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# Evaluating Potential Impacts of Climate Change on Hydro- meteorological Variables in Upper Blue Nile Basin, Ethiopia
# A Case Study of Finchaa Sub-basin

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**Abstract**
Climate change impacts are the main concern for sustainability of water management, water use activities and agricultural production throughout the world. Climate changes alter regional hydrologic conditions and results in a variety of impacts on water resource systems. The objective of this study is to assess the impact of climate change on the hydro climatology of Finchaa Sub-basin located in upper Blue Nile Basin of Ethiopia. The GCM (General Circulation Model) derived scenarios (HadCM3 A2a & B2a SRES emission scenarios) were used for the climate projection. The statistical Downscaling Model (SDSM) was used to generate future possible local meteorological variables in the study area. The down-scaled data were then used as input to the Soil and Water Assessment Tool (SWAT) model to simulate the corresponding future stream flow in of Finchaa Sub-basin. The time series generated by GCM of HadCM3 A2a and B2a and Statistical Downscaling Model (SDSM) indicate a significant increasing trend in maximum and minimum temperature values and a slight decreasing trend in precipitation for both A2a1 and B2a2 emission scenarios in sub-basin for all three bench mark periods. The hydrologic impact analysis made with the downscaled temperature and precipitation time series as input to the SWAT model suggested an overall decreasing trend in annual and monthly stream flow in the study area, in three benchmark periods in the future. Potential evapotranspiration in the watershed also will increase annually on average 3 to 16 % for the 2020s and 4 to 19 % for the 2050s and 2080s for both A2a and B2a emissions scenarios. As a result, at the ut let of the watershed the projected on average annual flow decrease by 5.59 %,9.03 %,11% and 2.16 %,4.15 and 3.46 % for the 2020s,2050s and 2080s for both A2a and B2a emissions scenarios. The paper also includes potential strategy recommendations to communities, policy and decision makers for measuring and enhancing effective adaptation option for future climate change impacts on hydrology.
**Keywords:** A2a, B2a, climate change; Finchaa sub-basin, GCM, SDSM, stream flow; SWAT

## 1. Introduction

Observed climatic changes indicate that Africa warmed 0.7 °c over the 20$^{th}$ century, with a decadal temperature increase of 0.05 °C (Adger et al. 2003; IPCC 2001). For East Africa this warming has been associated with an increase in precipitation in some areas. Projected Climate Change for Africa (Adger et al. 2003; IPCC 2001) indicates that there will be a regional warming ranging from 0.2 °C per decade (low scenario) to more than 0.5 °C per decade (high scenario), which will lead to a 5 to 20 % increase in precipitation from December–February (wet months) and 5 to 10 % decrease in precipitation from June–August (dry months). The Intergovernmental Panel on Climate Change's (IPCC, 2007) findings suggested that developing countries like Ethiopia will be more vulnerable to climate change due to their economic, climatic and geographic settings.

Many studies have been conducted to assess the impact of climate change on hydrology in different parts of the Nile River basin (Kim *et al.*, 2009; M. T. Taye *et al.*, 2011; Dile YT *et al.*, 2013; Enyew *et al.*, 2014; Lakemariam, 2015; Gebre, et al., 2015). Many of these studies indicated hydrological variability associated with climate change.

Finchaa sub-basin is normally endowed with land features that are characterized by large upstream water potential sites, intensive downstream irrigable lands and high head hydropower plant at the foot almost vertical canyons. In the sub basin there is a project called Finchaa, Amerti and Neshe multipurpose project. Finchaa and Amerti dams and reservoirs are the earliest in the Blue Nile basin and constructed in 1968 and 1984 respectively, whereas the construction of Neshe reservoir completed in 2011.The project comprises big irrigation for sugar factory and hydropower projects including the community water supply. The Finchaa system was expanded in 1980 by diverting Amerti flows into the Finchaa reservoir by construction a 20m high earth and rock fill dam on Amerti river and a 1.57 km long diversion tunnel. As a result, the capacity was upgraded to 134 MW by an additional turbine unit. Finchaa sugar plantation and its processing facility were developed in late 1990's and the Factory was inaugurated in 1999. The plantation is located downstream of the Finchaa power plant and it takes advantage of regulated flows provided by Finchaa reservoirs. Since the construction of the Finchaa, Amerti and Neshe multipurpose, downstream irrigation in the area has been expanding starting from

1968. The main sources of water for this all activities are the three reservoirs i.e. Finchaa, Amerti and Nesh reservoirs. There is an increasing demand for water which leads to competition for water among different sectors. Therefore because of this big project expansion in the watershed there is highly increase in deforestation that lead increase in temperature and decrease in precipitation (Daniel G., 2007) in the Finchaa sub-basin.

Therefore, it is good to understand the impact of climate change on the hydrological variables essentially involves taking projections of climatic variables (e.g. precipitation and temperature) at a global scale; downscaling these global-scale climatic variables to local-scale hydrologic variables, and computing hydrological components for hydro meteorological variability and hydrological impact in the future; to adapt to climate change. The objective of the study is to evaluate the impact of climate change on the hydro climatology of Finchaa Sub-basin.

## 2. Materials and Methods

### 2.1 Description of the Study area

Finchaa sub-basin lies between 9010' to 10000'N and 370 00' and 370 30'E. The sub-basin is located around 315 km north-west of Addis Abeba, in Blue Nile river basin. Finchaa sub-basin is a part of Abbay river basin which contains three watersheds (Finchaa, Amerti and Nesh watershed).The sub-basin has an area of 4089 km2.

