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Application of SWAT(Soil and Water Assessment Tool) for Abay River Basin: A Case of Didessa sub-basin Ethiopia

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ABSTRACT

In this study, thesemi-distributed modelSWAT(Soil and Water Assessment Tool), were applied to evaluatestreamflowof the Didessa sub-basin, which is one of the major sub-basins in the Abay river basin of Ethiopia. The study evaluated the quality of observed meteorological and hydrological data, established SWAT hydrological model, identified the most sensitive parameters,evaluated the best distribution for flow and developed peak flow for majortributary in the sub-basin. The result indicated that the SWAT model developed for the sub-basin evaluated at multi hydro-gauging stations and its performance certain with the statistical measures, coefficient about determination (R^2) and also the Nash coefficient (NS) with values ranging 0.62 to 0.8 and 0.6 to 0.8 respectively at daily time scale. The values ofR^2 and NS increase at a monthly time scale and found ranging from 0.75 to 0.92 and 0.71 to 0.91 respectively. Finally, Sensitivity analysis is performed to identify parameters that were most sensitive for the sub-basin. CN2, GWQMN, CH_K, ALPHA_BNK, and LAT_TIME are the most sensitive parameters in the sub-basin.

Introduction

Hydrological models have been widely applied for comprehending the hydrological process within the catchment since the last decades [1,2].The models are tools that depict the physical process regulating the conversion of precipitation to streamflow and to represent the catchment process in a simplified way. There are various hydrological models designed to simulate the relationship between rainfall and runoff under different temporal and spatial dimensions.The focus of these models will be to set a relationship between different hydrological components such as precipitation, evapotranspiration, surface runoff, groundwater movement. Hence, hydrological models required on a planmust bemore robust, and transparentas they would progressively depend ontomakeinformed decisionson the sharing andmanagement of limited water resources [3,4]. They consider the spatial and temporal changes of different factors [5,6]. Physically-baseddistributed watershed models play a major role in analyzing the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds. The Soil and Water Assessment Tool,a Physically-based, semi-distributed, continuous simulation model,is a guaranteeing model which has been broadly used to comprehend water quantity and quality issuesover a wide range of watershed scales and environmental conditions [7-9].In addition, Soil and Water Assessment Tool maybe ariver basin model formed in order to foresee the effect of land management practices on water, sediment, also agriculturalsubstanceyields, a complex watershed ofvarying soils, land use, and managementsituationsfor long periods of time. This model has been computationally efficient and easily makes use of available inputs dataand enables users to study long-term effects.On the other hand,the Soil and water assessment Tool may be capable to simulate anindividual watershed or a system of more than one hydrologically joined watersheds,each of which separated into sub basins. The sub basin created should finally partition to hydrologic response units (HRUs)depending on soil classifications and land usedistributions. Although the Didessa sub basin is a less studied sub basin of Upper Blue Nile, there have been several successful SWAT simulations at other sub basins of Blue Nile, Ethiopia. As a further contribution to SWAT simulations in Ethiopia, on this study, the Soil and Water Assessment Tool model is established to a sub basin of the Upper Blue Nile Basin, namely the Didessa sub basin. Likewise, SWAT model can also assist in decision making of the best management options for anthropogenic activitiesdramatically expanding in Ethiopia owingto population growth at an alarming rate and investment advancement of the country [11-13]And model based estimation of watershed outflow is the base ina monsoonal climate where the rainfall-runoff relationship of the several landscapes units have complexhydrology[14].Generally “watershed variables attributed to the differences in hydrological response of rainfall are soil properties, geology, anthropogenic activities, relief size, local climate and vegetation cover”[14-17]. Model based approximation of watershed outflowincreases the prognostic power of watershed hydrology, asthis provides a basis for planning of land management issues for developing and securing water resources [18]. Therefore, understanding the watersheds as sources for streamflowisof significant importance in the effective utilizationof water resources, to enhance management activities of water resources, and tomitigate adverse effectsof climate change. The riverof Didessa, the biggest tributary of Upper Blue Nile (Abay river of Ethiopia) sharesapproximately aboutone fourth of the total flow of Blue Nile [19]has an entire catchment area of 28,000 km^2.Although the sub basin has comparatively sufficient hydrological and meteorological data series, its hydrological situation has not been well investigated as compared with northern side sub basins of the Blue Nile (Tana sub basin).In relation with its catchment situation, the occurrence of the 2015 flood incidence at the coffer dam site, calling an urgent discussion and evaluation of the hydrological design of the coffer dam and the relief culvert [20] It further invites detail hydrological study to understand and differentiate dominant hydrological processes and parameters, which govern the hydrological condition of the sub basin. Therefore, this study is relevant to undestand the hydrological situation of the sub to make sustainable water resources development activity in the sub basin.The foremost objective of the study is to understand the hydrological situation of Didesa Sub basin that possible elaborated with the following specific objectives: to (1) analyse input data such as meteorologcal and flow records, (2) calibrate and validate SWAT model (3) find the sensitive parameters for the sub basin by using SWAT-CUP algorithm (Sufi-2), (4), identify the sub catchment which contributes the highest flow, (6)Evaluate the water balance of the main sub catchments of the sub basin using SWAT simulated flow.

Materials and Methods

Study area

Didessa sub-basin is located in the western part of Ethiopia between latitude 07^{0}40’ - 10^{0}0’ North and longitude 35^{0}32’ - 37^{0}15’ East (figure 1). The overall elevation in the basin variesbetween653 and 3144 meters above sea level.The absolute catchment coverage drained by the river is projected and delineated to be 28,229 km^{2}initiating from the mount of Gomma in South Western Ethiopia.The SWAT simulated averageyearlyprecipitationof the study area is found to be 1745mm. Most of the Didessa sub basin is found inhumid tropical climatewith heavy rainfall andmost of the annual preccipitation is recieved during one season named kiremt. The highest and lowest temperature ranges amidst 21.3 – 30.9^{0}C and 10.9 - 15.1^{0}C, respectively. From the assessment ofland use/cover, major land use types identified include moderately cultivated, dense woodland, intensively cultivated land, wooded grassland, open woodland, natural forest cover, natural forest with coffee, coffee farm with shade trees, riverine forest, bamboo, forest, plantation forest, settlement, shrub land, and open grassland. According to Oromia Water Work Design and supervision (OWWDSE)[20] of the Arjo Didessa dam project feasibility study of 2014 different land use types in a different land,the cover has been identified in the sub basin. These include mixed cultivation, coffee production, livestock production, subsistence, and commercial forest products utilization, on-timber products utilization, beekeeping, Wildlife management and utilization, infrastructure development, mining and investment activities on different activities.

