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Research article

The Response of Streamflow to Climate Change in Gumera Watershed, Blue Nile River Basin, Ethiopia

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Abstract

Change in water hydrology is caused by climate change. This study evaluates the response of stream flow to climate change. A study of the impact of climate change on streamflow and direct runoff in the Gumera watershed was carried out using the hydrologic model HEC-HMS. Climate change impact analysis was performed using a down scaled Regional Climate Model (RCM) called the Hadley Center Earth System Model (Had GEM-ES). In this model, bias correction was done for 365 days using power transformation for rainfall correction. The study showed that for the RCP2.6 scenario, streamflow decreases annually by 0.001% in the 2050's. It decreases annually with change of 0.01% for RCP4.5. The RCP8.5 scenario reveals an annual decrease in streamflow of 0.002%. The study provides a broad perspective on probable hydrologic alterations in the region, and the results provide useful input for sustainable water resource development.

Keywords

climate change impact;
streamflow
precipitation;
direct runoff;
HEC-HMS;
Gumera watershed;
Ethiopia

1. Introduction

Climate change is the greatest threat to agriculture and food security in the 21st century, particularly in many of the poor, agriculture-based countries of sub-Saharan Africa (SSA) with their low capacity to effectively cope [1]. Slight rises in temperatures will lead to greater loss of moisture, exacerbating drought, and desertification [2]. The climate of the Earth is changing; temperatures are increasing, and the amount and distribution of rainfall are being altered [3]. Climate change will

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greatly complicate the design, operation, and management of water-use systems [4]. Climate is just one of many factors challenging future water planners and managers [5]. The scientific knowledge of hydrological processes and natural responses to climate change and human activities are of great importance in both theoretical and practical spheres, and attract numerous researchers from all around the world. Climate change caused by increasing atmospheric concentration of carbon dioxide and other micro gases has altered the magnitude and timing of runoff to some extent. It is considerably significant for understanding the effects of climate change and human activities on stream-flow, and especially for quantifying the degree of the influences. The assessment of the impact of climate change and human activities can provide guidance for effectively developing and managing water resource projects in sustainable and productive ways [6].

Forecasts of medium-streamflow and low streamflow events under precipitation deficit conditions show less skill. Besides, simulations provide a plausible set of streamflow and water in semiarid regions that face changes in both precipitation and evapotranspiration [7].

In Ethiopia, water resource management is of paramount importance in the fostering of developmental activities in the regions. Therefore, in order to take water management resources in the Gumera watershed in a sustainable fashion, developmental activities like agriculture and other water resource development, assessment of streamflow changes with climate change is crucial.

This study examines and assesses the effect of climate change on the Gumera river using HEC-HMS model. It is focused on evaluating how climate change would influence the availability of water resources for the Gumera river basin in northwestern Ethiopia using various RCP climate scenarios for future climate projections. Furthermore, analyses of the impact of climate change on water resources of the basin will provide supportive information for future water resource management in the area. Climate change will have a profound impact on natural resources, of which water is one of the most important. With climate change, the amount of rainfall in many parts of Africa is expected to decline while variability may increase dramatically.

Both observational and downscaled future scenario data suggest a recent amplification of climate contrasts across the globe. The potential effect on water resources of global climate change in the past few decades has been of great concern. Disasters from climate/weather related natural phenomena such as floods, droughts, and landslides have had devastating effects. The situation has been aggravated by several other problems such as poor land use, unsustainable farming practices, and deforestation in the watershed. All climatic processes are likely to intensify, and not only will the average climatic conditions change, but their variability and frequency will also do so. These include the severity of extreme events such as floods, heat waves, and droughts. Climate model projections show an increase in the global mean near-surface air temperature [7].

The effects of climate change on water resource availability are affected by different factors such as temperature, evaporation, and runoff. The possible effects of climate change on the characteristics of the Gumera watershed under different RCP climate scenarios have not yet been identified and investigated. Therefore, this study focuses on possible streamflow changes that can occur with climate changes. The objectives of this study are to provide data and strategies that can help to alleviate these potential problems through the scientific study of the causative factors and consequences, and to contribute ample scientific information for water resource management of the area.

Previous research conducted related to climate change in this watershed indicated that the maximum and minimum temperatures would increase for all three scenarios in all future time horizons, and that the precipitation would show a decreasing trend in all future time horizons [8]. RCP8.5 was used as the input to calibrate the SWAT model for the investigation of the possible impact of potential climate change on the hydrology of the Gumara watershed. The HEC-HMS program computes streamflow by subtracting losses, transforming excess precipitation and adding base flow from the precipitation. The HEC-HMS project requires four model data components:

Basin Model, Precipitation Model, Control Specifications and Time Series data [9]. The aim of this study was to generate monthly and seasonal streamflow time series and inflow data for the Gumera river under different RCP's climate scenarios and to determine the magnitude/amount of runoff volume of the watershed.

