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Relationship Flow-Rainfall in the Stream Mikkes (MOROCCO)

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Abstract: This article tackles the relationship between flow and rainfall in 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. 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 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 % Flow % Rainfall % Pluviometry %Evapotranspiration % 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.

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 [1].

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 km^2 (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. 1). The central Mikkes basin is a part of the Saïs basin, which is furthermore a central part of the South Rifain Trough [2].

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 [2].

This article highlights the relationship between River flows and rain in the stream Mikkes.

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 were recorded from 1968 to 2009.

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 2

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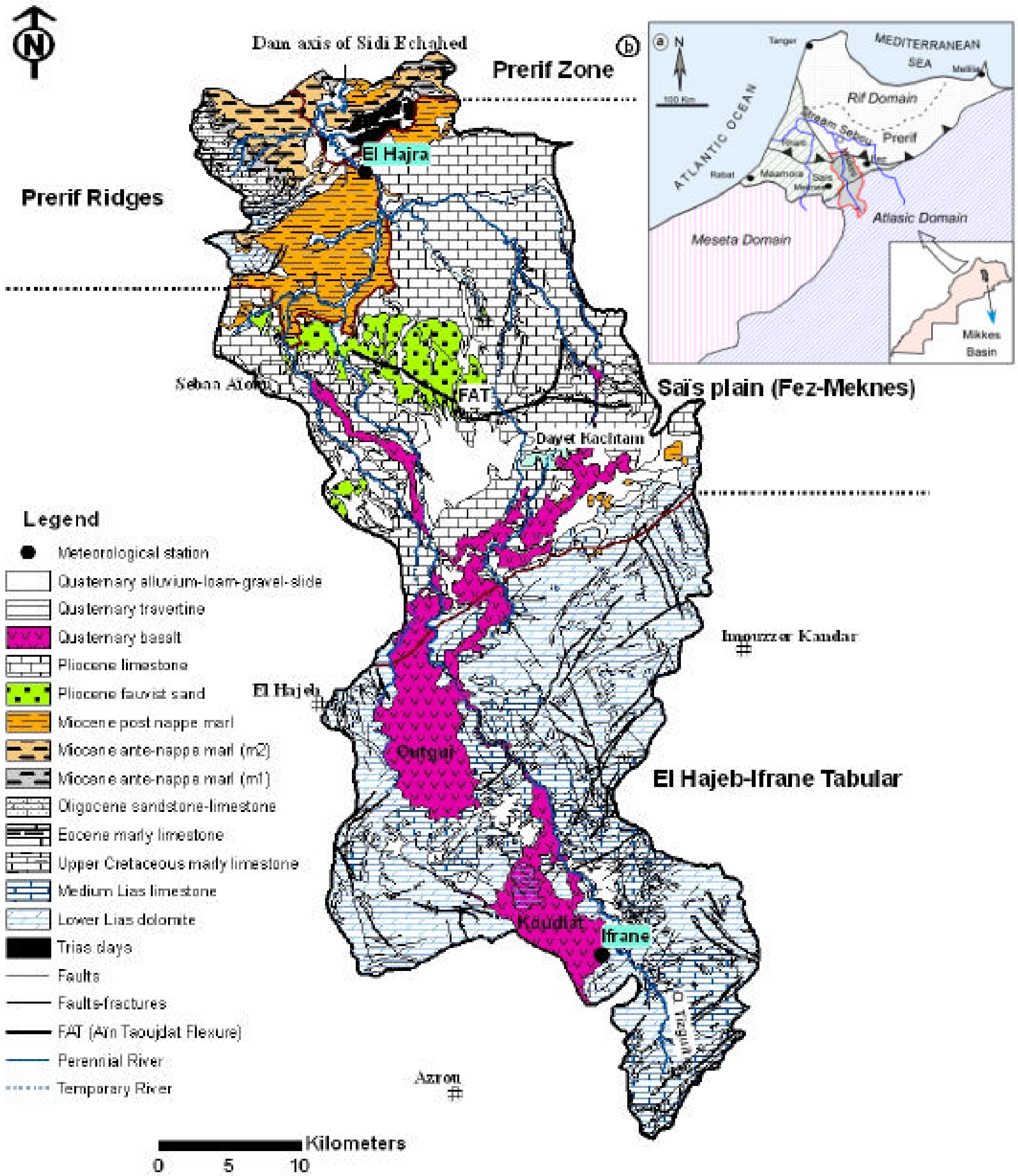

Fig. 1: a. Situation of the Mikkes basin, b. Geological map of the Mikkes basin (extracted from the geological map 1/100000, Rabat, Morocco, 1975).

