# Modeling the Hydrological Characteristics of Hangar Watershed, Ethiopia

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***Key findings:*** The Hydrological Characteristics of the Watershed were modelled.

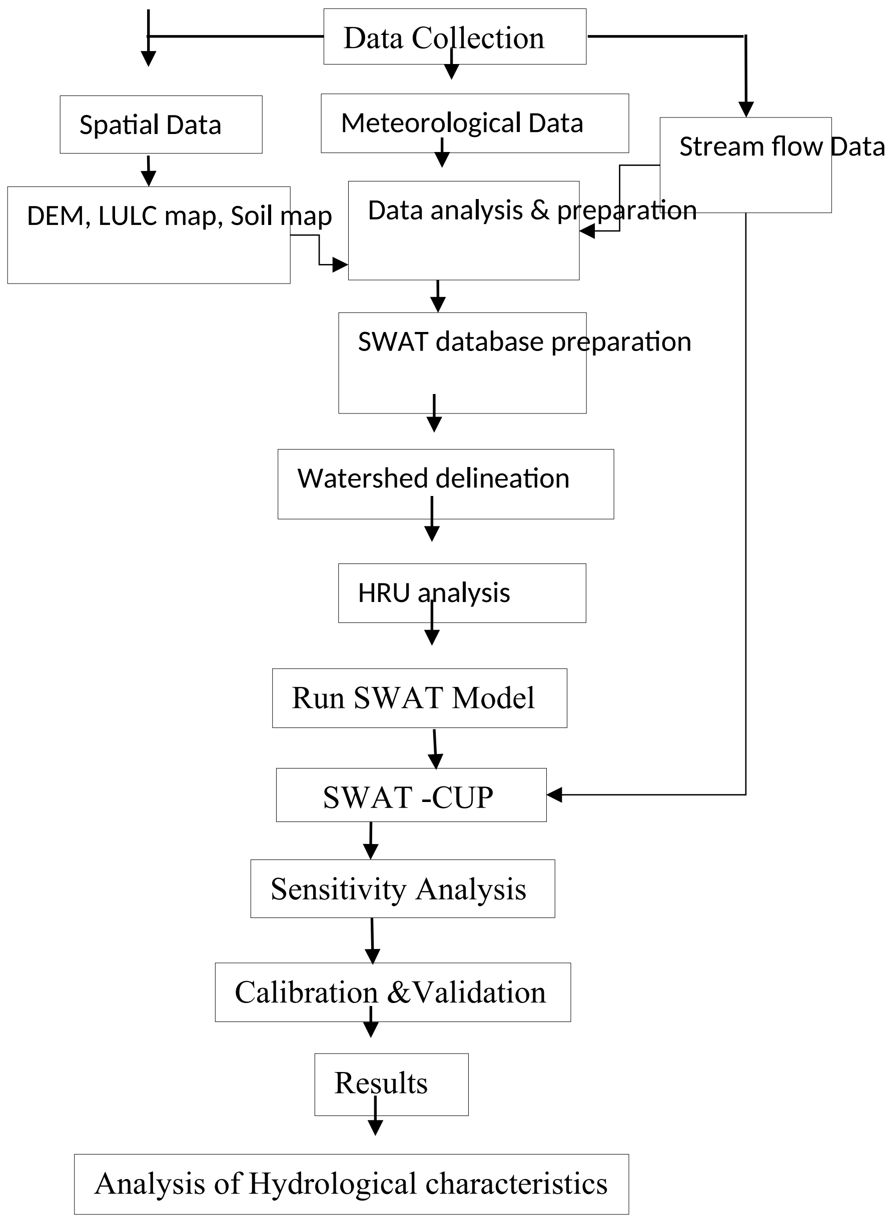


Figure 2: The conceptual frame work of SWAT Model Processing

## Abstract

Modelling the hydrological characteristics of watershed is a method of understanding behavior and simulating the water balance components of watershed for planning and development of integrated water resources management. The soil and water assessment tool (SWAT) physically based hydrological modelling was used for modelling hydrologic characteristics of the Hangar watershed. The data used for this study were digital elevation model (DEM), land use land cover data, soil map, climatological and hydrological data. The model calibrated and validated using measured streamflow data of 13 years (1990-2002) and 9 years (2003-2011) respectively including warm-up period. The SWAT model performs well for both calibration ($R^2$ = 0.87, NSE = 0.82 and PBIAS = +1.4) and validation ($R^2$ = 0.89, NSE = 0.88 and PBIAS = +1.2). The sensitivity analysis, which was carried out using 18 SWAT parameters, identified the 13 most sensitive parameters controlling the output variable and with which goodness-of-fit was reached. The analysis results indicated that the watershed receives around, 9.6%, 59.9%, and 30.5% precipitation during dry, wet and short rainy seasons respectively. The received precipitation was lost by 9.6 %, 40.5%, and 41.3% in the form of evapotranspiration for each seasons correspondingly. The surface runoff contribution to the Watershed were 3.8%, and 79.2% during dry and wet seasons respectively, whereas, it contributes by 17.0% during short rainy seasons.

## 1. Introduction

As water is a valuable part of our ecosystem that individuals has to be granted, predicting its availability for the next generation has become an essential task in a planning and resource management for hastily evolving area (Takala et al., 2016). The water resources availability assessment requires detailed insights into hydrological processes. However, studying the complexity of hydrological processes, needed for sustainable basin management, based on understanding rainfall characteristics and basin properties (Redfern et al., 2016). Thus, water systems should be modelled to design and meet present and future water demands, while maintaining a range of hydrologic variation necessary to preserve the ecological and environmental integrity of the basin. Modelling watershed water balance is a pre-requisite to understand the key processes of the hydrologic cycle (Tekleab et al., 2011).

