Civil and Environmental Research www.iiste.org
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.8, No.11, 2016

Assessment of Climate Change Impact on Flood frequency of Bilate River Basin, Ethiopia

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Abstract
Climate change have different impacts on many sectors among those impacts of climate change on water resources, especially on flood frequency of Bilate Watershed were discussed. The study was conducted to asses climate change impact on flood frequency of Bilate River basin. The input data such as (DEM-90m), soil, land use, meteorological data (precipitation, maximum and minimum temperature, wind speed, sunshine), Hydrological data (stream flow) were obtained from ministry of Water resource, irrigation and energy and national meteorology agency respectively. The obtained data was analyzed by using data analysis technique and the climate data was bias corrected for both temperature and precipitation using power transformation technique and linear regression method respectively and finally preferred as in put for HEC-HMS model to calibrate the stream flow data from the year 1988 to 2003 and validate from 2004 to 2010. The R^2 and Nash- Sutcliffe Efficiency (NSE) value for the Watershed were 0.75 and 0.611 for calibration and 0.78 and 0.623 for the validation respectively. Once the calibration was completed HEC-SSP software was used to done flood frequency analysis of the watershed using different type of distributions. The analysis was shows that among different type of distributions log normal and Pearson type (III) distributions are good and that are used to observe the climate change impact on flood frequency of Bilate River basin.
Keywords: Climate Change, HEC-HMS Model, RCP data HEC-SSP Software, Bilate River Basin.

Introduction

Climate change is considered as one of the biggest challenges of 21st century to the whole world will face. It is now widely accepted that climate change is already happening now and further changes is inevitable; over the last century (between 1906 and 2005) global temperature rose by about 0.74°C. This is occurred in two phases a further change is inevitable from 1910s to 1940s and more strongly from 1970s to present according to (IPCC, 2007).

Precipitation is one of the most important hydrological variables of the basin. In particular, it greatly influences the amount of water flowing through the water cycle and water availability. In general, the higher the precipitation, the more water is available; low precipitation and drought generally reduce water supply. Similar to precipitation, temperature is another important parameter in assessing the climate change impact on water resource system. According to climate model predictors, using several scenarios of greenhouse gas emissions, global mean temperature probably will increase from 1.1 to 6.4ocin the next 100year (IPCC, 2007).

In flood frequency analysis the objective is to estimate a flood magnitude corresponding to any required return period of occurrence. The resulting relationship between magnitude and return period is referred to as the Q-T relationship. Return period T, may be defined as the time interval for which a particular flood having magnitude Q_T(also known as quantiles) is expected to be exceeded (Admasu, 1989). Return period is also referred to as recurrence interval. The magnitude of flood is inversely related to their frequency of occurrence, high floods occurring less frequently than moderate flood (Admasu, 1989).

Therefore, the main objective of the research was to assess climate change impacts on flood frequency of Bilate River basin.

Study Area and Data Availability

Description of the study area

Bilate River basin is among the sub basins that are part of Abaya-Chamo basin, which is the sub-basin of the Rift Valley Lake basin. It is situated in the southern west part of the major catchments in the Ethiopia Rift Valley Lakes Zone. It is located highly between37^0 47’ 6’’ to 38^{0}C 20’ 14’’ E and 6 ^{0} 33’ 18’’ to 8^0 6’57’’ N longitudes and latitudes respectively. The basin covers a drainage area of about 5312 km^2 and the altitude of the region varies between 3382 masl and 1179 masl . Bilate river catchment drains from the north of the Abaya-Chamo Basin to Lake Abaya and constitutes about 38% of Lake Abaya basin.

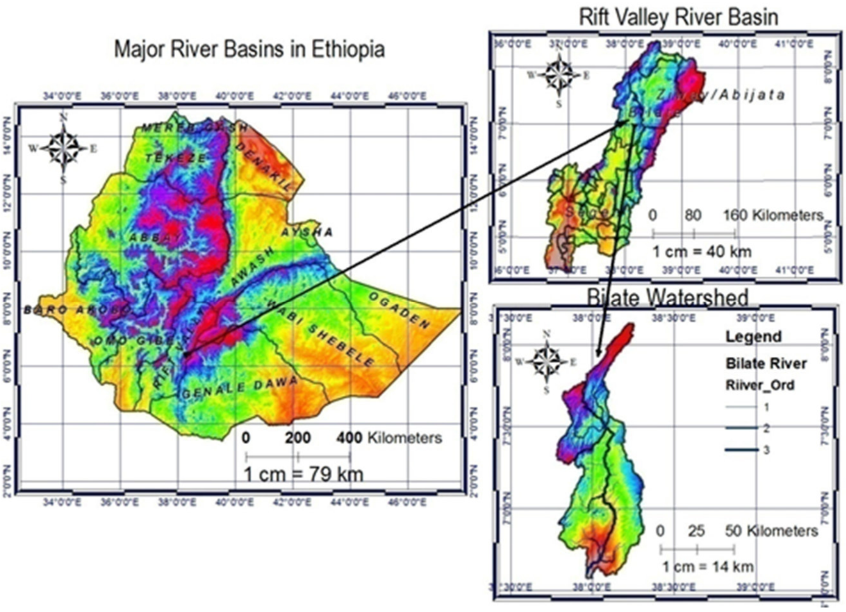


Figure 1: Location Map of the study area.

In the upstream watershed there are two tributaries, the Gudar and Weirariver. Gudar originates from near hosanna and flows east to reach Boyo swamp and Weira originates from Guragie zone. Both tributers join at the outlet of Boyo swamp and from river Bilate and flow southwards in to Lake Abaya.

There is a high spatial and temporal variation in rainfall in the study area. The total annual rain fall is between 1280- 1339mm in the upper part, 1061-1516mm in the middle and 769-956mm in the lower part of the study area.

Generally, in the highlands of Bilate basin (like hosanna), the mean annual temperature varies from 11^{O}C in August to 22°C in March /April while the temperature variation in the lower part of Bilate (Bilate state farm) generally is higher and ranges between 16°C in July to 30°C in January and March .

The commonly observed land use and land cover is riparian wood and bush land, pastoral gaze ring and scattered seasonal cultivation. Especially in Guragie highlands, there are cultivation of Inset, Banana and Cereals; mixed agriculture in pitches, cultivation of cereals and pulses grazing and forest harvesting is also common. In lower basin, large state farms (Abaya, Bilate-Tobaco monopole) were cotton, tobacco, and maize productions are available.

The dominant soil in the basin includes Vertic andosols with to sandy loam in the middle sub basin, Chromic luvisols from clay to sandy loam in upper sub basin, chromic vertisols in the lower and middle sub basin of sandy loam to loam pellic vertisols in the upper and middle sub basin,eutric nitosols eutric fluvisols in the midile and lower sub basin and Lithosols in the upper and lower sub basin of sandy soils; deep red to brownish soil associated with vertic andosols cover the rolling hills plains around Alaba to Wolyta Sodo.

