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RESEARCH ARTICLE

TRENDS OF HYDRO-METEOROLOGICAL DATA AND IMPACT OF CLIMATE CHANGE ON THE STREAMFLOW OF GILGEL GIBE 1 RIVER BASIN-ETHIOPIA

***[1]Tamene Adugna Demissie, [2]Fokke Saathoff, [3]Yilma Seleshi and [4]Gebissa, A.**

[1]Jimma University, Jimma Institute of Technology, Jimma, Ethiopia, P.O.Box 378
[2,3]Rostock University, Rostock, Germany
[4]Addis Ababa University, Addis Ababa Institute of Technology, Addis Ababa, Ethiopia

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ABSTRACT

The characteristics of hydro-meteorological changes in the Gilgel Gibe River Basin were analyzed based on the recorded data collected for a period greater than 25 years at 5 weather stations for rainfall, 3 stations for maximum and minimum temperature and 2 hydrological stations for streamflow. A non parametric trend test for monthly data shows an increasing trend for rainfall and temperature. The monthly streamflow recorded at 2 gauging stations has also indicated an increasing trend. The impact of climate change on the streamflow for the future period of the 2011 – 2040 was also assessed by using the Soil and Water Assessment Tool (SWAT) hydrological model using downscaled precipitation and temperature data obtained from ECHAM5 and HadCM3 model projections. The increase in streamflow of the past records can be partly explained by the climate change. The impact of climate change in the future period of 2011 – 2040 will slightly increase the streamflow of Gilgel Gibe 1 River.

INTRODUCTION

A time series analysis of hydro-meteorological data provides evidence that suggests climatic change. Evidence of climate change might therefore appear as positive or negative trends in natural time series (Khan, 2001)**.** Streamflow time series almost always exhibit seasonality owing to the seasonality of rainfall and other weather variables such as temperature in Ethiopia. For observed data that exhibit high seasonality, methods to analyze trends should be those that incorporate the seasonal component. In this study, the hydro-meteorological changes in space and time that have taken place in the study area is examined and their significance is also checked. In addition, the impact of climate change on the streamflow in the future period of 2011 – 2040 here after represented as 2020s will also be investigated. The climate change impacts on the streamflow and simulated sediment flux to Gilgel Gibe 1 hydropower reservoir for the future period of the 2050s has been investigated by Demissie *et al*., (2013). The same procedure is used in this study to evaluate the impact of climate change in the 2020s in addition to trend analysis of hydro-meteorological data. According to the IPCC 2007 fourth assessment report, the climate is expected to change mainly by an increase in anthropogenic greenhouse concentrations: global mean surface temperature increases, daily minimum temperatures are projected to increase faster than daily maximum, and the magnitude of mean precipitation generally increases with projected increase in intensity particularly in tropical regions and high latitudes. This change in climate is expected to change the regional hydrological conditions and result in a variety of impacts on water resource systems throughout the world (Zhang *et al*., 2007). Due to climate change the magnitude of streamflow might change, and this might affect the intended purpose water resources projects, which have been designed, based on the historically recorded data. Therefore, the objective of this study was to analyze the trend of the hydro-meteorological data and evaluate the potential impacts of climate change on the streamflow of Gilgel Gibe 1 River. The study result is based on hydrologic modeling under climate change and might provide an insight to planners and decision makers regarding the impact of climate change.The future temperature and precipitation changes projected by ECHAM5 and HadCM3 models under emission scenarios A2 and B1 were used to construct future climate series of the 2020s. The delta change approach was used to develop the future climate series. The calibrated and validated SWAT model by Demissie *et al.* (2013) for the same river basin was used.

Study area description

The Gilgel Gibe 1 project is located in the south-western part of Ethiopia, in Oromia Regional state. The reservoir is located at $7^{o}49`52.45``N$ latitude and $37^{o}19`18.79´´E$ longitude. The project is purely a hydropower scheme, with an installed capacity of 180MW. The reservoir has a live storage capacity of $657x10^{6}m^{3}$. The catchment area of the Gilgel Gibe basin is about $5125km^{2}$ at its confluence with the great Gibe River and about $4225km^{2}$ at the dam site. The Gilgel Gibe basin which drains in to the Gilgel Gibe 1 reservoir is located in between 7^{o} 19´07.15´N and $8^{o}12´09.49´´N$ latitudes and $36^{o}31´42.60´´$ E to $37^{o}25`16.05´´E$ longitudes. The basin is generally characterized by high relief hills and mountains with an average elevation of about 1700m above mean sea level. The basin is largely comprised of cultivated land. In general terms, the Gilgel Gibe basin is characterized by a wet climate with an average annual rainfall of about 1550 mm and an average temperature of $19^{o}C$. The seasonal rainfall distribution takes a uni-modal pattern with its maximum during the summer and minimum during the winter, influenced by the

