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Modeling the hydrological characteristics of Hangar Watershed, Ethiopia

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ABSTRACT

The hydrologic characteristics of the Hangar Watershed were modeled by using the Soil and Water Assessment Tool (SWAT) model. Digital elevation model, land use/land cover data, soil map, weather, and hydrological data were among the data used for this study. The measured streamflow data of (1990–2002) and (2003–2011) years were used for calibration and validation of the model, respectively, and its performance was good for both calibration and validation. The sensitivity analysis identified that the watershed is characterized by 13 sensitive parameters. 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 season, correspondingly. The surface runoff contribution to the watershed was 3.8%, and 79.2% during dry and wet seasons, respectively, whereas it contributes by 17.0% during short rainy seasons.

Key words: hydrological process, hydrology, modeling, water balance, water resources

HIGHLIGHTS

- The site-specific performance of the SWAT model was evaluated.
- The sensitive parameters with which the SWAT model is characterized were ranked.
- The hydrological characteristics of the watershed were modeled.
- The contribution of water balance components to the river were modeled.
- The water balance contribution status of the sub-basin was ranked.

1. INTRODUCTION

Land and water degradation because of on-site soil/nutrient loss and off-site pollution/sedimentation affect environmental systems. Landscape planning and management tools are important to execute best management practices focused on positions where they are required most (Tamene *et al.* 2014). Human activities interact with underlying natural landscape attributes, such as geology, soils, topography, vegetation, and climate, to influence stream ecosystem processes (Yousif & Sracek 2016). For instance, the rates of nutrient uptake in rivers decrease as the trend of urban development increases. As a result, the protection of aquatic ecosystem services often needs active management of human activities on the landscape, such as urbanization, agriculture, road construction, forestry, and mining (Petty *et al.* 2010). Water is a valuable part of the ecosystem that is granted to individuals. The prediction of its availability which is an essential task in planning and water resource management is governed by the determination of the hydrological characteristics of the watershed from which that water emerges (Takala *et al.* 2016). The water resources availability forecast requires detailed insights into the hydrological processes of the watershed. However, assessing the complexity of hydrological processes, needed for sustainable water resources management, based on understanding rainfall and other hydrological properties of the basin (Redfern *et al.* 2016). Thus, the hydrological behavior of the watershed should be modeled to design and meet present and future water demands. Modeling the water balance components of the watershed is a prerequisite to understanding the key processes of the hydrologic cycle (Singh & Frevert 2003).

The history of hydrological modeling varies from the Rational Method to modern distributed physically meaningful models (Arnold *et al.* 1998). Watershed modeling deals with the determination of the hydrologic processes at the watershed scale and integrating them in order to analyze the watershed responses (Singh & Frevert 2003; Tekleab *et al.* 2011). The experience of hydrological modeling can be found in the development of civil engineering in the nineteenth century for the design of roads, canals, city sewers, drainage systems, dams, culverts, bridges, water supply systems, and so on (Singh & Frevert 2003).

A watershed hydrology model is often a gathering of component models corresponding to different components of the hydrologic cycle. Watershed models are used in a wide spectrum of areas varying from water resources assessment and management to watershed management and its engineering design (Arnold & Fohrer 2005). If a watershed is mapped 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 (Arnold & Fohrer 2005; Boru *et al.* 2019). The use of topographic maps and digital elevation models has become common for delineating streams and representing the watershed by a stream network (Todini 2011; Mtibaa *et al.* 2018). The watershed representation is one of the essential constituents in watershed modeling, for it is this representation by which flow configuration and directions are decided (Amin *et al.* 2017).

Ethiopia faces a number of water-related challenges, including not satisfying demand after completion of water structures construction projects and unbalanced water distribution between different sectors and states, which comes from lack of well water budget modeling. Water resources management and development need knowledge of fundamental hydrologic operation and simulation capability at the river basin level (Yang *et al.* 2008). The current issues, which are initiating the relevance of hydrologic modeling, comprises the analysis of the impacts of change in land use/cover and climate on water resource availabilities, management of water supplies, and flooding (Linh *et al.* 2021). Intermingled water resource management of huge areas should be carried through the watershed modeling. Watershed modeling is basic for structured water resources management (Gashaw *et al.* 2018).

