# Impact of climate change on water resources in Morocco: The case of Sebou Basin

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# Impact of climate change on water resources in Morocco: The case of Sebou Basin

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**Abstract.** Morocco is a Mediterranean country facing water resources scarcity due to arid and semi-arid conditions, aggravated by the global climatic changes. In this paper, long term past trends of stream flow in relation to climatic data were studied in four sub-basins of the Sebou basin in northern Morocco. A hydrologic simulation was performed on one of the sub-basins using the IHACRES and HEC-HMS models. Over the last five decades, stream flow and precipitation data showed a cyclic trends as well as a general decline with variable amplitude from one sub-basin to another. Recorded stream flows are significantly correlated with the corresponding precipitation. The average curve fit for precipitations showed slopes ranging from –5.5 to –3.7, indicating rainfall decline over the past 50 years. Stream flow modelling with both IHACRES and HEC-HMS gave very reasonable simulations and were comparable over the studied series. Differences among years with contrasting climatic events were well depicted with HEC-HMS and gave total annual discharges ranging from 0.93 billion $m^3$/year for a dry year to 5.3 billion $m^3$/year for a wet year. The used models can be adopted as good tools for predictions of stream flow in response to climatic variability for better water resources management.

**Keywords.** Climate change – Stream flow – Modelling – IHACRES – HEC-HMS – Morocco.

***Impact des changements climatiques sur les ressources en eau au Maroc : Cas du bassin du Sebou***

***Résumé.*** *Le Maroc est un pays méditerranéen qui fait face à des problèmes de pénurie d'eau en raison de conditions arides et semi-arides, aggravées par les changements climatiques. Dans cet article, nous avons étudié la relation entre les écoulements de surface et les données climatiques au niveau de quatre sous-bassins du bassin de Sebou au nord du Maroc. L'analyse des données a montré qu'au cours des cinq dernières décades, les écoulements de surface et la pluviométrie ont suivi une tendance cyclique ainsi qu'un déclin général avec une amplitude variable d'un sous-bassin à l'autre. Les écoulements de surface sont significativement corrélés aux précipitations correspondantes. La courbe des précipitations montre une pente moyenne variant de –5,5 à –3,7, indiquant un déclin significatif de la pluviométrie au cours des cinquante dernières années. La modélisation des écoulements de surface en utilisant les modèles IHACRES et HEC-HMS a donné des simulations raisonnables et comparables. Les différences entre années ayant des évènements climatiques très contrastés ont été bien cernées avec le modèle HEC-HMS qui a donné des débits variant de 0,93 billions $m^3$/s pour une année sèche à 5,3 billions $m^3$/s pour une année humide. Les modèles testés peuvent être adoptés pour la prévision des débits des écoulements de surface en réponse aux changements climatiques pour une meilleure gestion des ressources en eau.*

***Mots-clés.*** *Changements climatiques – Écoulements de surface – Modélisation – IHACRES – HEC-HMS – Maroc.*

## I – Introduction

In Morocco, like in many arid and semi-arid Mediterranean areas, the recurrence of droughts in the last decades, mainly since the 60s, has tremendously impacted the precipitations and consequently the available mobilized water resources. Shortages of water have occurred during several years impacting water availability for several sectors (agriculture, urban, industry, etc.), and consequently induced a significant impact on the country's economy. A good knowledge and management of surface water resources relies on both a good understanding of the relationships of past fluctuations of precipitations and their consequent flows, as well as on a sound mitigation of future behaviour based on modelling for probable climatic situations.

This study aims at: (i) examining the relationship between observed precipitations and stream flows over the past 40 years in one of the major catchments in northern Morocco; and (ii) applying and comparing two models IHACRES and HEC-HMS for evaluating and predicting stream flows. IHACRES, is considered a lumped conceptual model requiring minimal input data, and is not very limiting. HEC-HMS is a rather semi-distributed model requiring detailed data and more complex parameterization.

## II – Methodology

This study was conducted on several sub-basins of the Sebou river basin, which is the major basin in Northern Morocco. The basin includes several catchments with downstream reservoirs, the largest being Al-Wahda built in 1996 on the Ourgha watershed with a capacity of 3.8 billion $m^3$.

Data for observed precipitations and stream flow were analysed for 4 sub-watersheds of the basin: Ourgha, Inaouen, Upper-Sebou and Rdom. The gages at the outlets of these sub-catchments were implemented at different times and therefore the series of data are available for different time periods. Simulated stream flows and total discharges for the period of 1997 to 2009 were computed as stated below and added to existing series of data to examine the entire period of 1959 to 2009. Comparisons among years was done for the period of September to August as they are more related to the Mediterranean seasonal periods as well as to the agricultural cycles (e.g. 1995-1996 will refer to September 1995-August 1996).

