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Prediction of Stream Flow and Sediment Yield of Kesem Watershed Using SWAT Model

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***Abstract* - Soil erosion is one of the most serious environmental problems since the fertile soil which is rich in nutrients gets removed. This erosion of soil reduces the capacity and life span of rivers and reservoirs. This has become severe problem which is a challenging management task for the water resource department. Thus soil resource need to be conserved for optimal land use for maintaining and improving soil productivity. Since mathematical models have great potential to support land use planning with the goal of improving water and land quality. In this study, the Soil and Water Assessment Tool (SWAT) model having an interface with Arc View GIS software is used for estimation of sediment yield for Kesem watershed. The model is calibrated and validated using observed runoff and sediment yield data.**

The SWAT model was used to estimate the runoff and sediment yield of Kesem watershed. The model was calibrated, validated, and assessed for evaluation to model ambiguity using Nash–Sutcliffe coefficient (NSE) and coefficient of determination (R2). Ten highly sensitive parameters were recognized for stream flow simulation of which CN2 (Initial SCS CN II value) factor was the most sensitive one and four highly sensitive parameters were recognized for sediment yield simulation of which SPCON (Linear parameters for sediment re-entrainment) was most sensitive one. The model was calibrated for a time period between 1995 to 2004 and validated from 2005 to 2009 for flow and sediment yield. During flow calibration the R2 and NS give as value of 0.68 and 0.67 respectively, and similarly for validation the R2 and NS give as value of 0.65 and 0.60, respectively. For sediment calibration the R2 and NS coefficient give as 0.77 and 0.64, respectively and sediment validation R2 and NS give as 0.65 and 0.54, respectively. The calibration and validation results found were good and satisfactory for both flow and sediment. The total observed flow for study area at gauged station was 15.52m3/s and the simulated flow by SWAT model was 14.15m3/s and observed annual sediment yield generated from rating curve at selected gauging station was found 29.62ton/ha/yr and the simulated yield by SWAT model was 25.75ton/ha/yr. From the model simulated output, sub-basins 2, 7, 5, and 18 were found to be the severely eroded sub-basins with annual average sediment yield of 22.01ton/ha, 19.29ton/ha, 19.09ton/ha and 18.93ton/ha, respectively. While, sub-basins 12 and 13 were found to be the least sediment sources with annual average sediment yield of 0.03 ton/ha and 0.06ton/ha respectively. Six scenarios were developed to decrease sediment yield in the catchment and sediment management approach were proposed in the Kesem catchment. By this study we come to know that the SWAT model is competent of predicting sediment yields and hence can be used as a tool for water resources planning and management in the study watershed.

Keywords: Soil Erosion, Sediment yield, SWAT, Kesem catchment.

I. INTRODUCTION

Sediment yield directs to the measure of quantity traded by a basin over a timeframe, which is likewise the sum that will enter a store situated at the downstream furthest reaches of the basin (Morris and Fan, 1998). The subject of residue yield modeling has pulled in the consideration of numerous researchers however absence of information, assets and broadly acknowledged strategies to anticipate/gauge sediments yields are a portion of the boundaries against this bearing of study (Summer et al., 1992; Shimelis et al., 2010). Enhanced soil disintegration, which is created because of the anthropogenic intercession, is representing an extreme test to the profitability of area by the loss of productive soil and to the life of stores by the testimony of residue. The procedure of soil disintegration and sediments transport and affidavit are nonlinearly identified with the causal elements and are exceptionally variable both spatially and transiently (White et al., 2005). Checking of these procedures is entirely perplexing and costly. Modelling gives an option way to deal with valuation of sediments yield furthermore a superior comprehension of residue development and conveyance. As of

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late, a portion of the conspicuous models like the Universal Soil Loss Equation (USLE) and its adjustments like the Modified USLE (MUSLE) and the Revised USLE (RUSLE) are progressively being utilized (Prabhanjan et al., 2015).

The soil and water appraisal tool (SWAT) is a substantially based model, which has been utilized all through the world for hydrological modeling and sedimentation yield concentrates on, to speak to the spatial marvels (Kaur et al., 2003). A Geographic Information system (GIS) has not just been utilized for association, stockpiling, procurement, and showcase of spatial information, additionally for undertakings like programmed watershed outline, adding spatial parameters, and incorporating different hydrological models. In light of the above perceptions and different reports, it can be inferred that SWAT is one of the favorable models for overflow and sediments yield demonstrating. What's more, it has been well recognized that remote Sensing and GIS can be adequately used to exhibit the overflow and sediment yield from watersheds. The main aim of the present study is to assess SWAT model performance and its applicability in

- Analyze the potential soil erosion of the catchment.
- To estimate the sediment yield of the watershed.
- To identify appropriate soil and water conservation measures in the catchments as the best management activities of the watershed.

II. METHODS AND MATERIALS

2.1 Location

Kesem watershed is located at the southern end of the Afar depression (rift) in Afar regional state, 225km East of Addis Ababa and 40 Km NW of Metehara town (Fig 1).

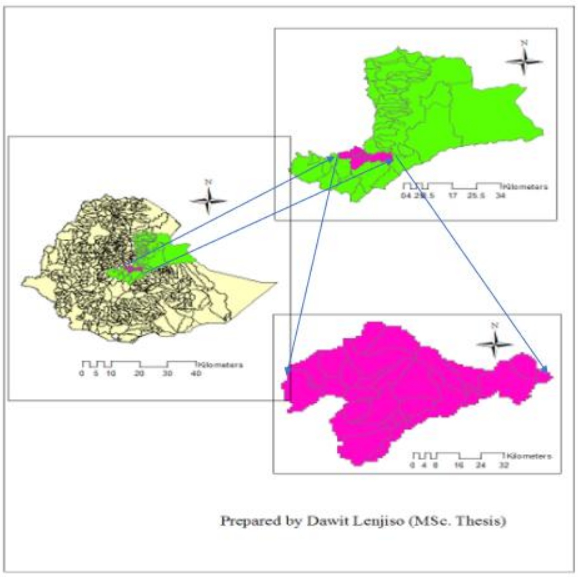

Figure 1: Location map of Kesem watershed

It lies in between latitudes around 8° 50′ and 9° 20′N and longitudes 39° 00′ and 40° 00′E. The Kesem river catchment to dam site covers about 3018.5 km2. It rises on the high Ethiopian plateau and descends the western scrap of the Great Rift Valley to join the Awash.

