Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

RESEARCH PAPER

Influence of Soil Type in Stream flow and Runoff Modeled for the Upper Didessa Catchment Southwest Ethiopia Using SWAT Model

Adisu Befekadu Kebede [1]*

1 Jimma University Jimma Institute of Technology, Faculty of Civil and Environmental Engineering, Department of Water Supply and Environmental Engineering, P.O.Box 378, Ethiopia

* **Corresponding author**, adisu04@gmail.com

Received on 23 November 2019
Received in revised form on 12 December 2019
Accepted on 13 December 2019

Editor: Maria Virginia Alves Martins, Universidade do Estado do Rio de Janeiro, Brazil

Citation:
Kebede, A.B., 2019. Influence of soil type in stream runoff for the upper Didessa catchment Southwest Ethiopia using SWAT model. Journal of Sedimentary Environments, 4 (4): 444-457.

Abstract

This study aimed to model the flow of streams and identify the sub-basins responsible for the high flow in the Didessa watershed, southwest Ethiopia, considering the regional soils types. Soil and Water Assessment Tool (SWAT) model was used to simulate stream flow and quantify surface runoff. The input data used were Digital Elevation Model (DEM), land use/land cover map, soil map and metrological data. The data were obtained from Ministry of Water, Irrigation and Electricity and National Meteorology Agency of Ethiopia. Simulation of SWAT was used to identify the most vulnerable sub-basins to the hydrological process. The model was calibrated and validated using the stream flow data. The simulated stream flow was calibrated by the SWAT-CUP2012 calibration sub-model of SWAT-CUP SUFI2. Sensitivity analysis showed that curve numbers (CN2), ALPHA-BNK and CH-K2 are the most sensitive top three parameters. The R^2 and Nash-Sutcliffe Efficiency (NSE) values were used to examine the model performance. The results indicate 0.84 and 0.80 for R^2 and 0.65 and 0.54 for NSE during calibration and validation, respectively. The average annual surface runoff in the delineated catchment was 774.13 mm. Changes in precipitation explained 89% of the variation in surface runoff, as more than 89% of precipitation from the catchment converted to surface runoff. The most three annual surface runoffs contributing were the 11, 23 and 5 sub-basins.

Keywords: Soil Type. Sensitivity analysis. Stream flow. Swat-Cup. Upper river basin.

1. Introduction

Nowadays, the quantity and quality of water becomes a major problem that needs serious attention, due to water sources have been polluted by wastes coming from several point and non-point sources. It leads to declining quantity of water sources that could no longer meet the ever-growing needs. This leads to declining quantity of water sources that could not no longer meet the ever-growing need (Sharpley et al., 2003). Nutrient enrichment of a stream from agricultural activities is affecting the management of river basins on a worldwide basis (Abudu, 2012). Sustainable management of water resources has been recent demanded throughout the world (Tilman, 2007).

In order to achieve water quality and quantity management goals, assessments of various water sources are required. This can avoid much water supply problems for communities depending on these fresh water bodies. Water resources may in a long-run become unsustainable due to deterioration of water quantity and quality.

The Ethiopian populations are engaged primarily in agriculture and depend heavily on available water resources; therefore, the assessment and management of available water resources is very critical (Jembere et al., 2016). Now, Ethiopia has embarked on extensive water resources development plan since a few years ago. Although development activities cover all major hydrographic basins in the country, the huge agricultural and hydropower potentials in the Abay (Upper Blue Nile) basin have attracted considerable attention (Adgolign et al., 2016).

Currently, there are a number of water resources development projects under construction and planning phases in Didessa Sub-basin of the Abbay Basin. Although the Didessa sub-basin study area provides the largest amount of the Blue Nile River flows, Didessa sub-basin areas are less studied (Sima et al., 2011).

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

RESEARCH PAPER

A sustainable agriculture requires a delicate balance between crop production, natural resources uses, environmental impacts and economics. To properly understand environmental risks and manage water source in watersheds, it is necessary to have knowledge of modeling and mechanism of evaluation. Commonly, water quantity and quality assessment at the watershed scale is accomplished using two techniques (Molina- Navarro et al., 2017): (1) watershed monitoring and (2) watershed modeling. As a result of continuous water quantity and quality monitoring is extremely expensive, time consuming and spatially impractical at catchment level, modeling has become a primary technology for analyzing amount of flow and its quality. Models also should be used to assess pollutant loadings allowed to be discharged in the receiving water bodies when measured data are insufficient to picture pollution within water shade (Taffese et al., 2014). This is because models provide quick and cost-effective assessment of water quantity and quality conditions, as they can simulate hydrologic processes, which are affected by several factors including climate change, soils, and agricultural management practices.

Therefore, the objectives of this study were to check the simulating efficiency of the SWAT model using secondary data and to identify highly vulnerable sub-basins with surface runoff. This could help to define a change in management strategy prior to the development of measures that negatively affect agricultural soil productivity or groundwater quality (Tufa and Feyissa, 2019; Feyissa and Tukura, 2019). This ability optimizes the use of the environment, maintaining its usefulness without harmful consequences, preserving the aesthetic qualities.

2. Materials and Methods

2.1 Description of the Study area

The study area is situated in Abay/Nile River basin to the south direction, called as Didessa sub-basin, which is situated in the south-western part of Ethiopia, in Oromia National Regional State. It is geographically located between 35°48'14" and 37°03'57" East longitudes and between 7°42'06"and 9°12'29" North latitudes. Total drainage area coverage at the outlet of delineated watershed was nearly 14,867 km² (Fig.1).

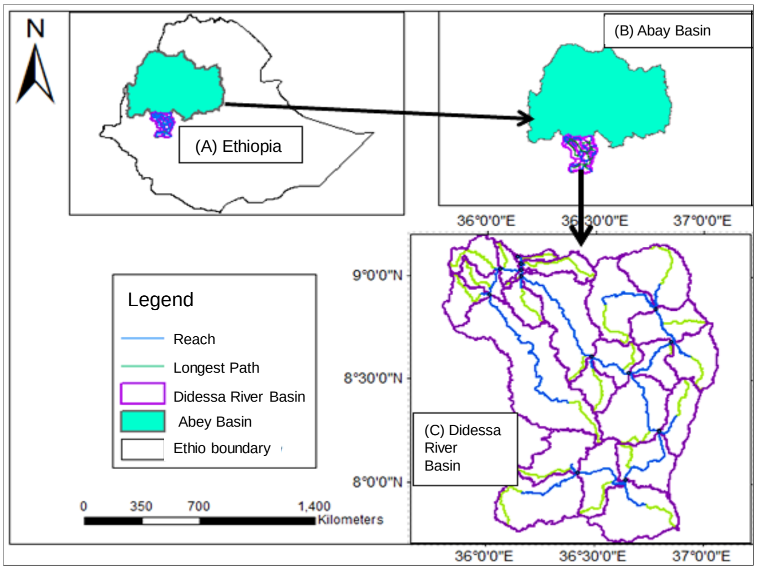

Fig. 1. Location of the Study area

The majority of the area is characterized by a humid tropical climate with heavy rainfall and most of the total annual rainfall is received during one rainy season, called kiremt.