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**Corresponding author: Tamene Adugna Demissie,* Jimma University, Jimma Institute of Technology, Jimma, Ethiopia, P.O.Box 378.

inter-tropical convergence zone (ITCZ). Figure 1 shows the location map of Gilgel Gibe 1 and cascade hydropower projects.

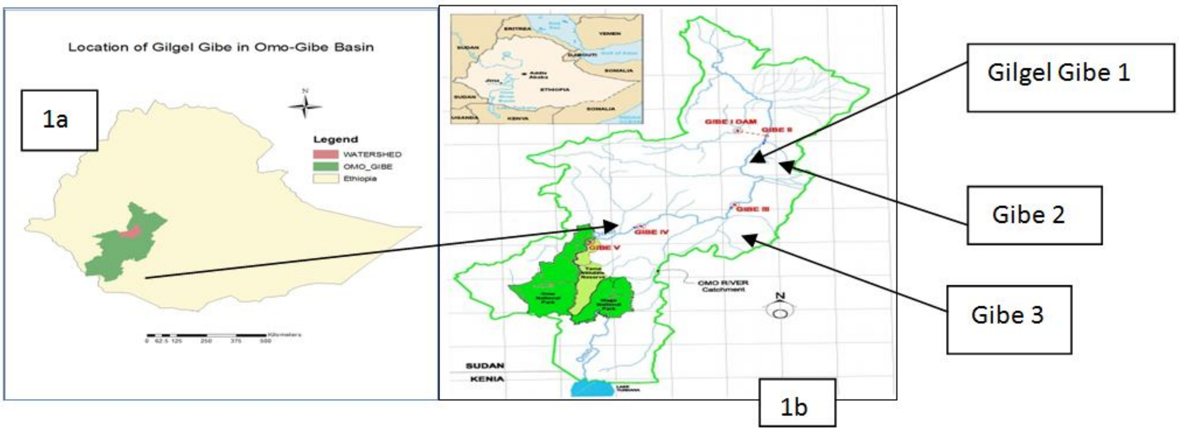

Fig. 1. Location map of Gilgel Gibe basin Source for Fig.1b): http://www.internationalrivers.org/resources/maps-gibe-dam

METHODOLOGY

Trend analysis of hydro-meteorological data

Spatial differences in streamflow trends can occur as a result of spatial differences in the changes in rainfall and temperature, and spatial differences in the catchment characteristics that translate meteorological inputs into hydrological response (Burn and Elnur, 2002). In this study, the river discharge and rainfall in the Gilgel Gibe catchment: two river gauging stations, Near Seka (upstream) and near Asendabo (downstream), five rainfall stations and three temperature stations were analyzed. This analysis seeks to determine if their values generally increase or decrease. The Seasonal Kendall method, a non-parametric test, is used for trend analysis because there are very few underlying assumptions about the structure of the data, making it robust against departures from normality (Helsel and Hirsch, 1992). In addition, the use of ranks rather than actual values makes it insensitive to outliers and missing values. Hirsch *et al.* (1982) suggest that the Seasonal Kendall, a nonparametric test, is preferred to the simple or seasonal regression tests when data are skewed, cyclic and serially correlated. The hydro-meteorological stations used for analysis were based on a long record of data (>25yrs) for validity of the time series and trend analysis results.

