

Sediment Yield Estimation and Identifying the Soil Erosion Prone Areas in Koysha Dam Watershed of Omo-Gibe Basin

Girma Bekele Goaba[1] Tadewos Adema Amona[2]
1. Hydraulic and Water Resources Engineering, Wolkite University,Wolkite Ethiopia
2. Hydraulic and Water Resources Engineering, WolaytaSodo University, Wolayta Sodo Ethiopia

Abstract
Sedimentation is huge problems that have threatened many reservoirs in Ethiopia. Koysha dam watershed is conditioned densely populated with intensive traditional agricultural practice and low soil and water conservation practice in left side. The left side of watershed is gentle slope terrain topography. This study has been conducted to estimate mean annual sediment yield of watershed, to identify and prioritize the most sensitive sub-watersheds with the help of Arc SWAT 2012 for planning reservoir sedimentation mitigating strategies at the watershed level. Based on a digital elevation model the catchment was divided in to 23 sub-basins using the dam axis as the main outlet. The current LULC map was downloaded from satellite. The pre-processing and both unsupervised and supervised classification was conducted in ERDAS Imagine 2015. By overlaying land use, soil and slope maps, sub-watersheds were further divided in to 241 HRUs. Arc SWAT Model was calibrated and validated using SUFI-2 SWAT-CUP optimization algorithms for stream flow rate and sediment yield data observed at dam axis, which transposed from other gauging stations. The model performance was evaluated by using both stream flow and sediment yield data. The study has revealed that Koysha dam residual watershed has mean annual sediment yield of 7.22 t/ha/year. Out of the 23 sub-watersheds, seven sub-basins produce above average sediment yields ranging from 8.79 -56.70 t/ha/yr, while the others yield below the average value. Out of the 23 sub-basins two sub-basins were prioritized for immediate implementation of watershed management interventions. The maximum sediment outflow of these two sub-basin are 26.33 and 56.7 t/ha/year and are characterized dominantly by cultivated land with average land slope of 31.45% and 28.74% respectively and with the dominant soil type of Humic Nitisols. The soil erosion was sensitive to cultivation land use and terrain steepness.
Keywords: Koysha dam watershed, Sediment yield, SWAT, Prioritization
DOI: 10.7176/CER/14-2-01
Publication date: April 30th 2022

1. INTRODUCTION

1.1 Background

Soil erosion is a serious problem in Ethiopian highland areas that increased sedimentation of reservoirs and lakes. The total soil loss into the rivers from landslide is estimated as 11 t/ha/yr. for the last 20 years and high variation among catchments in SSY due to the variation in the catchments characteristics (0.43 -132.08 t/ha/yr.) (Kissi, 2011). Reservoir sedimentation due to soil erosion by water, which is a dominant soil erosion type, is a major problem of reservoir operation in Ethiopia (Asmelash, Haile, & Bogale, 2017); (Mekonnen, et al, 2015); (Tadesse, 2013); (Haregeweyn, Tsunekawa, Tsubo, Meshesha, Nyssen, & Deckers, 2013). The mean annual sedimentation rate of Koka reservoir in Awash River estimated is 2303t/km^2/year, 13-20Mm^3/year, 17Mm^{3}year and forecasted the life span of with some decades as cited in (Kebede, 2012). (Haregeweyn, et al., 2006) demonstrated that the life span of half of all small irrigation dams in the Tigray Region has been significantly reduced because of high siltation levels. The Borkena and Adrako dams in this region had already been shut down even before the completion of construction. Mekonnen, *et al.* (2015) the dams in Amahara region have completely silted up before their design expectation period and some are threatened by accelerated sedimentation.

According to (Devi, et al, 2008) Gilgel Gibe I hydroelectric power dam has a high sedimentation load intercepted and estimated sediment load of 4.5 $*10^7$ tyear^{-1}, standing on this result the dam will reduce by half within 12 years and would be totally filled by sediments within 24 years unless the appropriate mitigation measures taken. The potential total annual soil loss from the study area (Gibe III catchment) was 9,700,823 tons per year and the average annual soil loss was estimated to be 7.47-ton ha^{-1}yr^{-1} (Belayneh , 2014). The high rates of sedimentation anticipated in Gilgel-Gibe III reservoir, where one-third of its space is reserved for sediments to accumulate over time (Hathaway, 2008).

1.2 Statement of Problem

All reservoirs are subjected to sedimentation and lack of adequate mitigation measures sedimentation threatens their sustainability. As well as the evident loss of storage capacity, the adequate and safe operation of water intakes and bottom outlets belonging to the vital outlet structures can be affected by the deposition of sediments in the reservoir (Anton J. Schleiss, et al, 2016). Sedimentation is a large problem in reservoirs in the river system within Ethiopia, existing condition of previously constructed reservoirs shows that significant portion of their storage capacities are lost to sedimentation every year (Tadesse, 2013).

As per (Takala, et al, 2016) soil erosion from the upstream of the Omo Gibe basin and the subsequent sedimentation in the downstream area is an immense problem threatening the existing and future water resources development of basin. Most of the rivers from upper part of the catchment drain largely cultivated land (Kemal , 2013 ; Belayneh , 2014). Different authors (Belayneh , 2014; Hathaway, 2008; Kebede, 2012) revealed that Gibe III dam, which is at the inlet point to Koysha dam is exposed to the high sedimentation load. Deforestation, overgrazing and intensive agriculture due to population pressure have caused accelerated erosion.

Koysha dam watershed is currently in distressing due to severe soil erosion and land degradation by water erosion. This has resulted in excessive sedimentation on Omo Kuraz Irrigation weir located downstream point of Koysha dam. Particularly sedimentation of the reservoir of Koysha dam is a great fear for the sustainability of Koysha project, which is under construction by huge investment. Therefore, understanding the impacts of soil erosion and looking for solutions to minimize is essential. To implement effective measures it is important to assess the magnitude of the problem in scientific way. No scientific study was conducted before regarding sedimentation on Koysha dam watershed.

Thus, the need for a scientific research was unquestionable for the study area. Therefore, this study attempts to detect and evaluate the annual average sediment yield to reservoir, identify the soil erosion prone sub-watershed. At the end of date, this study will indicate the target area to prioritize for developing mitigation strategies for sustainable soil and water resource conservation in study area, input for reservoir management and other decision makers.

1.3 Objectives of the study

General objective of the study is to estimate sediment yield and identify the soil erosion prone areas to prioritize the sub watersheds for soil conservation practice in or Koysha dam watershed (Gibe IV) of Omo-Gibe basin. Specifically the study anticipated to identify and prioritize soil erosion hotspots of the watersheds based on model simulated soil loss and to estimate the annual average sediment yield from Koysha dam watershed to the reservoir.

