RAINFALL RUNOFF MODELING USING HEC-HMS: THE CASE OF AWASH BELLO SUB-CATCHMENT, UPPER AWASH BASIN, ETHIOPIA

Wana Geyisa Namara [1*], Dr. Ing. Tamane Adugna Damise [2] and Fayera Gudu Tufa [3]

[1,2,3] Department of Hydraulic and Water resource Engineering, Jimma Institute of Technology, Jimma University, Jimma, Ethiopia

*Corresponding author: wageyisa15@gmail.com

Abstract

Rainfall runoff modeling is one of the most complex hydrological modeling due to the involvement of different watershed physical parameters. It is essential for the analysis of watershed hydrological response toward the received precipitation under the influence of watershed parameters. As it is a replica of watershed hydrological response, rainfall runoff modeling is essential to evaluate the general characteristics of total surface runoff at catchment's outlet. The main objective of this study was rainfall runoff modeling using HEC-HMS for Awash Bello sub-catchment. Hydro-meteorological data collected from the National Meteorological Agency and Ministry of Water Resource, Irrigation and Electricity were used for model calibration and validation. SCS-CN, SCS-UH, Muskingum and monthly constant method were used for precipitation loss modeling, transform modeling, flood routing and base flow modeling respectively. Nash Sutcliff Efficiency and coefficient of determination have been selected for model performance evaluation. The model had shown good performance both during calibration and validation with (NSE = 0.855, R^2= 0.867) for calibration and (NSE = 0.739, R^2 = 0.863) for validation respectively. PBIAS for calibration and validation were checked and they were within the acceptable range with a value of 4.59% and 5.67% respectively. By the successful accomplishing of calibration and validation, the peak flood from the model (573.7m^3/s) was compared with direct observed flow (546.4m^3/s) and model provided nearly the same result with the direct observed flow.

Keywords: Awash Bello Sub-Catchment, HEC-HMS, Rainfall Runoff Modeling

Introduction

A basin hydrological response that is obtained from the received precipitation and other basin parameters is commonly called hydrologic modeling. Hydrological models are utilized in various river basins all over the world for the better comprehension of the hydrological procedures and water resources accessibility (Sintayehu, 2015). It is important to use hydrological model today to assess and predict the water availability of river basins to develop strategies in order to cope with the changing environment. Rainfall runoff modeling is one of the most paramount hydrological modeling that is used to investigate the relationship between the rainfall and direct runoff generated under the influence of different watershed physical parameters (Salwa and Wardah , 2015 and Kishor *et al.*, 2014). Stream flow simulation from precipitation events have been advanced over numerous decades (Todini, 2007) in broad areas of water resource fields in terms of structure (James and Zhi-jia, 2010) complexity, data requirements and scale of application from field plot to global, with a similar wide range of purposes from floods to droughts, past to future climate changes, water resources and water quality management. The model helps in forecasting the impact of different watershed management practices upon the hydrologic response corresponding to the expected volume of surface runoff, and aims to aggregate information for better understanding of these practices (Kadam, 2010).

At whatever point information isn't accessible, rainfall runoff models are critical indicators that help in understanding the long-term impacts of different land use land cover change and land use management, which are complex and difficult to determine (Lenhart *et al.*, 2002). Regardless of the data scarcity, researchers have conducted rainfall runoff modeling in different river basins all over the world for various objectives. Kishor *et al.* (2014) have developed rainfall runoff model for Balijore Nala Watershed of Odisha, India in order to assess the interaction of the incoming precipitation and the produced surface runoff. Kimhuy e*t al.* (2016) have developed rainfall runoff modeling in order to investigate stream flow and water resources accessibility in Stung Sangker catchment of Mekong' Tonle Sap Lake basin in Cambodia. Bitew *et al.* (2019) created a precipitation spillover model for stream simulation in the Lake Tana Basin for case of Gilgel Abay catchment, Upper Blue Nile Basin, Ethiopia. Physically based precipitation overflow models that give a sound depiction of hydrological procedures can be utilized to anticipate the outcomes of environmental change and anthropogenic exercises on stream, silt and sediment transport (Muluneh *et al.*, 2009). However, in countries like Ethiopia, adequate data for hydrological modeling are difficult to access or not available. Furthermore, the limited availability of meteorological gauging stations does not spatially balance the available stream flow gauges and financial constraints do not allow data collection at all sites where projects are to be implemented (Muluneh *et al.*, 2009). This enhances the significance of rainfall runoff modeling, so as to investigate the

relationship among rainfall, watershed physical parameters and the generated surface runoff within the data scarce areas.

Awash Bello sub-catchment is located along the Awash River in the upper part of Awash River basin. It is one of the flood plains of the basin that faced frequent flood damage due to the over flow of the Awash River, especially during the month of June to September (Sintayehu, 2015). In order to control flood damage that frequently affects this area, it is imperative to know the flood inundation area. This mainly depends upon the peak flood values obtained at the outlet of the sub-catchment, but direct measuring of this peak flood at outlet point during the specified month is difficult, expensive and time consuming. In order to overcome these problems, it is essential to develop rainfall runoff modeling. Additionally, rainfall runoff modeling helps to identify the correlation between rainfall, watershed physical parameters and runoff volume generated at outlet.

In spite of its advantage in representing watershed hydrological response with data scarce areas, rainfall runoff modeling is a complex and time-consuming process to represent in mathematical form in manual computation (Rathod *et al*., 2015). As a result of this many users have been challenged in converting rainfall runoff relationship into mathematical equation. However, now a day computer-aided hydrological modeling technology have advanced rapidly and become the solution for such difficulties (Halwatura and Najim, 2013). These hydrological modeling technologies have emerged up with numerous rainfall runoff modeling tools like Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS), Soil and Water Assessment Tool (SWAT) and TOPMODEL. Owing to its simplicity, physically based characteristics, wide applicability and minimum but very important data utilization over the other modeling tools, HEC-HMS was selected for this study.