2. Materials and Methods

2.1 Description of the study area

The Gumera watershed is located in northwestern Ethiopia, in the southern Gondar administrative zone of the Amhara National regional state, 624 km north of Addis Ababa. It is drained by the Gumera river. This watershed (Figure 1) is part of the Abbay basin and more particularly part of Lake Tana sub-basin, which is situated on the northeastern side of Lake Tana. The watershed area comprises five woreda, namely Agre Genet, Arb Gebeya, Debre Tabor, Wenzaye, and Wereta. It lies between latitudes 11°30'0''N and 11°51'0''N and longitudes 37°40'0''E and 38°10'0'' E. After flowing for a length of 132.5km, the river joins Lake Tana. The watershed has a total drainage area of about 1163.23 km^2 above the gauging station located near the small town called Gumera.

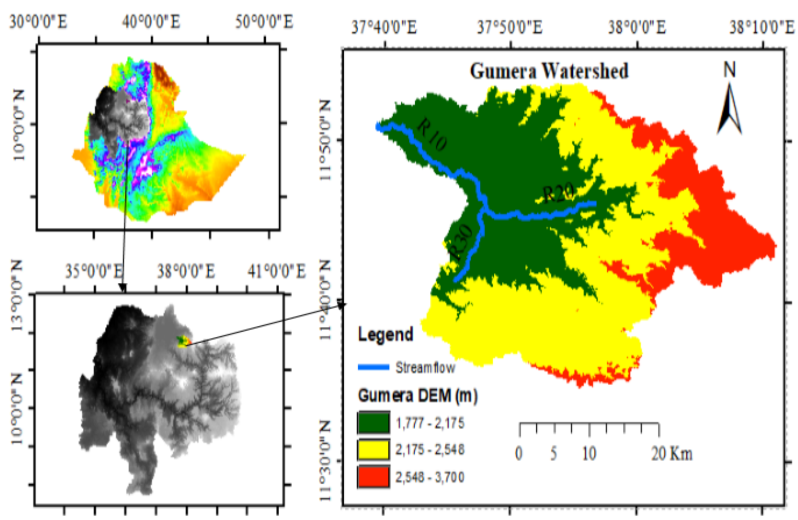

Figure 1. Location of the Gumera watershed

2.2 Climate

The annual rainfall distribution of selected meteorological stations from 1985-2016 is; Agre Genet, 1112.3-2404 mm with an annual mean of 1685.08mm; Arb Gebeya, 392.08-1849.31 mm with an annual mean of 1189.90 mm; Debre Tabor, 1104.23-2137.26 mm with an annual mean of 1524.76 mm; Wenzaye, 1088.70-3141.07 with an annual mean of 1616.41 mm; and Woreta, 991.85-3279.44 mm with an annual mean of 1526.54 mm. There is a high rate of average yearly evaporation between 3621.92 mm and 4174.81 mm. The meteorological records reveal that the yearly average evaporation is about 3819.89 mm.

2.3 Input data sources

Observed stream discharge/flow data from 1990-2006 were obtained from the Ministry of Water Resource of Ethiopia (MoWR), and daily observed streamflow data from 1990-2014 that had been collected from the Amhara Water Works Design and Supervision Enterprise, Bahirdar, were used for model calibration and validation. Observed daily rainfall/precipitation data from 1985-2016 were obtained from the National Metrological Agency of Ethiopia (NMA). Daily observed precipitation data were used as the input for the hydrological models; such data were operational and real-time data for the simulation model and were used for calibration and validation of the predicting model.

The maximum and minimum temperatures for Potential Evapo-transpiration (PET) estimation was obtained from the National Metrological Agency of Ethiopia (NMA) from 1985-2016. Evapo-transpiration (PET) is a climatic parameter and can be computed from weather data. Climate data that were downscaled to RCM were obtained from the International Water Management Institute (IWMI). Land use land cover, Soil data and the Degital Elevation Model (DEM) were obtained from the Ministry of Water Resources of Ethiopia (MoWR). Tools including ArcHydro, HEC GeoHMS HEC-HMS version 4.1, and Arc View GIS 10.1 were used in this study.

2.4 Methodology

2.4.1 Rainfall data analysis

In this study, before directly using the required data for the model, it was necessary to fill in the missing data and to check the quality of the observed data. Discharge and rainfall data quality was checked. Two analytical procedures for estimating rainfall and the spatial interpolation methods are used in this study as described below.

2.4.1.1 Arithmetic average method

This method is applied if the average annual rainfall of the station under consideration is within 10% of the average annual rainfall at the adjoining stations. The erroneous or missing rainfall at the station under consideration is estimated as the simple average of neighboring stations. Thus, if the estimate for the erroneous or missing rainfall at the station under consideration is P_{test} and the rainfall at M adjoining stations is $P_{base,\,i}$ (i = 1 to M), then:

$$P_{test} = \frac{1}{M}\left(P_{base,1} + P_{base,2} + P_{base,3} + \cdots + P_{base,M} \right) \tag{1}$$

Usually, the averaging of three or more adjoining stations is considered to give a satisfactory estimate [7].