2 MATERIALS AND METHODS

2.1 Description of the Study Area

The Omo-Gibe basin is one of the major river basins in Ethiopia and situated in the southwestern part of the country covering parts of Southern Nations, Nationalities and Peoples Region (SNNPR) and Oromia region. The basin covers an area of 79,000 km^2 with a length of 550 km and an average width of 140 km. The basin lies between $4^0$00'N & $9^0$22'N latitude and between $34^0$44'E & $38^0$24'E longitude. It is an enclosed river basin that flows in to the Lake Turkana, which forms its southern boundary. The total mean annual flow from the river basin is estimated to be about 16.6 BMC of water.

The Koysha Hydropower project located about 530 kilometers southwest of the capital, Addis Ababa. Koysha has an installed electricity generating capacity of 2,160 megawatts. Koysha watershed is the middle part of Omo Gibe basin and located between 5°00′00″ to7°30′00″ N latitudes and 36°30′00″ to 38°00′00″E longitudes as shown on Figure 1.

The elevation of Koysha watershed ranges between 3565 meter a.m.s.l in the northern and 517 meter a.m.s.l in the south with a mean elevation of 1526 meter a.m.s.l and Koysha dam point is located about 129 km downstream of Gibe III dam. Total catchment area of some 44325 km^2 (the residual catchment from Gibe III to Koysha corresponds to 10166 km^2).

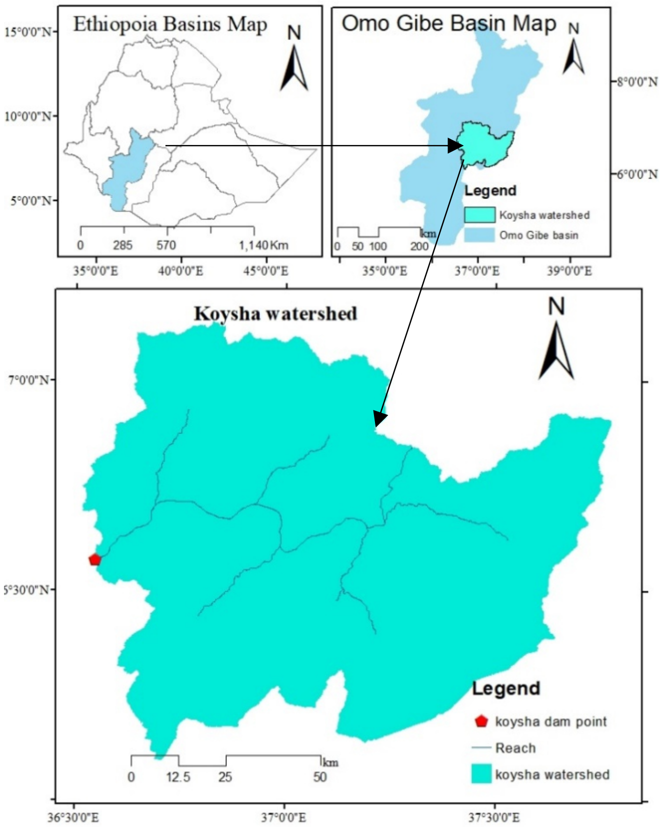

Figure 1 Location of the Study Area (Koysha Dam watershed)

2.1.1 Climate

Climatic condition of the watershed varies spatially with complex topographic influence. Upper part have unimodal precipitation pattern which receives maximum precipitation from June to September and lower part have bimodal precipitation pattern which receives the first maximum precipitation through April and May while the second maximum precipitation from September to the end of October. Koysha dam watershed shares the upper and lower Omo Gibe climatic conditions. The maximum and minimum mean monthly precipitation at upper part is 250mm and below 50mm, while in lower part 200mm and below 30mm respectively.

2.2.2 Land use/land cover and soil

The land cover types of the basin consists high percentage of cultivated lands including fallow next to woodlands (ITAB-consult plc, 2001). The densely populated people in the basin are mainly characterized by agricultural and agro-pastoral economic activity and life style. The lower Omo indigenous community daily life is directly linked with Omo Gibe River for domestic water source, livestock water demand and floodplain farming.

The dominant soil classes of the watershed are Lithic Leptosls, Humic Nitisols and Humic Alisols with their percentage areal coverage of 42%, 30% and 20% respectively.

2.2 Data Source and Materials

Two main data were needed. These are time series data (hydro meteorological data) and spatial data like, land use land cover map, DEM and soil map.

From 1989 to 2016 daily resolution climate data like precipitation, temperature, relative humidity, wind speed and solar radiation are accessed from Ethiopia National Meteorology Agency. Stream flow from 1991 to 2004 and sediment data are acquired from Ministry of water irrigation and energy office. DEM 30X30m for watershed delineation and other purpose is sourced from MoWIE.

Soil data was accessed from MoANR and the current LULC is prepared from LANDSAT satellite image using image processing tools (ERDAS 15 and Arc GIS10.3)

2.3 Data Analysis Method

The Meteorological data collected from National Meteorological Agency has a longer time series data for the catchments of Omo Gibe and rift valley basins of the ten meteorological stations within and around the watershed were Wolayta, Bale, Chida, Chencha, Gessuba, Zonga, Daramalo, Menteso, Chencha and Morka gauging stations(Figure 3-4). Out these stations were used while filling the missing precipitation data. For this study, a daily time series meteorological data of about 27 years was collected from 1989 to 2016 GC.

2.3.1 Filling missing precipitation

The data gap that may happen due to different factors, like: failure of the observer to make the necessary visit to the gauging station, Vandalism of recording gages or instrument failure (by mechanical or electrical malfunctioning) will reduce the quality of the data.

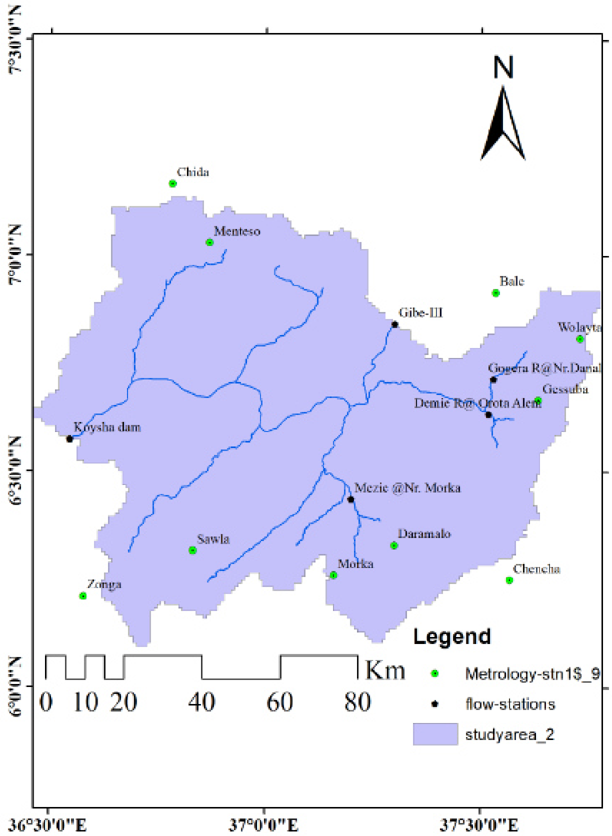

Figure 2 Metrology and flow measuring stations used for study

There are different methods for estimation of missing data, but IDW is used to fill the missing precipitation data. After filling the missed data, the relative homogeneity test was carried out. Two principal Metrologic stations, Wolayta sodo and Sawula were selected due to less missing data and their climatic region consideration. Accordingly, the precipitation data the stations are homogeneous to each other.

