is a low water in summer which is conditioned by an evapotranspiration. The mode of this River can be a pluvio-evaporal type. The positive correlation and proximity of temporal fluctuations curves between the River flow and the piezometric level of Saïs phreatic aquifer outside flood periods, suggests the assumption of a supply-drainage relationship between the aquifer and the River. The high deficit of the stream Mikkes (between 1968-1979 and 1980-2009) is about 76% and could be the combined effect of drought and exploitation of groundwater.

Key words: Stream Mikkes % Drought % Pluviometry % Evapotranspiration % Flow % Deficit

INTRODUCTION

The importance of water resources is well established, its management at all levels is imperative. Morocco is a country in climate mainly semi-arid to arid, characterized by strong rainfall contrast between winter and summer.

The drought has subsequently attracted great interest because of its relationship to global climate change, which would threaten water resources [1]. During the last three decades, Morocco has experienced several prolonged droughts. The effect of these years of drought on water availability basins has greatly exacerbated the deficit in water flow observed since 1970; the beginning of the deficit cycle across the whole country [2].

The stream Mikkes is a tributary of the stream Sebou. Its waters are regulated by the dam of Sidi Echahed. Its catchment area is located between the cities of Fez and Meknes. The region contains the cities of Ifrane, Aïn Taoujdat and many other centers. Its area is about 1600 km² (Fig. 1).

The study area covers three different structural sets: El Hajeb-Ifrane Tabular in the South, which is dominated by carbonate formations (Limestones and Dolomites Lias) and strong fractures. The Saïs basin in the center is formed by Lacustrine Limestone and Fauvist Sand of Pliocene; and Marls of Miocene. In the North, the Prerif is formed mainly by Marls Miocene and Clays Trias (Fig. 2). The central Mikkes basin is a part of the Saïs basin, which is furthermore a central part of the South Rifain Trough [3].

The hydrogeological context of the different regional structures implies the existence of three groundwater tables. El Hajeb-Ifrane Tabular is a free-water table circulating in the Limestones and Dolomites. It is supplied directly by precipitation. Clays Triassic and Paleozoic Schist form impermeable substratum of this aquifer. These carbonate formations burrow under the Mio-Plio-Quaternary cover the right South Rifain Trough for to become a deep confined aquifer. The depth of the Miocene Marls forming the roof of this aquifer is about 1500 m at drilling Aïn Allah (IRE N° 2370/15). The Plio-Quaternary formations as they are a phreatic water-table of Saïs [3].

This article first analysis of the spatio-temporal evolution of rainfall and temperatures in Mikkes basin. Second it highlights the sensitivity of River flows to the drought and the exploitation of Saïs phreatic groundwater.

