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Downscaling climate projections and hydrologic responses for regional water resources assessment: case of the Oum Er Rbia river basin, Morocco

Mounia El Azhari*, Dalila Loudyi**
** Laboratory of Process Engineering and Environment, Faculty of Sciences and Techniques, Hassan II University of Casablanca, B.P 146, Mohammedia 20650, Morocco.*
*** Laboratory of Process Engineering and Environment, Faculty of Sciences and techniques, Hassan II University of Casablanca, B.P 146, Mohammedia 20650, Morocco.*
Corresponding Author: Mounia El Azhari

ABSTRACT
Unlike other water river basins in Morocco, Oum Er-Rbia basin is extensively used to meet both local and regional water demands. Agricultural activities carried out within the basin account for 21% of the national agricultural added value. Moreover, an additional 181 Mm3/year is transferred to neighboring basins, namely Tensift and Bouregreg to come up with their water shortages. Besides, the basin surface water generates 70% of national hydropower. Extensive use of both groundwater and surface water resources of this basin conjugated with dry and wet years sequences have consequently compromised its role in securing the regional water balance. In this work, statistical downscaling using SDSM was applied to predict future climate, particularly temperature and precipitation, at the basin scale through two major RCP scenarios (optimistic 4.5 and pessimistic 8.5) from 2020 to 2099. Simulation results indicate that for both climatic scenarios, temperature tends towards an increase whereas precipitation tends toward a decrease. The impacts of these variations on Oum Er-Rbia water resources were shown through hydrologic modeling using HEC-HMS, simulations predict a flow decrease all over the basin. Besides, climate change adaptation actions tailored to the basin regional and national contexts are discussed as solutions to reduce the gap between water supply and demand.

Keywords - Climate change, downscaling, hydrological model, Oum Er-Rbia basin, regional water resources.

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I. INTRODUCTION

In most arid and semi-arid areas, countries rely on both groundwater and surface water resources to ensure the supply of agricultural, domestic and industrial while surface water is sometimes also used for energy production. Yet, this vital resource availability and sustainability is threatened by demographic, economic and environmental pressures ([1], [2], [3]). According to the United Nation Environmental Program (UNEP) center Plan Bleu, higher temperature and reduced rainfall are the key trends of future climate in the Mediterranean region, which will relate negatively to water resources [4].

Different studies discussed the impacts of climate change on water resources in different parts of the world. For instance, Abbaspour et al. [5] used the Soil and Water assessment tool (SWAT) to investigate the impacts of climate on precipitation, blue water and green water in Iran. Yu et al. [6] constructed a weather-generating model and used predicted variables as inputs to a continuous rainfall runoff model to assess changes in water resources in southern Taiwan. Gebremeskel and Kebede [7] used climatic model SDSM and hydrological model WetSpa to simulate the effect of climate change on the Werii watershed in Ethiopia.

In Morocco, groundwater resources are expected to decrease in the future under climate change stress as a consequence of demographic pressure and extensive pumping ([8], [9]). Morocco has a mobilized water potential of nearly 22 billion m3 summing 4 billion m3 of groundwater spread over 103 aquifers, of which 82 are superficial and 21 are deep, and 18 billion m3 of surface water stored in more than 140 dams all over the countrywide.

However, according to State Secretary in Charge of water (SSCW), overexploitation of groundwater due to shortages or unavailability of surface water caused withdrawal volumes to reach 5 billion m3 in 2014. Additionally, most of the largest dam reservoirs reached an alarming filling rate in 2017 due to deficit in precipitation (Hassan II dam: 16.7%, Mohamed V dam: 8.6%, Bine El Ouidane dam: 17.7%, Youssef Ben Tachfine dam: 20%).

Climate variability studies in the North African region as well as in Morocco indicated that all models predicted an increase in temperature and a decrease in precipitation ([10], [11], [12], [13]). In the next 80 years, climate will be very variable depending on regions and seasons with a general predominance of semi- arid Mediterranean climate.

According to a study conducted between 2011 and 2013 by both the Hydraulic basin Agency of Oum Er-Rbia (HBAOER) and the World Bank, dynamical downscaling method was used to determine the future projections of climate and their impact on water resources until 2060 through three general circulation models (GCMs).

The two models CCSM3 using the GES SRES A1B scenario from 1981-2000 and

ECHAM5 using SRES A1B scenario from 1971-2000) showed a reduction in rainfall from 0.01 to 0.3 mm per day per decade in the period 1971 to 2065 and. One model (ECHAM5 using SRES A2 scenario from 1971-2000) showed an increase in rainfall between 0.01 and 0.1 mm per day per decade over the same period. However, all three models agreed on an increase in temperature between 0.05 ° C and 0.7 ° C per decade from 1971 to 2065.