Hydrology has made enormous strides in understanding the behavior of small, relatively homogeneous (and unchanging) systems, but more research is needed to understand hydrologic system complexity at larger scales (e.g., catchments, regional aquifers, river basins, and whole ecosystems), than we have typically addressed (Ehret et al., 2014). The history of hydrological modelling ranges from the Rational Method to recent distributed physically meaningful models (Todini, E., 2011). Watershed modeling deals with modeling of the hydrologic processes at the watershed scale and integrating them in order to determine the watershed response (Amin, et al., 2017). The beginnings of hydrological modeling can be traced to the development of civil engineering in the nineteenth century for design of roads, canals, city sewers, drainage systems, dams, culverts, bridges, water supply systems, and so on (Singh, 2018).

A watershed hydrology model is often an assemblage of component models corresponding to different components of the hydrologic cycle. Watershed models are employed in a wide spectrum of areas ranging from water resources assessment, development, and management to watershed management to engineering design (Baker and Miller, 2013). If a watershed is represented as a distributed system, then its subunit delineation may be on the basis of geomorphologic, conceptual, digital terrain, digital elevation, segmentation, or hydrologic response unit considerations (Haag et al., 2018). The use of topographic maps and digital elevation models has become common for delineating streams and representing the watershed by a stream network (Haag and Shokoufandeh, 2019; Li et al., 2019). The watershed representation is one of the key elements in watershed modeling, for it is this representation through which flow configuration and directions are determined (Luo et al., 2011).

Ethiopia faces a number of water related challenges, including not satisfying demand after completion of water related construction projects and unbalanced water distribution between different sectors and states, which comes from lack of well water budget modelling. Water resources development and management require an understanding of basic hydrologic processes and simulation capabilities at the river basin scale (Adeogun et al., 2019). Current concerns that are motivating the development of hydrologic modeling include climate change, management of water supplies, flooding, and offsite impacts of land management (Kotir et al., 2016). Integrated water management of large areas should be accomplished within a spatial unit (the watershed) through modeling. Watershed modeling is fundamental to integrated management (Mirchi et al., 2010).