Many present watershed models are comprehensive, distributed, and physically-based (Singh 2018). They possess the ability to precisely simulate watershed behavior and have relevance to address an expansive span of environmental and water resources complications. A number of these models have also the capability to simulate water quality. The hydrological models are becoming implanted in mapping systems whose aim is much wider, embracing several disciplinary scopes (Baker & Miller 2013). Not long ago, the broader accessibility of distributed details, varying from soil classes and land use to radar rainfall, have smoothed the yield of simplified physically significant distributed hydrological models (Haag *et al.* 2018).

From the variety of available hydrological models, the selection of the one most suitable for any particular task is important; specifically, as each modeler be liable to possess or display the benefits of its own resemble (Haag & Shokoufandeh 2019). Soil and Water Assessment Tool (SWAT) is an up and running model that functions on a daily time step (Li *et al.* 2019). The goal in model evolution was to forecast the effect of land use/cover changes on water resources, agricultural chemical, and sediment yields in river basins. To fulfill the objective (Luo *et al.* 2011), the model (a) does not need calibration in case it is not possible on ungauged basins; (b) uses readily obtainable inputs for wide-ranging areas; (c) is computationally capable to work on wide catchments in an appropriate time, and (d) is continuous-time and efficient of simulating long intervals for determining the impacts of management alterations. The Soil and Water Assessment Tool model is a physically-based, semi-distributed model that employs a continual time scale (Adeogun *et al.* 2019). The SWAT model is integrated with ArcGIS-Geographical Information System as an ArcSWAT interface to analyze the data and construct the required input for the beginning modeling setup. Digital Elevation Model (DEM), climate data, streamflow data, soil data, and land use/land cover data constitutes the major SWAT model inputs (Kotir *et al.* 2016). During modeling setup, divided small tributaries can be further subdivided into areas, which comprises uniform land use/land cover, slope, and soil properties – Hydrologic Response Units (HRUs). The SWAT model processes depending on the form of water constituents in the water balance equation (Mirchi *et al.* 2010) are given in Equation (1) below:

$$\mathrm{SW_t} = \mathrm{SW_0} = \sum_{i=1}^{t} (\mathrm{R_{day}} - \mathrm{Q_{surf}} - \mathrm{E_a} - \mathrm{W_{seep}} - \mathrm{Q_{gw}}) \tag{1}$$

where:-

$\mathbf{SW_t}$ – the terminal soil–water capacity in mm of water
$\mathbf{SW_0}$ – the first soil–water volume on the i day in mm of water
t – the duration in days

$\mathbf{R_{day}}$ – the quantity of rainfall on the i day in mm of water
$\mathbf{Q_{surf}}$ – the quantity of surface runoff on the i day in mm of water
$\mathbf{E_a}$ – the quantity of evapotranspiration on the i day in mm of water
$\mathbf{W_{seep}}$ – the quantity of flowing water penetrating the vadose zone from soil profile on the i day in mm of water
$\mathbf{Q_{gw}}$ – the quantity of water comes back on the i day in mm of water.

Nowadays, Ethiopia tries to exploit its river basin potential and develop strong water resources management techniques including Grand Ethiopian Renaissance Dam (GERD). Hangar Watershed is located in agrarian potential areas of the Abbay Basin. Currently, the ministry tries out to recognize irrigable areas and put an expanded outline on alternatives and opportunities of increasing irrigation plan and decided that water availability becomes a constraint for the main sub-basin of the Abbay Basin (Boru *et al.* 2019). However, no study has been carried out in the Hangar in relation to the modelling hydrological characteristics of the watershed. Therefore, the objectives of this research were: (1) to characterize and evaluate the performance of the SWAT model for the Hangar Watershed, (2) to model characteristics of Hangar watershed in terms of water balance components, and (3) to rank water balance components contribution status of sub-basins to the watershed. The execution of these specific objectives is aimed to contribute to the decision of future best management practices.

Hangar River is one of the sub-basin of Abbay River with a prospective for supplying the need of ongoing and planned schemes on the basin. Yet, there is a gap in the concise and dynamic watershed management of the basin. A better understanding of the watershed characteristics is necessary for the Hangar River Basin, which is possible with knowing the full potential of the available water. This is fundamental information that contributes to the watershed's sustainable water resources management.