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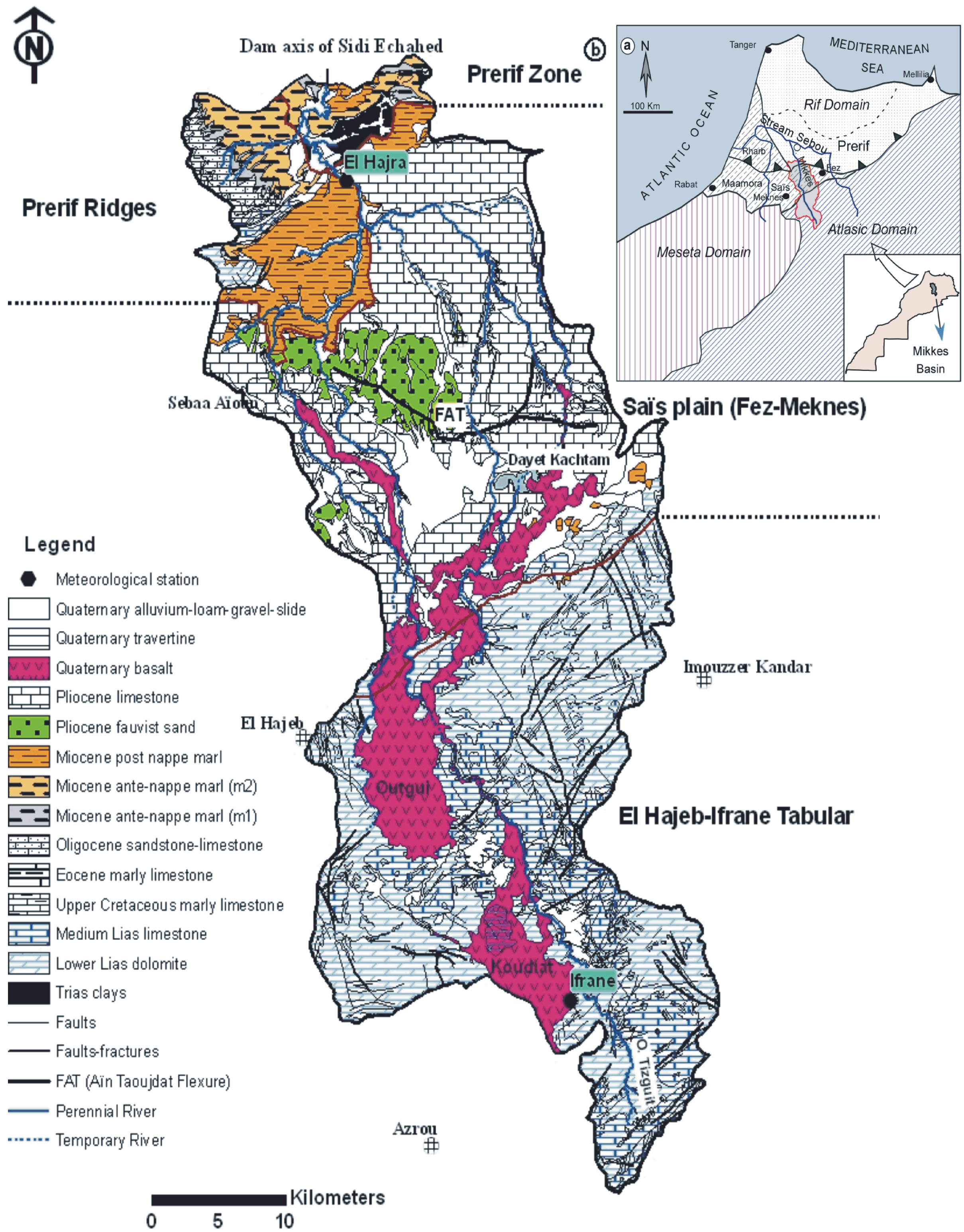
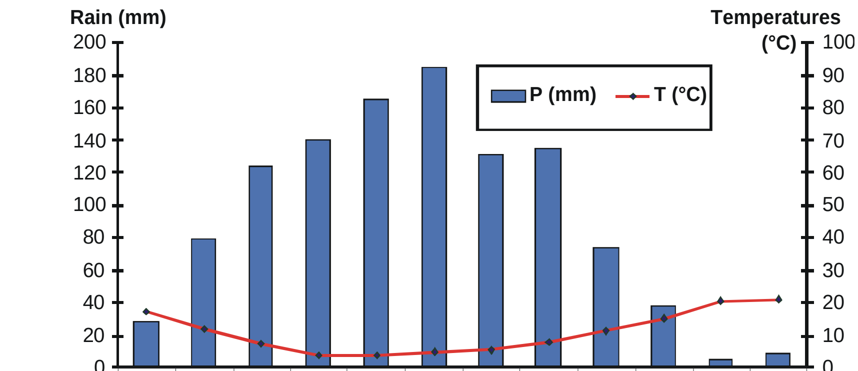
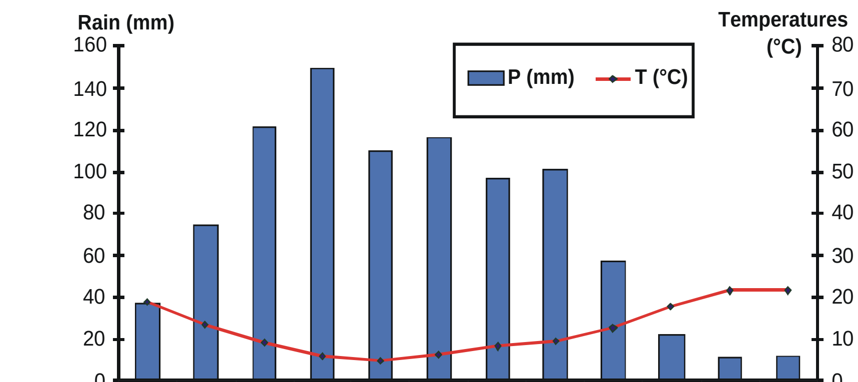


Fig. 1: a. Situation of the Mikkes basin, b. Geological map of the Mikkes basin (extracted from the geological map 1/100000, Rabat, Morocco, 1975).



	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
P (mm)	28.41	79.36	123.45	139.85	164.78	184.41	131.09	134.16	73.93	37.93	5.23	9.01
T (°C)	17.05	11.87	7.36	4.05	3.94	4.75	5.36	7.74	11.00	15.08	20.62	20.85

Fig. 2: Ombrothermic diagram of Ifrane station (1968-1979).



	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
P (mm)	36.79	74.50	120.97	149.17	109.50	116.33	96.79	101.33	57.05	21.62	10.96	11.93
T (°C)	19.00	13.52	9.09	5.89	4.73	6.30	8.14	9.50	12.67	17.79	21.70	21.74

Fig. 3: Ombrothermic diagram of Ifrane station (1980-2009).

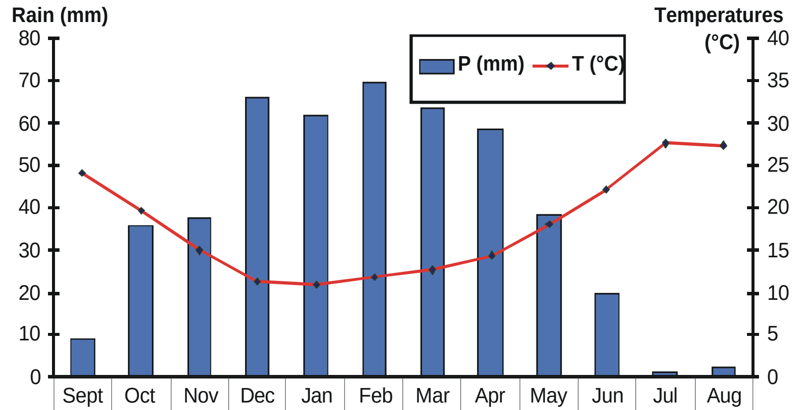
Methodology: In this study two meteorological stations are selected; first one is in Tabular Atlas while the other is in Saïs plain. The Ifrane station (altitude Z = 1600 m) is characterized as Tabular and El Hajra station (altitude Z = 215 m) in Saïs plain. Precipitations and temperatures were recorded from 1968 to 2009. Data for seasonal droughts of Ifrane and El Hajra stations show the extent of drought in the Tabular and in the plain. The magnitude of the drought is characterized in temporal and spatial terms.

Flow measurements of the stream Mikkes, are performed at the El Hajra station. The relationship River-groundwater was addressed by comparing the changes in flow of the stream Mikkes and those of the Saïs phreatic groundwater level.