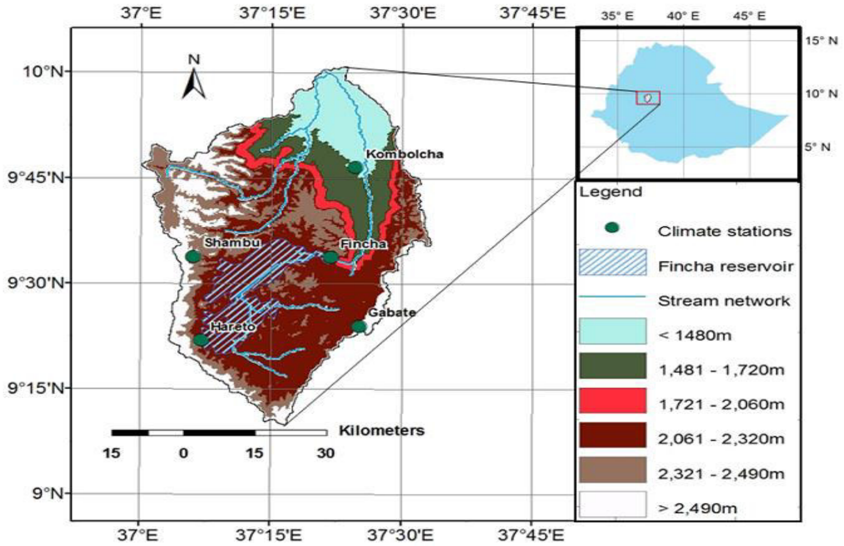



**Figure 1: Study area of Finchaa sub-basin**

### 2.1. Modelling approach

This study concerns the assessment of climate change impact on hydrology with the application of a semi-distributed physically based watershed model SWAT in the Finchaa sub basin. Statistical downscaling model (SDSM) was used for future climate generation. The procedure consists of using climatic output data from General Circulation Models (GCMs) to retrieve climate scenarios. The weather generator was then used to produce daily temperature and precipitation data to serve as an input data for the SWAT hydrological model to simulate stream flow. The future simulated results were then compared with the base line period as a means of obtaining the change caused by climate change.

The historical climate data and stream flow data have been collected from National Metrological Agency (NMA) and Ministry of Water Resources (MoWR) that used to calibrate and validate SWAT model. Before the calibration has been taken for the given model, watershed parameters are needed, these watershed parameters were watershed area, mean elevation, land use and the shape of the watershed. These parameters are taken from the output of the digital elevation model (DEM) that has been processed by GIS. Taking these watershed parameters, the historical flow and climate data calibration has been taken to determine the model parameters. Model calibration is tuning of model parameters based on checking results against observations to ensure similar response over time. This involves comparing the model outputs, generated with the use of historic meteorological observations, to recorded stream flows. In this process, model parameters varied until recorded flow patterns are accurately simulated. The manual calibration of this study was done based on the procedures recommended in SWAT user manual (Neitsch *et al*., 2002): first calibration of the water balance followed by that of temporal flow.

In order to utilize the calibrated model for estimating the effectiveness of future potential management practices, the model was tested against an independent set of measured data. This testing of a model on an independent set of data set is commonly referred to as model validation. As the model predictive capability was demonstrated as being reasonable in both the calibration and validation phases, the model was used for future predictions under different management scenarios. On the other hand, the coarser climate data (GCM) are downscaled in to finer spatial resolution regional climate data (RCM) and these regional climate data are further downscaled in to station level by using statistical downscaling model (SDSM 4.2.2), these downscaled data have been taken directly as an input of the model to assess the future climate change impact on hydro-climatology of the sub-basin.

### 2.3. Arc SWAT model approach

Watersheds can be subdivided into sub watersheds and further into hydrologic response units (HRUs) to account for differences in soils, land use, crops, topography, weather, etc. The model has a weather generator sub routine that generates daily values of precipitation, air temperature, solar radiation, wind speed, and relative humidity from statistical parameters derived from average monthly values. The model computes surface runoff volume either by using modified SCS curve number method or the Green & Ampt infiltration method. Flow is routed through the channel using a variable storage coefficient method or the Muskingum routing method. SWAT has three options for estimating potential evapotranspiration: Hargreaves, Priestley-Taylor, and Penman-Monteith. The model also includes controlled reservoir operation and groundwater flow model. The important equations used by the model are discussed below in detail. The detailed and complete descriptions are given in the SWAT theoretical documentation (Neitsch *et al.*, 2002). SWAT splits hydrological simulations of a watershed into two major phases: the land phase and the routing phase. The difference between the two lies on the fact that water storage and its influence on flow rates is considered in channelized flow (Neitsch *et al.*, 2002).

The land phase of the hydrologic processes is simulated based on the following water balance Equation:

$$SW_t = SW_o + \sum_{t=1}^{t}\left(R_{day} - Q_{surf} - E_a - \omega_{sweep} - Q_{gw}\right) \tag{1}$$

Where, $SW_t$ is the final soil water content (mm), $SW_o$ is the initial soil water content (mm), t is the time (days), $R_{day}$ is the amount of precipitation on day $i$ (mm), $Q_{sur}$ is the amount of surface runoff on day $i$ (mm), $E_a$ is the amount of evapotranspiration on day $i$ (mm), $w_{sweep}$ is the amount of water entering the vadose zone from the soil profile on day $i$ (mm) and $Q_{gw}$ is the amount of return flow on day $i$ (mm).