2.2 Data Required

- Digital Elevation Model (DEM): Topography is defined by a DEM that describe the elevation of any point in a given area at a specific spatial resolution. A 90 m by 90 m resolution DEM was used to delineate the watershed and to analyze the drainage patterns of the land surface terrain. Sub basin parameters such as slope gradient, slope length of the terrain, and the stream network characteristics such as channel slope, length, and width were derived from the DEM.
- Topographic maps
- Soil classes: SWAT model requires different soil textural and physio-chemical properties like soil texture (% clay, % sand, and % clay), organic content and bulk density were obtained from FAO database (FAO, 2002). Major soil types in the watershed are Lenthic Leptosols and Vertic Cambisols.
- LULC map: Land use is one of the most important factors that affect runoff, evapo transpiration and surface erosion in a watershed. Both soil and land use land cover data can be in shape file or grid format.
- Weather data: Weather data are amongst the indispensable inputs for SWAT model. Accordingly weather datas such as daily datas of rainfall, temperature (minimum and maximum), Wind Speed, Relative humidity and solar radiation were analyzed and prepared according to the model requirement (in dbf format). There is lack of full and realistic long period of meteorological data in our country, which can be solved by the aid of Weather generator that solves the problem by generating data from the existing observed data. The weather generator requires the daily values of all climatic variables from measured data or generated from values using monthly average data over a number of years. To generate the data, weather parameters values were developed by using WGN maker (Excel Macro Solver) and dew point temperature calculator DEW02 were used.

2.3 Hydrological Modelling

Hydrological models are the simplified mathematical demonstrations of a real hydrological system such as a river basin or a part of it. The main tools for hydrologist are the hydrological models used for different purposes such as water

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resource management, modelling of groundwater, watershed management for both urban and rural watersheds etc. SWAT model was developed by the USDA Agricultural Research Service (ARS), to assess the impacts of land use practices on sediment yield, water quality and chemical yields over long period of time in vast watersheds having different kinds of soils and land use practices. SWAT uses theModified Universal Soil Loss Equation (MUSLE) for the sediment yield calculation. Which is given as:

$$sed = 11.8\ (Qsurf*qpeak*area*ru)^{0.56} KUSLE*CUSLE*PUSLE*LSUSLE*CFRG$$

Where, " sed " is the sediment yield on a given day (metric tons), $Qsurf$ is the surface runoff volume (mm H2O/ha), $qpeak$ is the peak runoff rate (m^3 /s), $areah\ ru$ is the area of the HRU(ha), $KUSLE$ is the USLE soil erodibility factor (0.013 metric ton m2 ha /(m3 -metric ton cm)), $CUSLE$ is the USLE cover and management factor, $PUSLE$ is the USLE support practice factor, $LSUSLE$ is the USLE topographic factor and $CFRG$ is the coarse fragment factor." Model set up and execution is done following the flow chart as shown in fig.2 below.

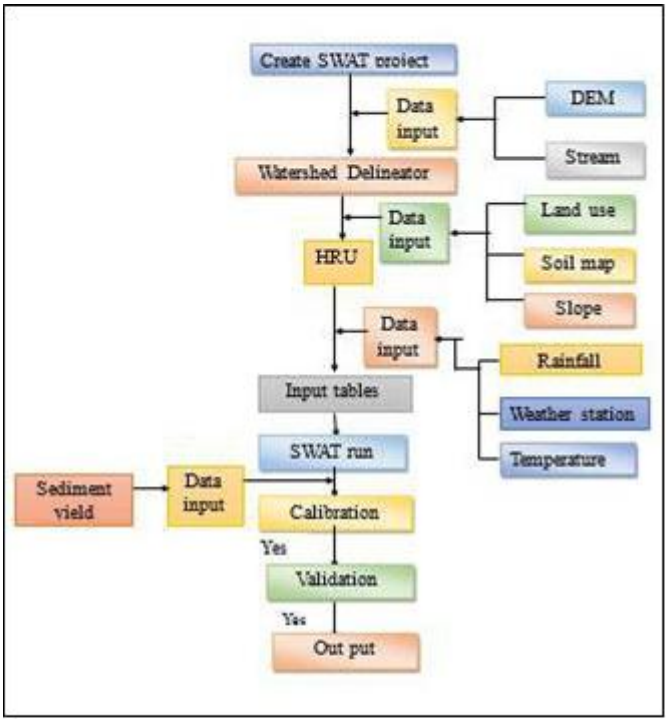

Figure 2: Flowchart for SWAT methodology

III. RESULTS AND DISCUSSIONS

The results and discussion may be combined into a common section or obtainable separately. They may also be broken into subsets with short, revealing captions. This section should be typed in character size 10pt Times New Roman, Justified.