Many current watershed models are comprehensive, distributed and physically based (Fatichi et al., 2016). They possess the capability to accurately simulate watershed hydrology and can be applied to address a wide range of environmental and water resources problems. Some of these models are also capable of simulating water quality. The models are becoming embedded in modeling systems whose mission is much larger, encompassing several disciplinary areas (Fatoyinbo, 2018). More recently, the wider availability of distributed information, ranging from soil types and land use to radar rainfall, have facilitated the production of simplified physically meaningful distributed hydroiogical models (Clark et al., 2017).

From the wide range of Hydrologic models available, the choice of the one most appropriate for any specific task is difficult, particularly as each modeller tends to promote the merits of his own approach (Addor and Melsen, 2019). SWAT (Soil and Water Assessment Tool) is an operational or conceptual model that operates on a daily time step (Nyeko, 2015). The objective in model development was to predict the impact of management on water, sediment and agricultural chemical yields in large river basins. To satisfy the objective (Shi et al., 2017), the model (a) does not require calibration (calibration is not possible on ungaged basins); (b) uses readily available inputs for large areas; (c) is computationally efficient to operate on large basins in a reasonable time, and (d) is continuous time and capable of simulating long periods for computing the effects of management changes.

Now a day's Ethiopia tries to exploit its river basin potential and develop strong water resources management techniques including Grand Renaissance Dam (GRD). Hangar sub-basin is one of the agricultural potential areas in the Abay Basin. At this time the ministry tries to identify irrigable areas and set an increasing scenario on possibilities and opportunities of expanding irrigation schemes and concluded that water availability become a constraint for major sub-basin of the Abbay Basin. However, so far no study has been carried out in the sub-basin in relation to the Hydrological modelling of watershed. Therefore, the main objective of this study is modelling Hangar watershed for future planning of water resource schemes and protection of the natural environment in Hangar river basin.

Hangar river basin is one of the tributaries of Abay basin with a potential for satisfying the demand of existing and proposed projects on the basin and downstream water users. Yet, there is a gap on concise and dynamic watershed management of the basin. Better understanding of the Watershed characteristics is necessary in Hangar River Basin, which is possible with knowing full potential of the available water. Consequently, there is a need to model the water resources potential of the basin. This is fundamental information that contribute to the basin’s sustainable water resources management.

## 2. METHODS AND MATERIALS

### 2.1. Study Area Description

This study was carried out in the Hangar River basin, which is located between a latitude of 9°35'00'' North and a longitude of 36°2'00" East in the west-central part of Ethiopia. The basin is one of the tributaries of the Abbay River basin (Figure 1) that ultimately contributes to the Blue Nile River. This Hangar basin consists of two regional zones and covers seventeen rural villages, into which an area of approximately 7673.87km$^2$ drains. The elevation of the basin ranges from 860 to 3210 m above the mean sea level. The sub-basin is bordered by Fincha'a sub-basin on west, Wonbera sub-basin on north, and Didessa sub-basin on south, southeast to Northeast sides.

As Hangar is one of the sub-basins in the Upper Blue Nile basin, one distinct rainfall season in between June and September as a result of once-a-year passage of intertropical convergence zone over the sub-basin. The distribution of precipitation and temperature over the catchment are strongly related to the altitude. The sub-basin experiences unimodal rainfall pattern from June to September and receives approximately 59.9% of its annual rainfall during the wet seasons. The mean annual rainfall of the sub-basin is ranging from 1246 mm at eastern lowlands to 2067 mm in highland areas.

The average annual daily maximum and minimum temperatures vary from 22.6 to 31.2 °C and 11.57 to 15.52 °C, respectively, over the sub-basin. Yearly maximum temperature is exhibited at the low land areas and lower maximum temperature is characterized in high land areas of Hangar sub-basin. Potential Evapotranspiration (PET) in the sub basin is generally between 1360 and 1555 mm per year.

The altitude in Hangar sub basin ranges approximately from 868 masl at lowlands to 3144 masl at the highland areas. The highlands of the sub basin have an altitude greater than 1800 masl up to 3144 masl. The lowlands have lower altitude less than 1200 masl in the western lowlands of the sub basin. Much of the area is gently undulating to rolling, gradually descending from about 1400 masl in the east to about 1250 masl in the west.