The Seasonal Kendall Test

The Seasonal Kendall test (Hirsch *et al.*, 1982) accounts for seasonality by computing the Mann-Kendall test on each of m seasons (in our case, m represents months) separately, and then combining the results. This means that January data are compared only with January, February only with February, etc. No comparisons are made across season boundaries. The Kendall statistic S for each month S_i, is summed over the years to form the overall statistic S_k as Eq.1.

$$S_K = \sum_{i=1}^{m} S_i \qquad \text{m=1… 12} \qquad (1)$$

When using equation (1) a positive value of S_K indicates that there is an upward trend in which the observations increase with time. On the other hand, a negative value S_K means that there is a downward trend. But it is necessary to check whether the trend is significantly different from zero. Considering the variable Y, (in this case rainfall, temperature and streamflow) and time T, S_i is calculated using the Eq.2.

$$Si=Pi-Mi \qquad (2)$$

Where P=the number of times the Y`s increase as T`s increase

M=the number of times the Y´s decrease as the T´s increase

Note that there are n(n-1)/2 possible comparisons to be made among the n data pairs. If all Y values increased along with the T values, S_K = n(n-1)/2. In this situation, the correlation coefficient τ should equal +1. When all y values decrease with increasing T, S_K = -n (n-1)/2 and τ should equal -1. Therefore dividing S by n (n-1)/2 will give a value always falling between -1 and +1. This then is the definition of tau (τ), measuring the strength of the monotonic association between two variables:

Kendall’s tau correlation coefficient

$$\tau = \frac{S_K}{n(n-1)/2} \qquad (3)$$

Where: S_k is kendall overall statstics, τ=tau, n=number of data

In this study, the package “Kendall” in free software R was used to detect trends in the rainfall, temperature and streamflow data.

Climate change scenario and GCM model

The IPCC developed a set of scenarios which can be used in the analysis of possible climate change, assessment of impacts, and adaptation and mitigation. The A1 and B1 story-line and scenario family describes a convergent world with population growth that peaks in the middle of the century and declines thereafter. The A2 and B2 story line and scenario family emphasizes local solutions to economic, social, and environmental sustainability projecting a more differential world. In this study, the A2 and B1 scenarios, which represent high and low GHG emission scenarios (IPCC, 2007), were adopted. GCMs are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations (www.ipcc-data.org/ddc_gcm-html). For this study, the out puts from ECHAM5-OM developed by Max-Planck-Institut for Meteorology Germany and HadCM3 developed by UK Met. Offices were used under the A2 and B1 IPCC emission scenarios. The monthly average values of 2m surface air temperature and total precipitation for baseline period of 1971– 2000 and the future period of 2011 – 2040 were downloaded from the World Data Center for Climate, Hamburg. The spatial resolution of GCMs is too coarse to resolve regional hydro-meteorological processes. Therefore, the raw outputs from GCM simulations are inadequate for assessing hydrologic impacts of climate change at regional scale (Hay *et al.*, 2000). Hence, the GCM data corresponding to the grid box closest to the study area was extracted and linearly interpolated in both longitudinal and latitudinal directions to Jimma station located in the catchment. Then the delta change method was applied to construct future temperature and precipitation series. Delta change method is the difference between the future and the present day estimates (Raghavan *et al.*, 2012). For this study changes are the difference between future climate projections 2011 – 2040 and the 1971 – 2000 baseline current climate simulations. These changes were used to adjust the observed time series of temperature and precipitation. Temperature was modified by the absolute difference between the monthly future and simulated climate, where as precipitation was modified by the relative difference between the monthly future and actual simulated by the GCM. The results of the delta change method are presented in Table 1 and Table 2.

Table 1. Changes in mean monthly temperatures under scenarios A2 and B1, and models ECHAM5, and HadCM3 with respect to their 20th century run (20c3m) 1971 – 2000 baseline

Period	Model	Scenario	Month											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011-2040	ECHAM5	A2	0.49	0.72	0.98	0.89	1.09	1.51	1.3	0.78	0.51	0.7	0.77	0.69
2011-2040	ECHAM5	B1	0.59	0.39	0.45	0.12	0.83	1.05	0.96	0.41	0.48	0.49	0.53	0.71
2011-2040	HadCM3	A2	0.93	0.8	0.78	0.96	0.94	1.09	1.02	0.82	0.86	0.95	0.97	1.07
2011-2040	HadCM3	B1	0.92	0.72	0.67	0.8	0.86	0.87	0.77	0.76	0.75	0.75	0.81	1.26

Table 2. Changes in mean monthly precipitation under scenarios A2 and B1, and models ECHAM5, and HadCM3 with respect to their 20th century run (20c3m) 1971 – 2000 baseline