Hydrological model of HEC-HMS has developed based on simulation of rainfall-runoff in watersheds that can model rainfall runoff relationship using a graphical interface (Rathod *et al*., 2015). It is a semi-distributed, physical based model developed with various methods for precipitation loss modeling, excess precipitation transformation to direct runoff, base flow and flood routing (Todini, 2007). Currently, many researchers have applied HEC-HMS for rainfall runoff modeling all over the world and have obtained satisfactory results. Abdessamed *et al*.(2018) developed a rainfall runoff model in a semi-arid region of Ain Sefra watershed in Algeria through employing a HEC-HMS model. They used frequency storm, Soil Conservation Service-Curve Number (SCS-CN) and Soil Conservation Service-Unit Hydrograph (SCS-UH) methods for meteorological modeling, excess precipitation modeling and excess precipitation transformation to direct runoff and obtained nearly the same computed and observed flow. Mokhtari *et al*. (2016) performed hydrologic modeling of rainfall runoff by means of HEC-HMS model on a watershed of the wadi Cheliff-Ghrib in Algeria, and based on their end results, they suggested that HEC-HMS is applicable and the result

was accepted for that particular area. Shahedi and Majidi (2012) utilized HEC-HMS hydrological model to simulate rainfall runoff in the watershed of Abnama situated in south Iran. They used Green-Ampt, SCS unit hydrograph and Muskingum routing techniques to calculate infiltration loss, rainfall surplus conversion to runoff and flow routing, and lastly found that the model had a decent correlation with the observed flow and was acceptable. Bitew *et al.* (2019) have applied HEC-HMS for stream flow simulation in Lake Tana Basin Upper Blue Nile Ethiopia. They used SCS-CN, SCS-UH and Muskingum method for precipitation loss, direct runoff and flood routing respectively. Based on the model result they suggested that HEC-HMS is valid and applicable in the Ethiopian context and it can be used for runoff modeling.

Materials and methods

Study area

Awash Bello sub-catchment is one of the frequently flood affected areas found in the upper part of Awash River Basin, Ethiopia. It is located to the south west of the basin in the upper part near the source of Awash River between 8º0'0'' to 9º1'0'' N latitude and 38º0'0'' to 38º50'0''E longitude on geographical basis (**Fig.1**) at distance of 55 km from Addis Ababa (capital city of Ethiopia).

Data Collection and Data Sources

Daily meteorological data from (1990-2015) for six rain gauging stations (**Table 1 and Fig .2**), located within and around Awash Bello sub-catchment, were collected from National Meteorological Agency (NMA). The HEC-HMS model calibration and validation were carried out at Melka-Kunture river gauging station, which is situated at the outlet of Awash Bello sub-catchment. For the successful completion of this objective, daily stream flow data of Melka Kunture river gauging station was collected from the Ethiopian Ministry of Water Resources, Irrigation and Electricity (MoWRIE) with additional stream flow data from two river gauging stations that were near the outlet. The data from these two river gauging stations were simply used for missing data value estimations at the outlet. Spatial data like Digital Elevation Model (DEM), Land use land cover and Soil data were collected from different sources.

For instance, high resolution DEM (i.e.12.5m X12.5m) was downloaded from ALASKA Satellite Facility website (https://vertex.dac.asf.alska.edu) and analyzed in Arc GIS for the extraction of watershed hydrological elements and physical parameters. This digital elevation model shows elevation ranges from low elevation to high elevation, (e.g. the interval of 1849m-3381m above mean sea level) (**Fig. 3**). The soil and land use land cover data were collected from the Ethiopian mapping agency and Ethiopian ministry of water resource, irrigation and electricity (MoWRIE) respectively.
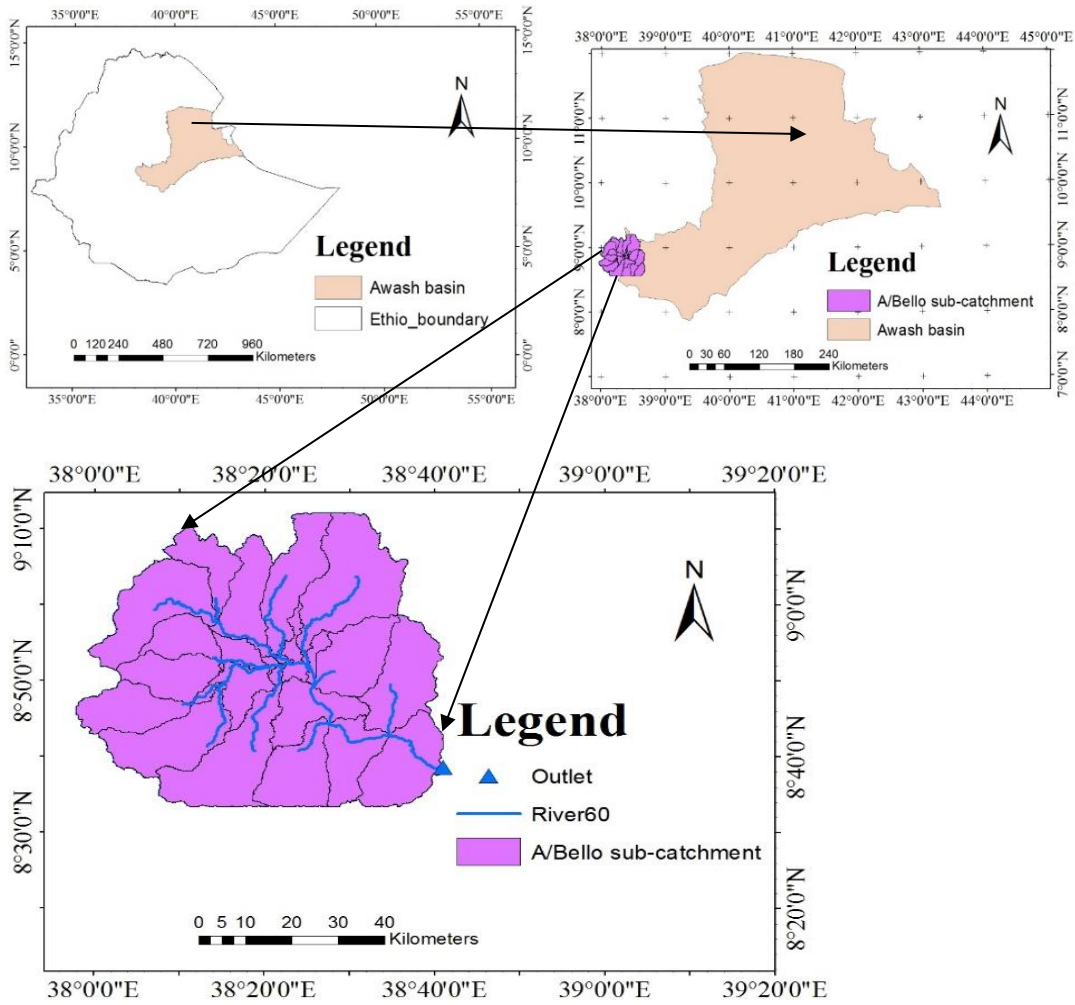
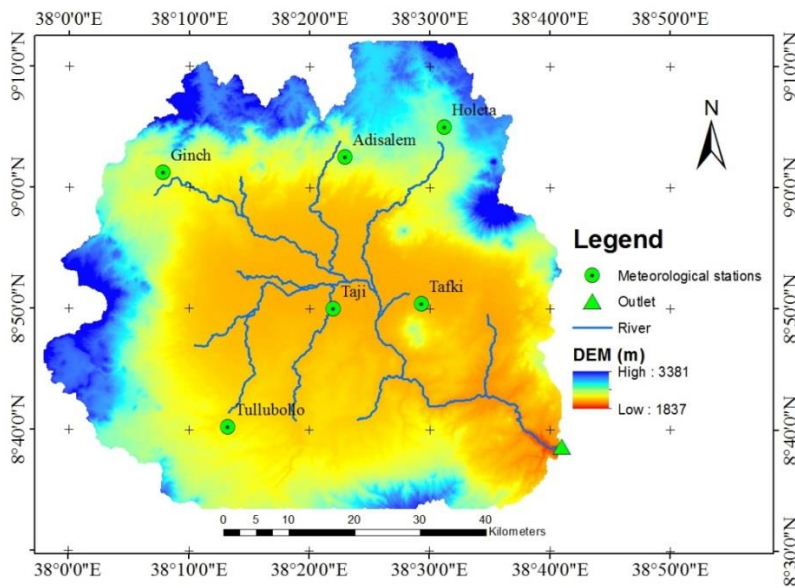**Fig. 1**: Location map of Awash Bello sub-catchment