2. STUDY METHODOLOGY

2.1. Description of the study location

This research was accomplished in the Hangar Watershed that is situated in the middle of latitude of 9°35′00″ North and a longitude of 36°2′00″ East in the East Wollega zone regional state of Oromia. The Hangar Watershed is among the sub-basin of the Abbay River (Figure 1), which potentially supply to the Blue Nile Basin. This Hangar Watershed comprises some part of Horro Guduru Wollega and majorly East Wollega zone and extends over an area of about 7,673.87 km^2. The watershed elevation varies between 844 and 3,207 m amsl. The watershed is surrounded from the west by Finchaa, from the north by Wonbera, and from the south by Didessa catchments.

Rainfall and temperature in the watershed vary related to the altitude. The unimodal rainfall pattern is experienced in the watershed between June to September. The average yearly precipitation in the watershed varies between 1,245 mm in lowland elevation to 2,066 mm in upland elevation. The watershed encounters average maximum and minimum daily temperatures of 22.5 to 31.1 °C and 11.6 to 15.5 °C, respectively. The lowland levels experienced maximum temperature and lower maximum temperature is exhibited at the upland areas of the Hangar Watershed.

2.2. Data collection and its analysis

The necessary data components demanded by the SWAT model (Fatichi *et al.* 2016) were spatial and temporal.

2.2.1. The spatial data

DEM of 12.5 m by 12.5 m was used for the delineation and topographic characterization of the watershed. It is also used to settle the watershed parameters such as slope, flow accumulation, flow direction, and stream network. For the present study, the classified land use/covers of the 2017 year were used. Haplic Alisols, Haplic Acrisols, Rhodic Nitisols, Dystric Leptosols, Haplic Nitisols, Eutric Leptosols, Eutric Vertisols, and Haplic Arenosols are identified as major soil types used for this study.

2.2.2. Observed meteorological and streamflow data

The SWAT model needs full daily weather data to analyze and generate the result. The collected missed daily rainfall and temperatures data were filled by Xlstat 2018 program. Xlstat is a program that utilizes available data to estimate the missed data during field records due to different reasons. The accuracy of the filled data could be checked at the time of consistency analysis. For this study, multiple leaner regression in Xlstat 2018 program was used to fill missed daily rainfall data from neighboring stations, and missed maximum and minimum daily temperature data were filled by average multiple imputation methods. Inconsistency of climatic data could happen during recording because of changes in conditions, changes in

