Sediment Yield Prediction Using Hydrological Models in Upper Gilgel Abbay and Megech Watersheds, Upper Blue Nile Basin, Ethiopia

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Abstract

Soil erosion, land degradation and loss of agricultural soils are major problems in Upper Blue Nile Basin of Ethiopia. The parameter efficient semi-distributed watershed model (PED-WM), soil and water assessment tool (SWAT) and the generalized watershed loading function (GWLF) are tested for the prediction capability of sediment yield in the Megech and Upper Gilgel Abbay watersheds. Model calibration and validation for the suspended sediment yield for Upper Gilgel Abbay and Megech watersheds was applied from 1997-2007 and 2008-2012; and 2000-2010 and2011-2014, respectively. NSE, R2 and PBIAS were used to evaluate the model performance. The monthly time step model efficiency of PED-W for Upper Gilgel Abbay watershed was found R^2, NSE and PBIAS (0.89, 0.77, -8.5) and (0.82, 0.81, 5.87) and for Megech watershed (0.85, 0.71, 6.54) and (0.83, 0.72, 12.1) during calibration and validation periods, respectively. On the other hand, the SWAT model efficiency for Upper Gilgel Abbay watershed was (0.84, 0.84, -2.7) and (0.62, 0.62, 3.5) and for Megech watershed (0.64, 0.63, 17.9) and (0.63, 0.60, 27.9) during calibration and validation period respectively. Whereas the efficiency of GWLF model was obtained (0.76, 0.58, -21.24) and (0.76, 0.60, -5.2) for Upper Gilgel Abbay watershed and (0.76, 0.57, 22.42) and (0.73, 0.58, 20.89) were for Megech watershed during calibration and validation period respectively. The result shows that almost all model performance ranges from satisfactory to very good agreement. The overall model performance indicated that PED-WM model was more appropriate model to predict sediment yield than SWAT and GWLF models.

Key words: Hydrological model, Gilgel Abbay, PED-WM, SWAT, GWLF and Megech

1. Introduction

Soil erosion and land degradation are a natural process causing soil loss and generating sediment yield from catchment area even in the absence of human alterations on land cover. Soil erosion by water occurs in two phases, involving the detachment of discrete particle sizes from the soil mass and their transport by erosive agents, and when sufficient energy is no longer offered to transport the particles to the surface, deposition occurs (Morgan *et al*., 1998). Renard (1997) noted that sediment transport is largely a role of topography and runoff velocity while deposition is a function of runoff velocity and sediment particle sizes. Bai *et al. (2008)* stated that soil erosions by runoff a major environmental problem, occupying 56% of the world-wide area. Also, the study indicated that soil loss is accelerated by human-induced soil degradation.

Soil erosion by water is particularly a serious problem in the high-rainfall Ethiopian highlands (Zimale *et al*., 2018). Similarly, as stated by Easton *et al*. *(2010)* soil erosion is arguably the virtually solid problem in the Blue Nile Basin, as it limits agricultural productivity in Ethiopia, erode benthos in the Nile, and results sedimentation of dams in downstream countries. According to Constable (1985) soil erosion considered to be a major agricultural problem in Ethiopia, particularly in the high lands (above 1500 m a.s.l) which constitute 43% of the total area of the country. The poor land use practice, improper land management and lack of a suitable soil conservation actions have played a major character in land degradation problem in Ethiopia (Setegn *et al*., 2008). Due to the silting of the reservoir, it is the most challenging problem in the Upper Blue Nile basin (Assfaw, 2019). So that estimation of sediment yields at the outlet of the watershed is necessary in order to establish mitigation measures along the watershed. Knowing the reliable amount of sediment yield collected at the outlet of the watershed is important to establish soil conservation measures at upstream of the watershed outlets. To compute the reliable amount of sediment yield deposited at the watershed outlet, hydrological models are needed.