Didessa watershed sub-basin has a number of tributaries that contribute to the Blue Nile River flow, and have a larger flow volume than other Nile river sub-basins.

The following are the methodology of the study components: Data collection, Data processing, Running model, Sensitivity Analysis, Calibration and validation of the model and Model result analysis. SUFI-2 calibration and Uncertainty analysis algorithms were used. Finally, calibration, validation of stream flow and appropriate systems to check the performance of the model with observed data was performed.

The main tools used for preparation and analysis of the impute data were: ArcGIS, ArcSWAT2012, SWAT CUP2012, PCPSTAT, Dew02.exe, Microsoft Excel, DEM, Meteorological, Hydrological map and data. SWAT model was used to assemble the study project, delineate the study area, analyze Hydrologic response unity (HRU), write all input tables, editing entries and simulate all entries.

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

JSE
RESEARCH PAPER

2.2 SWAT Model description

SWAT has been already validated in the different countries of the world for a variety of applications in hydrologic process and was developed for the simulation and to predict the impact of land management practices on water, sediment and agrochemical yields in large, complex watersheds with varying soils, land use and agricultural conditions over extended time periods (Neitch et al.,2005).

SWAT can be used to analyze small or large catchments by discretizing them into sub-basins, which are then further sub-divided. Ffor modeling purposes, the catchment is divided into a number of sub-basins which will be divided into hydrological response units (HRUs) each one having homogeneous land use, soil types, and management and slope characteristics. A daily water balance in each HRU is calculated based on daily precipitation, runoff, evapotranspiration, percolation, and return flow from subsurface and groundwater flow.

$$SWt = SWo + \sum_{i=1}^{t}(Rday - Qsurf - Ea - Wseep - Qgw) \qquad 1$$

Where: SWt - is the final soil water content (mm); SWo - is the initial water content (mm); $Rday$ - is the amount of precipitation on day i (mm); $Qsurf$ - is the amount of surface runoff on day i (mm); Ea - is the amount of evapotranspiration on day i (mm); $Wseep$ - is the amount of water entering the vadose zone from the soil profile on day i (mm); Qgw - is the amount of return flow on day i (mm); t - is the time (days).

2.3 Surface Runoff

SWAT uses two methods for calculating surface runoff namely; the modified SCS curve number method (USDA-SCS., 1972) and the Green & Ampt infiltration method (Green et al.,1911). The SCS curve number, which was used in this study, is a function of the soil permeability, land use and the antecedent moisture condition. In the curve number method, the curve number varies non-linearly with the moisture content of the soil. The Green & Ampt method (Green et al., 1911) requires sub-daily precipitation data and calculates infiltration as a function of the wetting front metric potential and effective hydraulic conductivity. The SCS curve number equation is calculated using the following equation:

$$Qsurf = \frac{(Rday - Ia)2}{(Rday - Ia + S)} \qquad 2$$

Where: $Qsurf$ - is the accumulated runoff or excess rainfall (mm H_2O); R day - is the rainfall depth for the day (mm H_2O); Ia - is the initial abstractions that includes surface storage, interception and infiltration (mm H_2O); and S - is the retention parameter (mm H_2O).

The retention parameter varies spatially due to changes in soils type, land use/land cover, management and slope and temporally due to changes in soil water content. The retention parameter is defined as:

$$S = 25.4 * \left(\frac{100}{CN} - 10\right) \qquad 3$$

Where:

CN- is the curve number for the day. The initial abstraction, Ia, is commonly approximated as 0.2S. Then the above equation becomes:

$$Qsurf = \frac{(Rday - 0.2S)2}{(Rday + 0.8S)} \qquad 4$$

Runoff will only occur when Rday> *Ia*. The peak runoff rate is the maximum runoff flow rate that occurs with a given rainfall event. The peak runoff rate is an indicator of the erosive power of a storm and is used to predict sediment loss. SWAT calculates the peak runoff rate with a modified rational method (Neitsch et al., 2005). The rational formula is:

$$qpeak = \frac{C * i * A}{3.6} \qquad 5$$

Where *qpeak* is the peak runoff rate (m^3/s) and; *C* is the runoff coefficient; *i* is the rainfall intensity (mm/hr.); A-is the sub-basin area (km^2) and; 3.6= is a unit conversion factor.

2.4 Potential Evapotranspiration

Potential evapotranspiration is a collective term that includes transpiration from the plant and evaporation from the water bodies and soil. Evaporation is the primary mechanism by which water is removed from a watershed. There are three methods of evaporation determination by SWAT model itself: Prestily-Taylor, Penman-Monteithmethod and Hargreves methods. Evapotranspiration is calculated using Penman-Monteith (equation 6) method (Neitsch et al., 2005). For this study, the Penman-Monteith method was selected as the method is widely used and all climatic variables required by the model are available for the stations in and around the study area.

$$ETo = \frac{0.408\Delta(Rn - G) + \gamma\frac{900}{T + 273} \cup 2(es - ea)}{\Delta + \gamma(1 + 0.34 \cup 2)} \qquad 6$$

Where: ETo – is the quantity of evapotranspiration (mm/day); Rn – is the net radiation at the crop surface (MJ/(m^2 day)); G - is the Soil heat flux density (MJ/(m^2 day)); T-is the mean daily air temperature at 2m height (^{0}C); U2 - is the wind speed at 2m height (m/s), es – is the Saturation vapor pressure(KPa); ea – is the actual vapor pressure (KPa); *es* - *ea* – is the saturation vapor pressure deficit (KPa); Δ - is the Slope vapor pressure curve (KPa/^{0}C) and; γ – is the psychometrics constant (KPa/^{0}C).

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

JSE
RESEARCH PAPER

2.5 Model input data preparation and their sources

2.5.1 Metrological data

The meteorological data which were gathered from National Meteorological- Agency of Ethiopia were organized, processed and arranged/transposed vertically to fit the model data requirement. The collected meteorological data c were precipitation, maximum and minimum temperature, relative humidity, wind speed and sunshine hours for five stations (Nekemte, Bedele, Arjo, Agaro and Dembi) from 1990 -2014. Nekemte and Bedele have been used as weather generator stations to fill missing data for the conventional meteorological stations (Fig. 2).

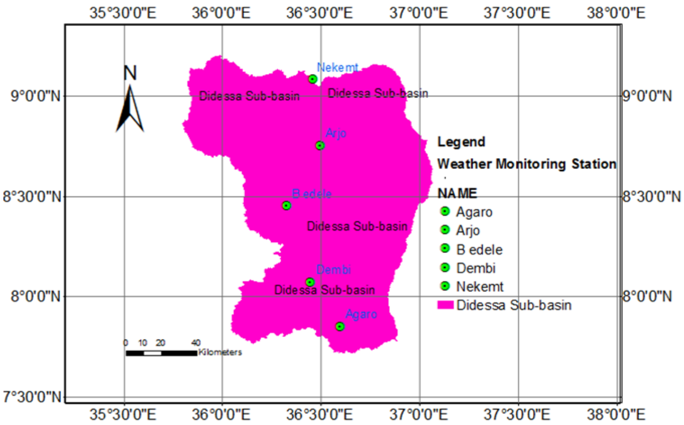

Fig. 2. Location of weather monitoring stations.