Gaussen Index and Water Balance: Trend of Morocco climate and in particular in Mikkes basin have the tendency of drought and warming which are certainly accompanied by a reduction of soil water content and therefore a deficit in water resources [4].

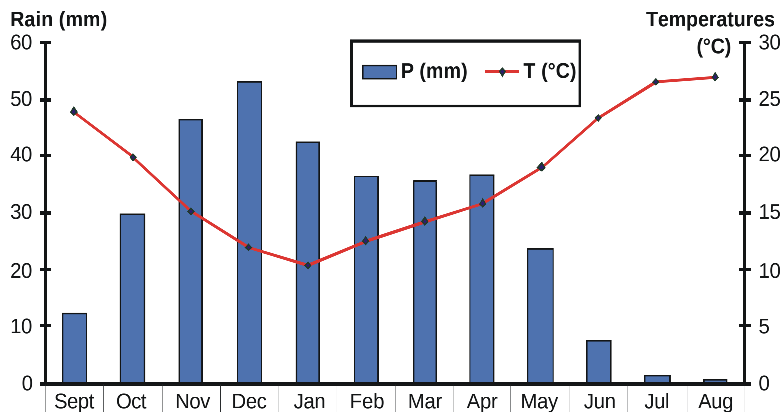
It is important to see the evolution of climate in Ifrane and El Hajra stations of Mikkes basin in terms of the Gaussen index and the Thornthwaite balance.

Gaussen Index: By combining the values of monthly precipitation in millimeters (P) and temperatures in degrees centigrade (T), the botanist H. Gaussen defined biologically dry month by the ratio P <2T [5]. It is important to know if there is a difference between the dry area of the Middle Atlas Tabular and that of the Saïs plain. The ombrothermic diagram in the Tabular for the period 1968-1979 is shown in Figure (2) and that of period from 1980 to 2009 in Figure (3). The 3rd diagram in the Saïs plain for the period 1968-1979 and the fourth diagram for the period 1980-2009 are shown in Figures 4 and 5.



	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
P (mm)	9.09	35.77	37.48	66.11	61.89	69.63	63.66	58.63	38.07	19.62	1.12	2.17
T (°C)	24.03	19.57	14.87	11.25	10.94	11.90	12.54	14.46	17.98	22.18	27.63	27.42

Fig. 4: Ombrothermic diagram of El Hajra station (1968-1979).



	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
P (mm)	12.45	29.84	46.45	52.95	42.35	36.38	35.41	36.66	23.55	7.52	1.48	0.60
T (°C)	23.88	19.90	15.12	12.04	10.43	12.54	14.32	15.80	19.05	23.38	26.52	26.94

Fig. 5: Ombrothermic diagram of El Hajra station (1980-2009).

In Tabular Atlas, represented by the Ifrane station, monthly variability in rainfall between the period 1968-1979 and that of 1980-2009, clearly appears (Figs 2 and 3). The general trend is the increase in temperature for each month (the air is warmer). While the trend of precipitation is declining, with the exception of months of July, August, September and December which witness increase in rainfall. Thus, this development is accompanied by an increase in the number of dry months. For the period 1968-1979, the number of dry months in the Tabular Atlas are three (July-August and September) (Fig. 2) and it becomes four months (June, July, August and September) for the period 1980-2009 (temporal drought) (Fig. 3). Drought shows itself in June (1980-2009) rather than in July for the period 1968-1979.

In plain of Saïs, the general trend is the increase in temperature for every month with the exception of September, August, July and January, when we notice a slight decrease in temperature. However, the trend of the height of rain is falling; except July, September and November when there is an increase in precipitation. These climate changes are accompanied by an increase in number of dry months. For the period 1968-1979, the number of months is 5 dry months (June, July, August, September and October) (Fig. 4) and it becomes six months (May, June, July, August, September and October) between 1980 and 2009 (drought temporal) (Fig. 5).

In addition, it is appeared that the early arrival (one month) of drought in the period 1980-2009 over the period 1968-1979.

By comparing the ombrothermic diagrams of Ifrane and those at the El Hajra station, we see that the number of dry months for the period 1968-1979 were three months in Tabular Atlas and also five months in Saïs plain. In Tabular Atlas the period of 1980-2009, the number of dry months are four, while they reach six months in Saïs plain. Thus the drought spreads and varies in time and space in Mikkes basin; spatio-temporal drought. The continuous renewal of anticyclonic situations during the hot season, due to the spread of important subtropical high, causes atmospheric stability and dryness almost universal. The worsening of the drought is also related to the nature of prevailing winds in this season: the south-east continental-hot winds (Chergui) represents an average 15 to 20% of total annual (thirty days). These winds result in a low humidity and high evapotranspiration. Only rain storms, especially in the Middle Atlas Tabular, sometimes come refresh time [6].

On the other hand, the only consideration of monthly rainfall-temperatures imperfectly expresses the magnitude of drought, because it must also consider the effect of potential evapotranspiration, which determines the seasonal rhythm of the quantity of water available for flow. The precipitation and potential evapotranspiration are two variables comparable, because they are assessed in depth of water. That said, they are obviously more evocative than the definitions based on the P/T which does not have any mathematical justification, since it establishes the link between quantities of different nature. In addition, the P/T does not take into account the available water in the soil which intervenes especially at the beginning of the dry season to delay its appearance. Water balances reflect this parameter which rhythm the magnitude of water deficit and hence the constraint of drought [7-9].

Thornthwaite Water Balance: It is a method of soil water balance, in which an estimated reserves of water easily usable in millimetres of water height. This method is accepted that the height of water stored in soil of Mikkes basin, which is taken up by evapotranspiration is 50 mm in maximum. Exceeding this limit RFU promotes infiltration or runoff.

