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Investigating impact of climate change scenarios on semi-arid watershed runoff

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***Abstract*— Northwest region of Iran is subject to impacts of climate change that may adversely change the water resources. Decrement in annual precipitation and winter precipitation as well as increase in temperatures are observed in recent decades. In this study, the impact of climate change on Ajichay watershed runoff was evaluated. Evaluation was done by quantifying the effect of climate change on the water budget components. Hydrological modeling was performed with SWAT model which was calibrated and validated successfully. Climate change and land use scenarios were used to compute the present and future climate change impacts on watershed runoff. According to the simulation results, almost all water budget components have decreased. SWAT was able to allocate less irrigation water because of the decrease of overall water due to the climate change. This ended in an increase of water stressed days and temperature stressed days whereas crop yields have decreased according to the simulation results. The results indicated that shortage of water is expected to be a problem in the future. In this way, investigations on switching to more efficient irrigation methods and to crops with less water utilization are recommended as adaptation measures to climate change impacts.**

Keywords*— *Climate change, watershed, runoff, SWAT.

I. INTRODUCTION (*Heading 1*)

The resonance of the hydrologic cycle is one of the most manifest traces caused by climate warming. Conversion in hydrological processes may in turn alter the altogether approachability and quality of water resources, and modify the spatiotemporal specification of hydrologic incidence, such as the timing of flow events, and the alternation and intensity of floods and droughts [1]. Mountainous areas have been projected to experience more severe impacts associated with climate change.

Climate change arises inherently, but human population growth and associated land-cover conversion (e.g., deforestation) and irritation of fossil fuel have remarkably catalyzed the increase of greenhouse gases [2]. Water is a principal natural resource that human essentially demand; main element to maintain socio-economic development activity [3]. Hence, water resource management issues must consider the possible efficacy of climate change that could better stress water accessibility for human application and natural ecosystems [4], and design the convenient scale accordingly. This is of uttermost substantial for arid and semi-arid areas [5].

This paper aimed to use SWAT to assess the climate change by related scenarios.

II. MATERIAL AND METHODS

A. *The Soil and Water model (SWAT)*

The Soil and Water Assessment Tool (SWAT) is a process-based model that simulates continuous time landscape processes at a catchment scale. The catchment is partitioned into Hydrological Response Units (HRUs) based on soil type, land use and slope classes. Model components include hydrology, weather, soil erosion, nutrients, soil discharge-SSL, crop growth, pesticides agricultural management and stream routing. The model divides watersheds into subwatersheds and further into hydrologic response units (HRUs) based on land use, soil, and slope information. The model requires several parameters to simulate hydrologic and water quality processes. These include weather, soils, ground water, channel, plant water use, plant growth, soil chemistry, and water quality parameters, as well as sub-basin and HRU characterization data. The SWAT model contains built-in climate, soils, and plant growth databases that can be used as data sources for climate, soil, and plant growth parameters. The basic parameters, as regards, are those relevant to land use, soil, topography and climate. The ArcGIS interface of the SWAT2012 version was employed to spatially discretize the study catchment. For the model calibration and validation monthly river discharge and SSL features data were used. The 100 m resolution data were used to create the Digital Elevation Model (DEM). The land use types and soil categories of the study area were obtained from the East Azerbaijan Regional Water. 30 precipitation stations and 15 hydrometric stations located within the watershed were used to drive the hydrologic model using monthly data. These stations have been in operation in different periods, but the selected period for all data was 1993 to 2014.