2.5.2 Hydrological Data

The stream flow data of the Didessa watershed was required for calibrating and validating the model. Therefore, daily and monthly stream flow data at different gauging stations in Didessa Sub-Basin (1990-2014) were collected from Ministry of Water, Irrigation and Electricity of Ethiopia.

2.5.3 Digital Elevation Model (DEM)

A Digital Elevation Model (DEM) of 30 m by 30m, in the Grid format and projected, was used in this study. The original DEM in geographic coordinate system was obtained from Ethiopian Ministry of water, Irrigation and Electricity. The minimum and maximum elevation of the study area above mean sea level was between 1032 m and 3169 m, respectively, with mean of 2101m (Fig. 3).

2.5.4 Land Use/Land Cover

The Land use/land cover (LULC) data combined with the soil cover data generates the hydrologic characteristics of the basin, which in turn determines the excess amounts of precipitation, recharge to the groundwater system and the storage in the soil layers. The land use shape file has been collected from Ministry of Water, Irrigation and Electricity of Ethiopia. Land use adjustment was done to fit SWAT data base and the prepared LULC was given as input to the model data of the SWAT to describe the HRU of the watershed (Fig. 4). Therefore, the impact of each type of LULC was considered in this model to calculate runoff in the basin. The land use/land cover was defined and then the land use layer was reclassified for analysis (Table 1)

2.5.5 Soil data

The soil data have been collected in shape file format from the Ministry of Water, Irrigation and Electricity of Ethiopia. Ten soil types were identified and prepared for SWAT input. Dystric nitosols are the dominant soil type followed by dystric combisols and eutric nitosols in the catchment (Fig. 5).

2.5.6 Consistency of data

Statistically XLSTAT2015 tool was used for filling missed data of rainfall and other meteorological data. Visual observation and double mass curve (DMC) were used to check the consistency for adjustment of inconsistent data. Accordingly, the double-mass curve of selected station Rainfall was drawn to check consistency of the data (Fig.6).

2.5.7 SWAT-CUP

SWAT-CUP is an interface that was developed for SWAT. SWAT-CUP is designed to integrate various sensitivity analysis, calibration, validation and uncertainty programs for SWAT using different interface. The recently developed SWAT-CUP interfaced program for calibration and uncertainty analysis procedures (Abbaspour et al., 2007) also made the SWAT model more attractive for the study.

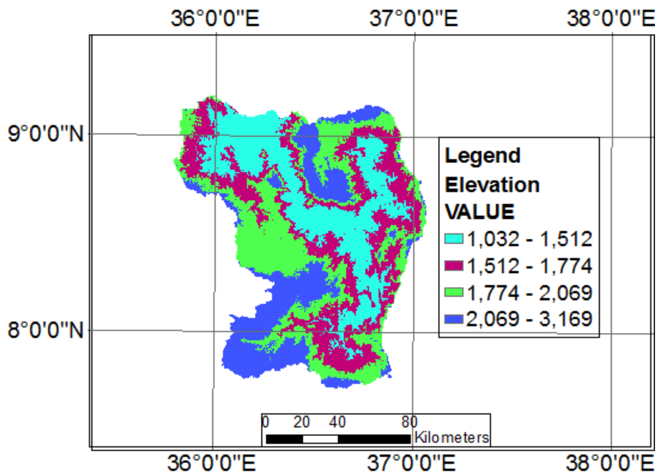

Fig. 3. Elevation map of upper Didessa sub-basins.

2.5.8 Sensitivity analysis

This analysis determines the sensitivity of the input parameters by comparing the output variance due to the input variability. This is useful not only for model development, but also for model validation and reduction of uncertainty (Hamby, 1994). The sensitivity analysis was carried out to identify the sensitive parameters to stream flow of the SWAT model.

