Estimation of Runoff and Sediment Yield Using SWAT Model: The Case of Katar Watershed, Rift Valley Lake Basin of Ethiopia

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Abstract: Estimating runoff and sediment yield at watershed level is important for better understanding of hydrologic processes and identifying hotspot area by using Soil and Water Assessment Tool (SWAT) model for intervention strategies. From the result of Global sensitivity analysis, 12 highly sensitive parameters identified. The obtained results were satisfactory for the gauging station (coefficient of determination ($R^2$)=0.8, Nash-Sutcliffe Efficiency (NSE)=0.6 and percent difference or percent bias (PBIAS)=0) from 1990 to 2005(16) years used calibration and ($R^2=0.6$, $ENS=0.55$and $PBIAS=1.2$) from 2006 to 2013(8 year) were used for validation period respectively. Among all sub-watersheds, nine sub watersheds were more vulnerable to soil loss and potentially prone to erosion risk, which was out of range of tolerable soil loss rate (18 t ha⁻¹ yr⁻¹). In conclusion, the SWAT model could be effectively used to estimate runoff and sediment yield; and identified hotspot area. In addition, the result could help different stakeholders to plan and implement appropriate interventions strategies in the Katar watershed.

Keywords: Runoff, Sediment Yield, SWAT, Calibration and Validation

1. Introduction

Out of 60 million hectares estimated to be agriculturally productive lands, about 27 million hectares are significantly eroded, 14 million hectares are seriously eroded and 2 million hectares have reached the point of no return [6]. Another report by the Soil Conservation Research Project [31] of Ethiopia indicated that the rate of soil loss in extreme cases ranges from 0 to 300 t ha⁻¹ yr⁻¹ with an average loss of 70 t ha⁻¹ yr⁻¹, which is beyond the concept of any tolerable soil loss.

Land cover change is massively and rapidly taking place, as elsewhere in the Ethiopian Central Rift Valley (CRV) [7] and CRV is one of the environmental vulnerable areas in the country. Katar watershed is under heavy pressures [17], climate change [34] and the intensification of agricultural development activities were increasing from time to time [32] as a result huge amount of soil losses from the study area, and some areas under high and sever soil erosion. Large area of Katar watershed covered by Haplic Luvisols (high clay content) and agriculture is the dominant activities in area. Hence, soil in some parts of sub watershed is highly eroded, due to fragile ecosystem and inherent erodi ble nature of the soils and some parts of this watershed is already taken out of cultivation due to land dissected by gully.

Most recently, watershed management is an approach followed by the government of Ethiopia in the form of mass mobilizations to protect soil from erosion in particular and to reverse land degradation in general [8, 13, 25]. However, past soil conservation efforts did not bring significant changes to the ongoing soil degradation problems [4, 24]. Whereas, dramatic reduction has been made in arresting soil erosion [11] and the approach has not been supported with intervention prioritizing techniques that identify highly susceptible erosion prone areas. Identification of erosion-prone areas using a distributed physical model that estimates
soil erosion rates with sufficient accuracy will be important for implementing appropriate erosion control practices [30].

Therefore, it is very important to assess the runoff and sediments yield from the watershed and develop sediment loss map in the area before formulation of any soil and water conservation strategies. Estimation of runoff and sediment yield not studied in depth in the Katar watershed. The Katar watershed is one of the central highland basins in the Rift Valley region of Ethiopia; where soil erosion is rampant. Hence, to solve this, there is a need to identify the most erosion prone areas in the watershed for appropriate watershed management. The SWAT model is a suitable model, which is used for estimating runoff and sediment loss and provided information for the sustainable development of the land and water resources of the study watershed.

Therefore, the purpose of this study was to estimate runoff and sediment yield from watershed and categorizing the watershed in terms of soil erosion rate and runoff potential and identify the most erodible subcatchment.

