Curve number values estimation using rain gauges and TRMM satellite data assessment into HEC-HMS hydrological model in the Upper basin of Oum Er Rbia, Morocco

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Introduction

Climate change has strongly impacted water resources in undeveloped countries nowadays. In this regard, to secure and manage water availability, many dams and reservoirs have been built (Tramblay et al., 2018). However, rainfall is a crucial part of the global water cycle (Min et al., 2020); it is the leading parameter of the hydrologic cycle. The characteristics of rainfall can change quickly from one place to another, even in small basins. Therefore, it is a double-edged sword. Droughts and floods can occur each year in different regions around the world, often causing considerable damage to crops, properties, human fatalities, etc. (Liu, 2015). Overall, rainfall is considered the most important meteorological parameter, and the accuracy of its spatial and temporal distribution is crucial for environmental monitoring and natural resource management (Adjei et al., 2015). Furthermore, water management projects in watersheds require the estimation of streamflow characteristics (Joo et al., 2013). Hydrological models have become important tools for understanding hydrological processes and estimating a basin's hydrological response to precipitation. The rainfall–runoff models, which are among the most essential tools used for making decisions regarding the development and management of water and land resources (El Hassan et al., 2013), Nowadays, many rainfall-runoff modeling studies have become widespread to figure out the processes in the water movement. With the increase in water demand and the difficulty of accessing fresh water, studies, which denote the relationship between rainfall and runoff, have achieved great significance. Suitable data is required in order to get an accurate relationship between rainfall and runoff in modeling. Therefore, rain gauges are the main instruments to provide basic measures of precipitation in a watershed for reliable hydrological simulation (Ouatiki et al., 2017). Due to the difficult access, local topography, development of regional economies, climatic conditions, and other limitations, ground-based measurement networks may not exist locally or may produce data infrequently. Especially in mountainous areas of the upper Oum Erbia catchment, where the distribution and the density of the rainfall-monitoring network are usually low (Boudhar et al., 2020).

The scarcity of data is a common problem in most of the basins in the world, especially in undeveloped and developing countries. To overcome this problem, new approaches are being used to get hydrological predictions in data-sparse regions. Advancements in Remote Sensing and computer sciences provide a great opportunity for researchers to predict runoff for ungauged basins (Sahour et al., 2016). Recently, with the improvement of the remote sensing technology and inversion algorithms based on satellite data , rainfall monitoring by satellites has got more and more attention (Min et al., 2020). In this regard, many research and studies have demonstrated the potential of satellite remote sensing in hydrological modeling, groundwater mapping, exploration, and management. Satellite-based precipitation products have advantages over ground-based observations in terms of spatial, temporal resolution and areal coverage, which provide a potential alternative source of data in locations where data is sparse or unavailable (Yang et al., 2017).

Actually, several precipitation estimator products (e.g., the Tropical Rainfall Measuring Mission 'TRMM') were generated based on remote sensing time series, are now available on a quasi-global scale. Among them, the Tropical Rainfall Measuring Mission (TRMM) is a joint USA/Japan satellite mission designed to survey the rain structure, rate, and distribution in tropical and subtropical regions (Liu, 2015), fill the lack of long-term precipitation data unavailability, and provide a good assessment of its spatiotemporal variability .

In Morocco, fewer studies have been undertaken with the TRMM products. Milewski et al. (2015) have evaluated four TMPA 3B42 products (V6, V7 temporary, V7, and reel time V7) against 125 rain gauges for assessing the accuracy of the TMPA products in a diverse topographical and climatic region. The study covered four basins in Morocco : the Moulouya basin, Sebou basin, Oum Er Rbia basin, and the Rif watersheds, but the analysis was focused only on the average annual precipitation. Moreover, the work done by Ouatiki et al. (2017) over the Oum Er-Rbia (OER) basin in the center of Morocco shows the robustness and accuracy of this product to estimate rainfall at three different time scales (daily, monthly, and annually). In addition, Tramblay and al., (2016) is the first one in Morocco who has evaluated this new source of precipitation data in hydrological modelling over the Oued El Makhazine basin located in northern Morocco.