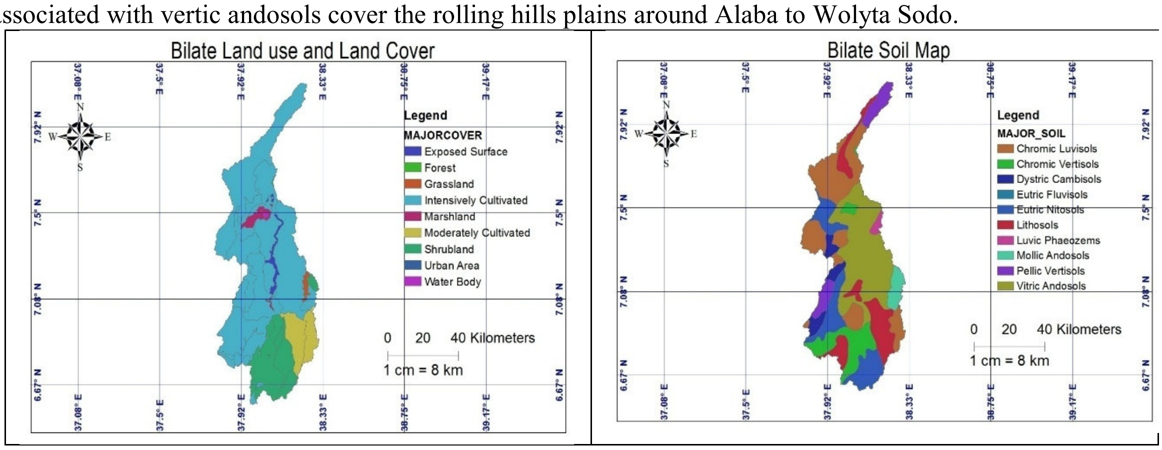


Fig 2: The land use land cover and soil map of the study area.

Collection of important data

Meteorological data

Meteorological data required as an input to the HEC-HMS model was collected from the National meteorological Agency of Ethiopia.The number of meteorological variables collected varies from station to station depending on the class of the stations that are grouped in to three. The first group of stations contains only rainfall data. The second group includes maximum and minimum temperature in addition to rainfall data. The principal station includes variables like relative humidity, sunshine hours and wind speed in addition to rainfall and temperature.

Stations such as Bedesa, Bilate tena, Fonko,Humbo tebela and Shone have only rainfall data. Thus these stations are not useful for hydrological model development. There for only five stations was selected for these study such stations are Alaba kulito, Bilate farm,Hossana, Bodity and Wulibareg station respectively.

Hydrological data
The stream flow of River Bilate was used for calibrating and validating the model. There are six gauging stations inside the sub basin but only two stations such as near Alaba kulito and Bilate Tena have long record. Gauging station near Bilate Tena was selected for calibration and validation of the model because the station is located at the outlet of the water shade. These data was collected from ministry of Water Energy and Irrigation (MoWEI), Hydrology department.

Climate scenario data
Regional Climate data was used to quantify the relative change of climate variables between the current and future time horizon which in turn was used as input to hydrological model for assessment of hydrological impacts. The Regional Climate data used for bias correction technique was obtained from the International Water Management Institute (IWMI)

Spatial data
Digital elevation model (DEM) of 90mx90m for the study area was obtained from ministry of water energy and irrigation (MoWEI) .Geographical coordinates, catchment area and other related spatial data were processed and delineated from the 90mx90m DEM using arc GIS 9.3 Version.

Methodology
Data analysis
Checking of data consistency
In this study double mass curve consistency checking techniques is used to check the consistency of the data, because it shows clearly the consistency of individual station cumulative data with cumulative average in one graph. The principle of double mass curve analysis is to plot accumulated values of the station, under investigation against accumulated value of another station, or accumulated values of the average stations, over the same period of time.

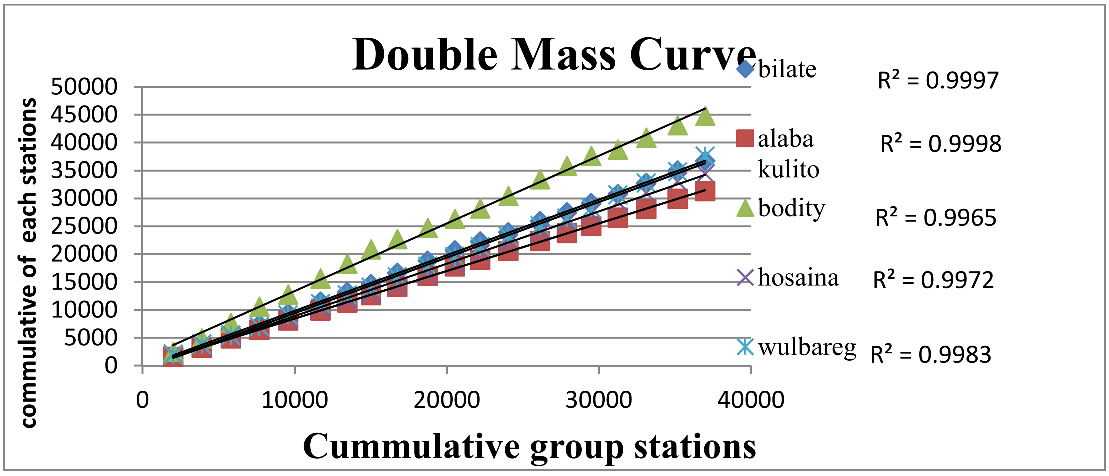


Fig 3: Double mass curve of the stations

Areal rainfall
Areal rainfall is the average rainfall over an area, and is referred to as the areal rainfall distribution and is restricted to long-term average values. It is expressed as a mean depth (mm) over the catchment area (Elizabeth M., 1994). Figure 4shows Thiessen polygon areal proportion of each selected stations in the sub-basin.

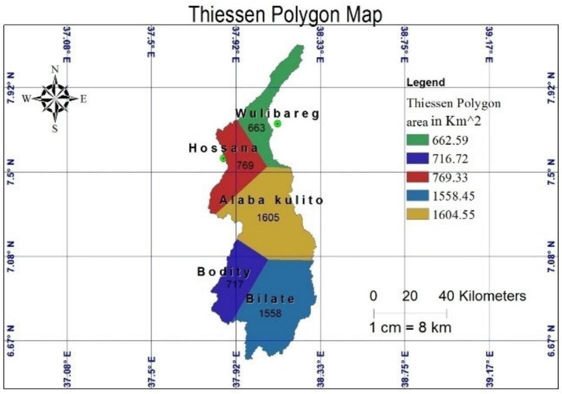


Figure 4: Thiessen polygon of sub-basin:

The areal rainfall R is given by equation:

$$R = \sum_{i=1}^{n} \frac{R_i * A_i}{A}. \qquad (1)$$

Where;

R_i = The rainfall measurements at n rain gauges

A_i = Corresponding to the rain gauge stations and

A = The total area of the catchment.

Determination of Evapotranspiration:

Potential evaporation was computed using the Penman Monteith method, which has been applied successfully in different parts of the world, was compared with other methods and is accepted as the preferred method for computing potential evaporation from meteorological data. Evapotranspiration, one of the factors that may create a soil deficient, thus controls the run-off generation from the subsequent storms. The method of calculating potential evapotranspiration depends on the data available. Monthly time step, evapotranspiration was estimated since monthly values change little from year to year; mean monthly values will usually be adequate.