To check the quality of the data cross correlation between the accumulated totals of the suspect gauge were checked or compared with the corresponding totals for a representative group of nearby gauge. The consistency of all the rainfall stations was checked by the double mass curve and the data are consistent. Accordingly, the stations are selected for this study are Chida, Meteso,Gessuba, Wolayta, Bele, Zonga, Sawula,Daramalo, Chencha and Morka.

2.4 Hydrological data analysis

Flow Data Analysis

In Omo Gibe basin the most hydrometric stations are located in upper part of the basin. Actually, there are some stations like (Demie River at Orota Alem, Gogera River near Dana1, Mazie near Morka) with poor data within residual Koysha dam watershed. But the upper Omo basin stations (Wabi near Wolkite , Great Gibe at Abelti, Gojeb near Shebe , Megech near.Gubere, Gogob near Endeber) are used to transfer flow in to ungauged Koysha dam point indirectly due to the data quality and basin representation.

2.4.1 Filling of missed data

Based on visual examination, stream flow records of each selected gauging station have a good quality of flow data that shows strong serial correlation. The missing data was filled by developing correlations between the station with missing data and any of the adjacent stations with the same hydrological features and common data periods.

2.4.2 Transferring of stream flow data

Both multiple source site area ratio and single source area ratio methods were used because of the area of gauged and ungauged value was close in their magnitude, they have relatively similar characteristics in soil, land use and topography. First flow was transferred from each point in to Gibe III dam point by multiple source site area ratio method (MAR) of regionalization. The transferred mean monthly flow was comparable with the output of SWIM hydrological model based un-gauged basin flow estimation and routed to gibe III from Abelti (Kemal , 2013) and the hydrology design data of Gibe III dam (Seyoum , 2015).

The single source site area ratio method was used to transfer flow from Gibe III dam point to Koysha dam point. The area ratio ungauged to gauged area is 1.3 at Koysha dam. This method performs best when the proportion of source to the interested site drainage area is within the range 0.5-1.5 (Ries III, 2007).

2.5 Sediment Data Analysis

The sediment data collected from ministry of water, irrigation and energy (MoWIE) was not in continuous time step. From the acquired three stations (Demie, Mazie and Gogari) only Demie station was selected based on its large area representation and good sediment concentration sample relative to remaining two stations. After the rating curve has been developed, the records of discharges are transformed into the records of sediment load and the general relationship can be written using a mathematical curve fitting method (Morris & Fan, 1998).

$C_s = aQ^b$ 1

where, C_s is sediment load in ton/day, Q is the discharge in m^3/s, a and b are regression constants.

The raw data collected from the MoWIE was the sediment concentration. Thus, the data of sediment, which was in concentration form, have to change into sediment load in ton per day to create the sediment-rating curve. This value was converted into sediment load by the time-series sediment-rating curve computing technique Equation 3.12 (Morris & Fan, 1998).

$Q_s = 0.0864*Q*C$………………………………………..………………...……………………………2

where, Q_s is the sediment load in (ton/day), Q is the flow of the stream (m^3/s), C is the sediment concentration (mg/l) and 0.0864 is conversion factor. Once the sediment load was calculated, the relation between the measured flow (m^3/s) and the calculated sediment load (ton/day) has been made in sediment rating curve.

The sediment-rating curve of Demie stream was developed by following the above procedure is

$Q_s = 28.214Q^{1.171}$

The mean monthly sediment load, which was used for sediment yield calibration and validation, was transformed from residual Koysha watershed flow using the above sediment-rating curve.

2.6 SWAT Model Inputs

2.6.1 Digital Elevation Model (DEM)

Slope has a powerful influence on erosion, it intervenes in erosion in terms of its form, gradient, length and position. As the gradient increases, the kinetic energy of the runoff increases. In theory, the longer the slope, the more runoff will accumulate, gathering speed and gaining its own energy, causing rill erosion and then more serious gullying. But the proportionality of either slope gradient or length with runoff and erosion cannot be analyzed alone; the interdependence and interaction with soil, land use land cover as well as management practice should be considered. The complex topography of the study area was discretized into multiple (five) slope class as level (0-3%), gentile (3-10%), moderately inclined (10-20), moderately steep (20-30), steep to very steep (>30%) Figure 3.

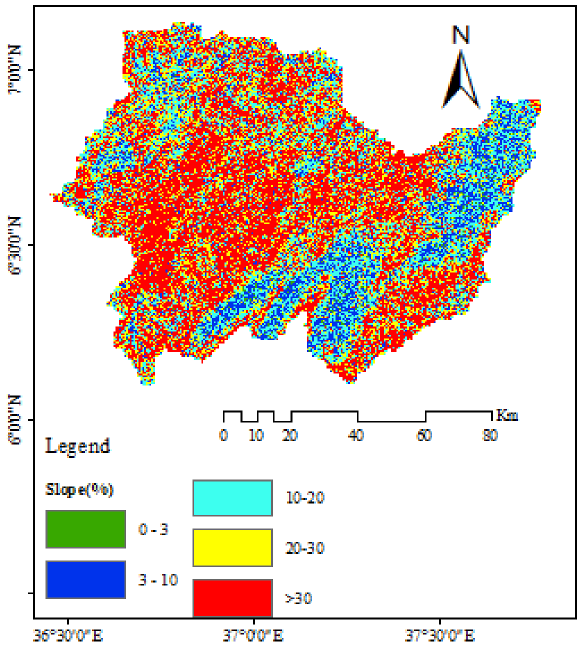

Figure 3 Slope classification study area

2.6.2 Land Use /Land Cover Data

Accessing and preprocessing Land Sat 8 Image

Satellite image of two scene from *https://glovis.usgs.gov/* Landsat 8 OLI/TIRS C1 Level-1 of acquisition date January 17/2017 with path 169 and row of 55 and 56 was used. The free downloaded raw image passed the preprocessing steps selecting bands, mosaicking the scenes, subsetting the area of interesting for this study. The bands coastal aerosol to short wave infrared (Band 1 to band 7) was selected for this study.