3.1 Stream Flow Modeling

3.1.1 Parameters sensitive to flow

Flow sensitivity analysis was carried out for a period of eighteen years, which includes 3 years of warm-up period (1992-1994), the calibration period (from January 1, 1995 to December 31, 2004) and the validation period (from January 1, 2005 to December 31, 2009). Twenty one (21) parameters were used as sensitivity analysis in different degree and 300 iterations has been done by SWAT_CUP sensitivity analysis for flow calibration. These parameters are used to calculate the amount of flow from the watershed. The parameter identification was done by using the monthly observed flow data. Table 1 show all the parameters used in the sensitivity analysis with their Range values and Fitted Values for flow calibration.

Table 1: List of initially selected parameters used in flow sensitivity analysis

Parameters	Description of Parameters	Types of parameters	Range Values		Fitted Values
			Min	Max	
CN2	Initial Soil Conservation Service (SCS) runoff curve number for moisture condition II (Unit less)	Surface runoff	35	98	78
AlPHA_BF	Base flow alpha factor (days)	Ground water	0	1	0.22
GW_DELAY	Ground water delay (days)	Ground water	30	350	313.17
GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)	Ground water	0	5000	3875
GW_REVAP	Ground water "revap" coefficient	Ground water	0.02	0.2	0.12

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RCHRG_DP	Deep aquifer percolation fraction	Ground water	0	1	0.05
REVAPMN	Threshold depth of water in the shallow aquifer for "revap" to occur (mm)	Ground water	6	14	10.98
SLSUBBSN	Average slope length	Geomorphology	10	150	138.89
ESCO	Soil evaporation compensation factor	Evapotranspiration	0	1	0.12
LAT_TTIME	Lateral flow travel time	Geomorphology	0	10	9.90
SOL_AWC	Available water capacity of the soil layer (mm/mm soil)	Soil water	0	1	0.23
HRU_SLP	Average slope steepness	Surface runoff	0	0.2	0.18
BLAI	Max leaf area index	Evapotranspiration	2	8	7.35
CANMX	Maximum canopy storage (mm)	Surface runoff	0	100	31.02
SOL_Z	Depth from soil surface to bottom of layer	Soil water	0	3500	2784
SOL_K	Soil conductivity (mm/hr)	Soil water	0	2000	1770
CH_N2	Manning's "n" value for the main channel	Channel process	0.01	0.3	0.25
CH_K2	Effective hydraulic conductivity in main channel (mm/hr)	Channel process	5	130	73.01
EPCO	Plant evaporation compensation factor	Evapotranspiration	0	1	0.5
SURLAG	Surface runoff lag coefficient	Surface runoff	1	12	3.34
OV_N	Manning's "n"value for overland flow	Surface runoff	0.01	30	9.12

3.1.2 Stream Flow Calibration and Validation

The calibration and validation was done by using observed stream flow data at Awara Melka station. The stream flow data was available at this station from January 1, 1995 to December 31, 2009. Out of those total stream flow data two-third used for calibration purpose and one–third used for validation purpose. The calibration period was carried out for ten years that is from January 1, 1995 to December 31, 2004 and the validation period carried out five years from January1, 2005 to December 31, 2009. The simulated flow was calibrated manually using the separated observed surface flow gauged at the outlet of the sub watershed. The calibration processes considered the parameters and their values were varied iteratively within the allowable ranges until satisfactory agreement between measured and simulated stream flow was obtained as shown in figure 3.

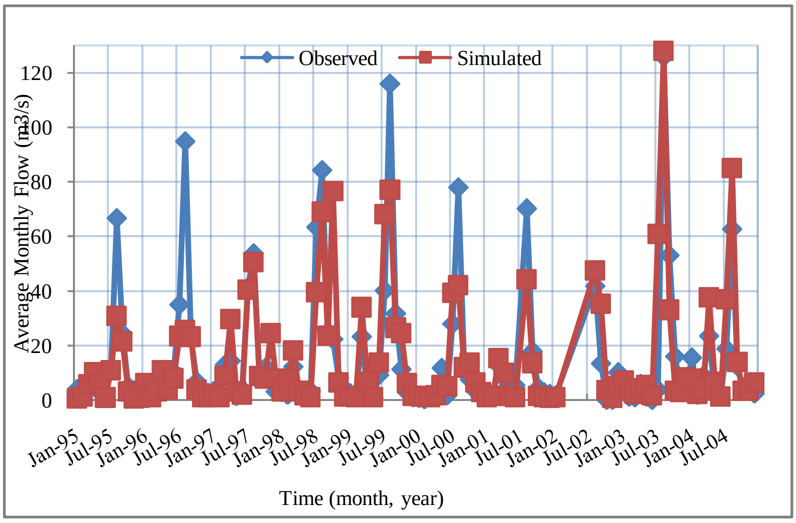

Figure 3: Mean monthly simulated and observed flow calibration

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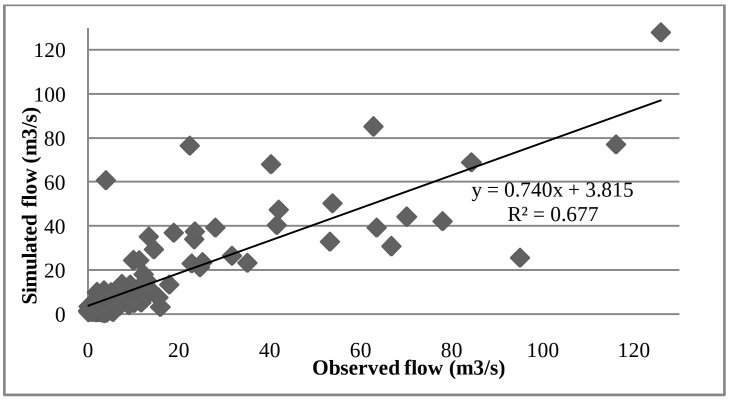

Figure 4: Goodness-of-fit for observed and simulated monthly flow calibration period

The model goodness-of-fit was evaluated and the model performance after adjusting all the parameters. Calibration resulted as observed in figure 4, after simulation found Correlation coefficient (R2) of 0.68, Nash Sutcliffe model efficiency (NSE) of 0.67, and Percent of biased (PBIAS) of 0.5.