2.4.1.2 Normal ratio method

This method is preferred if the average (or normal) annual rainfall of the station under consideration differs from the average annual rainfall at the adjoining stations by more than 10%. The erroneous or missing rainfall at the station under consideration is estimated as the weighted average of adjoining stations. The rainfall at each of the adjoining stations is weighted by the ratio of the average annual rainfall at the station under consideration and average annual rainfall of the adjoining station. The rainfall for the erroneous or missing value at the station under consideration is estimated as:

$$P_{test} = \frac{1}{M}(P_{base,1} + P_{base,2} + P_{base,3} + \cdots + P_{base,M}) \quad (2)$$

N_{test} = annual normal rainfall at the station under consideration
$N_{base,i}$ = annual normal rainfall at the adjoining stations (for i = 1 to M)
A minimum of three adjoining stations must be generally used for obtaining good estimates using the normal ratio method [7].

2.4.2 Evapotranspiration

Data for some weather variables are missing, and for this study the Hargreaves method was used for estimating potential evapotranspiration from temperature data according to methodologies. The general formula is described as follows:

$$ET_O = 0.0023 \times Ra(T_{mean} + 17.8) \times (T_{max} - T_{min})^{0.5} \quad (3)$$

Where Ra is extraterrestrial radiation in mm/day, T_{mean} is mean daily temperature in °C, T_{max} is maximum daily temperature in °C, and T_{min} is minimum daily temperature in °C.

2.4.3 Bias correction

Power transformation: correct the CV (Coefficient of Variation) as well as the mean. In this nonlinear correction, each daily precipitation amount P was transformed to a corrected P* using:

$$P^* = aP^b \quad (4)$$

Where: P* is the bias corrected daily precipitation, P is the uncorrected daily precipitation, and a and b are the transformation coefficients.

The correction of temperature only involves shifting and scaling to adjust the mean and variance. For this study, the corrected daily temperature T* was obtained as:

$$T^* = \overline{T_o} + \frac{\sigma}{\sigma}\left(\frac{T_o}{T_u}\right)(T_u - \overline{T_o}) \quad (5)$$

Where: T_u is the uncorrected daily temperature from RCA5, T_o is the observed daily temperature, and $\overline{T_o}$ is the observed daily mean temperature.

The following formula [8-10] was used to change the streamflow of the intermittent Gumera river to direct runoff. There were other methods of base flow and direct runoff separation from streamflow, and these methods were local minimum method and Recursive methods. These two methods overestimate baseflow and underestimate direct runoff. Therefore, Lyne formula was used for this study (equation 6).

$$q_k = a * q_{k-1} + \left(\frac{1+a}{2}\right) * (y_k - y_{k-1}) \quad (6)$$

Where
q_k: Direct runoff at time step k,
q_{k-1}: Direct runoff at time step k-1,
y_k: Total streamflow at time step k,
y_{k-1}: Total streamflow at time step k-1,
a: Filter parameter

2.4.4 Model performance evaluation

For this study, model performance during calibration and validation was evaluated using performance criteria such as the Nash and Sutcliffe simulation efficiency (NSE), coefficient of determination (R2), and Relative Volumetric Error (RVE).

2.4.4.1 Nash-Sutcliffe efficiency (NSE)

The value of NSE can range from -∞ to 1. A value closer to one indicates the better fit. The NSF can be used to compare the observed and simulated hydrographs. Values between 0.5 and 1.0 are generally viewed as an acceptable level of performance. It can be estimated as:

$$\mathrm{NSE} = 1 - \frac{\sum_{i=1}^{n}\left(Q_{obs,i} - Q_{sim,i}\right)^2}{\sum_{i=1}^{n}\left(Q_{obs,i} - \overline{Q_{obs,\imath}}\right)^2} \tag{7}$$

2.4.4.2 Pearson's product moment correlation coefficient and its square (coefficient of determination (R^2)

The values range from -1 to 1 (perfect correlation) and values greater than 0.6 are considered as acceptable. The R^2 can written as:

$$R^2 = \frac{\left[\sum_{i=1}^{n}\left(Q_{sim,i} - \overline{Q_{sim,\imath}}\right)\left(Q_{obs,i} - \overline{Q_{obs,\imath}}\right)\right]^2}{\sum_{i=1}^{n}\left[Q_{sim,i} - \overline{Q_{sim,\imath}}\right]^2 \sum_{i=1}^{n}\left[Q_{obs,i} - \overline{Q_{obs,\imath}}\right]^2} \tag{8}$$

2.4.4.3 Relative volume error (RVE)

The relative volume error quantifies the mass balance error between the observed and simulated discharge, and it ranges between -∞ and ∞. The model best performs if the RVE is close to zero and performs well if the value of RVE is between -5% to 5%.

$$\mathrm{RVE} = \frac{\sum_{i=1}^{n}\left(Q_{sim,i} - Q_{obs,i}\right)}{\sum_{i=1}^{n} Q_{obs,i}} \tag{9}$$

2.4.5 HadGEM-ES

HadGEM2-ES is a coupled AOGCM with atmospheric resolution of N96 (1.875◦ × 1.25◦) with 38 vertical levels and an ocean resolution of 1◦ (increasing to 1/3◦ at the equator) and 40 vertical levels. The model timestep is 30 min (atmosphere and land) and 1 h (ocean).