Fig. 2: Meteorological Stations Distribution along Awash Bello sub-catchment

Table 1: Coordinates and area of each meteorological station

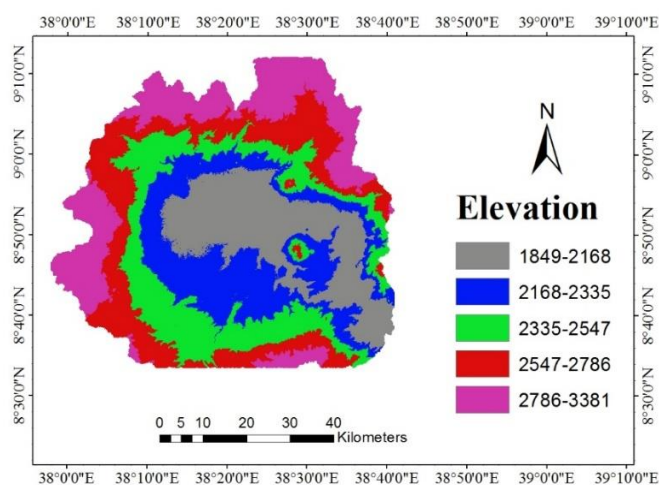| Name of station	Longitude (deg.)	Latitude (deg.)	Elevation(m)	Area (km²)
Ginchi	38.130	9.020	2376	705
Tullubollo	38.220	8.670	2100	1027
Addisalem	38.382	9.042	2372	480
Holeta	38.520	9.083	2382	419
Tafki	38.489	8.840	2063	1101
Taji	38.366	8.833	2091	561
M/kunture (outlet)	38.688	8.644	1860	4293

Fig. 3: Topographical elevation of Awash Bello sub-catchment

Data preparation and processing

Before utilization of hydro-meteorological data for analysis, it is advisable to undertake data preparation and assessment of missing data values. Today, numerous methods are available for missing data value estimation. Of the identified methods, normal ratio method was adopted for missing precipitation data filling, whereas linear regression method was used for estimating stream flow data discrepancy. Data consistency was computed using double mass curve, while other data quality tests such as homogeneity and stationarity were performed using XLStat statistical software.

Land use land cover and soil data of Awash Bello sub-catchment was clipped from the collected Ethiopia-land use land cover and soil map and reclassified in Arc GIS into five main classes based on the previous studies (**Fig. 4**). It was indicated that the abundant part of the Awash Bello sub-catchment was covered by cultivation and pellic vertisols respectively (**Table 2**).

Table 2: Reclassified LULC and Soil of Awash Bello sub-catchment

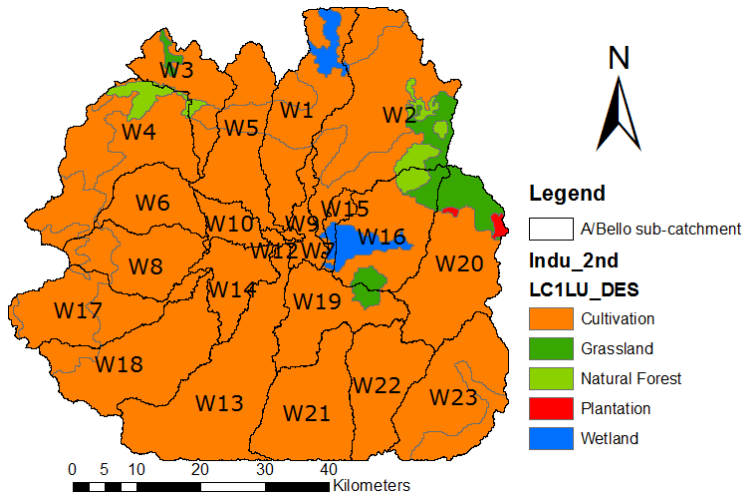| LULC type	Area (km^2)	% age		Soil Type	Area (km^2)	% age
Cultivation	3961	92.3		Pellic Vertisols	2891	69.9
Grassland	152	3.5		Orthic Solonchaks	530	12.8
Plantation	10	0.233		Chromic Vertisols	226	5.5
Wetland	79	1.8		Eutric Cambisols	389	9.4
Natural Forest	91	2.12		Chromic cambisols	98	2.4
Total	4293	100%		Total	4293	100%