Hydrological models are essentially a vital instrument in hydrologic response simulating for the utilization such as water resource management efforts, flood regulation and water quality evaluating (Wagener *et al*., 2010). They define the natural processes controlling the transformation of precipitation to runoff, whereas erosion modeling is focus on understanding the natural laws of processes that happen in the natural landscape (Setegn *et al*., 2009). Most of hydrological and erosion models are developed to express the hydrology, erosion and sediment yield processes (Oeurng *et al*., 2011).

These models are useful tools to understand the problems and help to identify acceptable solutions through best management practices (Borah and Bera, 2003). Applying the best management practice is good to soil conservation and land degradation, as well as useful to have information on spatial distribution of runoff (Moges *et al*., 2017) and sediment (Setegn *et al*., 2009). Thus, models for estimating sediment yield based on different management scenario are very important for reducing threats of the soil erosion.

The amount of surface erosion in the basin area and the rate of sediment transport in the channel stream contributes sedimentation problem in lakes, reservoirs and downstream areas (Setegn *et al*., 2009). In the Blue Nile Basin, many water-related projects have been constructed for the purpose of water supply, irrigation, hydroelectric power and etc. However, most of the structures are affected by sediment deposition, and this leads to reduction of reservoir storage capacity and reduce the functionality of structure. The Lake Tana basin is one of the most affected area by soil erosion, soil transport and land degradation (Setegn *et al.*, 2009). Setegn *et al. (2009)* stated that sediment yield is excess of 30 tons_ha-1 for each of the Lake Tana catchment area (18.4% of the watershed) was observed to be high-level erosion potential area.

The Megech watershed faced high sedimentation, and the mean annual sediment yield increased by 33.3% from 1998 land use land cover to 2016 land use land cover (Assfaw, 2020). To minimize sedimentation problem of the watershed, best soil conservation practices should be applied upstream of the watershed. However, to apply soil conservation practice upstream of the watershed, the reliable quantity of sediment yield in the watersheds must be estimated. So, in order to compute the reliable amount of sediment accumulation in Megech and Upper Gilgel Abbay watershed outlets, reliable hydrological models are needed.

One of the critical problems of Megech and Upper Gilgel Abbay watershed knows the best hydrological models for sediment yield prediction of the watershed for planning, designing and implementation of soil and water conservation practice. As a result, it is difficult to manage the sediment problem in proper manner. In addition, mostly Megech and Upper Gilgel Abbay sub basin has no long-time record data to estimate sediment yield, for suitable soil conservation practice.

In this study, the main objective is to evaluate sediment yield predictive capability of hydrological models in selected watersheds and evaluating the sediment yield at the watershed outlet, and the temporal variation of sediment yield in the watershed. Lastly, the hydrological model which performs reliable and best estimation of sediment yield for the selected watersheds will be determined.

2 Materials and Methodology

2.1 Description of the Study Area

Megech, and Upper Gilgel Abbay watersheds, are located in Abbay basin, in the Northern part of the Ethiopia highlands. The Megech River flows in the southern direction into Lake Tana (Assfaw, 2020). The mean annual rainfall of the watershed is around 1,130 mm, with 79% of it occurs between June and September. The total area of this watershed is 507 km^2.

The Gilgel Abbay River is the longest flow path of all the tributary rivers that drains to Lake Tana. The watershed has an area of 1660 km^2, like other watersheds of the basin, the main rainy season starts in June and extends to September, which accounts about 70 to 90% of annual rainfall (Kebede *et al*., 2006, Tarekegn and Tadege, 2006). Figure 1 shows the location of study areas.