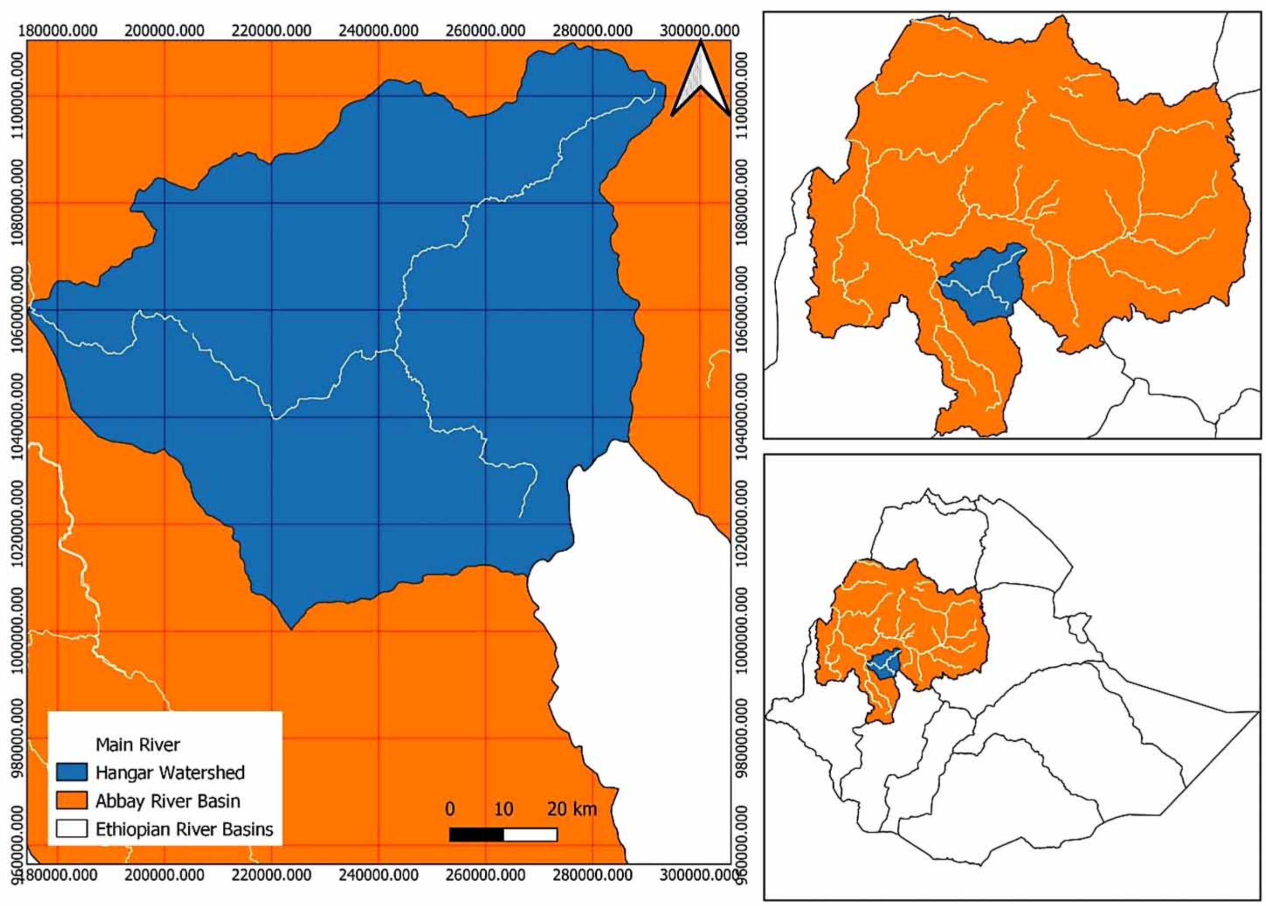

Figure 1 | Location of Hangar Watershed.

instrumentation, changes in gauge location, and changes in observation practices. Before using any weather data, it is necessary to analyze and check whether it is consistent or not. For this particular study, the consistency of recorded data for four stations was checked by a double mass curve and there was no need for corrections because they were correlated. The three stations (Alibo, Hangar Gute, and Gelila) contain only precipitation and temperature (minimum and maximum) data. However, the 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 were generated for Alibo, Hangar Gute, and Gelila stations from the Nekemte station. The parameters required for the weather generator were calculated using software programs PCP STAT.exe and dew02.exe. The program PCP STAT.exe using daily precipitation calculated the statistical parameters of daily precipitation data, whereas the program dew02.exe calculated the average daily dewpoint temperature per month using daily air temperature and humidity data. The calculated parameters for the weather generator were adjusted and added to the SWAT weather database table. Streamflow data is required for calibration and validation of the SWAT model.

2.3. The soil and water assessment tool model set-up

The 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 the 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 procedure 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 subbasins 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 inlets 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 gauge 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 (7,600 ha) is provided to get 61 sub-basins of the Hangar River Basin, and an outlet is defined, which 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 systems, 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 streamflow. 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 the objective of the study into consideration and paying attention to characteristics of HRUs as the key factors affecting the streamflow, 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 (Nobert & Jeremiah 2012). The SWAT model predicts the impacts at the sub-basin (sub-watershed) or further at the HRUs (Arnold *et al.* 2012; Gashaw *et al.* 2018). 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 HRU analysis. The prepared soil layers classified land use and land cover (LULC) and slope layers and delineated watershed by Arc SWAT were overlapped 100%.

Spatial scale data such as land use/land cover, soil, and slope were defined and analyzed in HRUs analysis. 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 the 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 the 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 1987–2017 by keeping three years (1987–1989) for the warm-up period to avoid the impacts of the initial conditions of the model.

2.4. The soil and water assessment tool-calibration and uncertainty procedures

The output files, which could be obtained after the SWAT model run are the results, generated corresponding to measured data and need to be calibrated and validated. SWAT Calibration and Uncertainty Procedures (SWAT-CUP) is a program that was developed to link the SWAT model output to calibration and validation programs (Addor & Melsen 2019). The SWAT-CUP requires outputs, which are extracted from the SWAT 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, sensitive parameters with which the hydrology of the watershed could be influenced were identified and the calibration and validation of the model were accomplished through the sequential uncertainty fitting interface-2 (SUFI-2) of SWAT-CUP.