Land Use and Land Cover Classes

Based on the priori knowledge of the study area, additional information from previous research and unsupervised classification result, seven different types of land use and land cover were identified for the study area. The identified land use types were Agriculture land, Forest, Bush & shrubs, Grassland, Open land, Urban & built-up and Water body. Image preprocessing and classification for the study performed using ERDAS imagine 2015. There are two approaches of classification, which are unsupervised and supervised classification. For this study, both unsupervised and supervised methods are considered. The sample number was fixed by using Fitzpatrick-Lins (1981) procedure, equation 3 that adopted from (Gebhard , 1998).

$$N = \frac{Z^2\,pq}{E^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 3$$

Where, N is the number of sample, Z=2, p is the expected percent accuracy, q is 100 minus p, E is the allowable error.

For the expected percent of accuracy of 85% with allowable error of 4, about 300 samples were collected. Considering above class and description the ground control points were collected direct field visit using GPS and google earth for non-accessible areas. From 300 GTPs, 70% were used for classification and the remaining 30% used for accuracy assessment. The land cover map (Figure 4) produced based on the pixel based maximum likelihood supervised classification through using ground truth points of the area.

The probability that a classified pixel from the (LC) map accurately corresponds with the referenced data is determined by the user's accuracy, while the Kappa statistic measures the difference between the true agreement of classified map and chance agreement of random classifier compared to reference data (Abubaker Haroun Mohamed Adam, et al, 2013). According to (J. Richard Landis & Gary G. Koch, 1977) the strength of agreement is subsitantial and accepted for this study. The devaition between expected and achieved accuracy may be the effect of study area size i.e. it was very large.

Table 1 Land use land cover classification accuracy assessment (error matrix)

		Classified data								
		B& Shr	Agr.	Forest	Gr.	Op	Ur & bu	Wtr.	Total	Pro. Accu , %
Reference data	Bush & shrubs	10	2	1	0	0	0	0	13	76.9
	Agriculture land	1	12	0	2	2	0	0	17	70.6
	Forest	1	0	10	1	0	0	0	12	83.3
	Grassland	3	2	0	14	0	0	0	19	73.7
	Open land	0	2	0	0	11	1	0	14	78.6
	Urban & builtup	0	1	0	0	2	9	0	12	75
	Water body	0	0	1	0	0	0	6	7	85.7
	Total	15	19	12	17	15	10	6	94	
	User Accuracy,%	66.7	63.2	83.3	82.4	73.3	90	100		72
		Over all accuracy								76.6
	Kappa statistics									0.72

Note: - *B&shr = Bush & shrubs, Agr = Agricultural land, Gr = Grassland, Op = Open land, Ur & bu = Urban and built up, Wtr = Water body, Pro. Accu = producer Accuracy*

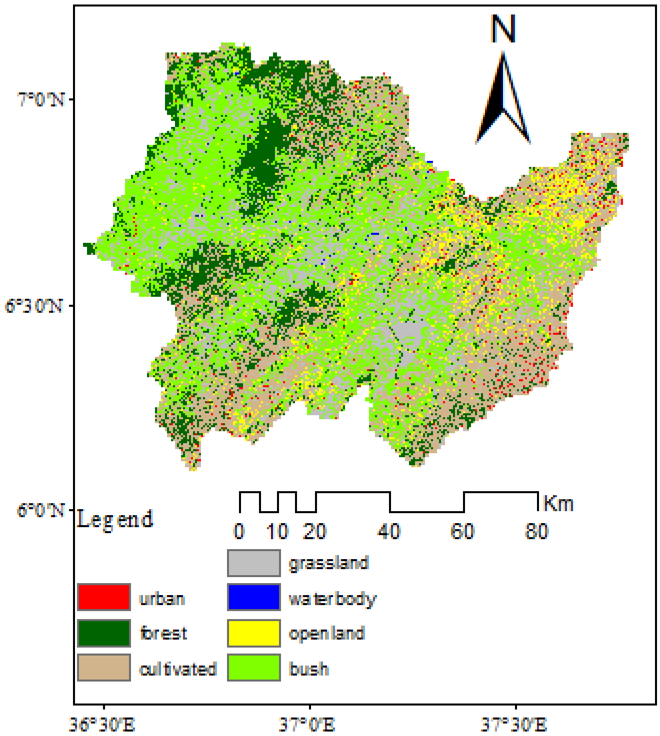

Figure 4 Land use land cover map of Koysha dam watershed

Table 2 Land use land cover class and its area coverage in study watershed area

LANDUSE	SWAT CODE	Area(ha)	%Wat.Area
Residential	URBN	13146.20	1.29
Forest-Deciduous	FRSD	163840.10	16.07
Agricultural Land-Generic	AGRL	285807.21	28.03
Range-Grasses	RNGE	159458.03	15.64
Water	WATR	1054.94	0.1
Summer Pasture	SPAS	69301.35	6.8
Range-Brush	RNGB	327030.97	32.07

2.7 Soil Data

Soil governs runoff generation in the watershed. SWAT model requires different soil physical and chemical properties soil texture, available water content, hydraulic conductivity, bulk density and organic carbon content for different layers of each soil type. The Omo gibe basin soil map was acquired from MoWIE (Figure 5) was used for this study.

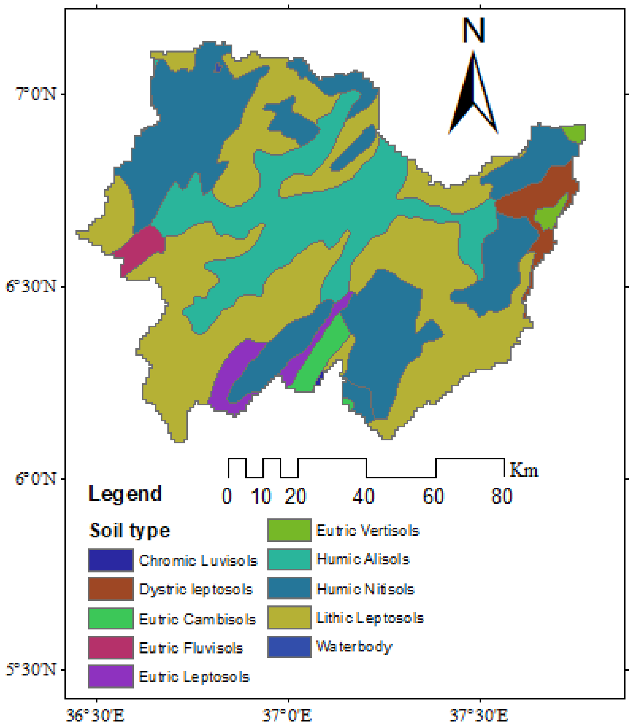

Figure 5 Soil map of the study area

To develop the SWAT user soil database the HWSD Accesses database, FAO soil viewer software and previous work review in the basin (Seyoum , 2015) was used to extract the physical and chemical properties. The dominant soil types in study area are lithic leptosols, Humic Nitisols and Humic Alisols.