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

JSE
RESEARCH PAPER

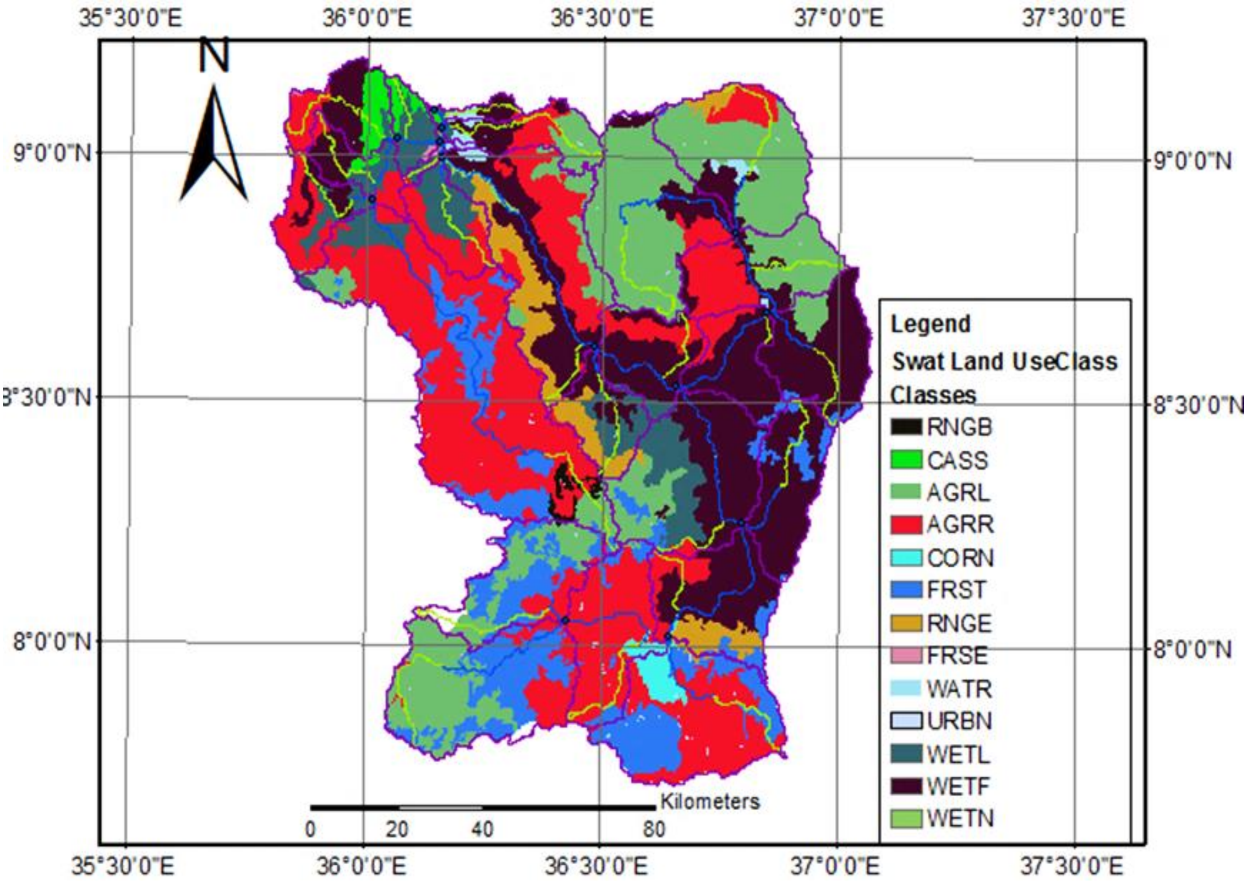

Fig. 4. SWAT Land use of Didessa sub-basins. The sub-basins acronyms and respective identification can be found in Table 1.

Tab. 1. SWAT Land use/land covers Analysis.

S.N	Land use/Land cover according to SWAT database	SWAT code	Area	
			Area (ha)	Coverage (%)
1	Range-Brush	RNGB	5513.0702	0.37
2	Cassava	CASS	17252.8956	1.16
3	Agricultural Land-Generic	AGRL	301465.104	20.28
4	Agricultural Land-Row Crops	AGRR	443024.201	29.8
5	Corn	CORN	12422.1029	0.84
6	Forest-Mixed	FRSTE	170799.277	11.49
7	Range-Grasses	RNGE	55573.1231	3.74
8	Forest-Evergreen	FRSE	1234.9422	0.08
9	Water	WATR	9345.8804	0.63
10	Residential	URBN	2274.1075	0.15
11	Wetlands-Mixed	WETL	99672.3444	6.71
12	Wetlands-Forested	WETF	365641.459	24.6
13	Wetlands-Non-Forested	WETN	2407.7933	0.16
		Total	1486626.3	100%

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

JSE
RESEARCH PAPER

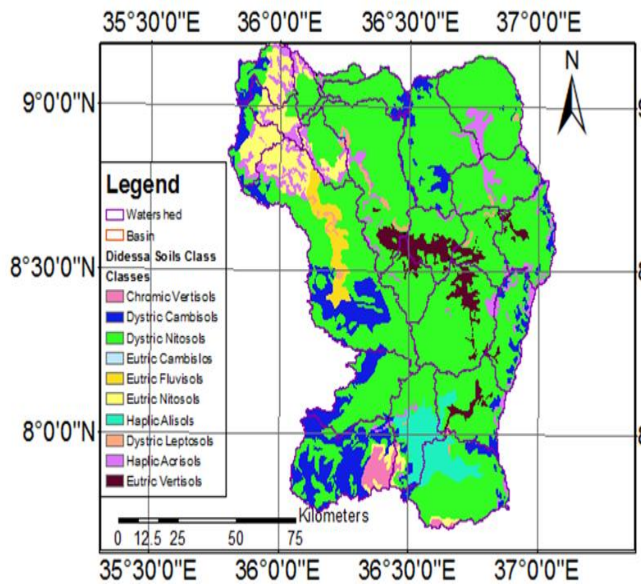

Fig. 5. Soil Map of upper Didessa sub- basins.

The analysis was done by the global sensitivity analysis using SWAT_CUP 2012. In a global sensitivity analysis, parameter sensitivities are determined by calculating the number of multiple regression systems, which regresses the Latin-hypercube generated parameters against the objective function values.

2.6 Model calibration and validation

Calibration and validation of the models are two main exercises that must be successfully achieved before using a model in hydrologic simulation. Reliable values for some parameters can only be found by calibration (Beven, 1989). Model validation is the process of representing that a given specific site model is capable of making sufficiently accurate simulation. The available flow data of 15 years (2000-2014) at Didessa near Arjo gauging station were used to run the default calibration. For the default calibration 15 flow parameters were used and the simulation was run for 500 times. By developing the graph of the observed flow and the simulated flow from the default calibration, the study period was divided into the calibration and validation period. Accordingly, warm up period of 2 years (1998-1999), calibration period of 9 years (2000-2008) and validation period of six years (2009-2014) were selected.

2.7 Model Efficiency

Two methods for goodness-of-fit measures of model predictions were used during the calibration and validation periods. These numerical model performance measures the fraction of the variation in the measured data that is replicated in the simulated model, which results are coefficient of regression (R^2) and the Nash-Sutcliffe simulation efficiency (NS). R^2 ranges from 0.0 to 1.0 with higher values indicating better agreement and the value of NS ranges from minus infinity to 1.0, with higher values indicating better agreement (Lagates et al., 1999).

R^2 is calculated by the following equation:

$$R^2 = \frac{[\sum_{i=1}^{n}(qsi - \bar{q}s)(qoi - \bar{q}o)]2}{\sum_{i=1}^{n}(\mathbf{qsi} - \bar{q}s)2\sum_{i=1}^{n}(qoi - \bar{q}o)2} \qquad 7$$

Where: qsi is the simulated stream flow in m^3/s; qoi is the observed stream flow in m^3/s; $\bar{q}s$ is the mean of the simulated value; $\bar{q}o$ is the mean of the observed value.

The Nash-Sutcliffe simulation of the model efficiency indicates the degree of fitness of the observed and simulated plots. It is calculated as follows with the same variables defined above:

$$NS = 1 - \frac{\sum_{i=1}^{n}(qoi - qsi)2}{\sum_{i=1}^{n}(\sum_{i=1}^{n}(qoi - \bar{q}o)^2} \qquad 8$$

2.8 SWAT Model Setup

The model is built completely in a GIS environment using a SWAT extension (www.brc.tamus.edu/swat/arcswat.html). All processes were performed through the interface in Geographic Information System (GIS) for SWAT version Arc SWAT 2012 interface with ArcGIS 10.3. The SWAT project setup processes involved: 1. Watershed delineation; 2. Sub-basin discretization; 3. HRU analysis and definition; 4. Weather data definition; 5. SWAT simulation; 6. Read SWAT result; 7. sensitivity analysis, and; 8. Calibration and validation. Following these procedures, the model input data, DEM (Digital Elevation Model), land use map, soil map and weather data were geo-processed step by step to set up the model.

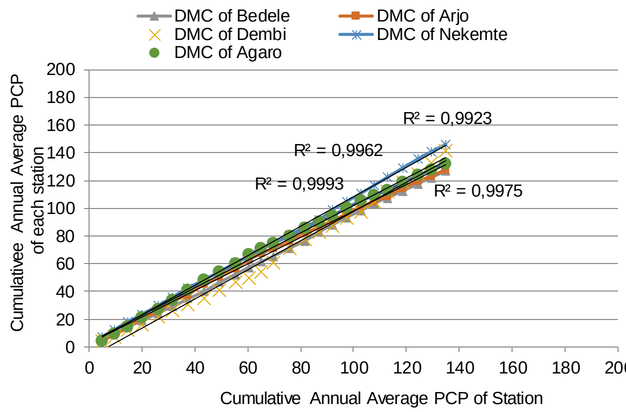

Fig. 6. Consistency checking for the rainfall data. PCP-precipitation; DMC -Double mass curve of each stations.