2.4.1. Analysis of sensitive parameters

Sensitivity analysis is an important procedure to distinguish necessary variables and its priority needed during calibration and validation of the hydrological model (Mtibaa *et al.* 2018). For this study, at the beginning, 18 flow parameters were selected from SWAT-CUP (Absolute_ SWAT_Value.txt). Global and One-at-a-time are two forms of sensitivity analysis (Nyeko 2015). For this purpose, a global form of sensitivity analysis that allows changing each parameter at a-time was employed. The t-stat

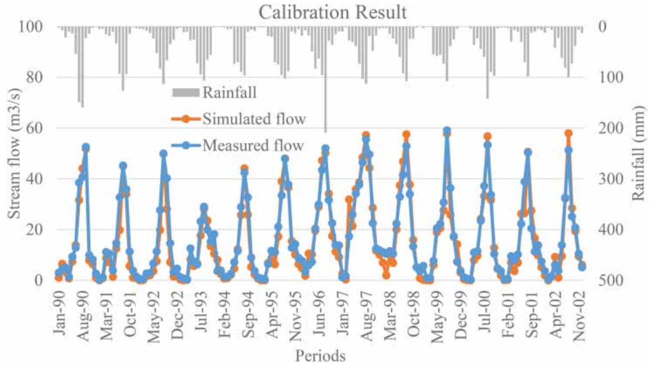

Figure 2 | Hydrograph of simulated versus observed flow during calibration.

and *p*-value indicate the measure and significance of sensitivity respectively (Shi *et al.* 2017; Qi *et al.* 2018) where greater absolute values of t-test indicate high sensitivity and *p*-value of zero results stand for larger significance.

2.4.2. Uncertainty analysis

As Neitsch *et al.* 2011 suggested, in distributed models uncertainty may arise due to model input, of the conceptual model, uncertainty from parameter and response. To get good value and help the conclusion regarding possible care policies for the case in land use/cover change, change in climate, allocation of water, and control of pollution, it is necessary to carry out calibration and uncertainty analysis of the model (Yang *et al.* 2008). For the study watershed, uncertainty analysis was carried out through the SUFI-2 algorithm which performed parameter uncertainty that accounted for all uncertainty.

2.4.3. Calibration and validation process

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 because it does not give a clear meaning. It is the process of overlaying the simulated outputs of the model to the observed streamflow. The level of simulated value representation accuracy with the measured data was determined during the validation task (Nasiri *et al.* 2020). It was accomplished by comparing the output of the model to the observed dataset in the absence of adjusting parameter values (Arnold *et al.* 2012). The process continued until the simulation of the validation period of the stream flows confirmed that the model performs satisfactorily. Calibration and validation of the model were undergone with 25 years of recorded streamflow data by using SUFI-2 (Linh *et al.* 2021). The streamflow data of (1987–1989) periods was used for model warm-up, (1990–2002) years for calibration (Figure 2), and (2003–2011) years for validation (Figure 3). To reduce the model output uncertainty and for the better characterization of the SWAT model parameters in the study watershed (Mtalo *et al.* 2012; Gashaw *et al.* 2018), the longest period of historical flow was used for calibration. The strength of the linear relationship between simulated output and measured data was determined by using standard regression statistics percent bias (PBIAS), Nash-Sutcliffe

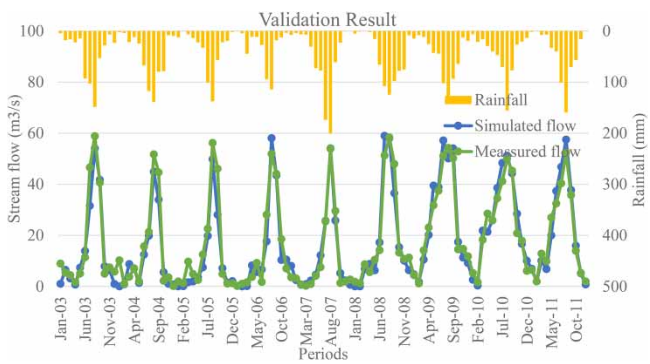

Figure 3 | Hydrograph of simulated versus observed flow during validation.

Table 1 | The reported performance ratings for R^2, NSE, and PBIAS for the SWAT model

Modeling phase	R^2	NSE	PBIAS	Performance rating
Calibration and validation	$0.75< R^2 \leq 1.00$	$0.75< NSE \leq 1.00$	$PBIAS \leq \pm 10$	Very good
Calibration and validation	$0.65< R^2 \leq 0.75$	$0.65< NSE \leq 0.75$	$\pm 10 \leq PBIAS \pm 15$	Good
Calibration and validation	$0.50< R^2 \leq 0.65$	$0.50< NSE \leq 0.65$	$\pm 15 \leq PBIAS \pm 25$	Satisfactory

efficiency (NSE), and determination coefficient (R^2) (User Manual 2014). The value of R^2 is accepted when it is larger than 0.5 and the greater value shows a small variance of error (Abbaspour 2013; Chaibou Begou *et al.* 2016). The interval values of NSE vary from $-\infty$ to one. The value is considered acceptable when it ranges from zero to one (Pechlivanidis *et al.* 2011). The average tendency of the simulated result becoming smaller or larger than the recorded one is measured by PBIAS of which the magnitude of zero represents optimum (Tejaswini & Sathian 2018).

