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Impacts of Climate Change Under CMIP5 RCP Scenarios on the Hydrology of Lake Ziway Catchment, Central Rift Valley of Ethiopia

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Abstract
This study predicts future runoff conditions under changing climate using multi model outputs from Coupled Model Intercomparison Project Phase 5 (CMIP5) over Lake Ziway Catchment in the Central Rift Valley of Ethiopia. Bias corrected precipitation, maximum and minimum temperature data from HadGEM2-ES, CSIRO-MK-3-6-0 and CCSM4 models under representative concentration pathways RCP8.5 and RCP4.5 were used as future climate. Soil and Water Assessment Tool (SWAT) is used to simulate the future inflows from Katar River and Meki River towards Lake Ziway. Maximum and minimum temperature increased under RCP8.5 and RCP4.5 scenarios however, precipitation showed reduction. The percentage change in monthly average precipitation showed extremes for HadGEM2-ES model which range between -51.19% during 2050s and +23.15% during 2080s under RCP8.5. The model output showed an annual decrement in runoff depth from Katar River up to 19.45% on RCP8.5 on CSIRO MK-3-6-0 model and maximum reduction was recorded on RCP4.5 at 17.49% for CCSM4 model. Meki River showed maximum annual reduction of 20.28% during 2080s on RCP8.5 for HadGEM2-ES model. Due to future reduction of River flow on the region optimal allocations for water use purposes at all levels of water resource development projects are crucial for future water planning and management.
Keywords: CMIP5; Lake Ziway Catchment; RCP; Runoff Estimation; SWAT model.

Introduction

In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans. Whatever its cause, natural and human systems has become sensitive to climate change (IPPC, 2014). Increased anthropogenic activities on industries and population expansion towards forested areas has increased the concentration of carbon dioxide on Earth's atmosphere has raised global surface temperature and affected precipitation amount (IPCC, 2014; NASA, 2010).

Lake Ziway serves for wide range of socio-economic activity in Ethiopia. Different water use sectors have recently increased their pressure on the water balance of Lake Ziway which is recharged by precipitation and two rivers namely Katar and Meki Rivers. Climate variability in the frequency and intensity of extreme events over the Ethiopian Rift Valley (Legesse et al., 2010; Mechal et al., 2015) has increased due to climate change. Changes in flow magnitude, variability on long-term mean annual stream flow and water availability issues in the region have been studied frequently (Seyoum et al., 2015; Ayenew, 2007; Alemayehu, 2006; Legesse et al., 2010). Existing studies have focused on IPCCs fourth assessment report to assess the future water potentials and little is known about the potential impacts on River flows from the Climate Model Intercomparison Project Phase 5 archive (CMIP5) outputs (Taylor et al., 2011).

Possible future changes in the precipitation and temperature extremes can be predicted by global circulation models (GCMs) (Gebre et al., 2015). On the Central Rift Valley, GCM simulations for daily data was collected from the Climate Model Intercomparison Project Phase 5 archive (CMIP5) (Taylor et al., 2011). These downscaled data provide a basis of Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). Representative concentration pathways (RCP) have been also introduced in the CMIP5 ensemble data, which are more comprehensive than Special Report on Emission Scenarios (SRES).

Lake Ziway catchment covering a total area of about 6991 km^2 contains Lake and River systems, where two Rivers namely Katar and Meki flowing towards Lake Ziway and one outflow River Bulbula flow towards Lake Abiyata. The flow scheme in the region passes through a densely populated area where water use for commercial farming, fishing and recreation by state and private sectors is gigantic. The outflow of Lake Ziway is an important source of the downstream terminal Lake Abiyata, whose quantity and quality is controlled by the outflow from Lake Ziway (Seyoum et al., 2015). Evaluation of climate change impacts on regional hydrology would greatly benefit policy makers and other stakeholders for better preparedness in the region. In this study, we used bias corrected climate model output of CMIP5 ensembles (HadGEM2-ES, CSIRO-MK-3-6-0 and CCSM4) for simulation of river flows for impact evaluation. Soil and Water Assessment Tool (SWAT) (Arnold et al., 1998; Neitsch et al., 2011) was tested over Lake Ziway catchment to generate future inflows under RCP 4.5 and RCP 8.5 scenarios for Katar and Meki Rivers respectively, using sequential uncertainty fitting algorithm (SUFI-2) (Abbaspour, 2013) and impact analysis was made using metrics that are useful for decision makers.

Materials and Methods

Study Area

Lake Ziway is located between 7°51'N to 8°7'N Latitude and 38°43'E to 38°57'E Longitude. It has an open water area of 434 km^2 with an average depth of 4 m and an elevation of 1636 m.a.s.l. Lake Ziway catchment falls in between 7°15'N to 8°30'N Latitude and 38°E to 39°30'E Longitude covering a total area of about 6991 km^2 (Figure 1).

It starts from the highlands of the Eastern part from which Meki River is originating, passes through the central parts of the East Shoa Zone where the Lake Ziway is located, and ends up in the Western Highlands of the Arsi Zone from which the Katar River is originating.