In order to take the appropriate measures to mitigate the negative impacts on OER river basin water resources, downscaled models are used as a tool to better apprehend climate change impacts on hydrological outputs. Indeed, local climate change scenarios are important for planning and managing water supply and demand [14]. In this context, two RCP scenarios (optimistic 4.5 and pessimistic 8.5) are developed using statistical downscaling method through SDSM. Predicted results of precipitation and temperature, alongside with calculated evapotranspiration from 2020 to 2099 are then used to simulate future flow in the basin for the same period through HEC-HMS hydrological model. Establishing and formulating the relationship between climate and water resources can help decision makers and planners choosing the best adaptation measures when allocating water to different users.

II. STUDY AREA

Hydraulic Basin of Oum Er-Rbia (HBOER) has a total area of 36972 km2, which represents almost 8% of Morocco's territory. Its main river, Oued Oum Er-Rbia, originates in the Middle Atlas and discharges into the Atlantic Ocean near the city of Azemmour (Fig. 1).

Fig.1 Location of the Oum Er-Rbia basin in Morocco

The basin experiences a high geographical variability of climate with arid climate in Rhamna plain, semi-arid climate in Tadla plain and wet climate in mountain areas. Precipitation in the basin decreases from West to East (1100-250 mm / year). Temperature varies between about 10 and 50 ° C, the minima and maxima being 3.5 ° C in January and 38°C in August. Potential evaporation can reach 1600-1800 mm / year [15].

Groundwater balance of the eleven major aquifers of Oum Er-Rbia basin shows an important deficit due to overexploitation and excessive pumping. Indeed, the exploitable volume is 300 million m3, while withdrawals for irrigation and drinking water are 553 million m3, generating a deficit of nearly 253 million m3 [15]. Surface water is generally regularized through twelve dams to allow the supply of drinking and irrigation waters, as well as hydropower production [16].

Groundwater tables in some aquifers as well as water supply in the most important dams of the hydraulic basin show a significant decrease as shown in Figures 2 and 3.

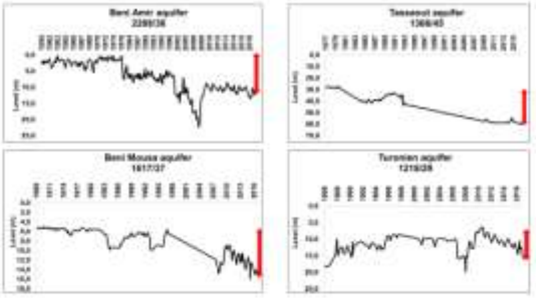

Fig.2 Groundwater levels evolution at some aquifers of Oum Er-Rbia basin (1970-2017).

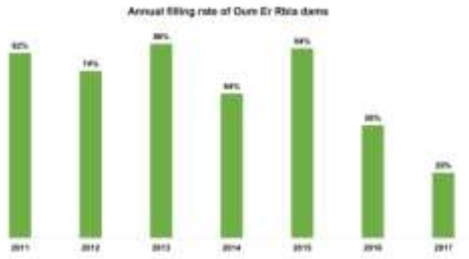

Fig.3 Evolution of the total annual filling rate of dams' reservoirs in Oum Er-Rbia basin (2011-2017).

III. DATA AND METHODOLOGY

3.1 Meteorological dataset

Measured rainfall and temperature data for five meteorological stations dispersed all over the basin with daily continuous dataset (Table 1) were obtained from the HBAOER for the period from 1980 to 2017.

Table 1. Characteristics of used meteorological stations

Station name	**Longitude**	**Latitude**
Taghat	-5.65	33
Al Massira dam	-7.63	32.47
Beni Mellal	-6.36	32.33
Tillouguite	-6.21	32.02
Hassan I	-6.82	31.82

Historical rainfall and temperature in the basin show a climatic pattern of increase in temperatures and decrease in precipitation with the alternation of wet and dry years.

3.2 Statistical downscaling

In order to project future climate change at a local scale, downscaling methods are generally used. They can relate coarse resolution General Circulation Models (GCMs) in the order of 100 to 300 Km to local variables such as rainfall, temperature and evapotranspiration ([17], [18]). According to Sehgal [19], GCMs are considered to be the most reliable tools to obtain global climate projections hundreds of years into the future.

Statistical downscaling requires minimal computing resources and is easy to use from many GCMs to represent a full range of uncertainties. It consists of establishing a statistical relationship between predictands, which are local variables like precipitation or temperature, and predictors which are variables characterizing the atmosphere on a large scale ([14], [20]). In this study, SDSM is used to assess future climate change in the basin. This tool was developed in order to build statistical relationships between large-scale predictors and local climate variables by using a combination of a stochastic weather generator and multivariate regression method to generate local meteorological variables ([21], [22], [23]). According to Wilby and Dawson [24], SDSM is applied in seven steps: 1) quality control and data transformation, 2) screening of predictor variables, 3) model calibration, 4) weather generation (observed predictors), 5) statistical analyses, 6) graphing model output, 7) scenario generation (climate model predictors).

