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# Streamflow Modeling Under the Impact of Climate Change. (Case Study of Dabus River Sub-Basin, Ethiopia)

Jemal Ibrahim Mohammed[1+] Bogale Gebramarim(PhD)[2]
1.Hydraulic and Water Resources Engineering, Institute of technology, Wollega University, PO box 395, Nekemte, Ethiopia
2.Hydraulic and Water Resources Engineering, Institute of technology, ArbaMinch University, PO box 21,Arbaminch, Ethiopia

**Abstract**
Currently the impact of climate change affects many water resources projects that result in pattern change of annual runoff, reservoirs pool level change, increasing of irrigation demand due to increasing temperature and evaporation and etc., and thus it is important to assess its impact on streamflow. This study mainly forecast streamflow of Dabus river Sub Basin. The future climate variables which were downscaled by Climate Limited area Model (CLM) at the basin level for A1B emission scenario was used for future flow simulation. For streamflow generation HEC-HMS model was used by using the bias corrected precipitation and Evapotranspiration which was estimated by FAO Penman-Monteith. After the flow was forecasted, the performance of the model was assessed via calibration at Dabus near Asosa, Sechi near Mendi and Aleltu at Nedjo using Relative Volume Error (D), coefficient of determination ($R^2$) and Nash-Sutcliffe Efficiency (NSE) performance coefficients. Then the model was validated using the parameters optimized during model calibration. The trend of Dabus streamflow forecasted at its outlet to main basin river (Abbay River) was assessed. The projected mean annual maximum temperature increases from the baseline period by $0.43^0$C, $1.3^0$C and $2.5^0$C for short-term, midterm and long-term respectively whereas minimum temperature increases by $0.47^0$C, $1.53^0$C and $2.83^0$C. Generally the projected future maximum and minimum temperature shows an increasing trend whereas precipitation shows variation (does not reveal clearly increasing or decreasing) for earlier century and decreasing trend in mid and late century. The evapotranspiration shows an increasing trend. The HEC-HMS model shows a good performance at Dabus near Asosa which resulted D=0.0066, $R^2$=0.90 and NSE=0.89 during calibration and D=4.9285, $R^2$=0.84 and NSE=0.82 during validation. The streamflow of Dabus River Basin shows an average annual increase of 2.83% for short-term forecast (2011-2040) and decrease of 2.83% and 4.56% for mid-term forecast (2041-2070) and long-term forecast (2071-2100) respectively.
**Keywords:** Dabus River Basin,Climate change,CLM, GIS Arc Hydro,HEC-GeoHMS,HEC-HMS,
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## Introduction

Forecasting streamflow response to potential impacts under future scenarios of climate change and variability is the first step to developing long-term water resource management plans. An understanding of the hydrological response of a river basin under changed climatic conditions would help to resolve potential water resources problems associated with floods, droughts and availability of water for irrigation, industry, hydropower, domestic and industrial use, and to develop the adaptation and preparedness strategies to meet these challenges (Singh, 2011). As a result this study is required for Dabu sub-basin.

Eventhough Streamflow forecasting is very important for flood mitigation and water resources management and planning such studies were not yet done in Dabus sub-basin, therefore this research focus on streamflow forecast and assessment climate change impact in this sub basin under A1B emission scenarios.

As a significance, Water resources planning and management efficacy is subject to capturing inherent uncertainties stemming from climatic and hydrological inputs and models. Streamflow forecasts, critical in reservoir operation and water allocation decision making, fundamentally contain uncertainties arising from assumed initial conditions, model structure, and modeled processes. Accounting for these propagating uncertainties remains a formidable challenge. Recent enhancements in climate forecasting skill and hydrological modeling serve as an impetus for further pursuing models and model combinations capable of delivering improved streamflow forecasts.

Therefore streamflow forecast will play great role to estimate inflow to the reservoir to handle problems of water allocation (reservoir operation) in the basin. Finally the intension of the study are forecast streamflow under climate change impact, to assess future climate change pattern and to generate streamflow time series for Dabus River under the impact of climate change.

## Description of the study area

The Blue Nile Basin (Abbay basin) is generally divided into 15 Sub-basins according to their configuration in topology, of which **Dabus Sub-basin** is one of the sub-basins which contribute high percent of water to the Abbay basin next to Dedesa sub basin. Table 1 shows List of main tributaries of Blue Nile (Abbay) basin, emerging from Ethiopia, whereas Figure 1 shows the shape of Abbay sub-basin particularly Dabus sub basin.

Table-1: List of main tributaries of Blue Nile (Abbay), emerging from Ethiopia (Wondye, 2009).

| S.No | Sub-basin | Catchment area ($km^2$) | Mean annual rainfall (mm) | Mean annual flow($Mm^3$) |
|---|---|---|---|---|
| 1 | Lake tana | 15054 | 1313 | 3809 |
| 2 | Beshilo | 13242 | 982 | 3920 |
| 3 | Weleka | 6415 | 1072 | 2072 |
| 4 | Jemma | 15782 | 1105 | 4798 |
| 5 | Muger | 8188 | 1347 | 2440 |
| 6 | Guder | 7011 | 910 | 2187 |
| 7 | Fincha | 4089 | 1766 | 1719 |
| 8 | Dedessa | 27531 | 1308 | 8028 |
| 9 | Dabus | 21030 | 2276 | 6246 |
| 10 | Beles | 14200 | 1655 | 4345 |
| 11 | South Gojam | 16762 | 1633 | 5012 |
| 12 | North Gojam | 14389 | 1336 | 4389 |
| 13 | wonbera | 12957 | 1160 | 3874 |
| 14 | Dinder | 14891 | n/a | 2797 |
| 15 | Rahad | 8269 | n/a | 1102 |
| 16 | Anger | 7901 | 1425 | 1980 |

The Dabus River drains an area of approximately 21030square kilometers. It originates in the high volcanic mountains to the south and flows generally northwards into a large and flat basin known as the Dabus swamp then continuous northward to the Blue Nile River. The River course has a drop of 616 and 638m at upper and lower Dabus dam sites at elevations of 1384 and 1362 m.a.s.l. respectively. The river further drops into an extremely deep narrow canyon prior to leaving the area. The Dabus River has an average annual flow of about 6246$Mm^3$ even though not yet exploited for hydropower.

**Location and climate**

The Dabus River is one of the major tributaries of the Abbay River, which flows for most of its length northwards. The river is known for its sustained flow even during the dry season, which is attributed to the presence of a swamp. The size of the swamp has been reported to be in the range of 600 to 900 $km^2$ (MoWR, 2002). Generally the location of Dabus sub-basin shown in figure 1.

The basin falls within the climatic classification of Tropical Climate II according to the modified copen system. The climate is characterized by a mean annual rainfall between 680 to 1200 mm. The rainfall distribution in the Dabus basin is monomodal, with the length of the wet season decreasing in the northern and north-western parts of the sub-basin. The average daily maximum and minimum temperature is 27.47 $^{O}C$ and 14.43 $^{O}C$ respectively. The average daily evapotranspiration of the basin is 4.32mm.