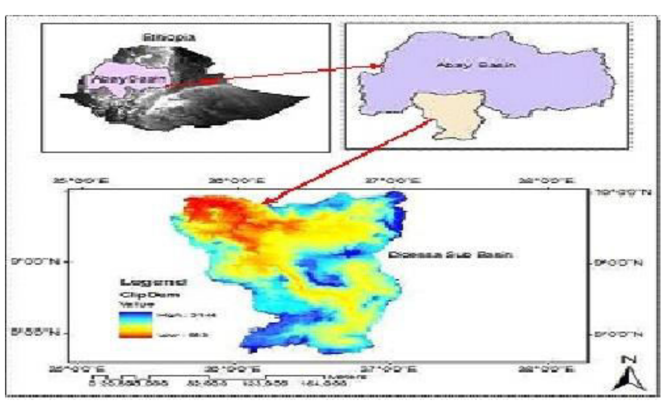


Figure1. Didessa Sub-basin study site, Abay basin, Ethiopia

Input Dataset and Sources of Data for the model

Swat requires daily weatherdata including precipitation,wind Speed, minimum and maximum temperature, relative humidityand solar radiation. Themaindata categories that were utilized in this study incorporate climate, hydrology, soils, land use/land cover information and more advanced DEM of 30mx30m spatial resolution(figure 2c).Weather or Climate information was gathered from the National Meteorological Agency of Ethiopiawhereas daily flow records were obtained from the Ministry of Water, Irrigation, and Energy of Ethiopia. Furthermore, landuse/cover ((MERIS land use land cover, 2009) were gotten from Oromia Water work Design and Supervision Enterprise (OWWDSE)[20]. Lastly, the Soil shape file was collected from Dr. Belete Berhanu,Soil geo-database of Ethiopia' prepared by [21].The meteorological stations are scatter populated and some stations base period is recent with a high missing record. In the case of unavailability of relative humidity,wind speed, and sun shine hour's data the model might have been run with daily rainfall and temperature. Underneath table **1** indicates recorded weathermonitoring stations plus accessible information of the time range utilized as an input of the study area.

Flow records obtained from the Ministry of Water and Energy in Ethiopia atthe relevant gauging station of the Didessa river basin are located near Dembi (Toba),Arjo Didesa near Arjo,Dabana near Abasina,Wama near Nekemte and Angar near Nekemte. These stations have data missing in their flow records as shown in table 2below. However, the missing data were completed in XLSTAT software, before using for SWAT model. Land use is one of the main factors influencing soil erosion; and evapotranspiration in a catchment [22]. The land use shape file of the study is MERIS (Medium Determination Imaging Spectrometer) based Glob-Cover of 2009 land cover map. This landuse map is clipped and projected for the study area before using it in the SWAT model. land use map after clipping it to study area and changed to relate for those swat predefined land use grouping. It holds a raster version of the Glob-Cover map with a spatial resolution of 30mx30m (figure 2a). Dominate land use or cover for this manuscript was mosaic vegetation or crop lands followed by closed to open shrub land. Simulation of SWAT necessitates soil composition of different properties like soil textural property, physical and chemical properties. The soil map utilized in this study was gotten from two sources. Firstly, the soil data base acquiredfrom Ministry of Water Resource Irrigation and Energy of Ethiopian has a shortage of several soil properties like (available moisture capacity, density, saturated hydraulic conductivity, percentage of sand, silt and clay) compulsory required in the model set up were not available in its data base. Secondly, due to the above data base was deficient in necessary information additional data were substantiated from another source like 'soil geo-database of Ethiopia' prepared by [15] with a spatial resolution of 30m x30m (figure 2b).

Filling Missing Rainfall and temperature Data

Missing data were completed in The XLSTAT software, downloaded from the website www.xlstat.com. As one of the functions of this software is completing missing data using advanced missing value treatment techniques.

Testing of dataset quality

Sometimes a significant change may occur in and around a particular rain gauge station. Such change occurring in a particular year will start affecting the rain gauge data, being reported from a particular station. In order to detect such inconsistency and to correct and adjust the reported rainfall values, a technique called double mass curve method is generally adopted in this study. In this method, a group of 8adjoining stations isselected in the vicinity of the suspicious stations. The mean daily rainfall values are serially arranged in reverse chronological order to fix relative consistency.

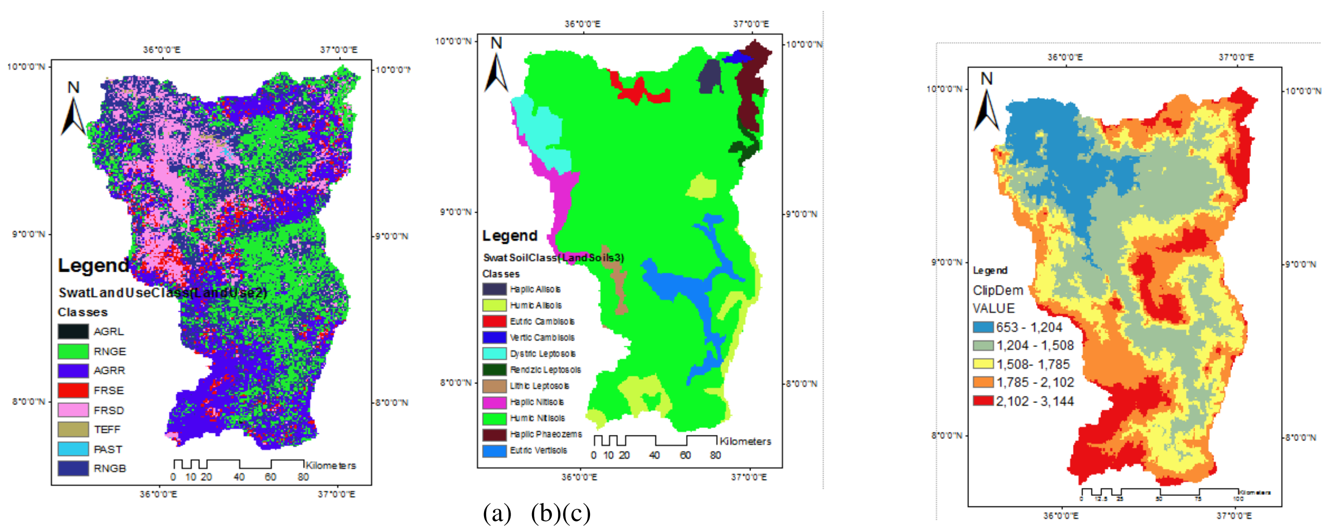
The observations from a certain station were compared with the mean of observations from numerousadjacent stations. In accepted double-mass computations, this testing involves removing from the arrangement the records from an uncertainstation and comparing them with the remaining data. Since all the datasets were reliable with the accepted totalities in the area, they are re-combined into the base period station. After the data of each station are arranged in descending order,the accumulative sums, station to be investigated and the base station; are plotted against each other and the line of best fit was sketched in the excel assignment sheet.