The modelling of stream flow was performed on the Ourgha sub-watershed only. Two models were used in this study: IHACRES and HEC-HMS. IHACRES (Identification of unit hydrographs and component flows from rainfall, evaporation and stream flow data) model is a lumped conceptual model which simulates the rainfall-runoff response of catchments as total stream flow. It uses temperature and rainfall data to estimate stream flow, with calibration parameters determined by comparison with observed stream flow data (Jakeman and Hornberger, 1993; Evans and Jakeman, 1998; Dye and Croke, 2003).

HEC-HMS is a semi-distributed hydrologic model developed by the Hydrologic Engineering Center of the US Army Corps of Engineers (USACE-HEC, 2009). HEC-HMS relies on two main models: (i) the Basin model, which defines the characteristics of the basin and its sub-basins; and (ii) the Meteorological model which defines the meteorological conditions for the sub-basins and requires precipitation and evapotranspiration data to be used in the simulations.

In this study, the IHACRES modelling was used over the whole catchment over the period of 1959 to 2009, with 3 different calibration periods: 5, 10 and 20 years. Simulation was performed for the period with available observed stream flows (1959-1996), as well as for the period of 1997-2009. In the case of HEC-HMS, the modelling was performed for the period of 2000-2009 and compared to that of IHACRES.

## III – Results and discussion

### 1. Climate and stream flow relationships

Data for annual cumulative precipitations and their corresponding average stream flows at the four sub-watershed outlets for the respective available record periods shows very important inter-annual fluctuations. Cumulative precipitation varied from 200 mm in dry years for Rdom to about 1060 mm in wet years for Ourgha. The year 1995-96 for instance was considered a wet year as it received a maximum rainfall, and showed the highest stream flows in all sub-watersheds. On the other hand, 1994-95 was the driest year, with minimal precipitations and stream flows. The high precipitations in 1995-96 were intense and caused severe erosion problems and important floods, while the drought of 1994-95 caused severe water shortage with impacts on many activities.

Further data analysis showed that dry and humid periods are recurrent with a return cycle of about 8 to 12 years. Dry years are becoming more frequent compared to humid or normal years. The recurrence of more dry years, were at some time considered conjectural. However, this recurrence underlines the fact that drought should be considered as a rather factual phenomenon, most probably linked to the climatic changes observed on a larger scale.

The linear fit to the observed precipitation shows that, in addition to the fluctuations, there is also a general trend towards a significant decline in total precipitation. Slopes of about –5.5, –4.2, –3.9 and –3.7 are obtained respectively for Ourgha, Inaouen, Upper Sebou and Rdom sub-watersheds respectively. This amounts to an average decline in the last 50 years varying from –285 mm in Ourgha to –180 mm in Rdom.

Climatic variations are therefore inducing major variations in stream flows and the consequent discharges reaching the dams downstream. These climatic variations, with the observed decline, can certainly be considered as a trend in response to the global climatic change observed regionally and worldwide.

## 2. Modelling

The calibration performed in the IHACRES model for the 3 periods assessed showed close correspondences between observed and simulated stream flows with $R^2_{Nash}$ (Nash and Sutcliffe, 1970) of 0.79, 0.84 and 0.85 respectively for the 5, 10 and 20 years time periods respectively. The minimal 5 years period was largely satisfactory. However, a period of 10 years is recommended, as longer periods did not show a significant increase of the $R^2$ values obtained.

The use of the 10 years calibration for simulation for the period of 1959-1996 (Fig. 1) gave very close simulated to observed stream flows with an $R^2_{Nash}$ of about 0.84. In general, the results show that IHACRES gave good predictions with the available data and with the calibration parameters obtained. Using the same calibration, the simulation was extrapolated to the period of 1997-2009, for which stream flow records are not available. The average monthly flow over this period is much lower than that of the period of 1995-96. The years of 1998-99 and 2004-2005 particularly presented the lowest flows with peaks not exceeding 200 $m^3/s$.