2. Materials and Methods

2.1. Description of the Study Area

2.1.1. Location and Topography

Katar watershed covers 3326.86 square kilometers (km²) is part of the Ziway Shala sub basin of main Ethiopia Rift valley. This internal drainage basin located in the central part of the Main Ethiopian Rift Valley. Geographically it is located between 7°21'33"-8°9'53"North latitude and 38°53'57"-39°24'46" East longitude. Katar River and its tributaries drain from southeast highland area to North West and enter Lake Ziway. Topographically, Katar catchment shows a well pronounced variation with the altitude ranging from around 1644m above sea level (masl) near Lake Ziway (at the outlet) to about 4171m above sea level (m.a.s.l) on the high volcanic ridges along the eastern watershed (Kaka and Galama Mountain).

![Map of Study Area](source: MOWIE, 2007).

2.1.2. Climate

According to the statistical analysis of the climatic data, the climate of the study area can be categorized as semi-arid to sub-humid type with a mean annual rainfall ranging from 744.8mm to 1046.0 mm, and with a mean annual minimum and maximum temperature ranging from 7.3°C to 13.8°C, and from 19.0°C to 28.1°C respectively. Local monitoring Climatic Variables between 1988-2013 years period for Katar
watershed are obtained from the National Meteorological Agency (NMA) of Ethiopia.

Table 1. Location of Weather Stations in Katar Watershed, Ethiopia.

| Name   | Coordinates  | Longitude UTM | Latitude UTM | Altitude m.a.s.l (m) |
|--------|--------------|----------------|---------------|----------------------|
| Assela | 508825       | 836762         |               | 2413                 |
| Kulumsa| 508814       | 893143         |               | 2211                 |
| Iteya  | 515425       | 894250         |               | 2060                 |
| Sagure | 509931       | 824602         |               | 2388                 |
| Bokoji | 516556       | 809127         |               | 2480                 |
| Ogolcho| 495697       | 888288         |               | 1682                 |

(Source: NMA)

2.2. SWAT Input Data Used

The most important spatial information needed were: Digital Elevation Model (DEM), land use or land cover and a soil.

2.2.1. Digital Elevation Model

The DEM is a common data source for developing topography dependent models. It is required to calculate the flow accumulation, stream networks, slope, and watershed delineation. Hence, 30 m by 30 m meter grid resolution DEM in raster format was used and projected to Transverse Mercator (UTM) on the spheroid of WGS-84 to correct the errors and fit into the model requirement. It is obtained from Ministry of Water, Irrigation and Electricity (MOWIE) of Ethiopia.

(i). Watershed Delineation

The watershed delineation operation uses and expands ArcGIS version 10.3 and Spatial Analyst extension functions to perform watershed delineation. The first step in the watershed delineation was loading the properly projected DEM. To reduce the processing time of the GIS functions, a mask was created over the DEM around the study area. Next, a polyline stream network dataset was burnt-into force SWAT sub-basin reaches to follow known stream reaches. Burning-in a stream network improves hydrological segmentation, and sub-watershed delineation. After the DEM, grid was loaded and the stream networks superimposed, the DEM map grid was processed to remove the non draining zones. The initial stream network and sub-basin outlets were defined based on drainage area threshold approach. The threshold area defines the minimum drainage area required to form the origin of a stream. Besides, those sub-basin outlets created by the interface and the outlet was manually added at the gauging stations where sensitivity analysis, calibration and validation tasks were later performed. Then, watershed delineation activity was finalized by calculating the geomorphic sub-basin parameter (Figure 2).

(ii). Hydrologic Response Unit Analysis

Hydrologic response units (HRUs) are lumped land areas within the sub-basin that are comprised of unique land cover, soil, slope and management combinations. In this study, the minimum threshold area required to discreted the sub watershed into homogeneous HRUs were selected as 20%, 20% and 10% threshold levels used for the land use, soil and slope respectively in combinations with multiple HRUs were used. The overlaid of land use, soil and slope maps resulted in the definition of 181 HRUs were identified.