The reference evapotranspiration is assessed in the ETo calculator software from meteorological data by means of the FAO Penman-Monteith equation. This method has been selected by FAO as the reference because it closely approximates grass ETo at the location evaluated, is physically based, and explicitly incorporates both physiological and aerodynamic parameters (FAO, 2010).The FAO Penman-Monteith equation (Allen et al., 1998) is given by:

$$ETo = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}U2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U2)} \qquad (2)$$

Where;

ETo = reference evapotranspiration [mm day-1],

Rn = net radiation at the crop surface [MJ m-2 day-1],

G = soil heat flux density [MJ m-2 day- 1],

T = mean daily air temperature at 2 m height [°C],

U2= wind speed at 2 m height [m s-1],

e_s= saturation vapor pressure [kPa],

e_a= actual vapor pressure [kPa],

es-ea= saturation vapor pressure deficit [kPa],

Δ= slope vapor pressure curve [kPa °C- 1],

γ= psychometric constant [kPa °C-1]

HEC –HMS Model set up

The main input data used for HEC-HMS are precipitation, evaporation, observed flow, base flow and different watershed characteristics obtained from Arc –Hydro and HEC-Geo HMS process for initial parameter estimation after converting data from geographic to hydrologic data structure in the HEC-Geo HMS the next step was configuration of the HEC –HMS model.

HEC-Geo HMS (Geo spatial hydrologic modeling extension)

HEC-Geo HMS program allows users to visualize spatial information, water shade characteristics, perform spatial analysis, delineate sub basins and streams, construct inputs to hydrologic models, and assist with report preparation working with HEC-Geo HMS through its interfaces, menus, tools, buttons and context sensitivity on line help allows the user to appropriately create hydrologic inputs that can be used directly with the HEC-HMS.

HEC-Geo HMS creates back ground map files, basin map files, meteorological model files, and a grid cell parameter file which can be used by HEC-HMS to develop a hydrologic model. The basin model file contains hydrologic elements and their hydrologic connectivity. The basin model file also includes sub-basin areas and other hydrologic parameters that could be estimate using Geospatial data.

HEC-HMS is a graphical user interface (GUI) model that requires the construction of three model components (i.e. basin model, meteorological model and control specification model) data input was (time series and gridded data) that is required for running the model to get simulated flow.

In general GEO-HMS uses spatial analyst tools to convert geographic information in to parameters for each of the basins and flow lines. These parameters are then used to create a HE C-HMS model that can be used within the model program.

Model calibration and validation

Model calibration

Model calibration is a systematic process of adjusting model parameter values until model results match acceptably the observed data. The objective function described by the quantitative measure of the match .in the precipitation runoff models; this function measures the degree of variation between the observed and computed hydrographs. The calibration process finds the optimal parameter values that minimize the objective function. Further, the calibration estimates some model parameters that cannot estimate by observation or measurement, or have no direct physical meaning. Calibration can be done weather manually or automatically. In the automatic calibration model parameters iteratively adjusted until value of the selected objective function is minimized.

The latest version of HEC–HMS 4.0 Model includes optimization manager that allows automated model calibration. The quantitative measure of the goodness-of-fit between the computed results from the model and the observed flow is called objective function. An objective function measures the degree of variations between computed and observed hydrographs. It is equal to zero if the hydrographs are exactly identical. The key to automated parameter estimation is a search method for adjusting parameters to minimize the objective function value and find optimal parameter value.

In this study, the objective function used two search methods available in HEC-HMS model. For minimizing the objective function and finding optimal parameter value

The first one is unvaried gradient method (UG): evaluate and adjust the parameter at a time while holding other parameter constant. And the second one is Nnelder and Mead method; uses a dawn hill simplex to evaluate all parameters simultaneously and determine which parameter to adjust. The tolerance determines the change in the objective function value that will terminate the search. That is, when the objective function change less than the specified tolerance, the search terminates. For this study unvaried gradient method (UG) was used to search optimal value.

Model validation

Model validation is process of testing model ability to simulate observed data other than the used for calibration, with acceptable accuracy. During this process, calibrated model parameters also not subject to change, their values are kept constant. The quantitative measures of the match are again the degree of variation between computed and observed hydrographs.

HEC–HMS model performance

For this study the model performance in simulating observed discharge was evaluated during calibration and validation by inspecting 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).

Nash - Sutcliffe efficiency, (NSE)

The Nash and Sutcliffe coefficient Efficiency (NSE) is a measure of efficiency that relates the goodness of –fit of the model to the variance of the measured data. NSE can range from 0 - to 1and an efficiency of 1 indicates a perfect Match between observed and simulated discharge. NSE value 0.9 and 1 indicates that the model performs very well while value between 0.6 and 0.8 indicates the model performance is well (Abeyou, 2008). The efficiency Proposed by Nash and Sutcliffe (Nash, 1970) is defined as one mines the sum of the absolute square difference between the predicated and observed values normalized by the variance of observed values during the period under investigation.

$$NES = 1 - \frac{\sum_{i=1}^{n}[Q_O - Q_S]^2}{\sum_{i=1}^{n}[Q_O - \overline{Q_O}]^2} \quad (3)$$

Where Q_o = Observed flow

Q_s = Simulated flow

$\overline{Q_o}$ = Average observed flow

Percent difference (relative volume error (D) is given as

The last performance measure, the RVE is used for quantifying the volume errors. This relative volume error can vary between positive infinitive and negative infinitive but when the value zero is generated it performs the best there is no difference between simulated and observed runoff occurs. A relative volume error less than positive 0.05 or negative 0.05indicates that a model performs is good while relative volume errors between +0.05% and +0.10% and −0.05%and −0.10% indicate a model with reasonable performance. This objective function should always be used in combination with another objective function that considers the overall shape agreement.

$$RV_E = \left(\frac{\sum_{i=1}^{n}(Q_{sim}-Q_{obs})}{\sum_{i=1}^{n}Q_{obs}}\right) * 100 \quad (5)$$

Where: RV_E = (% error): relative volume error,

Q_{sim} = simulated flow.

Q_{obs} = observed flow.

Result and Discussion

Evaluating climate scenario data

When comparing the historical climatic variables and generated future climate trends, it is generally observed that the future trends on average basis of minimum temperature for most of sub basins shows increasing trend whereas the maximum temperature is increasing and decreasing pattern for sub basins. But in the case of precipitation the future condition exhibits a fluctuating trend i.e. in some of sub basins increasing trend and on other sub basin decreasing trend this is due to complicated nature of precipitation process and its distribution on space and time evapotranspiration is also increasing trend.

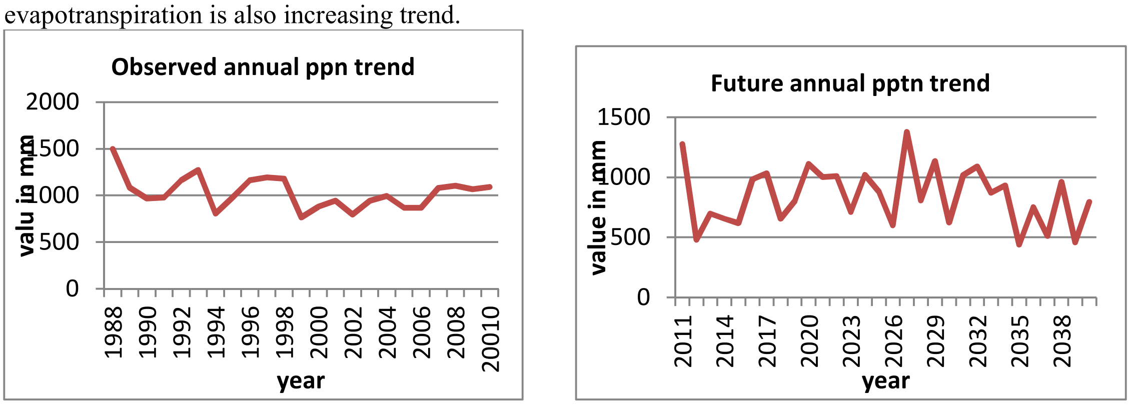


Figure 5: Observed and Future pattern of annual precipitation at Bilate River basin