Twenty-six predictors used in this study were derived from the second generation Canadian Earth System Model (CanESM2) developed by the Canadian Centre for Climate Modelling and Analysis (CCCma) of Environment and Climate Change in Canada for RCP 4.5 and 8.5 scenarios for the period 1980-2099. A partial correlation between the predictands and all predictors generated by CanESM2 model using SDSM allowed us to identify the appropriate predictors to work with. Values of partial correlation that tends towards +/-1 and significance level of $p<0.05$ were respected when choosing the best predictors [24]. Before downscaling future climate, it is primordial to calibrate and validate the established relationship between predictands and predictors. Data from 1980 to 2005 were used to calibrate SDSM and data from 2006 to 2017 were used for validation. Output modelled data will generate future climate from 2020 until 2099.

According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change IPCC, the Coupled Model Intercomparison Project Phase 5 (CMIP5) established new climate change scenarios called Representative Concentration Pathways (RCPs) [25]. Two GCM outputs of CMIP5 under RCP 4.5 and 8.5 representing medium stabilization scenario, and very high emission scenario, respectively were used to project future climate scenarios (Fig. 4). The RCP 4.5 scenario is a stabilization scenario where total radiative forcing is stabilized before 2100 by employing a range of technologies and strategies for reducing Greenhouse Gas (GHG) emissions, while the RCP 8.5 is characterized by increasing GHG emissions over time leading to high GHG concentration levels [23].

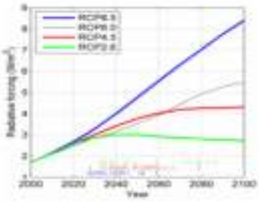

Fig. 4 Radiative forcing of different RCPs (IPCC, 2014)

3.3 HEC-HMS model

The U.S. Army Corps of Engineers at the Hydrologic Engineering Center were the first one to formulate the Hydrologic Engineering Center-Hydrological Modeling System (HEC-HMS), which is a rainfall–runoff simulation model that has been used for a wide range of basins from small urban areas to large river watersheds. A complete HEC-HMS model consists of four major components properly linked with each other: (1) a basin model; (2) a meteorological model; (3) input time series; and (4) a control specification.

In this study, the HBOER was divided into four sub-catchments: High OER, OER central, Oued El Abid and Oued Lakhdar-Tassaout (Fig. 5). Both SCS curve number and Clark Unit Hydrograph have been used for the loss and transform method respectively.

Fig. 5 HEC-HMS model of the OER sub basins

The spatial data required for the HEC-HMS model consists of digital elevation model (DEM), land use and hydrologic group soil (Fig. 6). In this study, a DEM with a resolution of 30 m was used to delineate the OER watershed, to extract flow direction and accumulation, to create streams, and to calculate sub-basin parameters. The basin parameters needed for this study such as the slopes of the different catchments and their longest flow path are extracted through ARCHYDRO tool, an extension of GIS.

The soil map for the basin was collected from the Harmonized World Soil Database which was developed by the Food and Agriculture Organization (FAO) with the collaboration of International Institute Of Applied Systems Analysis (IIASA), the International Soil Reference and Information Centre (ISRIC), the Institute of Soil Science of Chinese Academy of Sciences (ISSCAS), and the Joint Research Centre (JRC) of the European Commission (http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/).

The land cover map was retrieved from the FAO Geonetwork (http://www.fao.org/geonetwork). Both soil and land data were used to determine the basin hydrological properties used as inputs for the HEC-HMS model such as curve number (Fig. 6), percentage of imperviousness, time of concentration and storage coefficient.

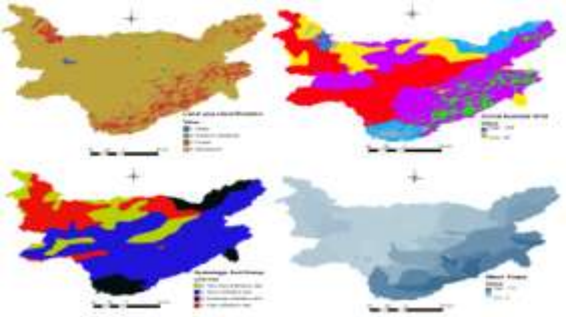

Fig. 6 Oum Er-Rbia basin characteristics (Land use classification, Curve number grid, Hydrologic soil group and Mean slope)

IV. RESULTS AND ADAPTATION MEASURES

4.1. Future climate projections

The best correlated predictor variables were selected for both precipitation and temperature for the two scenarios 4.5 and 8.5 (Table 2). Future scenario generation used predictors from CanESM2 for 4.5 and 8.5 emission scenarios for the period of 1981-2099. The baseline period was from 1980 to 2017 while the period 2020 to 2099 was used for the future climate scenarios.