#### 2.3.1. Surface Runoff Simulation

For the surface runoff process, it occurs whenever the rate of water application to the ground surface exceeds the rate of infiltration. SWAT provides two methods for estimating surface runoff: the SCS curve number procedure and the Green & Ampt infiltration method. Here is a brief description to both methods. The SCS curve number procedure is a function of the soil's permeability, land use and antecedent soil water conditions. Where the SCS runoff equation is an empirical model that came into common use in the 1950s.This equation is:

$$Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)} \tag{2}$$

Where $Q_{suf}$ The accumulated runoff or rainfall excess (mm), $R_{day}$: the rainfall depth for the day (mm), $I_a$: the initial abstractions (surface storage, canopy interception, infiltration prior to runoff) (mm), and $S$: the retention parameter.

Therefore, runoff will only occur only when $R_{day} > I_a$. Retention parameter $S$ is defined as:

$$S = 25.4\left(\frac{1000}{CN} - 10\right) \tag{3}$$

Where CN is the curve number for the day and the initial abstractions**,** $I_a$, is commonly approximated as 0.2S, then Equation 2 and 3 becomes:

$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{(R_{day} + 0.8S)} \tag{4}$$

SWAT calculates CN using soil classes and land uses classifications data.

#### 2.3.2. Peak runoff rate assessment

The peak runoff rate is the maximum runoff flow rate that occurs with a given rainfall event. The peak runoff rate is an indicator of the erosive power of a storm and is used to predict sediment loss. SWAT calculates the peak runoff rate with a modified rational method.

$$q_{peak} = \frac{\alpha_{tc} \cdot Q_{surf} \cdot Area}{3.6 \cdot t_{conc}} \quad (5)$$

Where $q_{peak}$ is the peak runoff rate (m3/s), $\alpha_{tc}$ is the fraction of daily rainfall that occurs during the time of concentration, $Q_{suf}$ is the surface runoff (mm),Area is the sub basin area (km2), $t_{conc}$ is the time of concentration for the sub basin (hr) and 3.6 is a unit conversion factor.
SWAT estimates the value of α using the following equation:

$$\alpha_{tc} = 1 - \exp\left[2.t_{conc}.\ln\left(1 - \alpha_{0.5}\right)\right] \quad (6)$$

Where: $t_{conc}$ is the time of concentration (h), and $\alpha_{0.5}$ is the fraction of daily rain falling in the half-hour highest intensity rainfall.

**2.3.3. Evapotranspiration assessment**

Evapotranspiration is a collective term that includes all processes by which water at the earth. Surface is converted to water vapor. It includes evaporation from the plant canopy, transpiration, sublimation and evaporation from the soil. The difference between precipitation and evapotranspiration is the water available for human use and management. Assessment of watershed evapotranspiration is critical in the assessment of water resource. SWAT calculates potential and actual evapotranspiration.

SWAT incorporated three numerical methods to estimate potential evapotranspiration PET. The Penman-Monteith method, the Priestley-Taylor method and the Hargreaves method, also user can enter PET manually. On the other side, SWAT calculates actual evapotranspiration ET after determine PET. SWAT first evaporates any rainfall intercepted by the plant canopy. Next, SWAT calculates the maximum amount of transpiration and the maximum amount of sublimation/soil evaporation. When PET is less than amount of free water held in the canopy, it assumes that ET = PET. However, when PET less than amount of free water held in the canopy, so no water will remains in the canopy after initial evapotranspiration. The Hargreaves method was developed in 1975 but several improvements were made to the original equation. The form used in SWAT was published in 1985 (Neitsch *et al*., 2005).

$$\lambda E_o = 0.0023.H_o.(T_{Max} - T_{Min})^{0.5}(T_{av} + 17.8) \quad (7)$$

Where: λ is the latent heat of vaporization (MJ kg-1); $E_o$ is the potential Evapotranspiration (mmd-1); $H_o$ is the extraterrestrial radiation (MJm-2d-1); $T_{mx}$ is the maximum air temperature for a given day ( $^0$C); $T_{mn}$ is the minimum air temperature for a given day ( $^0$C) and $T_{av}$ is the mean air temperature for a given day ( $^0$C).

**2.3.4. Determination of Impacted Stream Flow**

The sub-basin values of monthly temperature changes (deltas) and the monthly precipitation change factors (precipitation multipliers) found as an output from the GCM model and downscaled by the SDSM model were given as an input to the SWAT model. The remaining climatic and all other land use and soil hydrologic parameters used in model development under current climate conditions were assumed to be constant and remain valid under conditions of climate change.

The model calculates the impacted daily precipitation by simply multiplying the daily precipitation multiplier by the corresponding baseline daily precipitation values; whereas the impacted daily temperatures are calculated by adding the average daily delta values of the maximum and minimum daily temperature to the corresponding average baseline daily temperature.

$$R_{day} = R_{day}.\left(1 + \frac{adj_{pcp}}{100}\right) \quad (8)$$

Where: $R_{day}$ is the precipitation falling in the sub-basin on a given day (mm H2O), and $adj_{jpcp}$ is the percentage change in rainfall.

$$T = T + adj_{tmp} \quad (9)$$

Where: $T$ is the daily temperature (°C); $adj_{tmp}$ is the change in temperature (°C).

In order to simulate the seasonal variations in the climate conditions, the monthly delta and precipitation multiplier values were used and applied evenly on all the days of the month.