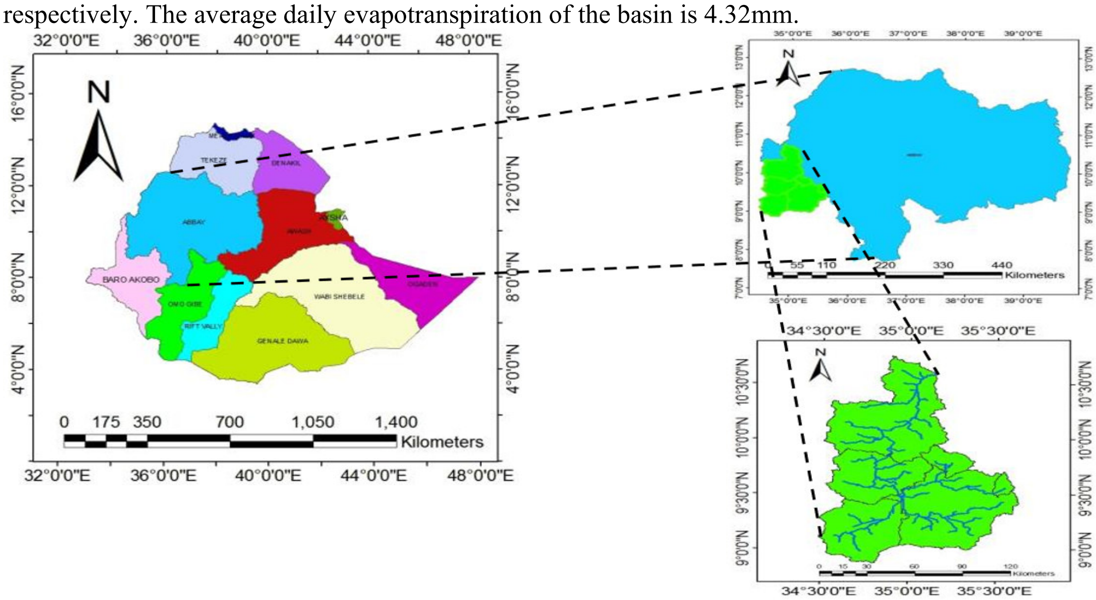



Figure 1: Location of study area (Dabus sub basin)

**Methodology of the study**

The methodology used in this study includes the following steps (1) Data collection; (2) extraction of climate data series from the climate change scenarios; (3) watershed-based hydrological modeling; Flow simulation

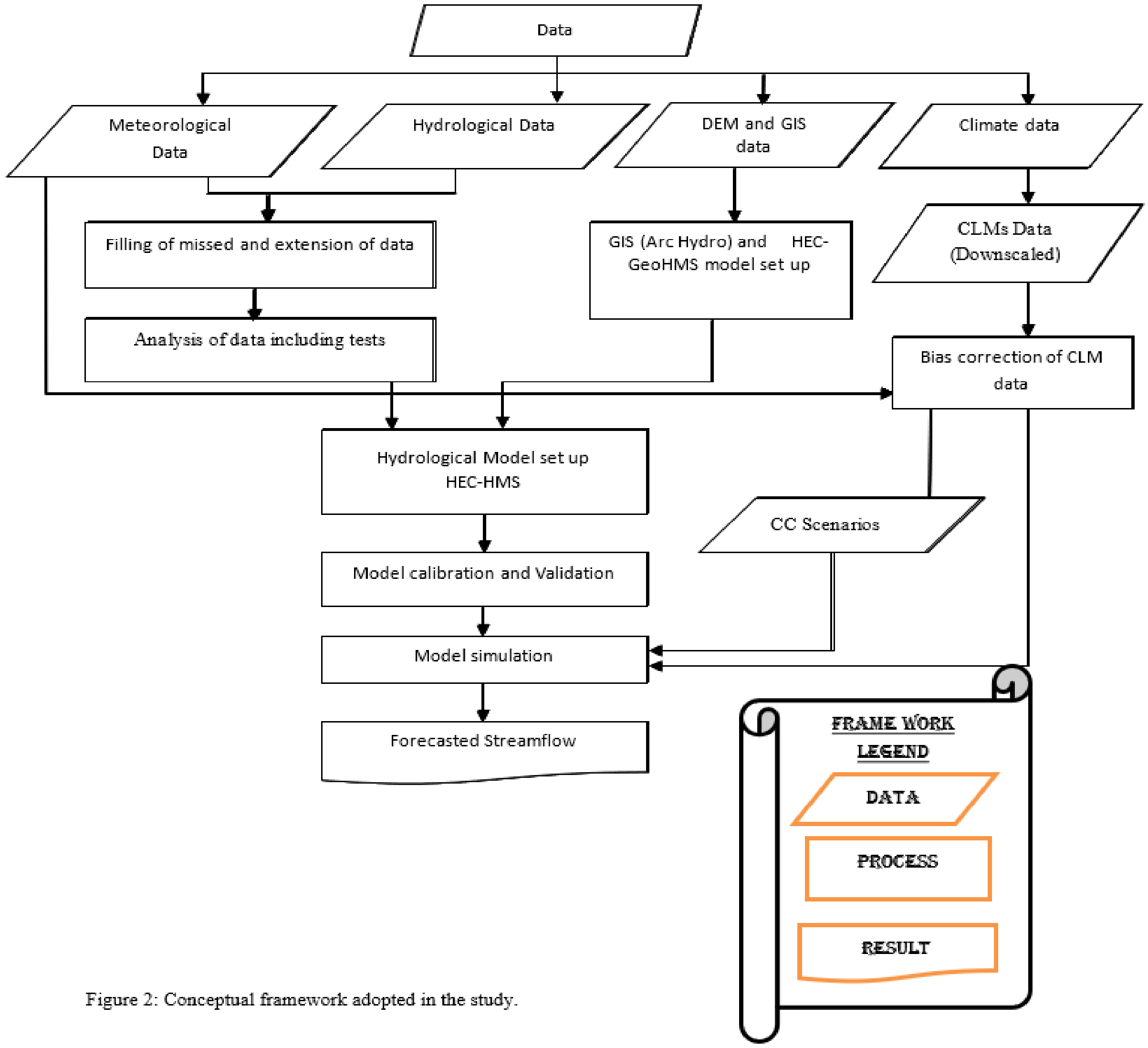



Figure 2: Conceptual framework adopted in the study.

**Climate Change Modeling**

In the study the dynamically downscaled local climate scenarios are used which are simulated by Climate Limited area model (CLM) using the CECHAM5 for a period of 120 years (1981 to 2100) on daily basis. This locally downscaled climate data was from boundary conditions for A1B emission scenario. The downscaled future climate parameters (i.e., precipitation, maximum and minimum temperature, wind speed, and net solar radiation) were corrected by using linear and power transformation bias correction method. The bias corrected data was used for future streamflow estimation.

**Geospatial Hydrologic Modeling Extension (HEC-GeoHMS):-** HEC-GeoHMS was used to visualize spatial information, document watershed characteristics, perform spatial analysis, delineate sub-basins and streams, and construct inputs to hydrologic models.

**Hydrological Modeling:-**Hydrologic Engineering Center’s Hydrologic Modeling System (HEC HMS) was selected for streamflow simulation**.**

**Analytical Components of HEC-HMS:-**HEC-HMS consists of separate models of the major hydrological processes and transports. It consists of runoff volume models, models of direct runoff (overland flow and interflow), base flow models, channel flow models. In the model the deficit and constant-rate loss model, Clark UH transform model, constant, monthly varying base flow method and Muskingum Routing Model were selected for model Calibration and Validation as well for future flow simulation.