Climate projection

Horizontally gridded CMIP5 model group outputs were employed to predict the past and the future climatic conditions of the area. Observed precipitation and temperature dataset at monthly time scale from 1980 to 2005 are downloaded from the model group web pages (https://climexp.knmi.nl/select.cgi). Coupled model output data (precipitation and surface air temperature) of a historical run from 1850 to 2005 and two future projection simulations from 2010 to 2099 under two Representative Concentration Pathways were obtained. The RCP4.5 represents a moderate mitigation scenario (van Vurren et al., 2011), while RCP8.5 represents the higher stabilization pathway, where wider range of radiative forcing across the RCP extensions are provided (Moss et al., 2010). Hence RCPs are required for planning the adaptation and mitigation option for the response of river flow by changing climate.

Outputs of coupled climate models, three GCMs were employed over Lake Ziway catchment, as shown in Table 1. The selection of the GCM model was based on how well models represent the past and the present climate, their resolution and other studies related to the impact of climate change on the Ethiopian Rift Valley and adjacent plateau. HadGEM2-ES, CSIRO-MK-3-6-0 and CCSM4 models are recognized as being capable of reproducing the precipitation and temperature pattern on the Ethiopian Rift (Asaminew et al., 2017; Negash et al., 2013; Jury, 2015).

The daily precipitation, Tmax and Tmin from 1980 to 2099, was extracted from grid cells covering Lake Ziway Catchment. The period from 1980 to 2005 was defined as the baseline period. While the future periods that are covered by this study are 2010–2040, 2041–2070, and 2071–2099 (denoted by the 2020s, 2050s, and 2080s, respectively) relative to the baseline period (1980–2005). Future climate time series were constructed using the delta change method (Fowler et al., 2007; Biniyam, 2017) which involves observed climate time series by mean changes (differences or ratios of changes) simulated with GCMs. The changes were determined as monthly temperature changes (in °C) and monthly precipitation changes (in %) from the base period (1980-2005) values.

CMIP5 GCM models were selected based on how well models represent the past and the present climate. In this regard bias correction of precipitation data has employed a nonlinear method which corrects coefficient of variation (CV) and the mean (Kahsay et al., 2018) Eqn. (1) while temperature correction is done by calculating monthly systematic biases (Biniyam, 2017; Negash et al., 2013) Eqn. (2).

$$P^{*} = aP^{b} \tag{1}$$

Where P* is the simulated data in the projection period, where 'a' and 'b' are the parameters obtained from calibration in the baseline period and subsequently applied to the projection period. They are determined by matching the mean and coefficient of variation (CV) of simulated data with that of observed data.

$$Tc = Tom + \frac{\partial o}{\partial r} * (Tr - Trm) \tag{2}$$

Where;

Tc is bias corrected future temperature, Tom is mean of observed temperature in base period, Trm is mean of RCPs temperature in base period and Tr is RCPs temperature of base period δ_r, and δ_o, represent the standard deviation of the daily RCPs output and observations in the reference period respectively.

SWAT model

SWAT model is a physically based distributed model designed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soil, land-use, and management conditions over long periods of time (Neitsch et al., 2011). SWAT divides the catchment into a number of sub watersheds or sub-basins. Sub-basins are further partitioned into hydrological response units (HRUs) based on soil types, land-use types, and slope classes that allow a high level of spatial detail simulation, where HRUs consist of unique combinations of homogenous soil and land use properties in each sub-basin (Arnold et al., 2012). The model predicts the hydrology at each HRU using the water balance Eqn.

(3).

$$SWt = SWo + \sum_{i=1}^{t}(Rday - Qsurf - Ea - Wseep - Qgw) \quad (3)$$

where SWt is the final soil water content (mm H2O), SWo is the initial soil water content on day i (mm H_2O), t is the time (days), Rday is the amount of precipitation on day i (mm H_2O), Qsurf is the amount of surface runoff on day i (mm H_2O), Ea is the amount of evapotranspiration on day i (mm H_2O), *W*seep is the amount of water entering the vadose zone from the soil profile on day i (mm H_2O), and Qgw is the amount water return flow on day i (mm H_2O).

A detail description of the different model components can be found in the SWAT Theoretical Documentation (Neitsch et al., 2011). The input data required for SWAT include weather data (1993-2013), a land-use map, a soil map, a Digital Elevation Map (DEM) (Table 2). Discharge data are also required for calibration of streamflow. Monthly flow data (1993-2007) measured at the Katar river, and Meki were used for the calibration of streamflow. This data was obtained from the Hydrology Department of the Ministry of Irrigation Water and Energy of Ethiopia (MoIWE).