## 3. Results and Discussion

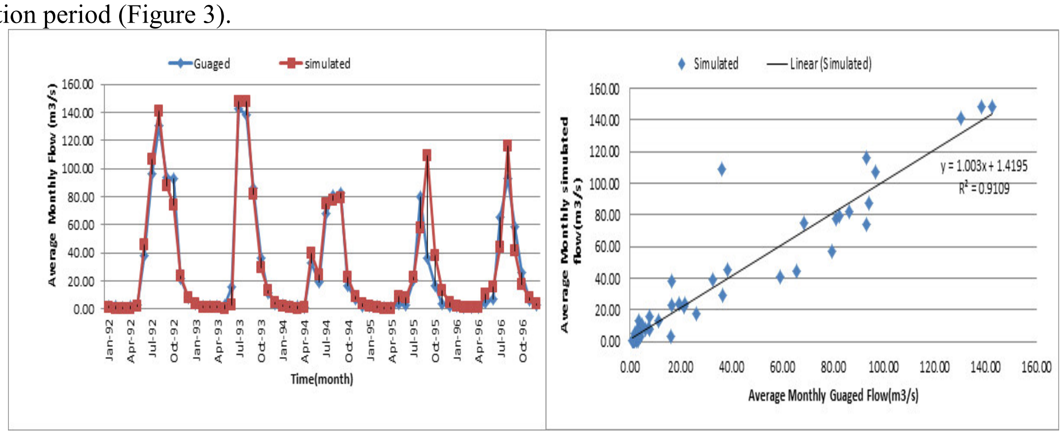
### 3.1. SDSM Model Calibration and Validation

The calibration was carried out from 1971-1985 for 15 years and the withheld data from 1986-2000 were used for model verification. Twenty mean ensembles of synthetic daily weather series generated using NCEP-reanalysis data for the verification of the calibrated model. The mean of the 20 ensembles of maximum temperature and minimum temperature values gave a better R2 values (R2=0.72 and R2 =0.68 respectively), inferring that future projections would also be well replicated. The model develops a better multiple regression equation parameters for the maximum and minimum temperature than the precipitation (R2 =0.46). These calibration results show that the simulated maximum and minimum temperature has better agreement with the observed results than the precipitation variables.

Validation was done based on 14 years simulation from 1986 to 2000. 20 ensembles (runs) of daily values were generated and the average of these ensembles was taken for comparison. During validation maximum temperature and minimum temperature values gave a better R2 values (R2=0.85 and R2 =0.78 respectively) and for precipitation (R2 =0.56). The downscaled model showed good performance during validation period in the cases of minimum and maximum temperatures and correlation coefficients that were found during the calibration step are more or less maintained.

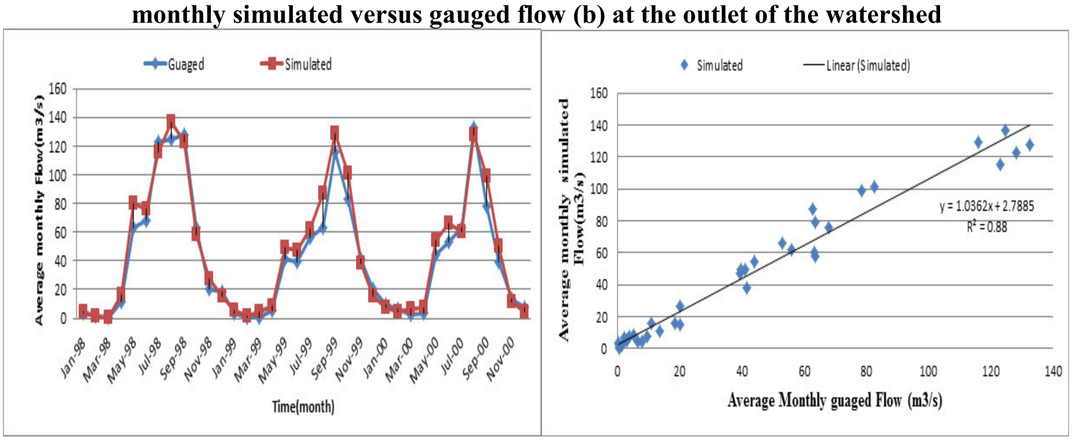
### 3.2. SWAT Model Calibration and Validation

The manual and automated calibration process was used to calibrate the model parameters using time series data from 1992 to 1996. Data from 1997 to 2000 were used to validate the model using the input parameter set. Time series plots and the statistical measures of coefficient of determination (R2) and Nash-Sutcliffe efficiency (ENS) were used to evaluate the performance of the model. The predicted and observed stream flow generally matched well. The results of the model calibration and validation showed reliable estimates of monthly stream flow with R2 = 0.92 and ENS = 0.91 during the calibration period (Figure 2) and R2 = 0.88 and ENS = 0.86 during the validation period (Figure 3).