During the creation of HRUs, the slope classified into the reasonable range. Accordingly, for this work to minimize complexity and use manageable data and considering the steepness of the area, the slope classified into five classes based on [20]. The results indicated (Table 2) that, more area of watershed covered by a slope ranges from 3-8, 0-3 and 8-15%, which covered an area of 136425.12 ha (41.01%), 76226.09ha (22.91%) and 80812.36 ha (24.29%) of the total watershed respectively and the least area covered by the slope of >30% which account 4541.36 ha (1.37%) from the total watershed.

![Figure 2. Digital Elevation Model (above) and slope classes (below) (Source: MOWIE, 2007).](image-url)
2.2.2. Land Use/Land Cover Data

The land use land cover data were acquired from the Rift Valley lake Basin Master plan 2007 in the form of shape files. The dominant land use land cover of study area after HRUs definition was as follows; According to the land use land cover data, the major part of the watershed was covered by Intensively Cultivated land which covered about 263287.83 ha (79.14%) of watershed area, and the lowest part of watershed covered by forest land which account about 291.80 ha (0.09%) of watershed from the whole watershed area (Table 3).

Table 3. Area coverage by each land use/Land cover type of the study area after the definition of HRUs.

| Major land use                          | SWAT Code | Katar Watershed | Area (ha) | Area Coverage (%) |
|-----------------------------------------|-----------|-----------------|-----------|-------------------|
| Intensively Cultivated                  | AGRC      | 263287.83       | 79.14     |                   |
| Moderately Cultivated                   | AGRl      | 38590.02        | 11.60     |                   |
| Exposed surface                         | EXPs      | 1399.97         | 0.42      |                   |
| Grassland                               | PAST      | 2395.03         | 0.72      |                   |
| Forest                                  | FRST      | 291.80          | 0.09      |                   |
| Afro-Alpine Green Vegetation            | FSRE      | 9177.65         | 5.76      |                   |
| Shrub-land                              | RNGB      | 7543.21         | 2.27      |                   |
| Total                                   |           | 332686.11       | 100       |                   |

2.2.3. Soil Data

Soil data were obtained from Rift Valley Lakes Basin (RVLB) integrated resource development master plan study project [21]. Some SWAT soil parameters were calculated by using Pedo Transfer Function (PTF) developed by [29]. From the identified soil, Halpuc Luvisols (LVh) is the dominant soil type covered an area of 194399.93 ha (58.43%) and Eutric Vertisols (VRe) soil type covered lowest area (13597.25 ha) (4.09%) of watershed from the total area of the study watershed (Table 4).

Table 4. Major soil types and area coverage (ha, %) of the study area after HRUs definition.

| Major soil types                      | Depth(cm) | Area (ha) | Area (%) |
|---------------------------------------|-----------|-----------|----------|
| Vitric Andosols (ANz)                 | 2000      | 2011.75   | 6.05     |
| Rhodic Nitisols (NTr)                 | 1200      | 104577.18 | 31.43    |
| Halpuc Luvisols (LVh)                 | 2000      | 194399.93 | 58.43    |
| Eutric Vertisols (VRe)                | 1450      | 13597.25  | 4.09     |
| Total                                 |           | 332686.11 | 100      |

2.3. Meteorological Data

Daily meteorological data obtained from National Meteorological Agency (NMA) of Ethiopia for the stations of: Asela, Eteya, Ogolcho, Kulumsa, Bokoji and Sagure from 1988 to 2013. However, some of the missing data were filled using predictions with linear regression equations. After filled missed rainfall data, Double Mass-Curve (DMC) analysis was used to check whether the existence was inconsistency or not in rain gauge stations. Finally, the weather data were prepared in text file format as required by the SWAT model.

2.4. Discharge or Runoff Data

The daily observed stream flow data was obtained at the outlet (Habura) of the watershed for 26 (1988-2013) years from Hydrology Department of Ministry of Water, Irrigation and Electricity for Katar River feeding to Lake Ziway. However, some of the missing daily discharge datas were filled using linear regression equation between the downstream and the upstream gauge for Katar river discharge relation. Then, after missed data were filled, the stream flow data used for calibrating and validating the model.