SWAT-CUP model

The SWAT-CUP tool (SWAT Calibration and Uncertainty Procedures) is a program that interfaces with ArcSWAT, to perform calibration, validation and sensitivity analysis of the SWAT model. The execution of the SWAT-CUP model involves the use of output files generated by SWAT model in ArcSWAT (Abbaspour, 2011). From the five different algorithms associated to SWAT, the SUFI-2 strategy is applied in this research since it can supply the widest marginal parameter uncertainty intervals of model parameters. The goodness of fit in SUFI-2 is quantified by the coefficient of linear correlation (R^2), the coefficient of Nash-Sutcliffe efficiency (NSE) and the coefficient of Percent bias (PBIAS) between the observed data and the best simulation. The formulas of these coefficients are given in the following equations:

$$R^2 = \frac{(\sum[Qsi - Qsi_{av}][Qob - Qob_{av}])^2}{\sum[Qsi - Qsi_{av}]^2 \sum[Qob - Qob_{av}]^2} \quad (4)$$

$$NSE = 1 - \frac{\sum(Qob - Qsi)^2}{\sum(Qob - Qob_{av})^2} \quad (5)$$

$$PBIAS = \frac{\sum_{i=1}^{n} Yi^{obs} - Yi^{sim})*100}{\sum_{i=1}^{n}(Yi^{obs})} \quad (6)$$

NSE is a normalized dimensionless statistic that implement the comparative size of the residual distinction compared to the measured data variance- (Nash & Sutcliffe, 1970). It shows how well the plot of observed versus simulated data fits the 1:1 line. PBIAS measures the average tendency of the simulated data to be larger or smaller than their observed counterparts (Gupta et al., 1999). It is the perversion of information being evaluated, expressed as a percentage. In addition, Yi obs is the i^{th} observation for the constituent being evaluated, Yi sim is the i^{th} simulated value for the constituent being evaluated, Ymean is the mean of observed data for the constituent being evaluated, and n is the total number of observations.

Basin delineation and HRU definition

The Lake Ziway watershed was delineated with an outlet point at the downstream sites of the Katar and Meki rivers. The overall watershed was further broken down into sub-basins based on the Algorithms provided by the SWAT model. With this information the model automatically delineates the Katar river basin area of 3241.6 km^2 in to 13 sub basins in this study and Meki river basin in to 2033 km^2 in to 9 sub basins. The Katar river basin results in 75 HRUs and Meki river basin results in 73 HRUs in the basin.

Results and Discussions

Analysis of Monthly and Seasonal Future Climate on Lake Ziway Catchment

For this study, monthly and seasonal analysis was taken for Ethiopian local season of Belg (March, April and May), Kiremt (June, July, August and September) and Bega (October, November, December, January and February) over Lake Ziway Catchment.

Maximum Temperature

There is a general increasing trend for maximum temperature from baseline period under RCP 4.5 and RCP 8.5 except for the months of March and September in all time periods under RCP 4.5 for HadGEM2-ES and CSIRO-MK 3-6-0 model. The maximum amount of average annual temperature is projected from HadGEM2-ES model under RCP 8.5 during 2080s and the minimum average annual temperature is projected from CSIRO-MK 3-6-0 model under RCP 4.5 during 2020s. The same trend has been also reported on the projected average annual temperature by (Belay et al., 2012; Monireh et al., 2013) where, increased extreme daily temperature events prevailed for future scenarios (Negash et al., 2013). Maximum amount of temperature change from RCP 8.5 is due to the fact that RCP 8.5 produces more greenhouse gas as compared to RCP 4.5, which is medium in greenhouse gas production (Riahi et al., 2011).

Minimum Temperature

For minimum temperature, there is a general increasing trend from baseline period under RCP 4.5 for the three models except on March for HadGEM2-ES, October on CSIRO-MK 3-6-0 and July CCSM4.

Precipitation

The overall result revealed that, percentage change in monthly average precipitation might range between -51.19% during January 2050s and +23.15% during February 2080s under RCP8.5 for HadGEM2-ES model (Figure 2). However, for RCP4.5 precipitations is projected to increase in amount by 2.69% on 2020s and decrease by 2.7%, and 1.6% during 2050s and 2080s, respectively which is having similar projection by (Monireh et al., 2013). However, seasonally maximum precipitation reduction is projected during the Ethiopian local rainy season of 'Kiremt' in all the model outputs. Furthermore, inter-annual and intra-seasonal rainfall variability in the Central Rift Valley is accompanied by a significant warming trend in temperature and reduction of rainfall can add stress to crop growth during this season. The occurrence of warming across Ethiopia is reported (Conway, 2000) and decline in precipitation up to 25% is also shown by (Monireh et al., 2013).

Hydrological Model Calibration and Validation Results

Sensitivity analysis

SWAT sensitivity analysis for lake Ziway Watershed indicates for flow calibration, about 11 parameters was reported as sensitive in different degree of sensitivity. Among these 11 parameters, only 9 & 8 of them have effect on the simulated result when changed on Katar river and Meki rivers respectively. So, on category specified by sensitivity classes, the parameters changed for flow calibration were those of from very high to small sensitivity class for both watersheds based on lower p-value and higher t-stat value are ranked Table 3.

Model calibration and validation

Model Calibration

The model calibration was done from (January, 1993-December, 2001) for Katar as well as Meki independently. Calibration resulted after simulation from (January, 1994-December, 2001) found a coefficient of determination (R^2) of 0.71 & 0.73 and Nash–Sutcliffe efficiency (NSE) of 0.64 & 0.7, for Katar and Meki respectively showing a good agreement between measured and simulated monthly flows. The calibration result demonstrates SWAT's ability to predict realistic flow for both catchments Figure 3 and Figure 4.