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 [3]. 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

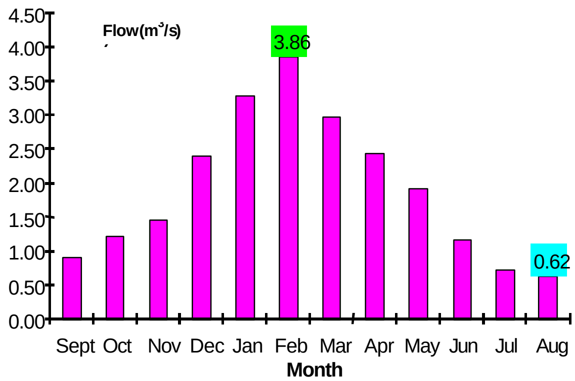

Fig. 2: Monthly average flows of the stream Mikkes (1968-2009).

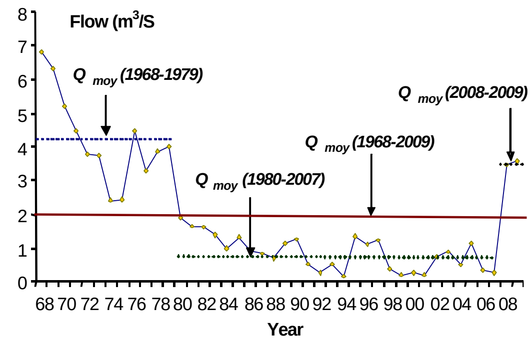

Fig. 5: Annual average flows of the stream Mikkes (1968-2009).

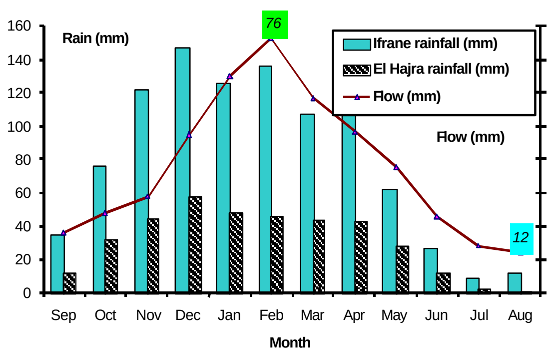

Fig. 3: Monthly rainfall at the Ifrane and El Hajra stations/monthly flows of the stream Mikkes (1968-2009).

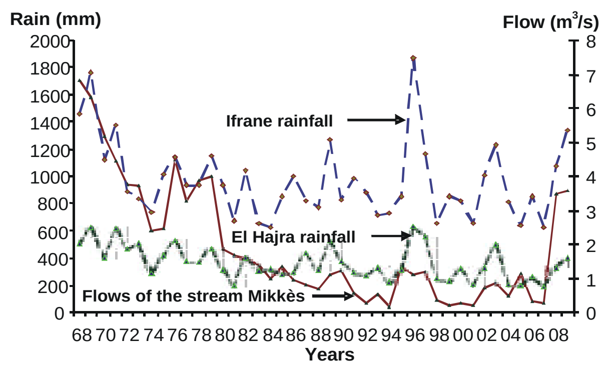

Fig. 6: Annual precipitation at the Ifrane and El Hajra stations/annual flows the stream Mikkes (1968-2009).

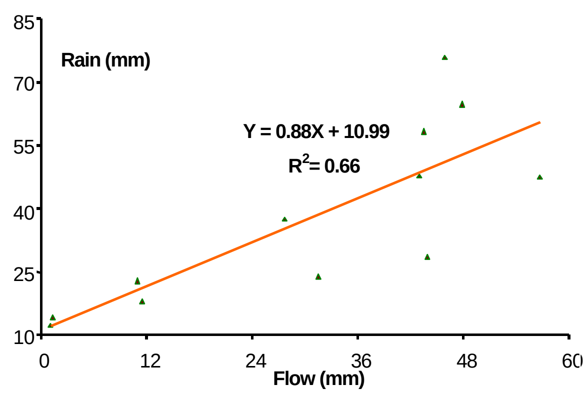

Fig. 4: Correlation between rainfall and monthly average flows of the stream Mikkes (1968 - 2009).

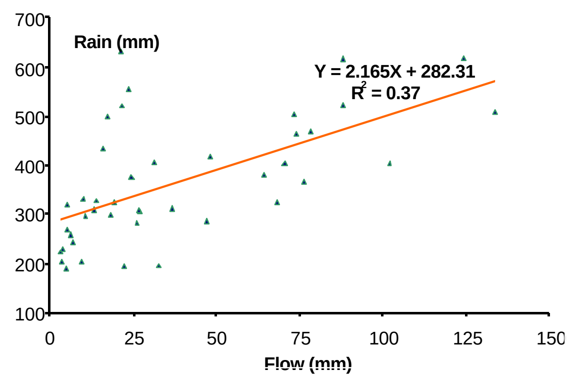

Fig. 7: Correlation between rainfall and annual average flowsof the stream Mikkes (1968 - 2009).