2.5. Sensitivity Analysis

The sensitivity analysis for this study area was done using Global sensitivity analysis methods. Model Sensitivity analysis is the step where the uncertainties of the modeling process could be evaluated and prioritized for the inclusion into the calibration process. It can be categorized into four classes.

Table 5. Sensitivity analysis index (Source: [28]).

| Class   | Index (I) | Sensitivity |
|---------|-----------|-------------|
| I       | 0≤|I|<0.05  | Very high   |
| II      | 0.05≤|I|<1.00  | High        |
| III     | 0.05≤|I|<0.2   | Medium      |
| IV      | 0<|I|<0.05 | Small to negligible |

2.6. Model Performance Evaluation

The performance of the model was evaluated by assessing the correlation between simulated and observed values. SWAT-CUP 2012 version was used to calibrate the model using Sequential uncertainty fitting (SUFIver2) [2]. In this study, during both calibration and validation periods, the goodness of-fit between the simulated and measured runoff was evaluated using the coefficient of determination ($R^2$), Percent difference or percent bias (PBIAS) and the Nash-Sutcliffe coefficient of efficiency [23]. According to SWAT developers [28]; they assumed an acceptable calibration for hydrology at a PBIAS < ±25%, $R^2 > 0.6$ and ENS > 0.5. To decide the accuracy of the model the value of each index obtained by the model compared with the value of hydrologic model performance ratings.
Table 6. General performance evaluation for stream flow on monthly time steps.

| Objective functions | R² | ENS | PBIAS | Performance Rating |
|---------------------|----|-----|-------|--------------------|
| R²<1.00             |    |     |       | Poor               |
| R²<0.7              |    |     |       | Unsatisfactory     |
| R²<0.50             |    |     |       | Unsatisfactory     |

(Source: [22, 23])

The R² is the magnitude of the linear relationship between the observed and the simulated values, and calculated as:-

$$R^2 = \left(\frac{\sum_{i=1}^{n}(O_i-\bar{O})(S_i-\bar{S})}{\sum_{i=1}^{n}(O_i-\bar{O})^2 \cdot \sum_{i=1}^{n}(S_i-\bar{S})^2}\right)^2$$  (1)

Where: Oi is the observed flow, Si is the modeled flow, and \(\bar{O}\) is the mean of the observed flow and \(\bar{S}\) is the simulated flows.

ENS = 1 - \left[\frac{\sum_{i=1}^{n}(Q_{m}-Q_{s})^2}{\sum_{i=1}^{n}(Q_{m}-\bar{Q})^2}\right]  (2)

Where: \(Q_m\) is the observed flow, \(Q_s\) is the simulated flow of the simulation.

The percent difference or percent bias (PBIAS) describes the tendency of the simulated data to be greater or smaller than the observed data values over a specified period (usually the entire calibration or validation period). A value close to 0% is best, with lower values indicating satisfactory model simulation.

$$PBIAS = \frac{\sum_{i=1}^{n}(Q_{m}-Q_{s})\cdot 100}{Q_{m}}$$  (3)

3. Results and Discussions

3.1. Sensitive Parameters for Stream Flow

According to the result, from the fifteen hydrologic parameters twelve hydrologic parameters were highly sensitivity and selected based on [18] to compute the sensitivity of the streams' flow and ranked based on the t-Stat (Table 7). The twelve highly sensitive parameters were the most driven parameters of stream flow and the left were none sensitive to stream flow. Therefore, attention was given to most twelve highly sensitive parameters during model calibration.