(a) (b)

**Figure 2: Calibration result of average monthly simulated and gauged flows (a) and Scatter plot of monthly simulated versus gauged flow (b) at the outlet of the watershed**




(a) (b)

**Figure 3: Validation result of average monthly simulated and gauged flows (a) and Scatter plot of monthly simulated versus gauged flow (b) at the outlet of the watershed**

### 3.3. Climate Change Scenarios Developed for the Future

In this study first the coarser climate data (GCM) are downscaled in to finer spatial resolution regional climate data (RCM) and these regional climate data are further downscaled in to station level by using statistical downscaling model (SDSM 4.2.2) and these downscaled data have been taken directly as an input of the model to assess the future climate change impact on hydrology of the sub-basin after calibration and validation done. The climate scenario for future period was developed from statistical downscaling using the HadCM GCM predictor variables for the two SRES emission scenarios (A2 and B2) for 90 years based on the mean of 20 ensembles and the analysis was done based on three 30-year periods centred on the 2020s (2011-2040), 2050s (2041-2070) and 2080s (2071-2099). The average annual precipitation in the watershed might reduce up to 9.84 %, 23.29 % and 41.51 % and 9.27 %, 20.71 % and 35.37 % in 2020s, 2050s, and 2080s for A2a and B2a emission scenarios, respectively as shown Figure 4 (a) and (b). This finding is not unique to this study, (Girma, 2012) found out that the CCLM downscaling resulted in the upper Blue Nile were 1.8, -6.6 and -6.4% in 2020s, 2050s and 2080s respectively. The result of this analysis confirmed also with the (IPCC, 2007) mid-range emission scenario show that compared to the (1961-1990) annual precipitation show a change of between 0.6 to 4.9% and 1.1 to 18.2% for 2030 and 2050 respectively.

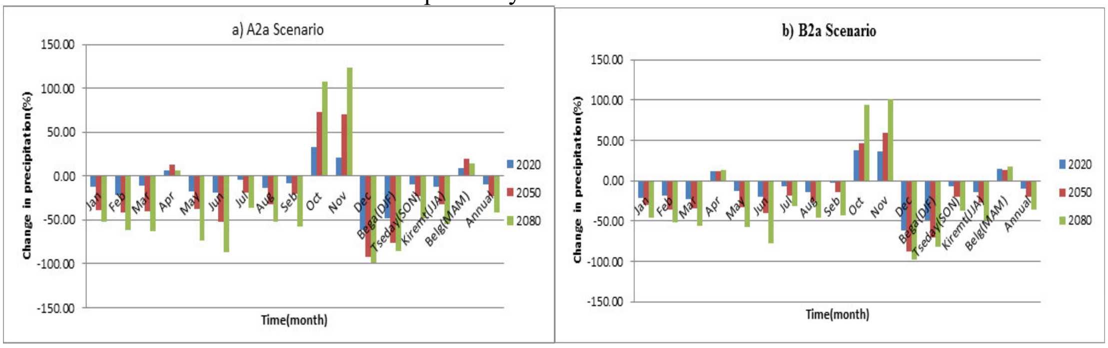



**Figure 4: (a) and (b) Change in average monthly, seasonal and precipitation for A2 and B2 emission Scenarios**

Besides, as shown in Figure 5 (a) and (b) the average annual maximum temperature might increase by 0.25 ⁰C, 0.60 ⁰C and 1.09 ⁰C and 0.50 ⁰C, 0.26 ⁰C and 0.86 ⁰C in 2020s, 2050s and 2080s for A2a and B2a emission scenario respectively. The result of this analysis confirmed with (S.G. Setegn *et al*., 2011) and (C. McSweeney *et al*., 2010) findings. The Maximum temperature showed an increasing trend in three future time horizons.

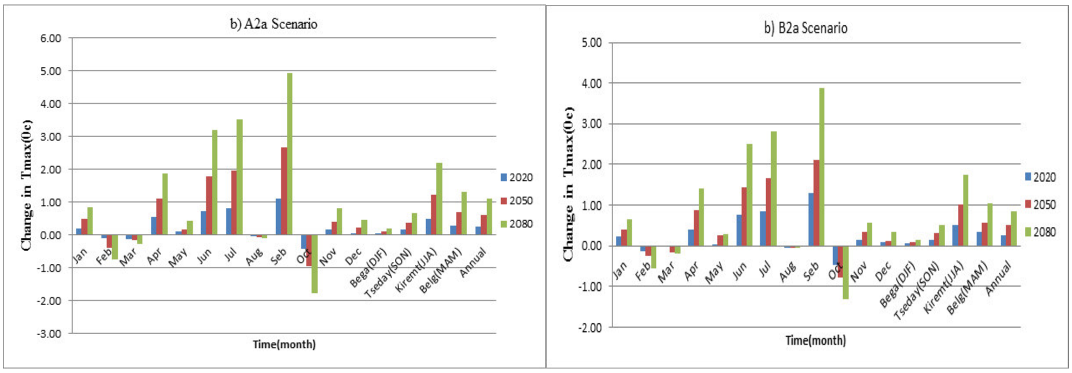
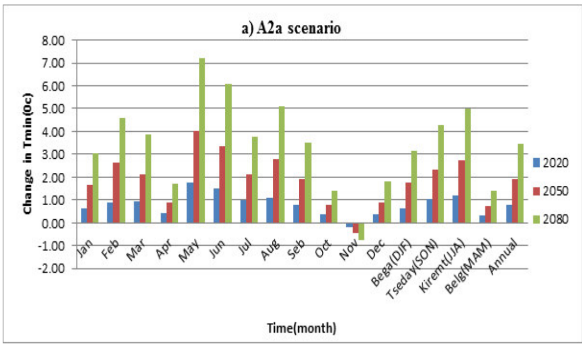



**Figure 5: (a) and (b) Change in average monthly, seasonal and annual maximum temperature for A2 and B2 emission Scenarios**

The average annual minimum temperature might increase by 0.25⁰C, 0.60 ⁰C and 1.09⁰C and 0.50 ⁰C, 0.26 ⁰C and 0.86 ⁰C in 2020s, 2050s and 2080s for A2a and B2a emission scenario respectively. Generally, the temperature change projection for the catchment is in line with the range produced in by other researcher over the Blue Nile River basin (C. McSweeney *et al*., 2010; Beyene *et al*., 2010; M. T. Taye *et al*., 2011; Lakemariam, 2015 and Gebre, *et al*., 2015). The projected minimum and maximum temperature in both future time horizons is within the range projected by (IPCC, 2007) average temperature increases ranging from 1.4°C to 5.8°C towards the end of century.