Table 1. List of Selected weather monitoring Stations and Available data sets for rainfall and climatic variables

Station Name	Zone	Station Elevation(m)	Latitude (Deg)	Longitude (Deg)	Data coverage (year)	% of missing Rainfall	% of missing Temp.
Bedele	Illubabor	2011	8.5	36.3	1980-2015	17	24.9
Arjo	Misrak Wellega	2565	8.8	36.5	1989-2015	27	33.1
Shambu	Misrak Wellega	2460	9.6	37.1	1980-2015	14	41.0
Nekemte	Misrak Wellega	2080	9.1	36.5	1980-2014	7	11.5
Gimbi	Mirab Wellega	1970	9.2	35.8	1980-2015	18	41.4
Nedjo	Mirab Wellega	1800	9.5	35.5	1980-2015	20	21.8
Jimma	Jimma	1718	7.7	36.8	1980-2015	5	4.6
Dedessa	Misrak Wellega	1310	9.4	36.1	1980-2015	18	38.1

Table 2. Basic Hydrometric monitoring description for Didesa River Basin

S.N	River	Station	Latitude Deg.	Min	Longitude Deg.	min	Catchment area (km^2)	Data coverage (year)	% Missing
1	Didessa	Arjo	8	41	36	25	9,981	1980-2014	6
2	Anger	Nekemte	9	26	36	31	4,674	1995-2004	7
3	Dabana	Abasina	9	02	36	03	2,881	1980-1985	12
4	Didesa	Nr. Dembi	9	30	36	35	1806	1985-2014	7
5	Wama	Nr. Nekemte	8	47	36	47	844	1980-1985	39



(a) (b)(c)

Figure 2. Physiographic data: (**a**) Didessa sub basin land cover; (**b**) soil type; (**c**) DEM

Seasonal Mann-Kendall Test is adapted to evaluate with a nonparametric test if a trend can be recognized in a series, evenwhen seasonal factors in the sequence.A nonparametric trend test has been primarilysuggestedvia [23]then advanced through [24]finallyget enhanced by way of [25] who accustomed to take into account seasonality as well. The null hypothesis Ho for these tests implies the absence ofa trend in the series. The next three hypothesesindicatepresence ofnon-null, negative, or positive trend.This test depends on values P-value and Kendall's tau. Kendall's tau shows a degree of relationship between two samples. P-value measures whether the null hypothesis was accepted or rejected. If the p-value falls below the significance level the alternative hypotheses will be accepted and vice versa. If the time series does have a trend, the data cannot be used for frequency analyses or modelling. Those time series with the trend cannot incorporate into hydrological or frequency analysis during modeling for hydraulic structures designs.

Selection of parameters for Sensitivity Analysis

Before calibration to begin, Parameters that were used in the SWAT model to other Upper Blue Nile sub basins were identified from previously published munuscript. Since this was not enough to get performance criteria, other parameters were gathered and added from the SWAT-CUP manual. About nineteen parameters (CN2, ESCO, SOL_AWC, GW_DELAY, GW_REVAP, REVAPMN, GWQMN, ALPHA_BF, RCHRG_DP, CH_K2, SURLAG, CH_N2, and SOL_K, CH_K2, ALPHA_BNK, SLSUBBSN, OV_N, LAT_TIME, ESCO, EPCO, and HRU_SLP) were incorporated into SWAT-CUP aligorithm (Sufi-2) to understand the level their sensitivity. Knowing the more sensitive parameters could make ease of the time required for calibration and validation. Furthermore, it is the technique to know the dominant parameters of the watershed that can influence the hydrological balance of the sub basin. The global sensitivity was determined toto depend on P-value. The smaller the p-value indicates the more sensitive parameter, whereas the larger the p-value point toward the less sensitive for the given watershed [26]. The values close to zero has more significance. According to [27], also sensitivity analysis significantly eases relative sensitivity of parameter identification, rises the accurateness of calibration and lessens uncertainty and the time necessary for it.

Data Processing and Model setup

Data processing, in this case, includes trend test and homogeneity tests for precipitation data of 8 stations in the Didessa sub basin from 1980 to 2014. Moreover, flow data of the sub basin is also tested for Arjo gauging station from the year 1980 to 2014, Dembi station from 1985 to 2014, Angar stations from 1995 to 2004, for Dabana stations from 1982 to 1985 depending on availability of flow data. The seasonal Kendall's test for each station is evaluated with XLSTAT software which shows that the data of all the stations are free of a trend. Alexanderson's SNHT(Standard Normal Homogeneity Test) test for Homogeneity is applied for testing of monthly rainfall. This test i.e. SNHT was established through [28]in order to sense analternation in a sequence of precipitation data. The test was recommended to series of the ratio of observations to compare with an average the ratio of several stations. After processing data, the output result shows that the series of precipitation data remained homogenous. The same procedure was followed to trend test, in trend test interface of XLSTAT and it is found that data are free of a trend. Similarly flow series were tested at different gauging stations of Didessa sub basinsuch as Didessa near Arjo (1980-2014), Dabana near Abasina (1980-1984), Didessa Near Dembi (1985-2014) and Angar Near Nekemte (1995-2004). And from trend and homogeneity test it is found that the flow data were homogeneous and no significant trend is found at all discharge gauging stations.

ArcSWAT version of 2012.10 of ArcGIS 10.1 interface downloaded from website http://swat.tamu.edu/software/arcswat/ is used for watershed delination, HRUs definition, and hydrological simulation. DEM was applied in watershed delination. And land use and soil shape file of the same spatial resolution was used in HRUs definitions. Landuse/soil/slope of thresholds 20/20/20 (%) respectively,produces 604 HRUs and 112 subbains. Recorded wheather input of daily rainfall and maximum and minimum temperature of 35 years used as an input file to produce the simulation. And three years warm up period is taking place to activate the Swat run step. Finally,the sequencial Uncertainity Fitting i.e SUFI-2 built in SWAT-CUP aligorithm was used to calibrate and validate the model. SWAT-CUP provides algorithms for auto-calibration, from which Sequential Uncertainty Fitting,Version 2 (SUFI-2) was chosen. SUFI-2 accounts for several sources of uncertainties such as uncertainty in driving variables e.g. rainfall, conceptual model, parameters and measured data [26]. It is not a fully automated calibration tool since it still requires the interaction of the modeller and knowledge about the parameters and their effects on the output [26]. In sufi-2 parameters are given ranges as found in Absolute_swat_values before performing iteration. Finally, the aligorithm provides the best estimation and optimum parameters range.

For this study, flow gauging stations like Dabana near Abasina and Wama near Nekemte left only with calibration as the limited observed discharge of fewer than 5 years are available after 1980 (starting year of SWAT model run). Initially, calibration was started on a monthly base to recognize the size of parameters, as well as seasonal characteristics of flow.After running the SWAT model on a monthly time step hydrological water balance is observed and base flow is overestimated. Then the daily calibration is succeeded to get more perfect parameter values about the watershed as well as to properly estimate annual flow volumes at necessary point or junction as shown in figure 3.

Model calibration and validation are done depending on the location of gauging stations as well as the presence of available gauged discharge data. For Dembi and Arjo daily flow data of 18 consecutive years with negligible missing is used for calibration and validation. Angar near Nekemte has 10 years available data within the range of SWAT run period where as Lower Dabana and Wama have 5 years and 4 years data within the range respectively. Hence due to absence, sufficient data calibration is done without validation at Dabana and Wama discharge gauging stations.