Before going in hand with spatial input data i.e. the soil map, LULC map and the DEM were projected into the same projection called UTM Zone 37N, which is a projection parameter for Ethiopia. The watershed delineation processes

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

JSE
RESEARCH PAPER

include, DEM setup, stream definition, outlet and inlet definition, watershed outlets selection and definition and calculation of sub-basin parameters. For the stream definition the threshold-based stream definition option was used to define the minimum size of the sub basins. The stream definition and the size of sub-basins were carefully determined by selecting threshold area or minimum drainage area required to form the origin of the streams. Choosing the threshold value of 29000 hectares, Didessa watershed was divided in to 25 sub-basins (Fig.7) and 253 Hydrological Response Units (HRUs), determined by unique inter-section of the LULC, slope and soil within the watershed. SWAT predicts the land phases of the hydrologic cycle separately for each HRU and routes to obtain the total loadings of the catchment.

For this study, 20% for land use threshold, 20% for soil and 10% for slope were used. The multiple slope option (an option which considers different slope classes for HRU definition) was selected. Based on the multiple slope options, four slope classes (0-4, 4-8, 8-12 and> 12) were selected for the entire river basin and the HRU was analyzed (Fig.8).

SWAT simulation run was carried out on the period of 1990-2014 climate data. Two years were taken for the warm-up period. The warm-up period is important to make sure that there are no effects from the initial conditions in the model.

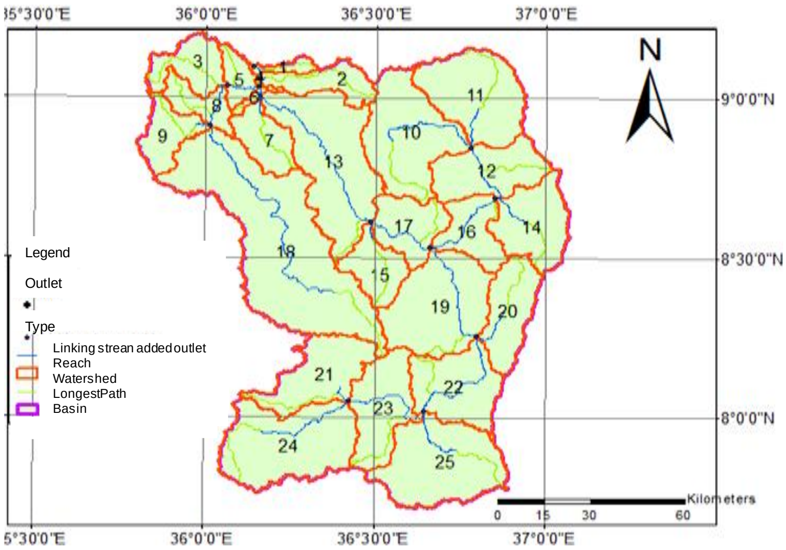

Fig. 7. Delineated Didessa watershed and sub-basins.

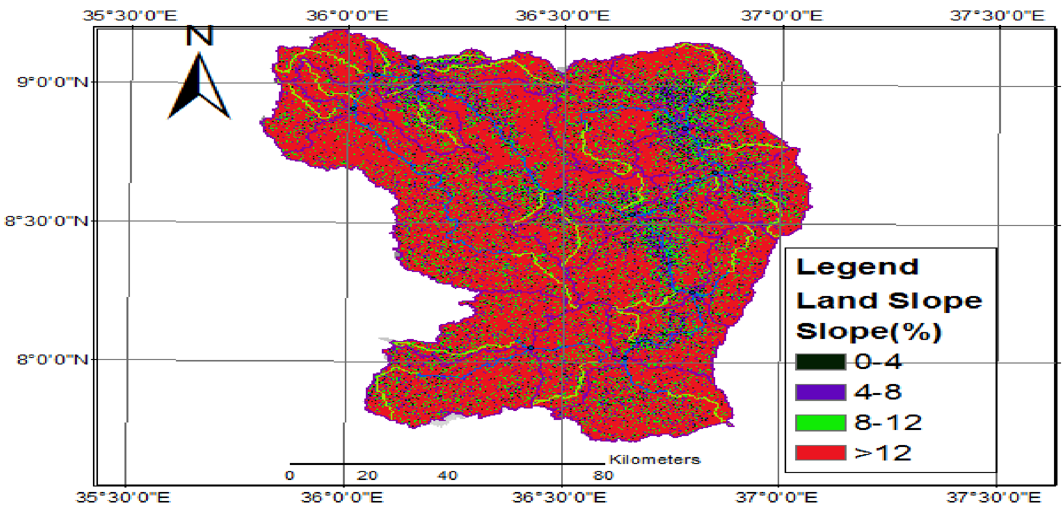

Fig. 8. Slope Distribution of Didessa watershed.

3. Results and Discussion

3.1 Sensitivity Analysis

Data analysed in this work are presented in supplemtary material (SM-Tables 1-4). Twenty-one parameters were considered for the model parameterization sensitivity analysis, only ten of them were effective and sensitive parameters that were responsible for monthly flow simulation analysis (Table 2). It has been observed that these sensitive parameters were mostly responsible for the model

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

JSE
RESEARCH PAPER

calibration and parameter changes during model interaction processes. The result of the sensitivity analysis indicated that these ten flow parameters were sensitive to the SWAT model. i.e., the hydrological process of the study area mainly depends on the action of these parameters.

The SCS runoff curve number for moisture condition (CN2) was found to be among the most sensitive parameters followed by base flow alpha factor for bank storage (ALPHA_BNK) and Effective hydraulic conductivity of the main channel (CH_K2) for the upper Didessa sub-basins. Tesfa (2016) showed a similar result, since the curve number was the most sensitive parameter for the current flow calibration in the Didessa watershed.

3.2 Stream Flow Calibration

The simulated stream flow was calibrated against monthly average flow with those selected sensitive parameters ordered in Table 2 by the SWAT-CUP2012 calibration sub-model of SWAT-CUP SUFI2. The calibration was done for the period of (2000-2008) for nine years with two years (1998-1999) keeping for model warm up or to initiate the model. The graphical methods, flow hydrography (Fig. 9) and values of statistical parameters of coefficient of determination (R^2) and Nash-Sutcliffe efficiency (NSE) were used as an indication of calibration acceptance. The calibration results showed good agreement between measured and predicted flow at the gauging station Didessa near Arjo of sub-watershed with an R^2 and NSE 0.84 and 0.65 respectively.