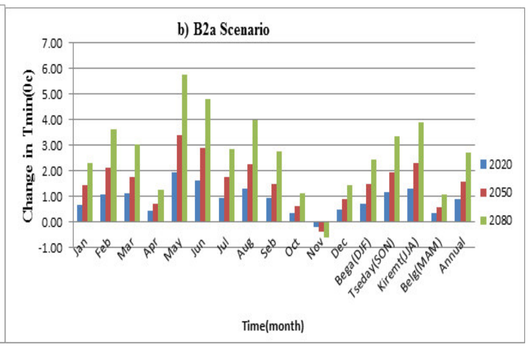
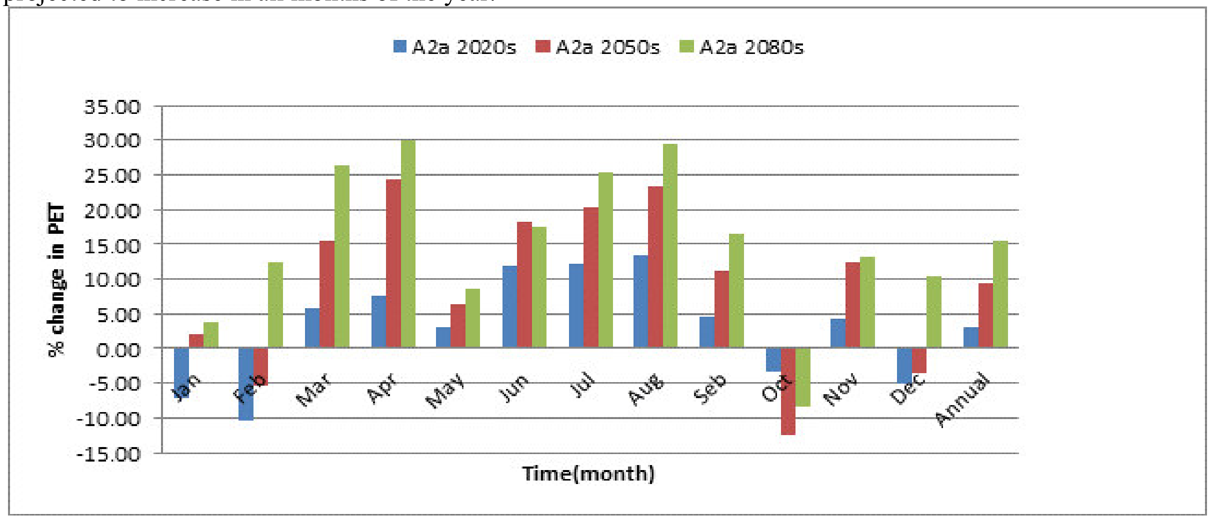



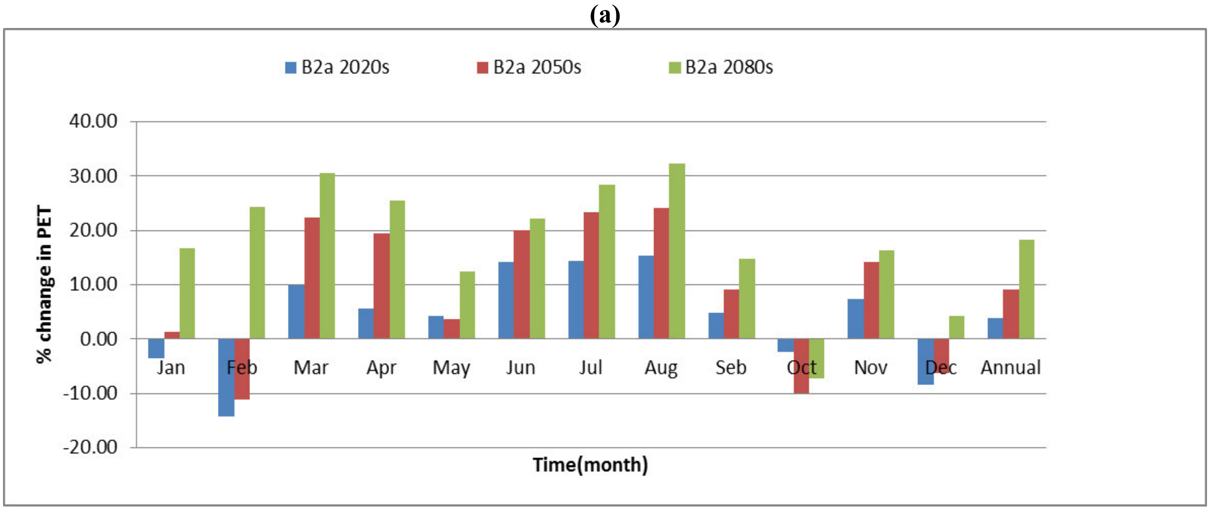

**Figure 6: (a) and (b) Change in average monthly, seasonal and annual minimum temperature for A2 and B2 emission Scenarios**

### 3.4. Evapotranspiration Response to change in climate

The simulations for the Finchaa sub-basin suggest that annual estimates of potential evapotranspiration are predicted to increase with increase in temperature. The projected on average annual increase in potential evapotranspiration is 3.10 %,9.38 %,15.39 % and 3.93 %,9.18, and 18.38 % for the 2020s,2050s and 2080s for both A2a and B2a emissions scenarios with respect to the baseline period (1980-2010) respectively. (Enyew *et al.*, 2014 and Gebre, *et al.,* 2015) results show that the end of the 21st century potential evapotranspiration is projected to increase in all months of the year.