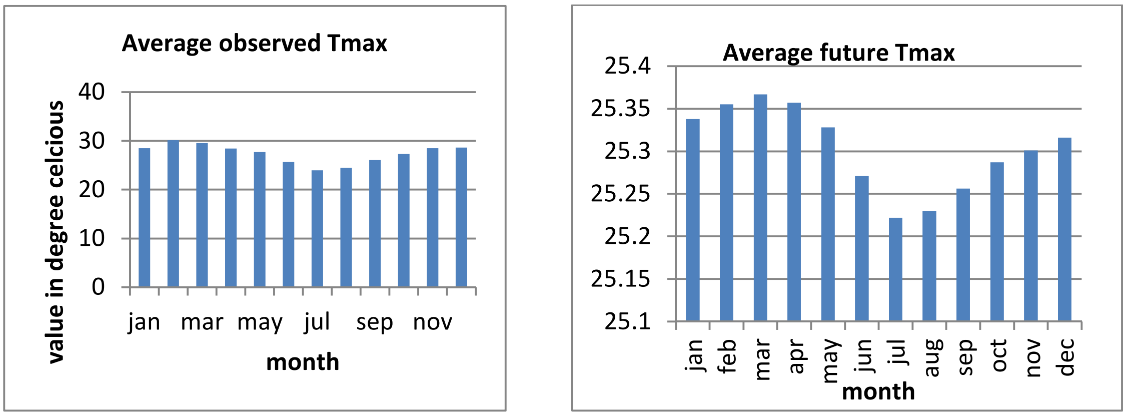
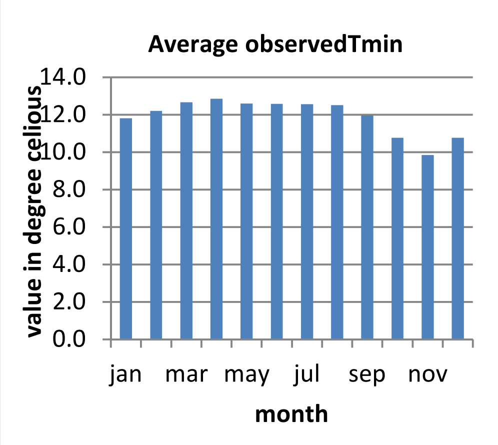


Figure 6: Average Observed and future maximum temperature

Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.8, No.11, 2016



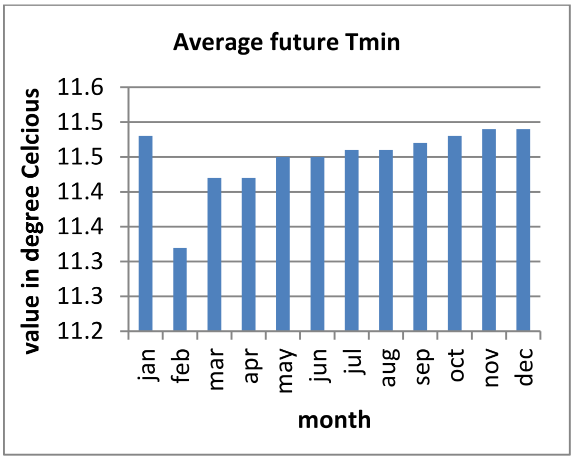


Figure 7: Averaged Observed and future minimum temperature

Future climate scenario generation

The climate scenario data was evaluated from CORDEX-Eth using Arc GIS software, selecting the Grid point data sets and monthly bias correcting the data for precipitation and temperature The bias correction applied for precipitation is power transform function i.e. $P_{corr} = a*P^{b}_{uncorr}$ .Statistical measures (M, S and Cv) are used to get a and b values. Power transformation constants obtained for precipitation are mention below in tabular form.

Table 1: Power transformation constants for precipitation

Power Transformation Constants (2011 - 2040)		
Month	a	b
January	0.970	0.02
February	0.99	0.05
March	1.00	0.05
April	10.79	0.49
May	3.50	0.84
June	0.58	1.47
July	0.45	1.43
August	0.74	1.40
September	0.38	1.55
October	1.37	1.06
November	3.09	0.93
December	1.00	1.00

The bias correction applied for temperature is linear transform function i.e. RCM* = a*RCM + b where: RCM* = corrected temperature, RCM = estimated temperature m = mean, S = standard deviation and Bias correction constants which are obtained in this study for maximum temperature and minimum temperature were explained below in tabular form respectively as that of precipitation.

Table 2: Linear transformation constants for maximum temperature

Linear Transformation Constants (2011 - 2040)		
Month	a	b
January	0.0	24.9
February	0.1	24.3
March	0.0	27.2
April	0.1	22.4
May	0.1	21.5
June	0.4	12.8
July	0.1	17.0
August	0.0	20.3
September	0.0	21.8
October	-0.1	24.3
November	-0.1	26.5
December	-0.1	28.0

Table 3: Linear transformation constants for minimum temperature

Linear Transformation Constants (2011 - 2040)		
Month	a	b
January	-0.03	11.73
February	0.01	12.67
March	0.02	14.16
April	0.00	14.20
May	0.06	12.48
June	0.07	12.33
July	0.04	11.92
August	0.01	12.35
September	-0.01	12.34
October	0.01	11.40
November	0.07	10.48
December	0.00	11.30

HEC-HMS model results

Calibration results

The HEC-HMS model is calibrated and validated for the observed period of 23 year (1988-2010) the best fit parameter sets are selected. For all gauging stations daily data for the basin from 1988-2003 was used for calibration and from 2004-2010 was validation and 1988 was for warm up period.

The base flow was calibrated automatically by the model using the observed data of areal precipitation and areal evapotranspiration and observed flow at the Bilate stations as shown in the figure below the calibration results shows that there is good agreement between the observed and simulated daily flows .This is demonstrated by Nash Sutcliffe efficiency (NSE) obtain to be 0.611 and the (R^2) obtain to be 0.75