3.3 Stream flow Validation

The model validation was done using stream flow data set for the period of six years (2009- 2014). The same number of simulations in the calibration was used. Statistical analysis of model performance during validation using regression plot indicates a good relationship between simulated and measured stream flow (Fig.10). The R^2 value of 0.8 obtained indicates a good model fit during validation. In addition, the objective function NSE of 0.54 indicates that the model performance during validation was satisfactory.

Although calibration and validation results were within an acceptable range for stream flow data, the value was low, especially for NSE. The reason may be related to the small number of data used during calibration and validation and there may have been inaccurate measurements during field data collection.

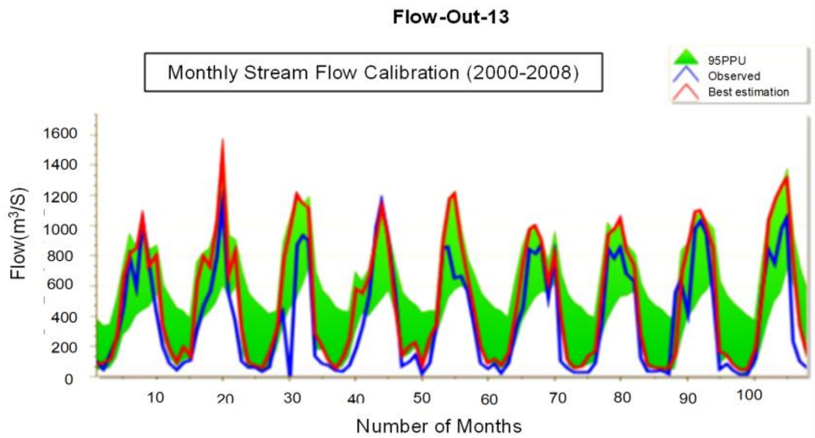

Fig. 9. Hydrograph of observed and simulated monthly stream flow during calibration.

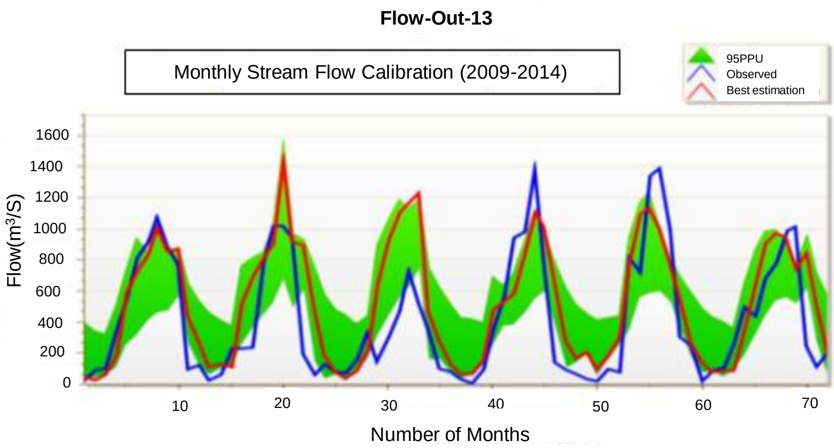

Fig. 10. Hydrograph of observed and simulated monthly stream flow during validation.

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

JSE
RESEARCH PAPER

Tab. 2. Flow Sensitivity parameter of Didessa sub-basins, based on t-stat and p-value

Nº	SWAT Input parameter	t-stat	p-Value	Ranking
1	CN2- SCS runoff Curve number for moisture condition II	12.053	0.000	1
2	ALPHA_BNK- Base flow alpha factor for bank storage	11.606	0.000	2
3	CH_K2- Effective hydraulic conductivity of the main channel	-5.896	0.000000008	3
4	SLSUBBSN- Average slope length	-4.360	0.000016785	4
5	HRU_SLP- Average slope steepness	3.376	0.000808214	5
6	SURLAG- Surface runoff lag coefficient	1.917	0.05594755	6
7	SOL_K- Saturated Hydraulic conductivity	1.628	0.104400046	7
8	SOL_AWC- Soil available water capacity	-1.602	0.110049056	8
9	ALPHA_BF- Base flow alpha factor (days)	-1.352	0.177131863	9
10	GW_DELAY- Groundwater delay (days)	1.338	0.181643988	10

3.4 Surface Runoff

The average annual runoff contribution was accounted for 774.13 mm (Fig.11). The maximum amount of runoff generated from the watershed in (2001) was 929.5 mm (14%). The minimum runoff generation was seen in the year (2003), which was about (572.64 mm; 8.43 %). The possible reason might be the slope condition, change in hydrological condition, soil physical and chemical nature, alteration of land use and land cover and level of effective watershed management methods applied over the area.

Based on simulated output of precipitation and surface runoff, the result strongly showed the close relationship (R^2=0.89) as indicated in scatter plot (Fig.12). More than 89% of precipitation from the catchment converted to surface runoff. It was seen a very close linear relationship between precipitation and contributed runoff as shown in Fig.12. This might be due to overland slope, ineffective land cover, and dominant agricultural practice and soil type vulnerability to erosion effect due to dominant soil type of the study area were dystric nitisols, which is well drained tropical soil with more than 30% of clay content in their subsurface horizon (Geleta, 2010).

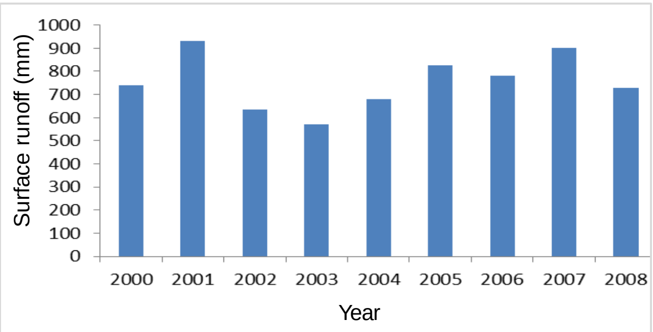

Fig. 11. Annual surface runoff of Didessa sub-basins (2000-2008).

4. Conclusion

The study has shown that GIS and SWAT 2012 are helpful tools in evaluating the hydrological responses on the medium catchment. Over all it is a reasonable annual predictor of the watershed responses for assessing the impacts of different management systems on water resources and non-point source pollution.

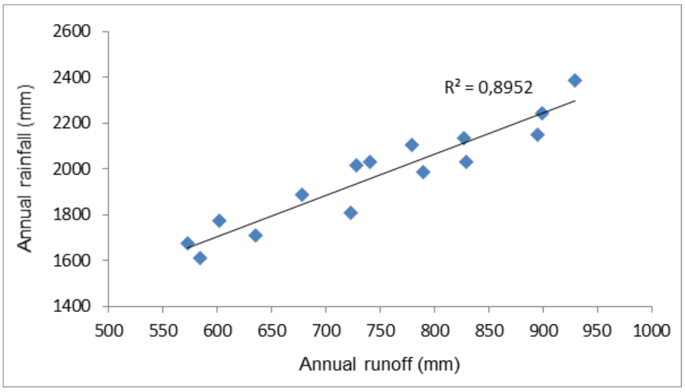

Fig. 12. Average Annual Rainfall-Run off curve.