Fig. 4: LULC of Awash Bello sub-catchment along with each sub-watershed

Pre-processing

The Arc GIS extension toolkit HEC-Geo HMS was used for watershed delineation, Basin model file, Gage model file, Met model file (**Fig. 5**) and Curve number generation were mainly used in HEC-HMS for model development. HEC-Geo HMS is used as an interface between Arc GIS and HEC-HMS, so that it can easily export data from GIS to HEC-HMS. For proper configuration of the watershed, HEC-HMS requires watershed background shape files and this was developed in HEC-Geo HMS and exported to HEC-HMS incorporating basin model file, gage and met model file.
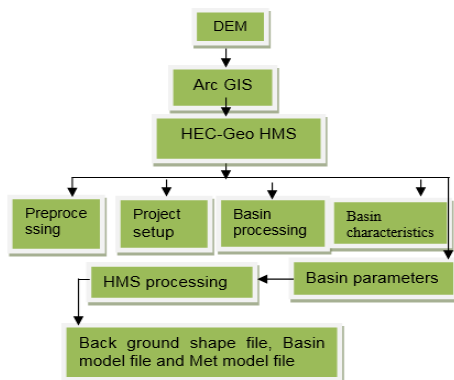

Fig. 5: HEC-Geo HMS preprocessing flow chart

Rainfall Runoff Modeling

The analyzed Hydro-meteorological data and the generated curve number were used in US Army Corps of Engineers Hydrologic Engineering Centers Hydrologic Modeling System (HEC-HMS) in order to extract rainfall runoff modeling. A hydro-meteorological data of 25 years (1990-2015) was used both for model calibration and validation. HEC-HMS consists of different methods for precipitation loss modeling, direct runoff modeling, base flow modeling and flood routing. For this study, Soil Conservation Services-Curve Number method, Soil Conservation Services –Unit Hydrograph method, Monthly constant and Muskingum method were preferred for precipitation loss modeling, direct runoff modeling, base flow, and flood routing respectively.

Precipitation loss

Precipitation loss is due different factors such surface depression, interception, evaporation, infiltration, etc. The Soil Conservation Service Curve Number was used in order to estimate excess precipitation, calculated through equation (1-3).

$$S = \frac{25400 - 254\,CN}{CN} \qquad (1)$$

Where:

- S - Potential maximum retention and CN- Curve Number,

$$I_a = 0.2S \qquad (2)$$

I_a – initial abstraction and it represents precipitation loss before the commencement of surface runoff.

Finally, the cumulative excess precipitation was calculated using equation (3).

$$P_e = \frac{(P - I_a)^2}{(P - I_a + S)} \qquad (3)$$

Where:

- P_e – effective precipitation and P – cumulative precipitation

Direct Runoff

SCS-UH was employed in order to convert excess precipitation to direct runoff. The SCS-UH here requires only basin lag time in minutes and was exported from HEC-Geo HMS for every sub watershed.

Flood Routing

HEC-HMS model contains different methods of flood routing that require various parameters. Among the different methods provided in the HEC-HMS for flood routing, the Muskingum method was selected. It was computed through equations (4-6). The calibrated and validated flood wave travel time (K= 0 -100) and weighted discharge coefficient (X= 0 - 0.5) was used in equation (6) for flood routing and equation (4) used for calculating the initial value of K.

$$K = \frac{V}{l} \qquad (4)$$

Where: k – flood wave travel time in hour, v – permissible velocity in m/s, l – reach length in m.

$$\frac{ds}{dt} = I - Q \qquad (5)$$

Where: $\frac{ds}{dt}$ - rate of change of storage per unit time, I – inflow, Q – outflow

$$S = k[xI + (1 - x)Q] \qquad (6)$$

Where: S – Storage, x-weighted coefficient of discharge, k-flood wave travel time

Model Performance Evaluation Criteria

HEC-HMS model performance herein the study was evaluated under two very important performance evaluation criterion. These were Nash Sutcliff Efficiency (NSE) and Coefficient of Determination (R^2). NSE is used to assess the predictive power of hydrological models or used to analysis the correlation between simulated and observed hydrological data. It is expressed by equation (7).

$$NSE = 1 - \frac{\left(\sum_{t=1}^{T}(Q^t{}_m - Q^t{}_o)\right)^2}{\sum_{t=1}^{T}(Q^t{}_o - \overline{Q_o})^{\wedge}2} \qquad (7)$$

Where: Q^t_m – modeled flow at time t, Q^t_o- observed flow at time t, $\overline{Q_o}$ - mean of observed flow.

The R^2 is a measure of the proportion of variance of a predicted outcome. Shows how well a regression model fits the data and is expressed by equation (8).

$$R^2 = \frac{\sum_{i=1}^{n}[(O_i - \bar{O})(S_i - \bar{S})]}{\sum_{i=1}^{n}(O_i - \bar{O})^{\wedge}2 \sum_{i=1}^{n}(S_i - \overline{S})^{\wedge}2} \qquad (8)$$

Where: O_i – observed flow at time i, $\overline{O}$ – mean observed flow at time i

S_i – Simulated flow at time i, $\overline{S}$ – mean simulated flow at time i

Percent bias (PBIAS) measures the average tendency of the simulated values to be larger or smaller than their observed ones. The optimal value of PBIAS is 0.0, with low-magnitude values indicating accurate model simulation and is expressed in equation 9.

$$PBIAS = (\sum_{i=1}^{n}(Q_i^o - Q_i^{sim})/\sum_{i=1}^{n} Q_i^o) * 100 \qquad (9)$$