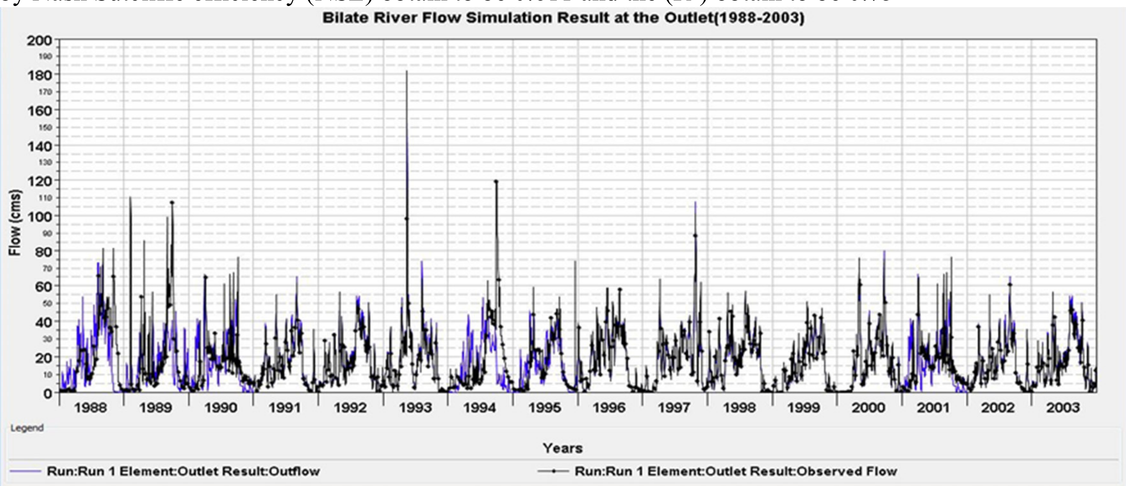


Fig 8: Calibration of the model

Validation results

The validation results show that there is good agreement between the observed and simulated daily flows. This is demonstrated by Nash Sutcliffe efficiency (NSE) obtain to be 0.623 and the (R^2) obtain to be 0.78

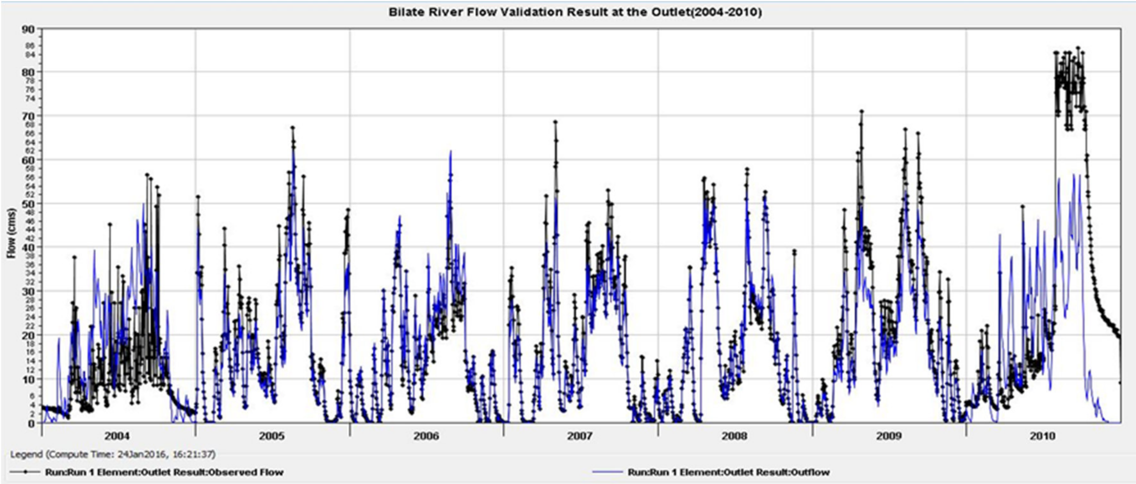


Fig 9: Validation of the model

Model Sensitivity analysis

Sensitivity analysis determines which parameters of the model have greatest impact on the model results. In this study a local sensitivity analysis was adopted for evaluating the event model .in the local sensitivity analysis the effect of each input parameter was determined separately by keeping other model parameters constant .The sensitivity parameter is selected from the value of sensitivity function the results showed that with respect to peak flood magnitude, the event model was most sensitive the Clarks storage coefficient. In terms of peak volume, the event model was most sensitive to the deficit constant loss parameter.

Table 4: result of sensitivity analysis

Project:Project 1 Optimization Trial:Trial 1

Start of Trial: 01Jan1988, 00:00 Basin Model: Bilate
End of Trial: 31Dec2003, 00:00 Meteorologic Model:Met_Model
Compute Time:22Jan2016, 14:12:34

Element	Parameter	Units	Initial Value	Optimized Value	Objective Function Sensitivity
Subbasin-1	Initial and Constant - Constant Rate	MM/HR	2.30	2.3203	-0.03
Subbasin-1	Initial and Constant - Initial Loss	MM	3	3.0000	0.00
Subbasin-1	Snyder Unit Hydrograph - Peaking Coefficient		0.360	0.33883	0.01
Subbasin-1	Snyder Unit Hydrograph - Standard lag	HR	0.36	0.36000	0.00
Subbasin-2	Initial and Constant - Constant Rate	MM/HR	2.97		
Subbasin-2	Initial and Constant - Initial Loss	MM	4		
Subbasin-2	Snyder Unit Hydrograph - Peaking Coefficient		0.355		
Subbasin-2	Snyder Unit Hydrograph - Standard lag	HR	7		
Subbasin-3	Initial and Constant - Constant Rate	MM/HR	2.97	2.9700	0.00
Subbasin-3	Initial and Constant - Initial Loss	MM	5	5.0000	0.00
Subbasin-3	Snyder Unit Hydrograph - Peaking Coefficient		0.36	0.33883	0.01
Subbasin-3	Snyder Unit Hydrograph - Standard lag	HR	8	8.0000	0.00

From the above table the most sensitive parameter for sub basin_1 is initial and constant rate loss, because its value is negative.

Simulated future flow of Bilate River basin

The simulated future flow is resulted from future climate scenario data which is also obtained by bias correcting the future climate scenario data of the study area, selecting the grid point data of the water shade. As mentioned above in bias correction method and the HEC-HMS model was used to simulate the future flow as follows.

When we observe the future flow from the graph below the maximum peak flow is about 147 cms and that was recorded in the year of 2036 and the minimum peak flow is about 32cms and that was also recorded in the year 2030. But the peak flow recorded as 218cms was considered to be as higher outlier.

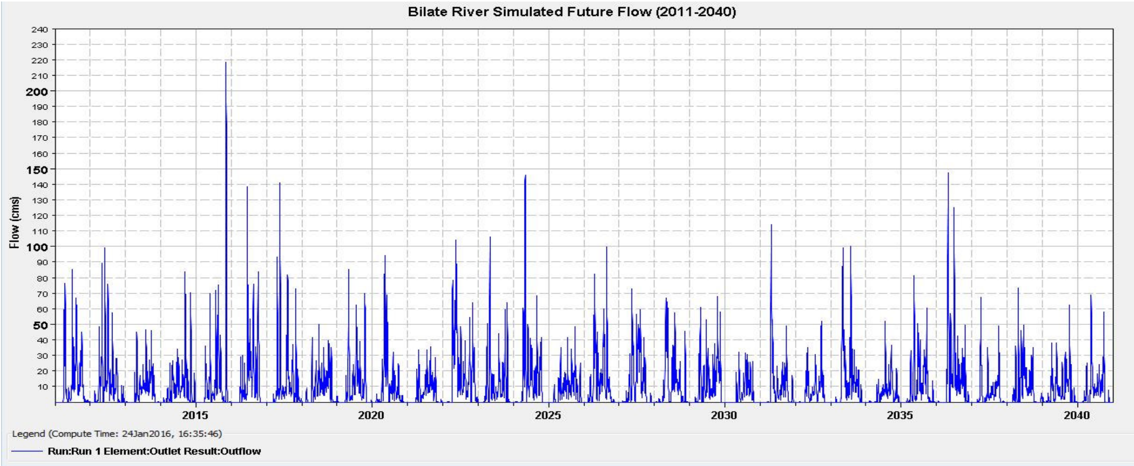


Fig 10: Future flow simulation

Quantifying possible impact of climate change on flood frequency of Bilate River basin

To quantify possible impacts of climate change on flood frequency the study used the HEC-SSP software. Since the objective is to study flood frequency, and the study focused on extreme events and select daily annual peak from each year of data set for prefer input data for the HEC-SSP software. Here the study used different types of distributions to analyze the frequency, to quantify its impact on flood frequency. Among different types of distribution this study used Normal, Log-normal, Person type (III) and log-person type (III) distributions for both current and future flood frequency.