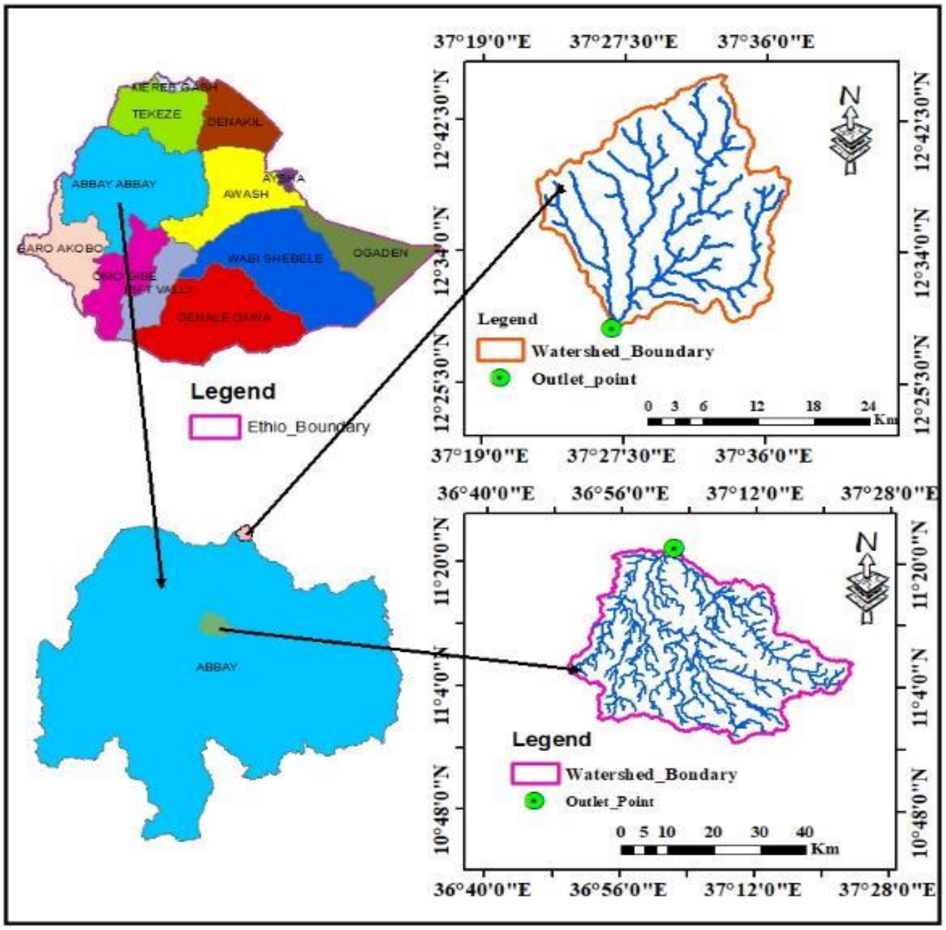

Figure 1. Location of Megech and Upper Gilgel Abbay Watershed

2.2 Data Collection and Analysis

The topography of the selected watersheds is described by using Digital Elevation Model (DEM) which was collected from Ministry of Water and Energy (MoWE). According to Weigel (1986) almost 62.63 percent of Megech watershed slope area lies from steep to very steep slope and 60.99% of Upper Gilgel Abbay watershed area lies from sloping to moderately steep slope.

Table 1. Topographic characteristic of the two watersheds based on slope (source: Weigel (1986)).

Slope (%)	Upper Gilgel Abbay Area Coverage (%)	Megech Area Coverage (%)	Description
0-2	3.65	6.67	Flat
2-10	44.65	20.68	Sloping

10-15	16.34	15.9	Moderately Steep
15-30	23.94	35.75	Steep
>30	11.5	26.88	Very Steep

Table 2. Land use/ Land cover and Soil type of Megech and Upper Gilgel Abbay watersheds

LULC	Megech	Upper Gilgel Abbay	Soil type	Megech	Upper Gilgel Abbay
	Coverage (%)			Coverage (%)	
Forest Land	1.43	1.24	Eutric Leptosols	0.71	-
Shrubs Cover	1.88	0.4	Humic Nitisols	12.62	-
Grass Land	4.98	1.35	Lithic Leptosols	70.63	-
Crop Land	90	96.7	Eutric Vertisols	13.16	1.85
Built Up Area	1.52	0.2	Haplic Luvisols	2.89	55.94
Open Water	0.13	0.1	Eutric Regosols	-	0.81
			Hapic Alisols	-	40.76
			Haplic Nitisols	-	0.64