Results and discussion

Data Quality Test

Hydrologic modeling system HEC-HMS requires high quality daily hydro-meteorological data. Therefore, before the utilization of any stream flow and weather data, it is essential to undertake a data quality test (Ercan *et al.*, 2008). For this study, data quality test such as data consistency, data homogeneity, and stationarity have performed. A double mass curve was used for precipitation data consistency test for all meteorological stations considered under Awash Bello sub-catchment and the final result indicated that all the stations were consistent over the year length as shown on the (**Fig. 6**).
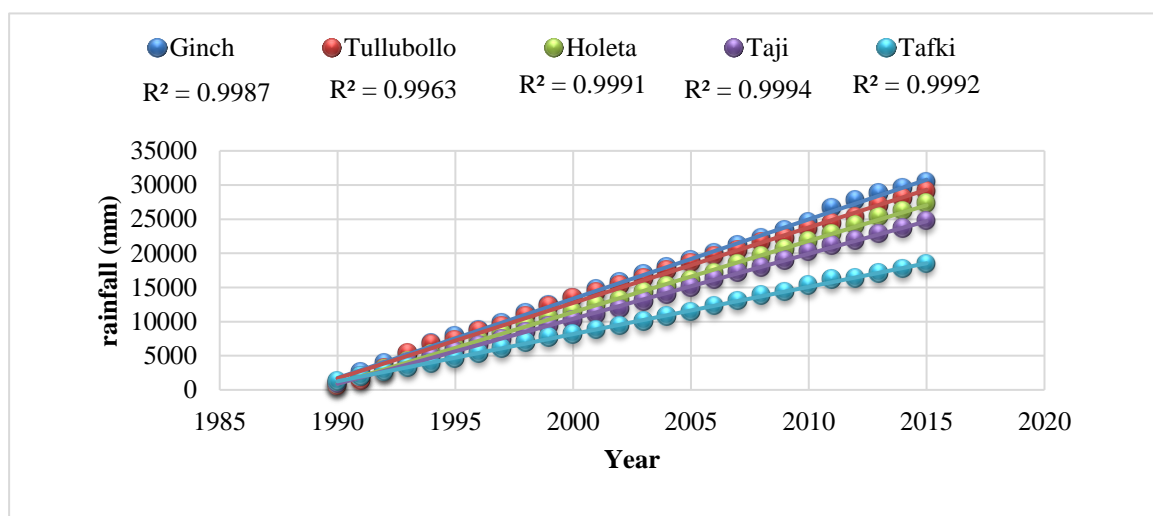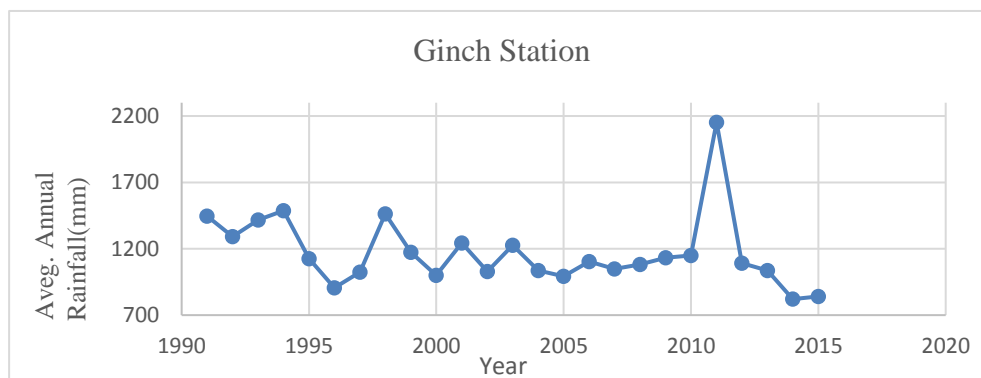

Fig. 6: Double mass curve Data consistency test

Data stationarity test was another data quality test for this study and it was conducted using XLSTAT professional software for hydrological data analysis. Of the six meteorological stations for which data stationarity test was conducted, two of them were indicated as shown in (**Fig. 7**).
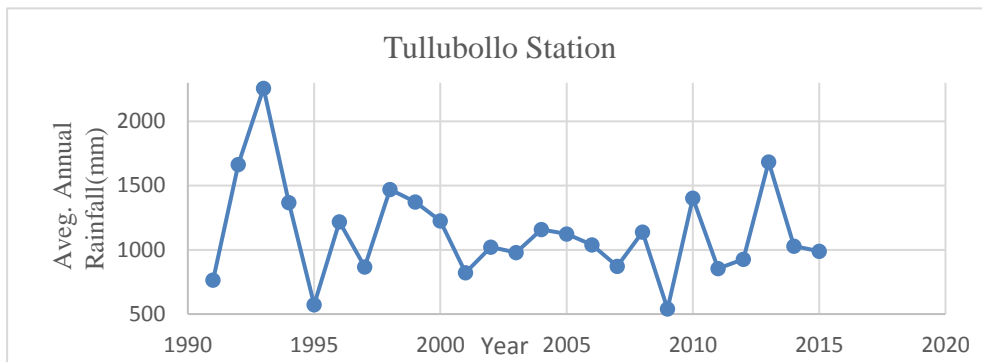
Fig. 7: Data stationarity test