Model performances were evaluated graphically and statistical procedures with that of quality criteria [29-31]. In this study model performance was evaluated with values of R^2(Coefficient of determination), NSE (Nash Sutcliffe) and PBISAS. The R^2provides for those extents of the discrepancy between observed and simulated with the linear association. Nash Sutcliffe defines the extents of variation between simulated to observed data discrepancy [38]. The Nash value situated between this interval (-∞,1] and the value close to zero shows as the model performance is more suitable [33-36]. PBIAS is taken as a clear quantifier for water balance errors[30-35] and value close to zero shows the more the value approaches the acceptable range.For stream flow, the performance rating which ranges between 0.75 < NSE <1.00 and PBIAS < ±10 is considered as very good for a monthly time scale.The model performance is supposed as good for values ranges between 0.65 < NSE <0.75 and ±10 <PBIAS < ±15. Values of NSE <0.50 and PBIAS > ±25 demonstrates unsatisfactory ranges of performance. The model performance was considered as satisfactory for an interval value ranges between 0.50 < NSE <0.65 and ±15 <PBIAS < ±25 [30]. The R^2, NSE, and PBIAS wereevaluated with the equations (1) up to (3)as follows:

$$NSE = 1 - \frac{\sum_{i=1}^{n}(Qi^{o} - Qi^{s})^2}{\sum_{i=1}^{n}(Qi^{m} - \overline{Q^{m}})^2}, \quad (1)$$

$$R^2 = \frac{\left[\sum_{i=1}^{n}(Q_{o,i} - \overline{Q_o})(Q_{s,i} - \overline{Q_s})\right]^2}{\sum_{i=1}^{n}\left(Q_{o,i} - \overline{Q_{mo}}\right)^2 \left(Q_{s,i} - \overline{Q_s}\right)^2}, \quad (2)$$

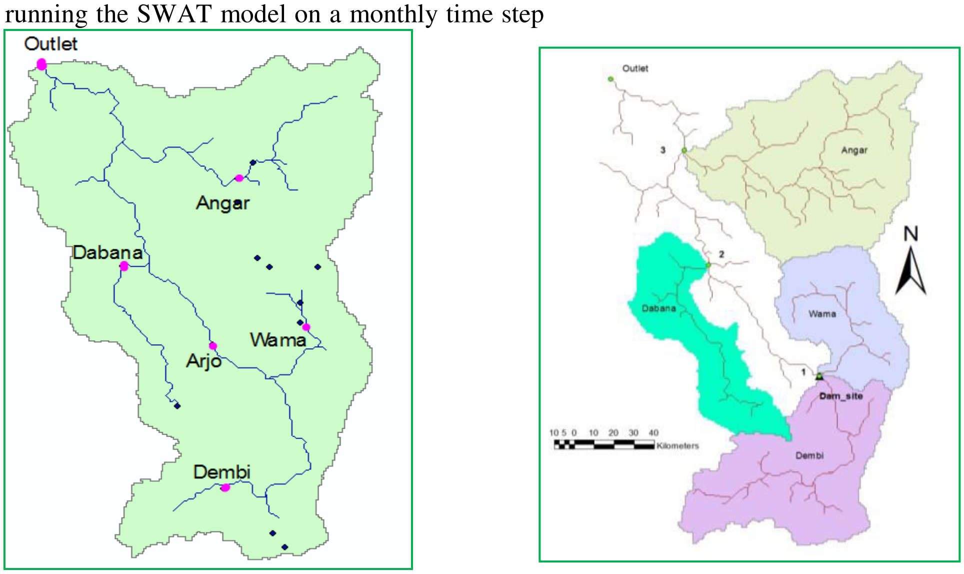
$$PBIAS = 100 * \frac{\sum_{i=1}^{n}(Q_o - Q_s)i}{\sum_{i=1}^{n} Q_{o,i}}, \quad (3)$$

Where, Qi^{o} and Qi^{s} represent measuredand Simulated flow at time step i, correspondingly, $\overline{Q^{o}}$ and $\overline{Q_s}$ areaverage of measured flow, *n* indicate the grand number of paired measured and observed discharge, *o*and *S* are mean measured and simulated discharge, consecutively.

Results

Model Calibration and validation

Initially, calibration was started on a monthly base to recognize the size of parameters, as well as seasonal characteristics of flow (table 3).After running the SWAT model on a monthly time step hydrological water balance is observed and base flow is overestimated. Then the daily calibration is succeeded to get more perfect parameter values about the watershed as well as to properly estimate annual flow necessary point or junction as volumes at shown in figure 3.



(**a**) (**b**)

Fig 3. (**a**) Location of flow-gauging stations, and (**b**) Junction (1, 2, 3) at which hydrograph is simulated

Even though model performance values are not shown in table 3 for these two gauging stations model is calibrated using observed flow. Didessa near Arjo gauging station data are classified in to two depending on hydrological change during 2005 in the Didessa sub basin. This change was observed during the trend test. Itmay be caused due to settlers of Hararghe population, and land clearing for sugar cane production in the sub basin. Flow data from 1997 to 2004 and from 2007 to 2014 are used for this watershed to understand the basin characteristics within the two ranges. In both calibration and validation, this model shows acceptable statistical values of performance measurements on the Didessa sub basin at all the gauging stations(table 3). In most stations, daily performance is greater than that of monthly in terms of PBIAS. Specifically, in some of the stations very good values of NSE and R^2were obtained and were ≥0.75 on a monthly time scale. Only one station i.e. Arjo showed low performance in the case of percent of biased(PBIAS)of -20 even though NS and R^2 are very good at a monthly time basis.Furthermore, since the average of data is simulated on a monthly time step, it is not good as a daily time step in water balance prediction at the necessary junction to estimate flow for design purposes. The SWAT parameters used in calibration, its optimum value and variation methods are indicated in table 4 below. For all the watersheds flow is well reproduced for both wet and dry season(figure 4). The global sensitivity of parameters was computed to simplify the time consumed in model calibration and validation. The ranks of sensitivity, which depend on the p-value obtained during iteration in the SWAT-CUP algorithm of Sufi-2 were tabulated in (Table A1) for gauging stations involved in this study. The parameter's rank given in the table was obtained during calibration on the daily time step. Among nineteen parameters selected for model calibration the CN_2 (curve number), (SOL_AWC(available water capacity), HRU_SLP(average slope steepness), (SOL_K)saturated conductivity, GW_REVAP(ground water revaporation coefficient),GWQMN (threshold water depth in the shallow aquifer for flow), and ALPHA_BF (base flow alpha factor) were found to be those with higher rank at a different outlet.

Table 3.Model performance statistics for the Didessa Sub basin at 4 discharge gauging stations.