2.2.1 Metrological Data Collection and Analysis

Daily precipitation, daily temperature (maximum and minimum), sunshine hour, relative humidity and wind speed were collected from national meteorological agency Bahir Dar branch. Identifying the meteorological station which influences on the watershed are critical points to analysis meteorological data. Therefore, by using Theisen polygon in ArcGIS 10.5, the nearest station which influenced in the watershed was selected depends on the available climatic variable, length of record period and weight of influence or coverage of the watershed. Therefore, the four meteorological stations which have an influence on the Megech watershed are Ambageorgies, Gonder, Maksegnit and Shembekit meteorological stations and six meterological data stations which have an influence on Upper Gilgel Abbay watershed are Dangla, Enjibara, Wotet Abbay, Sekela, Kessa and Quarit.

2.2.2 Hydrology and Sediment Data

Both the daily streamflow and sediment data were collected from the Ministry of Water and Energy (MoWE), from 2000 to 2014 at Azezo gauging station for Megech and from 1997 to 2012 at Merawi gauging station for Upper Gilgel Abbay. Unlike streamflow data, sediment data records exhibit several missing. Due to the lack of continuous suspended sediment records, the sediment rating curve was developed for this particular study by using the measured sediment records as a function of the corresponding streamflow values. The sediment rating curve is a widely applicable technique for estimating the suspended sediment load being transported by a river. It signifies a relationship between the stream discharge and sediment concentration or load (Clarke, 1994). The general relationship of suspended sediment rating curve is given by Eq. (1).

$$Qs = a * Q^b \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (1)$$

where: Qs is sediment load in t day^{-1}, Q is the stream discharge in $m^3\ s^{-1}$ and a & b are regression constants. The measured suspended sediment concentration (mg l^{-1}) was converted into sediment load (t day^{-1}) by using the following formula:

$$S = 0.0864xQxC \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

where: S is sediment load in (t day^{-1}), Q is streamflow ($m^3\ s^{-1}$), C is sediment concentration (mg l^{-1}) and 0.0864 is conversion factor. The suspended sediment rating curve equation for Megech and Upper Gilgel Abbay watershed is shown in Figure 2 and Figure 3 respectively.

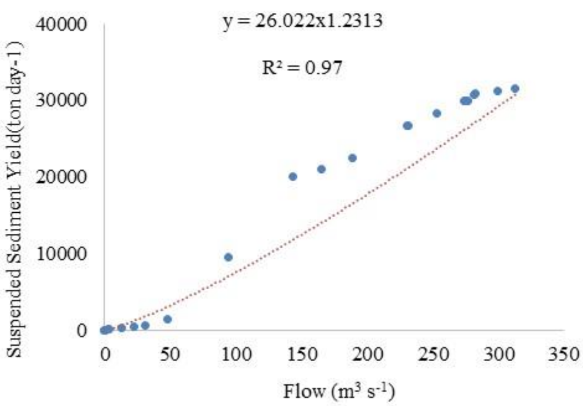

Figure 2. Suspended sediment rating curve for Megech watershed

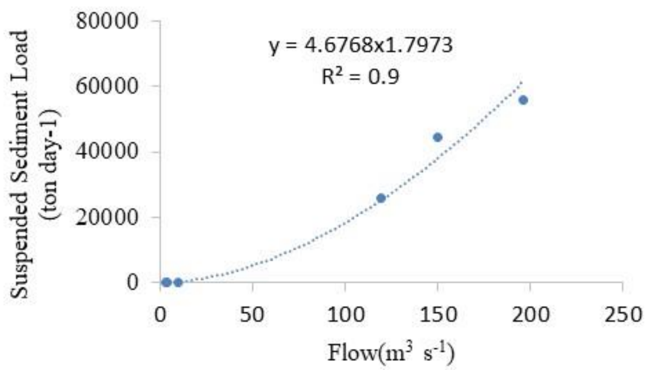

Figure 3. Suspended sediment rating curve for Upper Gilgel Abbay watershed

2.3 Watershed Models Selection

Three watershed models, namely Soil and Water Assessment Tool (SWAT), Parameter Efficient Semi-Distributed Watershed Model (PED), and Generalized Watershed Loading Function model (GWLF) were used to evaluate the sediment yield prediction capability of Megech and Upper Gilgel Abbay watersheds.