2.8 SWAT Model Setup

2.8.1 Watershed delineation and HRU definition

Based on the DEM, the study area was divided into 23 sub-watersheds using the Dam axis (Latitude 7.00° N, Longitude 37.00°E) as the main outlet Figure 3-1. To define the origin of streams a threshold area (150km^2) was set by the user and this threshold area determines the size and number of sub basins and detail of a stream network. By defining and overlaying the land use, soil type and slope of the study area the sub-watersheds were further divided into a total of 241 hydrologic response units (HRUs). 20%, 10% and 20% of land use, soil and slope were assigned respectively for defining of the HRUs.

2.8.2 Weather Data Definition

Weather generator (WGEN) in SWAT model used to generate climatic data and to fill missing values in the measured records. In Koysha watershed, some stations have no full weather data like relative humidity, solar radiation and wind speed. For this study, Wolayta and Sawula meteorological stations were synoptic stations, which have full weather data.

The weather generator developer called precipitation statistical analysis model (PCP STAT) was used to statistical analyzing of daily precipitation data needed to create user weather station files for SWAT model. Dew point (dew02) was additional parameter required for weather generator. It was used for generating average daily maximum and minimum temperature, humidity and dew point in month. The solar radiation was adopted from literature in the basin, for the same station. Weather stations geo-referenced using latitude, longitude and elevation data.

2.9 SWAT Model Simulation

2.9.1 Sensitivity analysis, Calibration and validation

Performing the calibration process for all model parameters of flow and sediment yield is computationally far-reaching and complex. Hence, sensitivity analysis for parameters of the SWAT model set up is important as parameter sensitivity analysis gives the order of parameters that contribute more impact to the output variance due to input variability. The model was calibrated by changing the parameters sequentially for obtaining optimum agreement between observed and simulated stream flow and sediment yield. The calibrated parameters of the model were then validated using an independent data set of 2001 to 2004 monthly stream flow and sediment yield data.

2.9.2 Evaluation of SWAT Model Performance

The performance of SWAT is evaluated using statistical measures to determine the quality and reliability of predictions when compared to observed values. When a single indicator is used it may lead to incorrect verification of the model. Instead a combination of Coefficient of determination (R^2), Percent bias (PBIAS) and Nash-Sutcliffe simulation efficiency (ENS) are the goodness of fit measures used to evaluate model prediction.

3. RESULTS AND DISCUSSIONS

3.1 General

The ability of SWAT model to sufficiently estimate the stream flow and sediment yield was evaluated through sensitivity analysis, model calibration and validation. The time series dataset from 1989 to 2004 and out of which 1989 to 1990 were used for model warm up period, 1991 to 2000 were used for calibration and 2001 to 2004 for validation period. The sensitivity analysis was done for both flow and sediment yield. The simulated flow and sediment yield were compared with the observed flow and sediment yields. Model performance was checked by statistical model performance indicators.

3.2 Stream Flow Simulation

3.2.1 Sensitivity Analysis, Calibration and validation of flow

The SUFI-2 algorithm in the SWAT-CUP software package was used for model calibration, validation, sensitivity and uncertainty analysis. Sensitivity analysis was performed considering 19 key hydrologic parameters based on previous literature sources in basin (Takala, et al, 2016, Belayneh, 2014) on monthly time resolution with observed flow data at Koysha dam point.

Based on the results obtained from sensitivity analysis using SUFI-2, the ranks of parameters assigned depending on p-value and t-stat. The larger in the absolute value of t-stat and smaller the p-value, the more the sensitive of the parameter (Abbaspour, 2015). A p-value of <0.05 is the generally accepted point to select sensitive parameters (Abbaspour, 2015). Accordingly, nine sensitive flow parameters in Koysha dam watershed were selected for calibration.

Calibration was performed at the outlet for stream flow over a 10-year period (01/1991 to 12/2000) with two years (1989-1990) keeping for model warm up. The calibrated parameter ranges were applied to an independent measured dataset, without further changes. For the validation period 1/2001 to 12/2004 the performance of model was evaluated at Koysha dam point.

The graphical (visual observation) method and values of statistical parameters, Nash-Sutcli e efficiency (NSE), coefficient of determination (R^2), and percentage of bias (PBIAS) indices were used as an indication of calibration acceptance. The values of statistical parameters of NSE, R^2 and PBIAS are 0.69, 0.75 and 4.86 during calibration and 0.72, 0.78 and -6.81 for validation period respectively.

The measured and simulated stream discharge values were represented in the hydrographs shown in Figure 6. The model outputs revealed that the model is good in simulating the stream flow for the study watershed.

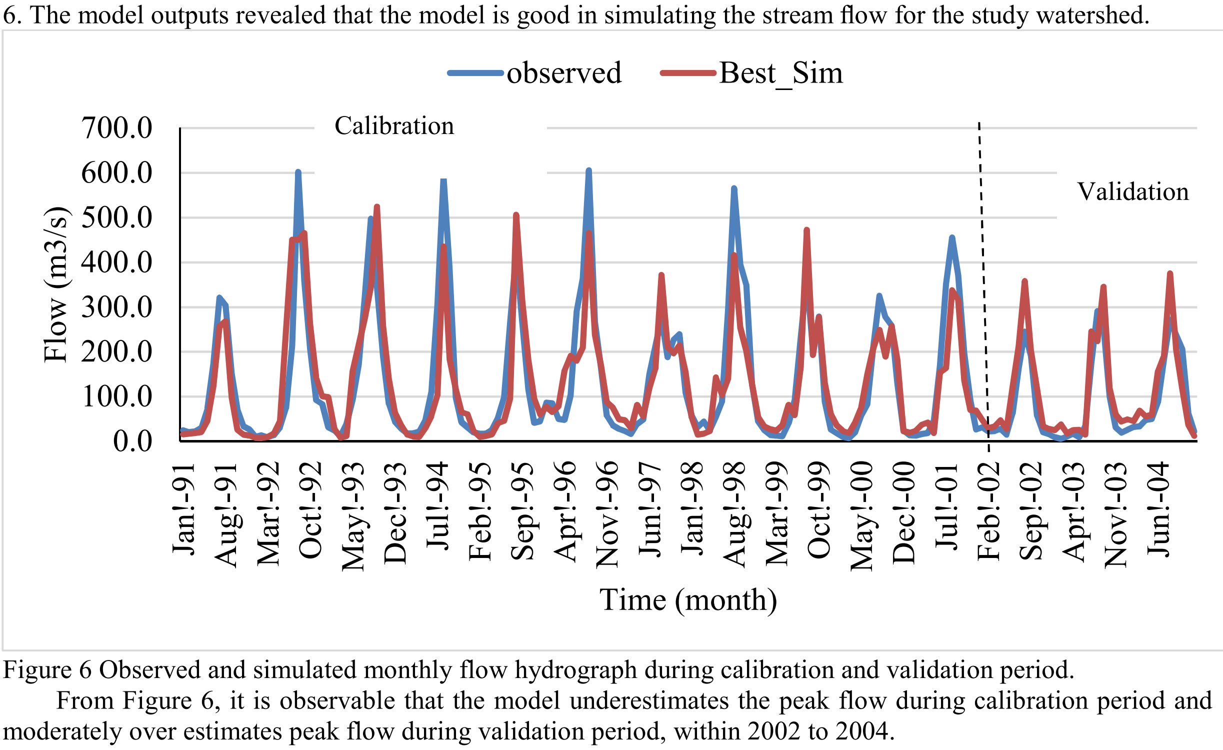

Figure 6 Observed and simulated monthly flow hydrograph during calibration and validation period.