Hence it is necessary to validate the stream flow to have a better estimation of the soil loss. The validation was done based on monthly basis from (2005-2009) without any parameter adjustment. The model with calibrated parameters was validated by using an independent set of measured flow data which were not used during model calibration to observe how much the simulation similar to the measured one. The figure 5 shows that the simulated flow line similarly follows the pattern of the measured flow line except deviation in some points.

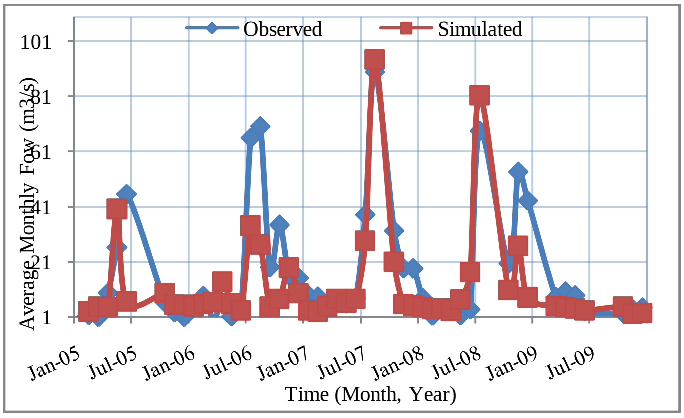

Figure 5: Monthly simulated and observed flows validation by Excel

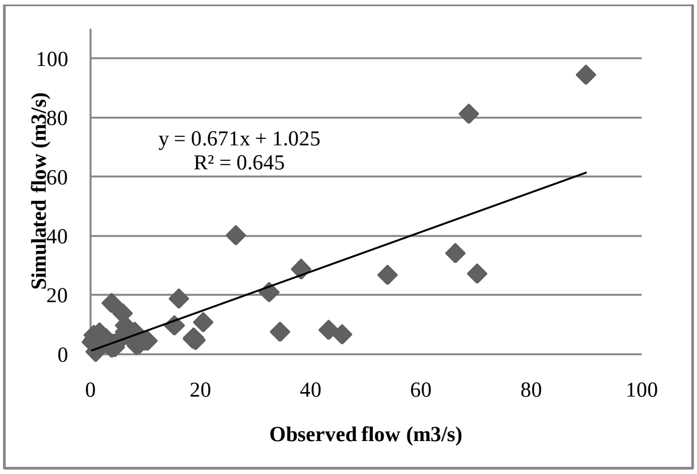

Figure 1: Goodness-of-fit for monthly observed and simulated flow validation period

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The above graphical representations as shown in figure 6 clearly show that, there is satisfactory agreement between model simulation and observed flow. Accordingly, match between monthly measured and simulated flows in the validation period were demonstrated by the Correlation coefficient (R2) of 0.65, Nash Sutcliffe model efficiency (NSE) of 0.60, and Percent of biased (PBIAS) of 26.8.

The performance remarks given in the following table 2 are based on the classification given by (Moria et.al. 2007). The model under estimate the stream flows from (1995-2001) and over estimate from (2002-2004) during calibration period. Similarly, under estimate the stream flows from (2005-2006) and over estimate from (2007-2008) during validation period.

Table 2: Evaluation of stream flow during calibration and validation periods

Monthly time step simulation	Mean monthly stream flows (m^3/s)		Model performance			Performance Remarks		
	Observed	Simulated	R2	NSE	PBIAS	R2	NSE	PBIAS
Calibration Period (1995-2004)	15.00	14.92	0.68	0.67	0.5	Good	Good	V.good
Validation Period (2005-2009)	16.75	12.26	0.65	0.60	26.8	Satisfy.	Satisfy.	Satisfy.

3.2 Sediment Yield Modeling

3.2.1 Parameters sensitive to sediment

The parameters included in the table 3 below were affecting the soil erosion simulation to some extent. These sediment parameters are used to compute the amount of sediment from a catchment (from upland) and from the channel (in stream sediment).

Table 3: List of initially selected parameters used in sediment yield sensitivity analysis

Sl no	Parameters	Description of parameters	Range (Min-Max)	Fitted value
1	SPCON	Linear re-entrainment parameter for channel sediment routing	0.0001-0.01	0.0069
2	SPEXP	Exponential re-entrainment parameter	1 - 1.5	1.002
3	USLE_C	USLE cover and management factor	0.001 – 0.5	0.248
4	SLSUBBSN	Average slope length	10 – 150	19.23
5	HRU_SLP	Average slope steepness	0 - 1	0.0036
6	RSDIN	Initial residue cover [kg/ha]	0 - 10000	3625
7	BIOMIX	Biological mixing efficiency	0 - 1	0.079
8	USLE_P	USLE support practice factor	0 - 1	0.233
9	CH_COV1	Channel erodibility factor	-0.05 – 0.6	0.26
10	CH_COV2	Channel cover factor	-0.001 – 1	0.008
11	USLE_K	USLE soil erodibility factor	0 - 2000	1108.3
12	CH_K2	Effective hydraulic conductivity(mm/h)	5-130	13.210

To see which parameter is highly sensitive to sediment from the list of parameters in Table 3 global sensitivity analysis was applied. Twelve parameters that directly affect the sediment yield and sediment transport in the watershed were analyzed and the result is tabulated in Table 4 below.