Table 1 summarizes the results obtained by this method. The actual evapotranspiration (ETR), which reflects water actually taken through the atmosphere is relatively stable both in El Hajra (325 mm) as Ifrane (387 mm). Therefore, water deficit (DH = ETP-ETR) is disproportionate between the two stations and is twice as large as El Hajra to Ifrane: 574 against 312 mm. It is water shortage needed to satisfy potential evapotranspiration. The comparison of actual evapotranspiration and precipitation inquires on the hydrological surplus (SH = P-ETR) feeding the flow in all its forms. The hydrological surplus is very low in El Hajra which is about 40 mm. While in Ifrane, it has a considerable amount of 578 mm. Thus, the stream Mikkes is fed mainly by the Middle Atlas Tabular which is well watered.

Table 1: ETR calculations by the Thornthwaite water balance (1968-2009)

1968-2009	Ifrane	El Hajra
P (mm)	965	365
ETP (mm)	699	899
ETR	387	325
DH (ETP-ETR)	312	574
SH (P-ETR)	578	40
% de SH	60	11

Table 2: Relationship altitude-evapotranspiration

Stations	Altitude (m)	P (mm)	ETR (mm)	SH	%
Ifrane	1635	965	387	578	60
El Hajra	215	365	325	40	11

Table 3: ETR calculations by the Thornthwaite water balance between (1968-1979) and (1980-2009)

	Ifrane (68-79)	Ifrane (80-09)	El Hajra (68-79)	El Hajra (80-09)
P (mm)	1112	907	463	326
T (°C)	10.8	12.4	17.94	18.3
ETP (mm)	649	706	900	907
ETR	364	390	342	308
DH (ETP-ETR)	285	316	558	599
SH (P-ETR)	748	517	121	18
% de SH	67	57	26	6

The short time of reconstitution of soil reserve in Ifrane is due to the abundance of rainfall, which allows a long saturation phase which lasts for seven months compared only to three months in El Hajra. Thus, any over rainfall favours the flowing or infiltration in Tabular Atlas than Saïs plain.

The hydrological surplus, which corresponds to effective infiltration, is high in Ifrane reaching 60% of rainfall. As for El Hajra the surplus does not exceed 11% and is distributed mainly in surface runoff.

Table 2 presents percentage of water surplus obtained from the ETR by the Thornthwaite water balance method, which is the most representative and most advantageous to the Mikkes watershed. It reappears that the hydrological surplus is more important in Ifrane where altitude and rainfall are higher and it is lower in El Hajra where altitude and rainfall are lower. Indeed, the evapotranspiration decreases as altitude increases.

Table 3 summarizes the results of ETR calculations by the Thornthwaite water balance between (1968-1979) and (1980-2009) in Ifrane and El Hajra stations.

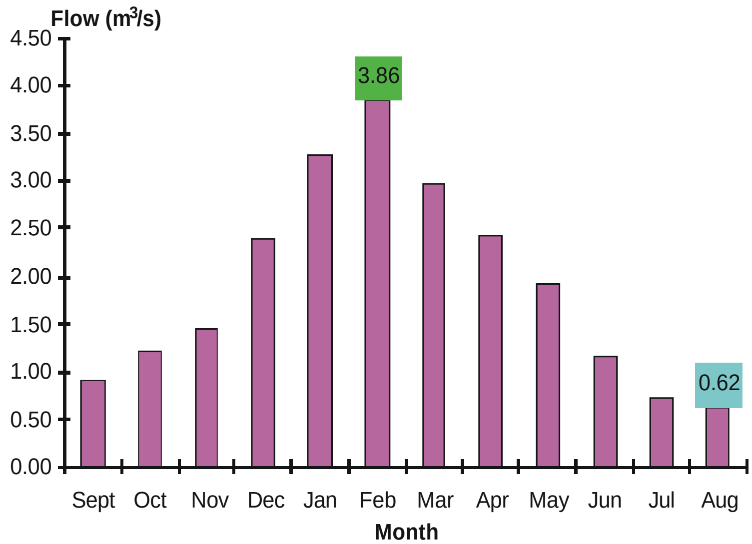


Fig. 6: Monthly average flows of the stream Mikkes (1968-2009).

These results conclude that the increase in temperature causes an increase in evapotranspiration and leads to a reduction of hydrological surplus.

Surface Water: To know the system of Rivers draining the study area, El Hajra hydrometric station was used to monitor the flow in Sidi Echahed's dam. This station is in operation since 1968 and its altitude is 215 m.

Monthly Flow: Studying of monthly flow of the stream Mikkes is very useful to know the River regime. Figure 6 shows monthly average flows calculated for a period of 42 years. It shows that there is one precipitation mode, which is rain origin. The propagation of flows of streams is not done under the same conditions, nor to the same proportions, in times of low water and high water period [10]. Monthly distribution of flows is used to classify the flow regime of a River: the hydrologic regime. It summarizes all of its hydrological characteristics and mode of variation. It is defined by variations in its flow usually represented by the graph of the average monthly flow. The monthly flows of the stream Mikkes are generally varies. They start to rise from September to reach the maximum in February (winter) with an average value of 3.86 m^3/s. During winter, Rivers collect much rainfall and generate an increased flow. However, during summer witness a decrease in flow (low water period), which continues to achieve its minimum in August with an average of 0.62 m^3/s. Monthly flows during dry periods of the year (July, August and September) are of low and they characterize the hydraulic continuity of Mikkes basin. The effects "delay" and "buffer" of the karst Mikkes basin are highlighted. Thus, the karst basin is characterized by a dry period in sustained low flow relatively abundant, with a delay of the direct action of rainfall on surface runoff. One might also note the extent of a base flow of about 620 L/s; portion flow of the stream Mikkes, which comes mainly from the groundwater basin. These are the geological formations of the subsoil, which by their storage potential and their transmissivity that have a significant effect on the groundwater contribution (base flow) at a flow of a River.