A total of 14 years historical data from 1988 to 2001 was used for calibration, 4years was used for validation (2002-2005).The model performance in simulating observed discharge was evaluated during calibration and validation by observing simulated and observed hydrograph visually and by calculating Nash and Sutcliffe efficiency criteria (NSE), coefficient of determination ($R^2$), and Percent difference/Relative Volume Error (D) were used.

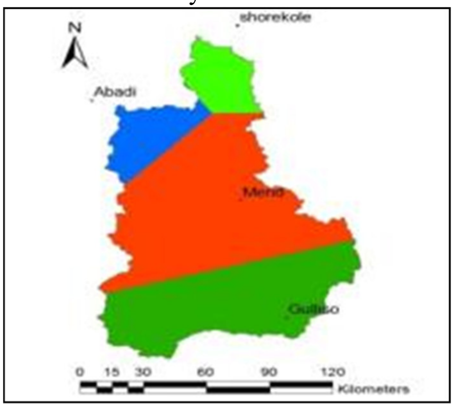
**Hydro-Meteorological Data Analysis**

Since engineering studies of water resources development and management depend heavily on hydrological data, the meteorological data tested for stationary, consistent and homogeneous when they are used for frequency analyses or to simulate a hydrological system. Missing data were filled by using regression equation from the station with full data record.

Table 2: Summary of Hydrological data filling and extension.

| Station Name | From Station | Regression Equation | $R^2$ | Remark |
|---|---|---|---|---|
| DabusNr. Asosa | Haffa | Qd=87.451*Qha+8.235 | 0.86 | Extended |
| SechiNr.mendi | Haffa | Qs=3.646*Qha+0.734 | 0.95 | Filled |
| Aleltu@ Nedjo | Haffa | Qa=1.551*Qha+2.886 | 0.74 | Filled |
| HohaNr. Asoss | | | | Used for Filling |
| HujurNr. Nedjo | | | | Used for Filling |
| HaffaNr. Asosa | | | | Used for Filling |

For areal data thiessen polygon method was used due to the large differences in the catches at therain gages and non-uniformly distribution of the rain gages throughout the study areas.



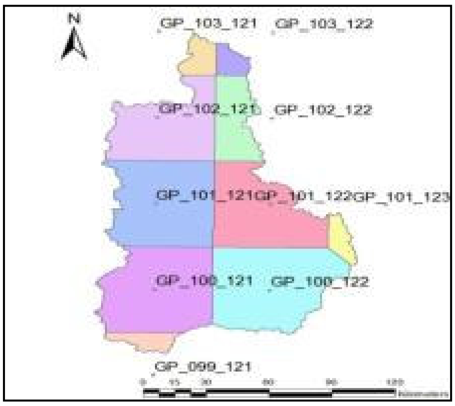



Figure 3: Thiessen polygon of Selected Meteorological stations.

Figure 0: Thiessen polygon of Selected GCM Grid point

Penman-Monteith method is adopted to calculate the daily potential evaporation to use during HEC-HMS model calibration and validation. Power Transformation method of bias correction is applied for precipitation and linear transformation method is used to correct temperature. In each case of bias correction it was intended to match the most important statistics (coefficient of variation and mean) on a scale of 30 days.

$P^* = aP^b$ --------------------------------------------------------------------------Power Transformation method

$T_{corr} = aT_{uncorr} + b$ --------------------------------------------------------------linear transformation method

Table 3: Values of correction constants a & b used for bias correction of RCM data.

| **Block/ Months** | **CLM data and their Correction constants a and b** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Precipitation** | | **Max. Temperature** | | **Min. Temperature** | | **ETo** | |
| | **a** | **b** | **a** | **b** | **a** | **b** | **a** | **b** |
| 1 | 66.575461 | 3.8E-09 | 1.00381 | -1.6434 | 0.826309 | 0.946757 | 7.61E-06 | 6.196132 |
| 2 | 6.0636945 | 0.090955 | 0.807329 | 5.126061 | 0.448998 | 6.920406 | 4.56E-07 | 7.241886 |
| 3 | 3.1102193 | 0.57435 | 0.722348 | 7.817436 | 0.583678 | 3.373884 | 0.072015 | 1.972107 |
| 4 | 3.0872957 | 0.617526 | 0.681677 | 8.722961 | 0.624095 | 2.141734 | 0.559702 | 1.126428 |
| 5 | 1.8086977 | 0.729226 | 0.718825 | 7.303044 | 0.807191 | -1.50456 | 1.427762 | 0.661953 |
| 6 | 3.2839756 | 0.609403 | 0.611604 | 10.21765 | 0.529337 | 3.923512 | 1.93265 | 0.4448 |
| 7 | 3.9855117 | 0.532526 | 0.439287 | 14.3815 | 0.598113 | 2.801073 | 1.398969 | 0.651025 |
| 8 | 3.3187728 | 0.645155 | 0.32334 | 16.90846 | 0.604125 | 2.405754 | 1.954919 | 0.387098 |
| 9 | 2.6448544 | 0.689344 | 0.322971 | 17.41565 | 0.993186 | -4.66651 | 1.952399 | 0.422641 |
| 10 | 2.7971952 | 0.70891 | 0.365757 | 16.68522 | 0.889529 | -1.93666 | 2.213072 | 0.308136 |
| 11 | 2.6332175 | 0.720931 | 0.475219 | 13.94719 | 0.683673 | 2.448604 | 1.748946 | 0.433098 |
| 12 | 7.6568377 | 1.41E-09 | 1.037278 | -2.50133 | 0.809114 | 0.579832 | 0.491927 | 1.055559 |

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## 5. Results and Discussion

### Climate change scenarios

In the study, the climate change scenarios were generated using dynamically downscaled regional climate data for A1B emission scenario. These data were downscaled for the period of 120 years using a Climate Limited area Model (CLM models) which was categorized as: base period (1981-2010), short-term forecast (2011-2040) and mid-term forecasts (2041-2070) and long-term forecasts (2071-2100) in order to forecast streamflow using these scenarios. The period from 1981-2010 was taken as a base period with which the comparison was made. Future scenarios have been assessed for the short-term forecast period (2010-2040) and Mid-term forecast (2041-2070) and Long-term forecast (2071-2100) for three climatic variables temperature, precipitation, and evapotranspiration.

### Maximum Temperature

The dynamically downscaled monthly average maximum temperature reveals good quality relations with the observed temperature for the baseline period after the bias correction has been made comparing with observed data for A1B emission scenarios. As illustrated in Figure 5 the monthly mean maximum of maximum temperature was seen in the month of May whereas monthly mean Minimum of maximum temperature was seen in the month November which later shifted to August month after bias correction has been made.