The SWAT model evaluation guideline based on performance rating was given in Table 1 (Van Liew and Garbrecht 2003). 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 1). These statistics were calculated using Equations (2)–(4):

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

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

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

In the above equations, Qm is the measured discharge, Qs is the simulated discharge, $\bar{Q}m$ is the average measured discharge, and $\bar{Q}s$ is the average simulated discharge (Dibaba *et al.* 2020). Details of the methodology followed in this study are shown in Figure 4.

3. FINDINGS AND DISCUSSION

3.1. Calibration and validation results

The simulated result of the model needs analysis under the changed parameter, after which hydrological characteristics of the watershed were modeled. The sensitivity of watershed hydrology to changes in parameters was studied under sensitivity analysis. 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 repeated procedures identifies thirteen most sensitive parameters at the end that are ranked depending on their t-stat and *p*-value at the end (Table 2). The performance of SWAT model was evaluated both during 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) (Shrestha *et al.* 2018).

3.2. Water balance components of Hangar Watershed

Components of the water balance of the Hangar Watershed were analyzed under the category of major water budgets. Far from its seasonal variation, the water sources of the study area were generated from rainfall. Ethiopia receives seasonal rainfall of different magnitudes. In the study area, relative to the months between March and May (short rainy seasons), and

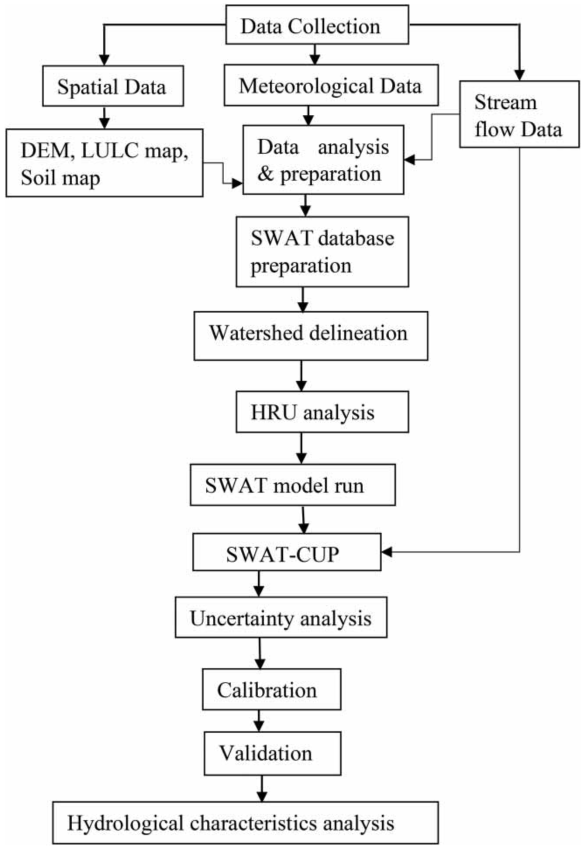

Figure 4 | The layout of the study.

October to February (dry seasons), the maximum monthly rainfall was recorded from June to September (wet seasons). 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, and 18.2% were lost due to evapotranspiration during each season, respectively. From the total water yield of the watershed,

Table 2 | Parameters with its rank of sensitivity

Order sensitivity	Name of parameter	t-stat	*p*-value
1	CN2.mgt – runoff curve number	–4.53	0
2	SURLAG.bsn – Surface runoff lag time	−2.02	0.07
3	CANMX.hru – Maximum canopy storage	1.63	0.13
4	GW_DELAY.gw – Groundwater delay	1.31	0.22
5	EPCO.hru – Plant uptake compensation factor	1.23	0.24
6	GW_REVAP.gw – Groundwater 'revap' coefficient	−0.97	0.35
7	ALPHA_BF.gw – Base flow alpha factor	0.94	0.37
8	GWQMN.gw – Threshold depth of water in the shallow aquifer required for return flow to occur	−0.82	0.43
9	ALPHA_BNK.rte – Base flow alpha factor for bank storage	0.7	0.5
10	REVAPMN.gw – Threshold depth of water in the shallow aquifer for 'revap' to occur	0.58	0.57
11	SOL_AWC.sol – Available water capacity of the soil layer	0.46	0.65
12	ESCO.hru – Soil evaporation compensation factor	−0.2	0.85
13	SOL_ALB.sol – Moist soil albedo	0.01	0.99