Period	Model	Scenario	Month											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011-2040	ECHAM5	A2	-35.3	25.1	-28.3	-20.5	-2.5	15	42.3	76.2	50.8	-16.5	-28	18.9
2011-2040	ECHAM5	B1	4.9	81.1	15.7	0	-12	19.9	35.3	63.2	48.7	-3.7	-13.8	19.1
2011-2040	HadCM3	A2	-1.8	3.8	30.5	6.7	-1.6	5.7	-3	10.9	1.1	-0.7	18.6	-3.6
2011-2040	HadCM3	B1	0.6	10.8	18	17.4	1.2	-4	-5.4	6	-6.5	-6.5	-2	28.9

Soil and water assessment tool model

Soil and water assessment tool model description

SWAT is a continuous daily water balance model which was developed to assist water resource managers in assessing the impact of management practices on water, sediment, and agricultural chemical yields in large ungauged basins (Arnold *et al*., 1998). For modeling purposes the catchment is divided into a number of subbasins which will be divided further into hydrological response units (HRU) based on soil type, land use/ land cover and slope classes. The SWAT model has two alternatives for computing surface runoff, and three methods for estimating potential evapotranspiration. For this study the USDA-Natural Resources Conservation Service run off curve number (CN2) method was used to estimate the surface runoff (USDA,1972), and evapotranspiration was estimated using the Penman – Monteith method (Monteith,1965). The SWAT model calculates the surface erosion within each HRU with the Modified Universal Soil Loss Equation (MUSCLE) (Williams, 1975). MUSLE predicts sediment yield as a function of surface runoff volume, peak runoff rate, area, soil erodibility, land cover, land support practices, topography, and percent coarse fragments in top soil layer. Channel sediment routing in SWAT is based on the maximum amount of sediment that can be transported from a reach segment, which is a function of peak channel velocity (Neitsch *et al*., 2011). Sediment routing is dominated by two processes: deposition and degradation. Degradation occurs when sediment concentration is less than maximum amount of sediment that can be transported from a reach segment, whereas deposition occurs when sediment concentration is greater than the maximum amount. The SWAT model is well formulated and considerable detail is provided regarding model structure, algorithms, and data input, and viewing of test results. SWAT version 2009 was used for this study. For detail descriptions of SWAT model refer (Neitsch *et al*., 2011).

SWAT Model set up

The SWAT model requires various spatial datasets and daily weather data for model setup. The spatial data required includes the digital elevation, land use, and soils data. The landcover/landuse and the soil data for the study area were obtained from the Waterbase web site (http://www.waterbase.org/download_data.html) as provided by Dr. Abbaspour of Eawag (http://www.eawg.ch/index_EN). The soil map produced from (FAO, 1995) and provided has almost 5000 soil types at a spatial resolution of 10kms. Some properties for two layers, 0 to 30 cm and 30-100 cm depth are also provided (Leon, 2011). The landcover classes in this area are Dryland Cropland and Pasture (CRDY, 36.7%), Grassland (GRAS, 15.6%), Savanna (SAVA, 14.4%), Evergreen Forest (FOEB, 22.7%), Mixed Forest (FOMI, 9.9%) and Cropland/woodland mosaic (CRWO, 0.7%). The soil types in the area are Nitosols. To delineate the watershed and extract the topographic parameters a 90m digital elevation map (DEM) was obtained from the consortium of spatial information (Jarvis, 2008). Using these spatial data sets and providing three slope classes i.e. 0 – 10%, 10 – 20%, and greater than 20%, 369 HRUs were derived. All the HRUs with landuse of Dryland, Cropland and Pasture were targeted for BMPs application and the impact of climate change was evaluated. The recorded daily weather data required to run the SWAT model were obtained from the National Meteorology Agency (NMA) of Ethiopia. The daily data of rainfall, maximum and minimum temperature, wind speed, Sunshine duration and relative humidity for two stations, namely Jimma and Sekoru were obtained. The data covers a period of 26 years from 1980 to 2005.