Table 7. Parameters used for sensitivity analysis.

| SWAT Parameters | Descriptions | t-Stat | Rank |
|-----------------|--------------|-------|------|
| Sol_K           | Saturated Hydraulic conductivity | -100.00 | 1 |
| GWQMN           | Threshold water depth in shallow aquifer (mm) | 50.00 | 2 |
| HRU_SLP         | Average slope steepness | -30.00 | 3 |
| CN2             | SCS runoff curve number | -28.00 | 4 |
| GW_DELAY        | Groundwater delay(days) | 20.00 | 5 |
| SOL_AWC         | Depth from soil surface to bottom | 12.00 | 6 |
| ESCO            | Soil evaporation compensation factor | -3.50 | 7 |
| ALPHABF         | Base flow alpha factor(days) | -3.50 | 8 |
| EPICO           | Plant uptake compensation factor | 2.50 | 9 |
| SOL_BD          | Moist bulk density | 2.50 | 10 |
| CANMX           | Maximum Canopy storage | -1.50 | 11 |
| CH_K2           | Effective hydraulic conductivity in the main channel | -1.50 | 12 |
| OV_N            | Manning's "n" value for overland flow | 0.00 | 13 |
| SURLAG          | Surface lag time | 0.00 | 14 |
| GW_REVAP        | Groundwater "revap" coefficient | 0.00 | 15 |

3.2. Model Performance Evaluation

3.2.1. Stream Flow Calibration

Calibration of stream flow has been performed depending on observed flow measurements. Final adjusted calibrated parameters and fitted values for stream flow as shown below (Table 8).

Table 8. Final calibrated parameters and fitted values of flow.

| SWAT Parameters | Descriptions | Range | Initial Value | Final Calibrated Value |
|-----------------|--------------|-------|---------------|------------------------|
| CN2             | SCS runoff curve number | *     | 0.0012        |                        |
| CANMX           | Maximum Canopy storage | 0-10  | 0             | 8.62                   |
| HRU_SLP         | Average slope steepness | 0-1   | 0             | 0.05                   |
| OV_N            | Manning's "n" value for overland flow | 0.01-30 | 0.03 | 5.02 |
SWAT Parameters | Descriptions | Range | Initial Value | Final Calibrated Value
---|---|---|---|---
SOL_BD | Moist bulk density | 0.85-2.5 | 0.85 | 2.5
Sol_K | Saturated Hydraulic conductivity | 0-2000 | 0 | 5.52
SOL_AWC | Depth from soil surface to bottom | 0-1 | 0 | 0.175
CH_K2 | effective hydraulic conductivity in the main channel | 0.01-500 | 0.01 | 23.44
EPCO | Plant uptake compensation factor | 0-1 | 0 | 1
GW_REVAP | Groundwater "revap" coefficient | 0.02-0.2 | 0.02 | 0.062
SURLAG | Surface lag time | 0.05-24 | 0.05 | 9.99
ALPHA_BF | Base flow alpha factor(days) | 0-1 | 0 | 0.00
GW_DELAY | Groundwater delay(days) | 0-500 | 0 | 41.5
ESCO | Soil evaporation compensation factor | 0-1 | 0 | 0.49
GWQMN | Threshold water depth in shallow aquifer (mm) | 0-5000 | 0 | 533

* SWAT default parameters.

After adjusting the highly sensitive parameters manually, calibration was then performed by using SUF-2 set up during the periods of 1990-2005 (1988 and 1989 used as a “warm-up” year). Calibration resulted of the correction coefficient ($R^2$), Nash–Sutcliffe simulation efficiency (NSE) and percent difference or percent bias (PBIAS) were 0.8, 0.6 and 0 respectively (Table 9), and shown a good agreement between measured and simulated monthly stream flow according to [22, 23]. The results fulfilled the requirements suggested by [28] for PBIAS < ±25%, $R^2 > 0.6$ and ENS > 0.5. In general, the model performs well in predicting the runoff from Katar watershed. A best-fit trend line was applied to each scatter plot, and the resulting line equation used to quantify model performance.