The hydrological regime of Rivers is influenced by precipitation, exchange with groundwater and samples [11]. Curve of monthly flows of the stream Mikkes for a period of 42 years (Fig. 7) shows that it is a simple oceanic pluvial regime characterized by two hydrological seasons: a period of high water and one of low water. The seasonality regime which is conditioned by the rainfall input and evapotranspiration. The seasonal flow type is a characteristic of climate zones deficit [12]. The regime of this River is classified as a rain-evaporal. The period of high water in winter is marked by a maximum flow in February with high precipitation, low temperatures and the minimal ETR. This, contributing a positive impact on the flow of Rivers which flow monthly is about 76 mm. Thus, it reappeared that flow curve follows the evolution of the rainfall with two months response time of the watershed: the maximum rainfall in December becoming maximum flow in February. The low water period is characterized by a minimum flow in August. The corresponding flow is the lowest with an average of about 12 mm (Fig. 7). This is more of a River's drainage of aquifer than a River receiving surface water runoff.

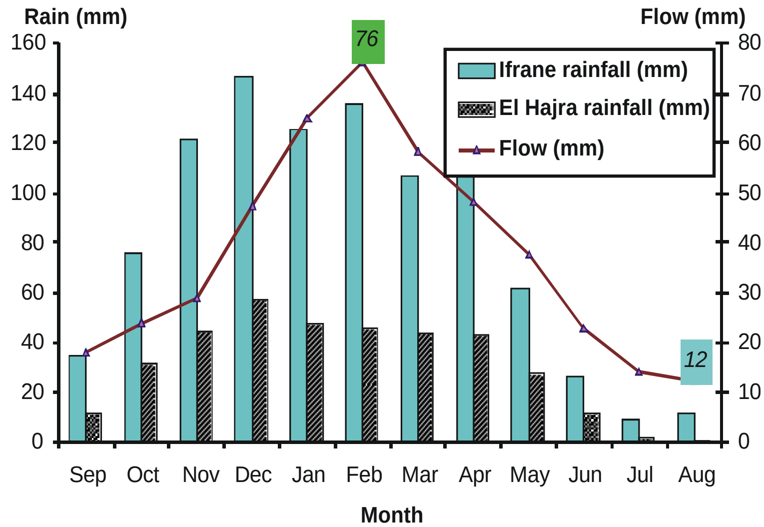


Fig. 7: Monthly rainfall at the Ifrane and El Hajra stations/monthly flows of the stream Mikkes (1968-2009).

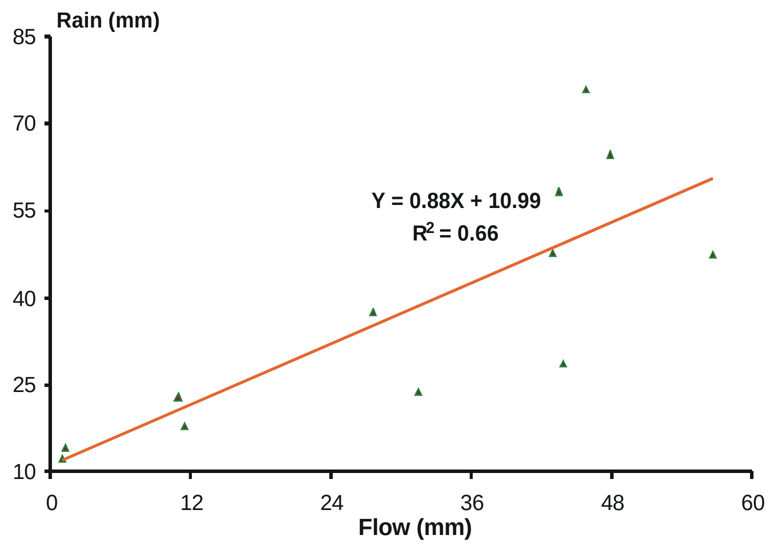


Fig. 8: Correlation between rainfall and monthly average flows of the stream Mikkes (1968-2009).

The ratio between the lowest monthly flow and the highest is around 16%. Therefore, the monthly changes of flow are very marked. This loss of water flow of the stream Mikkes during the year is mainly caused by less precipitation and high evapotranspiration. It is closely related to temperature on one side and to overexploitation of groundwater on another side.

To understand the hydrological response of Mikkes basin, a diagram of correlation between rainfall and monthly flows would be more significant. It is relatively good since its coefficient R is about 0.81 (Fig. 8). The precipitation is closely related to flow. This shows that either rain determines the flow, or either groundwater is contributing to flow.

In general, hydrological cycle is of type "charge/discharge" with wet winters, corresponding to high flows in River and high positions of groundwater level. Nevertheless, in dry summers with severe low flows in River and low groundwater level.

Annual Flows: Mean annual flow can be calculated from the arithmetic mean of monthly average flows. According to Remenieras [13], this average should be weighted taking into account number of actual days of each month.