### 2.2. SWAT Model

Soil and Water Assessment Tool (SWAT) is a physically-based semi-distributed model that operates on a continuous time scale (Qi et al., 2018). This model is coupled with ArcSWAT in ArcGIS Geographical Information System interface to process the datasets and construct the required input for the initial modeling setup. Major model components include DEM, weather, hydrology, soil and properties and land management (Neitsch et al., 2011). In SWAT, a watershed is divided into multiple sub-watersheds, which are then further subdivided into Hydrologic Response Units (HRUs) that comprise homogeneous land use, slope and soil characteristics. The hydrology model is based on the water balance equation (Figure 2).The hydrological components in the model are based on the water balance equation (Nasiri et al., 2020) given in Equation (1) below:

$$SW_t = SW_o + \sum_{i=1}^{t} ¿¿¿ \quad [1]$$

Where $SW_t$ is the final soil water content in mm $H_2O$, $SW_0$ is the initial soil water content on day i in mm $H_2O$, t is the time of days, $R_{day}$ is the amount of precipitation on day i in mm $H_2O$, $Q_{surf}$ is the amount of surface runoff on day i in mm $H_2O$, $E_a$ is the amount of evapotranspiration on day i in mm $H_2O$, $W_{seep}$ is the amount of water entering the vadose zone from soil profile on day i in mm $H_2O$, $Q_{gw}$ is the amount of return flow on the day i in mm.

## 2.3. SWAT Input Data Used

The necessary input data required for the SWAT model were Stream flow data which was collected from Ministry of Water, Irrigation and Electricity of Ethiopia (MoWIEE), Meteorological data which was collected from National Meteorological Service Agency of Ethiopia (NMSAE), DEM (Digital Elevation Model) that was downloaded from https://www.asf.alaska.edu/sar-data/palsar/, Land use land cover and Soil data which were collated from GIS department of Ministry of Water, Irrigation and Electricity of Ethiopia.

### 2.3.1 DEM, Land use/Land cover and Soil data

Digital Elevation Model (DEM) of 12.5m by 12.5m was used for the delineation and topographic characterization of the watershed. It is also used to determine the hydrological parameters of the watershed such as slope, flow accumulation, direction and stream network. These data were used as the input to the SWAT hydrological model to define the Hydrological Responses Units. Of the total area under study, the agricultural land is the most dominant land use (68.0%), followed by rangeland (24.6%). There are eight soil types in the study watershed. They are Haplic Alisols (38.14%), Eutric Leptosols (2.37%), Haplic Nitisols (3.6%), Eutric Vertisols (0.1%), Dystric Leptosols (12.94%), Haplic Acrisols (26.84%), Rhodic Nitisols (16.0%) and Haplic Arenosols (0.01%). About 66.67% of the study area is predominantly with a slope range of greater than 30%, while 22.22% of the area under study has a slope range of 8-30%.

### 2.3.2 Observed Meteorological and Stream flow data

The SWAT model needs full daily weather data to analysis and generates the result. The collected missed daily rainfall data were filled by Xlsat 2018 program, where multiple leaner regression used to fill missed daily rainfall data from neighboring stations and missed maximum and minimum daily temperature data filled by average multiple imputation methods. Inconsistency of climatic data could happen during record because of changes in conditions, changes in instrumentation, changes in gauge location, and changes in observation practices. Before using any weather data, it is necessary to analyze and checks whether it is consistent or not. For this particular study, the consistency of recorded data for four stations checked by double mass curve and no need for corrections because they correlated. The three stations (Alibo, Hangar Gute, and Gelila) contain only precipitation and temperature (minimum and maximum) data. However, Nekemte station contains all climatic data such as precipitation, temperature (minimum and maximum), sunshine, relative humidity, and wind speed. Therefore, sunshine, relative humidity, and wind speed data generated for Alibo, Hangar Gute and Gelila stations from Nekemte station. The parameters required for weather generator calculated using software programs PCP STAT.exe anddew02.exe. The program PCP STAT.exe using daily precipitation calculated the statistical parameters of daily precipitation data. Whereas, the program dew02.execalculated the average daily dewpoint temperature per month using daily air temperature and humidity data. The calculated parameters for weather generator adjusted and added into the SWAT weather database table. Stream flow data is required for calibration and validation of the SWAT model.