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Table 4: Lists of parameters sensitive to sediment and their rankings

Parameter Name	t-Stat	P-Value	Rank
CH_K2.rte	18.81	0.00	1
HRU_SLP.hru	-9.88	0.00	2
BIOMIX.mgt	-4.65	0.00	3
SLSUBBSN.hru	-2.99	0.00	4
USLE_P.mgt	-1.46	0.15	5
RSDIN.hru	1.34	0.18	6
USLE_C{..}.plant.dat	-1.10	0.28	7
CH_COV2.rte	-0.93	0.36	8
USLE_K(..).sol	-0.82	0.42	9
SPEXP.bsn	-0.81	0.42	10
SPCON.bsn	0.55	0.59	11
CH_COV1.rte	-0.26	0.80	12

The sensitivity of the parameter decreases with increasing rank number value and therefore, parameters at the bottom of the table are less sensitive.

Accordingly, the most sensitive parameters for sediment yield were: Effective hydraulic conductivity (CH_K2), Average slope steepness (HRU_SLP), Biological mixing efficiency (BIOMIX), and Average slope length (SLSUBBSN).

3.2.2 Sediment yield Calibration and Validation

After sensitivity analysis, the next step was calibrating sediment yield of the watershed. 3 years (1992-1994) was used for model warm up. So that model was calibrated (1995-2004). The calibration of sediment yield of the watershed was done based on sediment sensitivity analysis that has identified sensitive parameters and has effect on the simulated result when changed for sediment yield of the watershed, by varying iteratively within the allowable ranges of the parameters.

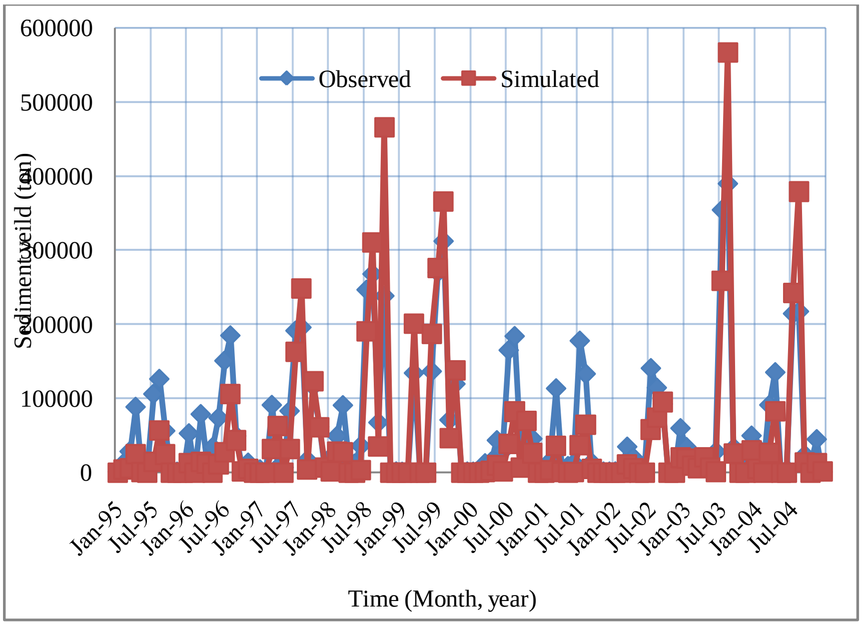

Figure 7: Monthly observed and simulated sediment yield calibration period by excel

As shown in figure 7 above, the model overestimate the peak monthly sediment yield from (1997-1999) and (2003-2004).

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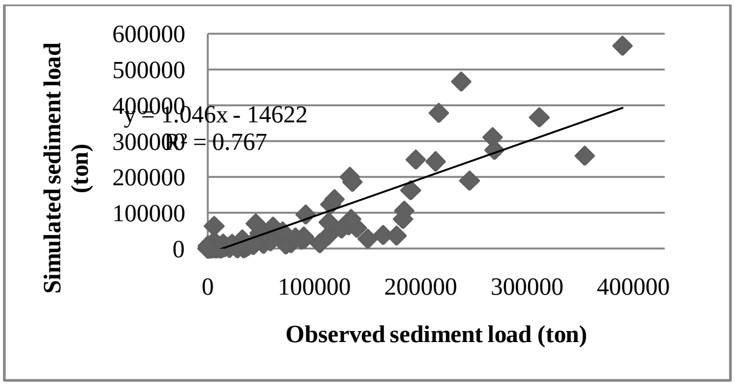

Figure 2 : Goodness-of-fit for observed and simulated sediment yield calibration period

The observed and the simulated values of the sediment yield were plotted against each other to determine the goodness-of-fit criterion of coefficient of determination by figure 8. Calibration resulted after simulation found Correlation coefficient (R2) of 0.77, Nash Sutcliffe model efficiency (NSE) of 0.64, and Percent of biased (PBIAS) of 19.8.

The SWAT model was validated for sediment from (2005-2009) using the same parameters, which were adjusted during calibration processes. Monthly model simulated sediment load against monthly measured sediment load were compared graphically and statistically as shown in figure 9.