Table 2. Chosen predictors for different stations for both scenarios

Predictand	Predictors	Predictand	Predictors	Predictand	Predictors
Al Massira station		Hassan I station		Beni Mella station	
Precipitation	p8_fgl p8_ugl prcpgl	Precipitation	p8_fgl p8_zgl p1zhgl	Precipitation	p850gl p8_fgl prcpgl
Temperature	p500gl p850gl tempgl	Temperature	mslpgl P500gl tempgl	Temperature	p500gl mslpgl tempgl
Taghat station			Tillouguite station		
Precipitation	p8_fgl prcpgl		Precipitation	p8_fgl p850gl	

			prcpgl
Temperature	mslpgl p500gl tempgl	Temperature	mslpgl tempgl p500gl

Future projections of mean annual precipitation and temperature for the period 2020 to 2099 are presented in figures 9 to 13. They show that for all stations, temperature will rise for both scenarios. This increase varies largely between RCP 4.5 and RCP 8.5 being more important for the later. For the scenario 8.5, temperature will inflate by 1.5°C in Safi, by 3.3°C in Al Massira, by 4.3°C in Beni Mellal, by 4.7°C in Hassan I, by 4.9°C in Taghat and by 5.3°C in Tillouguite. Whereas for the 4.5 scenario, temperature will inflate by 0.7°C in Safi, by 1.5°C in Al Massira, by 2.3°C in bothh Beni Mellal and Hassan I, by 2.4°C in Taghat and 2.6°C in Tillouguite. Precipitation adversely do not follow the same trends since it increases in the scenario 4.5 and decreases in the scenario 8.5 with the alternation of wet and dry years all over the period. In fact, precipitation increases by 19.5% in Al Massira, by 10.1% in Beni Mellal, by 25.2% in Taghat, by 15.6% in Tillouguite and by 26.8% in Hassan I. While it decreases by 11.8% in Al Massira, by 15.2% in Beni Mellal, by 20.1% in Taghat, by 12.4% in Tillouguite and by 28.7% in Hassan I.

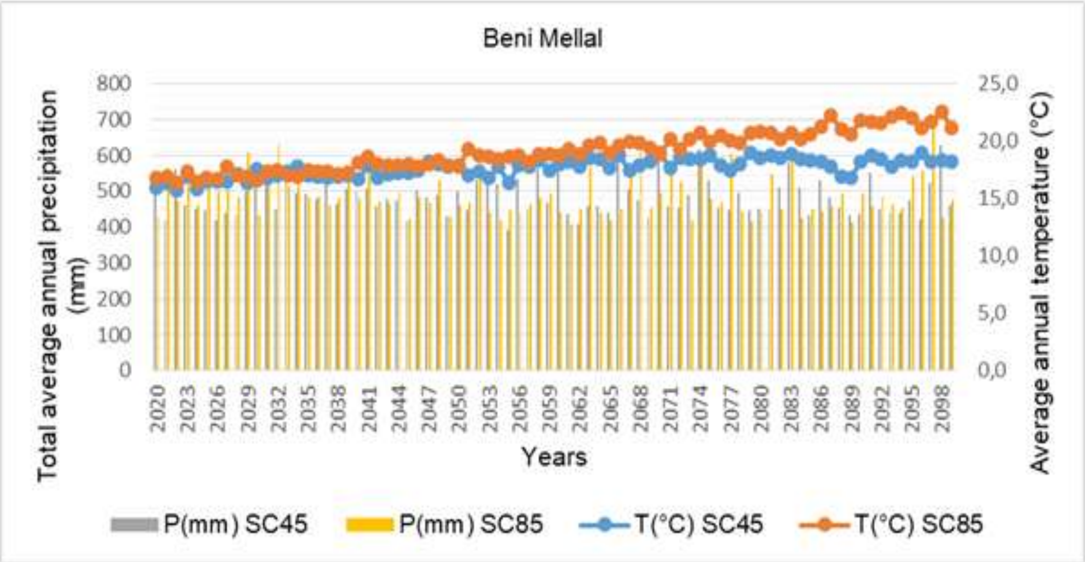

Fig. 9 Trend of average annual rainfall and temperature for RCP 4.5 and 8.5 scenarios from 2010 to 2099 for Beni Mellal station