Sensitivity analysis, model calibration and performance evaluation

Before calibration, sensitivity analysis was carried out by using one factor-At-a-Time (LH-OAT), an automatic sensitivity analysis tool implemented in SWAT. All the 27 flow- related parameters were taken and the eight most sensitive parameters depicted in Table 3– with their fitted values were selected according to their sensitivity for calibration. Their fitted values are obtained through calibration using Sequential Uncertainty Fitting-2 (SUFI-2) (Abbaspour *et al*., 2007). SUFI-2 algorithm accounts for several sources of uncertainties such as uncertainty in driving variables (e.g., rainfall), conceptual model, parameters, and measured data. The degree to which uncertainties are accounted for is quantified by a *P-factor* which is the percentage of measured data bracketed by the 95% prediction uncertainty (95PPU). The 95PPU is calculated at the 2.5% and 97.5% levels of the cumulative distribution of an output variable obtained through Latin hypercube sampling (Abbaspour *et al*., 2007). Another measure quantifying the strength of a calibration or uncertainty analysis is the R-factor which is the average thickness of the 95PPU band divided by the standard deviation of the measured data. The goosdness of calibration and prediction uncertainty is judged on the basis of the closeness of the *P-factor* to 100% and the *R-factor* to 0.The average thickness of the 95PPU band (P) and the R-factor are calculated by Eq.4 and Eq.5.

$$P = \frac{1}{n}\sum_{l=1}^{n}\left(Q_U - Q_L\right) \qquad (4)$$

$$R - factor = \frac{P}{\sigma_Q} \qquad (5)$$

Where: n is the number of observed data points, Q_U and Q_L are the 97.5th percentiles and 2.5th percentiles of the cumulative distribution of every simulated point respectively. σ_Q is the standard deviation of the measured variable Q. Next to calibration and validation, the model was evaluated to verify its robustness. In this study, the following methods were used (i) Nash – Sutcliffe efficiency (NS), and (ii) correlation between observed and simulated flows. The NS is computed as the ratio of residual variance to measured data variance. The NS is calculated using Eq.6.

$$NS = 1 - \left[\frac{\sum_{i=1}^{n} (Q_i^{obs} - Q_i^{sim})^2}{\sum_{i=1}^{n} (Q_i^{obs} - Q^{mean})^2} \right] \qquad (6)$$

The coefficient of determination R^2 value is an indicator of the strength of the linear relationship between the observed and simulated values. It ranges from 0 to 1, with higher values indicating better agreement. It is calculated using Eq. 7.

$$R^2 = \frac{\left[\sum_{i=1}^{n} (Q_i^{sim} - Q_{mean}^{sim})(Q_i^{obs} - Q_{mean}^{obs}) \right]^2}{\sum_{i=1}^{n} (Q_i^{sim} - Q_{mean}^{sim})^2 \sum_{i=1}^{n} (Q_i^{obs} - Q_{mean}^{obs})^2} \qquad (7)$$

RESULTS AND DISCUSSION

Trend analysis of rainfall, temperature and streamflow

The daily rainfall data for the period 1980-2007 was aggregated into monthly totals for Jimma and Sekoru stations and the available data for the period 1980-2005 have been used for Asendabo, Meteso and Limmu Stations and were analyzed for trend. The average monthly temperature data analyzed was of a period 1970 – 2005 for Jimma station and 1980 – 2005 for Asendabo and Sekoru stations. The results for monthly rainfall are presented in Table 4.

Table 4. Trends test for a monthly rainfall using the Seasonal Mann Kendall Method

Station	Score	Var (score)	Denominator	Tau	2 side p value
Jimma	196	30737.3	4532.9	0.043	0.26
Sekoru	-235	30692.3	4520.4	-0.052	0.18
Limmu	103	24675.7	3891.5	0.027	0.51
Asendabo	409	24678.3	3892.5	0.105	0.01
Meteso	-399	24699.0	3899.5	-0.102	0.01