## 2.4. The SWAT Model Set-Up

SWAT model was designed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying conditions over long periods of time (Arnold et al., 2012). There are various producers with which SWAT model proceed to give output for which past procedure is an input for the next one. Looking for the next task without properly completing one of these steps is impossible. After completion of SWAT database preparation, the first procedures in the SWAT model is to create a new project or DEM set up of having identified folder in which the whole work could be executed. Watershed delineation is the division of basins into smaller sub-basins for determining their contributions to the main Stream. The watershed delineation interface in Arc SWAT is separated into five sections including DEM Set Up, DEM-based Stream Definition (flow direction and accumulation and drainage network generation), Outlet and Inlet Definition, Watershed Outlet(s) Selection and Definition and Calculation of Sub-basin parameters. In order to delineate sub-basins networks, a critical threshold value is required to define the minimum drainage area required to form the origin of a stream. After the initial sub-basin delineation, the generated stream network can be edited and refined by the inclusion of additional sub-basin inlet or outlets. Adding an outlet at the location of established monitoring stations is useful for the comparison of flow concentrations between the predicted and observed data. Therefore, one basin outlet was manually edited into the watershed based on the known stream gage location that had streamflow data. As Vilaysane et al., (2015) indicated, the smaller the threshold area, the more detailed the drainage networks and the number of sub-basins and HRUs. In this study, the smaller area (7600 ha) is provided to get 61 sub-basins of the Hangar river basin and outlet is defined, in which it is later taken as a point of calibration of the simulated flows.

SWAT model used spatial data such as land use, soil, and slope to create different Hydrologic Response Units (HRUs) analysis system, which are the unique combinations of land use soil and slope type within each sub-basin. The multiple scenarios that account for 15% land use, 15% soil and 15% slope threshold combination give a better estimation of stream flow. As the percentage of land use, slope and soil threshold increases, the actual evapotranspiration decreases due to eliminated land use classes (Vilaysane et al., 2015). Taking objective of the study into consideration and paying attention to characteristics of HRUs as the key factors affecting the stream flow, a land use, soil and slope class threshold of 10%, 15%, and 15% were used respectively. Hence, the Hangar River basin results in 196 HRUs in the whole basin.

Categorizing sub-basins into HRUs increases accuracy and provides a much better physical description (Mtalo et al., 2012). The SWAT model predicts the impacts at the subbasin (sub-watershed) or further at the Hydrologic Response Units (HRUs) (Gashaw et al., 2018 and Arnold et al., 2012). The land use and soil classifications for the model are slightly different than those used in many readily available datasets and therefore the land use and soil data were reclassified into SWAT land use and soil classes prior to running the simulation. Definition and reclassification of Land use dataset, the definition of soil dataset, reclassification of soil and slope layers and overlay of land use, soil and slope layer were done during Hydrologic Response Unit analysis. The prepared soil layers classified LULC and slope layers and delineated Watershed by Arc SWAT were overlapped 100%. The reclassified SWAT land use/land cover, soil and slope are shown in Figure 2.

Spatial scale data such as land use/land cover, soil and slope were defined and analyzed in Hydrologic Response Units analysis (HRUs). The time scale data such as Rainfall data, Temperature data, Relative Humidity data, Solar Radiation data, and Wind speed data were prepared in the text format. The Weather generator data was developed for the principal station and imported into the SWAT database to generate solar radiation data, wind speed data and relative humidity data for secondary stations. The prepared time scale data and the developed weather generator data were loaded and written in this stage of model setup. The modification of the SWAT model database and input files is allowed in the edit SWAT input. The incorrectly inputted data could be edited so that correct output would be generated. The input to the model is finalized and the output is generated and read after running the model in the SWAT simulation. For this study, the SWAT model was run with the historic meteorological data of 1987 to 2017 by keeping three years (1987-1989) for warm-up period to avoid the impacts of the initial conditions of the model.