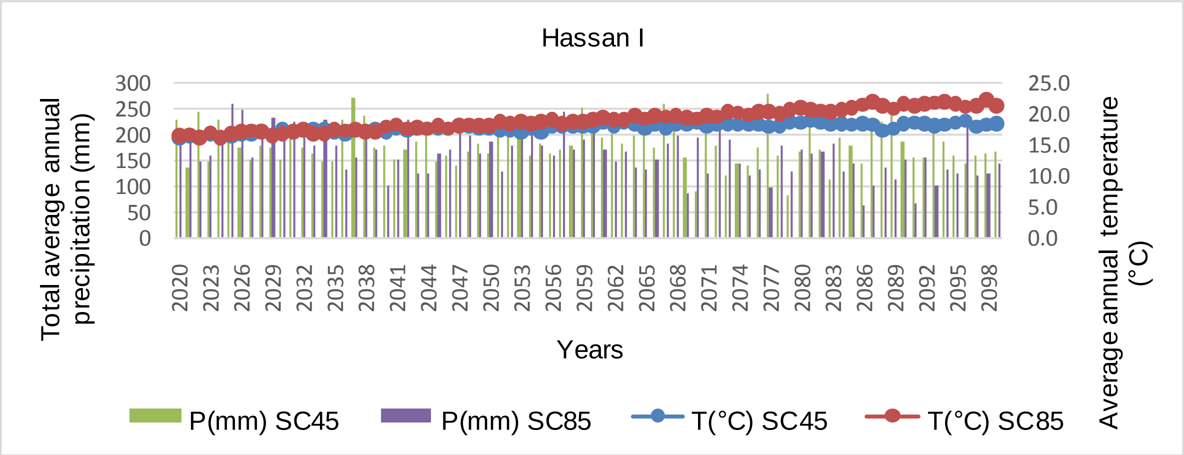

Fig. 10 Trend of average annual rainfall and temperature for RCP 4.5 and 8.5 scenarios from 2010 to 2099 for Hassan I station

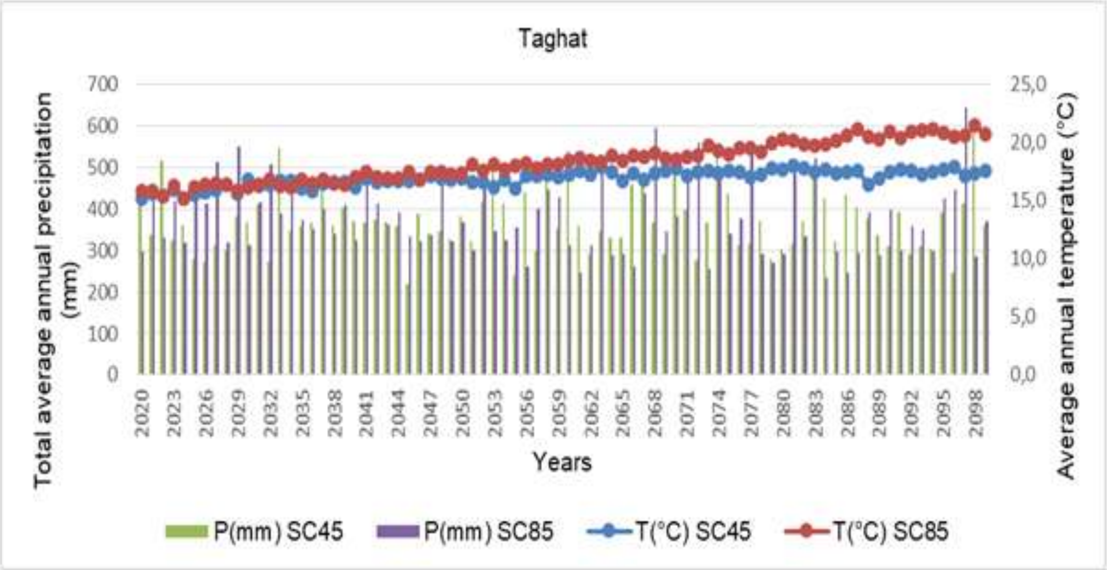

Fig. 11 Trend of average annual rainfall and temperature for RCP 4.5 and 8.5 scenarios from 2010 to 2099 for Taghat station