2.3.1 SWAT Model

SWAT is a physically-based continuous model for catchment scale simulations (De Vente *et al*., 2013, Setegn *et al*., 2008). The main input data to the SWAT model are: daily climate data, DEM, soil, land use/ land cover, observed discharge and sediment. Model calibration and validation for the suspended sediment yield for Upper Gilgel Abbay and Megech watersheds was applied from 1997-2007 and 2008-2012; and 2000-2010 and2011-2014, respectively.

The model was used for discharge and sediment yield simulation by dividing the watershed into sub watershed and the sub watershed also subdivide into small hydrologic response units (HRUs) which have the same soil, land use and slope classes.

SWAT calculates the surface erosion and sediment yield caused by rainfall and runoff within each HRU with the Modified Universal Soil Loss Equation (MUSLE), (Williams, 1975). MUSLE is a modified version of the Universal Soil Loss Equation (USLE) developed by (Wischmeier and Smith, 1978). While the USLE uses rainfall as an indicator of erosive power of energy, MUSLE uses the amount of runoff to simulate erosion and sediment yield. The modified universal soil loss equation is determined by Eq. 3 (Williams, 1995).

$$Sed = 11.8 * \left(Q_{surf} * q_{peak} * area_{hru}\right)^{0.56} * K_{USLE} * C_{USLE} * P_{USLE} * L_{USLE} * CFRG \ldots\ldots (3)$$

Where, Sed is sediment yield on a given day (metric tons), Q_{surf} is the surface runoff volume (mm/ha), q_{peak} is the peak runoff rate (m^3 s^{-1}), $area_{hru}$ is the area of the HRU (ha), K_{USLE} is the soil erodibility factor (0.013 metric ton m^2 hr (m^3 metric ton cm)), C_{USLE} is the cover and management factor, P_{USLE} is the support practice factor, L_{USLE} is the topographic factor, and CFRG is the coarse fragment factor.

2.3.2 PED-W Model

The PED model represents the local hydrological and erosion processes. It classifies the watershed into two runoff producing areas (periodically saturated areas and degraded hill slopes) and one recharge area (permeable hill slopes) that release the excess precipitation, the base flow and interflow. The two runoff producing areas are assumed to be sources of sediment while the base flow may pick up sediment at low concentrations from the banks. The hydrology model inputs are limited to precipitation, potential evapotranspiration, and nine landscape parameters. The sediment model uses the discharges predicted by the hydrology model and maximum six parameters for the erodibility of the soil at the beginning and end of the rainy phase for each of the three areas.

The model input data requirement for PED model are daily precipitation, evapotranspiration, the areal fraction, maximum storage for each zone and the inter flow and base flow time. Discharge and sediment yield data were used for calibration and validation of the parameter efficient distributed model (PED).

i. Hydrology module

The hydrology module will divide the watershed into three major areas, such as runoff contributing areas, degraded areas and hill slope areas. Runoff contributing areas were in turn divided into two: bare hardpan or bed rock catchment which produces runoff for little rainfall and the flatter bottom lands which produce runoff after saturation. The discharge Q at the outlet is written as:

$$Q = A_1Q_1 + A_2Q_2 + A_3(Q_B + Q_I) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

where Q_1 and Q_2 are saturation excess runoff from saturated and degraded areas (mm d^{-1}), Q_B and Q_I are base flow and interflow (mm d^{-1}), A1, A2 and A3 are area fractions of the saturated, degraded areas and the recharge hillside area, respectively.