From Figure 6, it is observable that the model underestimates the peak flow during calibration period and moderately over estimates peak flow during validation period, within 2002 to 2004.

3.3 Sediment Yield Simulation

3.3.1 Sensitivity Analysis, Calibration and Validation

During sensitivity analysis of sediment yield twenty-one sediment parameters were checked using SUFI-2 and ten sediment sensitive parameters were identified.

After the sensitive parameters of sediment yield were identified, calibration process took place for monthly sediment yield from 1/1991 to 12/2000. Model performance rating criteria for observed and simulated monthly average sediment yield indicated NSE and R^2 values of 0.64 and 0.72 for calibration and 0.61 and 0.68 for validation periods, respectively.

Calibrated and validated sediment yield results were used to develop sediment yield graph (Figure 7) for watershed outlet station.

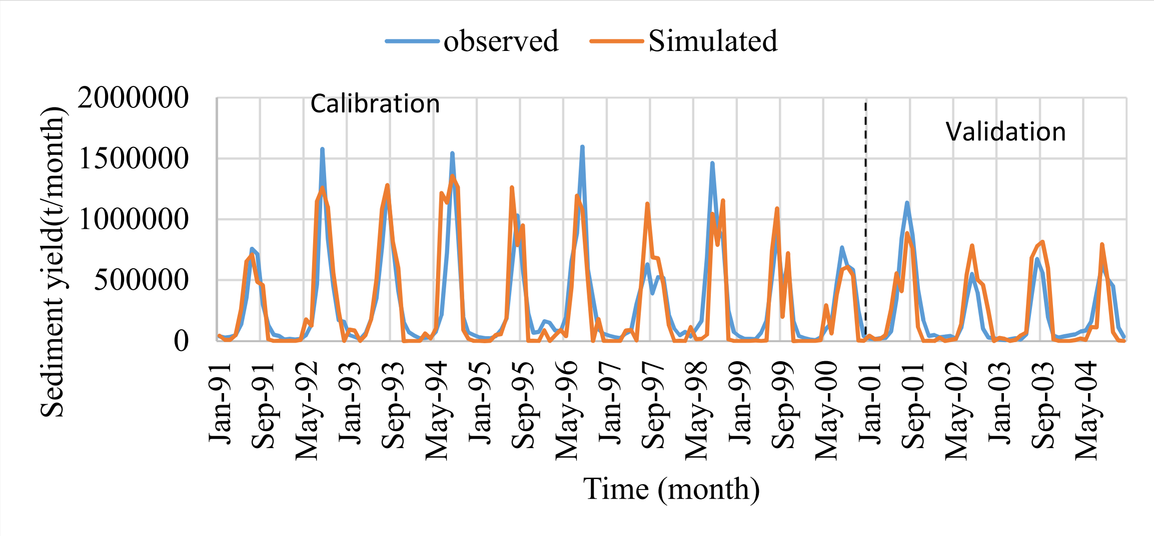

Figure 7 Observed and simulated sediment yield graph during calibration and validation period

Average annual sediment yield from study watershed after calibration and validation at Koysha dam point was 7.22t/ha/yr. for the simulation period. This annual average sediment yield from entire catchment is comparable with the previous study in Gibe III catchment in the same basin which is 7.47t/ha/yr (Belayneh , 2014), and 13.94t/ha/yr by (Betela, 2015). The slight deviation in figure may be due to the land use land cover variation within the upper and the middle Omo gibe basins, since the upper Omo catchment were agricultural intensive with densely settled population. The other point may be the effect of input data quality and quantity issue, the metrology stations in middle Omo basin were scatted distributed relative to upper Omo basin. Even the hydrology data used for this study was transferred from upper Omo basin and this may have significant effect on model output.

3.4 Spatial and Temporal Variability of Sediment Yield in the Watershed

Spatial variability of sediment yield for the watershed was identified from the simulated sediment yield. Tthe result showed the range to be between 1.19 to 56.70 t/ha/yr. with average of 7.22 t/ha/yr. for the sub-basins as shown in Table 3. Based on the spatial variability of sedimentation rate the potential area of intervention can be identified.

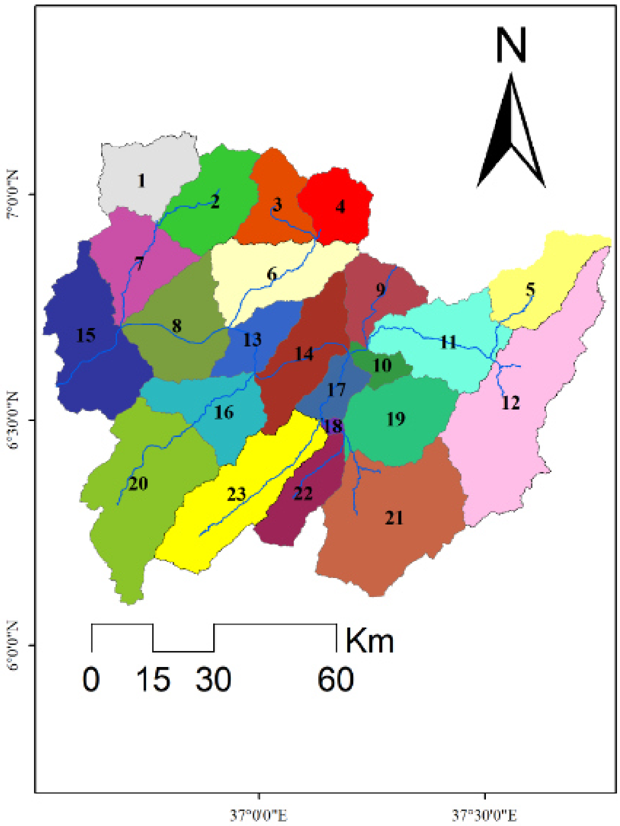

Figure 8 Sub basin of the study area identified during watershed delineation.

Table 3 Average annual sediment yield of each sub-basin

Sub basin	Sediment yield (t/ha/yr.)	Sub basin	Sediment yield (t/ha/yr.)	Sub basin	Sediment yield (t/ha/yr.)	Sub basin	Sediment yield (t/ha/yr.)
1	2.16	7	1.95	13	1.67	19	2.35
2	2.25	8	2.6	14	1.62	20	4.89
3	26.33	9	3.49	15	2.39	21	1.19
4	56.7	10	2.28	16	1.89	22	1.35
5	10.79	11	9.25	17	1.77	23	10.43
6	8.79	12	8.64	18	1.29		

Out of 23 sub basins seven sub-basins (3, 4,5,6,11,12 and 23) produce above average sediment yields ranging from 8.79 -56.70 t/ha/yr, while the others yield below the average value.