Model Validation

Like Model calibration, the model performance evaluation parameters were calculated and checked weather the model perform very well or not and within this the monthly stream flow of (R^2= 0.79 and NSE= 0.65) for Katar river and (R^2= 0.8 and NSE= 0.74) for Meki river.

Impact on Seasonal and Annual Flow of Katar River

For the HadGEM2-ES model maximum flow reduction was observed during the rainy season 'Kiremt' on average. It shows reduction of 10.78%, 17.58% and 19.23% for the periods of 2020s, 2050s and 2080s respectively under RCP 8.5 Figure 5. Generally, flow reduction from this model corresponds with the reduction in precipitation on the same season. CSIRO-MK 3-6-0 model has also shown maximum flow reduction during the rainy season 'Kiremt' on average basis. Generally, flow reduction from the model groups is also shown by previous study on the neighboring Awash River Basin ranging between 10% to 34% using different GCM outputs (Hailemariam, 1999). Annually, flow shows reduction for both scenarios has complied with the precipitation reduction. Therefore, the River flow is found to be very sensitive to variations in precipitation than temperature changes. The study done in the rift floor (Mechal, 2015) indicated that under high or low warming trends a very slight proportional change in evapotranspiration resulted in high relative change in ground water recharge and surface runoff. Also decrease in ground water recharge is reported on the northern part of Ethiopia on Tekeze river basin under future scenarios of RCP2.6 and RCP4.5 (Kahsay et al., 2018). This result shows the maximum flow reduction during rainy season of Kiremt that comply with previous study on the area (Zeray, 2007).

Impact on Seasonal and Annual Flow of Meki River

Flow reduction on Meki River was observed during 'Belg' season across all the model groups. Maximum flow reduction reaches 40.27% for the periods of 2050s under RCP 8.5 for the HadGEM2-ES model. A slight flow increment is observed during the local dry season of 'Bega' on HadGEM2-ES model for both concentration pathways Figure 6. Other slight increment is also predicted during the 2080s from CCSM4 model output under RCP 4.5 scenario during Belg and Kiremt which represents a range of technologies and strategies for reducing GHG until 2100 (van Verrun et al., 2011).

Flow reduction from this model furthermore has correspond with the reduction in precipitation on the same season. Annually maximum reduction is projected from model by 20.28% during 2080s from HadGEM2-ES model under RCP 8.5. On the other hand, CCSM4 model has shown minimum flow reduction by 1.1% during 2080s under RCP 4.5 Figure 6.

Seasonal change in flow volume from Katar and Meki rivers will have implication on the socio-economic conditions with respect to reduction for irrigation potential, Lake level (Seyoum et al., 2015) and on out flow river. Increased Bega stream flow for indicated periods and scenarios is desirable to exploit the irrigation potential of the sub-basins thereby improving the irrigated agricultural production in the area. Kiremt flow volume might show highest decrease for Katar River and Belg seasons show the highest reduction from Meki River for both scenarios, which will greatly affect Lake Ziway level. This effect has also been indicated by (Zeray, 2007; Alemayehu, 2006) drop on lake level that may rich up to two third of a meter, surface area might also shrink by 25.3 km^2, which is about 6% of the base period lake surface area.

On Central Rift Valley (CRV) human impacts contributed to the changes in the hydrology of Lake Ziway and Lake Abiyata causing a decrease in lake storage and prolonged dry periods (Seyoum, 2015). This shows a worsening trend of the recent lake level fluctuation and aerial coverage contraction. This combined with the unbalanced supply-demand equation in the watershed is expected to have significant impact on the lake water balance.

Other clear indicator is the fate of Bulbula River flowing out of Lake Ziway, recently its flow is observed to be intermittent and number of state and private farms that were operating on it were closed up. Hence, it is imaginable to predict its complete existence on future for indicated inflow scenarios. The increasing water abstraction for industrial and agricultural activities (Seyoum, 2015) due to economic development and population growth (Legesse, et al., 2010) is also likely to further reduce seasonal flows (Hailemariam, 1999) and downstream Lake Abiyata surface area (Seyoum, 2015). Furthermore, (IPCC, 2014) reported climate change over the 21st century is projected to reduce renewable surface water and groundwater resources in driest subtropical regions, intensifying competition for water among sectors. As this region is largely occupied by rural settlers they are expected to experience major impacts on water availability and supply, food security, infrastructure and agricultural incomes, including shifts in the production areas of food and non-food crops around the world (IPCC, 2014). Therefore, in Lake Ziway catchment, runoff is likely to decrease in the future and insufficient to meet future demands for water of the ever-increasing population in the region. Therefore, the region requires integrated basin-wide water management practice (Alemayehu, 2006).