Surface runoff generated from the saturated and degraded area was calculated by using Eq. 5 (Moges *et al.*, 2016):

$$\mathrm{Q_{sur2}} = \frac{\mathrm{S_{t-\Delta t} - S_{max} + (P - PET)\Delta t}}{\mathrm{\Delta t}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (5)$$

When, $(P - PET)\Delta t > S_{t-\Delta t} - S_{max}$

The base flow, Q_B and the inter flow, Q_I are then obtained as) (Steenhuis *et al*., 2009, Tilahun *et al*., 2013b, Moges *et al*., 2016).

$$Q_B = BS_t\left(\frac{1-\exp^{(-\alpha\Delta t)}}{\Delta t}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6) \qquad \text{when } BS_t > BS_{max}$$

$$Q_I = \sum_{\tau=1}^{\tau^*}(2 * P_{erc,I}\,(\tau^* - \tau)\left(\frac{1}{\tau^*} - \frac{\tau}{{\tau^*}^2}\right), \tau \le \tau^* \ldots\ldots\ldots\ldots\ldots (7)$$

where α = 0.69/t½ and where t½ is time taken in days to reduce volume of the base flow reservoir by half under no recharge conditions; τ is the day after the rainstorm and $P_{erc,I}$ is the amount of the percolate that reached the interflow storage and is calculated as the recharge in excess of what can be stored in the base flow reservoir, and τ^* is the duration of interflow after any rainstorm.

ii. The sediment module

In the sediment model, the two runoff source areas, (the saturated and degraded areas), are considered the main sources of sediment. Sediment yield is computed based on the suspended sediment concentration and the discharge of the rivers (Tilahun *et al*., 2013a). Erosion originates from the run-off producing region.

The concentration of sediment, C (g l^{-1}), in the river is obtained by dividing the sediment yield by the total watershed predicted discharge from the hydrological model.

$$C = \frac{A_1 {q_{r1}}^{1.4}[\alpha_{s1} + H(\alpha_{t1} - \alpha_{s1})] + A_2 {q_{r2}}^{1.4}[\alpha_{s2} + H(\alpha_{t2} - \alpha_{s2})]}{A_1 q_{r1} + A_2 q_{r2} + A_3(Q_B + Q_I)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

where the subscript numbers refer to the three areas introduced with Eq. 4, Q is the runoff (mm day^{-1}) calculated with the hydrology model, i.e., Q_1, Q_2 are calculated with Eq. 5, and Q_3 is the sum of Q_B in Eq. 6 and Q_1 in Eq. 7.

2.3.3 GWLF Model

GWLF model has been developed by (Haith and Shoemaker, 1987). The model predicts streamflow and sediment by a water-balance method, based on measurements of daily precipitation and the mean average daily temperature. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm, which predicts the mean soil erosion, using the component parts of rainfall energy (Wischmeier and Smith, 1978). Erosion from source area k on day t (Mg) is given by:

$$X_{kt} = 0.132 * RE_t * K_k * (LS)_k * C_k * P_k * AR_k \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

in which K_k, $(LS)_k$, C_k, and P_k are the typical values for soil erodibility, topographic, cover and management and supporting practice factors as specified for the Universal Soil Loss Equation (Wischmeier and Smith, 1978). RE_t is the rainfall erosivity on day t (MJ-mm/ha-h). The constant value 0.132 is a dimensional conversion factor related with the SI units of rainfall erosivity.

The total watershed sediment yield generated in month j (Mg) is

$$SX_j = SDR \sum \sum_{t=1}^{d_j} X_{kt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

where SDR is the watershed sediment delivery ratio. The transport of this sediment from the watershed is depends on the transport rate of runoff during that month. A transport factor TRj is defined as:

$$TR_j = \sum_{t=1}^{d_j} (Q_t)^5/3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

The sediment supply SX_j is allocated to months j, j + 1, …, 12 in proportion to the transport rate for each month. The total transport rate for months j, j + 1, …, 12 is proportional to B_j, where

$$B_j = \sum_{h=j}^{12} TR_h \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

The total monthly yield is the sum of all contributions from preceding months:

$$Y_m = TR_m \sum_{j=1}^{m} \left(\frac{X_j}{B_j}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

3. Results and Discussion

3.1 SWAT, PED-W, and GWLF Model Calibration and Validation

All the model parameters were calibrated on a monthly time series from 1997-2007 and 2008-2012; and 2000-2010 and 2011-2014, for Upper Gilgel Abbay and Megech watersheds respectively. The parameters are first determined by maximizing the efficiency criterion of the Nash–Sutcliffe efficiency coefficient (NSE), then the coefficient of determination (R^2), and percent bias (PBias).