Current flood frequency of Bilate River basin using different types of distribution

Normal distribution

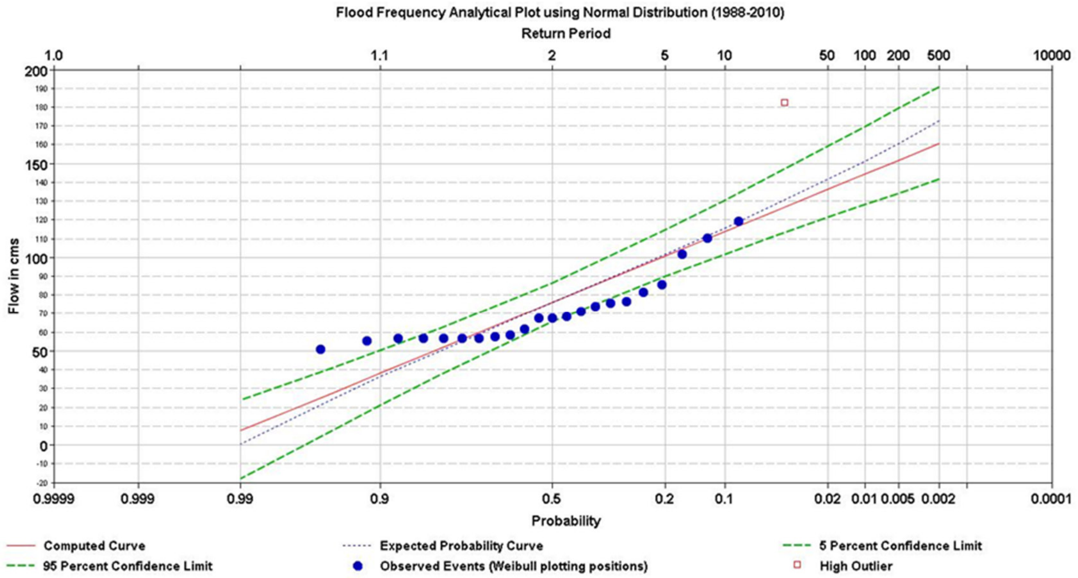


Fig 11: Normal distribution graphical result

Table 5: Bilate Annual Peak for current flow

Day Mon Year (Events Analyzed)	cms	Rank (Ordered Events)	Water Year	cms	Weibull Plot Pos
04 Sep 1988	81.300	1	1993	182.100*	4.17
08 Feb 1989	110.300	2	1995	119.100	8.33
06 Oct 1990	76.300	3	1989	110.300	12.50
02 Sep 1991	61.600	4	1998	101.500	16.67
30 Apr 1992	56.600	5	2010	85.500	20.83
15 May 1993	182.100	6	1988	81.300	25.00
02 Oct 1994	119.100	7	1991	76.300	29.17
19 Dec 1995	74.000	8	2000	75.600	33.33
17 Jun 1996	58.700	9	1996	74.000	37.50
27 Oct 1997	101.500	10	2009	71.040	41.67
03 Aug 1998	56.800	11	2007	68.500	45.83
19 Jul 1999	51.000	12	2005	67.305	50.00
05 May 2000	75.600	13	2002	67.300	54.17
09 Sep 2001	56.500	14	1991	61.600	58.33
21 Aug 2002	67.300	15	1996	58.700	62.50
29 Aug 2003	56.600	16	2008	57.800	66.67
18 Sep 2004	55.500	17	1998	56.800	70.83
20 Aug 2005	67.305	18	2003	56.600	75.00
28 Aug 2006	56.550	19	1992	56.600	79.17
04 May 2007	68.500	20	2006	56.550	83.33
31 Jul 2008	57.800	21	2001	56.500	87.50
28 Apr 2009	71.040	22	2004	55.500	91.67
23 Sep 2010	85.500	23	1999	51.000	95.83

Table 6: Systematic Statistics for normal distribution

Log Transform: , cms		Number of Events	
Mean	1.858	Historic Events	0
Standard Dev	0.133	High Outliers	0
Station Skew	1.536	Low Outliers	0
Regional Skew	---	Zero Events	
Weighted Skew	---	Missing Events	0
Adopted Skew	0.000	Systematic Events	23

From the above graph and table for the normal distribution the maximum peak flow is about 119 cms and which is obtained in the year of 1995; with Weibull plotting position of 8.33 whereas minimum peak flow is about 51cms with corresponding year of 1999 with that of Weibull plotting position of 95.83, from systematic statistics for the normal distribution the mean is obtained to be 1.858, standard deviation was about 0.133, station skew was 1.536 and adopted skew was 0 , Therefore the return period for maximum peak flow was about 12 year with corresponding probability of 0.08 and the return period for minimum peak flow was about 1.04 year with corresponding probability 0.96

In general when we observe the distribution not all of the observations were laid exactly on the 0.05 and 0.95 confident limit but some of the observations are laid exactly, some others close to the confident limit and some also exactly on the confident limit .but the exception is for one which is the higher outlier and that lied far from the confident limit.

Log normal distribution

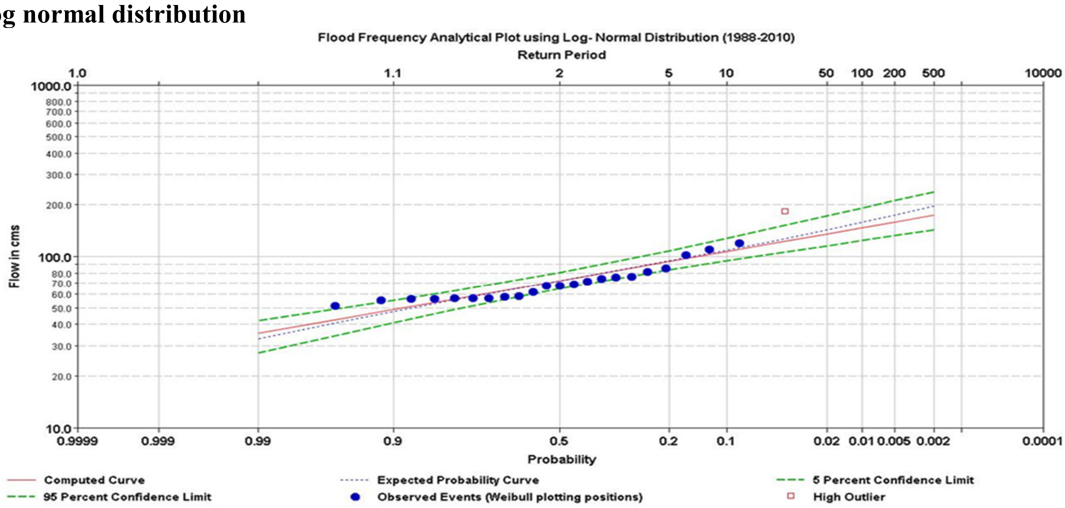


Fig 12: Log normal distribution graphical results

Table 1: Systematic Statistics for log normal distribution

Log Transform , cms		Number of Events	
Mean	1.858	Historic Events	0
Standard Dev	0.133	High Outliers	0
Station Skew	1.536	Low Outliers	0
Regional Skew	---	Zero Events	
Weighted Skew	---	Missing Events	0
Adopted Skew	0.000	Systematic Events	23

In the case of log normal distribution the maximum flow is obtained to be 119 cms and which is observed with the corresponding year of 1995, with the plotting position of 8.33 whereas the minimum peak flow was about 51cms with the corresponding year of 1999 and its Weibull plotting position was about 95.83, The systematic statics was most probably the same as normal distribution that was the mean about 1.858, standard deviation was 1.536 and adopted skew was 0. The return period for the maximum peak flow is about 12 year with corresponding probability of 0.08 and the return period for minimum peak flow was about 1.04 year with corresponding probability 0.96

When we compare log normal distribution with the normal one it is good because almost all of the observations are laid in the confident limit except the higher outlier.