The ability of SWAT to adequately simulate stream flows was evaluated through sensitivity analysis, model calibration and validation. The model was successfully calibrated and validated for the upper Didessa watershed and gives good result for the performance evaluation of the model. Therefore, SWAT can be utilized very well for hydrological simulations in the selected catchments and it is a capable tool for further analysis of the hydrological responses in the watershed. SUFI-2 was used for model calibration and validation and it has performed uncertainty analysis and calibrates the model for a greater number of parameters. The sensitivity analysis parameters using SWAT-CUP SUFI-2 model has pointed out ten most important parameters that control the stream flow of the watershed.

The SWAT model was calibrated for nine years and validated for six years considering two years warm up period on monthly basis to examine its applicability for simulating flow of upper Didessa watershed. The model performance during calibration and validation was 0.84, 0.8 and 0.65, 0.54 respectively for R^2 and NSE. This shown good agreement between the simulated flow and observed stream flow respectively. Hence, the coefficient of determination and Nash-Sutcliffe simulation efficiency values obtained proved

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

that the model is good to simulate the hydrological process of the catchments. The simulation of hydrological process has quantified the hydrological process in the basin using the reference conditions, defined from 2000-2010. The effect of precipitation, surface runoff, on stream flow was evaluated. The average annual surface runoff contribution was accounted as 774.13 mm. The highest annual surface runoff was supplied by the sub-basins 11, 23 and 5 of the watershed. The study area soil type is vulnerability to erosion, due to dominant soil type of study area were dystric Nitisols, which is well drained tropical soil with more than 30% clay in their subsurface horizon. Erosion and soil loss controlling mechanism is highly recommended for the study catchment.

Acknowledgement

The author is grateful to Ministry of Water, Irrigation and Electricity of Ethiopia and National Meteorological Agency of Ethiopia from where the raw data were collected.

References

Abbaspour, S., Cui, C.L., Saydi, M., King, J.P., 2007. Application of snowmelt runoff model (SRM) in Mountainous watersheds. A review. Water Science and Engineering 5(2), 123-136.

Adgolign, Bekele, T., Srinivasa, R.G.V.R., Yerramsetty, A., 2016. WEAP Modeling of surface water resources allocation in Didessa Sub-Basins, West Ethiopia. Sustainable Water Resources Management 2(1), 55-70.

Beven, K., 1989. 'Changing ideas in hydrology - The case of physically-based models'. Journal of Hydrology 105 (1-2), 157-172. https://doi.org/10.1016/0022-1694(89)90101-7

Feyissa, T.A., Tukura, N.G., 2019. Evaluation of the best-fit probability of distribution and return periods of river discharge peaks. Case Study: Awetu River, Jimma, Ethiopia. Journal of Sedimentary Environments, 4 (4): 361-368. https://doi.org/10.12957/jse.2019.46128

Geleta, H. I., 2010. Watershed sediment Yield Modeling for Data Scarce Areas.

Green, W., Ampt, G., 1911. Studies in Soil Physics, I: The Flow of Air and Water through Soils. Journal of Agricultural Sciences 4, 11 - 24.

Hamby, D., 1994. A review of techniques for parameter sensitivity analysis of environmental models. Environmental Monitoring and Assessment 32 (2), 135–154. https://doi.org/10.1007/BF00547132

Legates, D., McCabe, G.J., 1999. Evaluating the use of "goodness-of-fit" measures in hydrologic and hydroclimatic model validation. Water Resources Research 35(1), 233-241. https://doi.org/10.1029/1998WR900018

Minichil, J., Tesfa, G., Bogal, G.M., 2016. Evaluation of Land use Land caver change on Stream Flow: A case study of Didessa Sub-basin, Abay Basin, south western Ethiopia. International Journal of Innovations in Engineering Research and Technology 3(8), 2394-3696.

Molina-Navarro, E., Andersen, H.E., Nielsen, A., Thodsen, H., Trolle, D., 2017. The impact of the objective function in multi-site and multi-Variable Calibration of the SWAT model. Environmental Modeling and Software, 93, 255-267.

Neitsch, S.L., Arnold, J.G., Kiniry, J.R., Williams, J.R., 2005. Soil and Water Assessment Tool Theoretical Documentation. Blackland Research Center, Texas Agricultural Experiment Station and Grassland, Soil and Water Research Laboratory, Temple, TX.

Sharpley A.N., Jones, T.D., 2003. Agricultural Phosphorus and Eutrophication. United States, Department of Agriculture-Agricultural Research Service.

Sima, A.B., Bishop, P.K., 2011. Flow regime and land cover changes in the Didessa Sub-Basin of the Blue Nile River, South-western Ethiopia: Combining Empirical Analysis and Community perception Swedish University of Agricultural Sciences.

Taffese, T., Tilahun, S.A., Steenhuis, T.S., 2014. Phosphorus modeling, in lake Tana Basin, Ethiopia. Journal of Environment and Human 2, 47-55.

Tesfa, G., 2016. Sediment Yield Modeling of Didessa Sub Basin, Abay Basin, South-Western Ethiopia. Journal of Environment and Earth Science, 6(10), 120-127.

Tilman, D., 2007. Resource Competition and plant traits: A Response to Craine et al .2005: Forum. Journal of Ecology 95, 231-234.

Tufa, F.G. Feyissa, T.A., 2019. Spatial distribution of soil loss in Upper Didessa Watershed, Ethiopia. Journal of Sedimentary Environments, 4 (4): 434-443. doi: 10.12957/jse.2019.31411

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

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

JSE
RESEARCH PAPER

Supplementary Material (SM)

SM-Tab. 1. Annual precipitation of each station (mm).

year	Agaro	Arjo	Bedele	Dembi	Nekemte	average
2014	4.566	4.653	4.648	4.124	6.904	4.979
2013	4.795	4.105	5.197	3.479	5.384	4.592
2012	5.134	4.764	5.061	4.491	5.763	5.043
2011	6.712	6.743	4.233	4.102	5.508	5.460
2010	5.669	5.648	5.387	6.058	6.800	5.912
2009	7.090	6.868	4.868	3.846	5.542	5.643
2008	7.146	4.894	5.436	4.866	6.670	5.802
2007	7.579	7.579	5.431	4.421	5.953	6.193
2006	5.543	5.364	6.461	5.841	5.861	5.814
2005	5.871	5.871	5.660	5.766	6.161	5.866
2004	6.450	6.450	5.192	3.170	4.896	5.232
2003	4.879	4.879	3.960	4.251	5.034	4.601
2002	3.708	3.708	3.971	6.814	4.674	4.575
2001	5.132	5.132	5.932	10.046	5.321	6.313
2000	5.344	5.273	4.994	6.209	5.837	5.531
1999	4.461	4.838	6.363	5.498	5.542	5.340
1998	4.968	4.568	5.318	4.387	6.990	5.246
1997	5.446	5.000	5.484	5.535	6.000	5.493
1996	5.188	5.165	4.740	5.039	6.341	5.295
1995	3.638	3.604	5.038	7.056	5.641	4.995
1994	3.944	3.724	4.108	7.070	5.726	4.914
1993	5.397	5.514	4.918	7.255	6.882	5.993
1992	5.468	5.468	5.216	5.787	6.773	5.743
1991	3.943	3.857	4.553	8.103	5.018	5.095
1990	4.351	4.306	4.689	8.329	5.177	5.370