3.1.1 Calibration and Validation of SWAT Model for the Sediment Yield

Six sensitive parameters were selected for sediment calibration and validation for SWAT model. Linear parameter for computing the maximum quantity of sediment that can be restrained during stream sediment routing (Spcon), channel cover factor (Ch-Cov1 & Ch-Cov2), channel erodibility factor (Ch-Erod), USLE equation support practice factor (USLE-P), exponent parameter for estimating sediment restrained in channel sediment routing (Spexp) and moist soil albedo (SOL-ALB) are sensitive parameters were selected used sediment yield calibration and validation. For this study, auto-calibration or Sequential uncertainty fitting (SUFI-2) algorithms method was applied due to its easy implementation in comparison to other producers and the low number of models runs needed to reach good simulation.

Validation is a process of proving the performance of a model. Based on the available model input data parameters calibration and validation periods of Megech and Upper Gilgel Abbay by SWAT model were tabulated below.

Table 3. Calibrated values of sensitive sediment parameters for Megech and Upper Gilgel Abbay watersheds

		Fitted value		Megech		G.Abbay		Rank	
Parameter	Range	Megech	G.Abbay	p-value	t-value	p-value	t-value	Megech	G.Abbay
CH_COV2	0-1	0.047	0.50	0.21	-1.25	0.65	-0.46	1	2
CH_EROD	0-1	0.48	0.85	0.26	-1.13	0.09	1.68	5	4
SPEXP	1-2	2.0	1.112	0.63	0.49	0.21	1.24	6	6
USLE_P	0-1	-0.50	0.04	0.55	0.6	0.37	-0.89	2	1
SPCON	0.0001-0.01	-	0.0087	-	-	0.41	0.83	-	5
SOL_ALB	±25	0.34	-0.68	0.83	-0.22	0	24.57	3	3
CH_COV1	0-1	0.76	-	0	-8.1	-	-	4	-

In Megech watershed, the objective function of model performance measure of sediment yield NSE value (0.63, 0.60) was less than (Assfaw, 2019) (0.77, 0.81) during calibration and validation period, respectively, and has similar value of (Lemma *et al*., 2019) (0.61) during calibration period and less value of (Lemma *et al*., 2019) (0.7) in validation period in monthly time series. The reason for low NSE value of Megech watershed during calibration and validation may be inaccurate measurement and filling missed rain fall data as well as due to small sample suspended sediment data availability. In Megech watershed, the objective function of model performance measure of sediment yield R^2 value of (0.64, 0.63) had less value than (Assfaw, 2019) (0.82, 0.90) and (Lemma *et al*., 2019) (0.68, 0.81) during calibration and validation period, respectively, in monthly time series.

3.1.2 Calibration and Validation of the PED Model for the Sediment Yield

According to Moriasi *et al.* (2015) model performance criteria the value of NSE (0.77) and (0.81) good agreement and very good agreement during calibration and validation period respectively for Upper Gilgel Abbay watershed. Also, the sediment concentration R^2 value (0.89) and (0.82) a very good agreement during calibration and validation period respectively, on monthly time series. The model performance criteria the value of NSE (0.71) and (0.72) good agreement during calibration and validation period respectively, for Megech watershed on monthly time series. As shown on (Table 5) the sediment concentration R^2 value of (0.85) and (0.83) very good agreement during calibration and validation period respectively for Megech watershed on monthly time series.