2.4.6 Sensitivity analysis

Sensitivity analysis is a method used to determine which parameters of the model have the greatest impact on the model results. It ranks model parameters based on their contribution to overall error in model predictions. Sensitivity analysis can be local and global. In this study, a local sensitivity analysis was adopted for evaluating the continuous model.

3. Results and Discussions

In this study, a manual calibration method was adopted to determine practical parameter values from catchment characteristics by hand calculation in order to preserve hydrograph shape, minimum error in peak discharge, and volumes. The streamflow forecasting was conducted using the HEC-HMS model loss method, transform method, and constant monthly base flow method, which was adopted for two sub-basin and recession methods for one sub-basin to simulate streamflow at one common outlet. Areal precipitation and Evapotranspiration were used as model input data. The HEC-HMS model was calibrated and validated for the observed period of 25 years (1990-2014) (Table 1; Figure 2) because of the lack of available meteorological and discharge data, and optimized parameters were selected for streamflow simulation. The Relative Volume Error of the HEC-HMS model for Gumera watershed was 0.01%.

Table 1. Summary of calibration and validation results

Objective Function	Calibration	Validation
NSE	0.69	0.78
RVE	0.11	-0.15
R^2	0.84	0.90

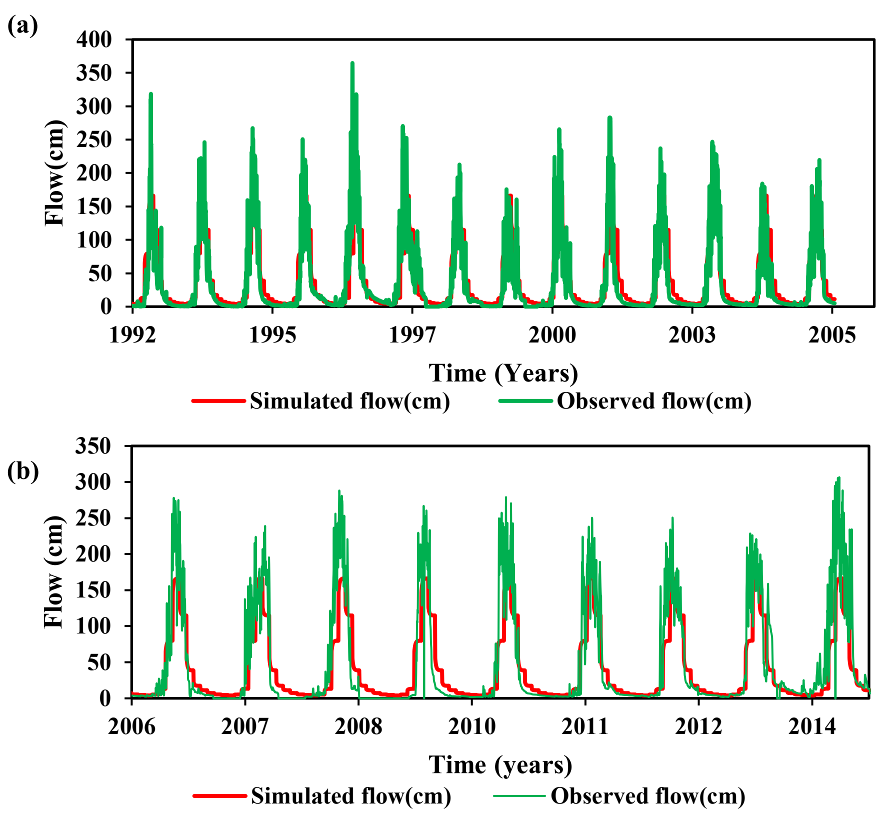

Figure 2. Graph of calibration (a) and validation (b) of observed versus simulated streamflow of Gumera watershed

The future climate scenarios (2011-2040) and (2041-2070) were carried out with downscaled and bias corrected RCP scenarios (2.6, 4.5 and 8.5). Precipitation, maximum temperature, and minimum temperature and Evapotranspiration for the future were used to generate the future flow of the river. The output of RCP scenarios was averaged or aggregated to characterize rainfall, temperature, and Evapotranspiration at monthly and seasonal scales. Classification at two different periods with 30 years interval was also made including the baseline period (1971-2000), short term (2011-2040) and medium term (2041-2070) periods.