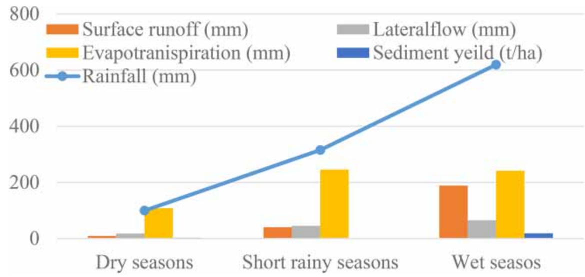

Figure 5 | Seasonal contribution of water balance components.

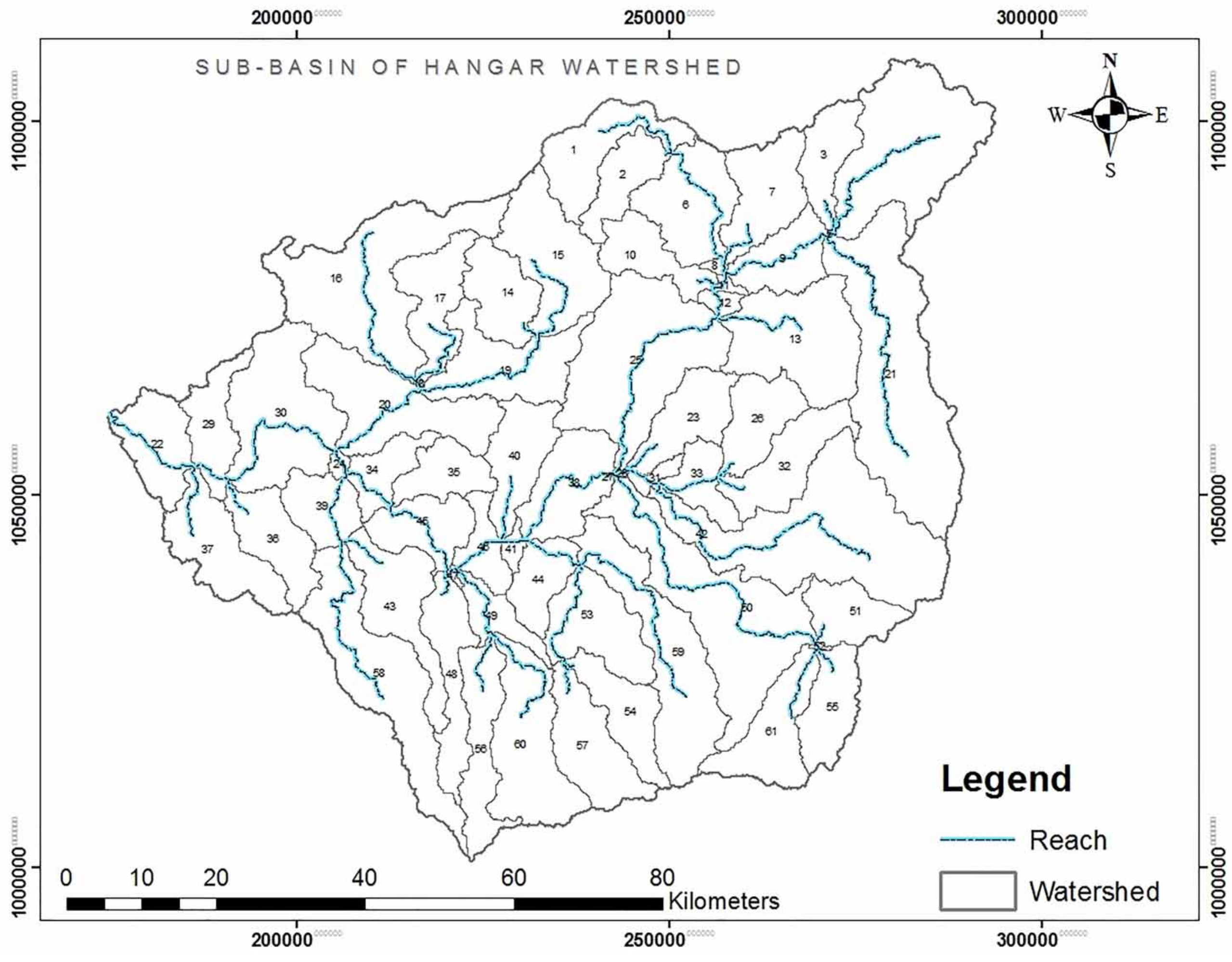

Figure 6 | Sub-basins of Hangar Watershed.