It is important to check if a set of data is homogeneous or not before any statistical technique is applied to utilize it. According to Karabörk *et al.* (2007) if a precipitation time series is homogeneous, all variability and changes of the series then can be considered due to the atmospheric processes. A data homogeneity test was conducted using XLSTAT hydro-meteorological data statistical analysis software. The final result indicated that the data were homogenous, meaning that all the data were came from a single population as shown in (**Fig. 8**).
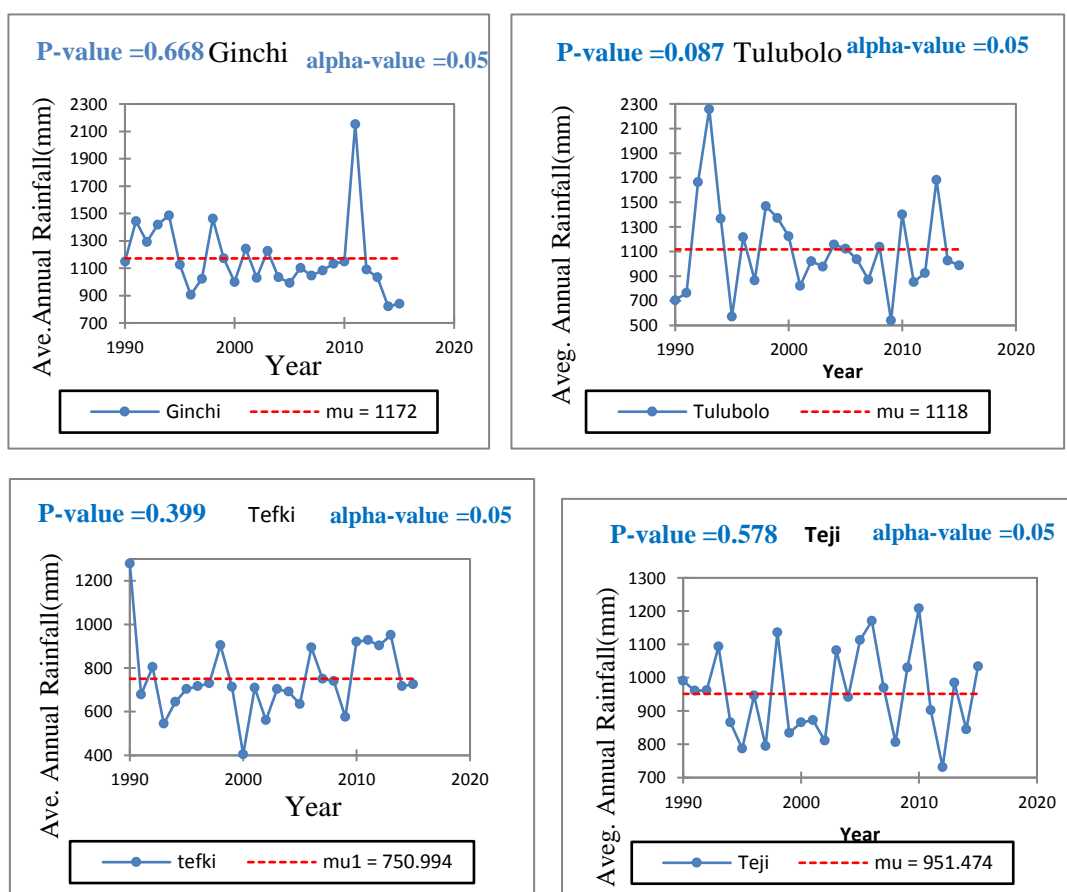

Fig. 8: Data homogeneity test

Rainfall characteristics

After undertaking all missing data value estimations and data quality tests, the monthly average rainfall for the whole Awash Bello sub-catchment and for each station was computed. The result of the computation shows that the Awash Bello sub-catchment obtains a maximum monthly average rainfall of 210mm in the month of July and a minimum monthly average rainfall of about 10mm in the month of December (**Fig. 9**).
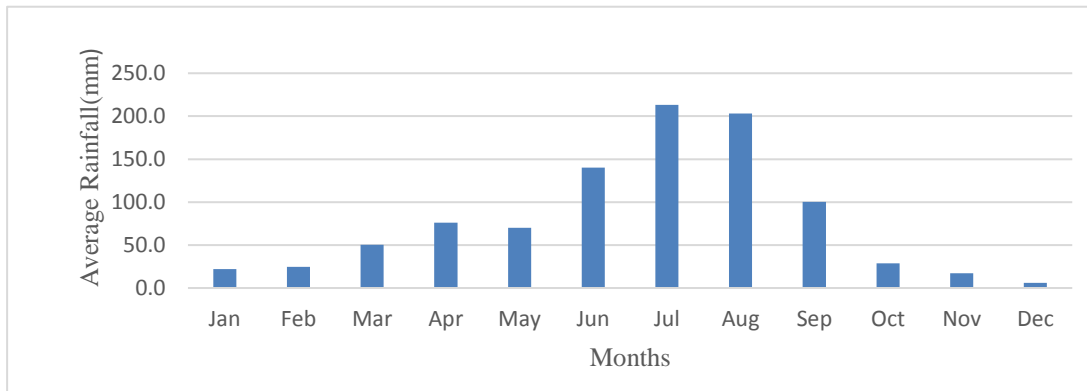

Fig. 9: Monthly average rainfall of Awash Bello sub-catchment

The rainfall characteristics for the individual rain gauging station was collected, indicating that each station obtains different maximum and minimum rainfall values at different months of the year. Of the rain gauging station included under Awash Bello sub-catchment, Tullu Bollo rain gauging station obtains a maximum and minimum rainfall of 275mm and 19mm, respectively (**Fig. 10**).

Fig. 10: Monthly average rainfall of each station

Watershed Physical Parameters

Even though there are various watershed physical parameters that affect the volume of surface runoff, this study focused on curve number, initial abstraction, basin lag time and potential maximum retention, as HEC-HMS mainly utilize these parameters. Curve number represents the impact of land use, land cover change and soil type upon the watershed response toward hydrological parameters (Bitew *et al*., 2019). For this study,

curve number was generated using HEC-Geo HMS in collaboration with Arc GIS (**Fig. 11**). As seen in (**Table 3**) and (**Fig. 11**), the value of the curve number for each sub-watershed ranged between 30 and 100 with a maximum value of 84.825, which indicate the wetland area of the sub-catchment.
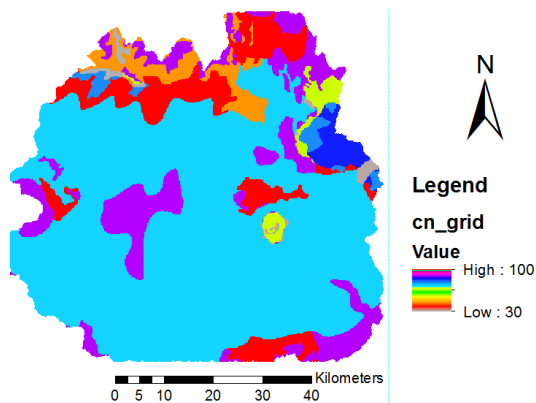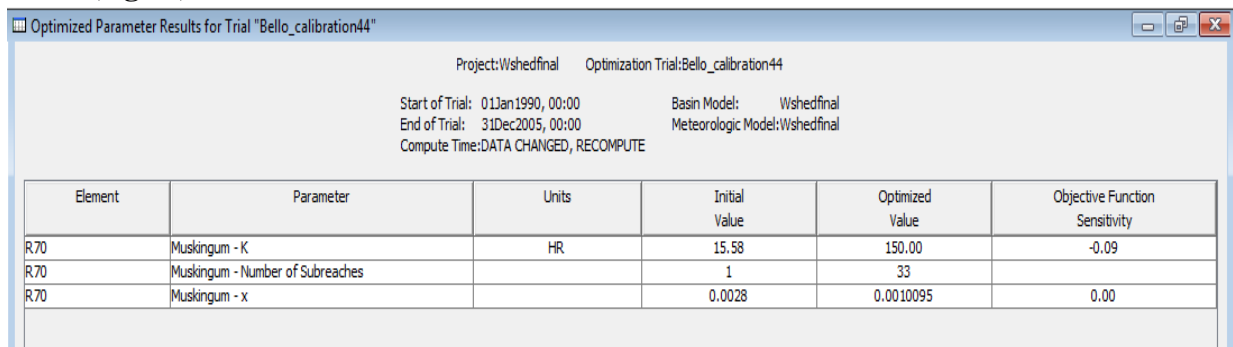

Fig. 11: Curve Number Grid

The other parameters were calculated based on the curve number result and grouped in Table (**Table 3**).