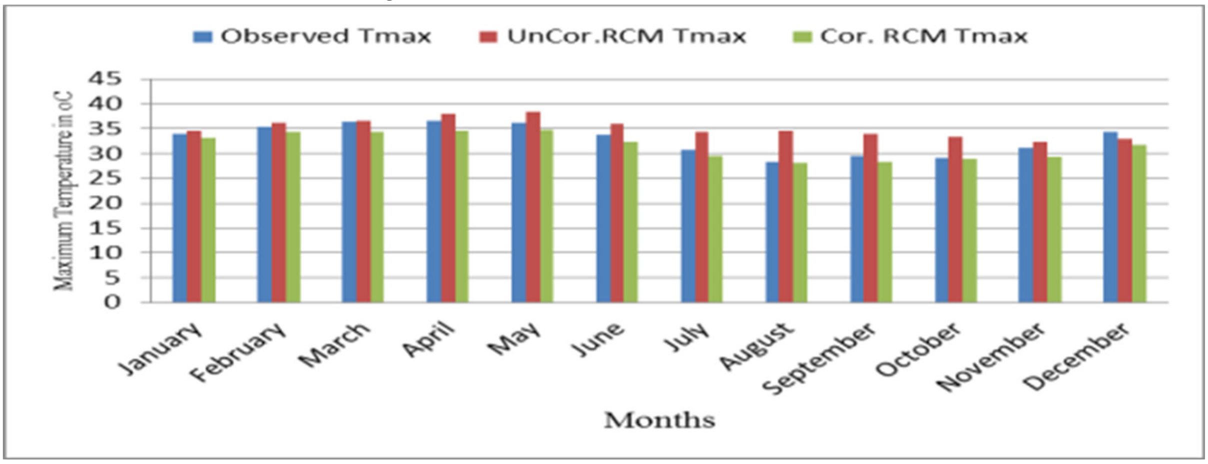


Figure 5: Downscaled, Bias Corrected and Observed mean monthly maximum temperature (1991-2010)

The projected maximum temperatures have generally shows an increase trend for A1B emission scenario in all future time of (2011-2040), (2041-2070), (2071-2100). (Figure 6)

Future projection of maximum temperatures has shown large temperature changes in the month of May for all time horizon of (2011-2040), (2041-2070) and (2071-2100) forecasts that has resulted in a temperature rise of 0.43$^{O}$C, 1.33$^{O}$C and 2.48$^{O}$C respectively as compared to the base period and shows the decreasing only in feature Scenarios of 2011-2040 in the months of August, September and October.

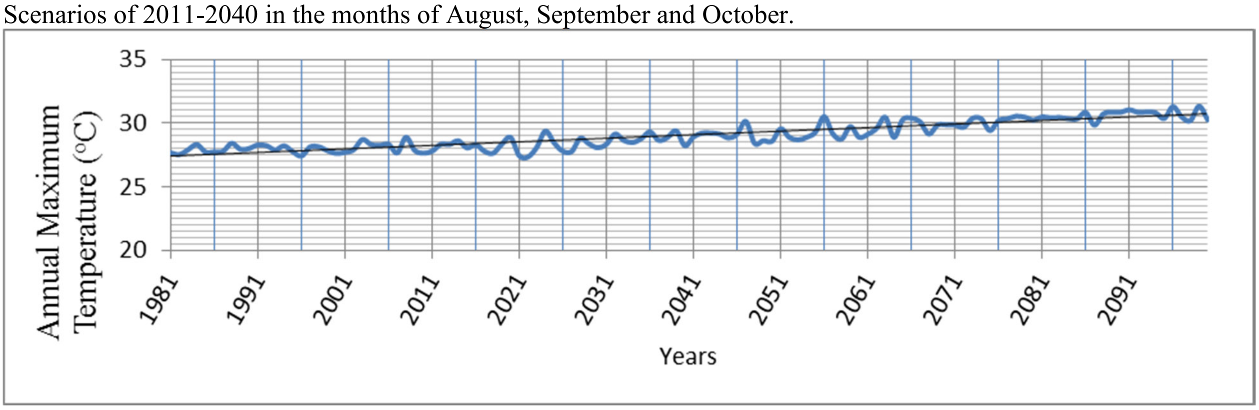


Figure 6: Trend of Annual Maximum Temperature (1991-2100).

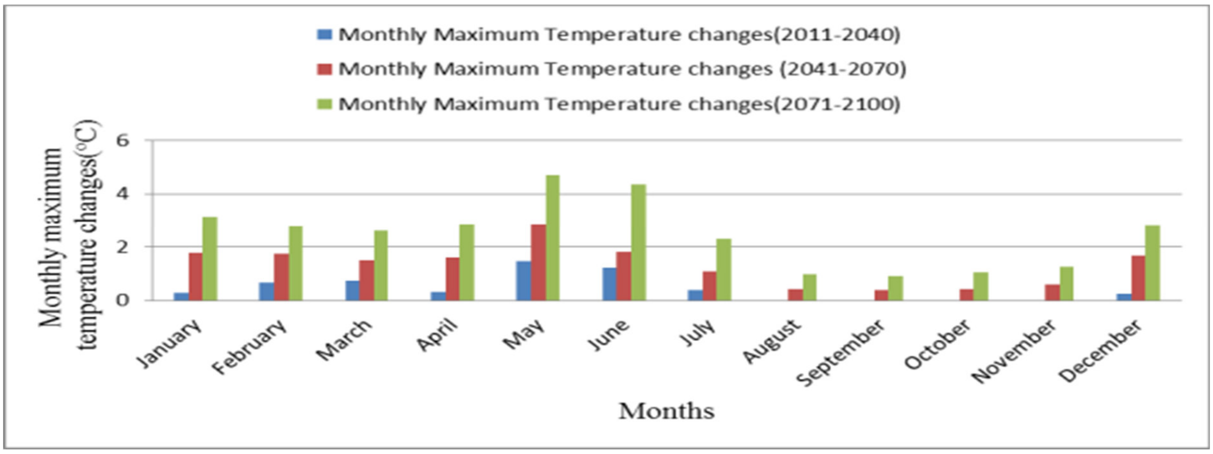


Figure 7: Percentage change of Monthly Maximum Temperature at different Future Scenarios while compared with baseline period.

**Minimum Temperature**

Like Maximum temperature, the dynamically downscaled monthly average minimum temperature reveals good quality relations with the observed temperature for the baseline period after the bias correction has been made comparing with observed data for A1B emission scenarios. The monthly mean maximum of minimum temperature was seen in the month of July whereas monthly mean Minimum of minimum temperature was seen in the month February which later shifted to January month after bias correction has been made. The projected minimum temperatures have generally shown an increase trend for A1B emission scenario in all future time horizon of (2011-2040), (2041-2070) and (2071-2100).

Future projection of minimum temperatures as maximum temperatures has shown large temperature changes in the month of May for all time horizon of (2011-2040), (2041-2070) and (2071-2100) forecasts that has resulted in a temperature rise of 0.47$^{O}$C, 1.53$^{O}$C and 2.83$^{O}$C respectively as compared to the base period and does not shows the decreasing throughout the future time horizons.

**Precipitation**

Unlike the maximum and minimum temperature the projected precipitation does not show an increase trend but it shows month to month variation in (1981-2040) and decreasing trend in (2041-2070) and (2071-2100) in addition to monthly variation. The monthly fluxes shows that mean monthly variation of precipitation in the time horizon of (2011-2040), (2041-2070) and (2071-2100) in which maximum decrease of monthly precipitation was recorded in the month of February (-208.93%), May (-55.84%) and May (-148.21%) respectively whereas maximum increase was recorded in the month of December 28.57%, 54.55% and 70.15% in all future time scenarios respectively under A1B emission scenarios.