Conclusions

CMIP5 model outputs from IPCC 5th assessment report has been used to assess the response of Katar and Meki River and their implication to Lake Ziway that was projected by using three GCMs and a semi distributed hydrologic model (SWAT). Projection of the three GCMs HadGEM2-ES, CSIRO-MK 3-6-0 and CCSM4 pointed out that temperature will increase and precipitation reduced for future periods denoted by 2020s, 2050s and 2080s.

The SWAT model output showed that HadGEM2-ES, CSIRO-MK 3-6-0 and CCSM4 models showed flow reduction during the rainy season ‘Kiremt’ on extreme case under RCP 8.5 on Katar River. CCSM4 model has shown maximum flow reduction by 25.75% during 2080s under RCP 4.5 which is the extreme as compared with the above model groups. On Meki River seasonally flow reduction was observed during ‘Belg’ across all the model groups. Maximum flow reduction reaches 40.27% for the periods of 2050s under RCP 8.5 for the HadGEM2-ES model. A slight flow increment is observed during the local dry season of ‘Bega’ on HadGEM2-ES and CCSM4 model.

Despite uncertainties on GCM and hydrological models, the result suggest early decrease in water use from different water use sectors in Lake Ziway Catchment as the best water resource management strategy. Furthermore, the integrated watershed development in Lake Ziway Catchment should be considered, to reduce the adverse impact of climate change particularly during local rainy season on rain fall dependent agriculture. Therefore, projected scenarios on River flow and climate change would significantly affects the livelihood of farmers and water using sectors in the area. Thus, concern for climate change and water management strategies should have to be given priority to mitigate the impacts. Furthermore, this study need to be extended to see the role of other climate model groups and use of new assessment reports, and further investigations on impact of other water sources like groundwater has to be done to fill the gap.

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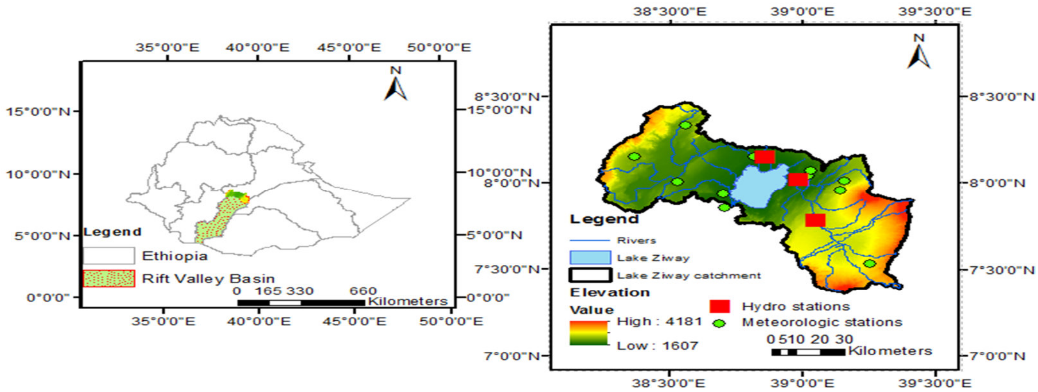

Figure 1: The study area showing the rift valley basin, lake Ziway, lake Ziway catchment with hydro meteorological gauging locations and rivers.