Generally, the regime of the stream Mikkes corresponds to a low flowing, it is 1.21 L/s/km² (1968-2009). Its flows present temporal variation, which generally tends to decrease. To establish the trend of the flow evolution of the stream Mikkes over the period

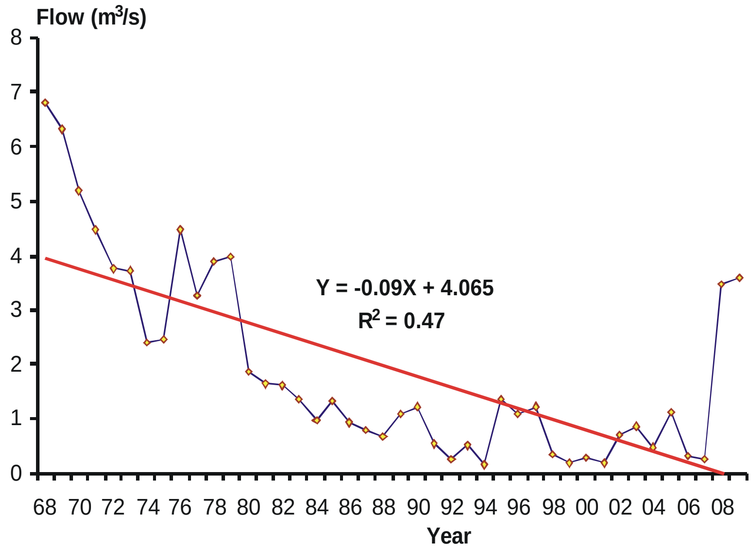


Fig. 9: Downward trend of annual average flows at El Hajra-Sidi Echahed stations for the period (1968-2009).

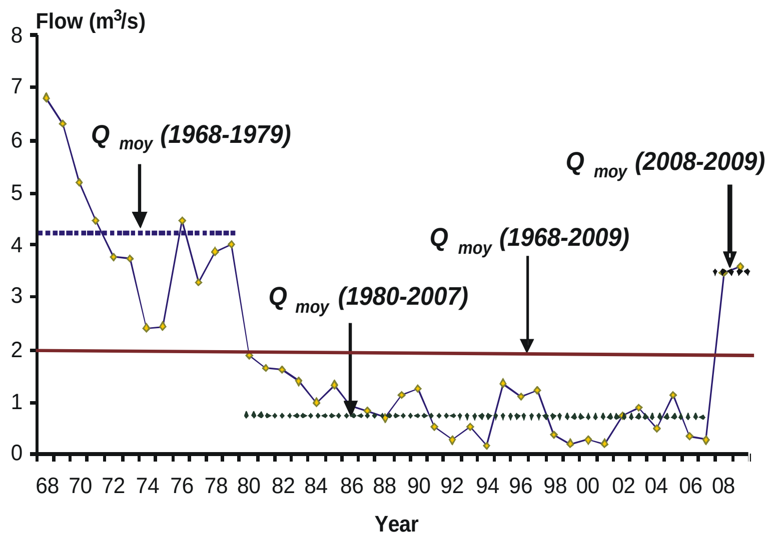


Fig. 10: Annual average flows of the stream Mikkes (1968-2009).

1968-2009, a linear regression on the annual flows for the years 1968 to 2009 is realized (Fig. 9).

During the years 1968-2009, the flow variations in the stream Mikkes present in general downward trend of the form:

$$Q(t) = 0.1t + 4.06$$

This trend shows a steady fall of flow, which is in average of around 0.1 m^3/s per year. The years before 1980, 2008 and 2009 correspond to years, which flows are above the average recorded between 1968 and 2009 (Q = 1.94 m^3/s). Maximum flow reaching a value of 6.81 m^3/s on 1968. While flows for other years are below average. These differences in inter-annual flows could be related to drought that experienced in region after 1980 (Fig. 10).

Figure 11 shows the influence of the average annual rainfall on the average annual flow of the stream Mikkes. Most studies on climate variability describe the variability of rainfall and runoff, with a link between these parameters [14-19].

Before 1980, generally, the flow evolution follows that of rainfall in the basin (Ifrane and El Hajra stations). Nevertheless, after 1980, it stands out. The years 1995, 1996, 1997, 2008 and 2009 were wet years in the Mikkes basin, which are followed by a peak of the River flow (the influence of rainfall on runoff).

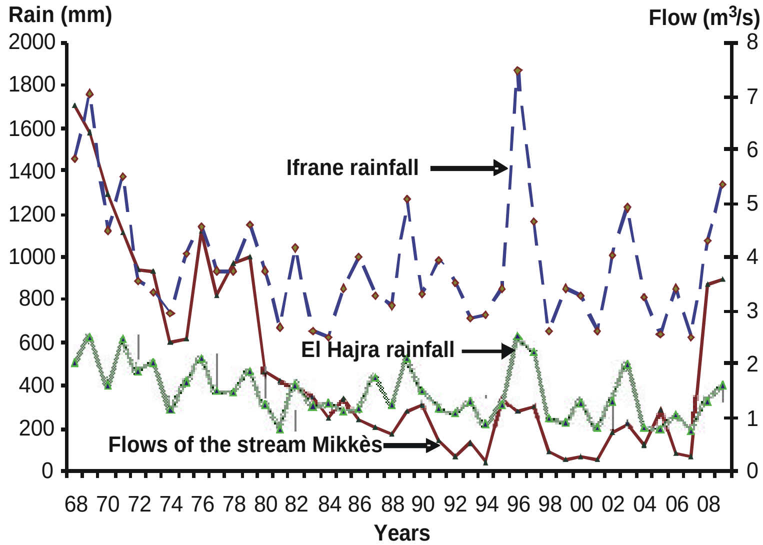


Fig. 11: Annual precipitation at the Ifrane and El Hajra stations/annual flows the stream Mikkes (1968-2009).