Time base	Calibration	(1997-2008)	(1997-2001)	(2006-2011)	(1997-2001)
	Statistic	**Dembi**	**Arjo**	**Arjo**	**Angar**
	R^2	0.66	0.74	0.74	0.8
	NSE	0.6	0.74	0.65	0.8
	PBIAS	-10.5	-6.1	-19.4	0.5
Daily	**Validation**	**(2009-2014)**	**(2002-2004)**	**(2012-2014)**	**(2002-2004)**
	R^2	0.70	0.70	0.64	0.62
	NSE	0.66	0.62	0.6	0.61
	PBIAS	-6	0.0	-4	-16.3
	Calibration	**(1997-2008)**	**(1997-2001)**	**(2006-2011)**	**(1997-2001)**
	R^2	0.80	0.87	0.75	0.82
Monthly	NSE	0.72	0.82	0.71	0.79
	PBIAS	-16.4	-10.5	2.5	-3.5
	Validation	**(2009-2014)**	**(2002-2004)**	**(2012-2014)**	**(2002-2004)**
	R^2	0.86	0.89	0.82	0.92
	NSE	0.83	0.84	0.81	0.91
	PBIAS	-13.3	-20	7.7	-13.4

The higher the value CN_2 indicates that the larger the surface runoff and the smaller the baseflow. This value of the CN_2 plays great to determine surface runoff for a given catchment using the USDA-SCS equation. The smaller the value of SOL_AWC leads to a decrease in surface runoff and increases the evapotranspiration and vice versa. The large the value of HRU_SLP the smaller the to peeak for over land which is crucial for flood warning. Increase in ground GW_REVAP shows a decrease in a decrease in base flow and deep percolation to ground water as this can affect the water balance of sub basin. Moreover, parameters that can affect flow are Manning's "n" value for the main channel (CH_N2), LAT_TIME, Lateral flow travel time, and OV_N (Manning's roughness coefficient) for overland flow was found. The CH_N2 fitted value for each main tributary plays a great role in the manning equation of of open channel design. The level of the parameter's sensitivity was different at different outlets. Nevertheless, the CN_2 (curve number) was the main sensitivity parameter for all outlets. After running of SWAT model hydrological water balance is observed and in fact base flow is overvalued. As can be seen in table 3 the negative values of PBIAS indicated that over estimating flow by the model. This may be due to the reason that the soil shape file applied in this model set up is single layered soil data. During iteration in the SWAT-CUP algorithm i.e., Sufi-2 calibration parameters are adjusted to fit observed and simulated hydrograph. To correct the late shift, the slope (HRU_SLP) increased, and Manning's roughness coefficient (OV_N), as well as the value of overland flow rate (SLSUBBSN), decreased. SCS runoff curve number (CN_2) value is getting increased to increase the value of the surface run off.

Table4 Parameters used in the calibration of the SWAT model and its optimum

Parameters	**Fitted Values**							
	Range	**Dembi**	**Arjo(1997-2004)**	**Arjo(2006-2014)**	**Angar**	**Dabana**	**Wama**	**Variation Methods**
V_ALPHA_BF	0-1	0.45	0.357	0.511	0.721	0.741	0.545	Replacement
V_ALPHA_BNK	-0.1-1	-0.01	0.745	0.327	0.457	0.175	0.755	Replacement
V_CH_K2	0-500	125.68	488.78	309.204	285.0	451.31	486.2	Replacement
V_CH_N2	-0.01- 0.3	0.273	0.191	0.056	0.389	0.276	0.213	Replacement
R_CN2	-0.25-0.25	0.11	0.124	0.15	0.107	0.153	0.1	Relative
V_EPCO	0-0.9	0.062	0.529	0.213	0.042	0.11	0.103	Replacement
V_ESCO	0-0.1	0.002	0.001	0.003	0.0022	0.0023	0.0021	Replacement
V_GW_DELAY	0-0.3	0.01	0.604	0.234	-0.001	0.01	0.005	Replacement
V_GW_REVAP	0-0.2	0.199	0.183	0.17	0.181	0.177	0.179	Replacement
V_GWQMN	0-5000	3044.4	4850	4616.7	1683.2	3705.5	4596.8	Replacement
R_HRU_SLP	-1-0.4	-0.871	0.784	-0.112	0.287	0.196	-0.665	Relative
V_LAT_TTIME	0-25	5.934	12.643	28.4	4.957	5.217	1.141	Replacement
V_OV_N	0-15	6.237	7.426	5.776	1.502	1.577	6.718	Replacement
V_RCHRG_DP	0-1	0.258	0.222	0.124	0.422	0.265	0.832	Replacement
V_REVAPMN	0-500	147.78	299.45	125.7	149.06	303.0	485.9	Replacement
V_SLSUBBSN	0-180	123.12	87.891	169.2	57.057	123.0	91.9	Replacement
R_SOL_AWC	-02-0.51	-0.049	-0.101	0.025	0.356	0.052	0.077	Relative
R_SOL_K	-0.1-0.25	-0.136	0.009	0.121	0.166	0.038	-0.02	Relative
V_SURLAG	0-30	16.74	20	10.4	4.711	6.258	12.5	Replacement

"V" replaces the existing value with the given value,"R" multiplies the existing value with (1+the given value)

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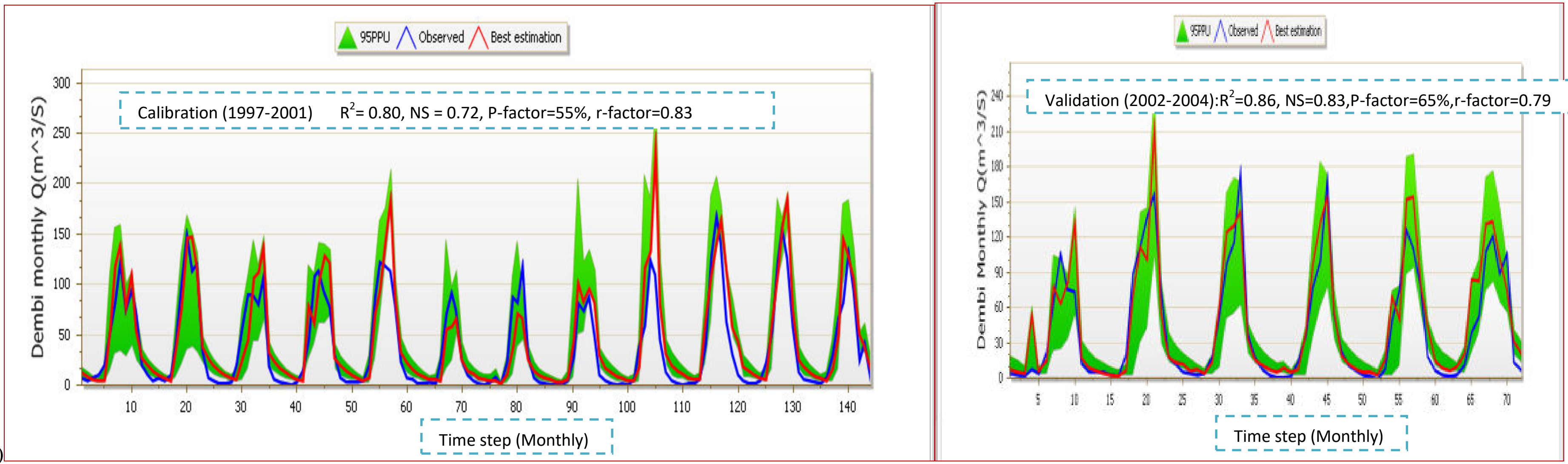
Therefore,thefitted values of parameters (table4) were needed in solving the problems of the complexhydro-geological process of the sub basin. As quantitative values of the parameters give approximatehydrological balance. Generally, it leads to give best management options of water reources and to augment development actities in the same sub basin.