Generally the mean monthly projected precipitation does not show an increasing or decreasing trend like maximum and minimum Temperature but it manifests great variation of rainfall for all future times horizon considered in this study under A1B global emission scenarios. The annual mean precipitation of the Dabus sub basin experiences a decrease of 0.74%, 13.44% and 33.78% for the time horizon of (2011-2040), (2041-2070) and (2071-2100) respectively under the A1B emission scenarios.

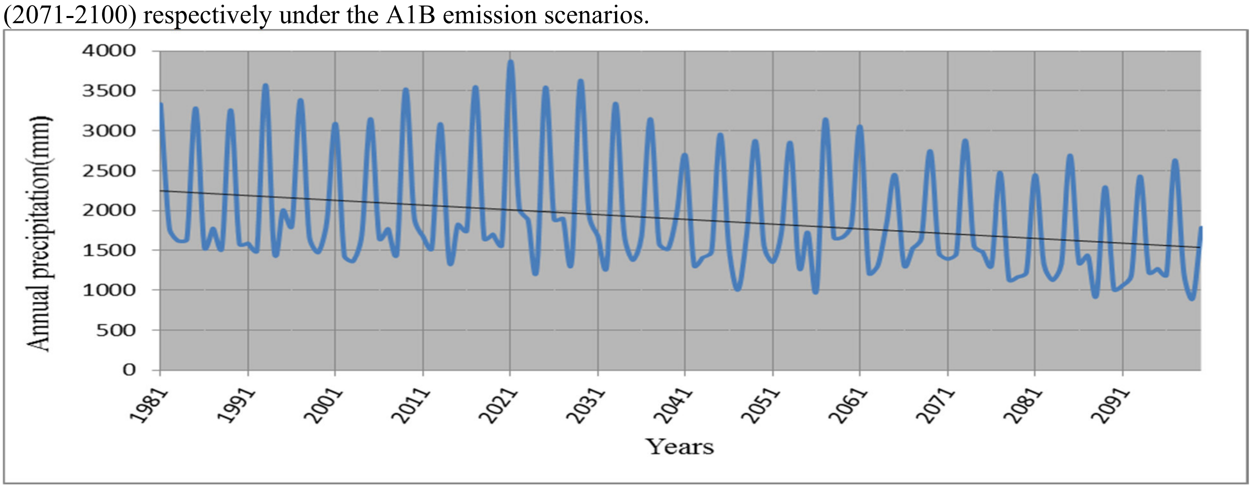


Figure 8: Projected Annual precipitation trend for A1B scenarios (1981-2100).

 

**Evapotranspiration**

The average annual evapotranspiration shows increases in amount by 2.41%, 7.73% and 15.67% in (2011-2040), (2041-2070) and (2071-2100) respectively under the A1B emission scenarios. Figure 9 shows an increasing trend of Evapotranspiration under the A1B emission scenarios for Dabus Sub basin. The rate of monthly evapotranspiration is found to increase comparatively at higher rate during the months of February and May in (2011-2040) and (2041-2070) and the month of February in (2071-2099) whereas slight decreasing rate in the months of August to December in (2011-2040), in the months of October to December in (2041-2070) and in the months of November and December in (2071-2099) under A1Bemission scenarios.

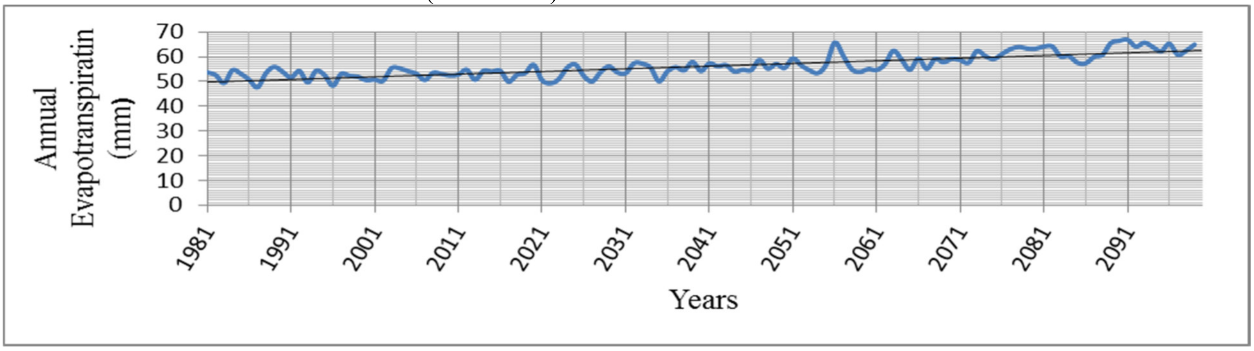


Figure 9: Projected Annual Evapotranspiration trend for A1B scenarios (1981-2100).

**Hydrologic Model (HEC-HMS) Results**

In this study HEC-HMS Hydrologic Model was used for Dabus sub basin Streamflow simulation. The basin model created by HEC-GeoHMS was imported to HEC-HMS and the parameter estimated in HEC-GeoHMS such as Clark time of Concentration, Clark storage coefficient, initial Deficit, Maximum deficit, Constant Rate and etc. was used as initial parameters for model simulation which later optimized based the acceptable value of NSE and $R^2$.

**HEC-HMS Model Calibration and Validation Results**

In this particular study among the existing methods in the model, the Univariate-Gradient Algorithm and the sum of squared residuals measure for goodness of fit have been applied for calibrating the model. As parameter estimation using optimization does not produce perfect results without the aid of manual calibration, it is aided by manual calibration. Figure 10 shows Hydrograph of Model Calibration at Dabus Gauge near Asosa. The 14- years of observed flow time-series data (1988 - 2001) of Dabus Gauge near Asosa, Sechi Gauge near Mendi and Aleltu Gauge at Nedjo have been used for model calibration whereas 4- years of observed flow time-series data (2002 - 2005) of the same stations was used Model validation. During both calibration and validation the peak flow was not captured in all gauging stations, as a result of this precipitation loss become unrealistically large. Figure 11 shows Hydrograph of Model Validation at Dabus Gauge near Asosa.