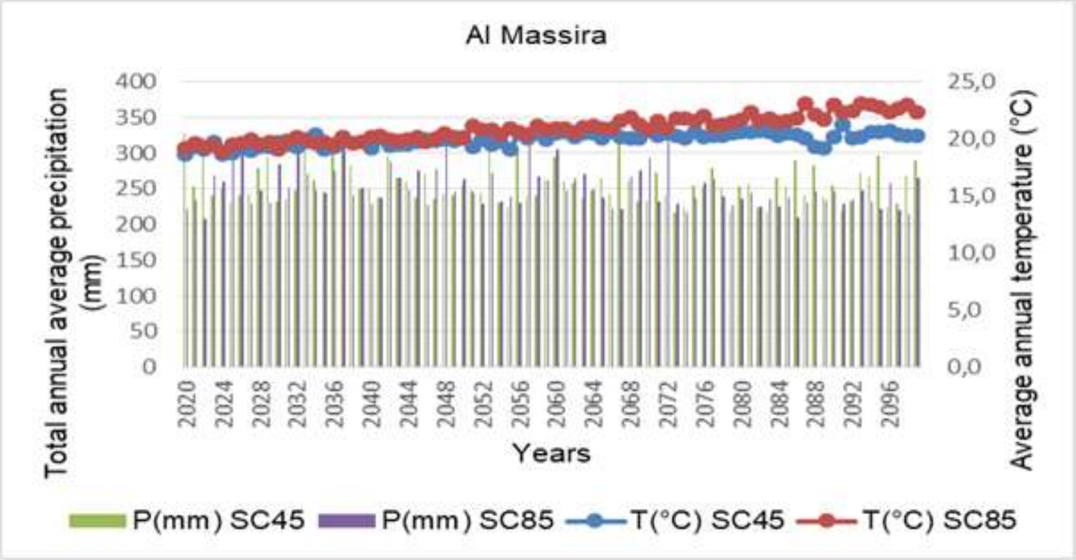

Fig. 12 Trend of average annual rainfall and temperature for RCP 4.5 and 8.5 scenarios from 2010 to 2099 for Al Massira station

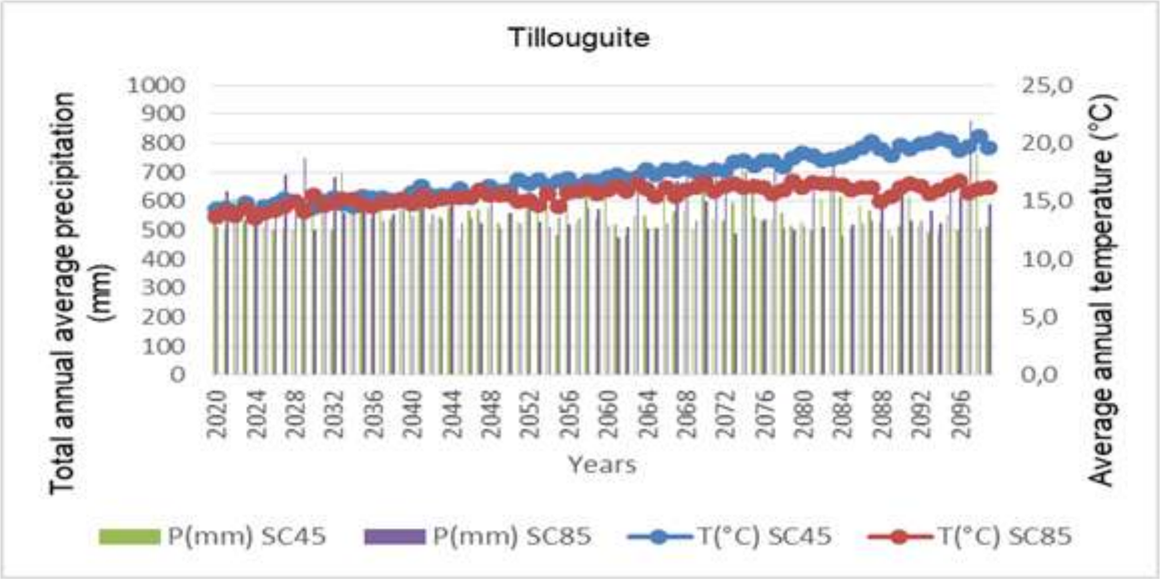

Fig. 13 Trend of average annual rainfall and temperature for RCP 4.5 and 8.5 scenarios from 2010 to 2099 for Tillouguite station

4.2. Water ressources change assessment and adaptation strategies

Future predicted precipitations and temperature for the period 2020 to 2099 were used as inputs to HEC-HMS model to obtain the outflow of the basin for the same period and for both RCP scenarios (Fig. 14). We calculated evapotranspiration using the obtained temperature with the Thornthwaite method (1).

$$ETP = 16 * \left(\frac{10 * T}{I}\right)^{a} * K \qquad (1)$$

Where: - ETP is the potential evapotranspiration in mm.

- T is mean temperature of the month in °C.
- I in the annual thermal index:

$$I = \sum_{m=1}^{12} \left(\frac{T(m)}{5}\right)$$

- a=0.016*I+0.5
- K is the correction that depend on the latitude of the station and the month.

It is clear that the sub-basins flows follow the same evolution of precipitation as whenever the year is rainy the flow is high. Indeed, for the sub basins of high Oum Er Rbia, central Oum Er Rbia and wadi Laabid, both highest flow rate and precipitation were recorded in the year 2098 for the scenario 4.5 and in the year 2097 for the scenario 8.5. For the sub basin of wadi Lakhdar Tassaout, highest precipitation and flow rate were recorded in the year 2077 for the optimistic scenario and in the year 2025 for the pessimistic scenario.