Table 9. Calibration results of average monthly observed and simulated flow.

| Parameter | Calibrated (1990-2005) |
|---|---|
| $R^2$(coefficient of determination) | 0.8 |
| NSE(Nash-Sutcliffe model efficiencies) | 0.6 |
| PBIAS (percent Bias) | 0 |

![Figure 3. Comparison between observed and simulated stream flow for calibration period (1990-2005) at Habura gauging station.](image3)

![Figure 4. Simulated and observed monthly stream flow during calibration period (1990–2005) at Habura gauging station.](image4)
3.2.2. Stream Flow Validation

Stream flow validation was conducted to ensure the validity of the calibration process from January 1st, 2006 to December 31, 2013. The $R^2$, Nash–Sutcliffe simulation efficiency (NSE) and PBIAS were obtained 0.67, 0.55 and 1.2 respectively (Figure 5 and Table 10), which showed a good correlation with the gauged stream flow. The results fulfilled the requirements suggested by [28] for PBIAS$<\pm 25\%$, $R^2 >0.6$ and ENS$>0.5$. In general, the model performs well in predicting the runoff from Katar watershed. A best-fit trend line was applied to each scatter plot, and the resulting line equation was used to quantify model performance.

$$y = 0.498x + 6.583$$

**Figure 5.** Comparison between observed and simulated stream flow for validation period (2006-2013) at Habura gauging station.

### Table 10. Validation results of average monthly observed and simulated flow.

| Parameter                              | Calibrated (2006-2013) |
|----------------------------------------|------------------------|
| $R^2$ (coefficient of determination)   | 0.67                   |
| NSE (Nash–Sutcliffe model efficiencies)| 0.55                   |
| PBIAS (percent Bias)                   | 1.2                    |

3.3. Spatial Distribution of Sediment Yield and Runoff in Katar Watershed

Assessing the soil formation rates of an area is vital for the evaluation of soil loss rate and the potential of soil regeneration once soil erosion is substantially reduced. The degree of erosion hazard in the Katar sub-watershed were reclassified in to four (Table 11) different erosion hazard classes based on Getachew et. al, (2017). According to prioritization map, sediment loss categorized into four (4) classes, such that 0-11, 11-18, 18-30 and 30-37.6tha$^{-1}$yr$^{-1}$.

**Figure 6.** Simulated and observed monthly stream flow during Validation period (2006–2013) at Habura gauging station.
Table 11. Sediment yield losses and Severity classes of Katar Watershed.

| Annual soil loss(tha$^{-1}$yr$^{-1}$) | Sub watershed | Severity classes | Area(ha) | Area (%) | Severity Ranks |
|--------------------------------------|---------------|-----------------|----------|----------|----------------|
| 0-11                                 | 1,2,3,5,7,8,9,10,11,14,16,17,18,19,23,26,27,28,29,30,33,34,35 | Low          | 207450.02 | 62.360  | 4              |
| 11-18                                | 4,13,21       | Moderate        | 13117.30 | 3.940   | 3              |
| 18-30                                | 6,12,15,22,25,31 | High          | 80862.16 | 24.304  | 2              |
| 30-37.6                              | 20,24,32      | Very high      | 31255.70 | 9.396   | 1              |

According to this study, sub watershed 6, 12, 15, 20, 22, 24, 25, 31 and 32 were categorized under high and very high soil loss and covered 33.7% of watershed in the study area (Figure 7 and Table 11). The soil losses from these sub watersheds is greater than maximum tolerable soil loss rate (>18 tha$^{-1}$yr$^{-1}$) and high surface runoff generated from these sub watershed and identified as erosion prone area in Katar watershed (Figure 7 and Table 11). The main reason for generating more runoff and sediment yield could be land degradation, poor land cover, improper land management (lack of soil and water conservation) and cultivating undulating slope without conservation. The acceptable soil loss that can maintain the economy and a high level of production [33, 9, 12] ranges from 5 to 11 tha$^{-1}$yr$^{-1}$ [27, 10] and also above the range of soil formation rate in the study area ranges from 6-10 tha$^{-1}$yr$^{-1}$ [15]. These sub watersheds were dominated by moderately gentle slope, agriculture and clay loam dominant soil (moderate infiltration capacity). Hence soil type, topography and agricultural activity is the principal factor for the sediment loss and surface runoff.