Table 3: Watershed physical parameters

Watersheds	Curve Number	Basin Lag time(second)	Maximum retention potential(mm)	Initial Abstraction(mm)
W23	79.682	229.35	64.77	16.52
W22	78.431	323.94	69.85	17.81
W21	78.223	330.08	70.71	18.03
W20	78.348	332.22	70.19	17.90
W19	76.657	329.45	77.35	19.72
W18	77.655	502.05	73.09	18.64
W17	78.156	322.48	70.99	18.10
W16	81.584	226.36	57.34	14.62
W15	84.825	149.86	45.44	11.59
W14	78.621	375.81	69.07	17.61
W13	77.237	537.49	74.86	19.09
W12	77	92.035	75.87	19.35
W11	77	72.365	75.87	19.35
W10	78.75	318.37	68.54	17.48
W9	77.521	309.6	73.65	18.78
W8	80.434	257.2	61.79	15.76
W7	77	89.323	75.87	19.35
W6	77.025	348.12	75.76	19.32
W5	78.519	357.97	69.49	17.72
W4	77.996	306.31	71.66	18.27
W3	73.391	249.46	92.09	23.48
W2	79.154	368.49	66.89	17.06
W1	80.347	307.21	62.13	15.84

Parameter Optimization

Parameter optimization is a systematic process of adjusting the model parameter values until the computed model results match acceptably with observed data (Bitew *et al.*, 2019). The quantitative measure of goodness of fit between the computed result from the model and observed flow is called an objective function. It measures a degree of variation between computed and observed hydrograph. It is zero if hydrographs are exactly identical (Nishan *et al.*, 2015). In this study, the objective function was to minimize the sensitive parameters. Among the different parameters used in HEC-HMS for this study, flood wave travel time (Muskingum-K) and weighted coefficient of discharge (Muskingum-X) were found to be the most sensitive parameters. Therefore, the objective function in this study was targeted to reduce these sensitive parameters to zero (**Fig. 12**).

Optimized Parameter Results for Trial "Bello_calibration44"

Project:Wshedfinal Optimization Trial:Bello_calibration44

Start of Trial: 01Jan1990, 00:00 Basin Model: Wshedfinal
End of Trial: 31Dec2005, 00:00 Meteorologic Model:Wshedfinal
Compute Time:DATA CHANGED, RECOMPUTE

Element	Parameter	Units	Initial Value	Optimized Value	Objective Function Sensitivity
R70	Muskingum - K	HR	15.58	150.00	-0.09
R70	Muskingum - Number of Subreaches		1	33	
R70	Muskingum - x		0.0028	0.0010095	0.00

Fig. 12: Optimized sensitive parameter result during calibration

By reducing parameter sensitivity like in **Fig. 12** for all reaches (tributaries) along the Awash Bello sub-catchment, the model output produced nearly the same value as observed flow, as shown in (**Fig. 13**).
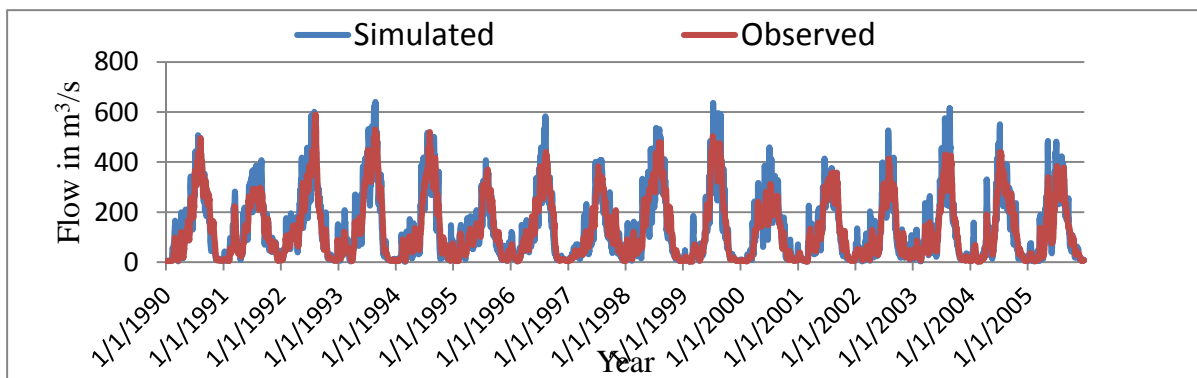

Fig. 13: Computed and observed flow comparison adopted from HEC-HMS during parameter optimization.

NSE, R^2 and PBIAS are the best criteria that widely used in order to verify the HEC-HNS model performance (Chea and Oeurng, 2017 and Bitew *et al.*, 2019). Both NSE and R^2 were applied to evaluate the model performance, and the HEC-HMS showed good performance with NSE = 0.855 and R^2 = 0.867. According to Kimhuy and Chantha, (2016) the value of NSE and R^2 that is ≥ 0.65 are acceptable and as the obtained value of these model performance evaluation criteria in this study are within the referred range, the model was

performed well. The computed and observed peak flow respectively were 640 m^3/s and 590.3 m^3/s (**Fig.14**). PBIAS was checked for model calibration and was found within the acceptable range, with a value of 4.59%.