B. *Climate change scenarios*

For the simulation of climate change scenarios, General Circulation Models (GCMs) [ECHAM5 (Roeckner et al., 2003); BCM (Déqué et al., 1994)] combined with three Regional Circulation Models (RCMs) [RACMO2 (van Meijgaard et al., 2008); RCA (Kjellström et al., 2005); REMO (Jacob, 2001)] were selected so that the uncertainty of the future scenarios would be taken into consideration; the above mentioned models are based on the A1B storyline. The A1 scenario family (which was used for land cover changes too) is based on rapid economic growth, increase in population until the mid-century and a decrease thereafter, and the introduction of new and more efficient technologies. The A1B scenario sets a balanced emphasis on all energy sources (IPCC, 2000). Finally, the three combinations used were ECHAM-RACMO, BCA-RCA and ECHAM_REMO, covering the 2010–2100 time period. The linear-scaling approach (Lenderink et al., 2007), which operates with monthly correction values based on the differences between observed and present simulated daily values, was used for the correction of bias (Teutschbein and Seibert, 2012).

C. Case study

This proposed frame work was extended to examine the ungauged site discharge-SSL processes in monthly scale for Talkhe rood (Ajichay) watershed which is located in semi-arid area of Iran. The monthly rainfall, discharge and SSL dataset used in this study were provided from East Azerbaijan regional water company. Talkhe rood watershed's hydrometric stations and rain gauges are located in northwest of Iran at Azerbaijan province (between 47° 45′ and 45° 30′ east longitude and 38° 30′ and 37° 45′ north latitude). Fig. 1 presents geographical location and digital elevation map (DEM) of Talkhe rood watershed which has potentially useful data about Talkhe rood watershed. The watershed drainage area is about 10853 km2 and covers about 25 percent of Urmia Lake. Watershed elevation varies between 1228 m and 3755 meters above the sea level. River discharge sheds into Urmia Lake, which makes it momentous for survival of the lake. Mean daily temperature varies from 2.5 oC in winter to 20 oC in summer. Relative humidity varies about 55 to 60 percent over year. Wind speed in western area is higher than eastern are which is 17.5 and 11.5 Km/h respectively. For purpose of predicting by Top-GK which includes the calibration and verification steps, dataset were divided into two parts. The first division as 75% of total data included the training set and the remaining 25% data set was used for the testing purposes. Discharge-SSL of Arzanagh station, which covers 12 years of discharge-SSL features, was assumed as ungauged site. Data duration is from 1993 to 2014 (except for Arzanagh station which is from 2002 to 2014).

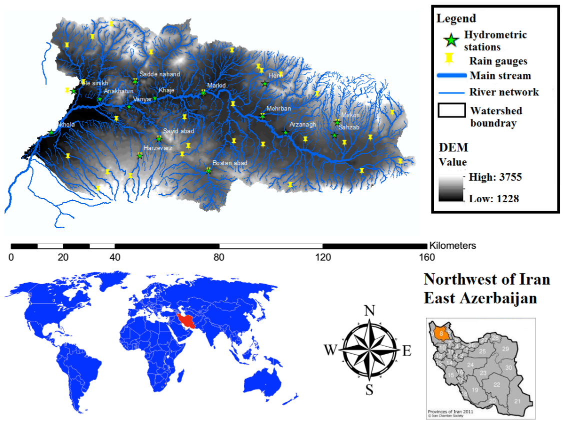

Fig. 1. Location of study area along with hydrometric stations and rain gauges.

D. Efficiency critria

In this study, two different criteria were used to measure the efficiency of the proposed forecasting methods; the root mean square error (RMSE) and the determination coefficient (DC). The RMSE and DC are used to demonstrate discrepancies between forecasts and observations (Adamowski and Chan, 2011). The RMSE is used to quantify modeling accuracy, which produces a positive value by squaring the errors. The RMSE increases from zero for perfect forecasts through large positive values as the discrepancies between forecasts and observations become increasingly large. Obviously, a high value for DC (up to one) and small value for RMSE indicate high efficiency of the model. Legates and McCabe (1999) indicated that a hydrological model can be sufficiently evaluated by these two statistics. These measures are not oversensitive to extreme values (outliers) and are sensitive to additive and proportional differences between model predictions and observations. Therefore, correlation-based measures (e.g. DC statistic) can indicate that a model is a good predictor (Legates and McCabe, 1999).