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

JSE
RESEARCH PAPER

SM-Tab. 2. Cumulative PCP of each station

Year	Agaro	Arjo	Bedele	Dembi	Nekemte	average
2014	4.566	4.653	4.648	4.124	6.904	4.979
2013	9.361	8.759	9.845	7.603	12.289	9.571
2012	14.495	13.522	14.906	12.094	18.052	14.614
2011	21.207	20.266	19.139	16.196	23.560	20.073
2010	26.876	25.914	24.526	22.254	30.360	25.986
2009	33.966	32.782	29.394	26.100	35.902	31.629
2008	41.112	37.676	34.829	30.966	42.572	37.431
2007	48.691	45.256	40.260	35.388	48.526	43.624
2006	54.234	50.620	46.721	41.228	54.387	49.438
2005	60.105	56.491	52.382	46.994	60.548	55.304
2004	66.555	62.941	57.573	50.165	65.444	60.536
2003	71.434	67.820	61.534	54.416	70.479	65.136
2002	75.143	71.529	65.505	61.229	75.153	69.712
2001	80.275	76.661	71.436	71.275	80.474	76.024
2000	85.619	81.934	76.430	77.484	86.310	81.556
1999	90.080	86.772	82.793	82.982	91.852	86.896
1998	95.048	91.340	88.111	87.368	98.842	92.142
1997	100.494	96.340	93.595	92.903	104.842	97.635
1996	105.682	101.504	98.336	97.942	111.184	102.929
1995	109.320	105.108	103.373	104.997	116.824	107.925
1994	113.264	108.833	107.482	112.067	122.550	112.839
1993	118.661	114.347	112.399	119.322	129.432	118.832
1992	124.129	119.815	117.616	125.110	136.206	124.575
1991	128.072	123.672	122.169	133.213	141.224	129.670
1990	132.423	127.977	126.858	141.542	146.401	135.040

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

JSE
RESEARCH PAPER

SM-Tab. 3. Weather Generator Parameters used in SWAT.

	Weather Generator Parameters used in SWAT for Nekemte									
Month	PCP_MM	PCPSTD	PCPSKW	PR_W1	PR_W2	PCPD	Tmp_max	Tmp_min	Hmd	Dewpt
Jan	8.60	1.49	7.35	0.05	0.30	2.28	26.07	12.30	0.40	10.50
Feb	12.56	1.73	5.34	0.07	0.52	3.84	27.43	13.24	0.35	10.00
Mar	52.64	4.96	4.62	0.16	0.60	9.40	27.60	14.04	0.89	11.10
Apr	101.96	7.65	3.34	0.23	0.66	12.44	26.56	14.37	1.15	12.37
May	247.89	12.50	2.72	0.37	0.78	20.48	24.58	13.83	2.30	14.23
Jun	391.80	14.74	2.62	0.84	0.89	27.32	22.40	12.90	2.86	15.48
Jul	405.87	15.71	1.91	0.87	0.89	28.52	20.99	12.79	2.20	15.41
Aug	406.12	14.60	1.96	0.80	0.91	29.00	21.07	12.85	2.20	15.54
Sep	295.56	11.27	1.73	0.75	0.86	26.48	22.43	12.78	1.55	15.74
Oct	151.96	9.01	2.73	0.34	0.71	17.76	23.84	12.85	1.29	14.58
Nov	47.92	4.97	4.70	0.16	0.45	7.32	24.39	12.62	0.93	13.29
Dec	16.02	2.96	8.58	0.05	0.36	2.68	25.03	12.11	0.75	11.73
		Weather Generator Parameters used in SWAT for Bedele								
Month	PCP_MM	PCPSTD	PCPSKW	PR_W1	PR_W2	PCPD	Tmp_max	Tmp_min	Hmd	Dewpt
Jan	16.46	2.40	7.42	0.09	0.32	3.92	27.03	12.09	0.63	10.79
Feb	20.13	2.90	7.06	0.09	0.45	4.36	28.36	12.82	0.80	8.72
Mar	68.88	5.93	4.12	0.19	0.59	10.16	28.16	13.73	1.14	10.83
Apr	114.16	7.74	2.79	0.25	0.64	12.64	27.62	14.02	1.08	13.65
May	231.47	10.73	1.78	0.38	0.74	19.20	26.05	13.58	1.27	15.50
Jun	321.71	12.62	1.83	0.71	0.78	23.92	24.39	12.89	2.18	17.31
Jul	284.79	11.01	1.59	0.69	0.81	25.20	22.57	12.86	1.31	17.01
Aug	293.68	11.24	1.62	0.81	0.83	26.48	22.78	12.85	1.25	16.98
Sep	295.55	11.94	1.98	0.70	0.79	23.96	24.25	12.65	1.74	17.29
Oct	150.14	9.49	2.77	0.24	0.64	13.16	25.10	12.37	1.49	16.18
Nov	36.36	4.43	5.04	0.13	0.40	5.52	25.67	12.03	0.89	14.68
Dec	20.03	3.14	6.75	0.08	0.31	3.32	26.38	11.85	0.76	12.64

Whereas: PCP_MM = average monthly precipitation [mm]
PCPSTD = standard deviation
PCPSKW = skew coefficient
PR_W1 = probability of a wet day following a dry day
PR_W2 = probability of a wet day following a wet day
PCPD = average number of days of precipitation in month
Tmp_max = average daily maximum temperature in month [°C]
Tmp_min = average daily minimum temperature in month [°C]
Hmd = average daily humidity in month [%]
Dewpt = average daily dew point temperature in month [°C]

Journal of Sedimentary Environments
Published by Universidade do Estado do Rio de Janeiro
4 (4): 444-457. October-December, 2019
doi: 10.12957/jse.2019.47322

JSE
RESEARCH PAPER

SM-Tab. 4. Run off yield based on Sub basin value.

Sub basin number	Runoff yield (mm)
1	516.84
2	821.83
3	773.37
4	738.27
5	834.70
6	434.89
7	746.43
8	698.89
9	717.34
10	503.18
11	1063.83
12	667.89
13	594.86
14	729.90
15	586.51
16	625.22
17	591.86
18	509.59
19	697.03
20	452.98
21	645.91
22	671.89
23	896.01
24	684.52
25	646.14
Avg.	673.99
Max	1063.83
Min	434.89