The sediment source map reclassified into five soil erosion hazard classes (very low, low, moderate, high and very high) based on the annual sediment yield as shown in Figure 9. Accordingly, sub-basins 3 and 4 fall under very high, while sub-basin 5 and 23 are under moderate erosion risk category. Sub-basin 5 is the catchment of Gogari River, which initiate from Wolayta administration zone, while sub-basin 23 is catchment of Zage River. The dominant SWAT land use land cover, soil and mean slope(%) are Agricultural Land-Generic, HUMICNIT(Humic Nitisols), 31.45%, and covered 28.74%, 19.65% and 28% of sub-basin 3, 4 , 5 and 23 respectively. These indicate that the spatial variability of sediment yield was more sensitive with agricultural land use and steepness of terrain.

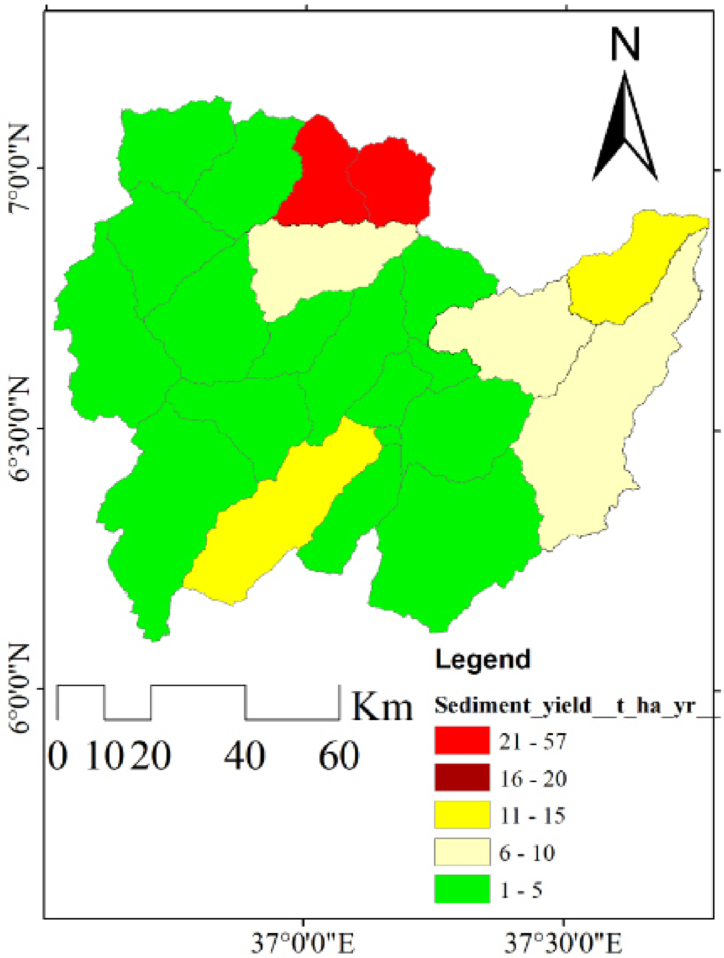

Figure 9 Spatial distribution of simulated annual sediment yield classes.

3.5 Temporal variability of sediment yield

The temporal variation of sediment yield in relation to precipitation and surface runoff at the Koysha dam was as shown Figure 10.

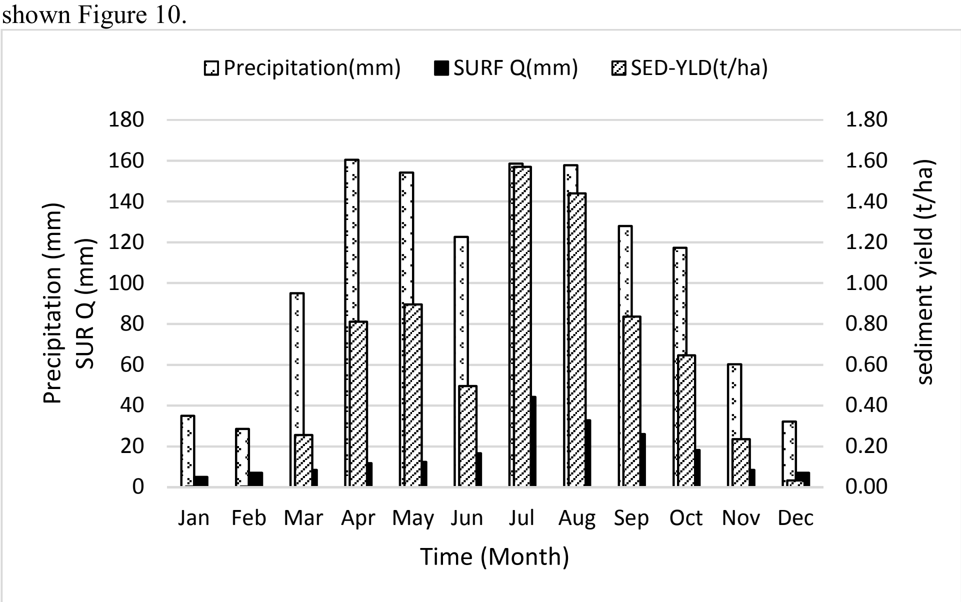

Figure 10 Sediment yield temporal variability with relation to precipitation and surface runoff.

Sediment yield for the watershed was highly correlated with precipitation and runoff. Figure 4-6 shows that high amounts of sediment yield occurred during rainy seasons, April through October. However, during July and August the sediment yield highly correlated with precipitation than other rainy seasons, this was due to intensive agricultural practice took place in these months.

The average maximum annual sediment load leaving the watershed is 6971977.8t/year, which corresponds to the maximum average annual precipitation 1866.7mm in 1997. Whereas the minimum annual sediment loads 236869.4t/year in 2015 corresponds to precipitation of 841.1mm, which is not the minimum one. This indicates that the sediment yield that was leaving the watershed did not correlate with precipitation. This can be due to the influence of another parameter change like land use and the infiltration rate of the soil or evaporation loss. In general still sediment load correlates with precipitation and surface runoff.

3.6 Prioritization of critical sub-catchments for sedimentation management

The critical sub-watersheds were identified and prioritized on the basis of average annual sediment yield simulated. The range of the tolerable soil loss level for various agro-ecological zones of Ethiopia was found from 2 to 18 t/ha/yr (Hurni, 1985). Accordingly, the simulated soil loss rate of some of sub-watersheds in the study area exceeds the maximum tolerable soil loss rate (18 t/ha/yr.). This fact shows how far soil erosion is a serious threat in the study area.