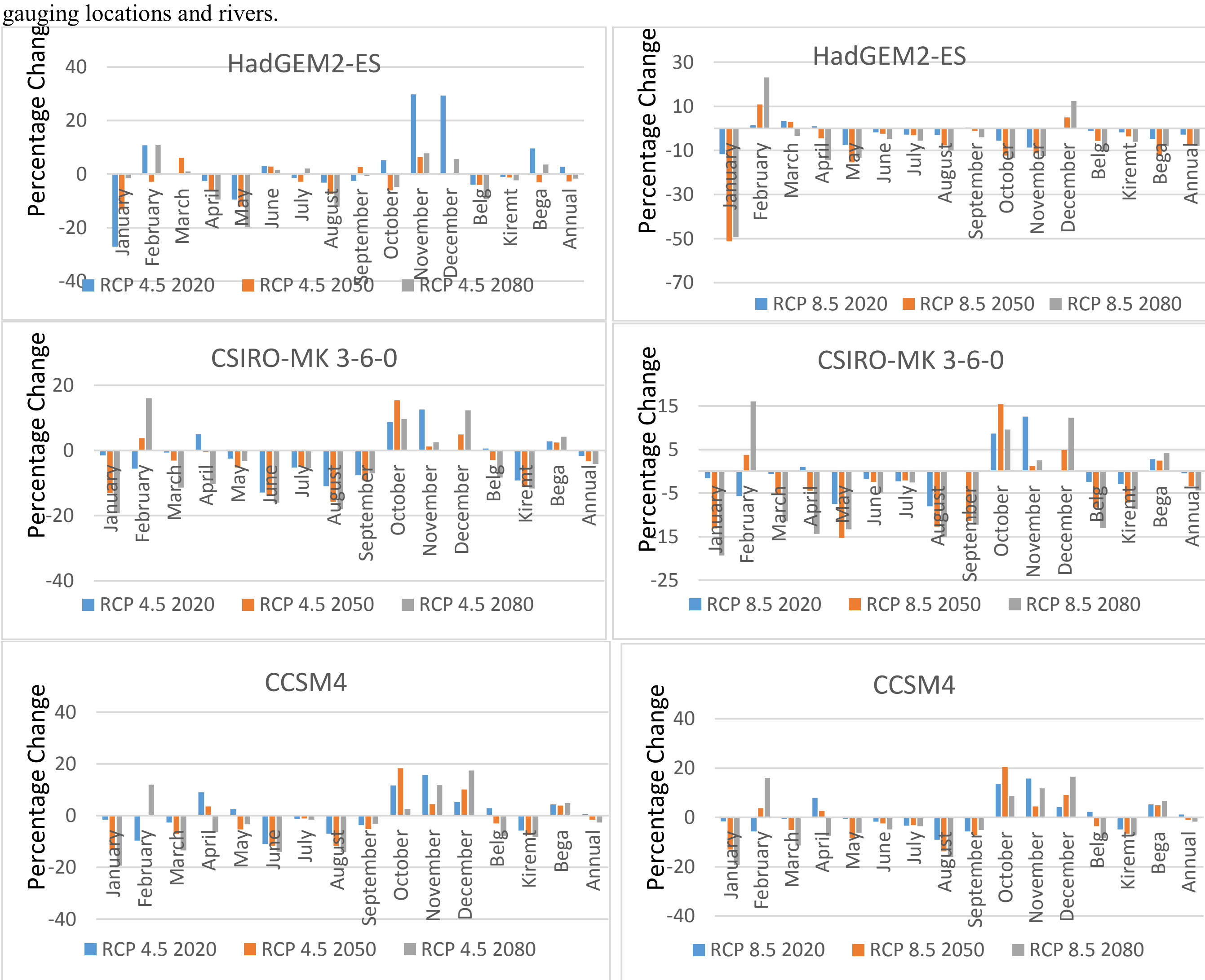

Figure 2: Percentage change in mean monthly and seasonal precipitation at different time horizon under RCP 4.5 and RCP 8.5 for the future period (2010-2099).

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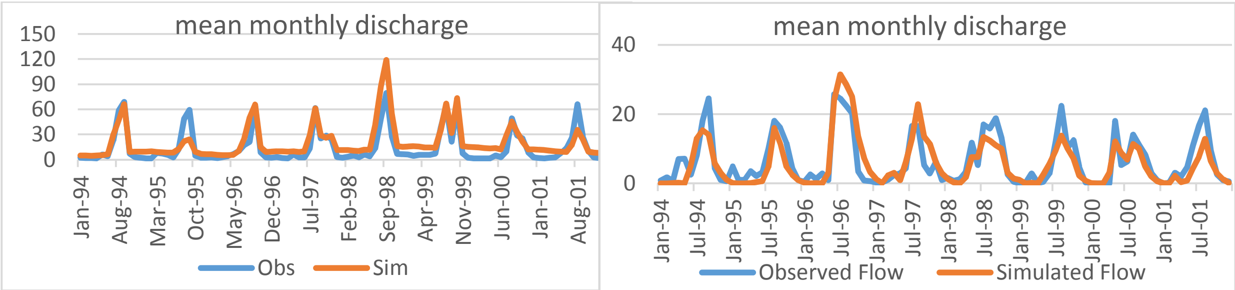

Figure 3: Monthly simulated and measured streamflow on calibration period (1994 – 2001) for Katar (left) and Meki (right) Sub-basin

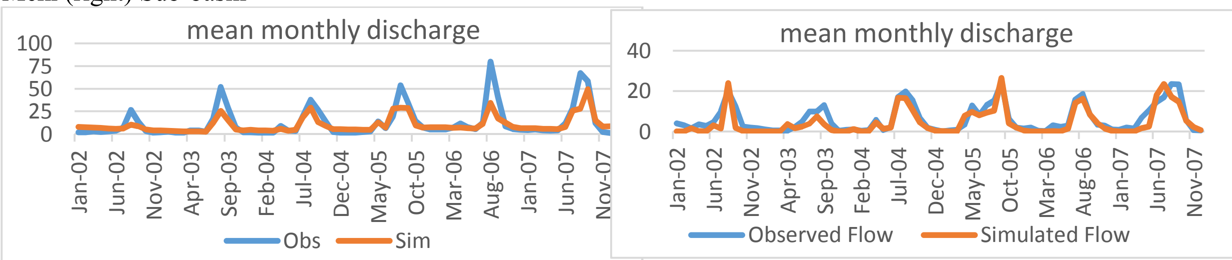

Figure 4: Simulated and measured monthly streamflow on during the validation period for Katar (left)Meki (right) Gauging Station (2002-2007)