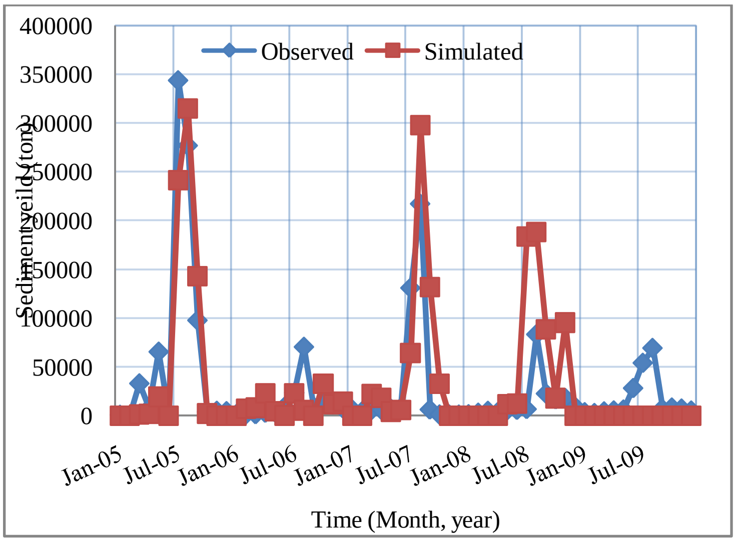

Figure 9: Monthly observed and simulated sediment yields validation period by Excel

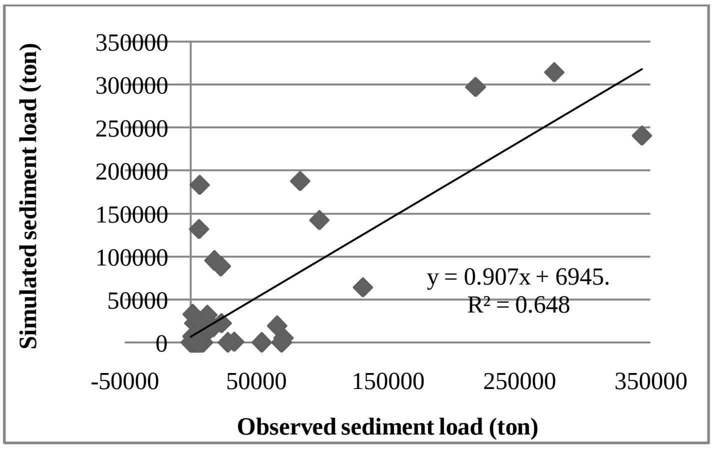

Figure 10: Goodness-of-fit for observed and simulated sediment yield validation period

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The goodness-of-fit for simulated and observed sediment during validation period were plotted as in figure 10. The statistical values in the monthly basis of sediment yield estimation in the validation period results (R2= 0.65, NSE= 0.54 and PBIAS=-14.2) as shown in table 5. The model over estimated the peak monthly sediment yield from (2007-2008) Figure 10 above.

3.2.3 Soil loss simulation and identification of sediment source areas

After the model was calibrated and validated, it was run for a period 18 years (1992 - 2009), then the overall simulated output can be used for further application and sediment source areas were identified Watershed. The total observed Stream flow at study area gauged station was 15.52m^3/s and the simulated of Stream flow by SWAT model is 14.12m^3/s. The total annual sediment yield from catchment into the reservoir calibration and validation period was estimated by SWAT model is 7,773,363 ton. The total catchment area of the study area is 301850 ha. Therefore, the annual specific sediment yield from the catchment can be calculated as the total sediment yield.

Table 5: Evaluation of sediment yield during Calibration and Validation periods

Monthly time step simulation	Average monthly sediment load (ton/month)		Model performance			Performance Remarks		
	Observed	Simulated	R2	NSE	PBIAS	R2	NSE	PBIAS
Calibration (1995-2004)	59714.47	47878.78	0.77	0.64	19.8	V.good	Good	Good
Validation (2005-2009)	29598.61	33798.49	0.65	0.54	14.2	Good	Satisf.	V.good

Divided by the area of the catchment which is equal to 25.75 ton/ha/year. From Kesem irrigation project feasibility study sediment yield estimated is 23 - 27 ton/ha/yr (Sir M Macdonald, 1986). Modeling of sediment yield for upper Awash, estimation of average annual sediment yield is 44.88ton/ha/yr (Tarik A, 2017).

The model is good result for the estimation of catchment stream flow and sediment yield in the study area. The SWAT model had 75 capabilities to identify areas within a watershed with high erosion and sediment yield. This helps to prioterize and formulates development and conservation plans in order to use available economic resource optimally. Since the erosion process occurred in the watershed is believed to be the major source of sediment load, it is important to give due attention for appropriate watershed development or soil and water conservation at least for those places which are major cause for higher sediment yield. Around 27 sub-basins are classified as per the model. Accordingly, the highest average soil loss was 22.01 tons/ha and it was observed from sub basin 2. The lowest average soil loss was 0.03 tons/ha and it was observed from sub basins number 12. The rest sub watersheds were categorized between the highest and lowest soil loss rate. As it was observed in the simulation soil loss was strongly related with soil type, land use and slope gradient. Highest soil loss was correlated with Vertic cambisols, Lenthic leptosols, and Eutric Vertisols soil types with shrub land use, cultivated land use, and sparsely vegetated land use system and slope gradient greater than 20%. Lowest rate was observed from Eutric leptosols and Eutric cambisols soil type with Wetland use and shrubland use system and slope gradient 0-10%. The slope gradient created opportunity for the runoff to get high velocity.

Sediment yield of a watershed is the summation of suspended and bed load. The analysis described below is suspended sediment load as shown in figure 11.

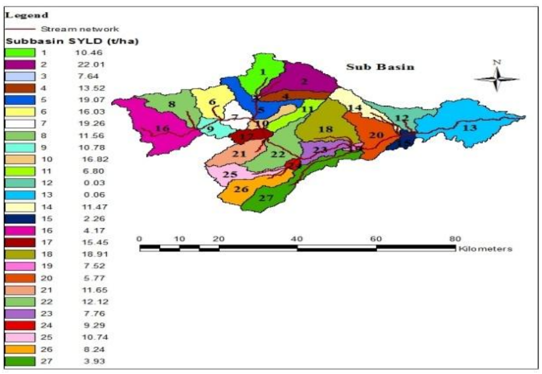

Figure 11: Average annual soil loss rates of sub-basins

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3.3 Identification of sub basins

The identification of sub basin of this study was done based on estimated mean annual soil loss. Rank was assigned based on the amount of mean soil loss in which the first rank was given to the sub watershed with maximum soil loss. Other ranks were assigned in decreasing order of soil loss intensity where the last rank goes to the sub watershed with the least soil loss.