III. RESULTS AND CONCLUSION

The model was calibrated with the observed runoff for the years 2002–2014 for all stations and validated for the priod of 1993–2002 for Arzanagh station. For the calibration, one year was used as a warm-up period of the model. Fig. 5 presents the comparison of simulated monthly discharges and SSL versus observed data for Arzanagh station for both the calibration (2002–2014) and verification periods (1993–2002). The calibrated parameters were all optimized for discharge and the range of SWAT parameter values for the Arzanagh station. The fit between the model discharge predictions and the observed discharge showed good agreement as indicated the evaluation of the RMSE and DC indices. The RMSE and DC values of the discharge for the calibration period were 0.85 and 3.8. Also DC=0.8 and RMSE=4.6 for verification period were obtained. For SSL modeling DC calibration=0.86 and DC verification= 0.8 along with RMSE calibration=254 and RMSE verification=

337 was captured. Selection of calibration and verification in such a way was for comparing capability of Top-GK and SWAT model to find missing values. In calibration stage, real values of Arzanagh station were imposed to the system. Results approved accuracy of TOP-GK over SWAT model by the means of RMSE and DC.

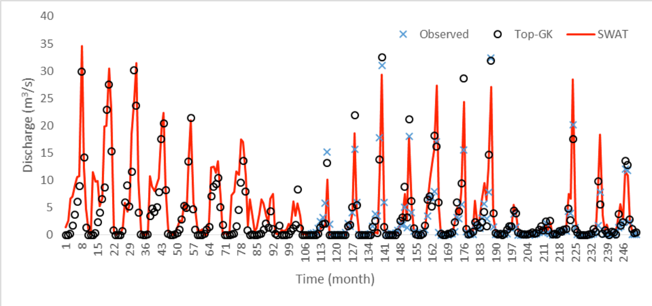

Fig. 2. Simulation results by SWAT.

As seen in Fig. 6, all the water-related components indicate that there was an Decreasee. Revap is the rise of groundwater to supplement the soil water deficit. Thus, a decrease of revap indicates that more water from groundwater storage has risen to supplement the deficiency. In other words, the model estimated that the soil became drier. SWAT estimated real evapotranspiration decreased as well indicating that less water is available for evapotranspiration. SWAT incorporates algorithms that estimate how much water the crops need and allocate that amount of water. If enough water is available at the source required amount is withdrawn; otherwise only available water is withdrawn. As seen in Fig. 3, SWAT was able to allocate less irrigation water because of the decrease of overall water due to the climate change. This also resulted in decrease of water stressed days and temperature stressed days (Table 3), whereas crop yields have decreased according to the simulation results given in Fig. 7, except for wheat and corn that require relatively less water. Groundwater quantity decreased for all climate change scenarios because of the decrease in groundwater recharge, as expected (Fig. 2). Changes in other hydrological variables such as the base flow are the results of a considerable decrease of the groundwater storage (Fig. 8a). In this study, soil water content was considered to be a relevant variable for the groundwater dependent ecosystems, since the area is partly covered by pine forests and shrubs that are an important part of the natural vegetation and form habitats for the terrestrial wild life. As the summers in the region are dry with high rate of evapotranspiration, amount of the soil water is important to maintain the natural vegetation.

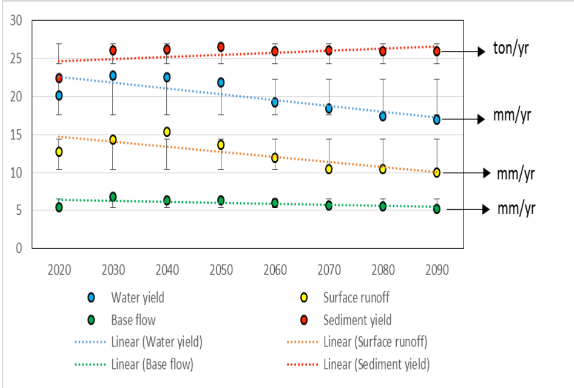

Fig. 3. Fig. 8. Simulation results for climate change scenarios including trends.

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