(a)

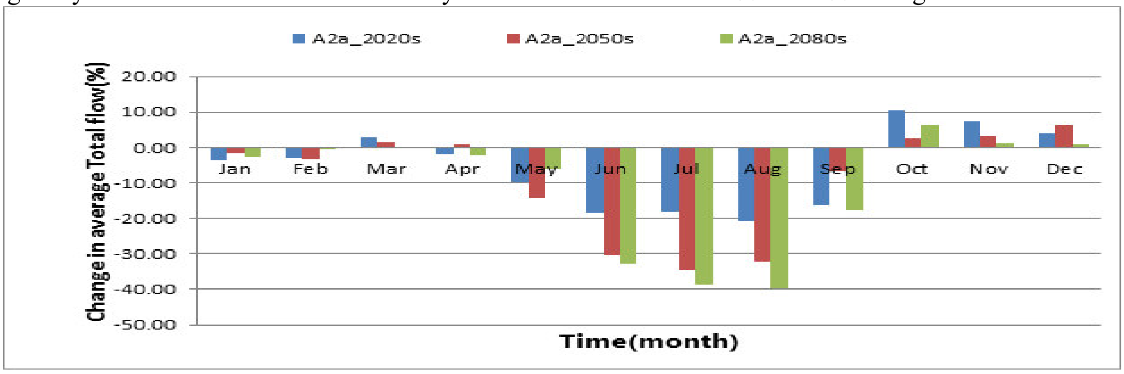



(b)

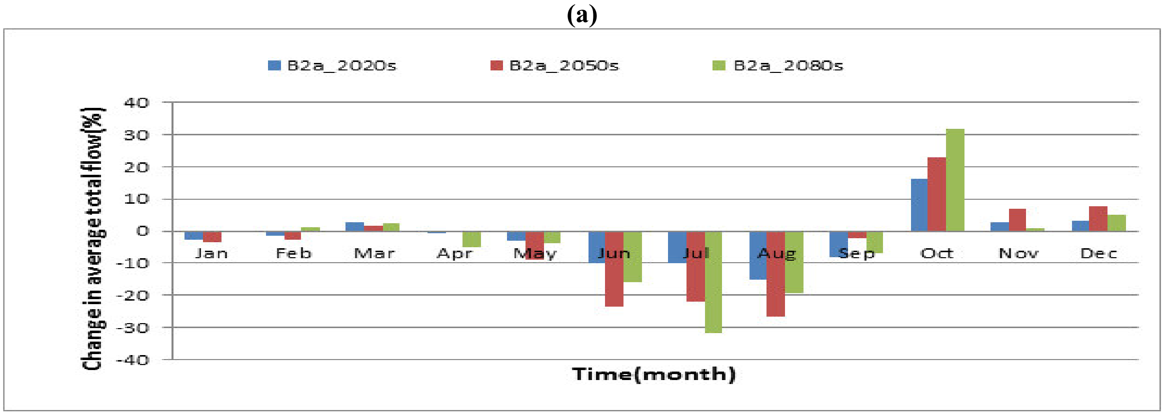
**Figure 7: Percentage change in monthly projected and annual potential evapotranspiration under A2 scenario (a) and B2 scenario (b)**

### 3.5. Projected changes in the mean annual and seasonal stream flow

The impact of climate change was analysed taking the 1980-2000 river flow as the baseline flow against which the future flows for the 2020s, 2050s and 2080s compared. Precipitation, minimum and maximum temperature were the climate change drivers considered for the impact assessment. The monthly percentage change in flow in both scenarios for the period 2020s, 2050s and 2080s are presented in Figure 8 "(a)" and "(b)" .In the 2020s for both A2a, and B2a scenario, the percentage change of average total monthly flow decrease for all the months except March, October, November and December. Decrease in flow volume may be observed in months which showed a decrease in monthly precipitation. (Dile YT *et al.*, 2013) results showed that the impact of climate change may cause a decrease in mean monthly flow volume between -40% to -50% during 2020s.