Table 6: Ranked sub-basins in terms of soil loss rates

Sub Watershed	Average Annual Soil loss (t/ha)	Rank	Area (ha)	Area (%)
2	22.01	1	16965.0	5.62
7	19.26	2	7063.2	2.34
5	19.07	3	12002.0	3.98
18	18.91	4	20625.0	6.83
10	16.84	5	4455.0	1.48
6	16.03	6	11402.0	3.78
17	15.45	7	4894.0	1.62
4	13.52	8	6588.5	2.18
22	12.12	9	17657.0	5.85
21	11.65	10	10487.0	3.47
8	11.56	11	13803.0	4.57
14	11.47	12	9530.5	3.16
9	10.78	13	5813.4	1.93
25	10.74	14	9413.8	3.12
1	10.46	15	12590.0	4.17
24	9.29	16	1559.2	0.52
26	8.24	17	12909.0	4.28
23	7.76	18	8340.6	2.76
3	7.64	19	364.5	0.12
19	7.52	20	1112.1	0.37
11	6.80	21	7118.3	2.36
20	5.77	22	15557.0	5.15
16	4.17	23	26544.0	8.79
27	3.93	24	18742.0	6.21
15	2.26	25	3671.7	1.22
13	0.06	26	33050.0	10.95
12	0.03	27	9600.9	3.18

Accordingly, the rank was classified based on the soil loss rate. Accordingly, the highly eroded was from sub basin 2, 7, 5, 18 and its average annual sediment yield was 22.01 t/ha, 19.29 t/ha, 19.07 t/ha, 18.91 t/ha respectively. These highly eroded sub basins are found in steep slope, heavy clay soil which is poor infiltration capacity soil and agricultural land use with poor conservation. These factors were responsible for aggravating the soil loss rate of the sub watersheds. Hence mitigation measures should be proposed based on the soil loss rate problem.

The spatial location of the sediment yield classes of sub-basins based on the classification of table 6 above are mapped as shown in Figure 12.

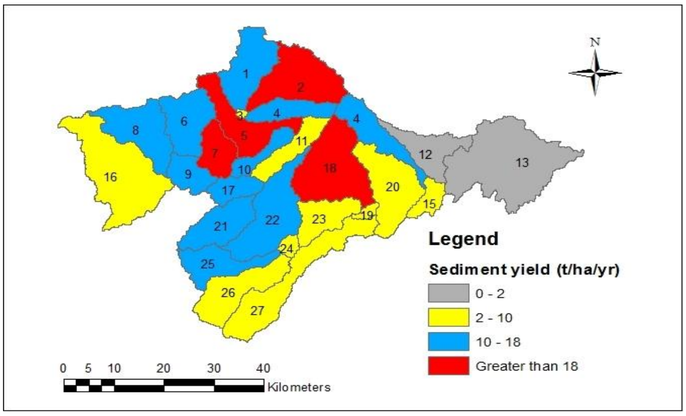

Figure 12: Spatial distribution of sediment yield of Kesem dam watershed sub-basin

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The identification of sub basin of this study was done based on estimated mean annual soil loss. Rank was assigned based on the amount of mean soil loss in which the first rank was given to the sub watershed with maximum soil loss. Other ranks were assigned in decreasing order of soil loss intensity where the last rank goes to the sub watershed with the least soil loss.

Table 7: Ranked sub-basins in terms of soil loss rates

Sub Watershed	Average Annual Soil loss (t/ha)	Rank	Area (ha)	Area (%)
2	22.01	1	16965.0	5.62
7	19.26	2	7063.2	2.34
5	19.07	3	12002.0	3.98
18	18.91	4	20625.0	6.83
10	16.84	5	4455.0	1.48
6	16.03	6	11402.0	3.78
17	15.45	7	4894.0	1.62
4	13.52	8	6588.5	2.18
22	12.12	9	17657.0	5.85
21	11.65	10	10487.0	3.47
8	11.56	11	13803.0	4.57
14	11.47	12	9530.5	3.16
9	10.78	13	5813.4	1.93
25	10.74	14	9413.8	3.12
1	10.46	15	12590.0	4.17
24	9.29	16	1559.2	0.52
26	8.24	17	12909.0	4.28
23	7.76	18	8340.6	2.76
3	7.64	19	364.5	0.12
19	7.52	20	1112.1	0.37
11	6.80	21	7118.3	2.36
20	5.77	22	15557.0	5.15
16	4.17	23	26544.0	8.79
27	3.93	24	18742.0	6.21
15	2.26	25	3671.7	1.22
13	0.06	26	33050.0	10.95
12	0.03	27	9600.9	3.18

Accordingly the rank was classified based on the soil loss rateas shown in table7. From tabulated results, the highly eroded was from sub basin 2, 7, 5, 18 and its average annual sediment yield was 22.01 t/ha, 19.29 t/ha, 19.07 t/ha, 18.91 t/ha respectively.

And low sediment yield was from sub basin 12 and 13 it were 0.03 t/ha and 0.06 t/ha respectively. The average annual of sediment yield of Tendaho sub-basins ranges between 26.66ton/ha ton 0.02ton/ha (Asmelash et al., 2017). These highly eroded sub basins are found in steep slope, heavy clay soil which is poor infiltration capacity soil and agricultural land use with poor conservation. These factors were responsible for aggravating the soil loss rate of the sub watersheds. Hence mitigation measures should be proposed based on the soil loss rate problem.