Pearson type (III) distribution

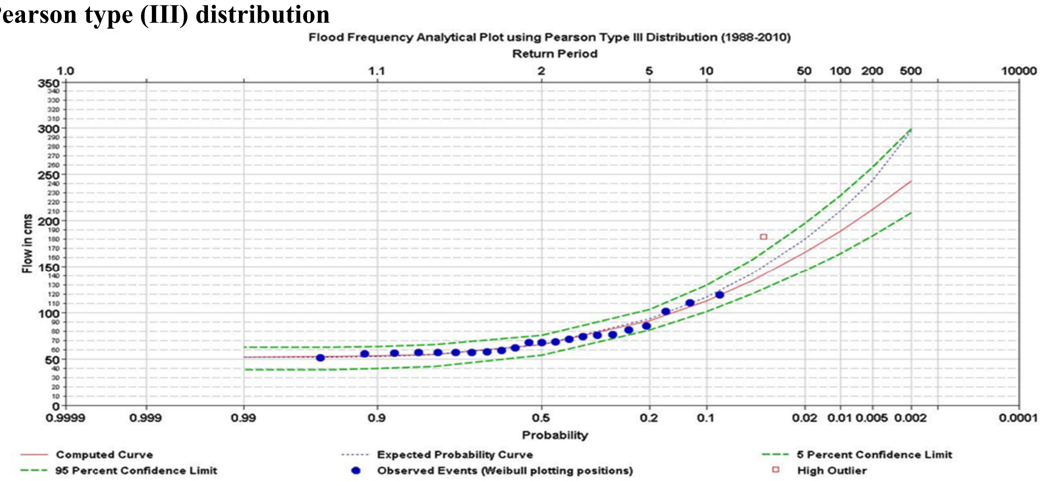


Fig 13: Pearson type (III) distribution graphical result

Table 2: Systematic Statistics for Pearson type (III) distribution

Log Transform , cms		Number of Events	
Mean	75.978	Historic Events	0
Standard Dev	29.434	High Outliers	0
Station Skew	2.454	Low Outliers	0
Regional Skew	---	Zero Events	0
Weighted Skew	---	Missing Events	0
Adopted Skew	2.454	Systematic Events	23

For the Pearson distribution the maximum peak flow is about 119 cms which is observed in the year of 1995 with Weibull plotting position of 8.33 whereas the minimum peak flow was about 51 cms with corresponding year of 1999 with that of plotting position of 95.83, When we observe the systematic statics for Pearson distribution the mean was obtained to be 75.978, standard deviation was 2.454 stations skew and adopted skew both are the same and obtained to be 2,454. The return period for maximum peak flow was about 12 year with corresponding probability of 0.08 and the return period for minimum peak flow was about 1.04 year with corresponding probability 0.96

Most of the observations are laid in the 0.05 and 0.95 confident limit except the higher outlier which is not laid in the confident limit

Log Pearson type (III) distribution

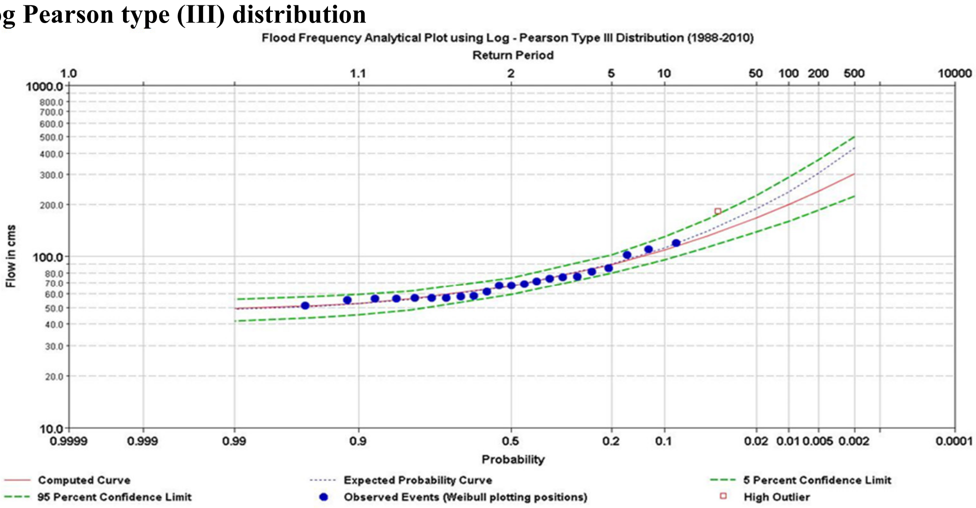


Table 3: Systematic Statistics for Log Pearson distribution

Log Transform: , cms		Number of Events	
Mean	1.858	Historic Events	0
Standard Dev	0.133	High Outliers	0
Station Skew	1.536	Low Outliers	0
Regional Skew	---	Zero Events	0
Weighted Skew	---	Missing Events	0
Adopted Skew	1.536	Systematic Events	23

For the log Pearson distribution the maximum peak flow is about 119 cms which is observed in the year of 1995 with Weibull plotting position of 8.33 whereas the minimum peak flow was about 51 cms with corresponding year of 1999 with that of plotting position of 95.83. Here the mean was about 1.858, standard deviation was about 0.133 and station skew was about 1.536 that was the same value as adopted skew. Return period for the maximum peak flow was about 12 year with corresponding probability of 0.08 and the return period for minimum peak flow was about 1.04 year with corresponding probability 0.96. Almost all of the observations

ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
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lied in the confident limit except the higher outlier.

Goodness of fit test

In this study selection of best fit distribution from candidate distribution obtained from the above mentioned analysis is done by using software which is called Easy Fit. Within this software all goodness of fit test such as Chi-Square, Kolmogorov Smirinove and Anderson Darling tests are done and the best fit distribution from the candidate is displayed automatically.

Table 19: Test for goodness of fit.

Distribution Type	Correlation Coefficient (R^2)	NASH-Sutcliffe
Normal	0.69	0.73
Log-Normal	0.83	0.85
Pearson Type III	0.97	0.89
Log-Pearson Type III	**0.89**	**0.88**

From the above table about the goodness of fit Pearson (III) distribution shows a good result. So we have selected this distribution for future studies.