The rest 23 sub watersheds were fallen under low soil loss rate < 11 tha$^{-1}$yr$^{-1}$ (Table 11 and Figure 7). The area classified under low soil loss is 62.36%; which is covered large area of watershed (Table 11). The result was agreed with the result of [9, 12], who state that the acceptable soil loss that can maintain the economy and a high level of production ranges from 5 to 11 tha$^{-1}$yr$^{-1}$ [27, 10]. In addition, soil formation rate in the study area ranges from 6-10 tha$^{-1}$yr$^{-1}$ [15]. Thus, this study agreed with above two authors; because the result of the study was within acceptable range (0-11 tha$^{-1}$yr$^{-1}$). However, higher/steep slopes are found along the boundaries of the watersheds and had less impact on the soil loss because of land cover and Afro Alpine Green Vegetation and forest covers this area. A report from China [19] indicated that, land with lower vegetation cover implying the extent of soil erosion and high amount of surface runoff generated. Similarly, a Nigerian study by [26] reported greater soil erosion in lands with poor vegetation cover. Hence, land cover took a lion share in reducing soil erosion and runoff potential by increasing infiltration capacity.

Figure 7. Map of sediment loss (above) and Runoff (below) of Katar watershed.
3.4. Prioritization for Intervention Planning

Because of resource limitations, implementing of soil conservation measures or watershed management in the entire watershed at a time is impractical. Thus, prioritization of intervention areas based on the severity and risks of soil erosion is imperative. The Katar watershed was classified and ranked into four priority classes indicated in Table 11 and Figure 7. Hence, based on the results, sub watershed 6, 12, 15, 20, 22, 24, 25, 31 and 32 were hotspot erosion area and prioritized for intervention (Table 11). The total area that soil erosion rate above the maximum tolerable erosion limit of 18 t ha⁻¹ yr⁻¹ [16] is 112117.86 ha, and covered 33.7% of the entire watershed (Table 11). Reasonable assessment of soil erosion is the core of any decision making.

In addition, similar studies stated that, undertaking soil conservation measures based on the given priority is a better option as also suggested by [5, 1, 3, 14] for their respective study sites. Therefore, priorities for intervention should be focused on high and very high soil eroded sub watershed to keep natural balance and minimized the effects silitation at downstream of the study area.

In generally, agricultural practice without conservation measure will aggravate the runoff processes in the study area. On flat slopes, deposition of sediments is the major constraint that can affect the down watershed mainly Lake Ziway and hydrology of watershed, and this constrains can be improved by applying integrated watershed management.

4. Conclusions and Recommendations

The SWAT-CUP SUF 2 model performance criteria for flow simulation resulted $R^2=0.8$, NSE=0.6, and PBIAS=0 for calibration and ($R^2=0.67$, NSE=0.55 and PBIAS=1.2) for validation periods, respectively. The results showed a good agreement between the measured and simulated average monthly stream flows during the calibration and validation periods. The SWAT model performed well in predicting the stream flow from the study watershed and the results were acceptable.

Generally, sub watershed 6, 12, 15, 20, 22, 24, 25, 31 and 32 were identified and more susceptible to soil erosion and more attention has to be given to this area, and the required treatments should be used on these area; such as practicing strip planting, terracing, soil bund, contour farming and others to reduce runoff volume and soil erosion. These structures should be practices in all land use of Katar watershed in generally, particularly on agricultural land use (intensively cultivated land). Identifying and prioritizing erosion susceptible areas for intervention are quite essential for this study area. On slope greater than 30% no need of conducting any agricultural activities, rather the area should be protected and conducting rehabilitation. The result of the study could help different stakeholders to plan and implement appropriate watershed management strategies in the study area. Therefore, future study will be focused on further analysis of the impacts of climate and land use change as well as soil and water conservation on the stream flow and sediment yield in the study watershed. In conclusion, the model developed could be used in prediction model to take appropriate measures in advance.

Conflict of Interest Statement

The authors declare that they have no competing interests.

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