Trend analysis was carried out on monthly rainfall. Out of the 5 stations, one station namely Asendabo has shown an increasing trend, positive score and Tau as shown Table 4 at 5% significance level, i.e. 2 side p value of less than 0.05, while Meteso station has shown a decreasing trend. The other stations, Jimma, Sekoru and Limmu did not show any significant trend at 5% significance level. Jimma and Limmu exhibit a slight increase in trend whereas Sekoru shows a decrease in trend. This finding which is based on few rainfall station records is in agreement with other studies conducted at the national level. For instance (McSweeney *et al*., 2007) stated that there is no a statistically significant trend in observed mean rainfall in any season in Ethiopia between 1960 and 2006. Similarly (Cheung *et al*., 2008) concluded in their study that, in the national and watershed-level analysis, neither the watersheds nor the nation was found to be experiencing any significant changes in annual rainfall for the time period covered by their study. In addition they have shown that Meteso station has been one of the station experienced a significant decline in annual rainfall. The same procedure applied for rainfall was used to determine the trend of temperature and streamflow data. Trend analysis of temperature data has indicated an increase for both maximum and minimum temperature at Jimma station, while both maximum and minimum temperature has shown a decreasing trend at Sekoru station. The minimum temperature at Asendabo station has indicated an increasing trend whereas the maximum temperature a decreasing trend. The streamflow data was analyzed for the period of 1980 – 2005 both for gauging station near Asendabo (downstream) and near Seka (upstream). Both stations show a positive slope at the 5 % significance level. This could be in part be explained by the slight increase in rainfall over the catchment. In addition, the increase in recorded temperature experienced in the catchment could not significantly reduce the surface water due to evaporation. Other activities, such as river water abstractions/diversions for agricultural purposes, that could cause reduced streamflow amounts is not so significant. The changes in streamflow records might be greatly as a result of changes in land cover/ land use in addition to the annual and seasonal distribution of rainfall. However, land cover/land use change impact is not considered in this study.

SWAT model calibration and performance evaluation

As stated in section 3.3.3 the model was calibrated and validated for monthly streamflow. The SUFI-2 calibration resulted in the P-factor and R-factor of 0.61 and 0.56 respectively. For measuring the goodness of fit, the NS of 0.707 and R^2 of 0.775 were obtained for calibration and the NS of 0.707 and R^2 of 0.767 for validation. Figures 2 and 3 shows the calibration and validation graphs respectively and Table 3 show sensitive parameters and fitted values by SUFI2. The simulation results were considered to be good if NS ≥ 0.75, and satisfactory if $0.36 \leq NS \leq 0.75$ (Van Liew and Garbrecht, 2003). The coefficient of determination R^2 value indicates the strength of linear relationship between simulated and observed value and it ranges from 0 to 1. The higher value of R^2 indicates a better agreement. As shown in Figure 2, the simulated monthly flow closely matched the observed values for the calibration period. For the validation period, the rising limb of the hydrograph and the peak discharge is simulated well and is an acceptable value.

Table 3. Parameters and fitted values

No	Sensitive parameter	Parameter description	Lower and upper bound	Fitted value
1	*m-CN2	Curve number	-0.2 to 0.2	-0.19
2	**v-Alpha_Bf	Baseflow alpha factor	0 to 1.0	0.824
3	v-GW_Delay	Ground water delay time	30 to 450	55.41
4	v-GW_Revap	Ground water revap coefficient	0 to 0.2	0.19
5	v-Gwqmn	Threshold water depth in shallow aquifer	0 to 2	0.875
6	v-Esco	Soil evaporation compensation factor	0.8 to 1	0.913
7	m-Sol_Awc	Available water capacity	-0.2 to 0.4	0.389
8	v-Canmx	Maximum canopy storage	0 to 100	76.25

Impact of climate change on streamflow

Figure 4 shows the change in mean monthly discharge with respect to control period of 1981 – 2000 of SWAT model simulation results due to climate change inputs of the ECHAM5 model and HadCM3 model under A2 and B1 scenarios. The SWAT model simulation for observed data of 1981 – 2000 is used as a control period for assessing the climate change impact. The SWAT simulation results for ECHAM5 model indicate that for the future period of 2020s under A2 scenarios, the monthly discharge is predicted to increase during April – September while it increases during February – September under B1 scenario. Under both scenarios, the highest increase is in August, with percentage increase of 3.9% and 3.6% for A2 and B1 scenarios respectively. For the remaining months, October – March under A2 and October – January under B1 scenario, the predicted discharge decreases, with the maximum percentage decrease of 6.5% and 4.0 % for A2 and B1 scenarios. For the future period of 2020s, the HadCM3 models under scenarios A2 predicts the increase in monthly discharge during May – September and it increases during April – September under B1 scenario. The maximum increase is predicted to take place in June under both scenarios with a maximum percentage value of 6.4 % for A2 and 8.0 % for B1. For the rest of the months, October – April under A2 scenario, and October – March under B1 scenario, the discharge is predicted to decrease. The maximum decrease is in December under A2 scenario with percentage value of 6.1, while the highest decrease is in January under B1 scenario with percentage value of 6.4.