According to this model results, from 2020 to 2099, flow will increase in wadi Laabid by 32.5% for the scenario 4.5 and by 0.9% for the scenario 8.5, in central Oum Er Rbia by 18.5% for the scenario 4.5 and by 1% for the scenario 8.5 and in high Oum Er Rbia by 31.2% for the scenario 4.5. Flow will decrease in Oued Lakhdar-Tassaout by 11.5% for the scenario 4.5 and by 15.3% for the scenario 8.5, it will also decrease in high Oum Er Rbia by 1.7% fo the scenario 8.5.

Fig. 21 Flow evolution in different sub basins of Oum Er-Rbia

In order to ensure a rational and sustainable management of water resources in Oum Er-Rbia basin and to guarantee water availability for all users under acceptable conditions considering climate change and its potential physical, ecological and socio-economic effects, it is primordial to integrate climate change as a factor when elaborating major programs and plans. At the level of the study area, several adaptation measures were implemented by different public and semi-public institutions allowing savings in water resources. These measures are desalination of seawater (100 million m3/year), collection and use of rainwater (1994 million m3/year), water saving (3 million m3/year), reuse of treated wastewater (35 million m3/year), water transfer (1419 million m3/year) and groundwater prospection and mobilization in mountainous regions.

V. CONCLUSION

By the year 2100, predicted climate scenarios obtained using statistical downscaling show an increase in temperature fluctuating between 0.8% in Ouled Sidi Driss and 10.2% in Al Massira for 4.5 scenario and between 2.8% in Al Massira to 15.4% in Tillouguite for 8.5 scenario. Results point out also a decrease in precipitation that varies from 3% in Tillouguite to 14.1% in Hassan I for the 4.5 scenario and from 5.3% in Tillouguite to 16.4% in Al Massira for 8.4 scenario. The only exception is the Ouled Sidi Driss station where precipitation will increase by 17.8% for 4.5 scenario and decrease by 12.4% for 8.5 scenario. HEC-HMS model results show clearly that the HBOER flow is directly affected by the precipitation fluctuations since it increases when precipitation increases and decreases otherwise. The most affected sub basins are those of Oued Lakhdar-Tassaout and central OER where flow will decrease by 48.4% and 57.1% respectively. However, to better understand the relationship between the variability of climate and water resources, we should take into account the impact of temperature variation and include the response of reservoirs to these changes.

Future water strategies and plans have to integrate climate change scenarios to predict future supplies and demand, as well as energy production. Other adaptation measures must be taken into consideration, in particular artificial groundwater recharge, exploration and mobilization of groundwater in mountainous areas, prohibition of irrigated perimeters extension and interdiction of new extraction demands.

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REFERENCES

[1]. Schwarzenbach RP, Egli T, Hofstetter T, Gunten UV, Wehrli B (2010) Global Water Pollution and Human Health. Annual Review of Environment and Resources 35:109-136. http://dx.doi.org/10.1146/annurev-environ-100809-125342

[2]. Eric H. Oelkers, Janet G. Hering, Chen Zhu; Water: Is There a Global Crisis?. Elements; 7 (3): 157–162. https://doi.org/10.2113/gselements.7.3.157

[3]. Abdulbaki D, Al-Hindi M,Yassine A, Abou Najm M (2017) An optimization model for the allocation of water resources. Journal of Cleaner Production 164:994-1006. https://doi.org/10.1016/j.jclepro.2017.07.024

[4]. Plan Bleu (2008) Climate Change and Energy in the Mediterranean.

[5]. Abbaspour KC, Faramarzi M, Ghasemi SS, Yang H (2009) Assessing the impact of climate change on water resources in Iran. Water Resour Res. http://doi.org/10.1029/2008WR007615

[6]. Yu PS, Yang TC, Wu CK (2002) Impact of climate change on water resources in southern Taiwan. Journal of Hydrology 260:161-175. https://doi.org/10.1016/S0022-1694(01)00614-X

[7]. Gebremeskel G, Kebede A (2018) Estimating the effect of climate change on water resources: Integrated use of climate and hydrological models in the Werii watershed of the Tekeze River basin, Northern Ethiopia. Agriculture and Natural Resources. doi: 10.1016/j.anres.2018.06.010.

[8]. Van Dijck SJE et al (2006) Desertification in northern Morocco due to effects of climate change on groundwater recharge. In: Kepner W.G., Rubio J.L., Mouat D.A., Pedrazzini F. (eds) Desertification in the Mediterranean Region. A Security Issue. NATO Security through Science Series, vol 3. Springer, Dordrecht. https://doi.org/10.1007/1-4020-3760-0_26

[9]. Bouchaou L, Tagma T, Boutaleb S, Hssaisoune M, El Morjani Z (2011) Climate change and its impacts on groundwater resources in Morocco: the case of the Souss- Massa basin. 129-144.