For RCP 2.6 scenario in the 2020s, the annual daily streamflow minimum daily flow was 39.29 cm and the daily peak flow at the outlet of the Gumera watershed was 39.35 cm (Figure 3). The mean annual daily streamflow was 39.32cm and the standard deviation was 0.02 cm in the 2020s. The long term mean annual Streamflow decreased with change in percent difference of 0.01% when compared to corrected baseline, and the mean annual uncorrected streamflow percent difference from uncorrected baseline decreased by 0.004%. The discrepancies between long term mean annual corrected and uncorrected streamflow in the 2020s were 0.01%.

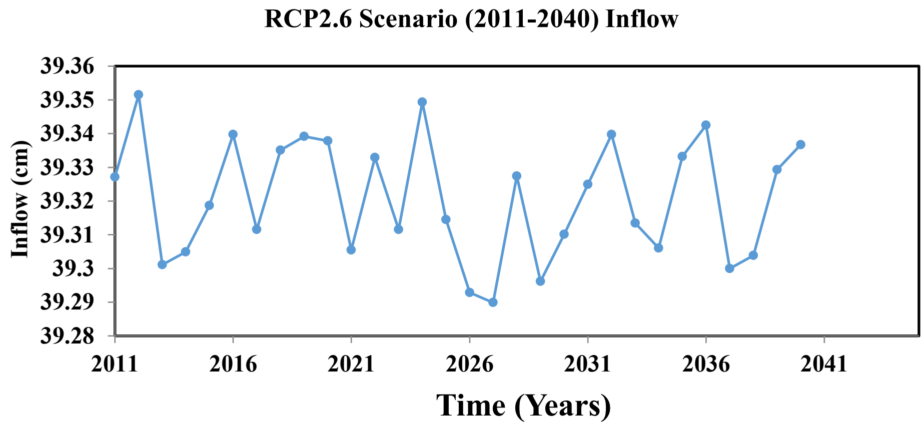

Figure 3. Daily annual streamflow of the Gumera watershed for RCP2.6 scenario in the 2020s

In comparison, the RCP2.6 scenario for the 2050s showed an annual daily minimum streamflow flow of 39.30 cm and the daily peak flow at the outlet of the Gumera watershed was 39.36 cm (Figure 4). The mean annual daily streamflow was 39.32 cm and the standard deviation was 0.01 cm in the 2050s. The long term mean annual streamflow decreased with change in percent difference of 0.001% when compared to corrected baseline, and the mean annual uncorrected streamflow percent difference from uncorrected baseline decreased by 0.01%. The discrepancies between long term mean annual corrected and uncorrected streamflow in the 2050s were -0.01%.

On a monthly scale, the difference of forecasted streamflow of RCP2.6 scenario from baseline (4.05 cm to 165.90 cm) ranges from -0.25% to 0.51% in May and April, respectively in the 2020s and it ranges from -0.35% to 0.13% in May and January, respectively in 2050s (Figure 5).

For the RCP4.5 scenario in 2020s, the annual daily streamflow minimum daily flow was 39.29 cm, and the daily peak flow at the outlet of the Gumera watershed was 39.35 cm. The mean annual daily streamflow was 39.32 cm, and the standard deviation was 0.01 cm in the 2020s. The long term mean annual streamflow decreased with a change in percent difference of 0.001% when compared to the corrected baseline, and the mean annual uncorrected streamflow percent difference from uncorrected baseline decreased by 0.01%. The discrepancies between long term mean annual corrected and uncorrected streamflow in the 2020s was -0.01%. However, the RCP4.5 scenario for

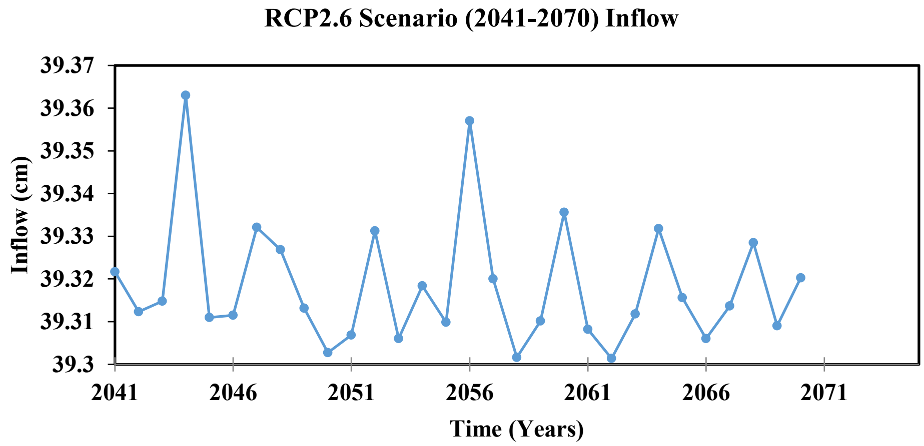

Figure 4. Daily annual streamflow of the Gumera watershed for RCP2.6 scenario in the 2050s