**(a)**



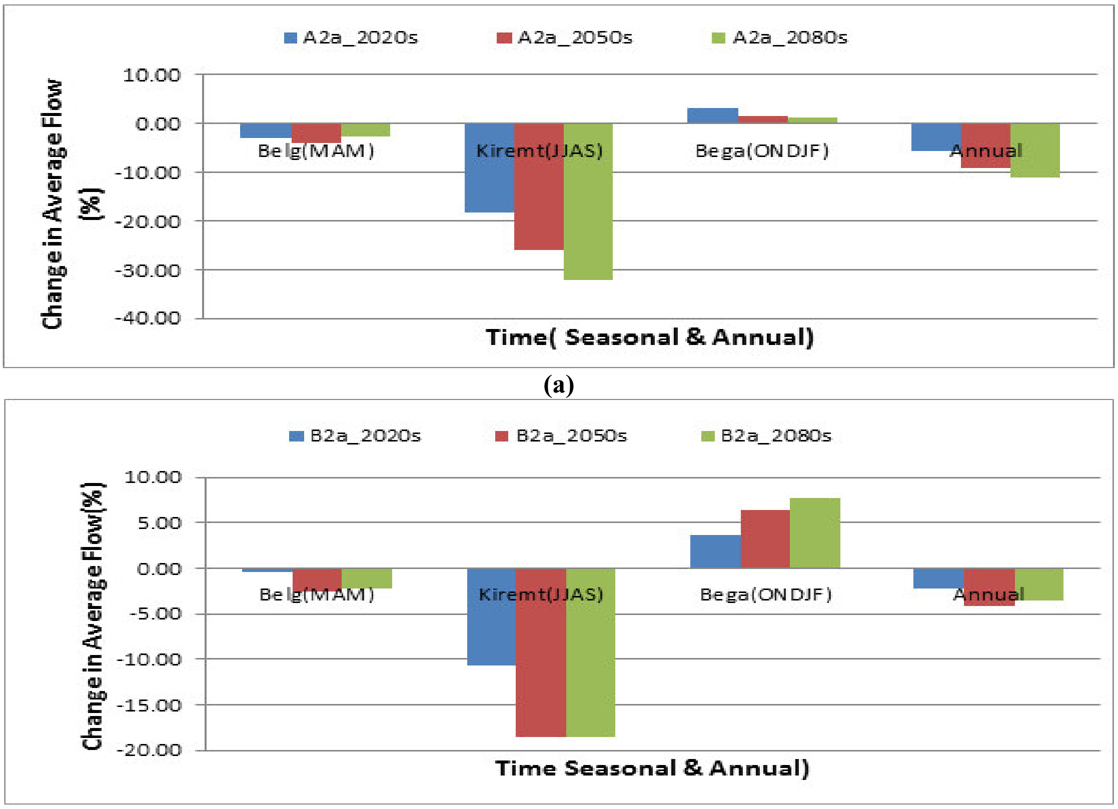

**(b)**

**Figure 8: (a) and (b) Percentage change of average total Monthly flow pattern at the out let of the watershed**

As can be seen from Figure 9 (a) and (b) there may be an annual decrease in flow volume for the next 90 years. Kiremt (JJAS) season is expected to show the larger share in decrease flow volume. The decrease may reach up to 32.23 % in 2080s for the A2a scenario and 18.51 % in 2080s for the B2a scenario in Kiremt season. But, Bega season shows a descent increases in flow volume. The increase ranges from 1.1 % to 3.1 % for the A2a scenario and 3.67 % to 7.79 % for the B2a scenario. In general due to the projected increase in temperature and reduce in precipitation leads to reduction in future annual stream flow as one goes from one period to the next.

The projected on average annual flow reduced by 5.59 %, 9.03 %, 11 % and 2.16 %,4.15, and 3.46 % for the 2020s,2050s and 2080s for both A2a and B2a emissions scenarios. This decrease of average total annual flow in both scenarios in 2011-2099 period might be due to the fact that decrease of a total average annual precipitation in Neshe and Finchaa station is higher than the increase of precipitation in Shambu station and slight increase of annual minimum and maximum temperature in both scenarios of Shambu station in SDSM out puts results. The overall decreasing pattern of the average total annual flow is mainly because of a decrease in average total seasonal flow in months of May, June, July, August and September for both A2a and B2a scenario.




(b)

**Figure 9: (a) and (b) Percentage change in projected mean annual and seasonal flow for both A2a and B2a scenario respectively**

## 4. Conclusions

Soil and Water Assessment Tool (SWAT) was successfully used to simulate, the impact of climate change on the hydro climatology of Finchaa sub-basin were assessed based on projected climate conditions by using GCM out puts of HadCM3 SRES A2a and B2a emissions scenarios with Statistical Downscaling (SDSM) modelling approach . The model is able to capture daily and patterns which can be proven by the regression coefficient and the Nash-Sutcliffe (1970) simulation efficiency values obtained during calibration and validation periods. Hence, it can be concluded that SWAT is able to accurately explain the hydrological characteristic of the Finchaa sub-basin.

The result of climatic projections of SDSM model simulations revealed that the climatic variables generally follow the same trend with the observed ones except for some extreme climatic events. The SDSM has good ability to replicate the historical maximum and minimum temperatures than precipitation. The mean of the 20 ensembles of maximum temperature and minimum temperature values gave a better $R^2$ values, inferring that future projections would also be well replicated. The model develops a better multiple regression equation parameters for the maximum and minimum temperature than the precipitation. This is mainly due to the conditional nature of precipitation. In conditional models, there is an intermediate process between regional forcing and local weather (e.g., local precipitation amounts depend on wet/dry day occurrence, which in turn depend on regional–scale predictors such as humidity and atmospheric pressure) (Wilby and Dawson, 2004).

For the Finchaa sub-basin the downscaled mean annual maximum and minimum temperature shows an increasing for all future time horizons for both A2a and B2a emission scenarios. Precipitation projection exhibited reducing in annual average precipitation for sub-basin all time horizons for both A2a and B2a emission scenarios.

The change in climate variables such as reduce in precipitation and increase in temperature there by increase in evapotranspiration which is very sensitive parameter that can be affected by changing climate than any other hydrological component are likely to have significant impact on Stream flow.

Therefore, decrease in future projected average annual flow and increase average annual potential evapotranspiration leads to reduce in water resource availability of the around watershed area. In addition to fluctuations on temperature and precipitation; also deforestation and population growth in area are among current trends over the sub- basin. Hence, it is good to incorporate the impacts of climate and land use or land cover changes over the Finchaa sub-basin.

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