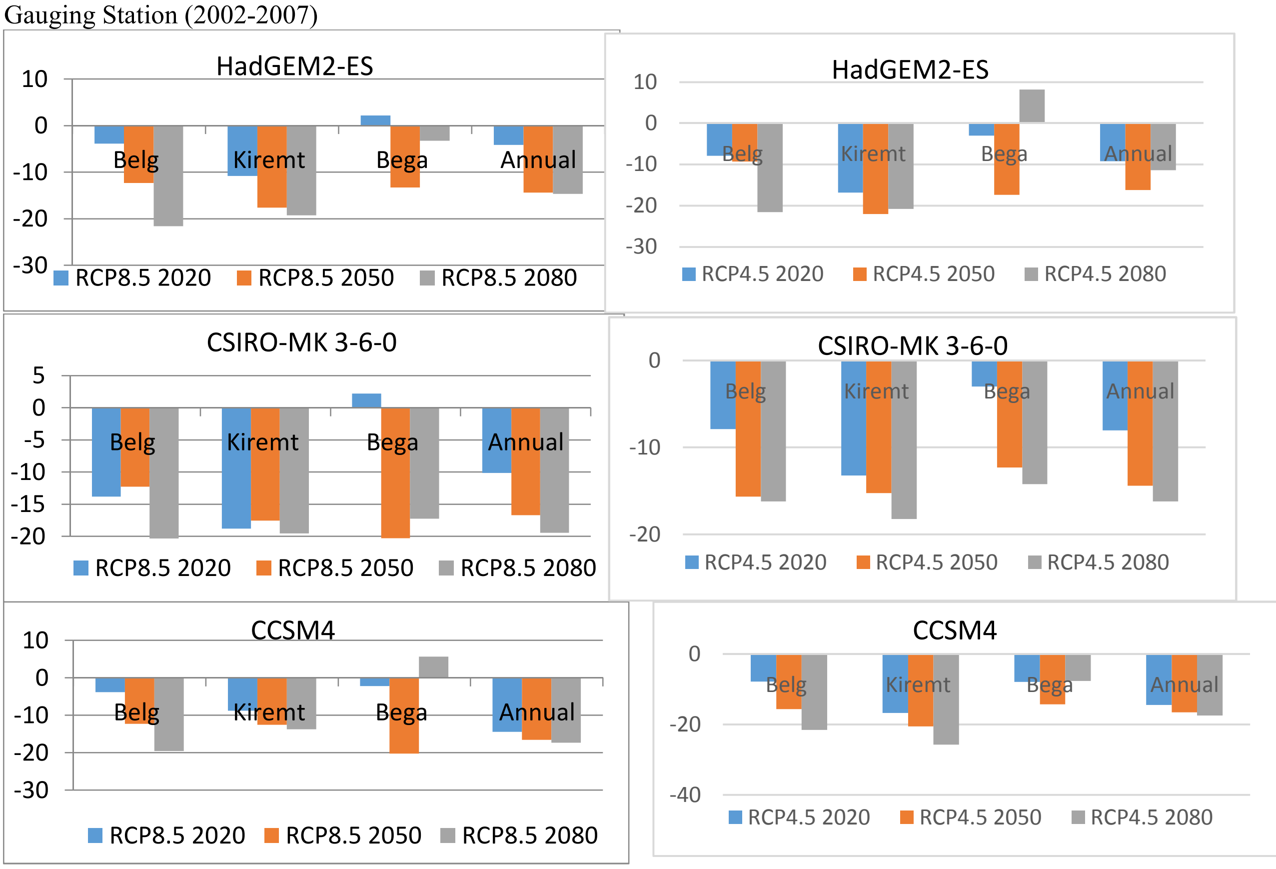

Figure 5: Percentage change in seasonal and annual inflow at Katar River with respect to baseline period for the HadGEM2-ES, CSIRO-MK 3-6-0 and CCSM4 model.