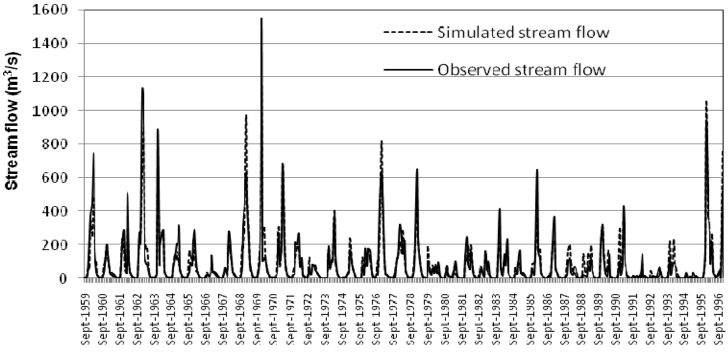


**Fig. 1. Observed and simulated average monthly stream flow for the Ourgha watershed for the period 1959-1996 using IHACRES.**

Comparisons between simulated average monthly flow values obtained by HEC-HMS and those obtained by IHACRES for the same period showed very close predictions by the two models (Fig. 2), with an $R^2_{Nash}$ of about 0.79. The slight difference expressed by the slope of the fitting curve (0.91) can be attributed to many factors (parameterization of the models), but is most probably due to the slight under-estimation by IHACRES previously mentioned.

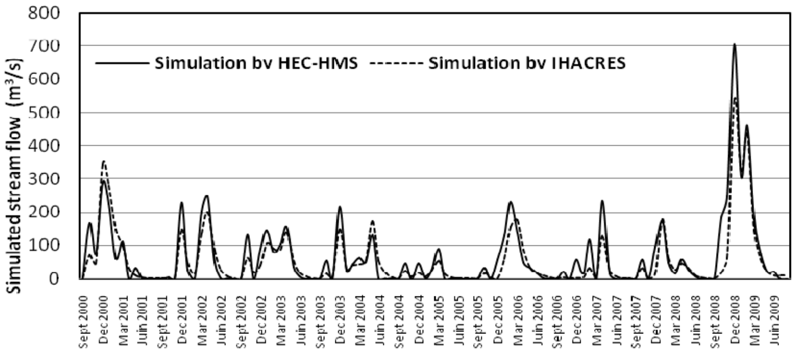


**Fig. 2. Simulated average monthly stream flow for the Ourgha watershed using IHACRES and HEC-HMS for the period 2000-2009.**

Comparison between contrasting years, dry (2004-2005), normal (2002-2003), and wet (2008-2009) illustrates the important differences that can occur for different climatic conditions (Fig. 3). The normal year and the wet year showed relatively well distributed rainfall and subsequent stream flows, while the dry year, with limited rainfall, showed very low stream flows, as well as a tendency for the occurrence of rainfall in the early season, followed by persisting dry conditions afterwards.

The average yearly discharge throughout the period of September 2000 to August 2009 was approximately 2.4 billion $m^3$/year. The comparison in terms of yearly discharge among the three contrasting years showed very different results. For 2002-2003, considered to be an average normal year with 720 mm, the total discharge was about 2.8 billion $m^3$, a value very close to the annual average (2.9 billion $m^3$) reported by the Sebou River Basin Agency (ABHS, 2009). On the other hand, 2004-2005 a dry year with 280 mm, yielded only 0.93 billion $m^3$, while 2008-2009 with annual precipitation of 1064 mm yielded 5.3 billion $m^3$. These values are of great importance in regard to the capacity of the watershed outlet reservoir of Al-Wahda dam, which has a capacity of 3.8 billion $m^3$; inter-annual and intra-annual fluctuations, especially with extreme conditions, definitely require a good management of the available water resources, in order to predict ahead of time scenarios of either shortage or excess water.

The precipitations over the past 50 years show that dry years are becoming, unfortunately, more frequent than wet or normal years. This trend will definitely be a challenge in early mitigations of stream flows and subsequently on managing surface water resources in a most probable climate change trend.

## IV – Conclusions

Precipitations and consequent stream flows studied in four sub-watersheds of the Sebou river basin in northern Morocco showed very important climatic fluctuations with an irregular, but cyclic trend of about 8 to 12 years. The recorded stream flows were significantly correlated with the corresponding precipitations, with differences in the degree of correlation mainly due to sub-basin characteristics. The data also shows a general decline of precipitation with variable amplitude from one sub-basin to another. The average curve fit for annual precipitations showed slopes ranging from –5.5 to –3.7, indicating an average rainfall decline that varies from 285 mm in the Ourgha to 180 mm in Rdom watersheds. Stream flow modelling with both IHACRES and HEC-HMS hydrologic models in the case of the Ourgha sub-watershed gave very reasonable simulations and were comparable over the periods studied. Simulations for years with contrasting climatic conditions gave total annual discharges ranging from 0.93 billion $m^3$ for a dry year to 5.3 billion $m^3$ for a wet year, with 2.8 billion $m^3$ for a relatively normal year. These differences are undoubtedly of important consequences with regard to managing the water storage (3.4 billion $m^3$) of the downstream reservoir. Both models can be adopted as a tool for prediction and monitoring of stream flow in response to climatic variability for sound water resources management. The results obtained, underline the impact of climate changes on precipitations and stream flows in the Sebou river basin.