Recently, more updated technical development has greatly improved the applicability of satellite-based precipitation as alternative rainfall inputs to ground-based rainfall estimates in large-scale hydrological models (Stisen and Sandholt, 2010). However, a recent analysis of event-based satellite precipitation error propagation in flood simulation shows that hydrological models have a dampening effect when satellite precipitation products are used to model mountain flood hydrology (Mei et al., 2016). The selection of the most appropriate model to be used depends on the basin characteristics, data availability, and the purpose of the research purposes.The semi-distributed conceptual model, Hydrologic Engineering Center-Hydrologic Modelling System (HEC-HMS), is widely used as a practical and research rainfall-runoff model in many countries(Joo et al., 2013). It was originally designed to simulate the precipitation–runoff processes of drainage basins in a wide range of geographic areas (El Hassan et al., 2013). Numurous researchers have used the HEC-HMS hydrological model to represent flow by simulated rainfall-runoff processes using rain gauges and TRMM data.

The Upper Oum Er Rabia Basin is confronted with a dynamic of land use, the relationships between types of soil, their plant cover, the different modes of use and their hydrological behavior. The aim of this study is to perform a sensitivity analysis to evaluate the impact of CN on direct runoff and to estimate the accurate one of the Upper Oum Er Rbia basin. For this purpose, we use the HEC-HMS hydrological model to develop a relationship between rainfall-runoff and CN for future water resource planning and development in the study area.

Study area

The area of study is the upper OumErRbia basin located between longitudes (33° and 33°5 N) and latitudes (5°01' and 5°08' W). It is a part of the central plateau and the Middle Atlas. It is the upstream part of the large watershed of the Oum Er Rbia River, which has its source at an altitude of 1,800 m, 47 km from the city of Khenifra (Benabdelouahab et al., 2020). The studied catchment area covers 1068, 28 km2 and has a stream length of 131, 26 km, with the majority of its area consisting of a mountainous range with elevations ranging from 864 m to 2400 m and characterized by a variety of relief and geological formations. The main geological units encountered in the basin are Paleozoic schists and quartzites, Triassic basalts and red clays, Lias, limestones and dolomites, as well as

Quaternary alluvium and colluvium. whereas The lands of the basin are mainly covered with rain-fed and irrigated agriculture fields, urbanized areas, natural forest patches, and bare soil.