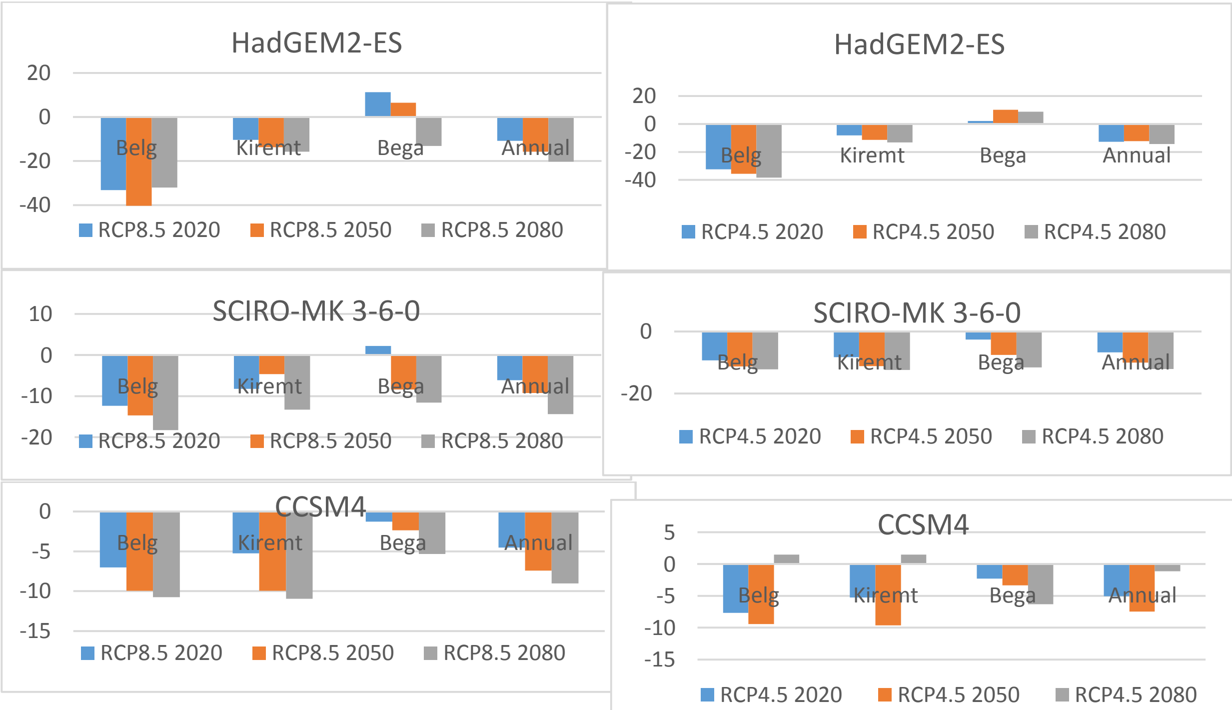

Figure 6: Percentage change in seasonal and annual inflow at Meki River with respect to baseline period for the HadGEM2-ES, CSIRO-MK 3-6-0 and CCSM4 model.

Table 1: Description of the climate models used in this study.

Model name	**Model center**	**Atmospheric Resolution (Longitude * Latitude)**
HadGEM2-ES	Hadley Centre for Climate Prediction and Research, Met Office, United Kingdom	1.875° * 1.25°
CCSM4	National Center for Atmospheric Research	1.25° * 0.9°
CSIRO-MK-3-6-0	Commonwealth Scientific and Industrial Research Organization, Australia	1.9° * 1.9°

Table 2: Data sources used in the initial setup of the SWAT model for the Lake Ziway Catchment.

Data type	**Data description**	**Scale**	**Data sources**
Topography	Elevation	20 m	Aster GDEM
Land-use	Land-use classification such as agricultural land, forest, and urban	1 km	MoIWE
Soil	Soil types and physical properties	10 km	FAO
Meteorology	Daily precipitation, minimum and maximum temperature, relative humidity, radiation	Daily	NMSA

Table 3: Calibrated parameters of flow and their fitted values and rank for Katar and Meki river

		Katar River				Meki River		
Rank	Parameter_Name	Fitted_Value	Min_value	Max_value	Parameter Name	Fitted Value	Min_value	Max_value
1	8:R_SOL_K(..).sol	-0.99998	-1.00014	-0.99981	1:R_SOL_Z(..).sol	-0.6453	-0.6454	-0.6452
2	2:V_ALPHA_BF.gw	0.037093	0.035176	0.038984	6:R_CN2.mgt	-0.2437	-0.2835	-0.2322
3	9:V_SFTMP.bsn	-0.65711	-0.75149	-0.49173	5:R_ESCO.bsn	0.32996	0.32986	0.32997
4	1:R_CN2.mgt	-0.16251	-0.16425	-0.16191	7:V_ALPHA_BF.gw	0.03857	0.03692	0.0408
5	11:R_OV_N.hru	-0.26289	-0.26547	-0.26176	8:V_GWQMN.gw	130.614	130.613	130.616
6	3:V_GW_DELAY.gw	308.4943	308.3842	309.2767	2:R_REVAPMN.gw	292.689	290.581	292.743
7	4:V_GWQMN.gw	821.1171	817.2775	823.3721	4:R_SOL_AWC (..).sol	-0.2116	-0.2117	-0.2116
8	7:R_SOL_AWC(..).sol	0.31291	0.312876	0.314902	3:R_BIOMIX.mgt	0.53562	0.5356	0.53563
9	6:V_ALPHA_BNK.rte	-0.00982	-0.01151	0.02219				
10	10:R_HRU_SLP.hru	0.150725	0.148563	0.151471				
11	5:V_ESCO.hru	0.043773	0.039845	0.044991				

Biography

My name is Tesfalem Abraham. I was born in 1990 in Hawassa town, Ethiopia. I have achieved my Bsc degree and Msc degree from Hawassa University. I have specialized in water resource engineering and management.

Tesfalem Abraham from Hawassa University is expert in climate modeling and hydrology. Recent Occupational field is Instructor at Hawassa University, Institute of Technology School of Biosystems and Environmental Engineering. I have relevant Research experience on Climate Change and Hydrology modeling. Furthermore, I conducted regional watershed management on Impact assessment of Land Use Land Cover Change on Hydrology Using SWAT Model on Lake Hawassa watershed in Hawassa University and government institutions. I also conducted some services on assessing the carbon stock potentials, land degradation processes and Prioritization in Lake Hawassa Watershed, Ethiopia. The out puts from the projects has been well accepted regional for the desired climate resilient environmental management programs in the country.