### 2.5. The SWAT-CUP Model

The output files, which could obtained after the SWAT model run are the results, generated corresponding to measured data and need to be calibrated and validated. SAT-CUP is an interface developed to provide a link between the input/output of a calibration program and the SWAT model (User Manual, 2014). It is a program used to implement parallel processing (SWAT Calibration and Uncertainty Procedures) (Khalid et al., 2018). After the model run, the SWAT-CUP requires outputs, which extracted from the model output files to do automate calibration. The uncertain model parameters are selected roughly at the beginning and systematically changed looking at their sensitivity after each simulation. Finally, the most sensitive parameters with which the hydrology of the watershed could influenced are identified and the model calibration and validation were performed by SWAT-CUP through SUFI-2.

#### 2.5.1 Parameter Sensitivity analysis

Sensitivity analysis is the process of determining the rate of change in model output with respect to changes in model inputs (parameters) (Khalid, K., et al., 2016). It is a necessary process to identify key parameters and parameter precision required for calibration and validation of the SWAT model. For this study, to identify the most important SWAT parameters, at the beginning

18 flow parameters were selected from SWAT-CUP (Absolute_ SWAT_Value.txt). In the SWAT-CUP sensitivity analysis of parameters can be performed in two ways: Global sensitivity analysis which allows changing each parameter at a time and One-at-a time sensitivity analysis which performs one parameter at a time only (Mehan et al., 2017). For this purpose, global sensitivity analysis was employed in SWAT-CUP 2012). The measure and significance of sensitivity were provided by indices such as t-stat and p-value, respectively (Chaibou Begou et al., 2016; Abbaspour, 2013) where, higher t-test in absolute values measures high sensitivity and zero p-value represents more significant.

### 2.5.2 Uncertainty Analysis

As Pechlivanidis et al., 2011 suggested, uncertainties in distributed models may arise from model input uncertainty, conceptual model (structural uncertainty), parameter uncertainty and response uncertainty. To get a good result and support decisions about alternative management strategies in the areas of land use and land cover change, climate change, water allocation, and pollution control, it is important that the model pass through a careful calibration and uncertainty analysis. For this study uncertainty analysis was carried out through SUFI-2 algorithm which performed parameter uncertainty accounted for all uncertainty.

### 2.5.3 Model calibration and validation

The Calibration is the tuning or adjustment of model parameters and their values, within the recommended ranges, to optimize the model output so that it matches with the measured set of data (Vilaysaneet al., 2015). These parameters could be adjusted manually or new parameters of past iteration would be copied from New_pars.txt to par_inf.txt for the continued iteration until the model output best matches with the observed data. This involves comparing the model results, generated with the use of historic meteorological data, to recorded stream flows. This study used Sequential Uncertainty Fitting-2 (SUFI-2) algorithm in SWAT-CUP 2012 for calibrating model outputs using gauged stream flow. The validation is the process of determining the degree in which a model or simulation is an accurate representation of the observed set of data from the perspective of the intended uses of the model (Chaibou Begou et al., 2016). It is a comparison of the model outputs with an independent dataset without further adjustments of the values of the parameters (Tejaswini and Sathian, 2018). The process continued until the simulation of validation period of the stream flows confirmed that the model performs satisfactorily. Therefore, in this study, calibration and validation were carried out using 25 years (1987–2011) of daily-observed flow data. The data was divided into model warm-up (1987-1989), calibration (1990–2002) and validation (2003–2011) periods. For a better parameterization of the SWAT model and to reduce the model output uncertainty (Gashaw et al., 2018), a longer calibration period was used.