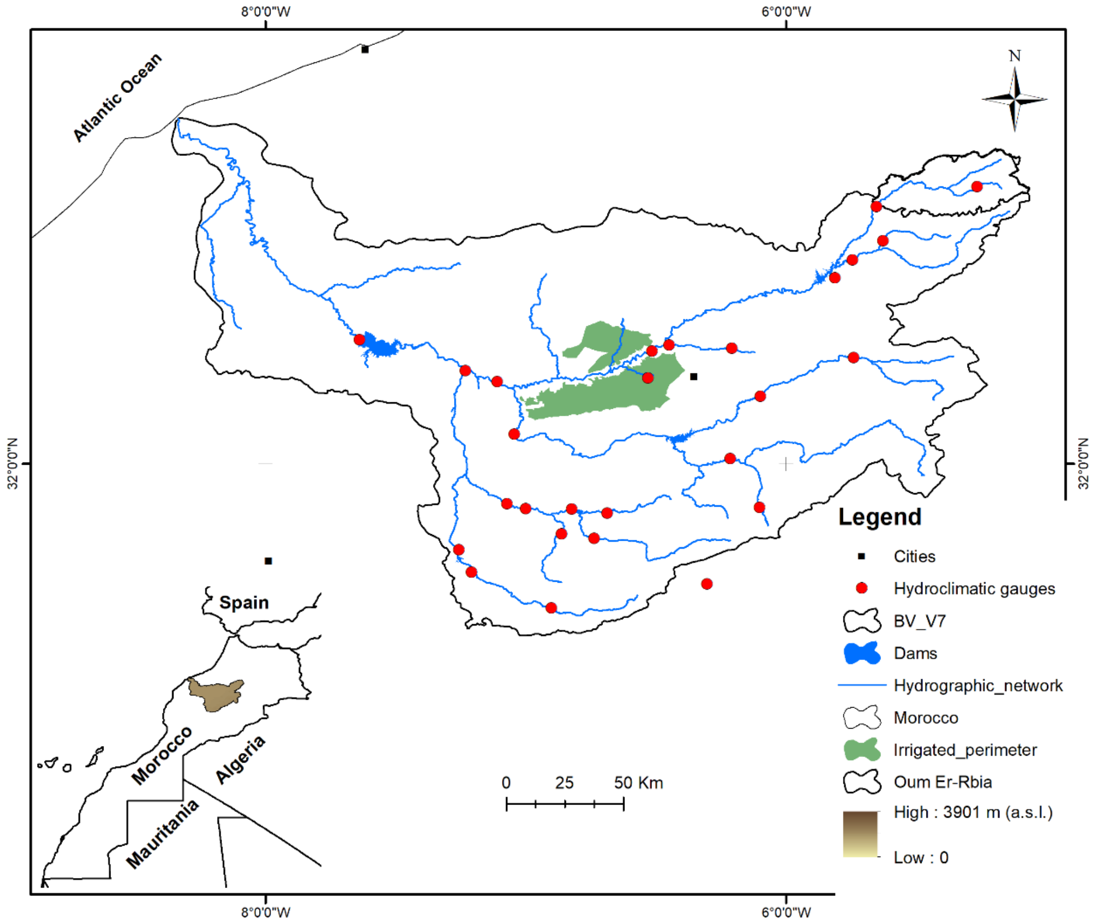

Fig. 1. Location of OumErRbia watershed in Morocco (ASTER, 30 m resolution, Map datum: UTM WGS 84);

Data collection

Input data is one of the most important parts of rainfall-runoff modelling and can be categorized into hydro-meteorological (rainfall and runoff) and physiographic (digital elevation model, land use/cover and soil type) databases. In this present study, two types of rainfall were used: rain gauges and satellite data. Rainfall and discharge data were delivered by the Oum Er-Rbia Hydraulic Basin Agency from 2000 to 2011. However, the satellite data used is TRMM. The data were extracted as NetCDF files with a spatial resolution of 0.25 x 0.25 and a daily time resolution. They were provided by NASA's Precipitation Measurement Missions website (https://pmm.nasa.gov/) for the period between 1 January 2000 and 31 December 2011. Furthermore, all basin characteristics were extracted using an ASTER-DEM (Advanced Space-born Thermal Emission and Reflection Radiometer) image at a resolution of 30 m.

Results :

A suitable CN must be chosen in order to have consistent results. As a result, we examine the sensitivity of the CN to determine the influence of the CN on initial loss and direct runoff using precipitation data for the six periods chosen in the study region in order to choose the most appropriate ranges of CN in the upper Oum Er Rbia basin. The model created for the research region was repeatedly run for CN values from 30–90 with increments of 0.5 utilizing the Nash-Sutcliffe efficiency coefficient (NSE) and root mean square error (RMSE).

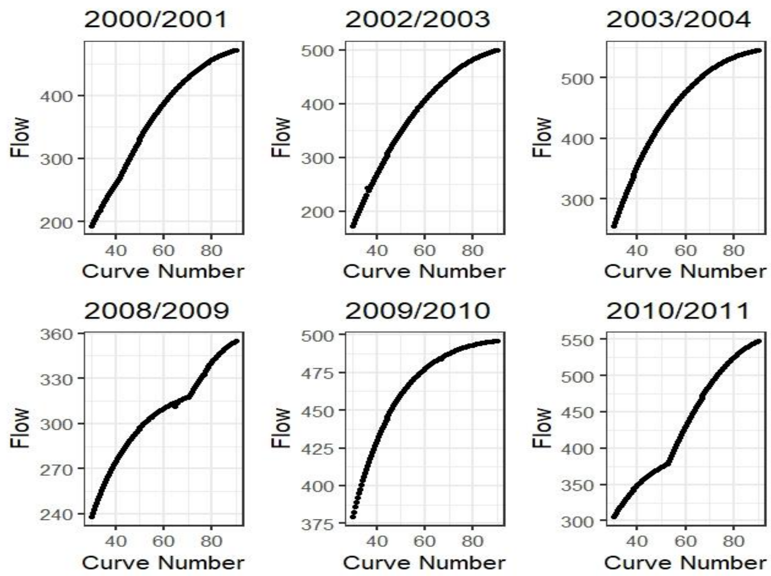

Fig.2. : Curve numbers and their associated discharges in sex analyzed periods

Figure 2 depicts the direct runoff for the Continuous-Process HEC-HMS model for the six studied periods, 2000–2001, 2002–2003, 2003–2004, 2008–2009, 2009–2010, and 2010–2011, ran for varied CNs. The findings indicate that higher CN overstated the anticipated runoff, which suggests that direct runoff rises as CNs rise. The graph shows that the range of CN 50–90 created a considerable maximum discharge, while CN 30–50 provided a minimal discharge while maintaining all other model parameters constant. In conclusion, the HEC HMS model's results showed a dynamic response to changing CN.