Table 4. PED-W model Sensitivity rank and fitted values

Component	Parameter	Fitted value		Sensitivity rank	
		G.Abbay	Megech	G.Abbay	Megech
Discharge	Area, A_1	0.2	0.1	2	5
	S_{max}, A_1	100	100	9	8
	Area, A_2	0.1	0.05	3	4
	S_{max}, A_2	75	75	8	9
	Area, A_3	0.7	0.75	1	1
	S_{max}, A_3	35	35	5	7
	BS_{max}	150	120	6	2
	t1/2	45	30	4	3
	τ^*	40	18	7	6
Sediment	α_t for A_3	0.9	0.5	1	1
	α_s for A_3	1	0.01	2	2

The PED model result shows that the relationship between observed and calculated sediment concentration are very good agreement.

3.1.3 Calibration and Validation of the GWLF Model Sediment Yield

Three sensitive parameters were selected for the calibration and validation of sediment. The selected parameters are sediment delivery ration, Erosivity coefficient, and USLE parameters were used for this study. The fitted values for sediment delivery ration, Erosivity coefficient, and USLE parameter (1.131, 0.343, varies (0-0.05) and (0.153, 0.727, varies (0-0.05) for Megech and Upper Gilgel Abbay, respectively.

The GWLF model efficiency of sediment yield during calibration and validation the value of R^2 had a good agreement both in Megech and Upper Gilgel Abbay watershed on monthly time series. The NSE value had a satisfactory during calibration and validation both in Upper Gilgel Abbay and Megech watershed. The PBIAS value had a satisfactory agreement during calibration and validation in Megech watershed. In the Upper Gilgel Abbay watershed the PBIAS had good agreement during calibration and very good agreement during validation period. Table 5 shows that the performance of the selected model.

Table 5. Summary selected model efficiency criteria for calibration and validation of sediment yield in two watersheds on monthly time series.

Watersheds	Models	**Calibration**				**Validation**			
		R^2	NSE	RSR	PBIAS	R^2	NSE	RSR	PBIAS
Upper Gilgel Abbay	SWAT	0.84	0.84	0.48	-2.7	0.62	0.62	0.62	3.5
	PED-W	0.89	0.77	0.47	-8.5	0.82	0.81	0.44	5.87
	GWLF	0.76	0.58	0.65	-21.24	0.76	0.6	0.64	-5.2
Megech	SWAT	0.64	0.63	0.61	17.9	0.63	0.6	0.64	27.9
	PED-W	0.85	0.71	0.54	6.54	0.83	0.72	0.55	12.17
	GWLF	0.76	0.57	0.66	22.42	0.73	0.58	0.65	20.89

4. Conclusions

Three watershed hydrological models were evaluated in simulating sediment yield in the Upper Gilgel Abbay and Megech watersheds in the Upper Blue Nile Basin. At a monthly time, step the sediment yield was simulated using PED- W, SWAT and GWLF models. The predicted sediment for both watersheds each outlet runoff amount and sediment yield were compared with measured data.

PED-WM was relatively better in predicting the sediment at the outlet of Merawi and Azezo gauging station for Upper Gilgel Abbay and Megech watersheds, respectively, followed by SWAT and GWLF. PED-WM model was also the most preferable to predict sediment yield in scale of watersheds (small to large) when compared to SWAT and GWLF model. This was due to the fact that the PED-WM was saturation excess and scaling up plots, which is the case in the Ethiopian highlands.

The model watershed properties were evaluated using split records of discharge and sediment (68.87% calibration and 31.13% for validation). Optimized parameters were validated after model calibration for watershed models, and the result indicated that a good relation between observed and simulated hydrological variables of the sediment yield.

The calibration and validation of the PED-MW, SWAT and GWLF models for Upper Gilgel Abbay and Megech watersheds can be used to assess the impact of land use change, management practices and soil conservation impact on flow and sediment dynamics in the watershed. Generally, for monsoon climates; the PED-W model is the best for the prediction of discharge and sediment at Upper Gilgel Abbay and Megech watersheds in the Upper Blue Nile basin.

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