Standard regression statistics like coefficient of determination ($R^2$) and Nash-Sutcliffe efficiency (NSE) determine the strength of the linear relationship between simulated and measured data (Lee et al., 2018). $R^2$ ranges from zero to one, with higher values indicating less error variance, and typically values greater than 0.5 are considered acceptable (Marek et al., 2016; Leta et al., 2017). NSE ranges between $-\infty$ and one, with NSE = 1 being the optimal value. Values between zero and one are generally viewed as acceptable levels of performance, whereas values less than zero indicates that the mean observed value is a better predictor than the simulated value, which shows unacceptable performance (Bhatta et al., 2019). Percent bias (PBIAS) measures the average tendency of the simulated data to be larger or smaller than their observed counterparts in which the optimal value of PBIAS is 0.0, with low-magnitude values indicating accurate model simulation (Shrestha et al., 2018). The SWAT model evaluation guideline based on performance rating was given in Table 2. Hence, for this study, the performance of the SWAT model was checked using values of coefficients of determination ($R^2$), Nash-Sutcliffe efficiency (NSE) and percent bias (PBIAS) based on their performance rating (Table 2). These statistics were calculated using Equations (2) to (4):

$$R^2=\frac{\sum_{i=1}^{n}[(Qmi-\overline{Q}m)(Qsi-\overline{Q}s)]^2}{\sqrt{\sum_{i=1}^{n}(Qmi-\overline{Q}m)^2\sum_{i=1}^{n}(Qsi-\overline{Q}s)^2}};0\leq R^2\leq 1$$

[2]

$$NSE=1-\frac{\sum_{i=1}^{n}\left[(Qmi-\overline{Q}si)\right]^2}{\sum_{i=1}^{n}\left[(Qmi-\overline{Q}m)\right]^2};-\infty\leq NSE\leq 1 \qquad [3]$$

$$PBIAS=100\left(\frac{\sum_{i=1}^{n}Qmi-\sum_{i=1}^{n}Qsi}{\sum_{i=1}^{n}Qmi}\right) \qquad [4]$$

In the above equations, Qm is the measured discharge, Qs is the simulated discharge, $\overline{Q}m$ is the Average measured discharge, and $\overline{Q}s$ is the average simulated discharge (Dibaba et al., 2020). Details of the methodology followed in this study are shown in Figure 2.

## 3. FINDINGS AND DISCUSSION

### 3.1. SWAT model calibration and validation

The SWAT model generated an output which was processed using land use land cover, soil, and slope as an input. The model output needs analysis under the changed parameter, after which hydrological impacts of LULCC could be discussed. The sensitivity of output of the SWAT model to changes in parameter was studied under sensitivity analysis. Parameter sensitivity analysis helps focus the calibration and uncertainty analysis and is used to provide statistics for goodness-of-fit (Brouziyne et al., 2017).

Because of the involvement of a wide range of data and parameters in the simulation process, calibration of outputs of big hydrological models like SWAT was quite a bulky task (Shimelash et al., 2018). Hence, sensitivity analysis minimizes the number of parameters to be used in the calibration and/or validation iteration and shorten the time required for it by identifying the most sensitive parameters largely controlling the behavior of the simulated process (Zeray et al., 2006). Sensitive parameters are selected randomly at the beginning of calibration and modified looking at their degree of sensitivity in SWAT-CUP SUFI2 from Global sensitivity at the end of each iteration. The sensitivity analysis, which was carried out using 18 SWAT parameters, identified the 13 most sensitive parameters controlling the output variable and with which goodness-of-fit was reached. The 13 most sensitive parameters are ranked based on its t-stat and p-value where CN2, SURLAG and CANMX are the most three top sensitive parameters in the study area (Table 2).