[10]. Hulme M, Wigley TML, Barrow EM, Raper SCB, Centella A, Smith S, Chipanshi AC (2000) Using a Climate Scenario Generator for Vulnerability and Adaptation Assessments: MAGICC and SCENGEN Version 2.4 Workbook. Climatic Research Unit, UEA, Norwich.

[11]. Born K, Christoph M, Fink AH, Knippertz P, Paeth H, Speth P (2008) Moroccan Climate in the Present and Future: Combined View from Observational Data and Regional Climate Scenarios. In: Zereini F., Hötzl H. (eds) Climatic Changes and Water Resources in the Middle East and North Africa. Environmental Science and Engineering (Environmental Science). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-85047-2_4

[12]. Driouech (2009a) Le changement climatique: Problématique mondiale/Réponse mondiale. Actes de la rencontre Internationale sur le Changement Climatique: Enjeux et perspectives d'adaptation pour le Maroc, organisée par l'Institut Royale des Etudes Stratégiques (IRES), Rabat le 16 Octobre 2009.

[13]. Mokssit A (2009) Le Changement Climatique au Maroc : Observations et Projections. Rencontre Internationale sur le Changement Climatique: Enjeux et perspectives d'adaptation pour le Maroc. Institut Royal des Etudes Stratégiques, Rabat, 16 Octobre 2009

[14]. Gulacha Metekiya M, Mulungu Deogratias MM (2017) Generation of climate change scenarios for precipitation and temperature at local scales using SDSM in Wami-Ruvu River Basin Tanzania. Physics and Chemistry of the Earth Parts A/B/C 100:62-72. https://doi.org/10.1016/j.pce.2016.10.003

[15]. El Azhari M, Loudyi D (2016) Groundwater management and potential climate change impacts on Oum Er Rbia basin, Morocco. Sustainable Hydraulics in the Era of Global Change Advances in Water Engineering and Research Edited by Sébastien Erpicum, Benjamin Dewals, Pierre Archambeau and Michel Pirotton. Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742 CRC Press 2016, 428–432.

[16]. Hydraulic Basin Agency of Oum Er-Rbia (HBAOER) (2012) Master plan of integrated water resources management (MPIWRM). (Document in French).

[17]. Chu JT, Xia J, Xu CY et al (2010) Statistical downscaling of daily mean temperature, pan evaporation and precipitation for climate change scenarios in Haihe River, China. Theor Appl Climatol 99: 149. https://doi.org/10.1007/s00704-009-0129-6

[18]. Rashid MM, Beecham S, Chowdhury RK (2015) Statistical downscaling of CMIP5 outputs for projecting future changes in rainfall in the Onkaparinga catchment. Science of The Total Environment 530–531:171-182. https://doi.org/10.1016/j.scitotenv.2015.05.024.

[19]. Sehgal V, Lakhanpal A, Maheswaran R, Khosa R, Sridhar V (2018) Application of multi-scale wavelet entropy and multi-resolution Volterra models for climatic downscaling. Journal of Hydrology 556:1078-1095https://doi.org/10.1016/j.jhydrol.2016.10.048

[20]. Anandhi A, Srinivas VV, Nanjundiah RS, Nagesh Kumar D (2008) Downscaling precipitation to river basin in India for IPCC SRES scenarios using support vector machine. Int. J. Climatol 28:401-420. https://doi.org/10.1002/joc.1529

[21]. Wilby, R.L., Dawson, C.W., Barrow, E.M., 2002. SDSM—a decision support tool for the assessment of regional climate change impacts. Environ. Model Softw. 17 (2), 145–157. http://dx.doi.org/10.1016/s1364-8152(01)00060-3.

[22]. Tatsumi, K., T. Oizumi, Y. Yamashiki, 2013. Introduction of daily minimum and maximum temperature change signals in the Shikoku region using the statistical downscaling method by GCMs. Hydrological Research Letters, 7(3); 48-53.

[23]. Zhang Y, You Q, Chen C, Ge J (2016) Impacts of climate change on streamflows under RCP scenarios: A case study in Xin River Basin, China. Atmospheric Research 178. 10.1016/j.atmosres.2016.04.018. https://doi.org/10.1016/j.atmosres.2016.04.018

[24]. Wilby, R.L., Dawson, C.W., 2007. Statistical Downscaling Model (SDSM), Version 4.2. Department of Geography, Lancaster University, UK.

[25]. IPCC Climate Change (2014) Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change / R. Pachauri and L. Meyer (editors) , Geneva, Switzerland, IPCC, 151 pages.

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