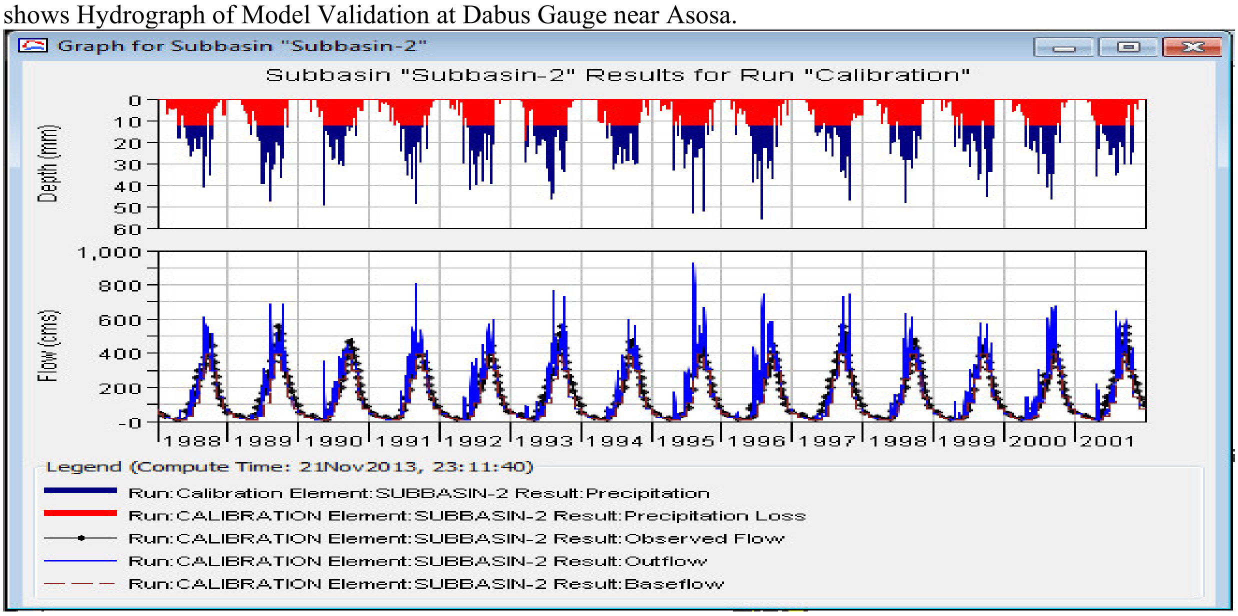


Figure 10: Daily Simulated flow Hydrograph calibrated and Observed flow at Dabus Gauge Nr Asosa Station Comparison (1988-2001).

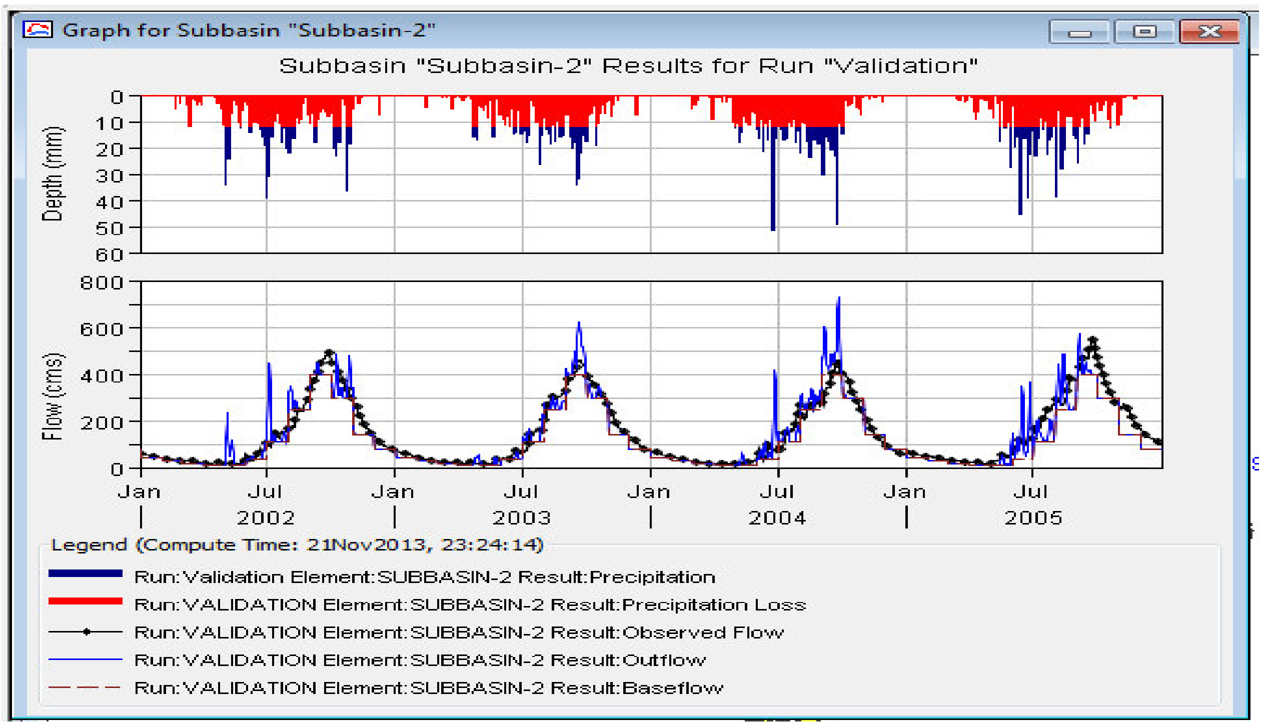


Figure 11: Daily Simulated flow Hydrograph Validated and Observed flow at Dabus Gauge near Asosa Station Comparison (2002-2005).

The Simulated Streamflow Hydrographs in both Calibration and validation have shown a very good counterpart with the corresponding observed hydrographs of equivalent time of consideration in volume but little bit it shows less performance in peak flow.

In this particular study, the model performance in simulating observed discharge has been evaluated using Nash and Sutcliffe efficiency criteria (NSE), coefficient of determination ($R^2$), Percent difference /Relative Volume Error (D) in both calibration and Validation. The results of the performance evaluation criteria of the HEC-HMS model are summarized in tabular form as shown in Table 4.

Table 4: Performance indices of model during Calibration and Validation.

| **Indices** | **Gauging Stations** | | | | | |
|---|---|---|---|---|---|---|
| | **DabusGauge Nr Asosa** | | **SechiGauge Nr Mendi** | | **AleltuGauge@Nedjo** | |
| | **Calibration** | **Validation** | **Calibration** | **Validation** | **Calibration** | **Validation** |
| NSE | 0.89 | 0.82 | 0.52 | 0.59 | 0.32 | 0.44 |
| $R^2$ | 0.91 | 0.84 | 0.52 | 0.59 | 0.34 | 0.44 |
| D | 0.0066 | 4.9285 | -0.1047 | -2.0995 | -0.0096 | -1.5131 |

The result of Calibration and Validation has revealed a very good simulation performance, satisfactory performance and less performance for the Dabus gauge, Sechi gauge and Aleltu gauge respectively in NSE and $R^2$performance indices according to the criteria point out by different researcher under section 4.1.4. Even though all stations shows a very good performance indices in Percent difference /Relative Volume Error (D) due to the great difference in other two performance indices only parameters optimized from Dabus Gauging station were used for future streamflow generation and future inflow to the reservoirs generation.

**Generated Streamflow of Dabus River**

Like areal precipitation of the sub basin, The Dabus streamflow of Dabus basin or merging to the main Abbay river Experiences flow variation for the time horizon of (1981-2040) and decreasing trend for the time horizon of (2041-2070) and (2071-2100). These shows that, the streamflow of the sub basin has strong relation with the precipitation of the basin that shown disordered variation as a result of global warming under A1B emission scenarios.

The rate of mean monthly streamflow of the Dabus sub basin at its outflow manifests high rate of decreasing in the month of May and June for the time horizon of (2011-2040) and May, June and July for the time horizon of (2041-2070), (2071-2100). In the other months it does not show such highly decreasing trend but it shows less significance of increasing trend on the basis of mean monthly flow. Generally the streamflow forecasted using HEC-HMS under the impact of climate change (A1B emission scenarios) in this study shows the variation of flow month to month for different year of study with insignificant decreasing or increasing of annual flow for consecutive years.