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 [4]. Curve of monthly flows of the stream Mikkes for a period

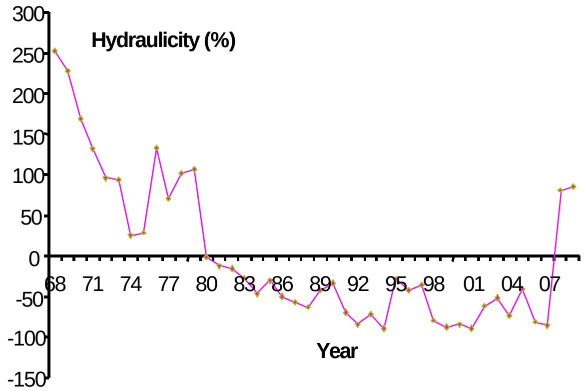

Fig. 8: Distribution of the annual flow of the stream Mikkes (1968-2009).

of 42 years (Fig. 3) 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 [5]. 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. 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. 3). This is more of a River's drainage of aquifer than a River receiving surface water runoff. 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 sI nce its coefficient R is about 0.81 (Fig. 4). 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 [6], 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/km^2 (1968-2009). Its flows present temporal variation, which generally tends to decrease. 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. 5).

Figure 6 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 [7-12].

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).

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. 7).

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

Table 1: 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

(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 1). On the other hand, to the demographic 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 8. Lapointe [13] 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.

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 [14]. 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 [14]. 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 [2].

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. Therefore, a reducing in River flows.

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/km^2.

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 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.

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REFERENCES

1. Mokhtar, B., 2004. Les ressources en eau au Maroc. UN Water-Africa.

2. Belhassan, K., M.A. Hessane and A. Essahlaoui, 2010. Interactions eaux de surface - souterraines: bassin versant de l'Oued Mikkès (Maroc). Hydrol. Sci. J., 55(8): 1371-1384.
3. Vançon, Jean-Pierre, 1996. Méthode d'étude des débits par corrélation. Hydrol. Sci. J., 11(3): 17-25.
4. Anonyme, 2005. Tableau de Bord de l'Environnement Poitou-Charentes. Thème Eaux Continentales, Conseil Régional Poitou-Charentes, Poitiers (France): pp: 98.
5. Aranyossy, J.F., 1989. Some aspect of the application of isotop technics in the sahelien countries. Asotopstechninics in the hydrological in arid and semi-arid regions. Proc.Adv.meet. Vienna.
6. Remenieras, G., 1976. L'hydrologie de l'ingénieur - Editions Eyrolles. Collection de la Direction des Etudes et Recherches d'Electricité de France, 2ème Édition, pp: 456.
7. Demarée, R.G. and C. Nicolis, 1990. Onset of the Sahelian drought viewed as a fluctuation induced transition. Quarterly J. the Royal Meteorological Society, 116(491): 221-238.
8. Hulme, M., 1992. Rainfall Changes in Africa: 1931-1960 to 1961-1990. International Journal of Climatol., 12(7): 685-699.
9. Janicot, S., 1992. Spatiotemporal variability of West African rainfall. Part I: Regionalization and typings. J. Climate, 5(5): 489-497.
10. Fontaine, B. and S. Bigot, 1993. West African rainfall deficits and sea surface temperatures. International J. Climatol., 13(3): 271-285.
11. Moron, V., 1994. Guinean and Sahelian rainfall anomaly indices at annual and monthly scales (1933-1990). International J. Climatol., 14(3): 325-341.
12. Paturel, J.E., E. Servat, B. Kouame and H. Lubes, 1997. Ouedraogo M, Masson JM. Climatic variability in humid Africa along the Gulf of Guinea. Part II: An integrated regional approach. J. Hydrol., 91(1-4): 16-36.
13. Lapointe, D., 1981. Eaux de surface du bassin versant de la rivière Nicolet. Programme de connaissances intégrées. Direction générale des eaux. Service des eaux de surface. Ministère de l'Environnement du Québec.
14. Belhassan, K., 2011. Comportement hydrologique, hydrogéologique et hydrodynamique du bassin versant de l'Oued Mikkès en amont du barrage de Sidi Echahed (Maroc), Thèse Doct. National. Univ. Sidi Mohammed Ben Abdellah. Fès, pp: 216.