188.7 mm and 40.4 mm were contributed by surface runoff during wet and short rainy seasons, respectively, while it contributes by 9.1 mm during dry seasons. The watershed received an average annual sediment yield of 22.6 tons per hectare. Average seasonal components of the water balance of the watershed were modeled (Figure 5). The contribution status of Hangar Watershed sub-basins (Figure 6) was elaborated in Table 3. The obtained results were in line with the results of the study obtained by an author (Galata *et al.* 2020) except it is discussed in average annual under the effect of land use/cover change.

Table 3 | Contribution status of sub-basins to water balance components of the watershed

Components of water balance	Level of contribution	Sub-basins
Surface runoff, mm	High (150 – 250)	3,7,9,13,21,22,26,28,29,31,32,33,42,50,51,55,61
	Medium (50–150)	6,8,10,11,12,14,16,17,18,19,20,24,25,30,34,35,36,37,38,39,40,41,43,45,46,47,52,54,58,59
	Low (<50)	1,2,4,5,15,23,27,44,48,49,53,56,57,60
Groundwater, mm	High (200–350)	2,4,5,15,56,57,59,60
	Medium (50–200)	1,3,6,7,9,10,13,14,16,17,18,21,23,24,25,26,27,30,32,42,44,45,48,49,50,51,52,53,55,58,61
	Low (<50)	8,11,12,19,20,22,28,29,31,33,34,35,36,37,38,39,40,41,43,46,47
Sediment yield, T/ha	High (50–110)	22,29,50,55,59,61
	Medium (10–50)	3,6,7,9,14,16,17,18,19,20,21,24,26,28,30,32,33,34,35,36,37,38,36,40,42,43,45,46, 47,54,56,57,58,60
	Low (<10)	1,2,4,5,8,10,11,12,13,15,23,25,27,31,41,44,48,49,51,52,53
Evapotranspiration, mm	High (600–650)	1,2,3,4,6,7,8,9,10,11,12,14,18,20,23,24,25,26,30,31,32,33,34,35,36,37,39,40,41,43, 44,45,46,47,49,53,58
	Low (<600)	5,13,15,16,17,19,21,22,27,28,29,38,42,48,50,51,52,54,55,56,57,59,60,61

4. CONCLUSION

The availability of water resources in various regions of the world face change due to changes in land use/cover and climate. The hydrological characteristics of the Hangar Watershed located in Ethiopia were modelled by the present study. The SWAT model simulated the result by using observed metrological data from 1987 to 2017. Calibration, validation, and sensitivity analysis were performed using the SUFI-2 algorithm of the SWAT-CUP. The performance of the model was evaluated based on the results of the standard regression statistics parameters ($0.75 < R^2 \leq 1.00$ and $0.75 < NSE \leq 1.00$) both during calibration and validation. To figure out the hydrological characteristics of the Hangar Watershed, the results of the study were analyzed 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 154.8 mm, 105.2 mm, and 19.9 mm during wet, short rainy, and dry seasons, correspondingly. The lost water in the form of evapotranspiration during wet and short rainy seasons was 40.5 mm and 41.3 mm, respectively, whereas 18.2 mm during dry seasons. The contribution of surface runoff for the watershed during wet and short rainy seasons were 188.7 mm and 40.4 mm, respectively, whereas the watershed receives 9.1 mm surface runoff during dry seasons. The status of sub-basin contributions to the watershed was ranked. Generally, the SWAT model possesses the capability to accurately simulate hydrological characteristics of the Hangar Watershed. However, there may be sources of uncertainty during the simulation of hydrological models. Therefore, this study's findings can be carefully accepted and become applied to water resources management and schemes development. In this study, only one hydrological model is used for simulation. Therefore, future researchers can conduct on a related topic with different hydrological models to compare the results.

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DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

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