The model generated output using model input parameters which kept within a realistic uncertainty range (Arnold et al., 2012). Therefore, to have the physical knowledge of the watershed, calibration carried out using SWAT–CUP (SWAT-Calibration and Uncertainty Programs) through Sequential Uncertainty Fitting-2 (SUFI-2). The SWAT model output was calibrated using 13 years measured streamflow data (1990-2002). The obtained $R^2$, NSE and PBIAS value during calibration were 0.87, 0.82 and +1.4 correspondingly (Figure 5).For the catchment with longtime series split sample test is involved (Shimelash et al., 2018) for which one part is used to calibrate the model, and the second part is used for testing (validating) if calibrated parameters produced simulations which satisfy goodness-of-fit tests. Therefore, since it has thirty-one years of data, split sample test was applied in this watershed for which measured streamflow data of 22 years was scaled 60% (1990-2002) for calibration to 40% (2003-2011) for validation. The value of $R^2$, NSE and PBIAS obtained during validation were 0.89, 0.88 and +1.2. $R^2$ is used to evaluate the accuracy of the simulated value when compared with the observed values whereas; the goodness-of-fit is measured with NSE (Shimelash et al., 2018). In general, the performance indices gained during the calibration (Figure 4) and validation (Figure 5) periods indicated an acceptable performance rate of the model in simulating the hydrological impacts of LULC changes over 1987 to 2017 periods (Figure 3).

## 3.2. Simulated water balance components of Hangar watershed

The simulated results of water balance components of the watershed were analysed under the category of major water budgets. Far from its seasonal variation, the major water sources of the study watershed was rainfall. Ethiopia receives seasonal rainfall of different magnitudes during wet seasons (June to September), short rainy seasons (March to May), and dry seasons (October to February). The result revealed that the watershed receives average seasonal rainfall of 154.8 mm and 105.2 mm during wet and short rainy seasons respectively, while it receives 19.9 mm during dry seasons. From the total received precipitation 40.5, 41.3, and18.2 percentage were lost due to evapotranspiration during each season respectively. The surface runoff contribution to the total water yield of the watershed were 188.7 mm and 40.4 mm during wet and short rainy seasons respectively, while it contributes by 9.1 mm during dry seasons. The average annual sediment yield of the watershed is 22.6 T/ha. The modelled average monthly water balance components of the watershed were discussed in figure 6. The contribution status of Hangar watershed sub-basins (Figure 7) were elaborated in table 3. The obtained results were consistent with the study carried by the author (Galata et al., 2020) except it is discussed in average annual under the impact of land use land cover change.

## Conclusion

Intensification of the global hydrological cycle due to global climate change is likely to change water resources availability in most regions of the world. This study models the watershed hydrological characteristics of Hangar River basin, Ethiopia. A simulation study was performed using the Soil Water Assessment Tool (SWAT) using observed metrological data of 1987-2017. Calibration, validation, and sensitivity analysis were performed using the Sequential Uncertainty Fitting (SUFI-2) algorithm of the SWAT Calibration and Uncertainty Programs (SWAT-CUP). The SWAT model calibration and uncertainty analysis showed Nash-Sutcliffe efficiency (NSE) values of 0.82 and 0.88 and coefficient of determination ($R^2$) values of 0.87 and 0.89 during calibration and validation periods, respectively, which are within the acceptable limit (NSE values >0.75 and $R^2$<1.0). The results of the study were analysed seasonally under wet (June to September), short rainy (March to May) and dry seasons (October to February). Accordingly, the watershed receives average seasonal rainfall of 154.8mm, 105.2mm and 19.9mm during wet, short rainy and dry seasons correspondingly. The lost water in the form of evapotranspiration during wet and short rainy seasons were 40.5mm and 41.3mm respectively whereas, 18.2mm during dry seasons. The surface runoff contribution to the watershed were 188.7mm and 40.4mm during wet and short rainy seasons respectively while it contributes by 9.1mm dry seasons. The status of sub-basin contributions to the watershed were ranked. Generally, the SWAT model possess the capability to accurately simulate hydrological characteristics of the Hangar. However, there may be sources of uncertainty during simulation of hydrological models. Hence, the findings of this study could be accepted with care and can be applied for water resources management and planning and development of different water resources schemes. For this study, only one hydrological model is used for simulation. Therefore, future researchers can conduct on related topic with different hydrological models to compare the results.

## Conflict of interest

Conflict of Interest- None

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