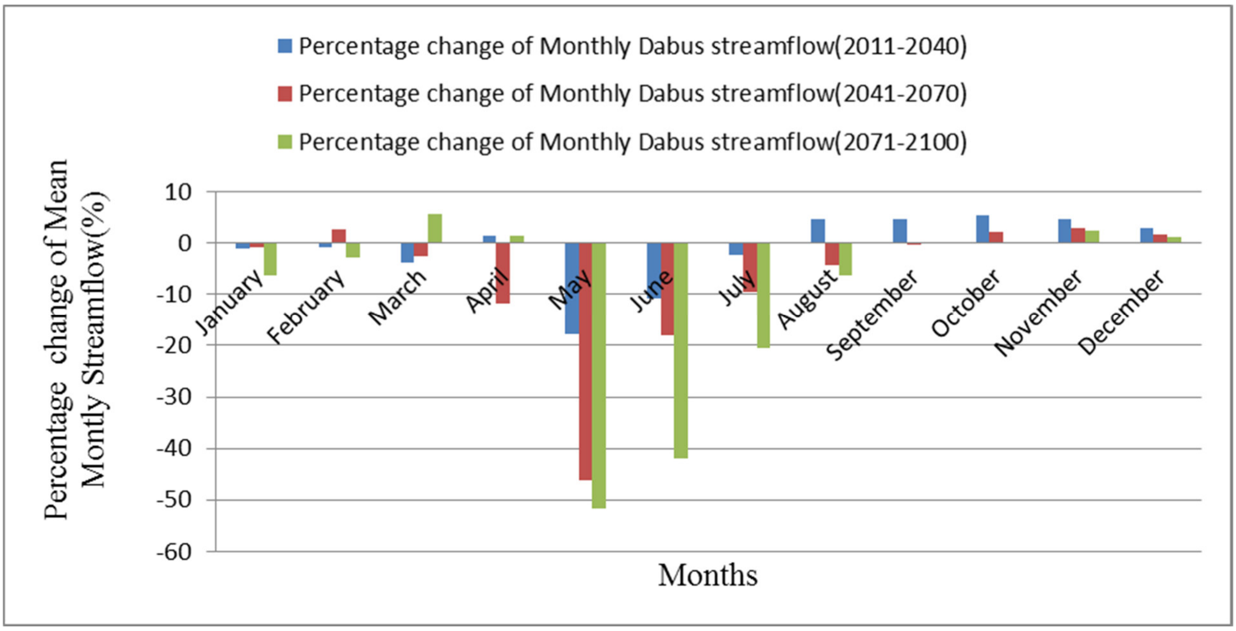


Figure 12: Percentage change of mean monthly Streamflow generated under A1B emission scenarios

### 1.1.1. Conclusions

Nature and especially climate is not easy to be exactly forecasted even with the advanced technologies of the 21[st]century. Human beings, at a larger scale, are still in the hands of climatic influences, where extreme events of floods and droughts keep on claiming many lives all over the world and brought unlimited effects on Water Resources Developments Like irrigation efficiencies and Hydropower production due to decreasing and disordered rainfall pattern all over the world. As a result of these, the study of climate change impact assessment of Dabus sub basin streamflow is highly essential. In this study the streamflow and inflow to reservoirs were forecasted by HEC-HMS model. Based on this particular study the following are concluded:

1. The result of climate projection reveals that the CLM model has very good ability to replicate the historical maximum and minimum temperature for the observed period; but due to its conditional nature and high variability in space it reveals that less ability to replicate for the observed precipitation with the simulated precipitation.
2. Generally both dynamically projected maximum and minimum temperature shows an increasing trend for the next century, but the precipitation doesn't show significant difference for future scenarios where it shows variation in short-term forecast (2011-2040) and less decreasing trend in mid-term forecast (2041-2070) and long-term forecast (2071-2100) for A1B emission scenario.
3. The evaporation from the Dabus sub basin (open water) generally shows an increasing trend which will be increased highly from decade to decade i.e. 2% in earlier century (2011-2040), 6.62% in mid-century (2041-2070) and 50% in late century (2071-2100). Generally 19.5% of monthly average increase of evapotranspiration will be expected at the end of the next century in Dabus sub basin under A1B emission scenario. The increasing of the Evapotranspiration causes its own impact on the reservoir water balance by decreasing the reservoir volume which later expose the reservoirs to supply deficit i.e. reduce volumetric reliability.
4. The HEC-HMS model calibrated and validated in daily time step at three gauging stations: Dabus near Asosa, Sechi near Mendi and Alelt at nedjo were manifest less performance at Sechi near Mendi and Aleltu at Nedjo and very good performance at Dabus near Asosa. Having the optimized parameters at Dabus near Asosa the model has simulated the observed discharge in reasonably good manner particularly in simulating runoff volume on the daily basis. Generally the model has revealed a good performance at Dabus near Asosa with performance indices of Nash and Sutcliffe Efficiency value = 0.90, Coefficient of Determination $R^2$ value = 0.89, and relative Volume, Error, D = 0.0066 on the Daily basis. Hence, HEC-HMS model shows well performance in simulating observed flow, as a result of this it was used for future flow simulation based on CLM predicted precipitation and estimated evapotranspiration under A1B emission scenarios.

### Recommendations

From the result of this particular study the following main recommendations are highly recommended.

1. In this study the effect of climate change was assessed using the climate variables downscaled dynamically under A1B emission scenarios but using this single emission scenarios may not fully replicate the effect of

climate on water resource projects therefore it is better if another emissions scenarios and downscaling methods of finer resolution are adopted and the differences should be assessed.

**References**

Abeyou Wale. (2008). Hydrological balance of lake tana upper blue nile,Ethiopia. *Internation Institution for Geo-informatics and Earth observation*.

Habtom. (2009). *Evaluation of Climate Change Impacton Upper Blue Nile Basin Reservoirs,(Case Study on Gilgel AbayReservoir, Ethiopia)*. Arbaminch: Unpublished MSc thesis.

Hashimoto et al. (1982). Reliability, resiliency and vulnerability crireria for water resource system performance evaluation. *WaterResources Research 18*, 14-20.

William A. Scharffenberg and Matthew J.Fleming. (2010). Hydrologic Modelling System. In U. A. Engineer. Washington DC, 20134-1000: US Army Corps of Engineer.

Allen, R. e., D. R., & &. M. (1998). Crop evapotranspiration Guidelines for computing crop water requirements.

Awulachew, A. D. (2009). Blue Nile Basin Characterization and Geospatial Atlas. *International Water Management Institute*, (p. 6). Addis Ababa, Ethiopia.

B.C.Hewitson, R. C. (1996). Climate downscaling: techniques and application . *Climate Research*.

Bergstrom S. (2001). Climate change impacts on runoff in Sweden – assessments byglobal climate models, dynamical downscaling and hydrological modelling. *Climate Research 116*, pp. 101-112.

Bryson Bates et. al. (2008). *Climate Change and Water.* IPCC Secretariat, Geneva, 210 pp: aper of the Intergovernmental Panel on Climate Change.

C. C. WARNICK . (1984). *Hydropower Engineering.* Moscow, ldaho: Prentice-Hall. Inc., Englewood Cliffs.

Chang, M. and R. Lee. (1974). Objective of Double-Mass Curve Analysis. *Water Resources Research*, 10(6):1123-1126.

Conway, D. (2004). *Canadian Foundation for Climate and Atmospheric Sciences (CFCAS).* CFCAS Annual Report.