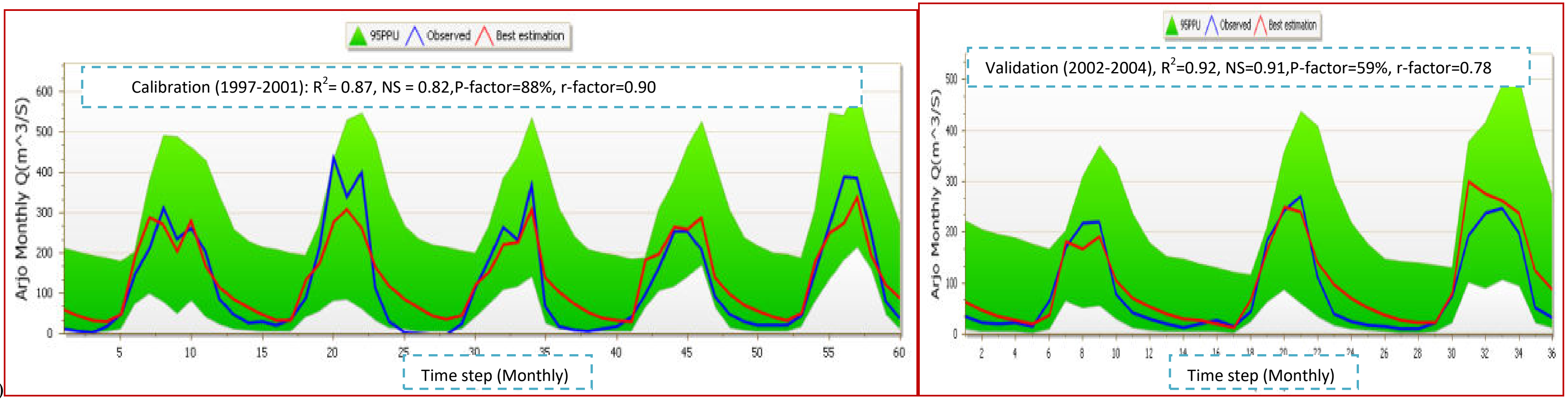
Water Balance of Didessa Sub Basin

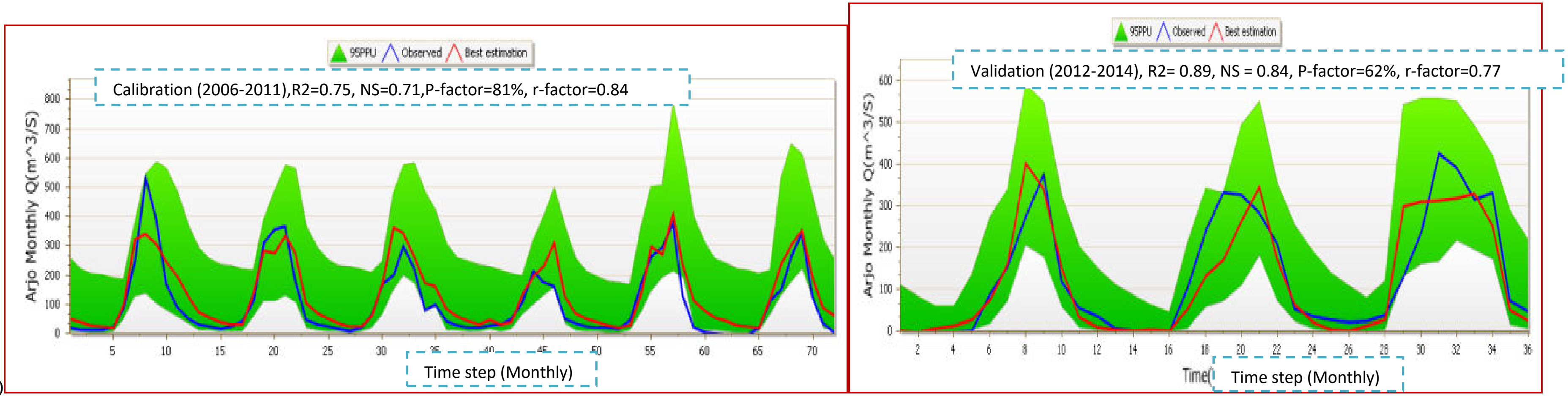
Water balance analysis of the sub basin is done with given land use. In addition, the calibrated parameters are reinserted during ArcSWAT run for each watershed to get an appropriate balance. This sort of evaluation has been required to acquire an Understanding of the whole hydrological response ofcatchment. At the same time, it provides for an essential consideration of the rainfall-runoff association through a long period of time. The outcome of such investigation considers the general breakdown of precipitation and their proportions which defining runoff from sub basin, subsurface and evapotranspiration, and etc. This evaluation involves a comparison of input climate data to that of observed stream flow. The breaking of inputs to the output water balance components could aid in deciding those possibilities sensitivities of the watershed to change in land use or land cover. The general long term hydrological water balance and hydrological parameters estimated and tabulated in table 5.

(a)

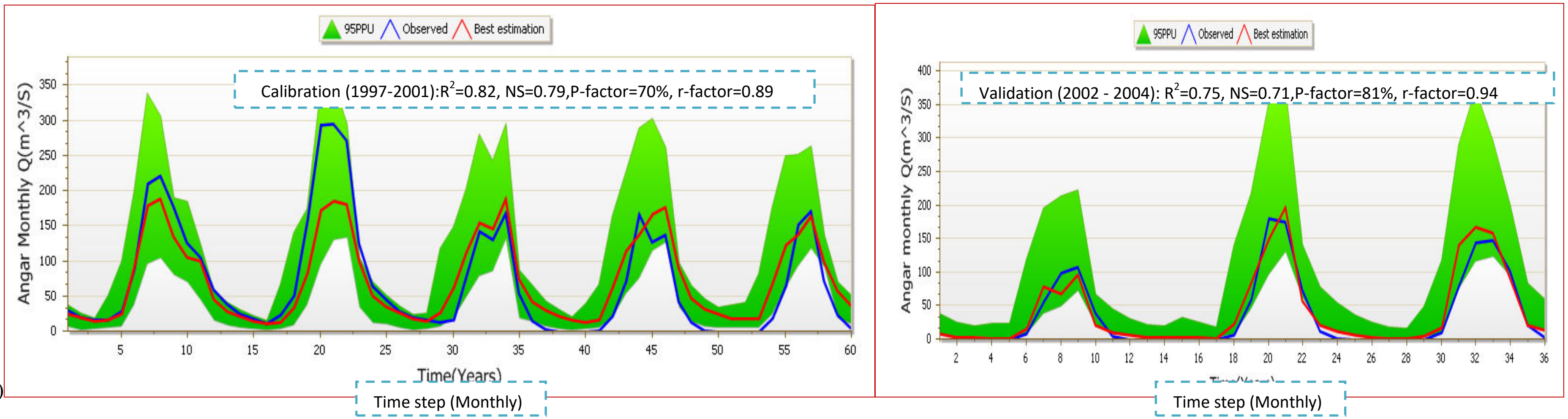

95PPU
Observed
Best estimation
Calibration (1997-2001) R2= 0.80, NS = 0.72, P-factor=55%, r-factor=0.83
Dembi monthly Q(m^3/S)
Time step (Monthly)
Validation (2002-2004):R2=0.86, NS=0.83,P-factor=65%,r-factor=0.79
Dembi Monthly Q(m^3/S)
Time step (Monthly)