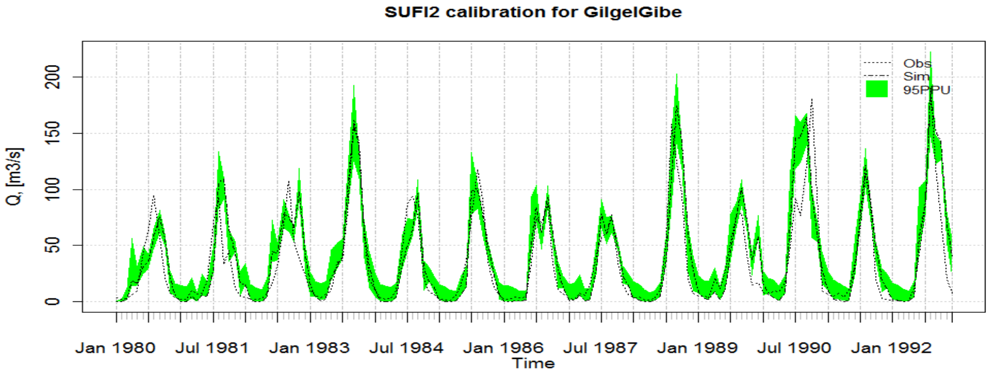

Fig.2. Monthly discharge calibration

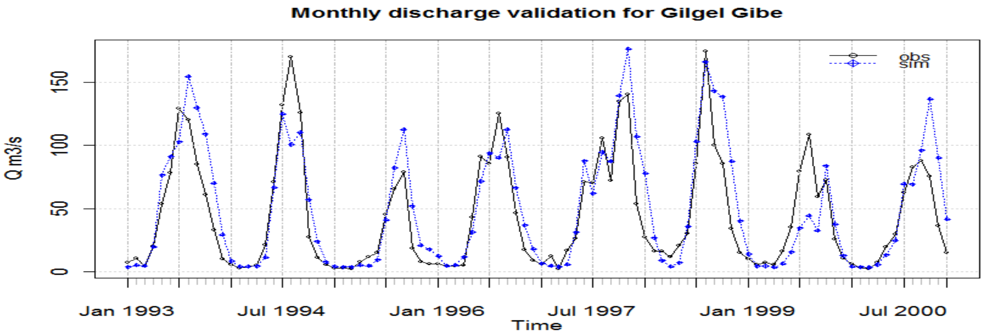

Fig. 3. Monthly discharge validation

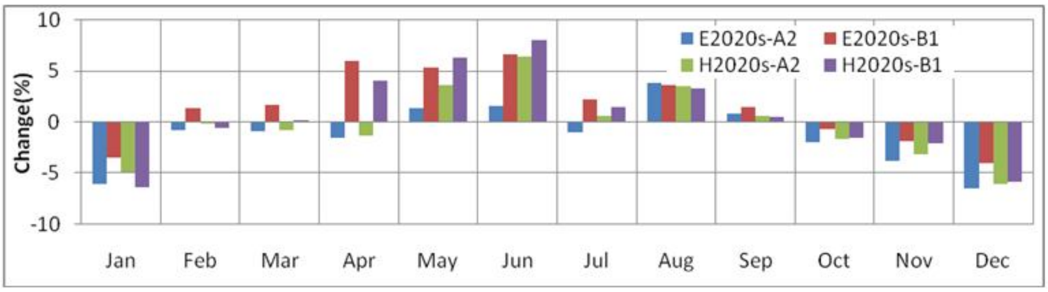

Figure 4. Future period 2011 – 2040 monthly change in stream flow with respect to 1981 – 2000

Conculsions

In this study, the trend of hydro-meteorological data and the impact of climate change was examined on the future streamflow of Gilgel Gibe River. The future period of the 2020s was considered and average emperature and precipitation data using the delta change method was constructed. Generally both the ECHAM5 and HadCM3 models predict an increase in average temperature and rainfall in the study area. The absolute monthly difference for temperature and relative difference for precipitation between the future period and baseline period was determined and superimposed on the historical to run the calibrated and validated SWAT hydrological model. The result from the SWAT model as compared to the control period of 1981 – 2000, shows an increase in streamflow for the 2020s. This implies that the streamflow will keep increasing for the considered future period. The increase in the trend of recorded and GCM projected rainfall, increases the streamflow. The streamflow in the short term, future period of the 2020s will increase and this indicates as there will not be shortage of flow due to climate change in this period. However, this does not mean that the hydropower generation capacity will not be affected. Climate change may increase the erosion from the upper catchment and sedimentation of the reservoir which will impair the intended purpose of the hydropower project.