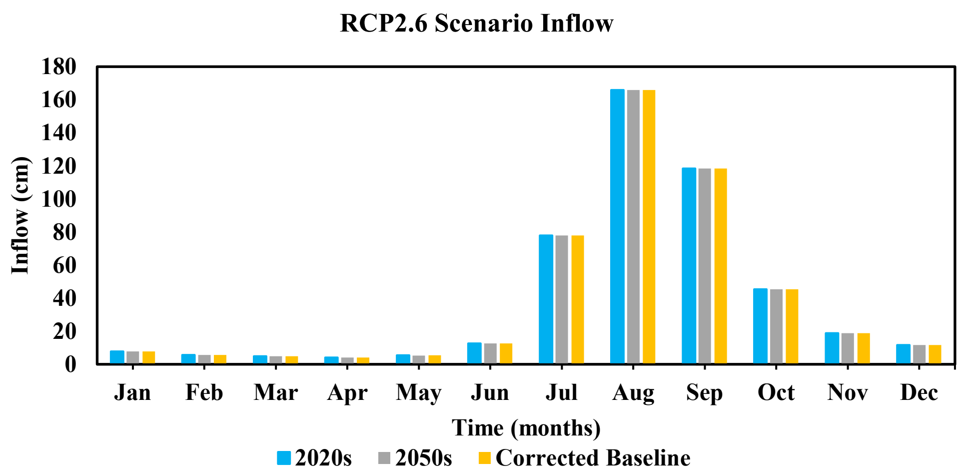

Figure 5. Future monthly forecasted daily streamflow of Gumera watershed for RCP2.6 scenario

2050s revealed an annual daily streamflow minimum daily flow of 39.29 cm, and the daily peak flow at the outlet of the Gumera watershed was 39.35 cm. The mean annual daily streamflow was 39.31 cm, and the standard deviation was 0.02 cm in the 2050s. The long term mean annual streamflow decreased with a change in percent difference of 0.01% when compared to the corrected baseline, and the mean annual uncorrected streamflow percent difference from uncorrected baseline decreased by 0.01%. The discrepancies between long term mean annual corrected and uncorrected streamflow in the 2050s was 0%. On a monthly scale, the difference of forecasted streamflow of RCP4.5 scenario from baseline (4.05 cm to 165.90 cm) ranged from -0.38% to 0.32% in May and January, respectively in the 2020s and it ranged from -0.71% to 0.29% in May and April, respectively in the 2050s.

For the RCP8.5 scenario in the 2020s, the annual daily streamflow minimum daily flow was 39.29 cm and the daily peak flow at the outlet of the Gumera watershed was 39.37 cm. The mean annual daily streamflow was 39.32 cm and the standard deviation was 0.02 cm in the 2020s.

The long term mean annual streamflow decreased with a change in percent difference of 0.003% when compared to corrected baseline, and the mean annual uncorrected streamflow percent difference from uncorrected baseline decreased by 0.01%. The discrepancies between long term mean annual corrected and uncorrected streamflow in the 2020s were -0.01%.

For the RCP8.5 scenario in the 2050s, the annual daily streamflow minimum daily flow was 39.30 cm, and the daily peak flow at the outlet of the Gumera watershed was 39.37 cm. The mean annual daily streamflow was 39.32 cm and the standard deviation was 0.02 cm in the 2050s. The long term mean annual streamflow decreased with a change in percent difference of 0.002% when compared to corrected baseline, and the mean annual uncorrected streamflow percent difference from uncorrected baseline decreased by 0.01%. The discrepancies between long term mean annual corrected and uncorrected streamflow in the 2050s were -0.01%. The difference of forecasted streamflow of RCP8.5 scenario from baseline (4.05 cm to 165.90 cm) ranged from -0.38% to 0.40% in May and January, respectively in the 2020s, and it ranged from -0.45% to 0.15% in May and January, respectively in 2050s on a monthly scale.

This study discovered that for the future time horizon in the 2020s, the bias corrected streamflow of RCP2.6 was overestimated maximally in winter when seasonal change was 0.09% compared with corrected baseline, and it was normally estimated in spring and summer when seasonal change was 0% compared to corrected baseline (4.75 cm to 85.52 cm) (Figure 6). Seasonally in the future time horizon for the 2050s, the bias corrected streamflow of RCP2.6 was overestimated maximally in autumn when seasonal change was 0.03% compared with corrected baseline, and it was underestimated minimally in spring when seasonal change was -0.16% compared to corrected baseline (4.75 cm to 85.52 cm) (Figure 6).