(b)


95PPU
Observed
Best estimation
Calibration (1997-2001): R2= 0.87, NS = 0.82,P-factor=88%, r-factor=0.90
Arjo Monthly Q(m^3/S)
Time step (Monthly)
Validation (2002-2004), R2=0.92, NS=0.91,P-factor=59%, r-factor=0.78
Arjo Monthly Q(m^3/S)
Time step (Monthly)



(c)



(d)

***Figure 4**. Simulated and observed hydrographsat monthly time steps: (a) Dembi,(b), and (c) Arjo ,(d) Angar.*

Table 5.Hydrological water balance ratio and hydrological variables

Hydrology (water balance ratio)	**Dembi**	**Arjo**	**Dabana**	**Wama**	**Angar**
Stream flow/precipitation	0.21	0.2	0.28	0.15	0.20
Base flow/total flow	0.21	0.28	0.27	0.32	0.39
Surface run-off/total flow	0.79	0.72	0.73	0.68	0.61
Percolation/precipitation	0.28	0.34	0.29	0.36	0.35
Deep recharge/precipitation	0.07	0.13	0.08	0.3	0.15
ET/precipitation	0.55	0.51	0.50	0.48	0.52
Hydrological variables (all units in mm)	Dembi	Arjo	Dabana	Wama	Angar
Evap. and transpiration	964.5	951.7	932.8	961.5	860.3
Precipitation	1740	1862.9	1861.7	1990.2	1669.9
Surface run-off	287.4	264.71	376.41	209.1	204.5
Lateral flow	3.37	5.2	13.42	98.92	17.66
Return flow	74.9	95.24	124.6	0.0	115.14
Mean annual flow (m^3/s)	84.5	209.3	67.6	86.1	147.2
Annual water yield (mm)	482.6	630.6	656.4	902.3	583
Annual water yield ($10^9 m^{3)}$	3.1	6.60	2.15	2.71	4.6
Catcment Area ($Km^{2)}$	5532.1	11358.1	3246.4	3336.8	7988.2

The flow of major tributaries

Average monthly basin rainfall, Evapo-transpiration, surface flow, Potential Evapo-transpiration, and average basin yield are obtained From ArcSWAT output. From this out put one can understand the hydrological situation of the basin in terms of months with high and minimum surface and base flow. To easily understand the hydrological situation of the sub basin, it is better to classify the output into two major categories i.e. wet and dry season which is common in Ethiopia. According to the climate of the study area, the wet season ranges from May to October where as dry season is when precipitation is almost negligible and for all months between November and April. Peak flow and lowermost flow are developed during the month of August and April respectively. The study also extended to evaluate the water yield of the major tributaries to identify the catchment which contributes maximum annual flow along with their catchment area. The four major tributaries of the Didessa sub basin are Angar,Dembi or Toba,Wama, and Dabana in their consecutive order of catchment size. Generally, the Didessa sub basin contributesabout a quarter of the average flow of the Abay basin of Ethiopia. According to the simulated output flow volume of about 10.7 Billion meter cube of flow is annually donated to the Upper Blue Nile of Ethiopia from the Didessa sub basin. In percentage, it shares about 26% of Abay basin (54.810^9 m^3) which is measured at Sudan border[41].

Conclusion

In this study,the SWAT model wasapplied to understandthe hydrological situation of the Didessa sub basin. Model assisted hydrological characterization of the Didessa sub basin was handled with different hydrological procedures and methods. First the observed metrological and hydrological data were statistically tested and found to be consistent and free of the trend. The idea of input data testing such as meteorological and flow record analysis (homogeneity test, trend test) is required because if the trend is detected in the data it cannot be utilized as input for the model.

The SWAT Hydrological model for the sub basin was established, calibrated and validated by means ofmeasureddaily and monthly discharge at gauged places in the study area. The calibration and validation of the model were measured by the R² (coefficient of determination) and the NS (Nash Sutcliff) model efficiency parameter of at monthly and daily time scale. The values of R^2 and NS were found in accepted range as indicated by Arnold et al. [16, 30] for all watersheds suchas Dembi, Arjo Didessa, and Angar at a daily time scale. The values of R^2 and NS increase at a monthly time scale and fall in a very good range for all of the tributary watersheds. Sensitivity analysis realizes parameters that were the most sensitive for the sub basin. And each parameter is arranged based on their sensitivity rank for each watershed.CN2, GWQMN, CH_K, ALPHA_BNK and LAT_TIME are the most sensitive parameters in the Didessa sub basin.

Therefore, the hydrological process in the Didessa sub basin is characterized using the simulated stream flow at major sub catchments. This characterization includes developing stream flow hydrograph, identification of sub catchment with the highest annual flow, peak flow analysis using fitted probabilistic distribution and frequency analysis.

Finally, this study indicates the SWAT model is appropriate to simulate the hydrological situation of the Didessa sub basin of Blue Nile of Ethiopia, with accepted parameter ranges.