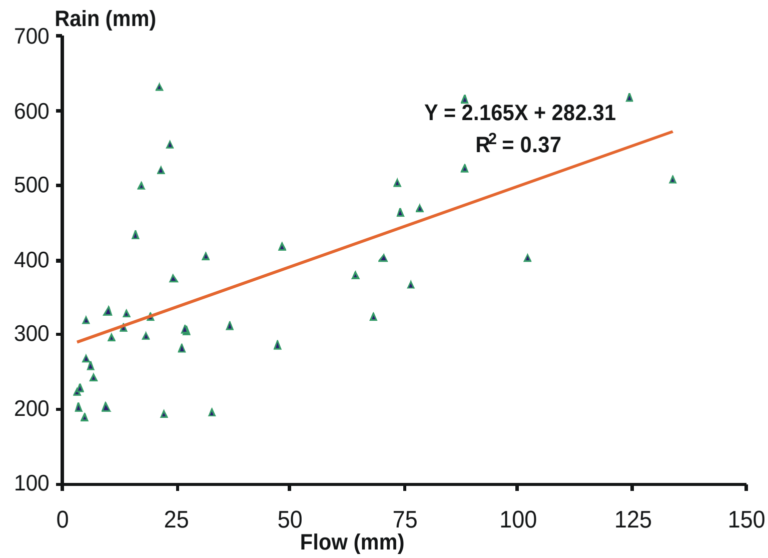


Fig. 12: Correlation between rainfall and annual average flows of the stream Mikkes (1968-2009).

Rainfall and flow are not well linked, which supposes that the flows come from rain and other resources (groundwater). Thus, low correlation coefficients (R = 0.61) can be explained by the fact that the permeable lithology of the basin (especially in El Hajeb-Ifrane Tabular) favours the infiltration of a part of the rainwater. It is responsible for reducing the annual flow of runoff and consequently the correlation coefficient is low (Fig. 12).

Between the periods 1968-1979 and 1980-2009, the decreasing rate of flows Mikkes River is around 76%. The rate of decrease in annual rainfall is about 18% at Tabular Atlas and 30% in Saïs plain. Indeed, the drop in flows (83 mm to 20 mm), is more important than rainfall (463 to 326 mm). This should be linked on one hand, to drought (accompanied by higher temperatures thus higher evapotranspiration) which has a negative effect on the flowing of the stream Mikkes but differently across the basin (Table 4). On the other hand, to the demographic

Table 4: Water deficits of the stream Mikkes

Period	P. Ifrane (mm)	P. El Hajra (mm)	Flow (mm)
1(68-79)	1112	463	83
2(80-09)	907	326	20
Proportion (2/1)	82	70	24
Déficit (%)	18	30	76

Table 5: Average flows observed for different phases; ratios between different phases and the average flow during the study period; Q = 1.94 m^3/s

Period	Average flow (m^3/s)	Variation with average flow Q (%)	
1968-1979	4.23	+54.14	Humid
1980-2007	0.84	-130.95	Dry
2008-2009	3.53	+45.04	Humid

development, agricultural and industrial which had a negative impact on water resources. This impact resulted in a reduction of natural water flows, leading to the overexploitation of groundwater. This has led to the disruption of balance of the system by the drying up of springs, the continued decline in water levels of groundwater and reducing surface water inputs.

For better characterizing of change in water regime of the stream Mikkes, the annual hydraulicity, which involves the inter-annual module for the period between 1968-2009, is shown in Figure 13. Lapointe [20] defined the annual hydraulicity as:

The hydraulicity is the difference between the module of the year considered and the module considered inter-annual of the period (1968-2009) as a percentage of the latter.

Before 1980, hydraulicity values were positive. Nevertheless, after 1980; with exception of 2008 and 2009 the values become negative.

Generally the years 1980 to 2007 have a low flow; negative values of hydraulicity, which confirms that those years, were dry. Table 5 shows the detection of discontinuities of the flows evolution.

The dry period, has a large deficit over 130%. Finally, since the 80's, the average flows of different phases are demonstrated deficits relative to average flow. However, the stream Mikkes shows an increase of over 45%, it is undoubtedly the major hydrological occurrence of this River after a dry period of 27 years (1980-2007).

This phenomenon could be attributed to the fact that Tabular surface layers were almost saturated with water before 1980. This saturation was mainly due to two factors: on one hand, the high rainfall which was around 668 mm/year (average Thiessen) corresponding to an average annual flow of 4.23 m^3/s. On the other hand, the number of samples did not exceed a few hundred in the Saïs aquifer and a few dozen at the Liasic aquifer (Saïs deep aquifer and the El Hajeb-Ifrane Tabular). This had an influence on the distribution of infiltration/runoff. Indeed, a high aquifer promotes the runoff and therefore a positive hydraulicity. After 1980 (exception of the 2008 and 2009 years) there was a decreasing in the piezometric level resulting in desaturation of superficial layers of Tabular triggered by low rainfall and an increase in the number of sample points for drinking water and irrigation purposes. The average annual rainfall during the period 1980-2009 is about 538 mm/year (average Thiessen) and corresponds to an average annual flow of about 2.1 m^3/s during this same period, the groundwater Mikkes basin has been overexploitation of water resources. The samples in 2001 exceeded thousands of water points in Saïs phreatic water-table and hundreds at Liasic aquifers and low rainfall promoted infiltration at depends of runoff water, which resulted in negative hydraulicity. In short, the relation rainfall-flow depends on water status of the unsaturated zones of the aquifer [3].