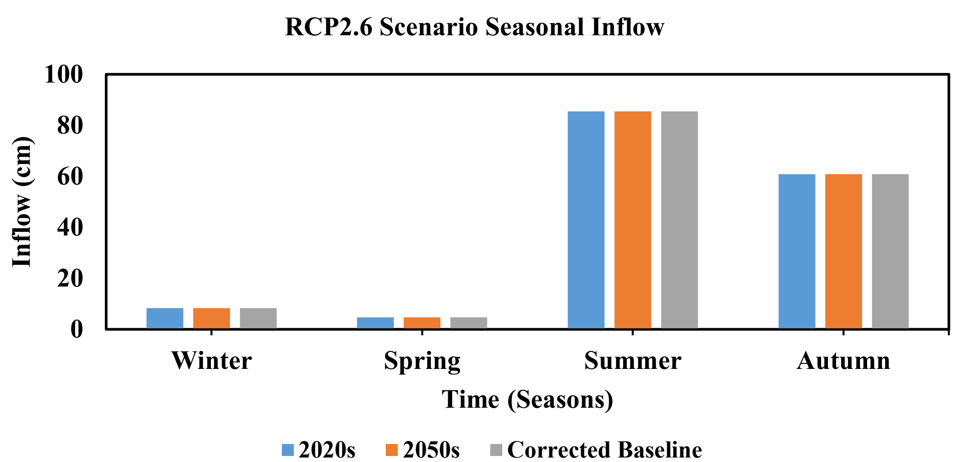

Figure 6. Seasonal forecasted streamflow of the Gumera watershed for RCP2.6 scenario

Seasonally in the future time horizon of the 2020s, the bias corrected streamflow of RCP4.5 was overestimated maximally in winter with seasonal change of 0.12% when compared with corrected baseline, and it was underestimated minimally in spring with seasonal change of -0.11% when compared to corrected baseline (4.75 cm to 85.52 cm). Seasonally in the future time horizon of the 2050s, the bias corrected streamflow of RCP4.5 was overestimated maximally in autumn with seasonal change of 0.01% when compared with corrected baseline, and it was underestimated minimally in spring with seasonal change of -0.25% when compared to corrected baseline (4.75 cm to 85.52 cm).

For the future time horizon of the 2020s, the bias corrected streamflow of RCP8.5 was overestimated maximally in winter with seasonal change of 0.13% compared with corrected baseline, and it was underestimated minimally in spring when seasonal change was -0.18% compared to corrected baseline (4.75 cm to 85.52 cm). Seasonally in the future time horizon of 2050s, the bias corrected streamflow of RCP8.5 was overestimated maximally in autumn when seasonal change was 0.03% compared with corrected baseline, and it was underestimated minimally in spring with seasonal change of -0.02% compared to corrected baseline (4.75 cm to 85.52 cm). A summary of the RCP scenario of seasonal change in percent of forecasted streamflow of the 2020s and 2050s from corrected baseline is shown in Table 2.

Table 2. RCP scenario of seasonal change in percent of forecasted streamflow of the 2020s and 2050s from baseline

RCP	**Future Projection**	**Seasonal Change (%)**			
		Winter	**Spring**	**Summer**	**Autumn**
2.6	2020s	0.09	0.00	0.00	0.01
2.6	2050s	-0.02	-0.16	-0.01	0.03
4.5	2020s	0.12	-0.11	-0.01	0.00
4.5	2050s	-0.02	-0.25	-0.01	0.01
8.5	2020s	0.13	-0.18	-0.01	0.02
8.5	2050s	-0.02	-0.02	-0.01	0.03

According to this study, future streamflow decreased during the 2020s and 2050s for three RCP scenarios (RCP2.6, RCP4.5, and RCP8.5), and seasonally it decreased during the rainy season in summer because corrected streamflow was less than corrected streamflow baseline. This was probably because future precipitation decreased, and Evapotranspiration increased, and the temperature was increasing. Furthermore, the streamflow change per year was much less than changes in precipitation because small impervious change of the Gumera watershed was considered during the running of the HEC-HMS model. Therefore, the inhabitants of the Gumera watershed should use irrigation and they must manage their water resources carefully during the periods from 2011-2040 and 2041-2070. Another study revealed that, due to climate change, the streamflow of the watershed was found to increase by 4.06%, 3.26%, and 3.67% under RCP 2.6, RCP 4.5 and RCP 8.5 scenarios, respectively [1]. The temperature and sediment load are shown to increase in the future while the rainfall and streamflow decrease [2]. Climate change scenario modelling suggested that the precipitation would increase from 7% to 48%, and that streamflow from the BNB could increase by 21% to 97% [3].

This study showed that future runoff decreased during the 2020s and 2050s for three RCP scenarios: RCP2.6, RCP 4.5, and RCP8.5. Therefore, the inhabitants of the Gumera watershed should use irrigation and they must manage their water resources during the periods from 2011-2040 and 2041-2070. Furthermore, the average annual magnitude of runoff of future Gumera watershed for RCP2.6 in the 2020s was 1965.43 cm and 1965.88 cm in the 2050s. Next, for RCP4.5, the average annual magnitude of runoff for the future Gumera watershed in the 2020s was 1966.63 cm and 1966.36 cm in the 2050s. Lastly, for RCP8.5, the average annual magnitude of runoff of future Gumera watershed in the 2020s was 1966.50 cm and it was 1966.18 cm in the 2050s.