Conflicts of Interest: The author declares no conflict of interest

References

1. Tufa, D.F.;Abbulu,Y.E.;Srinivasarao, G.V. Watershed Hydrological Response to Changes in Land Use/Land Covers Patterns of River Basin: A Review. International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD) **2014**, 4,157-170.
2. Gebrekristos, S. T. Understanding Catchment Processes and Hydrological Modelling in the Abay/Upper Blue Nile Basin, TU Delft, The Netherlands,**2015**.
3. Chang, J.; Zhang, H.; Wang,Y.; Zhu, Y.Assessing the impact of climate variability and human activity to streamflow variation.Hydrol. Earth Syst. Sci.**2016**, 20, 1547–1560,doi:10.5194/hess-20-1547-2016
4. Fu, G.; Charles,S.P. and Chiew, F.H.A two-parameter climate elasticity of streamflow index to assessclimate change effects on annual stream flow. Water Resource. Research **2007**,13,p43, doi:10.1029/2007WR005890
5. Conway D. A water balance model of the Upper Blue Nile in Ethiopia. Hydrological sciences journal 1997Apr 1,42(2),265-86,doi=10.1.1.399.6328
6. Tekleab, S.;Uhlenbrook, S.; Mohamed, Y.;Temesgen, M.;Savenije, H.H.;Wenninger,J.Water balance modeling of Upper Blue Nile catchmentsusing a top-down approach.Hydrol. Earth Syst. Sci.**2011**,15(7),2179–2193,doi:10.5194/hess-15-2179-2011
7. Sith,R.; Nadaoka,K. Comparison of SWAT and GSSHA for High Time Resolution Prediction of Stream Flow and Sediment Concentration in a Small Agricultural Watershed. *Hydrology* **2017**, *4*, 27; doi:10.3390/hydrology4020027
8. Arnold, Jeffrey, G. et al. SWAT: Model use, calibration, and validation. *Transactions of the ASABE* 55.4 **2012**,1491-1508.
9. Gassman, P.W.; Reyes, M.R.; Green, C.H.; Arnold, J.G. The soil and water assessment tool: Historical development, application, and future research directions. *Trans. ASABE***2007**, *50*, 1211–1250.
10. Neitsch, S.L.; Arnold, J.G.; Kiniry, J.R.; Williams, J.R. *Soil and Water Assessment Tool: Theoretical Documentation—Version 2009*; Grassland, Soil and Water Research Laboratory, Agricultural Research Service:College Station, TX, USA, **2009**; p. 618.
11. DeFries, R.;Eshleman, K.N.Land-use change and hydrologic processes: a major focus for the future. Hydrol. Process.,**2004**, 18(11), 2183–2186,doi:10.1002/hyp.5584
12. Ali, H.; Descheemaeker, K.;Steenhuis, T.S.;Pandey, S.Comparison of landuse and landcover changes, drivers and impacts for a moisture-sufficient and drought-prone region in the Ethiopian highlands. Exp. Agric.**2011**, 47, 71–83,doi: 10.1017/S0014479710000840.
13. Zeleke, G.; Hurni, H. Implications of land use and land cover dynamics for mountain resource degradation in the Northwestern Ethiopian highlands. Mt. Res. Dev.**2001**,21, 184– 191.
14. Sivapalan, M.;Blöschl, G.;Merz, R.; Gutknecht, D. Linking flood frequency to long term water balance: incorporating effects of seasonality. Water resource research**2005**,41(6),1-17,doi:10.1029/2004WR003439
15. Berhanu, B.; Seleshi, Y.; Demisse, S.S.; Melesse, A.M. Flow Regime Classification and Hydrological Characterization: A Case Study of Ethiopian Rivers. Water**2015** , 7(6), 3149-3165; doi:10.3390/w7063149
16. Arnold, J.G.; Srinivasan, R.; Muttiah, R.S.; Williams, J.R. Large-area hydrologic modeling and assessment. Part I. Model development.J. American Water Res. Asso. **1998**, 34(1): 73-89.
17. McDonnell, J.J.; Sivapalan, M.; Vaché, K.; Dunn, S.; Grant, G.; Haggerty, R.; Hinz, C.; Hooper, R.; Kirchner, J.; Roderick, M.L.; Selker, J. Moving beyond heterogeneity and process complexity: A new vision for watershed hydrology. Water Resources Research**2007 Jul 1**, 43(7).
18. Saxena, R. K.; Verma, K. S.; Chary, G. R.; Srivastava, R.; and Barthwal, A. K. IRS-1C data application in watershed characterization and management. Int. J. Remote Sens**2000**. 21(17), 3197–3208.
19. Muluneh, T.;Mamo, W. Morphometric Analysis of Didessa River Catchment in Blue Nile Basin, Western Ethiopia. Science, Technology and Arts Research Journal**2014**, 3(3): 191-197.
20. Fesea,B. (Oromia Water Work Design and Supervision Enterprise, Addis Ababa, Oromia, Ethiopia). Personal communication, 2017.
21. Berhanu, B.; Melesse,A.M.; Seleshi,Y. GIS-based hydrological zones and soil geo-database of Ethiopia. Catena **2013**, 104 , 21–31
22. Mengistu, D.T.; Moges, S.A.; Sorteberg,A. Retraction Notice. Journal: Journal of Water Resource and Protection, **2016**, 8(1).
23. Mann, H.B. "Nonparametric tests against trend. *Econometrica: Journal of the Econometric Society* **1945**, 245-259,DOI: 10.2307/1907187
24. Kendall M. Multivariate analysis. Charles Griffin,**1975**
25. Hirsch,R.M.; Slack,J.R. A nonparametric trend test for seasonal data with serial dependence. Water Resources Research**1984 Jun 1**, 20(6):727-32.
26. Abbaspour KC, Vejdani M, Haghighat S, Yang J. SWAT-CUP calibration and uncertainty programs for SWAT. InMODSIM 2007 International Congress on Modelling and Simulation, Modelling and Simulation Society of Australia and New Zealand 2007 Dec (pp. 1596-1602).
27. Lenhart, T.;Eckhardt, K.;Fohrer, N.;Frede,H.G. Comparison of two different approaches of sensitivity analysis. Physics and Chemistry of the Earth, Parts A/B/C**2002 Dec 31**, 27(9):645-54.
28. Alexanderson,G.L.; Wetzel,J.E.; A simplicial 3-arrangement of 21 planes. Discrete mathematics **1986 Jun 1**,60,67-73.
29. Tolson, B.A.; Shoemaker, C.A. dynamically dimensioned search algorithm for computationally efficient watershed model calibration. *Water Resour. Res.* **2007**, *43*, 1–16.

30. Moriasi, D. N.; Arnold, J. G.; Van Liew, M. W.; Bingner, R. L.; Harmel, R. D.; Veith, T. L. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Transactions of the ASABE**2007**, 50, 885-900.,http://dx.doi.org/10.13031/2013.23153
31. Gupta, H. V.;Sorooshian, S.; and Yapo, P.O. Status of automatic calibration for hydrologic models: Comparison with multilevel expert calibration. J. Hydrologic Eng**1999**, 4(2),135-143
32. Nash, J.E.; Sutchliffe, J.V. River flow forecasting through conceptual models. Part 1-A discussion of principles.*J. Hydrol.* **1970**, *10*, 282–290.
33. Krause, P.; Boyle, D.P.; Base, F. Comparison of different efficiency criteria for hydrological model assessment. *Adv. Geosci.* **2005**, *5*, 83–87.
34. Santhi, C.; Arnold, J.G.; Williams, J.R.; Dugas, W.A.; Srinivasan, R.; Hauck, L.M. Validation of the SWAT model on a large river basin with point and nonpoint sources. *J. Am. Water Res. Assoc.* **2001**, *37*, 1169–1188.
35. Van Liew, M.W.; Garbrecht, J. Hydrological simulation of the little Washita river experimental watershed using SWAT. *J. Am. Water Res. Assoc.* **2003**, *39*, 413–426.
36. Kite,G.W. Frequency and risk analyses in hydrology. Water Resources; 1977.
37. Lehner, B.;Döll, P.; Alcamo, J.;Henrichs, T.;Kaspar, F. Estimating the impact of global change on flood and drought risks in Europe: a continental, integrated analysis. Climatic Change **2006Apr 1**, 75(3),273-99.
38. Apipattanavis, S.; Rajagopalan, B.; and Lall, U. Local polynomial–based flood frequency estimator for mixed population. *Journal of Hydrologic Engineering***2010**, *15*(9), 680-691.
39. Singo,L.R; Kundu,P.M.; Odiyo,J.O.; Mathivha,F.I. and Nkuna,T.R. Flood Frequency Analysis of Annual Maximum Stream Flows for Luvuvhu RiverCatchment.2012https://www.researchgate.net/publication
40. Mehrannia, H.&Pakgohar,A. USING EASY FIT SOFTWARE FOR GOODNESS-OF-FIT TEST AND DATA GENERATION.International. Journal of Mathematical Archive-5(1), 2014, 118-124
41. Awulachew,S.B.;Yilma, A.D.;Loulseged, M.;Loiskandl, W.;Ayana, M.;Alamirew, T. Water resources and irrigation development in Ethiopia. Iwmi; **2007**.
42. BCEOM*I* Abay River Basin Integrated Master Plan. Main Report, MoWR, Addis Ababa 1999.