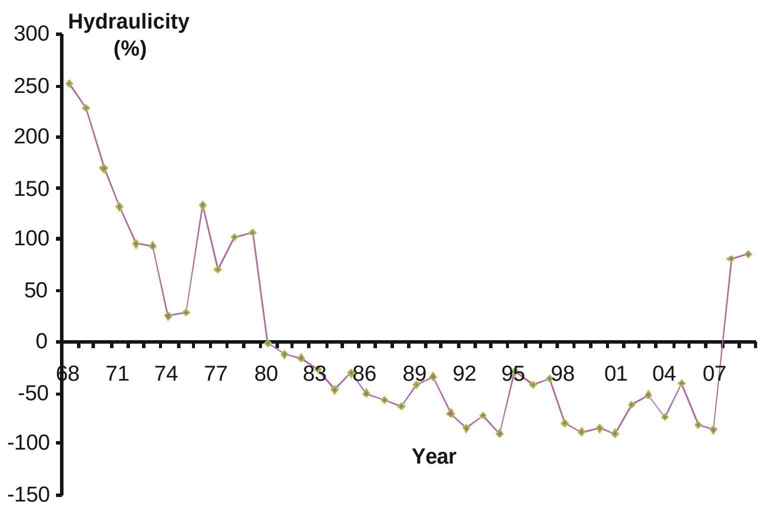


Fig. 13: Distribution of the annual flow of the stream Mikkes (1968-2009).

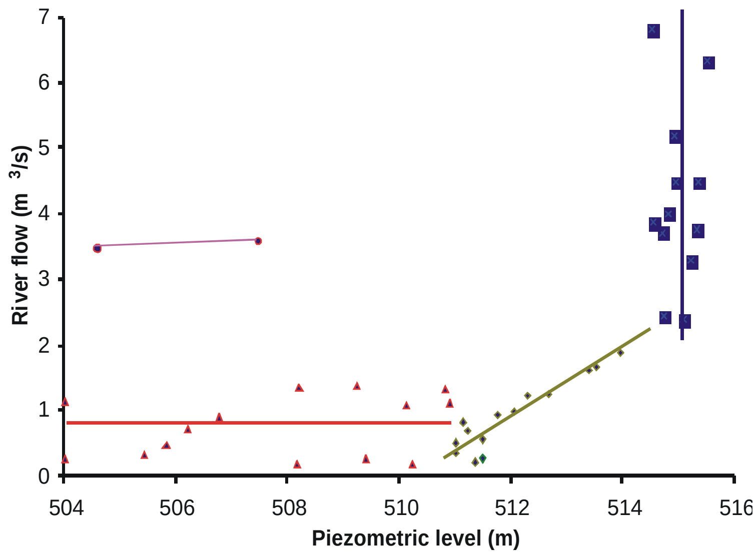


Fig. 14: Relation between piezometric level of the Saïs aquifer and River flow (1968-2009)

Exchange Groundwater-River: The direction of exchanges is based on the relative River level positions and piezometric levels in Saïs phreatic aquifer. The relation between groundwater and River level is shown in Figure 14 where four zones can be distinguished. The first one is for levels below 511 m and low flows (<2 m^3/s), it is characterized by independence between flow of the River and the piezometric level groundwater. The second is for levels between 511 and 514 meters. It is characterized by a significant dependence between the flow and the piezometric level groundwater. The third one for levels higher than 514 m and flows above 2 m^3/s. It is characterized by an almost independence between flows and piezometric levels: the flow of the River rises to the same level of the groundwater. The fourth zone corresponds to levels between 504 and 507 m and flow between 3 and 4 m^3/s. It is characterized by a positive correlation between the flow and the groundwater level.

Thus, first zone corresponds to the low flow in the River that does not appear to be affected by changes in piezometric level of Saïs aquifer. The rainfall water infiltrates into the unsaturated zone, but less than the saturated zone to influence the level groundwater. For levels between 511 and 514 m, a good correlation between the piezometric level and flow of the River emphasizes a close relation between the groundwater and the River. This range of level presents a renewable resource by charging and also the level which flow overflow springs. The piezometric levels above 514 m (and below the topography surface), correspond to a flow mainly from flood runoff that are not reflected on the heights of the groundwater given by the runoff speed more than the infiltration speed in the groundwater. For levels between 504 and 507 m and flow between 3 and 4 m^3/s, a good correlation between groundwater levels and River flow shows a relationship groundwater-River.

CONCLUSION

The basin of the stream Mikkes is among all Morocco basins, experienced dry periods. Since 1980, there has been a steady decline in rainfall combined with an increase in air temperature. Therefore, a reducing in River flows. The magnitude of seasonal drought is well observed in Tabular Atlas and Saïs plain. In the period 1968-1979, the number of dry months was three months in Tabular Atlas and five months in Saïs plain. Nevertheless, for the period 1980-2009, the number of dry months in Tabular Atlas is four months and it is 6 months in Saïs plain: spatio-temporal drought.

The regime of the Mikkes River is a rough oceanic system supported by the groundwater with a low flowing, which is about 1.21L/s/km².

The monitor measures monthly flows during the period 1968-2009, shows that the period of high water occurs from the month of December with a maximum flow in February. This is primarily due to increased winter precipitation. The period of low water in summer is manifested by a low flow and is caused mainly by low rainfall, high temperatures and high evapotranspiration. It is caused too by the increasing of samples number. Indeed, this River is rain-evaporal type. The water infiltrated in the Lias limestones and resurface as springs (base flow is about 620 L/s).

Calculation of the hydraulicity shows that for years before 1980, 2008 and 2009; the values of hydraulicity were positive, while after 1980 the values become negative in spite of the heavy rainfall recorded for some years between them. The negative hydraulicity is the result of sample increasing after 1980, which become huge in the beginning 2000s. This fact constitutes the disruption of hydrological regime and thus the behaviour of aquifers.

The relationship between groundwater-and River show that the lowering of surface water reserves in the Mikkes basin is the combined effect of drought and exploitation of Saïs aquifer.

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