4. Conclusions

The use of downscaled RCP scenarios to evaluate the climate change impact on streamflow change was explored here. These scenarios are a supplement that can be used to evaluate climate change impact on streamflow of the Gumera watershed, but it is only one method to evaluate climate change impact. Therefore, careful usage of these RCP scenarios to evaluate climate change impact is mandatory. However, the following conclusions were drawn from this study:

- Sensitivity analysis was made for HEC-HMS model parameter and Recession-Recession Constant was found to be more sensitive and recession ratio and unit hydrograph lag time were found to be less sensitive.
- Precipitation, temperature (maximum and minimum), Evapotranspiration, streamflow, and direct runoff were analyzed monthly and seasonally under different RCP scenarios for two future time horizons during 2011-2040 and 2041-2070.
- The trend of maximum temperature increased by 3.94%,5.64% and 6.12% for RCP2.6, RCP4.5 and RCP8.5 respectively during 2011-2040.
- The trend of maximum temperature increased by 5.25%,9.43% and 11.34% for RCP2.6, RCP4.5 and RCP8.5 respectively during 2041-2070.
- The trend of minimum temperature increased by 9.29%,9.6% and 10.78% for RCP2.6, RCP4.5 and RCP8.5 respectively during 2011-2040.
- The trend of minimum temperature increased by 10.57%,16.42% and 14.04% for RCP2.6, RCP4.5 and RCP8.5 respectively during 2041-2070.
- The trend of Evapotranspiration increased by 2.36%,4.68% and 4.94% for RCP2.6, RCP4.5 and RCP8.5 respectively during 2011-2040.
- The trend of Evapotranspiration increased by 3.83%,7.75% and 10.99% for RCP2.6, RCP4.5 and RCP8.5 respectively during 2041-2070.
- The seasonal change of rainfall, Sstreamflow change and direct runoff from the corrected baselines for RCP2.6, RCP4.5 and RCP8.5 in the 2020s and 2050s showed decreases in wet (summer) seasons.
- This study contributes scientific information regarding the future upcoming climate change impact on Gumera watershed hydrology, with an emphasis on streamflow. The research findings will be beneficial to evaluate water storage during flooding events in wet seasons, and for further agricultural and different water resource development.
- This study indicated that the future streamflow will decrease in the two-time horizons of 2011-2040 and 2041-2070. Therefore, greater effort will be required by the inhabitants of Gumera watershed if they are to successfully conserve water during wet or summer seasons and have water available for irrigation and water resource development during the indicated future time horizons.

References

[1] Chakilu, G.G., Sándor, S. and Zoltán, T., 2020. Change in stream flow of Gumara watershed, upper Blue Nile Basin, Ethiopia under representative concentration pathway climate change scenarios. *Water*, 12(11), 3046, https://doi.org/10.3390/w12113046.

[2] Frederick, K.D. and Major, D.C., 1997. Climate change and water resources. *Climatic Change* 37, 7-23.
[3] Houghton, J.T., Meira, L.G., Callander, B.A., Harris, N., Kattenberg, A. and Maskell, K., 1996. *Climate change 1995: the Science of Climate Change*. Cambridge: Cambridge University Press.
[4] Gleick, P. and Shiklomanov, I.A., 1989. *The Impact of Climate Change for Water Resources. Second Meeting of IPCC WG-2, WMO/UNEP*. Geneva: World Climate Programme Publication Series.
[5] Robert, T., Watson, M.C. and Richard, H.M., 1996. *Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change*. New York: Cambridge University Press.
[6] Kangsheng, W. and Carol, A.J., 2007. Hydrologic response to climatic variability in a Great Lakes Watershed, a case study with the SWAT Model. *Journal of Hydrology*, 337(1-2), 187-199.
[7] IPCC Report, 2014. *IPCC Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. [online] Available at: https://www.ipcc.ch/report/ar5/syr/.
[8] Mersha, C., 2015. *Modeling the Impact of Climate Change on the Hydrological Regimes of Gumara Watershed*. MSc. Arba Minch University, Ethiopia.
[9] Grijsen, J.G., Visvanath, R. K., Qazi, R.L., Bhat, N.K., Chakrabarti, S.P., Trivedi, R.C. and Abbi, S.D.S., 1999. *Hydrology Project Training Module: How to Correct and Complete Rainfall Data*. [online] Available at: http://cwc.nic.in/main/HP/download/10.
[10] Lyne, V. and Hollick, M., 1979. Stochastic time-variable rainfall-runoff modeling. *7th Hydrology and Water Resources Symposium*, Institute of Engineers Australia, June 10-12, 1979, pp. 89-93.