As per the research conducted by Hurni (1983), the range of the tolerable soil loss level for the various agro-climatic zones of Ethiopia was found to be 2 to 18 t/ha. Therefore, more of Kesem dam sub basins were found in the range of the tolerable soil loss level. But, the annual soil loss rate at some sub-basins of Kesem dam watershed was above this tolerable limit. In addition, based on the relative soil erosion and sediment delivery of the sub-basins, the authors have classified the sediment delivery of the sub-basins into four classes (Table 8), for quick mitigation and decline of the sediment yield at Kesem dam reservoir.

Table 8: Eroded soil delivery classes of sub-basins

Sediment yield interval (t/ha/yr)	Erosion class
Greater than 18	Highly eroded
10–18	Moderately eroded
2 – 10	Acceptable erosion
0–2	Negligible erosion

The spatial location of the sediment yield classes of sub-basins based on the classification of table 8, above are mapped as shown in figure 13.

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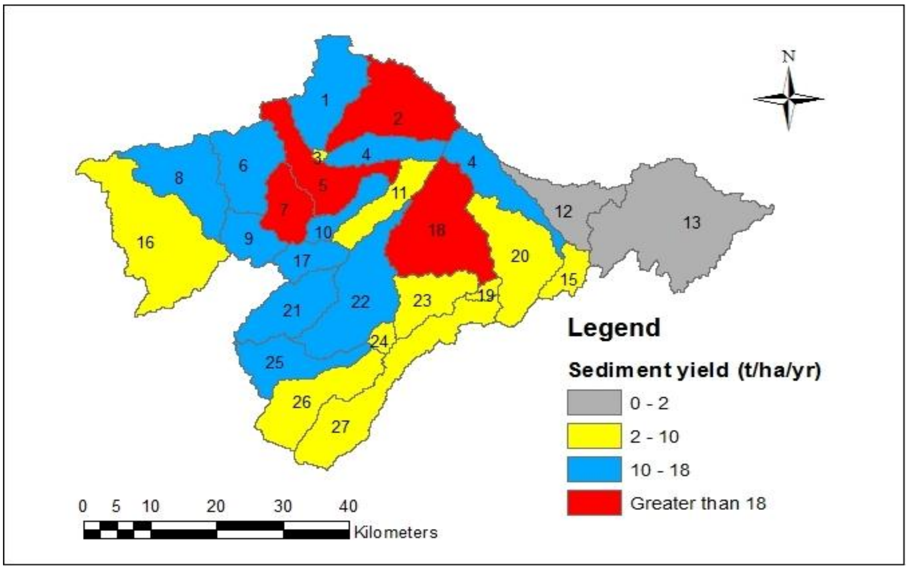

Figure 13: Spatial distribution of sediment yield of Kesem dam watershed sub-basin

The sediment yield from a given watershed is dominantly related to rainfall and runoff, soil erodibility, slope length and steepness, cropping and management of the soil, and any supporting practices implemented to prevent erosion (Dilnesaw and Bonn, 2006).

3.4 Scenarios developing and Mitigation measures

Changes in land use/land cover affect the hydrological cycle, biodiversity, radiation budgets and other processes. These changes on the other hand affect the storm runoff and sediment transport in the catchment. Therefore, analyzing the effect of land use/land cover change on the hydrology and sediment transport is one of the essential parts of this study. To do this it is necessary to develop scenarios that reflect the changes made to the watershed land use. Scenario analysis enables us to apply improved management practices and decision making.

The scenarios may be developed based on future land use plan in the watershed if there is any. But, in the absence of future master plan, the scenarios can be developed by changing the land use by a specified percentage and quantify the changes caused by the conversion of one land use type to the other.

The dominant land use in the study area is Agricultural land. Therefore, scenario development was made by changing the agricultural land to different land uses in the watershed to see scenario and two best Management Practices (BMP): applying grass strip area between a slope of 0 to 25% and terracing (Stone bunding) area between a slope of 0 to 25%. Therefore, six scenarios were compared to the baseline i.e. the original land use. These scenarios were developed to evaluate the sediment yield change from the watershed.

The scenarios are:

Scenario_0 = Initial land use
1. Scenario_1: 10% of agricultural land is changed to sparsely vegetated land grassland
2. Scenario_2:10% of agricultural land is changed to shrubland
3. Scenario_3:20% of agricultural land is changed to shrubland
4. Snenario_4:30% of agricultural land is changed to Shruband
5. Snenario_5:40% of agricultural land is changed to shrubland
6. Scenario_6:50% of agricultural land is changed to shrubland

As it has been observed from table 9, that changing different land use existed in study area, the above developed scenario shows that small reduction of sediment yields in the catchment. Therefore, it is preferable to apply another best management practices like a forestation, applying grass strip and terracing (Stone bunding) area between a slopes of 0 to 25% was recommended.

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Table 9: Summary of scenario development result

Scenarios	Period (1992-2009)		
	Average sediment yield (tons/ha/yr)	Difference	Sed. Change (%)
S0	18.10	-	-
S1	18.09	-0.01	-0.06
S2	18.07	-0.03	-0.17
S3	18.03	-0.07	-0.39
S4	17.99	-0.11	-0.61
S5	17.87	-0.23	-1.3
S6	17.80	-0.30	-1.7

IV. CONCLUSION

The model behaved well for the calibration and validation periods for both flow and sediment yield. During flow calibration the R2 and NS give as value of 0.68 and 0.67 respectively, and similarly for validation the R2 and NS give as value of 0.65 and 0.60, respectively. For sediment calibration the R2 and NS coefficient give as 0.77 and 0.64, respectively and sediment validation R2 and NS give as 0.65 and 0.54, respectively. It can be concluded that model performs good for both the flow and sediment yield evaluation.

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