Future flood frequency of Bilate River basin using Pearson (III) distribution

Fig 20: Bilate Annual Peak for future flow

Events Analyzed				Ordered Events			
Day	Mon	Year	cms	Rank	Water Year	cms	Weibull Plot Pos
14	Jun	2016	138.500	1	2036	147.500	6.45
22	May	2017	140.600	2	2024	146.000	9.68
28	Jun	2018	50.100	3	2017	140.600	12.90
02	May	2019	85.400	4	2016	138.500	16.13
16	May	2020	94.200	5	2031	114.000	19.35
26	Aug	2021	35.400	6	2023	106.200	22.58
18	May	2022	104.300	7	2022	104.300	25.81
05	May	2023	106.200	8	2033	100.200	29.03
04	May	2024	146.000	9	2026	99.400	32.26
03	Oct	2025	48.600	10	2020	94.200	38.71
26	Aug	2026	99.400	11	2019	85.400	41.94
30	Apr	2028	67.000	12	2035	81.000	51.61
18	Oct	2029	67.600	13	2038	73.100	54.84
26	May	2030	32.300	14	2027	72.700	58.06
26	Apr	2031	114.000	15	2040	68.800	61.29
01	Oct	2032	51.800	16	2030	67.600	64.52
21	Jul	2034	51.700	17	2037	67.300	67.74
16	May	2035	81.000	18	2028	67.000	70.97
01	May	2036	147.500	19	2040	62.300	74.19
06	Apr	2037	67.300	20	2032	51.800	77.42
29	Apr	2038	73.100	21	2034	51.700	80.65
12	Oct	2039	62.300	22	2018	50.100	83.87
24	May	2040	68.800	23	2026	48.600	87.10

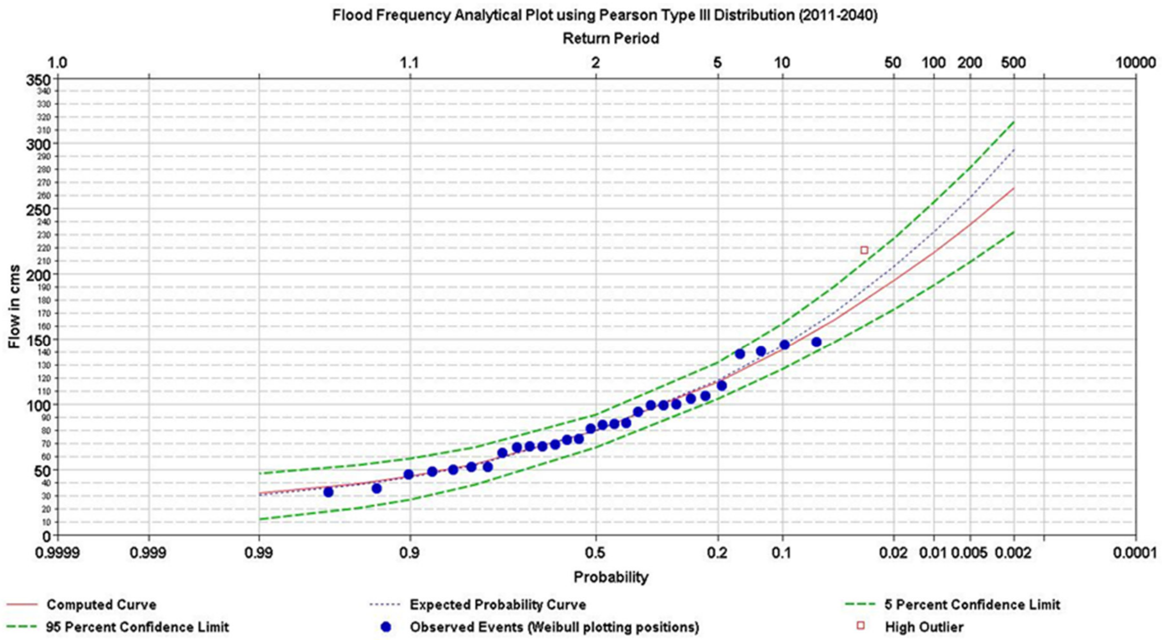

Fig 19: Pearson type (III) distribution graphical results

Table 21: Systematic Statistics for Pearson type (III) distribution

Log Transform: cms		Number of Events	
Mean	87.957	Historic Events	0
Standard Dev	40.240	High Outliers	0
Station Skew	1.285	Low Outliers	0
Regional Skew	---	Zero Events	0
Weighted Skew	---	Missing Events	0
Adopted Skew	1.285	Systematic Events	30

Form the Pearson type (III) distribution the maximum peak flow is about 147 cms which is observed in the year of 2036 with Weibull plotting position of 6.45 whereas the minimum peak flow was about 32 cms with corresponding year of 2030 with that of plotting position of 96.77. When we observe the systematic statics for Pearson distribution the mean was obtained to be 87.957, standard deviation was 40.240 stations skew and adopted skew both are the same and obtained to be 1.285.

The return period for maximum peak flow was about 20 year with the corresponding probability of 0.08 and the return period to minimum peak flow was about 6 month with corresponding probability of 0.95. Most of the observations are laid in the 0.05 and 0.95 confident limit except the higher outlier which is not laid in the confident limit.

Conclusion and Recommendation

Conclusion

The future trend of temperature and precipitation shows that there was change in climate when compared with observed temperature and precipitation i.e. temperature shows increasing trend and precipitation shows increasing and decreeing trend that clearly shows there is change in climate. This change in climate results change in flood frequency of the study area. This analysis for the study area has a development of computer-based models that are powerful tools for investigating the impacts of climate change on flood frequency of Bilate watershed. Therefore an integrated approach of hydrology and meteorology data with spatial data is used to analyze climate impact on the flood frequency of the study area.

The aim of this study was to evaluate climate change impact on flood frequency for the years of 2006 to 2035 for future 30 years of Bilate watershed using HEC SSP software. A result of calibrated and validated of the HEC-HMS model was good because it fulfills the model performance criteria. And the HEC SSP software was used to analyze flood frequency of the study area with different type of distribution such as (Normal, log Normal Pearson type (III) and Log Pearson type (III) but only Pearson type (III) distributions shows better result for current flow. So we have selected this to study the future flood frequency of the study area. Since when we have seen the precipitation and temperature of the study area have changed future flow and the flood frequency also changed, it can be concluded that Bilate watershed had experienced a significant climate change for the future 30 years.

Recommendation

Climate changes are the most significant factors driving hydrological changes surface runoff, decrease of infiltration, high flooding event etc. The simplest method to analyze climate change impact on flood frequency is led to find the solutions for managing the climate change. The good thing is that when we keep our environment free from causes of climate change we serve ourselves from its impact.

- Assessing climate change impact on flood frequency with hydrologic models could be applied to predict the potential impacts of climate change on the stream flow of the watershed.
- Different type of distributions such as normal, log normal, Pearson type (III) and log Pearson type (III) distributions are used for assessment of climate change impact on flood frequency of Bilate River basin .But according to goodness of fit test only log normal and Pearson type (III) distributions are show a good result so I recommend that these two distributions are useful for the further studies for the same watershed.
- The locations of the stations that I have selected are not exactly located in the watershed and part of the flow data for the watershed is missing which makes it a challenge to make a good calibration of the model
- HEC HMS model were calibrated using observed data at gauging station, in order to improve the model performance the weather station should be improve both in quality and quantity. Hence it is highly recommended to establish a good network of both hydrological and meteorological station

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