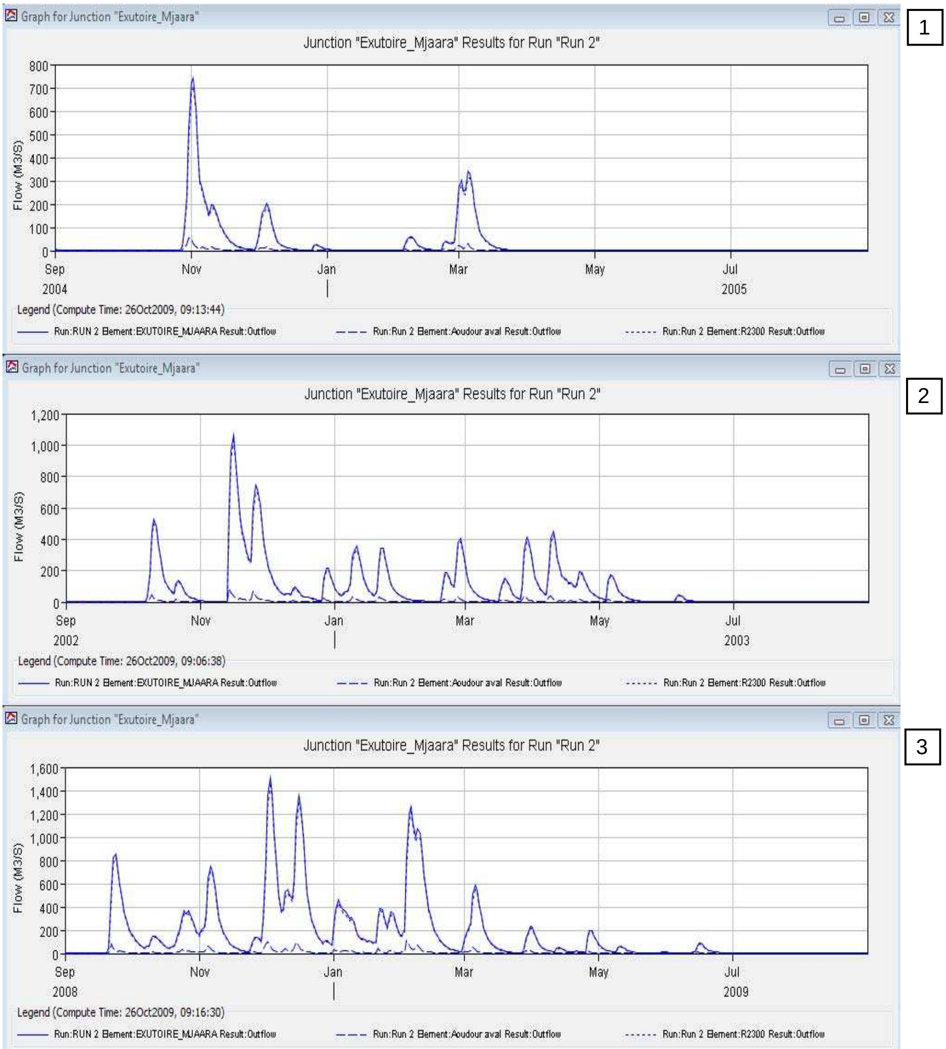


**Fig. 3. Simulated flows for the Ourgha watershed for three contrasting years: (1) dry: 2004-2005, (2) normal: 2002-2003 and (3) wet: 2008-2009.**

## References


**ABHS (Agence de Bassin Hydraulique du Sebou), 2009.** *Bassins hydrauliques/Ressources en eau/Eaux de surface*. Available in: http://www.abhsebou.ma/accueil.cfm.

**Dye P.J. and Croke B.F.W., 2003.** Evaluation of streamflow predictions by the IHACRES rainfall-runoff model in two South African catchments. In: *Environmental Modelling and Software*, Vol. 18, p. 705-712.

**Evans J.P. and Jakeman A.J., 1998.** Development of a simple, catchment-scale, rainfall-evapotranspiration-runoff model. In: *Environmental Modelling and Software*, 13, p. 385-393.

**Jakeman A.J. and Hornberger G.M., 1993.** How much complexity is warranted in a rainfall-runoff model? In: *Water Resources Research*, 29, p. 2637-2649.

**Nash J.E. and Sutcliffe J.V., 1970.** River flow forecasting through conceptual models. Part 1. A discussion of principles. In: *Journal of Hydrology*, 27(3), p. 282-290.

**USACE-HEC (US Corp of Engineers-Hydrologic Engineering Center), 2009.** *Hydrologic Modelling System HEC-HMS.* Available in: www.usace.army.mil.