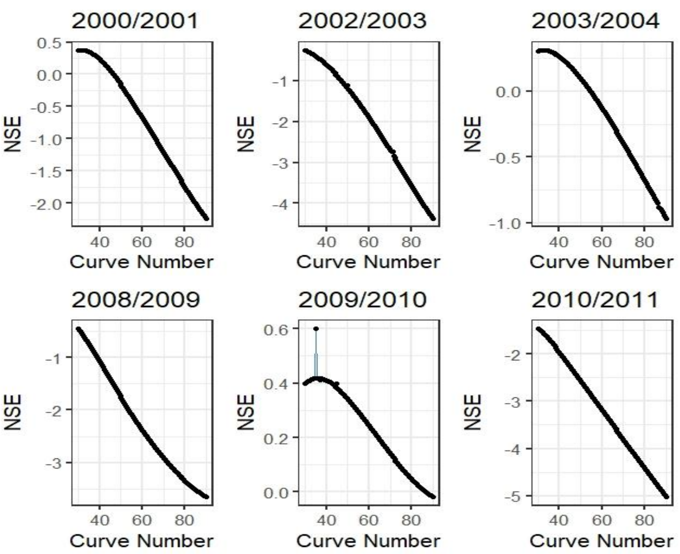

Fig.3.: Curve number versus Root mean square error (RMSE)) in overall analyzed periods

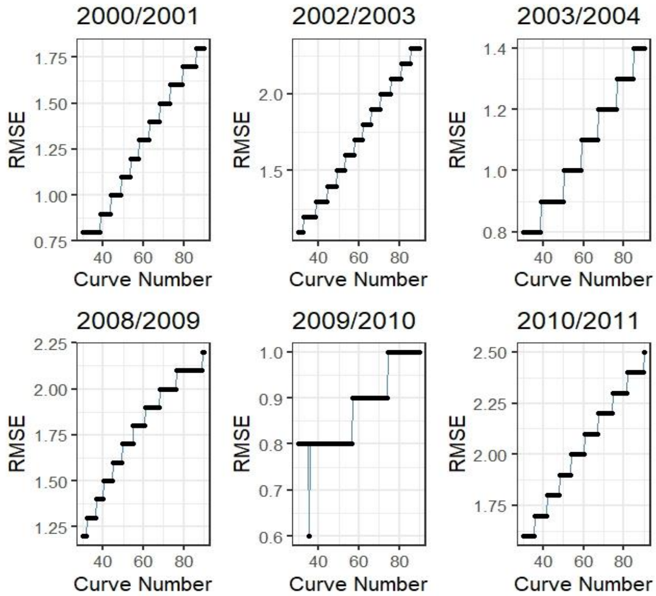

Fig.4.: Curve number versus Nash-Sutcliffe efficiency coefficient (NSE) in overall analyzed periods

Figures 3 and 4 shows how the values of the two efficient criteria, NSE and RMSE, vary when different CN values for the six periods under consideration are used. The plots illustrate that as the CN of the watershed rises, the efficiency of the predicted runoff volume to the parameter CN continually declines. In fact, when the uncertainties for CN estimations were analyzed, negative NSE and higher RMSE values were discovered. These results indicate a poor match between the estimated and observed runoff, particularly in ranges where CN values ranged from 40 to 90. On the other hand, a noteworthy value of CN that emerged in the 2009–2010 era provides respectively good and satisfactory values of NSE and RMSE in the watershed.

Conclusion

The paper presents a case study of rainfall-runoff modeling for a mountainous sub-catchment in the upstream part of the OER watershed using two different precipitation data sets : rain gauge data and satellite rainfall (TRMM). A semi-distributed HEC-HMS hydrological model was used for streamflow simulation purposes. On the other hand, we analyze the sensitivity of the simulated runoff to CN using two efficiency criteria: NSE and RMSE. We conducted the analysis using the continuous streamflow simulation in the HEC-HMS model by changing CN values and keeping all other parameters constant. From the analysis of outcomes, the following conclusions can be extracted

Acquiring a precise CN value is imperative as an input in the semi-distributed conceptual model Hydrologic Engineering Center-Hydrologic Modelling System (HEC-HMS) (Rizal et al., 2018). According to the results obtained during sensitivity analysis, the model results when changing the CN values show an alarming trend in the availability of water, which may have serious consequences. Moreover, most negative values of NSE and higher values of RMSE appeared in the charts, particularly when CN varied from 40-90, which can indicate that this range was not suitable to estimate runoff in our studied basin. whereas the most satisfactory values of NSE and RMSE were produced by the CN ranging from 30 to 40, especially in the 2009/2010 period, which may be considered as the most appropriate simulation range for the Upper Oum Er-Rbia watershed.

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