The first two sub watersheds (3 and 4) from which the annual sediment yield values are greater than the tolerable limit were prioritized for watershed management efforts. The areal coverage of these two sediment prone sub-basins was 5.3% from the whole watershed. These sediment prone sub-basins are located upper western part of the study watershed typically Mansa river upper catchment, which is the main tributary for residual Koysha dam watershed that initiate from agriculture intensive Loma, Mareka and Esara Woradas of Dawuro zone. These two critical sub-basins assigned as the top priorities and recommended for the immediate future conservation plans of Koysha dam watershed.

4 CONCLUSION

The Koysha dam watershed currently has an annual average stream flow of 107.2 m^3/s and annual average sediment yield of 7.22 t/ha/yr.

The study has shown that sub-watershed sediment yields are highly variable. Hence, the critical sub-watersheds were identified and prioritized on the basis of average annual sediment yield. Out of the 23 sub-watersheds, two sub-watersheds were identified with sediment yields above the tolerable limit. The watershed numbers 3 (26.33 t/ha/yr) and 4 (56.7 t/ha/yr) were in the very high sediment yield group which needs attention in sediment mitigating measures of the watershed for sustainable use of the Koysha dam. About 94.7% of the watershed experiences from very low to moderate soil erosion rates, 5.3% experiences extreme erosion rates.

The study shown that the spatial variability of soil erosion was more sensitive to agricultural land use and steepness of terrain. The sediment yield critical sub-basins, sub-basin 3 and 4 were prioritized based on average annual sediment yield for immediate mitigation measures.

The seasonal variability of sediment yield and stream flow from the individual sub-basins shows maximum stream flow and sediment yield were observed during heavy rainfall seasons (April to October).

References

Betela, B. (2015). *Swat Based Runoff - Sediment Yield Modeling and Development of Management Options(Gibe III).* Arbaminch Ethiopia.

Belayneh , G. (2014). *Spatial Erosion Hazard Assessment for Proper Intervention: The Case of Gibe-III Dam Catchment, Southwest Ethiopia.* Ethiopia: Haramaya University.

Hathaway, T. (2008). *What Cost Ethiopia's Dam Boom?* International Rivers.

Kemal , A. M. (2013). *The Effect of Climate Change on Water Resources Potential of Omo Gibe Basin, Ethiopia.* vorgelegt von: Universität der Bundeswehr München.

Kissi, E. (2011). *Rainfall-runoff Dynamics, and Sediment Source and Yield in Gilgel Gibe Catchment.* Jimma University. Addis Abeba: PHE Ethiopia Consortium.

Ries III, K. (2007). The National Streamflow Statistics Program: A Computer Program for Estimating Streamflow Statistics for Ungaged Sites. In *Hydrologic Analysis and Interpretation* (Vols. 4-A6, p. 37). U.S. Geological Survey Techniques and Methods.

Seyoum , T. G. (2015). *Modeling of Cascade Dams and Reservoirs Operation for Optimal Water Use: Application to Omo Gibe River Basin, Ethiopia.* Germany: University of Kassel.

Takala, W., Adugna, T., & Tamam, D. (2016). The effects of land use land cover change on hydrological process of Gilgel Gibe, Omo Gibe Basin, Ethiopia. *International Journal of Scientific & Engineering Research, 7*(8), 117-128.

Abbaspour, K. (2015). *SWAT-CUP:SWAT Calibration and Uncertainty Programs-AUser Manual.* Eawag2015.

Abubaker Haroun Mohamed Adam, Elhag A.M.H, Salih, & Abdelrahim . M. (2013). Accuracy Assessment of

Land Use & Land Cover Classification (LU/LC) "Case study of Shomadi area Renk County-Upper Nile State, South Sudan". *International Journal of Scientific and Research Publications*.

Anton J. Schleiss, Mário J. Franca, Carmelo Juez, & Giovanni De Cesare. (2016). Reservoir sedimentation. *Journal of Hydraulic Research, 6*(54), 595-614.

Asmelash, T., Haile, A. S., & Bogale, G. (2017). Sediment inflow estimation and mapping its spatial distribution at sub-basin scale: the case of Tendaho Dam, Afar Regional State... *Ethiopian Journal of Environmental Studies & Management, 10*(3), 315 – 339.

Devi, R., Tesfahune, E., Legesse, W., Deboch, B., & Beyene, A. (2008). Assessment of siltation and nutrient enrichment of Gilgel Gibe dam, Southwest Ethiopia. *Bioresource Technology, 99*(5), 975-979.

Gebhard , B. (1998). A Review of Assessing the Accuracy of Classifications of Remotely Sensed Data and of Methods Including Remote Sensing Data in Forest Inventory. *International Institute for Applied Systems Analysis*.

Haregeweyn, N., Poesen, J., Nyssen, J., De Wit, J., Haile, H., Govers, G., et al. (2006). Reservoirs in Tigray: characteritics and sediment deposition problems. *Land Degradation and Development, 17*, 211-230.

Haregeweyn, N., Tsunekawa, A., Tsubo, M., Meshesha, D., Nyssen, J., & Deckers, J. (2013). Reservoir sedimentation and its mitigation strategies; a case study of the Ethiopian highlands. *presented at the Hydro 2013:Water storage and hydropower development for Africa* (pp. 1-8). Addis Abeba,Ethiopia: Hydro 13 proceedings.

Hurni, H. (1985). Erosion-Productivity-Conservation Systems in Ethiopia. *Proceedings of 4th International Conference on Soil Conservation*, (pp. 654-674). Maracay,Venezuela, 3-9 November 1985.

ITAB-consult plc. (2001). *Implementation Strategy for River Basin Integrated Development Master Plan final report.* Ministry of Water Resources, Addis Abeba,Ethiopia.

J. Richard Landis, & Gary G. Koch. (1977). The Measurement of Observer Agreement for Categorical Data. *BIOMETRICS*, 159-174.

Kebede, w. w. (2012). Watershed management An option to sustain dam and reservoir function in Ethiopia. *Journal of Environmental science and Technology*, 1-12.

Mekonnen, M., Keesstra, S., Baartman, J., Ristema, C., & Melesse, A. (2015). Evaluating Sediment Storage Dams:Structural Off-site Sediment Trapping Measures In Northwest Ethiopia. *Cuadernos de Investigacion Geografica*, 7-22.

Morris, G., & Fan, J. (1998). *Reservoir Sedimentation Handbook, Design and Management of Dams, Reservoirs, and Watersheds for Sustainable Use.* New York: McGraw-Hill Book Co.

Tadesse, T. B. (2013). *Sedimentation and Sustainability of Hydropower Reservoirs: Cases of Grand Ethiopian Renaissance Dam on the Blue Nile River in Ethiopia.* Msc. Thesis, Norwegian University of Science and Technology, Department of Hydraulic and Environmental Engineering, Norwaign.