After adjusting all the sensitive parameters and completing model setup, 10 years (2006-2015) of raw hydro-meteorological data was added to the HEC-HMS in order to assess model validity. The model outcome agreed with the observed flow (**Fig.15**), ensuring model validity with the new raw data. The model performance evaluation criterion indicated that the model performed well with raw data during model validation with NSE = 0.739 and R^2 = 0.863. The end result of the model indicated that the HEC-HMS can be applicable for Awash Bello sub-catchment, as it generated a near equivalent value with the direct observed value at outlet of the sub-catchment. This HEC-HMS model end product was 573.7m^3/s whereas the observed peak flow at outlet was 546.4m^3/s (**Fig. 15**). During validation, the model provided a satisfactory value of PBIAS of 5.67%, which can be acceptable for model validation.
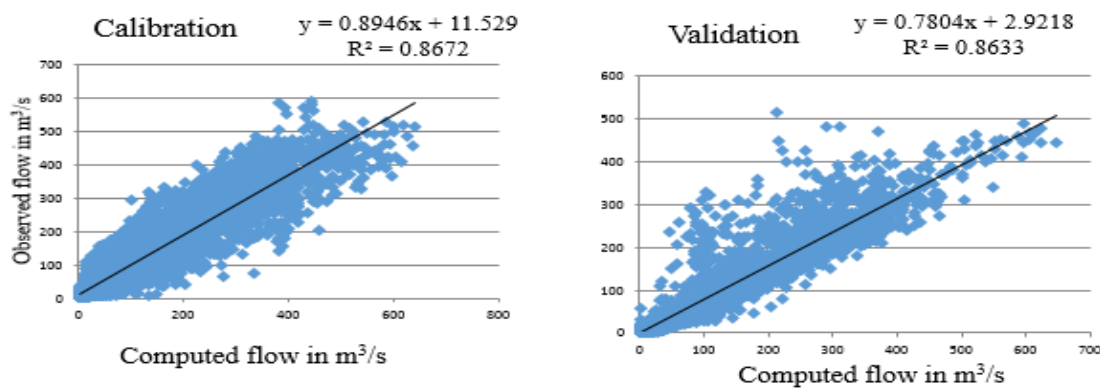

Fig. 14: Coefficient of determination during parameter optimization

Fig. 15: Computed and observed flow comparison during calibration

For this study about 23 sub-watsheds were extracted from DEM of Awash Bello sub-catchment using HEC-Geo HMS through the aid of Arc GIS and used for the investigation of rainfall response at every outlet of each sub-watershed under the influence of different land use land cover, mostly cultivation. The rainfall response along the various sub-watershed of the Awash Bello sub-catchment was shown as in the (**Table 4**).

This table indicated that the rainfall runoff proportionality (correlation coefficient) was very low and most of the received rainfall goes under infiltration than surface runoff, as the abundant parts of Awash Bello sub-catchment are agricultural land (i.e. highly permeable). On the other hand, the rainfall runoff coefficient was very high over every reach (tributary) and each generated large amount of runoff (**Table 5**). This means that all the reaches of the sub-catchment gave a quick response to the received precipitation compared to the sub-watersheds undertaken under the Awash Bello sub-catchment.

Table 4: Rainfall response over every sub-watershed

Sub-wshed	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16	W17	W18	W19	W20	W21	W22	W23
Runoff(m^3/s)	150	181	139.7	83.7	122	75	3.5	72.0	32.4	23.3	2.3	6.1	222.3	64.3	11.8	126.8	139.2	103.3	119.6	172.6	134.4	106.4	159.3

Table 5: Rainfall runoff response over the reaches

Reach	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Runoff (m^3/s)	490.52	545.71	479.3398	391.09	309.06	440.52	514.19	449.96	517.1	532.86

Reliable estimates of stream flow from a catchment are required to help policy makers to inform decisions on water planning and management. All Rainfall-Runoff (R-R) models are the simplified characterizations of the real-world system (Moradkhani and Sorooshian, 2009). A runoff model helps to visualize the response of water systems due to changes in the land-use and meteorological events (Abdessamed *et al.*, 2018). Physical processes that convert rainfall to runoff are conceptualized with set of equations by employing various parameters that describe the catchment. Modeling surface runoff is challenging as the calculation involves complexities with many interconnected variables (Kishor *et al.*, 2014). However general model components include inputs, governing equations, boundary conditions or parameters, model processes and outputs.

There are wide ranges of Rainfall Runoff models currently used by researchers and practitioners; however, their applications are highly dependent on the purposes for which the modeling is undertaken (Nishan *et al.*, 2015 and Bitew *et al.*, 2019). As many of the Rainfall Runoff models are used merely for research purposes for the purpose of understanding the hydrological processes that govern a real-world system, some were developed and employed as tools for simulation and prediction that in turn allows decision makers for proper planning and operation in the context of flood risk management, inundation and flood hazard mapping, for real time reservoir operation and water resources allocation. For instance, the real-time flood forecasting and warning that is operational in many countries, utilizes the results of rainfall-runoff modeling. So far, these hydrological models also estimate flood frequencies, provide inputs for flood routing and inundation

prediction. For the case of this study, the main target of rainfall runoff modeling was to obtain peak flood at the outlet of the sub-catchment that was later used in the computation of flood inundation mapping and it can be used for decision makers concerning the flood damage.

Conclusion

HEC-HMS has been used for rainfall runoff modeling of Awash Bello sub-catchment Awash River basin Ethiopia. Watershed physical parameters such as Curve Number grid, Basin lag time, initial abstraction, maximum potential retention, flood wave traveling time (K), and weighted coefficient of discharge (X) have been used as input data in addition to stream flow and precipitation data. Curve Number grid and basin lag time were generated using HEC-Geo HMS. Among the watershed physical parameters used for rainfall runoff modeling of this study, flood wave travel time (K) and weighted coefficient of discharge (X) have been more sensitive and model calibration and validation were carried out.

NSE and R^2 have been used for model performance evaluation. Both during calibration and validation, the model shown good performance with a preferred model performance evaluation criterion in the acceptable range (i.e. NSE = 0.855 during calibration and NSE = 0.739 during validation). The final peak flow obtained from the model was nearly close to the observed peak flow, and it was 573.7m^3/s while observed peak flow 546.4m^3/s.

With these results one can conclude that HEC-HMS can be applicable in order to develop rainfall runoff modeling for the specified sub-catchment and computed flow can be represented the direct observed flow with further sub-catchment investigation and modification.

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