REFERENCE

Abbaspour, K.C., Vejdani, M., Haghighat, S. (2007) *(extended ABSTRACT 4th International SWAT conference workshops 2007)* SWAT-CUP Calibration and Uncertainty Programs for SWAT. UNESCO-IHE Institute for Water Education.

Arnold, J.G., Srinivasan, R. Muttiah, R.S., and Williams, J.R (1998) Large area hydrologic modeling and assessment Part I: Model development. *JAWRA J. Am. Water Resour. Assoc.*, 34:73-89

Burn, D.H. and M.A. Hag Elnur (2002) Detection of Hydrologic Trends and Variability. *Journal of Hydrology* 255 (2002), 107-122

Cheung, W.H., Senay, G.B., and Singh, A (2008) Trends and spatial distribution of annual and seasonal rainfall in Ethiopia. *Int. J. Climatol.* DOI: 10.1002/joc.1623

Demissie, T. A., Saathoff, F., Seleshi,Y.,Gebissa, A(2013) Climate change impact on the streamflow and simulated sediment flux to Gilgel Gibe 1 hydropower reservoir-Ethiopia, European International Journal of Science and Technology,Vol.2. No.2.

FAO.1995. Digital soil map of the World and derived soil properties Food and Agricultural Organization of the United Nations, Rome.

Hay, L.E, Wilby, R.L., and Leavesley, H.H (2000) Comparison of Delta Change and Downscaled GCM Scenarios For three mountainous basins in The United States, *J. Am. Water Resour. Assoc*., 36, 387-397.

Helsel, D.R. and Hirsch, R.M (1992) *Statistical Methods in Water Resources*. Book 4, Hydrologic Analysis and Interpretation

Hirsch, R.M., Slack, J.R. and Smith, R.A (1982) Techniques of trend analysis for monthly water quality data, *Water Resour. Res.* 18, 107–121

IPCC, 2007: Climate Change (2007). The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

Jarvis, A., Reuter, H.I., Nelson, A., Guevara, E (2008) Hole-filled Seamless SRTM data Version 4, *International Centre for Tropical Agriculuture (CIAT)*, available from (http://srtm.csi.cgiar.org).

Khan, A. R (2001). *Analysis of hydro-meteorological time series: Searching evidence for climatic change in the Upper Indus Basin.* Lahore, Pakistan: *International Water Management Institute.* (IWMI working paper 23).

Leon, L.F. (2011). Step by Step Geo-Processing and Set-up of the Required Watershed Data for MWSWAT (MapWindow SWAT), Version 2.

McSweeney, C., New, M. and Lizcano, G (2007) UNDP Climate Change Country Profiles Ethiopia.

Monteith, J.L (1965). Evaporation and environment. Symposia of the Society for Experimental Biology19: 205-234.

Neitsch, S.L., Arnold, J.G., Kiniry, J., Williams, J.R(2011)Soil and water assessment tool theoretical documentation (version 2009), Grassland, Soil and Water Research Laboratory-Agricultural Research Service Blackland Research Center-Texas AgriLife Research.

Raghavan, S.V., Vu, M.T. and Liong, S-Y (2012) Assessment of future stream flow over the Sesan catchment of the Lower Mekong Basin in Vietnam. *Hydrol. Process.* 26, 3661–3668. DOI: 10.1002/hyp.8452.

US department of Agriculture-Soil Conservation Service (USDA-SCS) (1972) National Engineering Handbook, Section IV, Hydrology, 4-102.

Van Liew, M.W., and Garbrecht, J (2003) Hydrologic Simulation of the Little Washita river experimental watershed using SWAT. *Journal of American Water Resources Association* 39(2):413-426.

Williams, J.R (1975) Sediment-yield prediction with universal equation using runoff energy factor.p.244-252.In Present and prospective technology for predicting sediment yield sources: *Proceedings of the sediment-yield workshop*, USDA Sedimentation Lab., Oxford.MS, 1972. ARS-S-40.

Zhang, X., R.Srinivasan, R., Hao, F (2007) Predicting Hydrologic Response to Climate Change in the Luohe River Basin Using the SWAT model, *Transactions of the ASABE* Vol.50(3): 901-910.

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