Cunderlik M. and Simonovic, S. P. (2007). Hydrologic Models for Inverse Climate Change Impact Modeling, the 18th Canadian Hydrotechnical Conference on Challenges for Water Resources Engineering in a Changing World, Winnipeg, Manitoba, August 22-24, .

Dahmen & Hall. (1990). *Screening of Hydrological Data.* WageningeqThe Netherlands: International Institute for Land Reclamation and Improvement/ILRI.

Engineer, U. A. (2007). HEC-ResSim-Reservoir System Simulation. In U. A. Engineer, *HEC-ResSim-Reservoir System Simulation.* US Army corps of Engineer, Institute of water Resources, Hydrological Engineering Center.

Engineer, U. S. (2000). *Hydrologic Modelling System HEC HMS Technical Reference manual.* United State Arms Corps of Engineer Institute of water resources.

FAO. (1988). Irrigation and Drainage paper 56. In F. A. Organization.

Girma, Y. (2008). Hydrological Response of a Catchment to Climate Change, Case Study on Upper Beles Sub-basin,Upper Blue Nile, Ethiopia. *Msc Thesis at UNESCO-IHE Institute for Water*.

Hashimoto, T. S. (1982). *WaterResources Research*, 14-20.

Hashimoto, T., Stedinger, J.R., Loucks, D.P. (1982). Reliability, resiliency and vulnerability crireria for water resource system performance evaluation. *WaterResources Research 18* , 14-20.

Hostetler S.W. et al., A. J. (2011). *Dynamically downscaled climate simulations over North America: Methods, evaluation and supporting documentation for users:.* U.S. Geological Survey Open-File Report 2011-1238.

Hostetler, S. A. (2011). *Dynamically downscaled climate simulations over North America: Methods, evaluation and supporting documentation for users.* U.S. Geological Survey Open-File Report 2011-1238.

Hurst et al. (2007). HEC-ResSim Reservoir Simulation System. In U. A. Engineer.

Ines, A. V. M. and Hansen, J. W. (2006). Bias correction of daily GCM rainfall for crop simulation studies. *Agricultural and Forest Meteorology 138*, PP. 42-45.

IPCC. (2007). *Climate change 2007: Impact, Adoptation and Vulnerablity.* 32 Avenue of the Americas, New York, NY 10013-2473, USA: Cambridge University Press.

IPCC-TGCIA. (1999). Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment. In T. M. Version 1. Prepared by Carter, *Intergovernmental Panel on Climate Change, Task Group on Scenarios for Climate Impact* (pp. 35-40).

Jothiprakash, R. V. (2004). *Intermittent reservoir daily-inflow prediction using lumped and distributed data multi-linear regression models.* Bombay: Department of Civil Engineering, Indian Institute of Technology, Bombay 400 076, India.

Jothiprakash, S. M. (2004). Community wells for sustainable irrigation in tank commands:. *30th WEDC International Conference, Vientiane, Lao PDR,.* India.

Leander, R. and Buishand. (2007). Resampling of regional climate model output for the simulation of extreme

river flows. *J. Hy-drol., 332, 487–496, doi:10.1016/j.jhydrol.2006.08.006*.
Makkeasorn, A. (2008). Short-term streamflow forecasting with global . *ELSEVIER*.
Martial Bernoux, L. B. (2011). Main recommendations for the elaboration of the baseline climate asseessment. *FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS*.
McCuen, R. H. (1998). Hydrologic Analysis and design. In R. H. McCuen, *Hydrologic Analysis and design* (pp. 208-210). Upper Saddle River, New Jersey 07458: University of Maryland.
Mearns, L. O. (2009). Methods of Downscaling Future Climate Information and Applications. *National Center for Atmospheric Research* .
Ministry of Water Resources. (2002). DABUS MEDIUM HYDROPOWER PROJECT .
Modini, C. (2010). *USING HEC-RESSIM FOR COLUMBIA RIVER TREATY FLOOD CONTROL.* Chan Modini, Senior Hydraulic Engineer, Corps of Engineers, Hydrologic Engineering Center, Water Resource Systems Division,.
Motovilov Y.G., G. L. (1999). *Regional model of hydrological cycle.Application to the NOPEX region.* Department of Geophysics, University of Oslo.
MoWR, F.-E. (2002). *DABUS MEDIUM HYDROPOWER PROJECT.* Addis Ababa.
Musa, J. J. (2013). Stochastic Modelling of Shiroro River Stream flow Process. *American Journal of Engineering Research (AJER)*, 51-55.
Naylor, R. L. (2008). Managing Food Production Systems for Resilience. In R. L. Naylor, *Principles of Natural.* New york: Springer, in press.
P. Novak, A. M. (2004). *Hydraulic Structures.* 11 New Fetter Lane, London EC4P 4EE,New York,: Spon Press.
Richard G. Allen, L. S. (1998). Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56. In *Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56.* Rome,Italy: FAO - Food and Agriculture Organization of the United Nations.
Richard Moss,et al. (2007). *Towards new scenarios for analysis of emissions, climate change, impacts, and response strategies, IPPC expert meeting report.* Geneva: Intergovernmental Panel on Climate Change.
Simonovic, L. L. (2009). Streamflow Forecast and Reservoir opeartion. *Water Resour Manage(2010) 24*, 84-104.
Singh, A. I. (2011). Streamflow Response to Climate Change. *Water Resource Management (2012) 26:1409–1424*.
Smith, J. a. (1998). *Climate change scenarios. In Handbook on Methods of Climate Change Impacts Assessment andAdaptation Strategies.* October, Amsterdam: Tol (eds.)]. UNEP/IES, Version 2.0.
T.R. Carter, M. H. (1999). *Guidelines on the use of scenario data for climate impact and adaptive Assessment, Version 1.* Task Group on Scenarios for Climate Impact Assessment Intergovernmental Panel on Climate Change.
Teklu Erkossa et al. (2000). Impacts of Improving Water Management of Smallholder Agriculture in the Upper Blue Nile Basin.
Terink et al, R. T. (2009). *Bias correction of temperature and precipitation data for regional climatemodel application to the Rhine basin.* The Netherlands: Copernicus Publications on behalf of the European Geosciences Union.
Thomas et al. (2004). Global streamflows – Part 2: Reservoir storage–yield performance. *Journal of Hydrology*.
Tsegaye.E. (2006). *Regionalization of potential Evapotranspiration prediction for Blue Nile (Abbay) river basin, Ethiopia.* Arba Minch University, Ethiopia: M.Sc thesis.
US Army corps of Engineer. (2010). Hydrologic Modeling System HEC-HMS. In *US Army corps of Engineer.* US Army corps of Engineer,Institute of water resources HEC.
US Army corps of Engineer, H. E. (2010,Version 5). In *HEC-GeoHMS, Geospatial Hydrologic Modelling Extension.* US Army Corps of Engineers.
Wale, A. (2008). *Hydrological balance of lake tana upper blue nile,Ethiopia.* The Netherlands: Internation Institution for Geo-informatics and Earth observation.
Wilby, RL, and TML Wigley. (1997). Downscaling general circulation model output: a review of methods and limitations.
www.ipcc.ch. (2013). *Working Group I: The Scientific Basis*. Retrieved 10 25, 2013, from www.ipcc.ch